K S INSTITUTE OF TECHNOLOGY, BANGALORE

DEPARTMENT OF MECHANICAL ENGINEERING

COURSE FILE

NAME OF THE STAFF : RAJESH G L

SUBJECT CODE/NAME : 18ME15 / ELEMENTS OF MECHANICAL ENGINEERING

SEMESTER/YEAR : I / I

ACADEMIC YEAR : 2020 – 21

BRANCH / SECTION : ECE / D

COURSE INCHARGE

HOD

Head of the Department
Dept. of Mechanical Engg.
K.S. Institute of Technology
Bengaluru - 560 109.

PRINCIPAL

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K.S. INSTITUTE OF TECHNOLOGY
BENGALURU - 560 109

VISION AND MISSION OF THE INSTITUTE

VISION

"To impart quality technical education with ethical values, employable skills and research to achieve excellence"

MISSION

- To attract and retain highly qualified, experienced & committed faculty.
- To create relevant infrastructure.
- Network with industry & premier institutions to encourage emergence of new ideas by providing research & development facilities to strive for academic excellence.
- To inculcate the professional & ethical values among young students with employable skills & knowledge acquired to transform the society.

VISION AND MISSION OF THE DEPARTMENT

VISION:

"To groom incumbents to compete with their professional peers in mechanical engineering that brings recognition"

MISSION

M1 : To impart sound fundamentals in mechanical engineering.

M2 : To expose students to new frontiers.

M3: To achieve engineering excellence through experiential learning and team work.

PROGRAM EDUCATIONAL OBJECTIVES (PEOs)

PEO1: To produce graduates who would have developed a strong background in basic science and mathematics and ability to use these tools in Mechanical Engineering.

PEO2: To prepare graduates who have the ability to demonstrate technical competence in their fields of Mechanical Engineering and develop solutions to the problems.

PE03: To equip graduates to function effectively in a multi-disciplinary environment individually, within a global, societal, and environmental context.

PROGRAM SPECIFIC OUTCOMES (PSOs)

It is expected that a student in mechanical engineering will possess an:

PSO1: Ability to apply concept of mechanical engineering to design a system, a component or a process/system to address a real world challenges

PSO2: Ability to develop effective communication, team work, entrepreneurial and computational skills

PROGRAM OUTCOMES (POs)

Engineering Graduates will be able to:

- ✓ **Engineering knowledge:** Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.
- ✓ **Problem analysis:** Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
- ✓ **Design/development of solutions:** Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.
- ✓ **Conduct investigations of complex problems:** Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.
- ✓ **Modern tool usage:** Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.
- ✓ **The engineer and society:** Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.
- ✓ **Environment and sustainability:** Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.
- ✓ **Ethics:** Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.
- ✓ **Individual and team work:** Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.
- ✓ **Communication:** Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.
- ✓ **Project management and finance:** Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.
- ✓ **Life-long learning:** Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

K. S INSTITUTE OF TECHNOLOGY, BENGALURU-560109

CALENDAR OF EVENTS: I SEMESTER (2020-2021)

SESSION: December 2020 - April 2021

Week No.	Month	Day						Days	Activities
		Mon	Tue	Wed	Thu	Fri	Sat		
1	DEC	14*	15	16	17	18	19	6	14*-Commencement of I Semester/Induction Programme
2	DEC	21	22	23	24	25 H	26	5	25-Christmas
3	DEC /JAN	28	29	30	31	1	2	6	
4	JAN	4	5	6	7	8	9	6	
5	JAN	11	12	13	14 H	15	16	5	14-Makara sankaranthi
6	JAN	18 T1	19 T1	20 T1	21	22	23	6	
7	JAN	25	26 H	27 BV	28 ASD	29	30	5	26-Republic Day
8	FEB	1	2	3	4	5	6	6	
9	FEB	8	9	10	11	12	13	6	
10	FEB	15	16	17	18 T2	19 T2	20 T2	6	
11	FEB	22	23	24 BV	25ASD	26	27	6	
12	MAR	1	2	3	4	5	6	6	
13	MAR	8	9	10	11 H	12	13	5	11-Maha Shivaratri
14	MAR	15	16	17	18	19	20	6	
15	MAR	22	23	24	25 T3	26 T3	27 T3	6	
16	MAR/ APR	29 LT	30 LT	31 LT	1 LT	2 H	3	5	2-Good Friday
17	APR	5 IT	6 IT	7 IT	8	9	10*	6	* Last Woking Day
Total No of Working Days : 97									

Total Number of working days (Excluding holidays and Tests)=75

H	Holiday	
BV	Blue Book Verification	
T1,T2, T3	Tests 1,2, 3	
ASD	Attendance & Sessional Display	
LT/ IT	Lab Test	Improvement Test
TA	Test attendance	

Monday	17
Tuesday	16
Wednesday	17
Thursday	15
Friday	15
Saturday	17
Total	**97**

13/3/21

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K.S.INSTITUTE OF TECHNOLOGY
LIST OF STUDENTS STUDYING IN I SEMESTER
FOR THE ACADEMIC YEAR 2020-2021
ELECTRONICS & COMMUNICATION ENGINEERING
CHEMISTRY CYCLE - SECTION D

SL NO	NAME OF THE STUDENT	STUDENT MOBILE NUMBER	STUDENT EMAIL ID	GENDER	DATE OF BIRTH	STUDENT AADHAR NUMBER	ADMISSION QUOTA	FATHER MOBILE NUMBER	MOTHER MOBILE NUMBER
1	ABHISHEK .J	9148909784	Abhiacchu03@gmail.com	Male	03-01-2002	834490962130	MANAGEMENT	9108332157	6362850169
2	ADITI DUBEY	9483670316	aditidubey2002@gmail.com	Female	16-03-2002	991583223129	MANAGEMENT	9901768702	9916143291
3	AFEEFA SHARIEFF	8722100935	afeefa.mms@gmail.com	Female	20-10-2002	711814434889	CET		7848078518
4	AJAY B.G	9663870637	ajaybg2002@gmail.com	Male	26-02-2002	6260 3599 0045	CET	9535128057	9663870637
5	AJAY GIRISH	+918660588332	ajaygirish72@gmail.com	Male	06-06-2002	265544669688	CET	9972038553	9980761620
6	AKASH .M	9113643268	akashtorotto@gmail.com	Male	03-08-2001	284690655844	MANAGEMENT	9538482446	9980491699
7	ASHRIT MADHAV VADIRAJ	+918546813044	madhav261102@gmail.com	Male	26-11-2002	7588 1693 0131	CET	9167955657	9930813044
8	B.S.HEMASHREE	8553847390	hemashreekadam@gmail.com	Female	24-03-2002	486555026340	MANAGEMENT	8762265058	9449204361
9	BHARATH M	6366325889	bharath3292@gmail.com	Male	09-02-2002	2068 8721 1795	CET	7090600434	7619212525
10	BHAVITHA. B	7676182692	bhavithapriya02@gmail.com	Female	19-08-2002	404835165240	CET	8762182437	8762182437
11	BHUVANESHWARI.K	9731745184	bhuvik108@gmail.com	Female	23-04-2002	299534272314	CET	9845978879	7022608417
12	CHAITANYA. K	7204977937	Reddychaitanya401@gmail.com	Male	16-03-2002	531684148181	MANAGEMENT	9343776218	6362534647
13	CHAITHRA K	9964411457	jayalakshmisomayaji1971@gmail.com	Female	06-04-2002	731729312281	SNQ	9964411457	9686610271
14	CHALLAGUNDLA SAI SRUJITHA	7815834446	saisrujitha18@gmail.com	Female	18-01-2002	826492538470	COMEDK	9000558141	9390481542
15	CHALLAGUNDLA UMADEVI	6302775314	challagundlaumadevi14@gmail.com	Female	20-11-2002	847690841654	MANAGEMENT	9505737070	6303475858
16	CHAYA.S	8147025259	chayas2002@gmail.com	Female	23-03-2002	6534 4122 3905	MANAGEMENT	9448561585	9845198388
17	CHETHAN KUMAR J	9916319428	Chethankumarchethan20@gmail.com	Male	20-07-2002	577525137476	CET	9591087284	7349610103
18	CHETHAN KUMAR T	8971023827	chethankumar2420@gmail.com	Male	24-09-2002	696056864872	MANAGEMENT		7019722049
19	CHETHAN. G	8310415628	gchethan866@email.com	Male	30-04-2003	242387540674	CET	9066605369	8971800934
20	DARSHAN KUMAR	9902618252	darshu061202@gmail.com	Male	06-12-2002	334415471891	MANAGEMENT	8861840262	8861840262
21	DARSHAN.K	9148379478	darshan2243k@gmail.com	Male	22-04-2003	555053979701	CET	6363852337	9535250529
22	DEEPAK S	9380662154	deepakadithya1127@gmail.com	Male	27-08-2002	228590410766	MANAGEMENT	9741857589	9035259827
23	DHAMINI. J	9513680207	dhaminij0289@gmail.com	Female	02-07-2002	858427564110	CET	7829033976	7760916277
24	DHRUVA KUMAR. S	8073976871	dhruvakumar26190@email.com	Male	15-02-2002	488972805041	MANAGEMENT	9448212059	9886280175
25	DIVYA N	8310365659	divyanmurthy09@gmail.com	Female	09-05-2002	2584 0792 7811	MANAGEMENT	9945977171	9972629197
26	ESHWAR BIRADAR	7588247068	eshwarbb2003@gmail.com	Male	03-01-2003	6394 2491 9032	CET	7588247068	9108697635
27	G BHAVANA PRIYADARSHINI	8296196955	bhavanagorthi@gmail.com	Female	14-10-2002	441790519959	CET	9449977675	8973709003
28	GAGAN.H.C	6364769333	gagan888.hc@gmail.com	Male	01-06-2002	267277963799	MANAGEMENT	9845440151	9880883234
29	GAGANA B S	6360024748	gagana8904604388@gmail.com	Female	18-09-2002	3821 8246 7296	MANAGEMENT		
30	GANDHAMANI C M	9741398268	cmgandhamani@gmail.com	Female	07-04-2002	6292 4686 3760	MANAGEMENT	9448233568	8892243982
31	GOMITHA R C	8618246907	rcgomitha@gmail.com	Female	02-06-2002	2426 6738 5462	CET	9620403338	7892682264
32	HARINI K	9900704653	kharini810@gmail.com	Female	24-03-2002	765401615750	MANAGEMENT	7259806961	6364485871
33	HARSHITH GOWDA AR	8123266819	harshithgowdaa04@gmail.com	Male	04-09-2002	725548783776	CET	9008273087	8197111248
34	HARSHITHA .B.L	7892192846	harshithabl15@gmail.com	Female	15-06-2002	5375 7342 8223	MANAGEMENT	9845757201	9740154601
35	HARSHITHA J	9113684507	jjayaram223@gmail.com	Female	23-09-2002	544252455949	MANAGEMENT	9980381766	9113684507
36	HARSHITHA N	8884395624	harshithan392@gmail.com	Female	22-12-2002	970382753294	MANAGEMENT	8884951994	9448617364
37	INCHARA. P	6361694403	TejuPc182@gmail.com	Female	24-01-2002	624993685627	MANAGEMENT	8105544866	6361694403
38	JAMPULA CHAITHANYA KRISHNA	7780665993	chaithanyajampula1@gmail.com	Male	30-04-2003	882064083124	MANAGEMENT	9059040509	9705377583
39	JAMUNA S.G	9353868269	Jamuna123@gmail.com	Female	16-02-2002	946865933228	SNQ	8123389095	7259354979
40	JANHAVI R	8073864130	Janvirajjanviraj042@gmail.com	Female	13-02-2003	850121372273	CET	8073057764	6366086700
41	JAYANTH.H	9632619829	jayanth.h6174@gmail.com	Male	09-02-2002	712845687141	CET	9880767316	9141073697
42	S. ARUN KUMAR	9480515998	rahularunkumar5@gmail.com	Male	13-01-2003	235640391692	CET	9060001979	9480515998
43	SACHIN N M	8431949810	sachinmnagol@gmail.com	Male	13-07-2002	2817 8086 3559	CET	9972077572	
44	SADHANA.SRINIVAS	6361916229	sadhana.srinivas6@gmail.com	Female	05-06-2002	4794 0804 3066	MANAGEMENT	9108587382	9108287469
45	SAKSHAM SINGH	7892803406	singh.saksham221201@gmail.com	Male	22-12-2001	313639322623	MANAGEMENT	8217679314	9741628210
46	SANDEEP Y H	9741435215	sandeepyhsandeepyh@gmail.com	Male	01-07-2002	530408564559	CET	9901889154	9880711052
47	SANGEETHA G S	8496954392	Sangeethareddys90@gmail.com	Female	04-10-2002	527463128627	CET	8722322382	8088038955
48	SANJANA G.	7676947607	sanjanatantry03@gmail.com	Female	14-07-2002	7174 7766 4635	MANAGEMENT	9448242991	9844456741
49	SANJANA T GADIKAR	7411745642	sanjanatgadikar@gmail.com	Female	14-09-2002	5935 7755 1098	MANAGEMENT	9900137102	7411724316
50	SANJANA.G	9743932931	Sanjana.gurunaths@gamil.com	Female	28-08-2002	397481751848	MANAGEMENT	9686474373	8277201905
51	SHAKTHI ANBAZHAGAN M	6363195088	anbumuniyappa@gmail.com	Male	25-09-2002	4963 6596 9096	CET	9980122908	9844201698
52	SHARATH M	8050032264	Sharathm5684@gmail.com	Male	18-09-2002	912381707743	CET	9480075656	8277784542
53	SHASHANK.S	08867116224	Shashanksiddaraj2002@gmail.com	Male	04-05-2002	203779413522	CET	9535220016	7975633792
54	SHIVAREDDY.B A	9686526103	shivareddyba56@gmail.com	Male	10-01-2001	814334274002	CET	9731055616	9902595576
55	SHREYA H PADMANABHA	7676869258	shreyah532@gmail.com	Female	01-06-2002	380931056507	MANAGEMENT	9902308548	9743042590
56	SHREYAS M S	8050289057	shrems08@gmail.com	Male	21-08-2002	3522 9176 1549	MANAGEMENT	9845447704	9900379104
57	SHEYAS P S RAO	6364557803	sshreyas578@gmail.com	Male	27-09-2002	881405628965	MANAGEMENT	9343835454	9341229890
58	SHWETA DEEPAK K	8050289057	shrems08@gmail.com	Male	21-08-2002	3522 9176 1549	MANAGEMENT	9845447704	9900379104
59	RAMESHWAR	7411390961	makrerameshwar6@gmail.com	Female	22-07-2001	5372 6183 8603	CET	9972331377	
60	ARCHANA.M								

K.S. INSTITUTE OF TECHNOLOGY, BANGALORE -109
DEPARTMENT OF MECHANICAL ENGINEERING
INDIVIDUAL TIME TABLE FOR THE YEAR - 2020-21 (ODD SEMESTER)

W.E.F. : 20/1/2021

NAME OF THE FACULTY : MR. RAJESH G L

PERIOD	1	2	10.20 AM 10.35 AM	3	4	12.25 PM 1.30 PM	5	6	7
TIME DAY	8.30 AM 9.25 AM	9.25 AM 10.20 AM		10.35 AM 11.30 AM	11.30 AM 12.25 PM		1. PM 2.25 PM	2.25 PM 3.20 PM	3.20 PM 4.15PM
MON			TEA BREAK			LUNCH BREAK			
TUE							I D		
WED		I D							
THU				I D					
FRI							I D		
SAT	I D						I D		

	Sub-Code	Subject Name	Sem	Section
Subject 1	18ME15	ELEMENTS OF MECHANICAL ENGINEERING	I	D

HOD

Head of the Department
Dept. of Mechanical Engg.
K.S. Institute of Technology
Bengaluru - 560 109.

Principal

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K.S INSTITUTE OF TECHNOLOGY, BENGALURU-109
OFF-LINE CLASSES TIME -TABLE FOR I SEMESTER (2020-2021)
CHEMISTRY CYCLE

Branch Electronics & Communication Engg — SECTION D

Class Teacher Mrs SHYLAJA K R

Seminar Hall Third Floor — OFF-LINE CLASSES W.e.f. 20.01.2021

PERIOD	1	2		3	4		5	6	7
TIME/ DAY	8.30 AM - 9.25 AM	9.25 AM - 10.20 AM	10.20 AM - 10.35 AM	10.35 AM - 11.30 AM	11.30 AM - 12.25 PM	12.25 PM- 1.15 PM	1.15 PM - 2.10 PM	2.10 PM - 3.05 PM	3.05 PM - 4.00PM
MON	CPS 18CPS13	CHE 18CHE12	BREAK	MATHS 18MAT11	BE 18ELN14	LUNCH - BREAK	← 18 CHEL 16 D1 / 18CPL17 D2 →		
TUE	CHE 18CHE12	BE 18ELN14		CHE 18CHE12	MATHS 18MAT11		EME 18ME15	CPS 18CPS13	LIB
WED	CPS 18CPS13	EME 18ME15		CHE 18CHE12	MATHS 18MAT11		← 18 CHEL 16 D2 / 18CPL17 D3 →		
THU	BE 18ELN14	CPS 18CPS13		EME 18ME15	CHE 18CHE12		COURSE DISCUSSION	MENTORS MEET	
FRI	←18 CHEL 16 D3 / 18CPL17 D1 →				BE 18ELN14		EME 18ME15	MATHS 18MAT11	ENG 18EGH18
SAT	EME 18ME15	CPS 18CPS13		MATHS 18MAT11	BE 18ELN14		COURSE INTERACTIVE SESSION		

SUBJECT CODE	SUBJECT NAME	FACULTY NAME
18MAT11	CALCULUS AND LINEAR ALGEBRA	Mrs LAKSHMI C
18CHE12	ENGINEERING CHEMISTRY	Dr KIRAN KUMAR S R, Mrs SHYLAJA K R
18CPS13	C PROGRAMMING FOR PROBLEM SOLVING	Mr Krishna Gudi
18ELN14	BASIC ELECTRONICS	Mrs VISHALINI DIVAKAR
18ME15	ELEMENTS OF MECHANICAL ENGINNERING	Mr RAJESH G L
18CHEL16	ENGINEERING CHEMISTRY LABORATORY	Dr KIRAN KUMAR S R, Mrs SHYLAJA K R, Mrs RADHIKA N P
18CPL17	C PROGRAMMING LABORATORY	Mr Krishna Gudi, Mr Prashanth H S
18EGH18	TECHNICAL ENGLISH-I	Mrs ANURADHA M V

Head of the Department
Department of Science & Humanities

18/1/21
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Principal
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BANGALORE - 560 062

K. S. INSTITUTE OF TECHNOLOGY

#14, Raghuvanahalli, Kanakapura Main Road, Bengaluru-5600109

DEPARTMENT OF MECHANICAL ENGINEERING

CO-PO MAPPING 2020-2021

Course: ELEMENTS OF MECHANICAL ENGINEERING

Course Incharge: Mr. RAJESH G.L/ Dr. K.V.A BALAJI

Type: Core	**Course Code:**18ME15

No of Hours per week

Theory (Lecture Class)	Practical/Field Work/Allied Activities	Total/Week	Total teaching hours
4	0	4	55

Marks

Internal Assessment	Examination	Total	Credits
40	60	100	3

Aim/Objective of the Course:

1. Learn the fundamental concepts of energy, its sources and conversion with simple numerical.
2. Comprehend the basic concepts of thermodynamics and find its properties by working out simple problems.
3. Understand the working concepts of boilers, turbines, pumps, internal combustion engines and refrigeration and study simple problems.
4. Learn and distinguish different methods of metal joining techniques.
5. Enumerate and understand the knowledge of working of conventional machine tools, their specifications and applications.

Course Learning Outcomes:

After completing the course, the students will be able to,

18ME15.1	**Demonstrate** different types of sources of energy; environmental issues like global warming, Ozone depletion, Basic concepts of thermodynamics and steam.	**Understanding (K2)**
18ME15.2	**Illustrate** the Boilers and its accessories; principle of operation of different types Turbines and pumps; types of IC engines, Refrigeration and air conditioning and its working principle.	**Understanding (K2)**
18ME15.3	**Explain** the Properties, composition and application of engineering metals; Joining processes, belt drive and gear drives; Machining process like Lathe and milling process; Advanced machining processes like CNC and Robots.	**Understanding (K2)**
18ME15.4	**Calculate** the internal energy, entropy and enthalpy of thermodynamic system; thermodynamic properties of steam; the efficiency, power and other related working parameters of IC engines.	**Applying (K3)**
18ME15.5	**Derive** the length of the belt in open and cross belt drive and **solve** the related problems of Belt drive and gear drives.	**Applying (K3)**

MODULE-1 **Sources of Energy**: Introduction and application of energy sources like fossil fuels, hydel, solar, wind, nuclear fuels and bio-fuels; environmental issues like global warming and ozone depletion. **Basic concepts of Thermodynamics**: Introduction, states, concept of work, heat, temperature; Zeroth, 1st, 2nd and 3rd laws of thermodynamics. Concept of internal energy, enthalpy and entropy (simple numerical). **Steam**: Formation of steam and thermodynamic properties of steam (simple numerical). LO: At the end of this session the student will be able to, 1. Explain the renewable and non-renewable energy sources and its environmental impact. 2. Define basic concepts of thermodynamics 3. Understand the formation of steam and its thermodynamic properties.	CO1 CO4 14 hrs PO1-3 PO6-2 PO7-2 PO9-1 P10-1 PO12-2 PSO1-2 PSO2-3
MODULE-2 **Boilers**: Introduction to boilers, classification, Lancashire boiler, Babcock and Wilcox boiler. Introduction to boiler mountings and accessories (no sketches). **Turbines**: Hydraulic Turbines — Classification and specification, Principles and operation of Pelton wheel turbine, Francis turbine and Kaplan turbine (elementary treatment only). **Hydraulic Pumps**: Introduction, classification and specification of pumps, reciprocating pump and centrifugal pump, concept of cavitation and priming. LO: At the end of this session the student will be able to, 1. Classify and explain boilers with illustrations. 2. Classify and explain the working principle of hydraulic turbines. 3. Classify and explain the working principle of hydraulic pumps	CO2 14hrs. PO1-3 PO5-1 PO9-1 P10-1 PO12-2 PSO1-2 PSO2-3
MODULE —3 **Internal Combustion Engines** Classification, IC. Engines parts, 2 and 4 stroke petrol and 4-stroke diesel engines. P-V diagrams of Otto and Diesel cycles. Simple problems on indicated power, brake power, indicated thermal efficiency, brake thermal efficiency, mechanical efficiency and specific fuel consumption. **Refrigeration and Air conditioning** Refrigeration - Definitions - Refrigerating effect, Ton of Refrigeration, Ice making capacity, COP, relative COP, Unit of Refrigeration. Refrigerants, Properties of Refrigerants, List of commonly used refrigerants. Principle and working of vapor compression Refrigeration and vapor absorption Refrigeration. Domestic refrigerator. Principles and applications of air conditioners, window and split air conditioners. LO: At the end of this session the student will be able to, 1. Classify and explain the working principle of I.C Engines. 2. Define the basic concepts and working principle of Refrigeration	CO2 CO4 14hrs PO1-3 PO6-1 PO9-1 P10-1 PO12-2 PSO1-2 PSO2-3

MODULE -4 **Properties, Composition and Industrial Applications of engineering materials** Metals — Ferrous: cast iron, tool steels and stainless steels and nonferrous: aluminium, brass, bronze. Polymers - Thermoplastics and thermosetting polymers. Ceramics - Glass, optical fiber glass, cermets. Composites – Fiber reinforced composites, Metal Matrix Composites Smart materials —Piezoelectric materials, shape memory alloys, semiconductors and insulators. **Joining Processes:** Soldering, Brazing and Welding Definitions. Classification and methods of soldering, brazing and welding. Brief description of arc welding, oxy-acetylene welding, TIG welding, and MIG welding. **Belt drives** Open & crossed belt drives, Definitions -slip, creep, velocity ratio, derivations for length of belt in open and crossed belt drive, ratio of tension in flat belt drives, advantages and disadvantages of V belts and timing belts, simple numerical problems. **Gear drives** Types—spur, helical, bevel, worm and rack and pinion. Velocity ratio, advantages and disadvantages over belt drives, simple numerical problems on velocity ratio. LO: At the end of this session the student will be able to, 1. Understand the properties of common engineering materials. 2. Define different joining processes and classify them. 3. Understand and classify transmission systems such as belt drives and gear drives.	CO3 CO5 14hrs PO1-3 PO2-2 PO5-1 PO6-2 PO9-1 P10-1 PSO1-2 PSO2-3
Module 5 **Lathe** - Principle of working of a centre lathe. Parts of a lathe. Operations on lathe - Turning, Facing, Knurling, Thread Cutting, Drilling, Taper turning by Tailstock offset method and Compound slide swivelling method, Specification of Lathe. **Milling Machine** - Principle of milling, types of milling machines. Working of horizontal and vertical milling machines. Milling processes - plane milling, end milling, slot milling, angular milling, form milling, straddle milling, and gang milling. (Layout sketches of the above machines need not be dealt. Sketches need to be used only for explaining the operations performed on the machines) **Introduction to Advanced Manufacturing Systems** **Computer Numerical Control (CNC)**: Introduction, components of CNC, open loop and closed loop systems, advantages of CNC, CNC Machining centres and Turning centres. **Robots**: Robot anatomy, joints and links, common robot configurations. Applications of Robots in material handling, processing and assembly and inspection. LO: At the end of this session the student will be able to, 1. Explain the working principle and operations on lathe 2. Explain the working principle and processes on Milling machine 3. Understand advanced Manufacturing systems such as CNC and Robots.	CO3 14hrs PO1-3 PO2-1 PO9-1 P10-1 PO12-2 PSO1-2 PSO2-3

Text Books: - (specify minimum two foreign authors text books)

1. Elements of Mechanical Engineering, K. R. Gopalakrishna, Subhas Publications, Bangalore, 2008.
2. Elements of Mechanical Engineering, Vol.-1 & 2, Hajra Choudhury, Media Promoters, New Delhi, 2001 .

Reference Books:

1. Elements of Mechanical Engineering, R.K. Rajput, Firewall Media, 2005.
2. Elements of Mechanical Engineering, Dr. A. S. Ravindra, Best Publications, 7th edition, 2009.
3. CAD/CAM/CIIVI, Dr. P Radhakrishnan, 3rd edition, New Age International Publishers, New Delhi.
4. Introduction to Robotics: Mechanics and Control, Craig, J. J., 2nd Ed. Addison—Wesley Publishing Company, Readong, MA, 1989.
5. Introduction to Engineering Materials", B.K. Agrawal, Tata McGraHill Publication, New Delhi.
6. Thermal Science and Engineering", Dr. D.S. Kumar, S.K. Kataria & sons Publication, New Delhi.

Useful Websites

https://nptel.ac.in
www.icrank.com
www.howstuffworks.com
https://ocw.mit.edu/index.htm

Useful Journals

- International Journal of Machine Tools & Manufacture
- International Journal of Manufacturing Research
- Journal of Energy Resources and Technology
- International Journal of Air-Conditioning and Refrigeration

Teaching and Learning Methods:

1. Lecture class: 50 hrs.
2. Self-study: 3 hrs.
3. Practical classes: 2 hrs.

Assessment:

Type of test/examination: Written examination
Continuous Internal Evaluation(CIE): 40 marks (Average of total three tests will be considered)
Test duration: 1 :30 hr

Semester End Exam(SEE): 60 marks (students have to answer all main questions)
Examination duration: 3 hrs

CO to PO Mapping

PO1: Science and engineering Knowledge
PO2: Problem Analysis
PO3: Design & Development
PO4: Investigations of Complex Problems
PO5: Modern Tool Usage
PO6: Engineer & Society
PO7: Environment and Society
PO8: Ethics
PO9: Individual & Team Work
PO10: Communication
PO11: Project Mngmt & Finance
PO12: Lifelong Learning

PSO1: Ability to apply concept of mechanical engineering to design a system, a component or a process/system to address a real world challenges
PSO2: Ability to develop effective communication, team work, entrepreneurial and computational skills

CO to PO Mapping

CO	PO	PO1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO1 1	PO 12	PSO 1	PS O2
	K-level														
18ME 15.1	K2	3	-	-	-	-	2	2	-	1	1	-	2	2	3
18 ME 15.2	K2	3	-	-	-	-	-	-	-	1	1	-	2	2	3
18ME 15.3	K2	3	-	-	-	-	1	-	-	1	1	-	2	2	3
18 ME 15.4	K3	3	2	-	-	-	2	-	-	1	1	-	-	2	3
18ME 15.5	K3	3	1	-	-	-	-	-	-	1	1	-	2	2	3
Average		3	1.5	-	-	-	1.6	2	-	1	1	-	2	2	3

Justification for CO-PO mapping

CO	PO	Justification
CO1	PO1	Mapped to 3 as students are able to understand engineering knowledge of energy resources and how it is actually produced.
	PO6	Mapped to 2 as students attained the engineering and society knowledge by understanding the different sources of energy.
	PO7	Mapped to 2 as students attained the engineering and society knowledge by understanding the environmental issues like global warming, Ozone
	PO9	Mapped to 1 as students participate individually and work in team in the interactive sessions of the class and assignment.
	PO10	Mapped to 1 as students are able to communicate the knowledge gain in interactive or presentation of the learnt knowledge in the class.
	PO12	Mapped to 2 as the students are required to upgrade their knowledge of the Engineering material properties and the modern manufacturing processes.
	PSO1	Mapped to 2 as the students are enriched by this module to choose and use the proper material and manufacturing method for the different application.
	PSO2	Mapped to 3 as the student are made to understand and illustrate the processes and applications of the different energy resources.
CO2	PO1	Mapped to 3 as students are able to enrich their engineering knowledge with the understanding of the working and constructional features of boilers, turbines and IC engines
	PO9	Mapped to 1 as students participate individually and work in team in the interactive sessions of the class and assignment.
	PO10	Mapped to 1 as students are able to communicate the knowledge gain in interactive or presentation of the learnt knowledge in the class.
	PO12	Mapped to 2 as the students are required to upgrade their knowledge of the turbines, boilers and IC engines and its applications.
	PSO1	Mapped to 2 as the students are enriched by this module to choose and use the proper setup to develop the energy for the different application in the future.

	PSO2	Mapped to 3 as the student are made to understand and communicate working processes and applications of the turbines boilers and IC engines.
CO3	**PO1**	Mapped to 3 as students are able to augment their engineering knowledge in selection of materials and machining processes for the effective utilization of resources.
	PO6	Mapped to 1 as students perceive the engineering and society standards of different metals, its properties and its processing operations for effective selection of processes and materials for different applications.
	PO9	Mapped to 1 as students participate individually and work in team in the interactive sessions of the class and assignment.
	PO10	Mapped to 1 as students are able to communicate the knowledge gain in interactive or presentation of the learnt knowledge in the class.
	PO12	Mapped to 2 as the students are required to upgrade their knowledge of the material properties and machining processes and its applications.
	PSO1	Mapped to 2 as the students are endowed to understand the different properties and their application and the different machining operations for the manufacturing the efficient products.
	PSO2	Mapped to 3 as the student are made to demonstrate the material properties and effective manufacturing processes and applications.
CO4	**PO1**	Mapped to 3 as students are able to augment their engineering knowledge in selection of materials and machining processes for the effective utilization of resources.
	PO2	Mapped to 2 as the students are able to solve the related problems of steam properties and power calculations of the IC engine.
	PO6	Mapped to 2 as students able to use the engineering and society standards like steam tables and calculate the different properties of the steam and calculate the efficiency problems.
	PO9	Mapped to 1 as students participate individually and work in team in the interactive sessions of the class and assignment.
	PO10	Mapped to 1 as students are able to communicate the knowledge gain in interactive or presentation of the learnt knowledge in the class.
	PSO1	Mapped to 2 as the students are made understand the parameters of the steam and its properties and IC engine to enrol the performance of the Heat engines.
	PSO2	Mapped to 3 as the student develops the capability to understand the different performance of the factors and its calculation and present them to show case their performance.
CO5	**PO1**	Mapped to 3 as students are able to use the engineering knowledge to derive the equation of the different types of power transmission methods and solve the related problems.
	PO2	Mapped to 1 as the students are able to solve the related problems Belt drives and gear drive systems.
	PO9	Mapped to 1 as students participate individually and work in team in the interactive sessions of the class and assignment.
	PO10	Mapped to 1 as students are able to communicate the knowledge gain in interactive or presentation of the learnt knowledge in the class.
	PSO1	Mapped to 2 as the students are made understand the power transmission system and able to calculate the parameters of the mechanical systems.
	PSO2	Mapped to 3 as the student develops the capability do calculation parameters of the power transmission system and present them to show case their performance.

CO PO mapping for the events to be conducted after gap identification

Sl. No.	Gap Identification	CO	Relevant PO Mapping
1	Work with team and individual in communicating their knowledge attained.	**CO1,CO2,CO3,CO4,CO5**	**PO9** and **PO10** mapped to 1 as students will participate in the quiz session and given opportunity to present their learnings in the class.
2	There is no Engineering Society and governing forum information is discussed.	**CO1, CO3, CO4**	**PO6** is mapped to **2**; to cover this knowledge transfer to understand the engineering society's information to the students particularly for material standards and process standards.
3	Modern developments of the Turbines, boilers and IC engines were not covered in the syllabus.	**CO1,CO2,CO3**	**PO9** mapped to 1, **PO10** mapped to 1 and **PO12** mapped to 2 as the students are assigned to demonstrate the presentation on relevant advanced or present developments.

Signature of Course in charge

Signature of HOD-ME

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Kammavari Sangham (R) 1952

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DEPARTMENT OF MECHANICAL ENGINEERING

NAME OF THE STAFF : RAJESH G L

SUBJECT CODE/NAME : 18ME15/ ELEMENTS OF MECHANICAL ENGINEERING [EME]

SEMESTER/YEAR : 1st / I/ D Sec

ACADEMIC YEAR : 2020-2021

Sl. No.	Topic to be covered	Mode of Delivery	Teaching Platform	No. of Periods	Cumulative No. of Periods	Proposed Date
MODULE 1: Sources of Energy, Basic Concepts of Thermodynamics, Steam						
1	Introduction to sources of energy	Online	Zoom	1	1	28/12/2020
2	Application of energy sources like fossil fuels, hydel, solar, wind, nuclear fuels and bio-fuels	Online	Zoom	1	2	29/12/2020
3	Wind, nuclear fuels and bio-fuels	Online	Zoom	1	3	30/12/2020
4	Environmental issues like Global warming and ozone depletion.	Online	Zoom	1	4	31/12/2020
5	Introduction, states, concept of work, heat	Online	Zoom	1	5	1/01/2021
6	Temperature; Zeroth, 1st, 2nd and 3rd laws of thermodynamics.	Online	Zoom	1	6	2/01/2021
7	Concept of internal energy, enthalpy and entropy (simple numerical).	Online	Zoom	1	7	4/01/2021
8	Formation of steam.	Online	Zoom	1	8	5/01/2021

9	Thermodynamic properties of steam	Online	Zoom	1	9	6/01/2021
10	Thermodynamic properties of steam- Contd	Online	Zoom	1	10	7/01/2021
11	Exercise Problems	Online	Zoom	1	11	8/01/2021
MODULE 2: Boilers and Turbines						
12	Introduction to boilers, classification	Online	Zoom	1	12	9/01/2021
13	Lancashire boiler, Babcock and Wilcox boiler.	Online	Zoom	1	13	11/01/2021
14	Introduction to boiler mountings and accessories (no sketches).	Online	Zoom	1	14	12/01/2021
15	Hydraulic Turbines — Classification and specification,	Online	Zoom	1	15	13/01/2021
16	Principles and operation of Pelton wheel turbine	Online	Zoom	1	16	15/01/2021
17	Francis turbine and Kaplan turbine (elementary treatment only).	Online	Zoom	1	17	16/01/2021
18	Hydraulic Pumps: Introduction,	Online	Zoom	1	18	18/01/2021
19	Classification of pumps	Online	Zoom	1	19	19/01/2021
20	Classification- contd. (In-depth discussion)	L+D	BB	1	20	20/01/2021
21	Specification of pumps	L+D	BB+LCD	1	21	21/01/2021
22	Reciprocating pump	L+D	BB	1	22	22/01/2021
23	Centrifugal pump, Concept of cavitation and priming.	L+D	BB+ LCD	1	23	23/01/2021
MODULE 3: Internal Combustion Engines, Refrigeration and Air conditioning						
24	Classification, I C. Engines parts,	L+D	BB	1	24	25/01/2021
25	2 and 4 stroke petrol and 4-stroke diesel engines.	L+D	BB	1	25	27/01/2021
26	P-V diagrams of Otto and Diesel cycles.	L + D	BB LCD	1	26	1/02/2021
27	Simple problems on indicated power, brake power, indicated thermal efficiency, brake thermal efficiency, mechanical efficiency and specific fuel consumption.	PS	BB	1	27	2/02/2021

28	Simple problems on indicated power, brake power, indicated thermal efficiency, brake thermal efficiency, mechanical efficiency and specific fuel consumption.	PS	BB	1	28	4/02/2021
29	Simple problems on indicated power, brake power, indicated thermal efficiency, brake thermal efficiency, mechanical efficiency and specific fuel consumption.	PS	BB	1	29	5/02/2021
30	Definitions – Refrigerating effect, Ton of Refrigeration,	L+D	BB	1	30	6/02/2021
31	Ice making capacity, COP, relative COP, Unit of Refrigeration.	L+D	BB	1	31	8/02/2021
32	Refrigerants, Properties of Refrigerants, List of commonly used refrigerants.	L+D	BB	1	32	9/02/2021
33	Principle and working of vapor compression Refrigeration and vapor absorption Refrigeration.	L+D	BB+LCD	1	33	11/02/2021
34	Domestic Refrigerator window, Principles, Applications of air conditioners, split air conditioners.	L+D	BB+LCD	1	34	12-13/02/2021
MODULE 4: Properties, Composition and Industrial Applications of Engineering Materials						
35	Metals — Ferrous: cast iron, tool steels and stainless steels.	L+D	BB	1	35	15/02/2021
36	Nonferrous: aluminum, brass, bronze. Polymers Thermoplastics and thermosetting polymers.	L+D	BB	1	36	16/02/2021
37	Ceramics - Glass, optical fiber glass, cermets.	L+D	BB	1	37	18/02/2021
38	Composites – Fiber reinforced composites, Metal Matrix Composites Smart materials.	L+D	BB	1	38	20/02/2021
39	Piezoelectric materials, shape memory alloys, semiconductors and insulators.	L+D	BB	1	39	22/02/2021
40	Definitions. Classification and methods of soldering, brazing and welding.	L+D, LW	Lab Visit	1	40	23/02/2021

41	Brief description of arc welding, oxy-acetylene welding, TIG welding, and MIG welding.	L+D	BB+LCD	1	41	1/03/2021
42	Open & crossed belt drives, Definitions -slip, creep, velocity ratio.	L+D	BB	1	42	2/03/2021
43	Derivations for length of belt in open and crossed belt drive, ratio of tension in flat belt drives,	L+D	BB	1	43	5/03/2021
44	Advantages and disadvantages of V belts and timing belts, simple numerical problems.	L+D, PS	BB	1	44	8/03/2021
45	Types—spur, helical, bevel, worm and rack and pinion. Velocity ratio,	L+D, PS	BB+LCD	1	45	12/03/2021
46	Advantages and disadvantages over belt drives, Simple numerical problems on velocity ratio.	L+D	BB+ LCD	1	46	15/03/2021
MODULE 5:Lathe, Milling Machine, Introduction to Advanced Manufacturing Systems						
47	Principle of working of a center lathe. Parts of a lathe.	L+D	BB+LV	1	47	18/03/2021
48	Operations on lathe - Turning, Facing, Knurling, Thread Cutting, Drilling,	L+D	BB+LV	1	48	19/03/2021
49	Taper turning by Tailstock offset method and Compound slide swiveling method,	L+D	LCD	1	49	20/03/2021
50	Specification of Lathe.	L+D	BB	1	50	22/03/2021
51	Principle of milling, types of milling machines.	L+D	BB	1	51	23/03/2021
50	Working of horizontal and vertical milling machines.	L+D	BB	1	52	25/03/2021
51	Milling processes - plane milling, end milling, slot milling,	L+D,LW	BB, Lab Visit	1	53	26/03/2021
52	Angular milling, form milling, straddle milling, and gang milling.	L+D	LCD	1	54	27/03/2021

52	Introduction, components of CNC,	L+D	BB	1	55	29/03/2021
53	Open loop and closed loop systems, advantages of CNC,	L+D	BB	1	56	30/03/2021
54	CNC Machining centers and Turning centers, Robot anatomy, joints and links,	L+D	BB	1	57	31/03/2021
55	Common robot configurations, Applications of Robots in material handling, Applications of Robots in material handling,	L+D	BB+LCD	1	58	9/04/2021
56	Processing and Assembly – Applications of robots – contd. Applications of robots in inspections (Quality control)	L+D	BB+LCD	1	59	10/04/2021

Signature of Course Incharge

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DEPARTMENT OF MECHANICAL ENGINEERING

ASSIGNMENT QUESTIONS

Academic Year	**2020-2021**		
Batch	**2020-2024**		
Year/Semester/section	**I/I/D**		
Subject Code-Title	**18ME15-ELEMENTS OF MECHANICAL ENGINEERING**		
Name of the Staff	**RAJESH G.L**	**Dept**	**ME**

Assignment No: 1 **Total marks:10**
Date of Issue: 25/1/2021 **Date of Submission: 30/1/2021**

Sl. No	Assignment Questions	K Level	CO	Marks
1.	Explain briefly i) Global Warming ii) Ozone depletion	K2	CO1	01
2.	Explain briefly the principle of conversion of solar energy directly into electrical energy in a solar cell.	K2	CO1	01
3.	With a neat sketch explain the principle of operation of a typical wind mill.	K2	CO1	01
4.	Explain briefly any two of the following; Zeroth law, first and second law of thermodynamics.	K2	CO1	01
5.	A stationary mass of gas at its initial state $0.4m^3$ and 0.105MPa was compressed at constant pressure to final state of $0.2m^3$ and 0.105MPa. The heat transfer from the gas during the process was 42.5kJ. Calculate the change in internal energy of the gas.	K2	CO1	01
6.	Explain the concept of heat and work transfer with diagram.	K2	CO1	01
7.	Explain idler pulleys and illustrate their different configurations	K2	CO4	01
8.	Briefly explain classification of polymers with a neat sketch.	K2	CO4	01
9.	Explain any two engineering materials briefly and give examples for their uses.	K2	CO4	01
10.	What are transmission elements? How are they classified?	K2	CO4	01
			Total	10

Rajesh GL
Signature of Course Incharge

27/1/2021
Head of the Department

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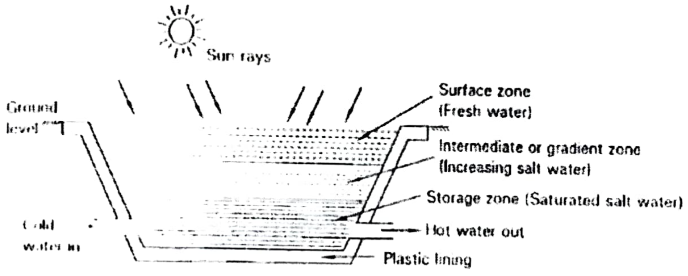
K.S. INSTITUTE OF TECHNOLOGY, BANGALORE - 560109

I SESSIONAL TEST QUESTION PAPER 2020 – 21 ODD SEMESTER

SCHEME AND SOLUTION (Assignment-1)

Degree : **BE**
Branch : **EC**
Course Title : **Elements of Mechanical Engineering**

Semester : **I (D)**
Course Code : **18ME15**
Max Marks : **30**

Q. No	SOLUTION	MARKS
1	**Solar energy utilization using solar pond:** *Construction* ▪ Usually solar pond is constructed below the ground level. ▪ There are three distinct zones in a solar pond, with salt content increasing from top surface of the pond to its bottom. ▪ Storage zone: lower zone of water, rich in salt content and it is the area where solar radiation is absorbed and stored. ▪ Surface zone: Upper zone of water which is cold and has very low salt content. ▪ Intermediate zone: Separates the upper zone of cold water and the lower zone of the hot water and forms an important area in the solar pond.	02
		02
	Operation ▪ As solar radiation is absorbed, the hot water in the storage zone cannot rise due to high salt content in it while the cold water at the surface of the pond having less salt content cannot sink, because the water below (intermediate zone) has a rich salt content and is comparatively denser. ▪ The hot water thus remains in the bottom layer of the pond from which useful heat may be withdrawn and used for various purpose.	02

2	**Zeroth law of thermodynamics:** When two systems are each in thermal equilibrium with a third system, then the two system are also in thermal equilibrium with each other.	02
	I law of thermodynamics: When a closed system undergoes a thermodynamic cycle, the net heat transfer is equal to the net work transfer. $\oint \delta Q = \oint \delta W$	02
	III Law: The entropy of a pure substance in thermodynamic equilibrium approaches zero as the temperature approaches zero. $\lim_{T \to 0} S = 0$	02
3	**Solution : Initial condition of gas (state 1) :** Volume of gas = $V_1 = 0.4\ m^3$ Pressure = $P_1 = 0.105\ MPa = 0.105 \times 10^6\ N/m^2$ ($\because$ mega = 10^6 and $Pa = N/m^2$) **Final condition (state 2) :** Volume $V_2 = 0.2\ m^3$ Pressure = $P_2 = 0.105\ MPa = 0.105 \times 10^6\ N/m^2$ Note that since $P_1 = P_2$, the compression process takes place at constant pressure.	01
	Heat transfer from the gas = $Q = -42.5\ kJ$ ($-^{ve}$ sign indicates heat is rejected from the system) w.k.t. change in internal energy = $\Delta E = Q - W$ ----- (1) But work $W = ?$	01
	w.k.t. displacement work = $W = \int_1^2 P.dv = P(V_2 - V_1)$ $W = (0.105 \times 10^6)(0.2 - 0.4) = -21 \times 10^3 \frac{N}{m^2} \times m^3 = -21 \times 10^3\ Nm$ Work = $-21\ kJ$ ($\because$ kilo = 10^3 and Nm = Joule)	02
	Now equation (1) becomes, $\Delta E = -42.5 - (-21) = -21.5$ $\therefore$ Change in internal energy = ΔE = **− 21.5 kJ** ($-^{ve}$ sign indicates decrease in internal energy of the system)	02
4	**Ozone layer depletion:** ▪ Ozone depletion refers to the gradual thinning of the earth's ozone layer in the upper atmosphere, caused by the release of chemical compounds containing gaseous chlorine or bromine from industries and other emissions from human activities. ▪ Ozone layer is a deep layer in the stratosphere encircling the earth, that has large amounts of ozone in it. ▪ Ozone layer shields the entire earth from the harmful UV radiation of the sun thereby protecting the living beings on the earth. ▪ In 1970's it was discovered that man made chemicals called chlorofluorocarbons (CFC's) that were released into the atmosphere gradually decompose, releasing chlorine atoms that destroy the ozone in the ozone layer. ▪ Each chlorine atom has the ability to destroy tens of thousands of ozone molecules.	03

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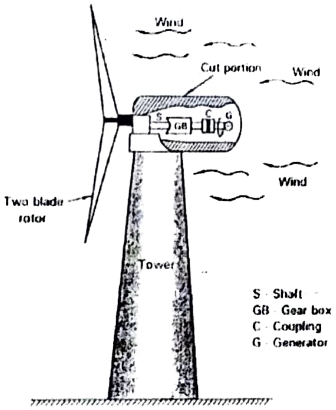
rt ID : VTUG0

	- The depletion of ozone layer thus leads to its inability to shield the UV radiation reaching the earth's surface thereby increasing the radiation effects like skin cancer, eye cataracts and damage to immune system. **Global warming:** - A gradual increase in the average temperature of the earth's atmosphere and its oceans, a change that is believed to be permanently changing the earth's climate. - The climatic change is due to the increased volumes of CO_2 and other green house gases (toxic gases) released by the burning of fossil fuel, land clearing, agriculture and other emissions created by human activities that have occurred over past years. - The gases form a layer in the atmosphere and trap the sun's radiation which in turn makes the planet warmer. - Global warming leads in rising sea levels due to the melting of the polar ice caps as well as an increase in occurrence and severity of storms, droughts and other severe weather events.	03
5	**Wind energy and its conversion:** 	03
	Operation of wind mill: - The kinetic energy of the flow of wind causes the blades to rotate at slow speeds. - The gear box comprising of many gears is used to increase the rotational speed of the shaft to that range required to produce electricity. - The high speed of the shaft thus drives the generator to produce electricity. - The power produced by the generator is transferred down the tower to the power grid system and then through the transmission lines.	03

6 **Concept of heat and work transfer:**

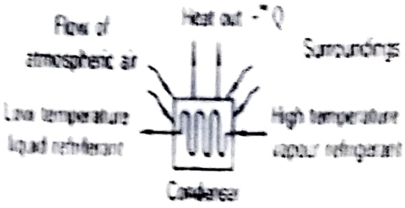
Heat:

- It is defined as the transfer of energy taking place across the boundary of a system or between two different bodies due to the temperature difference between them.
- Heat is transferred naturally from a body of higher temperature to a body of lower temperature.
- Heat is denoted by Q and expressed in kJ. 02

Sign convention

- If heat is transferred from the surroundings to the system, it is considered as +ve.
- If heat is transferred from the system to the surroundings, it is considered as –ve.

(a) Heat added to convert water into steam



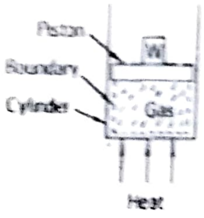
(b) Heat rejected to atmosphere by the refrigerant 01

Work:

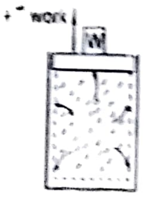
- In thermodynamics, work refers to the energy transfer between the system and its surroundings by a mechanism through which the system can spontaneously exert macroscopic forces on its surroundings.
- In simple words, work is the energy transfer, associated with a force acting through a distance. Denoted by W and expressed in kJ.

Sign convention

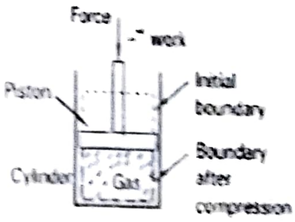
- If work is done by the system, it is considered as +ve. 02
- If work is done on the system it is considered as –ve.



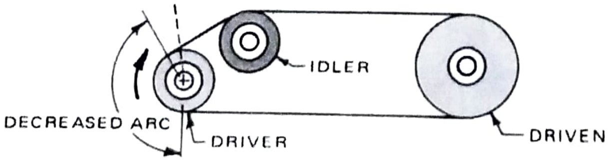
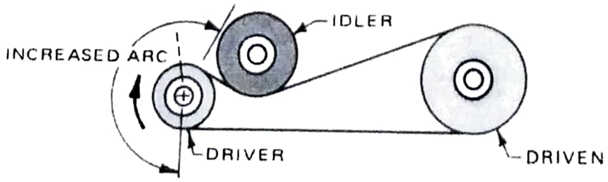
(a) Heat supplied to system

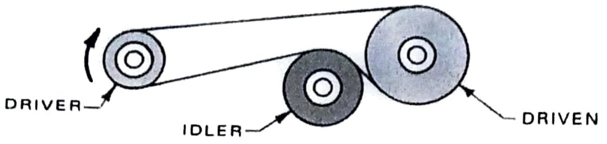
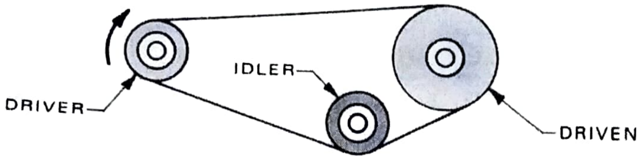


(b) Work done by the system



(c) Work done on the system 01

7	List of engineering materials: ▪ Polymers – thermoset and thermoplastics ▪ Metals – Ferrous and non ferrous metals ▪ Ceramics – glasses, cermets ▪ Composites – PMC, MMC, CMC ▪ Smart materials – piezoelectric, shape memory alloy ▪ Insulators and semi-conductors Two of them explained with examples of their uses	02 04
8	Polymers: Group of polymers that are built from relatively simple units called monomers through a chemical polymerization process. Classification of polymers: ▪ Thermoplastics – Polyethylene, polystyrene, PVC, polypropylene, nylon, Teflon etc. ▪ Thermosetting plastics – Epoxy, polyester, phenol formaldehyde etc Any one polymer explained along with the process used to manufacture a product	01 02 03
9	Classification of transmission elements: ▪ Flat belts ▪ V-belts ▪ Rope drives ▪ Chains ▪ Gears ▪ Timing belts Any two explained	02 04
10	An IDLER Pulley is neither a driver nor a driven pulley but used in a belt drive to increase the angle of contact and thereby the transmission efficiency.  (A) INSIDE IDLER PULLEY, AT LEAST AS LARGE AS THE SMALL SHEAVE, ON THE SLACK SIDE OF THE DRIVE  (B) OUTSIDE IDLER PULLEY, AT LEAST 1.3 LARGER THAN THE SMALL SHEAVE	02

	 (C) OUTSIDE IDLER PULLEY ON THE TIGHT SIDE OF THE DRIVE  (D) INSIDE IDLER PULLEY ON THE TIGHT SIDE OF THE DRIVE	04

Signature of Course Incharge

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DEPARTMENT OF MECHANICAL ENGINEERING

ASSIGNMENT QUESTIONS

Academic Year	2020-2021		
Batch	2020-2024		
Year/Semester/section	I/I/D		
Subject Code-Title	18ME15-ELEMENTS OF MECHANICAL ENGINEERING		
Name of the Staff	RAJESH G.L	Dept	ME

Assignment No: 2 **Total marks:10**
Date of Issue: 24/2/2021 **Date of Submission: 06/3/2021**

Sl. No	Assignment Questions	K Level	CO	Marks
1.	Explain the formation of steam at constant pressure with the help of T-H diagram.	K2	CO1	01
2.	With the neat labelled diagram, explain the operation of Babcock and Wilcox steam boiler.	K2	CO2	01
3.	Discuss the function/features of the following boiler mounting and accessories i) Pressure gauge ii) Blow off cock iii) Steam separator iv) Air preheater.	K2	CO2	01
4.	Mention the advantage, disadvantage and applications of Lancashire steam boilers.	K2	CO2	01
5.	Estimate the amount of heat needed to convert 5kg of water at 50°C into steam at a pressure of 9bar and with 250°C of superheat. Take specific heat at constant pressure for superheated steam as 2.1kJ/kg K and specific heat of water as 4.187kJ/kg K.	K2	CO1	01
6.	3kg of wet steam at 6.0 bar pressure is heated. Determine the enthalpy when it is i) 75% dry ii) Superheated to 300°C.	K2	CO1	01
7.	Differentiate between soldering, brazing and welding.	K2	CO4	01
8.	Explain Oxy-acetylene welding process with a neat sketch.	K2	CO4	01
9.	List different types of gears and explain any one with its advantages.	K2	CO4	01
10.	What are gear trains? How are they classified?	K2	CO4	01
			Total	10

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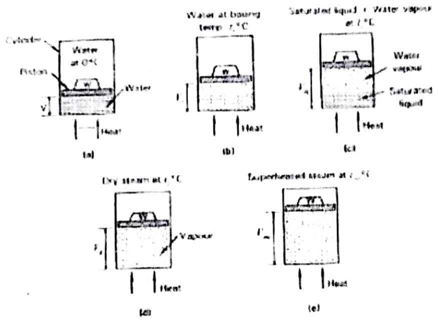
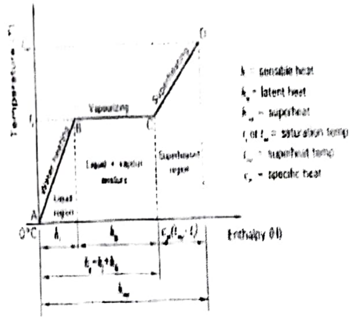
K.S. Institute of Technology

K.S. INSTITUTE OF TECHNOLOGY, BANGALORE - 560109
II SESSIONAL TEST QUESTION PAPER 2020 – 21 ODD SEMESTER

SCHEME AND SOLUTION (Assignment-2)

Degree	**:**	**BE**	**Semester**	**:**	**I (D)**
Branch	**:**	**EC**	**Course Code**	**:**	**18ME15**
Course Title	**:**	**Elements of Mechanical Engineering**	**Max Marks**	**:**	**30**

Q. No	SOLUTION	MARKS
1	**Steam formation at constant pressure** Consider 1kg of water at 0°C taken in a cylinder, fitted with a freely moving piston. A weight W is placed over the piston as shown in Figure. The weight of the piston and weight W placed over the piston exerts a constant pressure P on the water. Let V be the volume occupied by the water in the cylinder. The condition of water at 0°C is represented by a point A on the temperature-enthalpy (T-H) diagram. When water is heated at constant pressure, it is converted to steam.  Figure 3.1 Formation of steam at constant pressure  Figure 3.2 Temperature enthalpy (TH) diagram	02
	The various stages involved in the process are ▪ On heating, the temperature of the water rises and at a certain temperature water begins to boil/evaporate. The temperature at which water starts boiling is known as saturation temperature and is denoted by t_s. The heating of water from °C to the saturation temperature (t_s) is shown by line AB on T-H diagram. At this temperature, there is a slight increase in the volume of water (V_f) as shown in figure. ▪ When water is heated beyond the saturation temperature, there will be no rise in temperature but evaporation of water takes place (water starts converting into steam). At this stage, water exists as a two-phase mixture containing saturated liquid and water vapour occupying volume V_{fg}. The steam in this condition is called wet steam.	02

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Evaporation of water continues at the same saturation temperature until the whole of the water is completely converted into steam (Line BC on T-H diagram).
At point C, the steam formed does not contain water vapour and hence the steam in this state is called dry steam or dry saturated steam, occupying volume V_g.
If the heating is further continued at point C, the temperature of the steam increases above the saturation temperature and this temperature is called superheat temperature (t_{sup}). The steam in this condition is called superheated steam (Line CD on T-H diagram) occupying volume V_{sup}.

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Given:- Mass of wet steam = 3kg, P = 6bar
From tables, t_s=158.83°C, h_f= 670.38kJ/kg, h_{fg} = 2085.8kJ/kg, h_g = 2756.2kJ/kg

a) 75% dry (x=0.75)
$h_w = h_f + x\ h_{fg}$
h_w = 670.38+(0.75×2085.8)
= 2234.73kJ/kg [For 1kg of steam]
= 2234.73×3
= 6704.19kJ [For 3kg of steam]

b) Superheated to 300°C
$h_{sup} = h_g + Cp_s(t_{sup} - t_s)$
h_{sup} = 2756.2+2.25(300-158.83)
= 3073.83kJ/kg[For 1kg of steam]
= 3073.83×3
= 9221.49kJ [For 3kg of steam]
</td>
<td>01
02
03</td>
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<tr>
<td>3</td>
<td>
Advantage, disadvantage and applications of Lancashire boiler
<table>
<tr><th>Advantage</th><th>Disadvantage</th></tr>
<tr>
<td>1. It has high thermal efficiency; the thermal efficiency is about 80 to 90%.
2. It is easy to operate.
3. Easy to maintain.
4. Generate a large amount of steam and hence more reliable.</td>
<td>1. It has a limited grate area due to the small diameter of the flue tubes.
2. The steam production rate is low.
3. Low-pressure type boiler, so high-pressure steam is not produced.
4. Tedious maintenance of brickwork.</td>
</tr>
</table>
<i>Applications:</i> Employed in sugar mills, textile and paper industries
</td>
<td>04
02</td>
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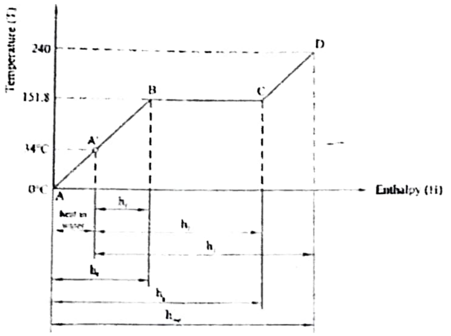
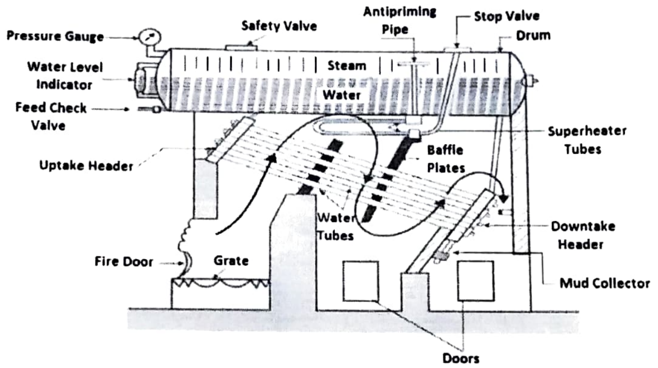
</table>

4	**Step 1** Data Mass of steam = 3 kg. Pressure = P = 5 bar Initial temperature of water = 34°C C_{ps} = 2 25 kJ/kg K, C_{pw} = Specific heat of water = 4.187 kJ/kg K From steam tables, at P = 5 bar, we have t_{sat} = 151.8°C, h_f = 640 1 kJ/kg h_{fg} = 2107 4 kJ/kg and h_g = 2747 5 kJ/kg	01
		
	∴ Heat already in water (portion AA') = $m\, C_{pw}\, \Delta T$ (m = Mass of water = 1 kg) ΔT = change in temperature= 34°C – 0°C = 34°C ∴ Heat already in water = 1 × 4.187 × 34 = 142.35 kJ/kg	01
	Step 2 When steam is wet with $x = 0.8$ Let H_w = heat required to convert 1 kg of water at 0°C into wet steam w.k.t enthalpy of wet steam (between points A & B) = $h_w = h_f + x\, h_{fg}$ = 640.1+ (0.8×2107.4) H_w = 2326.02 kJ/kg Let h_l = actual quantity of heat supplied to produce 1 kg of wet steam from water whose initial temperature is 34°C ∴ $h_l = h_w$ – heat already in water = 2326.02 – 142.35 h_l = 2183.67 kJ/kg of steam ∴ to produce 3 kg of steam, heat required = h_l = 3×2183.67 **h_l = 6551.01 kJ for 3 kg of steam** Thus 6551.01 kJ of heat is required to produce 3 kg wet steam from water at 34°C.	02
5	**Babcock and Wilcox boiler** ▪ Horizontal, externally fired, stationary, natural circulation water tube boiler. ▪ Steam pressure of 12-18bars (Range of pressure) ▪ Evaporation capacity 20,000-40,000 kg/hour. ▪ Application: generation of high pressure steam in thermal power plants. Working: ▪ First water starts to flow into the water tubes from drum through down take header.	01

- The water present in the inclined water tubes gets heated up by the hot flue gases. The coal burning on the grate produces hot flue gases and it is forced to move in zigzag way with the help of baffle plates.
- As the hot flue gases come in contact with water tubes, it exchanges the heat with water and converts it into steam.
- The steam generated is moved upward through up take header which gets collected at upper side in the boiler drum.
- T-tube is provided in the drum. This anti-priming pipe filters the water content from the steam and allows only dry steam to enter into superheater.
- The superheater receives the water free steam from the T-tube. It increases the temperature of steam to desired level and transfers it to the steam stop valve.
- The superheated steam from the steam stop valve is either collected in a steam drum or made to strike on the steam turbine for electricity generation.

04



Babcock and Wilcox Boiler

03

6

Solution :

Step 1 Data

Mass of dry steam = m = 2 kg, Pressure = 7 bar Initial temperature of water = 25°C.

From steam tables, at P = 7 bar, we have,

$t_{sat} = 165^\circ C$, $h_f = 697.1$ kJ/kg, $h_{fg} = 2064.9$ kJ/kg & $h_g = 2762$ kJ/kg

The details are plotted on the T-H diagram as shown in figure P.17

01

Step 2 To find h_t

Heat initially present in water (AA') = $m\, C_{pw}\, \Delta T$ (m = 1 kg of water & C_{pw} = 4.18 kJ/kg K)

$= 1 \times 4.18 \times (25 - 0) = 104.5$ kJ/kg

02

Let h_g = heat required to convert 1 kg of water at 0°C into dry saturated steam.

w.k.t. enthalpy of dry steam = $h_g = h_f + h_{fg}$

From steam tables, at P = 7 bar, we have, h_g = 2762 kJ/kg

Let h_t = actual heat required to produce 1 kg of dry steam from water at 25°C

$\therefore\ h_t = h_g$ − heat already in water = 2762 − 104.5

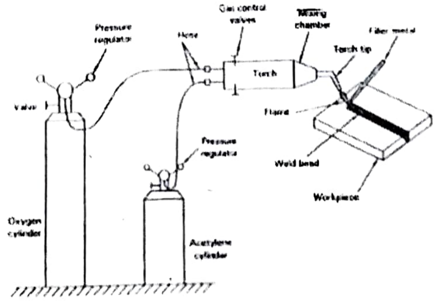
h_t = 2657.5 kJ/kg of steam

02

$\therefore$ to generate 2 kg of dry steam, heat required, $h_t = 2 \times 2657.5 = 5315$

h_t = 5315 kJ for 2 kg of dry steam

01

7	**Oxy-acetylene welding process** • Principle: When oxygen and acetylene are mixed in suitable proportions in a welding torch and ignited, the flame resulting at the tip of the torch has a temperature ranging from 3100°C-3500°C which is sufficient enough to melt and fuse the workpiece metals. Filler metal may or may not be used during the process.	01
	• Construction details: ▪ Two large cylinders: one containing oxygen at high pressure and the other containing acetylene gas. ▪ Two pressure regulators fitted on the respective cylinders to regulate or control the pressure of the gas flowing from the cylinders to the welding torch as per requirements. ▪ Welding torch: Used to mix oxygen and acetylene gas in proper proportions and burn the mixture at its tip. ▪ A match stick or a may be used to ignite the mixture at the torch tip.	02
	▪ Operation: ▪ By adjusting the pressure regulators, suitable proportions of oxygen and acetylene gases enter into the welding torch. ▪ The gases get mixed in the torch and are issued from the torch to burn in the atmosphere. ▪ A match stick is used to ignite the gas at the torch tip. The resulting flame at the torch tip has a temperature ranging from 3100-3500°C and this heat is sufficient enough to melt the workpiece metals. ▪ Since a slight gap usually exists between the two workpieces, a filler metal may be used to supply the additional material to fill the gap. ▪ The molten metal of the filler metal combines with the molten metal of the workpiece and upon solidification form a single piece of metal.	03
		02
8	**Different types of gears:** i. Spur gear ii. Bevel gear iii. Helical gear iv. Worm gear v. Rack and Pinion gear	01
	Explanation of any one type of gear	03

9

A gear train is two or more gear working together by meshing their teeth and turning each other in a system to generate power and speed. It reduces speed and increases torque

02

Types of gear trains

- Simple gear train
- Compound gear train
- Planetary gear train

02

10

Differences between soldering, brazing and welding

Sl. No.	Soldering	Brazing	Welding
1.	Low temperature process. Base metals are not melted	Base metals are not melted, but heated to suitable temperature	High temperature process wherein base metals are heated above their T_m
2.	Filler metal is not same as that of base metal	Filler metal is not same as that of base metal	Filler material used is of the same material as that of base metal
3.	Joint is formed by diffusion of the filler metal into the base metal	Diffusion of filler metal into the base metal associated with surface alloying	Solidification of the molten filler metal with the molten base metal
4.	Strength of the joint is comparatively low	Strength lies between that of welded and soldered joint	Much stronger than the base metal
5.	No heat effected zone	Heat affected zone is not too much when compared to welding	Heat affected zone is affected to a large extent
6.	Finishing operations are not required	Sometimes brazed joints require finishing	Requires finishing operations like grinding, filing etc
7.	Sheet metal work and electronic industries	Arts, jewellery works	Fabrication and structural works

08

Signature of Course Incharge

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DEPARTMENT OF MECHANICAL ENGINEERING

ASSIGNMENT QUESTIONS

Academic Year	2020-2021		
Batch	2020-2024		
Year/Semester/section	I/I/D		
Subject Code-Title	18ME15-ELEMENTS OF MECHANICAL ENGINEERING		
Name of the Staff	RAJESH G.L	Dept	ME

Assignment No: 3
Date of Issue: 11/3/2021
Total marks:10
Date of Submission: 24/3/2021

Sl. No	Assignment Questions	K Level	CO	Marks
1.	With a neat sketch, explain the working of tangential flow turbines.	K2	CO2	01
2.	Explain the construction and operation of reciprocating pumps with a neat diagram.	K2	CO2	01
3.	Discuss the concept of cavitation and priming in centrifugal pump.	K2	CO2	01
4.	With a PV diagram, explain the working of Otto cycle engines.	K2	CO3	01
5.	Differentiate between vapour compression refrigeration and vapour absorption refrigeration cycle.	K2	CO3	01
6.	Obtain an expression for length of belt in cross belt drive.	K2	CO5	01
7.	Explain briefly the following i) taper turning, ii) boring iii) gang milling iv) angular milling.	K2	CO5	01
8.	What are machine tools? How are they classified?	K2	CO5	01
9.	Explain the working of horizontal milling machine with a neat sketch.	K2	CO5	01
10.	Define robot. Write down the industrial applications of robot.	K2	CO5	01
			Total	10

Signature of Course Incharge

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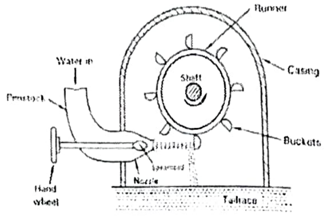
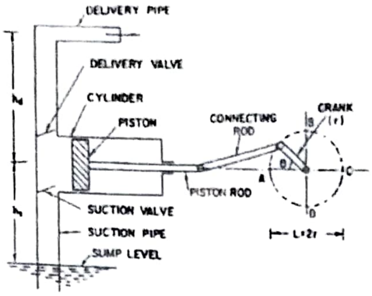
III SESSIONAL TEST QUESTION PAPER 2020 – 21 ODD SEMESTER

SCHEME AND SOLUTION (Assignment-3)

Degree : **BE** **Semester** : **I (D)**
Branch : **EC** **Course Code** : **18ME15**
Course Title : **Elements of Mechanical Engineering** **Max Marks** : **30**

Q. No	SOLUTION	MARKS
1	**Pelton wheel:** Tangential flow impulse turbine in which potential energy of water is converted into kinetic energy to form high speed water jet and this jet strikes the wheel tangentially to make it rotate.	01
	Parts: Nozzle with a spear head, Runner & Buckets, Turbine Casing	01
	Working: ▪ Water from the reservoir having potential energy flows through the penstock and enters the nozzle. ▪ Potential energy of water is completely converted into kinetic energy in the nozzle. The high velocity water jet from the nozzle impinge on the hemispherical blades fixed around the runner wheel. ▪ The impulse force due to the high velocity jet sets the runner wheel into rotary motion. ▪ The shaft coupled to the runner wheel also rotates thereby doing useful work. ▪ The work produced at the output shaft is used to drive a generator to produce electricity.	02
		02
2	**Reciprocating pump:** ▪ In reciprocating pump, the pressure energy of fluid is increased by pushing the fluid using piston/plunger that reciprocates in closed fitting cylinder.	01
	▪ Parts of reciprocating pump: Cylinder with piston and piston rod, Crank and connecting rod, Suction pipe and delivery pipe. ▪ When electric motor is energized (switched ON), the crank rotates, transferring motion to the piston, which reciprocates (to and fro movement) inside the cylinder.	01

	▪ I half cycle: When crank rotate from point A to C (180° rotation), piston moves towards right of the cylinder, creating partial vacuum within the cylinder. ▪ Since atmospheric pressure acting on the water in sump > than suction pressure inside the cylinder, water from sump is forced in suction pipe to move into the cylinder. ▪ The force of fluid opens the suction valve, causing it to move into the cylinder. The delivery valve remains closed during this action.  ▪ II half cycle: When crank rotates from point C to A (180°), piston moves towards left of cylinder from extreme right side. ▪ The movement of piston towards left, increases the pressure of the fluid inside the cylinder more than atmospheric pressure. Hence suction valve closes and delivery valve opens. ▪ The liquid is forced into the delivery pipe to get discharged to required destination (tank).	02 02
3	**Concept of cavitation in centrifugal pump:** ▪ Phenomenon of formation of vapour bubble and its subsequent collapse in the low pressure region around the pump parts. ▪ Identified by a clear audible noise and vibrations caused by the violent collapse of vapour bubbles. ▪ Bubble formation: It usually occurs when a liquid is subjected to changes of pressure such that the static pressure goes lower than the liquid's vapour pressure which will cause the formation of bubbles in the liquid. ▪ When subjected to higher pressure, the bubbles implode. When these implosions happen near a solid material for e.g. impeller, the bubbles implode with a micro-jet hitting the material surface, causing erosion. ▪ Repeated bursts of micro-jets will cause further erosion which spreads and ultimately results in catastrophic equipment failure. ▪ The power consumption for pump operation increases and also there is a decrease flow pressure. ▪ Precautionary measures to avoid cavitation in pumps a) Ensure suitable liquid level in suction pipe b) Lower the water temperature	03

37	1KS20EC037
38	1KS20EC03
39	1KS20EC
40	1KS20E
41	1KS2

eport IP

	c) By suitable impeller design d) Periodic checking of clogged strainers and blockages in pipes. e) Ensures that the pressure of fluid at all points within the pump remains above saturation pressure. **Priming in centrifugal pump:** ▪ Process of filling fluid into the casing, suction pipe and delivery pipe up to the delivery valve before starting the pump. ▪ Priming is required in order to remove the air entrapped in the pump, thereby reducing the risk of pump damage during start-up. ▪ Pressure developed inside the pump ∝ density of fluid in it. ▪ In case, if air is trapped in the pump and the impeller is allowed to rotate, pressure energy of fluid is not sufficient to lift up; because density of fluid is less [due to presence of air particle]. ▪ The presence of air in the pump creates a small negative pressure at the suction pipe that prevents suction of fluid from sump ▪ In order to eliminate the trapped air, pump is filled with fluid before starting it. [when filled with fluid, the pump is said to be primed]	03
4	**4-s Petrol engine:** ▪ Works on Otto cycle (Otto cycle engines). ▪ Charge used: mixture of air and petrol supplied by carburettor in suitable proportions. ▪ The charge is ignited by spark generated by a spark plug (S.I engines). ▪ Uses of 4-s petrol engine: scooters, motor bikes, cars, large boats etc. ▪ Four different strokes performed : i. Suction stroke ii. Compression stroke iii. Power stroke/expansion stroke/working stroke iv. Exhaust stroke Suction stroke: ▪ At the beginning of suction stroke, piston is at the TDC and is about to move towards BDC [inlet valve – opened, exhaust valve – closed]. ▪ The downwards movement of piston produces partial vacuum (suction) in the cylinder, which draws fresh air and petrol mixture through the inlet valve. ▪ When the piston reaches BDC, suction stroke ends and inlet valve is closed. ▪ The suction of fuel mixture takes place at atmospheric pressure [Line AB in *pv* diagram]. With this stroke, crankshaft rotates through 180° / half revolution. [The energy required for the piston movement is taken from the battery]. Compression stroke: • Piston moves from BDC to TDC [both inlet and exhaust valve remains closed].	01 02

1KS20EC033	38	38	37	

- As the piston moves upwards, air-petrol mixture gets compressed due to which p and T of mixture increases.
- The compression process is adiabatic in nature [Curve BC]
- When piston about to reach TDC, spark plug initiates spark that ignites the air-petrol mixture.
- Combustion of fuel mixture takes place at constant volume [Line CD](constant volume cycle engines).
- With this stroke, crankshaft rotates by another 180° / half revolution.

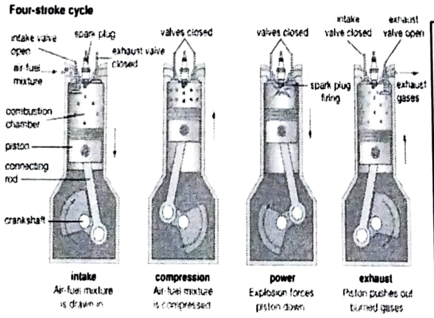
Power stroke: 03

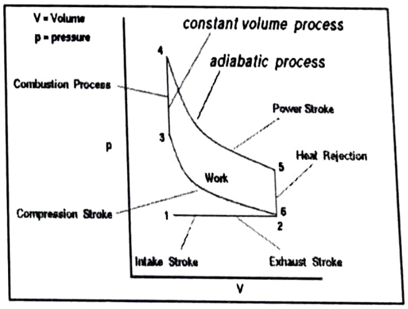
- During this stroke, both valves will remain closed.
- As the combustion of fuel takes place, the burnt gases expands and exert a large force on the piston causing it move rapidly from TDC to BDC.
- The force/power is transmitted to the crankshaft through the connecting rod. As a result, crankshaft rotates at high speed [Clutches – gears – wheels of vehicle]
- The expansion of gases is adiabatic in nature [Curve DE].
- Power/working/expansion stroke

Exhaust stroke:

- Towards the end of expansion stroke, the exhaust valve opens and inlet valve remains closed.
- A part of burnt gases due to their own expansion escapes out of the cylinder through exhaust valve [drop in pressure at constant volume inside the cylinder – Line EB]
- The exhaust stroke begins when the piston starts moving from BDC to TDC [Energy for this stroke – flywheel]
- As the piston moves upwards, forces remaining burnt gases to the atmosphere through exhaust valve [Line BA]
- When the piston reaches TDC, the exhaust valve closes and the working cycle is completed.

In the next cycle, the piston starts moving from TDC to BDC, the inlet valve open allowing fresh air to enter into the cylinder and the process continues. Thus in 4-s engines, the working cycle is completed when crankshaft rotates through 720° or two revolutions.





04

5

Differences between VCR and VAR (any six)

Sl. No.	VCR system	VAR system
1.	Vapour refrigerant is compressed	Vapour refrigerant is absorbed and heated
2.	Work is performed by the compressor for the heat transfer.	System makes use of heat source such as combustion of LPG
3.	Mechanical energy required is more [refrigerant vapours are compressed to high pressure]	Energy required is less [Pump is used to circulate the refrigerant]
4.	No restriction for the type of refrigerants used	Refrigerants which are soluble in another solution are used.
5.	electric power is required to run the compressor	Not dependent on electric power.
6.	Noisy, more maintenance cost	Absence of moving parts makes the system run quiet, low maintenance cost
7.	Built in capacity = 1000 Tons	Above 1000 Tons
8.	Coefficient of performance of the system decreases with increase in load	At reduced loads, the system is almost as efficient as at full load
9.	Chances of refrigerant leakage	No chance of refrigerant leakage
10.	Domestic, commercial and industrial applications	Food storage in recreational vehicles

06

6

Commonly used refrigerants are Ammonia, sulphur dioxide, carbon dioxide, freon and HFC's

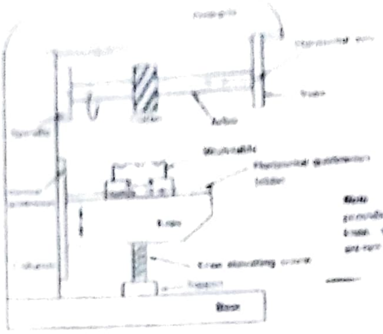
02

7

Horizontal spindle milling machine:

Part	Feature/functions
Base	• Strong and a hollow part, which forms the foundation of the machines and upon which all other parts are mounted. • Serves as sump for cutting fluid. • A pump and filtration system can be installed in the base. • Hole provided in the center of the base, houses the support for the elevating screw that raises and lowers the knee.
Column	• A vertical hollow casting combined with base to form a single casting. • The column houses the spindle, bearings and drive units [gears, clutches, shafts and shifting mechanism] for transmitting power from the electric motor to the spindle at desired speeds. • Front face of the vertical column is provided with a square or dovetail type guideways on which the knee slides up and down.
Spindle	• Hollow shaft supported by the column with suitable bearings that absorb both radial and thrust loads. • The spindle is made hallow and tapered inside, to accept standard arbors. • Spindle obtains power from the motor and transmits it to the arbor. • The arbor carrying the cutter rotates about a horizontal axis.
Overarm	• Mounted on the vertical column, supports the yoke, which in turn supports the free end of the arbor.
Knee	• Casting that slides up and down on the vertical guideways provided on the column by means of an elevating screw. The knee supports the saddle.

04



(a) Front view of a horizontal spindle column and knee milling machine

04

Part	Feature/functions
Saddle	• Mounted on the knee is provided with two guideways on its top and bottom surfaces. • The slides are machined at right angles to each other. • The lower slide fits the slide provided on the top of the knee and facilitates horizontal movement of the saddle. • The upper slide provided on the saddle accepts the slide provided on the bottom surface of the worktable.
Work table	• Larger in size and rests on the saddle. • The bottom surface of the table has a dovetail slide that fits in the slide on the top surface of saddle. This facilitates the work table to move longitudinally or at right angles to the movement of the saddle. • Work table is provided with T-slots all along its length for mounting work holding devices which enables the workpiece to be clamped rigidly on the table. • Work table may be manually controlled or power fed. • A dial graduated in thousandth of an inch is provided to allow table movement and placement.

02

8 **Applications of robot:** Used to move materials or work parts from one location to another [pick and place application], Used to load and unload parts at the production industry, Performing a process on a work part [welding, grinding, coating etc] in automotive industries, Used to assemble the various components of a product like picking a part and inserting into another part with precise placement and orientation.

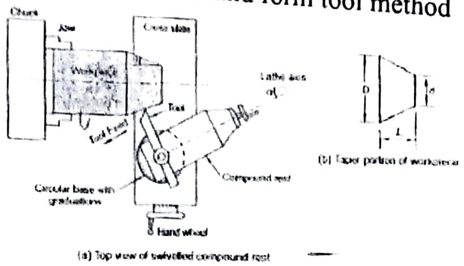
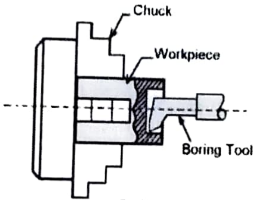
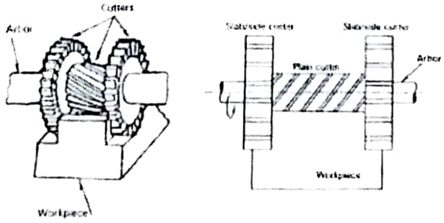
02

9 **Machine tool**: Machine used to remove extra material from its surface by forcing single point or multipoint cutting tool against the workpiece is termed as machine tools.

Example: Lathe, milling machine, shaping machine, grinding machine, drilling machine.

02

Explanation of any one machine tool 04

10	i. **Taper turning**: Process of producing a conical surface from a cylindrical shaped workpiece. A taper is produced when the cutting tool moves at an angle to the axis of rotation of the workpiece. Methods of producing taper, Swivelling of compound rest, Off-setting the tailstock, Taper turning attachment and form tool method  (a) Top view of swivelled compound rest (b) Taper portion of workpiece	02
	ii. **Boring:** Process of enlarging a hole that has already been drilled by means of a cutting tool (or of a boring head) is termed as boring. Boring is used to achieve greater accuracy of the diameter of a hole, and can be used to cut a tapered hole.  Boring	02
	ii. **Gang milling**: Operation in which two or more cutters are mounted on the same arbor, so that different profiles required on the workpiece can be milled simultaneously in a single pass. All the cutters used may be of the same type or of different types depending on the type of surface being milled.  	02

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K.S. INSTITUTE OF TECHNOLOGY, BANGALORE - 560109
I SESSIONAL TEST QUESTION PAPER 2020 – 21 ODD SEMESTER

SET – A

USN

Degree : B.E
Branch : EC
Subject Title : Elements of Mechanical Engineering
Duration : 90 Minutes

Semester : I (D)
Subject Code : 18ME15
Date : 30/01/2021
Max Marks : 30

Note: Answer ONE full question from each part.

Q No.	Question	Marks	CO mapping	K-Level
PART-A				
1(a)	With a neat sketch, **explain** solar energy utilization using solar pond.	6	CO1	K2 (Understanding)
(b)	**Explain** the following laws of thermodynamics by mentioning their statements. a) Zeroth law b) First law c) Third law	6	CO1	K2 (Understanding)
(c)	A stationary mass of gas at its initial state 0.4m^3 and 0.105MPa was compressed at constant pressure to final state of 0.2m^3 and 0.105MPa. The heat transfer from the gas during the process was 42.5kJ. **Calculate** the change in internal energy of the gas.	6	CO1	K2 (Understanding)
OR				
2(a)	**Explain** briefly i) Ozone depletion ii) Global warming.	6	CO1	K2 (Understanding)
(b)	**Write a note** on wind energy and its conversion.	6	CO1	K2 (Understanding)
(c)	**Explain** the concept of heat and work transfer with diagram.	6	CO1	K2 (Understanding)
PART-B				
3(a)	**List** the various materials that find applications in engineering. **Explain** any two of them briefly and give example for their uses.	6	CO4	K2 (Understanding)
(b)	What are polymers? How are they classified? **Explain** any one polymer in detail how it is processed to manufacture a product.	6	CO4	K2 (Understanding)
OR				
4(a)	Classify the transmission elements and **explain** any two of them.	6	CO4	K2 (Understanding)
(b)	**Explain** idler pulleys and illustrate their different configurations.	6	CO4	K2 (Understanding)

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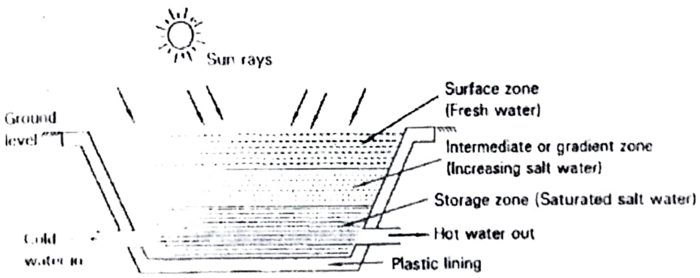
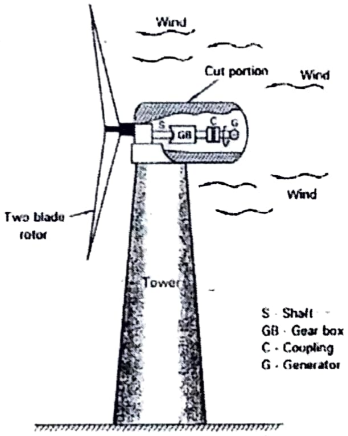
I SESSIONAL TEST QUESTION PAPER 2020 – 21 ODD SEMESTER

SCHEME AND SOLUTION (SET A)

Degree	: **BE**		**Semester :**	**I (D)**
Branch	: **EC**		**Course Code :**	**18ME15**
Course Title	: **Elements of Mechanical Engineering**		**Max Marks :**	**30**

Q. No	SOLUTION	MARKS
1 (a)	**Solar energy utilization using solar pond:** *Construction* ▪ Usually solar pond is constructed below the ground level. ▪ There are three distinct zones in a solar pond, with salt content increasing from top surface of the pond to its bottom. ▪ Storage zone: lower zone of water, rich in salt content and it is the area where solar radiation is absorbed and stored. ▪ Surface zone: Upper zone of water which is cold and has very low salt content. ▪ Intermediate zone: Separates the upper zone of cold water and the lower zone of the hot water and forms an important area in the solar pond.	02
		02
	Operation ▪ As solar radiation is absorbed, the hot water in the storage zone cannot rise due to high salt content in it while the cold water at the surface of the pond having less salt content cannot sink, because the water below (intermediate zone) has a rich salt content and is comparatively denser. ▪ The hot water thus remains in the bottom layer of the pond from which useful heat may be withdrawn and used for various purpose.	02

(b)	**Zeroth law of thermodynamics**. When two systems are each in thermal equilibrium with a third system, then the two system are also in thermal equilibrium with each other	02
	I law of thermodynamics. When a closed system undergoes a thermodynamic cycle, the net heat transfer is equal to the net work transfer $$\oint \delta Q = \oint \delta W$$	02
	III Law: The entropy of a pure substance in thermodynamic equilibrium approaches zero as the temperature approaches zero. $$\lim_{T \to 0} S = 0$$	02
(c)	**Solution : Initial condition of gas (state 1) :** Volume of gas $= V_1 = 0.4\ m^3$ Pressure $= P_1 = 0.105\ MPa = 0.105 \times 10^6\ N/m^2$ ($\because$ mega $= 10^6$ and $Pa = N/m^2$) **Final condition (state 2) :** Volume $V_2 = 0.2\ m^3$ Pressure $= P_2 = 0.105\ MPa = 0.105 \times 10^6\ N/m^2$ Note that since $P_1 = P_2$, the compression process takes place at constant pressure.	01
	Heat transfer from the gas $= Q = -42.5\ kJ$ ($-^{ve}$ sign indicates heat is rejected from the system) w.k.t. change in internal energy $= \Delta E = Q - W$ ---- (1) But work $W = ?$	01
	w.k.t. displacement work $= W = \int_1^2 P.dv = P(V_2 - V_1)$ $$W = (0.105 \times 10^6)(0.2 - 0.4) = -21 \times 10^3 \frac{N}{m^2} \times m^3 = -21 \times 10^3\ Nm$$	02
	Work $= -21\ kJ$ ($\because$ kilo $= 10^3$ and $Nm =$ Joule) Now equation (1) becomes, $\Delta E = -42.5 - (-21) = -21.5$ $\therefore$ Change in internal energy $= \Delta E =$ **– 21.5 kJ** ($-^{ve}$ sign indicates decrease in internal energy of the system)	02
2 (a)	**Ozone layer depletion:** ▪ Ozone depletion refers to the gradual thinning of the earth's ozone layer in the upper atmosphere, caused by the release of chemical compounds containing gaseous chlorine or bromine from industries and other emissions from human activities. ▪ Ozone layer is a deep layer in the stratosphere encircling the earth, that has large amounts of ozone in it. ▪ Ozone layer shields the entire earth from the harmful UV radiation of the sun thereby protecting the living beings on the earth. ▪ In 1970's it was discovered that man made chemicals called chlorofluorocarbons (CFC's) that were released into the atmosphere gradually decompose, releasing chlorine atoms that destroy the ozone in the ozone layer. ▪ Each chlorine atom has the ability to destroy tens of thousands of ozone molecules.	03

	▪ The depletion of ozone layer thus leads to its inability to shield the UV radiation reaching the earth's surface thereby increasing the radiation effects like skin cancer, eye cataracts and damage to immune system. **Global warming:** ▪ A gradual increase in the average temperature of the earth's atmosphere and its oceans, a change that is believed to be permanently changing the earth's climate. ▪ The climatic change is due to the increased volumes of CO_2 and other green house gases (toxic gases) released by the burning of fossil fuel, land clearing, agriculture and other emissions created by human activities that have occurred over past years. ▪ The gases form a layer in the atmosphere and trap the sun's radiation which in turn makes the planet warmer. ▪ Global warming leads in rising sea levels due to the melting of the polar ice caps as well as an increase in occurrence and severity of storms, droughts and other severe weather events.	03
(b)	**Wind energy and its conversion:** 	03
	Operation of wind mill: ▪ The kinetic energy of the flow of wind causes the blades to rotate at slow speeds. ▪ The gear box comprising of many gears is used to increase the rotational speed of the shaft to that range required to produce electricity. ▪ The high speed of the shaft thus drives the generator to produce electricity. ▪ The power produced by the generator is transferred down the tower to the power grid system and then through the transmission lines.	03

(c)

Concept of heat and work transfer:

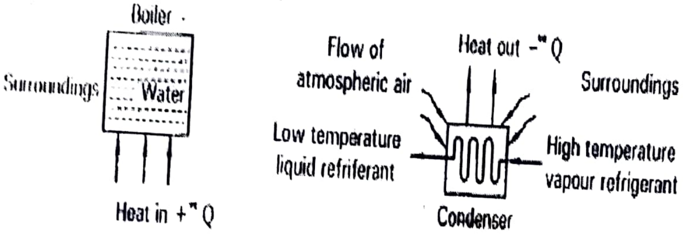
Heat:

- It is defined as the transfer of energy taking place across the boundary of a system or between two different bodies due to the temperature difference between them.
- Heat is transferred naturally from a body of higher temperature to a body of lower temperature.
- Heat is denoted by Q and expressed in kJ.

Sign convention

- If heat is transferred from the surroundings to the system, it is considered as +ve.
- If heat is transferred from the system to the surroundings, it is considered as –ve.

02



(a) Heat added to convert water into steam

(b) Heat rejected to atmosphere by the refrigerant

01

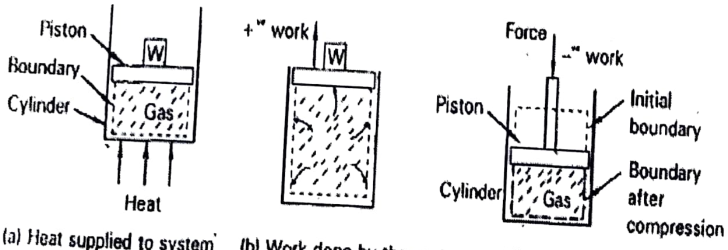
Work:

- In thermodynamics, work refers to the energy transfer between the system and its surroundings by a mechanism through which the system can spontaneously exert macroscopic forces on its surroundings.
- In simple words, work is the energy transfer, associated with a force acting through a distance. Denoted by W and expressed in kJ.

Sign convention

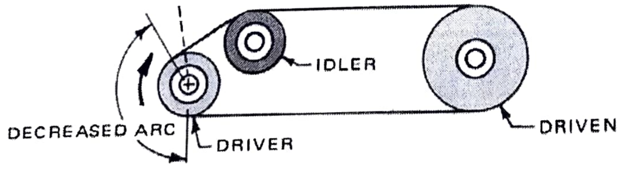
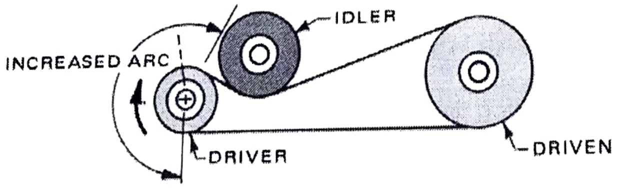
- If work is done by the system, it is considered as +ve.
- If work is done on the system it is considered as –ve.

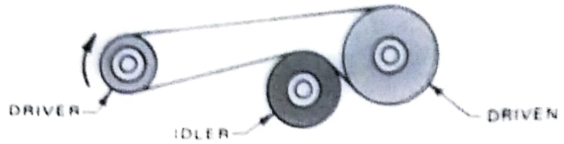
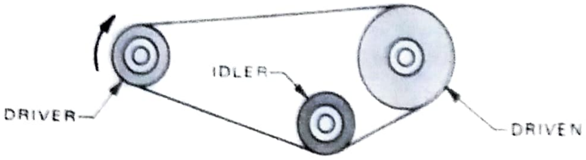
02



(a) Heat supplied to system (b) Work done by the system (c) Work done on the system

01

3 (a)	List of engineering materials: ▪ Polymers – thermoset and thermoplastics ▪ Metals – Ferrous and non ferrous metals ▪ Ceramics – glasses, cermets ▪ Composites – PMC, MMC, CMC ▪ Smart materials – piezoelectric, shape memory alloy ▪ Insulators and semi-conductors	02
	Two of them explained with examples of their uses	04
(b)	Polymers: Group of polymers that are built from relatively simple units called monomers through a chemical polymerization process.	01
	Classification of polymers: ▪ Thermoplastics – Polyethylene, polystyrene, PVC, polypropylene, nylon, Teflon etc. ▪ Thermosetting plastics – Epoxy, polyester, phenol formaldehyde etc	02
	Any one polymer explained along with the process used to manufacture a product	03
4 (a)	Classification of transmission elements: ▪ Flat belts ▪ V-belts ▪ Rope drives ▪ Chains ▪ Gears ▪ Timing belts	02
	Any two explained	04
(b)	An IDLER Pulley is neither a driver nor a driven pulley but used in a belt drive to increase the angle of contact and thereby the transmission efficiency.  (A) INSIDE IDLER PULLEY, AT LEAST AS LARGE AS THE SMALL SHEAVE, ON THE SLACK SIDE OF THE DRIVE  (B) OUTSIDE IDLER PULLEY, AT LEAST 1.3 LARGER THAN THE SMALL SHEAVE	02

	 (C) OUTSIDE IDLER PULLEY ON THE TIGHT SIDE OF THE DRIVE  (D) INSIDE IDLER PULLEY ON THE TIGHT SIDE OF THE DRIVE	04

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I SESSIONAL TEST QUESTION PAPER 2020 - 21 ODD SEMESTER

SET - B

USN

Degree : B.E

Branch : EC

Subject Title : Elements of Mechanical Engineering

Duration : 90 Minutes

Semester 1 (D)

Subject Code 18ME15

Date 30/01/2021

Max Marks 30

Note: Answer ONE full question from each part.

Q No.	Question	Marks	CO mapping	K Level
	PART-A			
1(a)	**Write a note** on environmental issues pertaining to Ozone layer depletion and Global warming.	6	CO1	K2 (Understanding)
(b)	**Explain** the following laws of thermodynamics by mentioning their statements. a) Zeroth law b) First law c) Second law.	6	CO1	K2 (Understanding)
(c)	**Explain** how electricity is generated using nuclear energy.	6	CO1	K2 (Understanding)
	OR			
2(a)	With a neat sketch, **explain** solar energy utilization using solar cell.	6	CO1	K2 (Understanding)
(b)	**Define** the following terms i) Thermodynamic cycle ii) System and surroundings iii) Enthalpy iv) Entropy of a system.	6	CO1	K2 (Understanding)
(c)	A stationary mass of gas at its initial state 0.4m^3 and 0.105MPa was compressed at constant pressure to final state of 0.2m^3 and 0.105MPa. The heat transfer from the gas during the process was 42.5kJ. **Calculate** the change in internal energy of the gas.	6	CO1	K2 (Understanding)
	PART-B			
3(a)	What are polymers? How are they classified? **Explain** any one polymer in detail how it is processed to manufacture a product.	6	CO4	K2 (Understanding)
(b)	**Classify** the transmission elements and explain any two of them.	6	CO4	K2 (Understanding)
	OR			
4(a)	List the various materials that find applications in engineering. **Explain** any two of them briefly and give example for their uses.	6	CO4	K2 (Understanding)
(b)	Explain idler pulleys and **illustrate** their different configurations.	6	CO4	K2 (Understanding)

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I SESSIONAL TEST QUESTION PAPER 2020 – 21 ODD SEMESTER

SCHEME AND SOLUTION (SET B)

Degree : **BE**
Branch : **EC**
Course Title : **Elements of Mechanical Engineering**
Semester : **I (D)**
Course Code : **18ME15**
Max Marks : **30**

Q. No	SOLUTION	MARKS
1 (a)	**Ozone layer depletion:** ▪ Ozone depletion refers to the gradual thinning of the earth's ozone layer in the upper atmosphere, caused by the release of chemical compounds containing gaseous chlorine or bromine from industries and other emissions from human activities. ▪ Ozone layer is a deep layer in the stratosphere encircling the earth, that has large amounts of ozone in it. ▪ Ozone layer shields the entire earth from the harmful UV radiation of the sun thereby protecting the living beings on the earth. ▪ In 1970's it was discovered that man made chemicals called chlorofluorocarbons (CFC's) that were released into the atmosphere gradually decompose, releasing chlorine atoms that destroy the ozone in the ozone layer. ▪ Each chlorine atom has the ability to destroy tens of thousands of ozone molecules. ▪ The depletion of ozone layer thus leads to its inability to shield the UV radiation reaching the earth's surface thereby increasing the radiation effects like skin cancer, eye cataracts and damage to immune system.	03
	Global warming: ▪ A gradual increase in the average temperature of the earth's atmosphere and its oceans, a change that is believed to be permanently changing the earth's climate. ▪ The climatic change is due to the increased volumes of CO_2 and other green house gases (toxic gases) released by the burning of fossil fuel, land clearing, agriculture and other emissions created by human activities that have occurred over past years. ▪ The gases form a layer in the atmosphere and trap the sun's radiation which in turn makes the planet warmer. ▪ Global warming leads in rising sea levels due to the melting of the polar ice caps as well as an increase in occurrence and severity of storms, droughts and other severe weather events.	03

(b) **Zeroth law of thermodynamics**: When two systems are each in thermal equilibrium with a third system, then the two system are also in thermal equilibrium with each other. 02

I law of thermodynamics: When a closed system undergoes a thermodynamic cycle, the net heat transfer is equal to the net work transfer. 02

$$\oint \delta Q = \oint \delta W$$

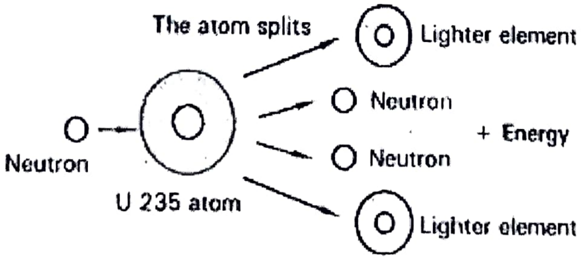
II Law: *Kelvin-Planck statement*: It is impossible for any device/machine that operates in a cycle to receive heat from a single reservoir and produce a net amount of work. There is always a degradation or loss of energy in the process of producing mechanical work from the heat supplied.

Clausius statement: It is impossible for any device/machine working in a cyclic process to transfer heat from a body at a lower temperature to a body at a higher temperature without the aid of an external agency. [In simple words, heat cannot flow naturally from a cold body to a hot body without the help of work input] 02

(c) **Generation of electricity using nuclear energy:**

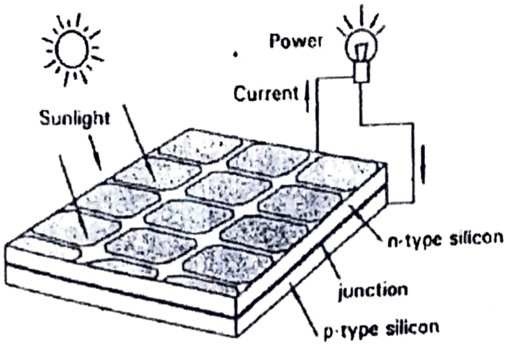
- The fuel most widely used for nuclear fission is Uranium – 235.
- In nuclear fission, a small particle called neutron hits the uranium atom and splits it, releasing a great amount of energy in the form of heat and light. Also more neutrons are released due to bombardment.
- These neutrons go on to bombard other uranium atoms and the process repeats over and over again resulting in a chain reaction.
- The chain reaction gives off enormous heat energy, which is used to boil water to form super heated steam.
- The steam thus formed is used to drive the turbine, which in turn drives the generator to produce electricity.

04

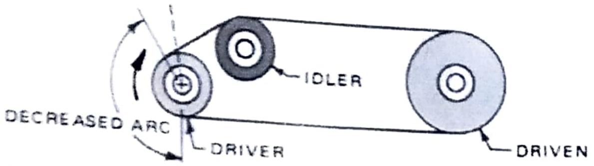
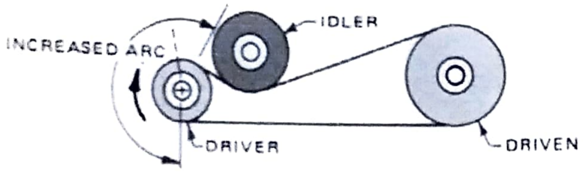
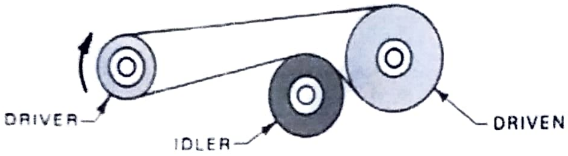
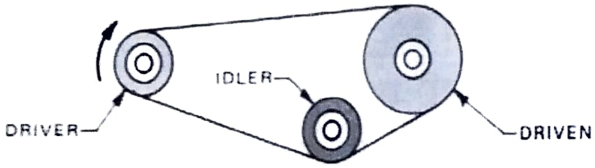


02

Figure 1.7 Nuclear Fission

2 (a)	**Solar energy utilization using solar cell:** *Construction* ▪ Solar cell is a device that directly converts the sun's radiation into electrical energy. ▪ It is made up of at least two layers of semiconductor material like silicon doped with impurities in order to increase the conductivity of the material. ▪ The first layer has a positive charge (p-type silicon), while the next layer a negative charge (n-type silicon).	02
		02
	Operation ▪ As known, sunlight is composed of photons or particles of solar energy. When sunlight strikes the photovoltaic cell, the semiconductor material absorbs photons from the light. ▪ When enough photons are absorbed by the negative layer of the semiconductor material, electrons get dislodged which then moves towards positive layer. This flow of electrons constitutes an electric current. ▪ The electricity generated by the photovoltaic cell can be used directly or stored in batteries. ▪ The power output can be increased by connecting a number of photovoltaic cells together in a sealed package called a module.	02
(b)	i) *Thermodynamic cycle:* A linked sequence of processes in which the working substance undergoes a series of state changes accompanying with heat and work transfer and finally returning to its initial state.	01
	ii) *System*: A thermodynamic system is defined as a specific quantity of matter or region in space on which our attention is focussed for thermodynamic analysis.	01
	iii) *Sourrounding*: A three dimensional space outside the thermodynamic system that has a direct relationship on the behaviour of the system	01
	iv) *Enthalpy of a system*: Total heat content of a system. It is defined as the sum of internal energy (U) of a system and the product of the pressure (P) and volume (V) of the system. $H = U + P.V$.........kJ/kg	02
	v) Entropy: It is the amount of energy that is lost to surrounding at a specific temperature.	01

(c)	**Solution : Initial condition of gas (state 1) :** Volume of gas = $V_1 = 0.4\ m^3$ Pressure = $P_1 = 0.105\ MPa = 0.105 \times 10^6\ N/m^2$ ($\because$ mega = 10^6 and $Pa = N/m^2$) **Final condition (state 2) :** Volume $V_2 = 0.2\ m^3$ Pressure = $P_2 = 0.105\ MPa = 0.105 \times 10^6\ N/m^2$ Note that since $P_1 = P_2$, the compression process takes place at constant pressure. Heat transfer from the gas = $Q = -42.5\ kJ$ ($-^{ve}$ sign indicates heat is rejected from the system) w.k.t. change in internal energy = $\Delta E = Q - W$ ----- (1) But work W = ? w.k.t. displacement work = $W = \int_1^2 P.dv = P(V_2 - V_1)$ $W = (0.105 \times 10^6)(0.2 - 0.4) = -21 \times 10^3 \frac{N}{m^2} \times m^3 = -21 \times 10^3\ Nm$ Work = $-21\ kJ$ ($\because$ kilo = 10^3 and Nm = Joule) Now equation (1) becomes, $\Delta E = -42.5 - (-21) = -21.5$ $\therefore$ **Change in internal energy = $\Delta E = -21.5$ kJ** ($-^{ve}$ sign indicates decrease in internal energy of the system)	01 01 02 02
3 (a)	Polymers: Group of polymers that are built from relatively simple units called monomers through a chemical polymerization process. Classification of polymers: ▪ Thermoplastics – Polyethylene, polystyrene, PVC, polypropylene, nylon, Teflon etc. ▪ Thermosetting plastics – Epoxy, polyester, phenol formaldehyde etc Any one polymer explained along with the process used to manufacture a product	01 02 03
(b)	Classification of transmission elements: ▪ Flat belts ▪ V-belts ▪ Rope drives ▪ Chains ▪ Gears ▪ Timing belts Any two explained	02 04
4 (a)	List of engineering materials: ▪ Polymers – thermoset and thermoplastics ▪ Metals – Ferrous and non ferrous metals ▪ Ceramics – glasses, cermets ▪ Composites – PMC, MMC, CMC ▪ Smart materials – piezoelectric, shape memory alloy ▪ Insulators and semi-conductors Two of them explained with examples of their uses	02 04

(b)	An IDLER Pulley is neither a driver nor a driven pulley but used in a belt drive to increase the angle of contact and thereby the transmission efficiency.  **(A) INSIDE IDLER PULLEY, AT LEAST AS LARGE AS THE SMALL SHEAVE, ON THE SLACK SIDE OF THE DRIVE**  **(B) OUTSIDE IDLER PULLEY, AT LEAST 1.3 LARGER THAN THE SMALL SHEAVE**  **(C) OUTSIDE IDLER PULLEY ON THE TIGHT SIDE OF THE DRIVE**  **(D) INSIDE IDLER PULLEY ON THE TIGHT SIDE OF THE DRIVE**	02 02 02

Rajesh G L

Signature of Course Incharge

27/1/2021

Head of the Department

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K.S. INSTITUTE OF TECHNOLOGY, BANGALORE - 560109

II SESSIONAL TEST QUESTION PAPER 2020 - 21 ODD SEMESTER

SET - A

USN

Degree	B.E	**Semester**	I (D)
Branch	EC	**Subject Code**	18ME15
Subject Title	Elements of Mechanical Engineering	**Date**	27/02/2021
Duration	90 Minutes	**Max Marks**	30

Note: Answer ONE full question from each part

Q No	Question	Marks	CO mapping	K-Level
	PART-A			
1(a)	**Explain** the working of Babcock and Wilcox steam boiler with a neat sketch	8	CO2	K2 (Understanding)
(b)	3kg of steam is generated at 5bar from water at 34°C. **Determine** the quantity of heat required when steam is wet having dryness fraction of 0.8. Assume Cp_s = 2.25kJ/kg K & Cp_w = 4.187 kJ/kg K [At 5bar, t_{sat} = 151.8°C, h_f = 640.1kJ/kg, h_{fg} = 2107.4kJ/kg & h_g = 2747.5kJ/kg]	4	CO1	K2 (Understanding)
(c)	3kg of wet steam at 6.0 bar pressure is heated. **Determine** the enthalpy when it is i) 75% dry ii) Superheated to 300°C	6	CO1	K2 (Understanding)
	OR			
2(a)	**Explain** the formation of steam at constant pressure with the help of T-H diagram	6	CO1	K2 (Understanding)
(b)	**State** the advantage, disadvantage and applications of Lancashire steam boilers	6	CO2	K2 (Understanding)
(c)	**Estimate** the amount of heat needed to convert 5kg of water at 50°C into steam at a pressure of 9bar and with 250°C of superheat. Take specific heat at constant pressure for superheated steam as 2.1kJ/kg K and specific heat of water as 4.187kJ/kg K. [At 9bar, t_{sat} = 175.4°C, h_f = 742.6kJ/kg, h_{fg} = 2029.5kJ/kg & h_g = 2772.1kJ/kg]	6	CO1	K2 (Understanding)
	PART-B			
3(a)	**Differentiate** between soldering, brazing and welding	8	CO4	K2 (Understanding)
(b)	List different types of gears and **explain** any one with its advantages	4	CO4	K2 (Understanding)
	OR			
4(a)	**Explain** Oxy-acetylene welding process with a neat sketch	8	CO4	K2 (Understanding)
(b)	**What** are gear trains? How are they classified?	4	CO4	K2 (Understanding)

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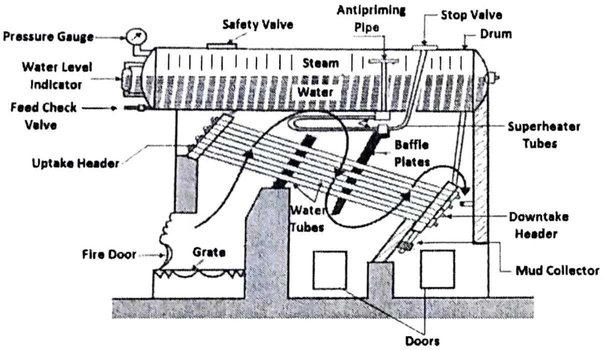
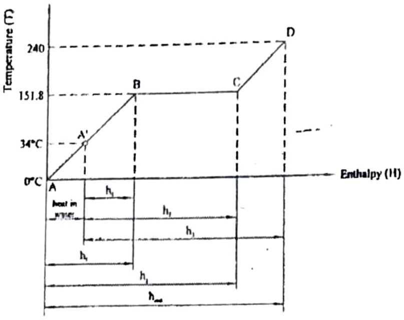
K.S. INSTITUTE OF TECHNOLOGY, BANGALORE - 560109
II SESSIONAL TEST QUESTION PAPER 2020 – 21 ODD SEMESTER

SCHEME AND SOLUTION (SET A)

Degree : **BE**
Branch : **EC**
Course Title : **Elements of Mechanical Engineering**
Semester : **I (D)**
Course Code : **18ME15**
Max Marks : **30**

Q. No	SOLUTION	MARKS
1 (a)	**Babcock and Wilcox boiler** ▪ Horizontal, externally fired, stationary, natural circulation water tube boiler. ▪ Steam pressure of 12-18bars (Range of pressure) ▪ Evaporation capacity 20,000-40,000 kg/hour. ▪ Application: generation of high pressure steam in thermal power plants.	01
	 Babcock and Wilcox Boiler	03
	Working: ▪ First water starts to flow into the water tubes from drum through down take header. ▪ The water present in the inclined water tubes gets heated up by the hot flue gases. The coal burning on the grate produces hot flue gases and it is forced to move in zigzag way with the help of baffle plates. ▪ As the hot flue gases come in contact with water tubes, it exchanges the heat with water and converts it into steam. ▪ The steam generated is moved upward through up take header which gets collected at upper side in the boiler drum. ▪ T-tube is provided in the drum. This anti-priming pipe filters the water content from the steam and allows only dry steam to enter into superheater.	

	- The superheater receives the water free steam from the T-tube. It increases the temperature of steam to desired level and transfers it to the steam stop valve. - The superheated steam from the steam stop valve is either collected in a steam drum or made to strike on the steam turbine for electricity generation.	04
(b)	**Step 1** Data Mass of steam 3 kg, Pressure = $P = 5$ bar Initial temperature of water = 34°C C_{ps} = 2.25 kJ/kg K, C_{pw} = Specific heat of water = 4.187 kJ/kg K From steam tables, at P = 5 bar, we have t_{sat} = 151.8°C, h_f = 640.1 kJ/kg. h_{fg} = 2107.4 kJ/kg and h_g = 2747.5 kJ/kg  	
	∴ Heat already in water (portion AA') = $m\ C_{pw} \Delta T$ (m = Mass of water = 1 kg) ΔT = change in temperature= 34°C – 0°C = 34°C ∴ Heat already in water = 1 × 4.187 × 34 = 142.35 kJ/kg	01
	Step 2 When steam is wet with $x = 0.8$ Let H_w = heat required to convert 1 kg of water at 0°C into wet steam w.k.t. enthalpy of wet steam (between points A & B) = $h_w = h_f + x\ h_{fg}$ = 640.1+ (0.8×2107.4) H_w = 2326.02 kJ/kg	01
	Let h_l = actual quantity of heat supplied to produce 1 kg of wet steam from water whose initial temperature is 34°C ∴ $h_l = h_w$ – heat already in water = 2326.02 – 142.35 h_l = 2183.67 kJ/kg of steam	01
	∴ to produce 3 kg of steam, heat required = h_l = 3×2183.67 h_l = **6551.01 kJ** for 3 kg of steam Thus 6551.01 kJ of heat is required to produce 3 kg wet steam from water at 34°C.	01

(c)	Given:- Mass of wet steam = 3kg, P = 6bar From tables, t_s=158.83°C, h_f = 670.38kJ/kg, hfg = 2085.8kJ/kg, hg = 2756.2kJ/kg	01
	a) 75% dry (x=0.75) $h_w = h_f + xh_{fg}$ h_w = 670.38+(0.75×2085.8) = 2234.73kJ/kg [For 1kg of steam] = 2234.73×3 = **6704.19kJ [For 3kg of steam]**	02
	b) Superheated to 300°C $h_{sup} = h_g + Cp_s(t_{sup}-t_s)$ h_{sup} = 2756.2+2.25(300-158.83) = 3073.83kJ/kg[For 1kg of steam] = 3073.83×3 = **9221.49kJ [For 3kg of steam]**	03
2 (a)	**Steam formation at constant pressure** Consider 1kg of water at 0°C taken in a cylinder, fitted with a freely moving piston. A weight W is placed over the piston as shown in Figure. The weight of the piston and weight W placed over the piston exerts a constant pressure P on the water. Let V be the volume occupied by the water in the cylinder. The condition of water at 0°C is represented by a point A on the temperature-enthalpy (T-H) diagram. When water is heated at constant pressure, it is converted to steam. The various stages involved in the process are ▪ On heating, the temperature of the water rises and at a certain temperature water begins to boil/evaporate. The temperature at which water starts boiling is known as saturation temperature and is denoted by t_s. The heating of water from °C to the saturation temperature (t_s) is shown by line AB on T-H diagram. At this temperature, there is a slight increase in the volume of water (V_f) as shown in figure. ▪ When water is heated beyond the saturation temperature, there will be no rise in temperature but evaporation of water takes place (water starts converting into steam). At this stage, water exists as a two-phase mixture containing saturated liquid and water vapour occupying volume V_{fg}. The steam in this condition is called wet steam. Evaporation of water continues at the same saturation temperature until the whole of the water is completely converted into steam (Line BC on T-H diagram). ▪ At point C, the steam formed does not contain water vapour and hence the steam in this state is called dry steam or dry saturated steam, occupying volume V_g.	04

- If the heating is further continued at point C, the temperature of the steam increases above the saturation temperature and this temperature is called superheat temperature (t_{sup}). The steam in this condition is called superheated steam (Line CD on T-H diagram) occupying volume V_{sup}.

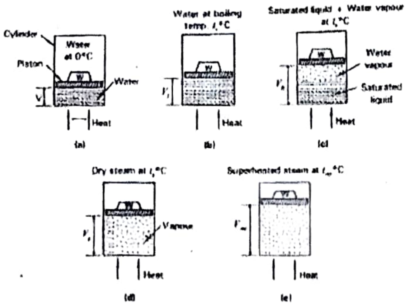


Figure 3.1 Formation of steam at constant pressure

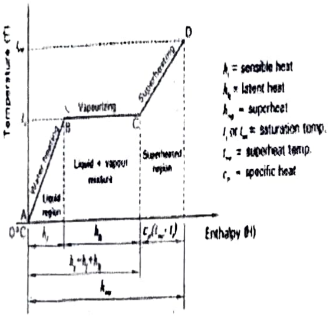


Figure 3.2 Temperature-enthalpy (TH) diagram

02

(b)

Advantage, disadvantage and applications of Lancashire boiler

Advantage	Disadvantage
1. It has high thermal efficiency; the thermal efficiency is about 80 to 90%. 2. It is easy to operate. 3. Easy to maintain. 4. Generate a large amount of steam and hence more reliable.	1. It has a limited grate area due to the small diameter of the flue tubes. 2. The steam production rate is low. 3. Low-pressure type boiler, so high-pressure steam is not produced. 4. Tedious maintenance of brickwork.

04

Applications: Employed in sugar mills, textile and paper industries 02

(c)

Given: m = 5kg, P = 9bars, Cps = 2.1kJ/kgK, Cpw = 4.187kJ/kgK, t_s = 175.35°C, t_{sup} = 250°C. 01

i) Heat already present in water = m C_{pw} dT = 1×4.187×(50-0) = **209.35kJ/kg** 01

ii) $h_{sup} = h_g + C_{ps}(t_{sup} - t_s)$
$= 2030.5 + 2.1(250-175.35)$
$= 2187.265$ kJ/kg 01

iii) Let h_1 = actual heat required to convert 1kg of water at 50°C to wet steam at 250°C

$h_1 = h_{sup}$ - Heat already present in water
= 2187.265-209.35
= 1977.915kJ.kg [For 1kg of steam] 01
= **9889.575kJ** [For 5kg of steam] 02

3 (a)

Differences between soldering, brazing and welding

Sl. No.	Soldering	Brazing	Welding
1.	Low temperature process. Base metals are not melted	Base metals are not melted, but heated to suitable temperature	High temperature process wherein base metals are heated above their T_m
2.	Filler metal is not same as that of base metal	Filler metal is not same as that of base metal	Filler material used is of the same material as that of base metal
3.	Joint is formed by diffusion of the filler metal into the base metal	Diffusion of filler metal into the base metal associated with surface alloying	Solidification of the molten filler metal with the molten base metal
4.	Strength of the joint is comparatively low	Strength lies between that of welded and soldered joint	Much stronger than the base metal
5.	No heat effected zone	Heat affected zone is not too much when compared to welding	Heat affected zone is affected to a large extent
6.	Finishing operations are not required	Sometimes brazed joints require finishing	Requires finishing operations like grinding, filing etc
7.	Sheet metal work and electronic industries	Arts, jewellery works	Fabrication and structural works

08

(b)

Different types of gears:

i. Spur gear
ii. Bevel gear
iii. Helical gear
iv. Worm gear
v. Rack and Pinion gear

01

Explanation of any one type of gear

03

4 (a)

Oxy-acetylene welding process

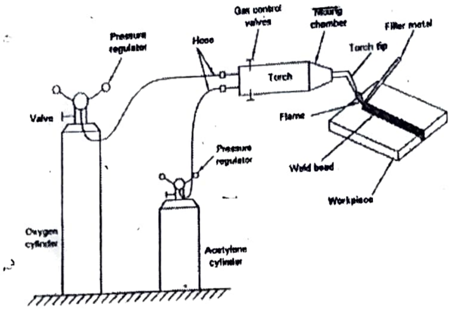
- Principle: When oxygen and acetylene are mixed in suitable proportions in a welding torch and ignited, the flame resulting at the tip of the torch has a temperature ranging from 3100°C-3500°C which is sufficient enough to melt and fuse the workpiece metals. Filler metal may or may not be used during the process.

02

- Construction details:
    - Two large cylinders: one containing oxygen at high pressure and the other containing acetylene gas.
    - Two pressure regulators fitted on the respective cylinders to regulate or control the pressure of the gas flowing from the cylinders to the welding torch as per requirements.
    - Welding torch: Used to mix oxygen and acetylene gas in proper proportions and burn the mixture at its tip.
    - A match stick or a may be used to ignite the mixture at the torch tip.

02

- Operation:
    - By adjusting the pressure regulators, suitable proportions of oxygen and acetylene gases enter into the welding torch.

	▪ The gases get mixed in the torch and are issued from the torch to burn in the atmosphere. ▪ A match stick is used to ignite the gas at the torch tip. The resulting flame at the torch tip has a temperature ranging from 3100-3500°C and this heat is sufficient enough to melt the workpiece metals. ▪ Since a slight gap usually exists between the two workpieces, a filler metal may be used to supply the additional material to fill the gap. ▪ The molten metal of the filler metal combines with the molten metal of the workpiece and upon solidification form a single piece of metal.  	02 02
(b)	A gear train is two or more gear working together by meshing their teeth and turning each other in a system to generate power and speed. It reduces speed and increases torque Types of gear trains • Simple gear train • Compound gear train • Planetary gear train	02 02

Signature of Course Incharge

Head of the Department

K.S. INSTITUTE OF TECHNOLOGY, BANGALORE - 560109

II SESSIONAL TEST QUESTION PAPER 2020 – 21 ODD SEMESTER

SET – B

USN

Degree	: B.E	Semester	: I (D)
Branch	: EC	Subject Code	: 18ME15
Subject Title	: Elements of Mechanical Engineering	Date	: 27/02/2021
Duration	: 90 Minutes	Max Marks	: 30

Note: Answer ONE full question from each part.

Q No.	Question	Marks	CO mapping	K-Level
	PART-A			
1(a)	**Explain** the formation of steam at constant pressure with the help of T-H diagram.	6	CO1	K2 (Understanding)
(b)	3kg of wet steam at 6.0 bar pressure is heated. **Determine** the enthalpy when it is i) 75% dry ii) Superheated to 300°C. [At 6bar, t_{sat} = 158.8°C, h_f = 670.4kJ/kg, h_{fg} = 2085.0kJ/kg & h_g = 2755.5kJ/kg]	6	CO1	K2 (Understanding)
(c)	**State** the advantage, disadvantage and applications of Lancashire steam boilers.	6	CO2	K2 (Understanding)
	OR			
2(a)	3kg of steam is generated at 5bar from water at 34°C. **Determine** the quantity of heat required when steam is wet having dryness fraction of 0.8. Assume Cp_s = 2.25kJ/kg K & Cp_w = 4.187 kJ/kg K. [At 5bar, t_{sat} = 151.8°C, h_f = 640.1kJ/kg, h_{fg} = 2107.4kJ/kg & h_g = 2747.5kJ/kg]	4	CO1	K2 (Understanding)
(b)	**Explain** the working of Babcock and Wilcox steam boiler with a neat sketch.	8	CO2	K2 (Understanding)
(c)	**How** much heat energy is required to generate 2kg of dry saturated steam at 7bar from feed water at 25°C? [At 7bar, t_{sat} = 165°C, h_f = 697.1kJ/kg, h_{fg} = 2064.9kJ/kg & h_g = 2762.0kJ/kg]	6	CO1	K2 (Understanding)
	PART-B			
3(a)	**Explain** Oxy-acetylene welding process with a neat sketch.	8	CO4	K2 (Understanding)
(b)	List different types of gears and **explain** any one with its advantages.	4	CO4	K2 (Understanding)
	OR			
4(a)	**What** are gear trains? How are they classified?	4	CO4	K2 (Understanding)
(b)	**Differentiate** between soldering, brazing and welding.	8	CO4	K2 (Understanding)

Signature of Course Incharge

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K.S. INSTITUTE OF TECHNOLOGY, BANGALORE - 560109

II SESSIONAL TEST QUESTION PAPER 2020 - 21 ODD SEMESTER

SCHEME AND SOLUTION (SET B)

Degree : BE **Semester** : I (D)
Branch : EC **Course Code** : 18ME15
Course Title : **Elements of Mechanical Engineering** **Max Marks** : 30

Q No | SOLUTION | MARKS

1 (a)

Steam formation at constant pressure

Consider 1kg of water at 0°C taken in a cylinder, fitted with a freely moving piston. A weight W is placed over the piston as shown in Figure. The weight of the piston and weight W placed over the piston exerts a constant pressure P on the water. Let V be the volume occupied by the water in the cylinder. The condition of water at 0°C is represented by a point A on the temperature-enthalpy (T-H) diagram. When water is heated at constant pressure, it is converted to steam.

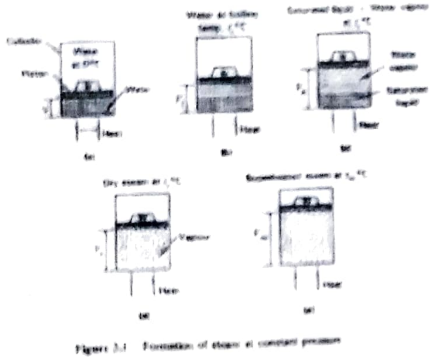


Figure 3.1 Formation of steam at constant pressure

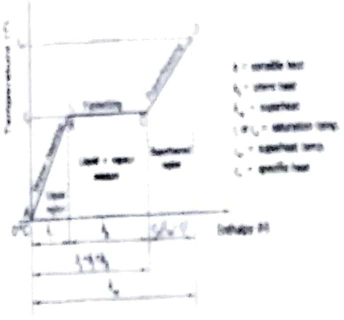


Figure 3.2 Temperature-enthalpy (TH) diagram

02

The various stages involved in the process are

- On heating, the temperature of the water rises and at a certain temperature water begins to boil/evaporate. The temperature at which water starts boiling is known as saturation temperature and is denoted by t_s. The heating of water from °C to the saturation temperature (t_s) is shown by line AB on T-H diagram. At this temperature, there is a slight increase in the volume of water (V_1) as shown in figure.

02

- When water is heated beyond the saturation temperature, there will be no rise in temperature but evaporation of water takes place (water starts converting into steam). At this stage, water exists as a two-phase mixture containing saturated liquid and water vapour occupying volume V_{fg}. The steam in this condition is called wet steam.

- Evaporation of water continues at the same saturation temperature until the whole of the water is completely converted into steam (Line BC on T-H diagram).
- At point C, the steam formed does not contain water vapour and hence the steam in this state is called dry steam or dry saturated steam, occupying volume V_g. 02
- If the heating is further continued at point C, the temperature of the steam increases above the saturation temperature and this temperature is called superheat temperature (t_{sup}). The steam in this condition is called superheated steam (Line CD on T-H diagram) occupying volume V_{sup}.

(b) Given:- Mass of wet steam = 3kg, P = 6bar 01

From tables, t_s=158.83°C, h_f = 670.38kJ/kg, h_{fg} = 2085.8kJ/kg, h_g = 2756.2kJ/kg

a) 75% dry (x=0.75)

$h_w = h_f + x\ h_{fg}$

$h_w = 670.38+(0.75\times2085.8)$

= 2234.73kJ/kg [For 1kg of steam] 02

$= 2234.73\times3$

= **6704.19kJ [For 3kg of steam]**

b) Superheated to 300°C

$h_{sup} = h_g + Cp_s(t_{sup}-t_s)$

$h_{sup} = 2756.2+2.25(300-158.83)$

= 3073.83kJ/kg[For 1kg of steam]

$= 3073.83\times3$ 03

= **9221.49kJ [For 3kg of steam]**

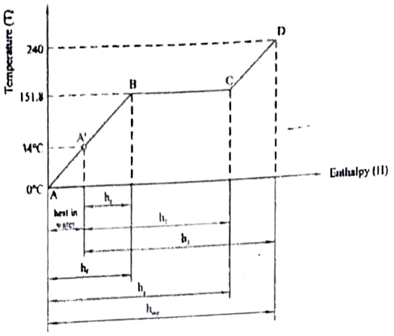
(c) **Advantage, disadvantage and applications of Lancashire boiler**

Advantage	Disadvantage
1. It has high thermal efficiency; the thermal efficiency is about 80 to 90%. 2. It is easy to operate. 3. Easy to maintain. 4. Generate a large amount of steam and hence more reliable.	1. It has a limited grate area due to the small diameter of the flue tubes. 2. The steam production rate is low. 3. Low-pressure type boiler, so high-pressure steam is not produced. 4. Tedious maintenance of brickwork.

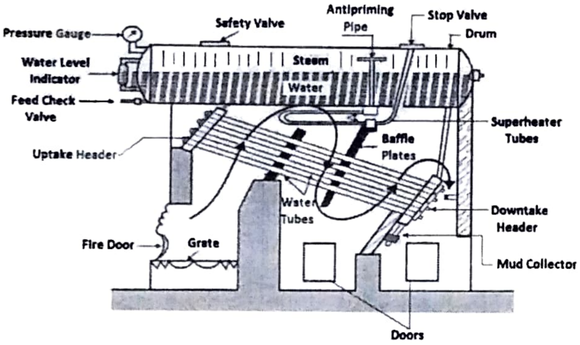
04

Applications: Employed in sugar mills, textile and paper industries

02

2 (a)	Step 1 Data Mass of steam 3 kg, Pressure = $P = 5$ bar Initial temperature of water = 34°C C_{ps} = 2.25 kJ/kg K, C_{pw} = Specific heat of water = 4.187 kJ/kg K From steam tables, at P = 5 bar, we have t_{sat} = 151.8°C, h_f = 640.1 kJ/kg. h_{fg} = 2107.4 kJ/kg and h_g = 2747.5 kJ/kg  ∴ Heat already in water (portion AA') = $m\ C_{pw}\ \Delta T$ (m = Mass of water = 1 kg) ΔT = change in temperature= 34°C – 0°C = 34°C ∴ Heat already in water = 1 × 4.187 × 34 = 142.35 kJ/kg Step 2 When steam is wet with $x = 0.8$ Let H_w = heat required to convert 1 kg of water at 0°C into wet steam w.k.t. enthalpy of wet steam (between points A & B) = $h_w = h_f + x\ h_{fg}$ = 640.1+ (0.8×2107.4) H_w = 2326.02 kJ/kg Let h_l = actual quantity of heat supplied to produce 1 kg of wet steam from water whose initial temperature is 34°C ∴ $h_l = h_w$ – heat already in water = 2326.02 – 142.35 h_l = 2183.67 kJ/kg of steam ∴ to produce 3 kg of steam, heat required = h_l = 3×2183.67 h_l = 6551.01 kJ for 3 kg of steam Thus 6551.01 kJ of heat is required to produce 3 kg wet steam from water at 34°C.	01 01 02
(b)	**Babcock and Wilcox boiler** ▪ Horizontal, externally fired, stationary, natural circulation water tube boiler. ▪ Steam pressure of 12-18bars (Range of pressure) ▪ Evaporation capacity 20,000-40,000 kg/hour. ▪ Application: generation of high pressure steam in thermal power plants. Working: ▪ First water starts to flow into the water tubes from drum through down take header.	01

- The water present in the inclined water tubes gets heated up by the hot flue gases. The coal burning on the grate produces hot flue gases and it is forced to move in zigzag way with the help of baffle plates.
- As the hot flue gases come in contact with water tubes, it exchanges the heat with water and converts it into steam.
- The steam generated is moved upward through up take header which gets collected at upper side in the boiler drum.
- T-tube is provided in the drum. This anti-priming pipe filters the water content from the steam and allows only dry steam to enter into superheater. 04
- The superheater receives the water free steam from the T-tube. It increases the temperature of steam to desired level and transfers it to the steam stop valve.
- The superheated steam from the steam stop valve is either collected in a steam drum or made to strike on the steam turbine for electricity generation.



Babcock and Wilcox Boiler 03

(c)

Solution :

Step 1 Data

Mass of dry steam = m = 2 kg, Pressure = 7 bar Initial temperature of water = 25°C.

From steam tables, at $P = 7$ bar, we have, 01

$t_{sat} = 165°C$, $h_f = 697.1$ kJ/kg, $h_{fg} = 2064.9$ kJ/kg & $h_g = 2762$ kJ/kg

The details are plotted on the T-H diagram as shown in figure P.17

Step 2 To find h_l

Heat initially present in water (AA') = $m\ C_{pw}\ \Delta T$ (m = 1 kg of water & C_{pw} = 4.18 kJ/kg K)

$= 1 \times 4.18 \times (25 - 0) = 104.5$ kJ/kg 02

Let h_g = heat required to convert 1 kg of water at 0°C into dry saturated steam.

w.k.t. enthalpy of dry steam = $h_g = h_f + h_{fg}$

From steam tables, at $P = 7$ bar, we have, $h_g = 2762$ kJ/kg

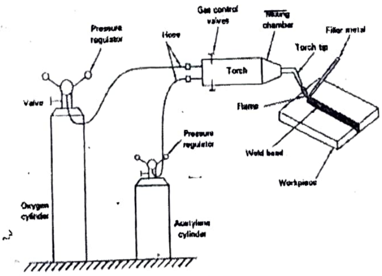
Let h_l = actual heat required to produce 1 kg of dry steam from water at 25°C

$\therefore h_l = h_g$ – heat already in water = 2762 – 104.5 02

$h_l = 2657.5$ kJ/kg of steam

$\therefore$ to generate 2 kg of dry steam, heat required, $h_l = 2 \times 2657.5 = 5315$ 01

$h_l = 5315$ kJ for 2 kg of dry steam

3 (a)	**Oxy-acetylene welding process** • Principle: When oxygen and acetylene are mixed in suitable proportions in a welding torch and ignited, the flame resulting at the tip of the torch has a temperature ranging from 3100°C-3500°C which is sufficient enough to melt and fuse the workpiece metals. Filler metal may or may not be used during the process.	01
	• Construction details: ▪ Two large cylinders: one containing oxygen at high pressure and the other containing acetylene gas. ▪ Two pressure regulators fitted on the respective cylinders to regulate or control the pressure of the gas flowing from the cylinders to the welding torch as per requirements. ▪ Welding torch: Used to mix oxygen and acetylene gas in proper proportions and burn the mixture at its tip. ▪ A match stick or a may be used to ignite the mixture at the torch tip.	02
	▪ Operation: ▪ By adjusting the pressure regulators, suitable proportions of oxygen and acetylene gases enter into the welding torch. ▪ The gases get mixed in the torch and are issued from the torch to burn in the atmosphere. ▪ A match stick is used to ignite the gas at the torch tip. The resulting flame at the torch tip has a temperature ranging from 3100-3500°C and this heat is sufficient enough to melt the workpiece metals. ▪ Since a slight gap usually exists between the two workpieces, a filler metal may be used to supply the additional material to fill the gap. ▪ The molten metal of the filler metal combines with the molten metal of the workpiece and upon solidification form a single piece of metal.	03
		02
(b)	**Different types of gears:** i. Spur gear ii. Bevel gear iii. Helical gear iv. Worm gear v. Rack and Pinion gear	01
	Explanation of any one type of gear	03

4 (a) A gear train is two or more gear working together by meshing their teeth and turning each other in a system to generate power and speed. It reduces speed and increases torque

02

Types of gear trains
- Simple gear train
- Compound gear train
- Planetary gear train

02

(b) **Differences between soldering, brazing and welding**

Sl. No.	Soldering	Brazing	Welding
1.	Low temperature process. Base metals are not melted	Base metals are not melted, but heated to suitable temperature	High temperature process wherein base metals are heated above their T_m
2.	Filler metal is not same as that of base metal	Filler metal is not same as that of base metal	Filler material used is of the same material as that of base metal
3.	Joint is formed by diffusion of the filler metal into the base metal	Diffusion of filler metal into the base metal associated with surface alloying	Solidification of the molten filler metal with the molten base metal
4.	Strength of the joint is comparatively low	Strength lies between that of welded and soldered joint	Much stronger than the base metal
5.	No heat effected zone	Heat affected zone is not too much when compared to welding	Heat affected zone is affected to a large extent
6.	Finishing operations are not required	Sometimes brazed joints require finishing	Requires finishing operations like grinding, filing etc
7.	Sheet metal work and electronic industries	Arts, jewellery works	Fabrication and structural works

08

Signature of Course Incharge

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K.S. INSTITUTE OF TECHNOLOGY, BANGALORE - 560109

III SESSIONAL TEST QUESTION PAPER 2020 – 21 ODD SEMESTER

SET – A

USN

Degree : **B.E**
Branch : **EC**
Subject Title : **Elements of Mechanical Engineering**
Duration : **90 Minutes**

Semester : **I (D)**
Subject Code : **18ME15**
Date : **26/03/2021**
Max Marks : **30**

Note: Answer ONE full question from each part.

Q No.	Question	Marks	CO mapping	K-Level
	PART-A			
1(a)	With a neat sketch, **explain** the working of Pelton wheel	6	CO2	K2 (Understanding)
(b)	**Explain** the construction and working of reciprocating pumps with a neat diagram.	6	CO2	K2 (Understanding)
(c)	**Discuss** the concept of cavitation and priming in centrifugal pump.	6	CO2	K2 (Understanding)
	OR			
2(a)	With a PV diagram, **explain** the working of 4-s petrol engines.	10	CO3	K2 (Understanding)
(b)	**Differentiate** between vapour compression refrigeration and vapour absorption refrigeration cycle.	6	CO3	K2 (Understanding)
(c)	**List** any four commonly used refrigerants.	2	CO3	K2 (Understanding)
	PART-B			
3(a)	**Explain** horizontal spindle milling machine with a neat sketch.	10	CO5	K2 (Understanding)
(b)	Write a note on applications of robot.	2	CO5	K2 (Understanding)
	OR			
4(a)	**What** are machine tools? Explain with an example.	6	CO5	K2 (Understanding)
(b)	**Explain** the following i) taper turning, ii) Boring iii) gang milling	6	CO5	K2 (Understanding)

Signature of Course Incharge

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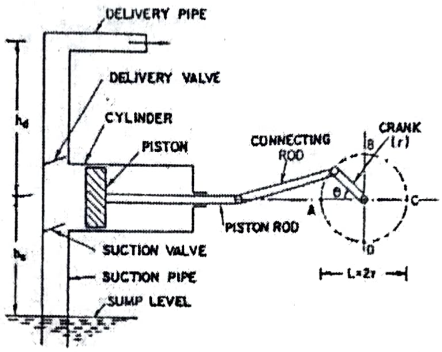
III SESSIONAL TEST QUESTION PAPER 2020 – 21 ODD SEMESTER

SCHEME AND SOLUTION (SET A)

Degree	:	**BE**	**Semester**	:	**I (E)**
Branch	:	**EC**	**Course Code**	:	**18ME15**
Course Title	:	**Elements of Mechanical Engineering**	**Max Marks**	:	**30**

Q. No	SOLUTION	MARKS
1 (a)	**Commonly used refrigerants;** 1. Ammonia 2. Sulphur dioxide 3. Carbon dioxide 4. Freon 5. HFC/CFC's	02
	Applications of AC's: (any two) • In residential buildings, including family houses, duplexes and apartments • Institutional buildings – hospitals, computer laboratories etc. • Commercial buildings – malls, shopping centres, restaurants, office etc. • Transportation – in cars, buses, ships, aircraft and space craft.	02
(b)	TIG welding process: • <u>Principle</u>: Type of welding process in which the workpiece are joined by the heat obtained from an electric arc struck between a non-consumable tungsten electrode and the workpiece, in presence of an inert gas atmosphere.	01
	• <u>Construction details</u>: ❖ It consists of a welding torch in which a non-consumable tungsten alloy electrode [0.5-6.4mm diameter] is held rigidly in the collet. ❖ Various alloy like Zr, thorium, lanthanum etc., are alloyed with tungsten to improve arc stability, better current carrying capacity, and resistance to contamination. ❖ TIG welding makes use of inert gas like argon or helium to protect the welding area from atmospheric gasses [O, N] which cause fusion defects and porosity in the weld metal. ❖ The shielding gas flow from the cylinder through the passage in the electrode holder and then impinges on the work piece. ❖ Pressure regulator and flow meters are used to regulate the pressure and flow of gas from the cylinder. ❖ Either AC or DC can be used to supply the required current.	02

	▪ I half cycle: When crank rotate from point A to C (180° rotation), piston moves towards right of the cylinder, creating partial vacuum within the cylinder. ▪ Since atmospheric pressure acting on the water in sump > than suction pressure inside the cylinder, water from sump is forced in suction pipe to move into the cylinder. ▪ The force of fluid opens the suction valve, causing it to move into the cylinder. The delivery valve remains closed during this action.  ▪ II half cycle: When crank rotates from point C to A (180°), piston moves towards left of cylinder from extreme right side. ▪ The movement of piston towards left, increases the pressure of the fluid inside the cylinder more than atmospheric pressure. Hence suction valve closes and delivery valve opens. ▪ The liquid is forced into the delivery pipe to get discharged to required destination (tank).	02 02
(c)	**Concept of cavitation in centrifugal pump:** ▪ Phenomenon of formation of vapour bubble and its subsequent collapse in the low pressure region around the pump parts. ▪ Identified by a clear audible noise and vibrations caused by the violent collapse of vapour bubbles. ▪ Bubble formation: It usually occurs when a liquid is subjected to changes of pressure such that the static pressure goes lower than the liquid's vapour pressure which will cause the formation of bubbles in the liquid. ▪ When subjected to higher pressure, the bubbles implode. When these implosions happen near a solid material for e.g. impeller, the bubbles implode with a micro-jet hitting the material surface, causing erosion. ▪ Repeated bursts of micro-jets will cause further erosion which spreads and ultimately results in catastrophic equipment failure. ▪ The power consumption for pump operation increases and also there is a decrease flow pressure. ▪ Precautionary measures to avoid cavitation in pumps a) Ensure suitable liquid level in suction pipe b) Lower the water temperature	03

	c) By suitable impeller design d) Periodic checking of clogged strainers and blockages in pipes. e) Ensures that the pressure of fluid at all points within the pump remains above saturation pressure. **Priming in centrifugal pump:** ▪ Process of filling fluid into the casing, suction pipe and delivery pipe up to the delivery valve before starting the pump. ▪ Priming is required in order to remove the air entrapped in the pump, thereby reducing the risk of pump damage during start-up. ▪ Pressure developed inside the pump $\propto$ density of fluid in it. ▪ In case, if air is trapped in the pump and the impeller is allowed to rotate, pressure energy of fluid is not sufficient to lift up; because density of fluid is less [due to presence of air particle]. ▪ The presence of air in the pump creates a small negative pressure at the suction pipe that prevents suction of fluid from sump ▪ In order to eliminate the trapped air, pump is filled with fluid before starting it. [when filled with fluid, the pump is said to be primed]	03
2 (a)	**4-s Petrol engine:** ▪ Works on Otto cycle (Otto cycle engines). ▪ Charge used: mixture of air and petrol supplied by carburettor in suitable proportions. ▪ The charge is ignited by spark generated by a spark plug (S.I engines). ▪ Uses of 4-s petrol engine: scooters, motor bikes, cars, large boats etc. ▪ Four different strokes performed : i. Suction stroke ii. Compression stroke iii. Power stroke/expansion stroke/working stroke iv. Exhaust stroke Suction stroke: ▪ At the beginning of suction stroke, piston is at the TDC and is about to move towards BDC [inlet valve – opened, exhaust valve – closed]. ▪ The downwards movement of piston produces partial vacuum (suction) in the cylinder, which draws fresh air and petrol mixture through the inlet valve. ▪ When the piston reaches BDC, suction stroke ends and inlet valve is closed. ▪ The suction of fuel mixture takes place at atmospheric pressure [Line AB in *pv* diagram]. With this stroke, crankshaft rotates through 180° / half revolution. [The energy required for the piston movement is taken from the battery]. Compression stroke: • Piston moves from BDC to TDC [both inlet and exhaust valve remains closed].	01 02

- As the piston moves upwards, air-petrol mixture gets compressed due to which p and T of mixture increases.
- The compression process is adiabatic in nature [Curve BC]
- When piston about to reach TDC, spark plug initiates spark that ignites the air-petrol mixture.
- Combustion of fuel mixture takes place at constant volume [Line CD](constant volume cycle engines).
- With this stroke, crankshaft rotates by another 180° / half revolution.

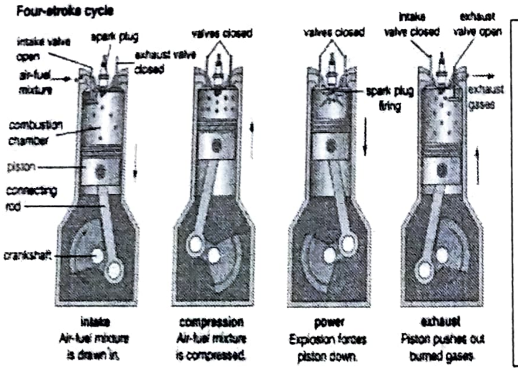
Power stroke:

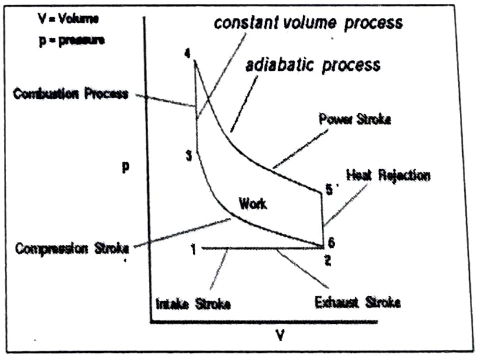
- During this stroke, both valves will remain closed.
- As the combustion of fuel takes place, the burnt gases expands and exert a large force on the piston causing it move rapidly from TDC to BDC. 03
- The force/power is transmitted to the crankshaft through the connecting rod. As a result, crankshaft rotates at high speed [Clutches – gears – wheels of vehicle]
- The expansion of gases is adiabatic in nature [Curve DE].
- Power/working/expansion stroke

Exhaust stroke:

- Towards the end of expansion stroke, the exhaust valve opens and inlet valve remains closed.
- A part of burnt gases due to their own expansion escapes out of the cylinder through exhaust valve [drop in pressure at constant volume inside the cylinder – Line EB]
- The exhaust stroke begins when the piston starts moving from BDC to TDC [Energy for this stroke – flywheel]
- As the piston moves upwards, forces remaining burnt gases to the atmosphere through exhaust valve [Line BA]
- When the piston reaches TDC, the exhaust valve closes and the working cycle is completed.

In the next cycle, the piston starts moving from TDC to BDC, the inlet valve open allowing fresh air to enter into the cylinder and the process continues. Thus in 4-s engines, the working cycle is completed when crankshaft rotates through 720° or two revolutions.





04

(b) **Differences between VCR and VAR (any six)**

Sl. No.	VCR system	VAR system
1.	Vapour refrigerant is compressed	Vapour refrigerant is absorbed and heated
2.	Work is performed by the compressor for the heat transfer.	System makes use of heat source such as combustion of LPG
3.	Mechanical energy required is more [refrigerant vapours are compressed to high pressure]	Energy required is less [Pump is used to circulate the refrigerant]
4.	No restriction for the type of refrigerants used	Refrigerants which are soluble in another solution are used.
5.	electric power is required to run the compressor	Not dependent on electric power.
6.	Noisy, more maintenance cost	Absence of moving parts makes the system run quiet, low maintenance cost
7.	Built in capacity = 1000 Tons	Above 1000 Tons
8.	Coefficient of performance of the system decreases with increase in load	At reduced loads, the system is almost as efficient as at full load
9.	Chances of refrigerant leakage	No chance of refrigerant leakage
10.	Domestic, commercial and industrial applications	Food storage in recreational vehicles

06

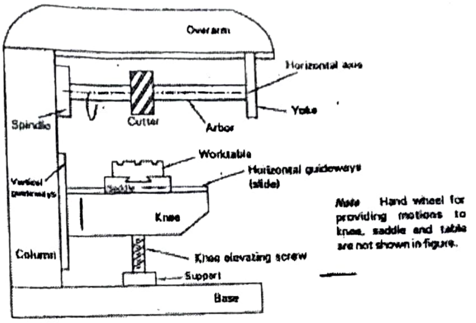
(c) **Commonly used refrigerants** are Ammonia, sulphur dioxide, carbon dioxide, freon and HFC's

02

3 (a) **Horizontal spindle milling machine:**

Part	Feature/functions
Base	• Strong and a hollow part, which forms the foundation of the machines and upon which all other parts are mounted. • Serves as sump for cutting fluid. • A pump and filtration system can be installed in the base. • Hole provided in the center of the base, houses the support for the elevating screw that raises and lowers the knee.
Column	• A vertical hollow casting combined with base to form a single casting. • The column houses the spindle, bearings and drive units [gears, clutches, shafts and shifting mechanism] for transmitting power from the electric motor to the spindle at desired speeds. • Front face of the vertical column is provided with a square or dovetail type guideways on which the knee slides up and down.
Spindle	• Hollow shaft supported by the column with suitable bearings that absorb both radial and thrust loads. • The spindle is made hallow and tapered inside, to accept standard arbors. • Spindle obtains power from the motor and transmits it to the arbor. • The arbor carrying the cutter rotates about a horizontal axis.
Overarm	• Mounted on the vertical column, supports the yoke, which in turn supports the free end of the arbor.
Knee	• Casting that slides up and down on the vertical guideways provided on the column by means of an elevating screw. The knee supports the saddle.

04



Note Hand wheel for providing motions to knee, saddle and table are not shown in figure.

(a) End view of a horizontal-spindle column and knee milling machine

04

Part	Feature/functions
Saddle	• Mounted on the knee is provided with two guideways on its top and bottom surfaces. • The slides are machined at right angles to each other. • The lower slide fits the slide provided on the top of the knee and facilitates horizontal movement of the saddle. • The upper slide provided on the saddle accepts the slide provided on the bottom surface of the worktable.
Work table	• Larger in size and rests on the saddle. • The bottom surface of the table has a dovetail slide that fits in the slide on the top surface of saddle. This facilitates the work table to move longitudinally or at right angles to the movement of the saddle. • Work table is provided with T-slots all along its length for mounting work holding devices which enables the workpiece to be clamped rigidly on the table. • Work table may be manually controlled or power fed. • A dial graduated in thousandth of an inch is provided to allow table movement and placement.

02

(b) **Applications of robot:** Used to move materials or work parts from one location to another [pick and place application], Used to load and unload parts at the production industry, Performing a process on a work part [welding, grinding, coating etc] in automotive industries, Used to assemble the various components of a product like picking a part and inserting into another part with precise placement and orientation. 02

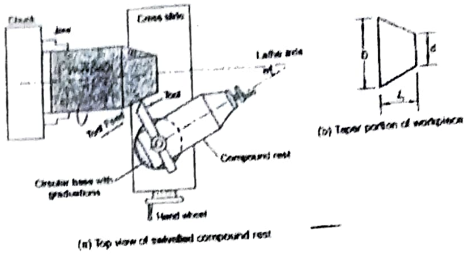
4 (a) **Machine tool**: Machine used to remove extra material from its surface by forcing single point or multipoint cutting tool against the workpiece is termed as machine tools.

Example: Lathe, milling machine, shaping machine, grinding machine, drilling machine. 02

Explanation of any one machine tool 04

(b)

i. **Taper turning**: Process of producing a conical surface from a cylindrical shaped workpiece. A taper is produced when the cutting tool moves at an angle to the axis of rotation of the workpiece.
Methods of producing taper, Swivelling of compound rest, Off-setting the tailstock, Taper turning attachment and form tool method

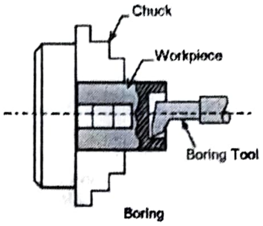


(a) Top view of swivelled compound rest

(b) Taper portion of workpiece

02

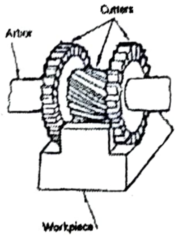
ii. **Boring:** Process of enlarging a hole that has already been drilled by means of a cutting tool (or of a boring head) is termed as boring. Boring is used to achieve greater accuracy of the diameter of a hole, and can be used to cut a tapered hole.

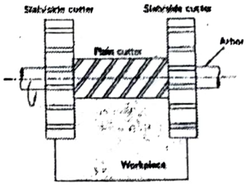


Boring

02

ii. **Gang milling**: Operation in which two or more cutters are mounted on the same arbor, so that different profiles required on the workpiece can be milled simultaneously in a single pass. All the cutters used may be of the same type or of different types depending on the type of surface being milled.





02

Signature of Course Incharge

Head of the Department

K.S. INSTITUTE OF TECHNOLOGY, BANGALORE - 560109

III SESSIONAL TEST QUESTION PAPER 2020 – 21 ODD SEMESTER

SET – B

USN ☐☐☐☐☐☐☐☐☐☐

Degree : B.E
Branch : EC
Subject Title : Elements of Mechanical Engineering
Duration : 90 Minutes

Semester : I (D)
Subject Code : 18ME15
Date : 26/03/2021
Max Marks : 30

Note: Answer ONE full question from each part.

Q No.	Question	Marks	CO mapping	K-Level
	PART-A			
1(a)	**Explain** the construction and working of reciprocating pumps with a neat diagram.	8	CO2	K2 (Understanding)
(b)	With a PV diagram, **explain** the working of 4-s petrol engines.	8	CO3	K2 (Understanding)
(c)	**List** any four commonly used refrigerants.	2	CO3	K2 (Understanding)
	OR			
2(a)	With a neat sketch, **explain** the working of Pelton wheel.	6	CO2	K2 (Understanding)
(b)	**Differentiate** between vapour compression refrigeration and vapour absorption refrigeration cycle.	6	CO3	K2 (Understanding)
(c)	**Discuss** the concept of cavitation and priming in centrifugal pump.	6	CO2	K2 (Understanding)
	PART-B			
3(a)	**Explain** horizontal spindle milling machine with a neat sketch.	8	CO5	K2 (Understanding)
(b)	**What** are machine tools? Mention any two advantages of CNC's over machine tool.	4	CO5	K2 (Understanding)
	OR			
4(a)	**Define** robot. Write a note on applications of robot.	4	CO5	K2 (Understanding)
(b)	**Explain** the following i) taper turning, ii) facing iii) gang milling iv) straddle milling.	8	CO5	K2 (Understanding)

Signature of Course Incharge

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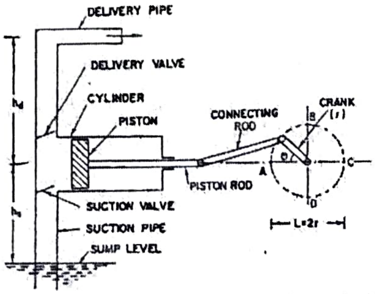
K.S. INSTITUTE OF TECHNOLOGY, BANGALORE - 560109
III SESSIONAL TEST QUESTION PAPER 2020 – 21 ODD SEMESTER

SCHEME AND SOLUTION (SET B)

Degree : BE **Semester :** I (D)
Branch : EC **Course Code :** 18ME15
Course Title : Elements of Mechanical Engineering **Max Marks :** 30

Q. No	SOLUTION	MARKS
1 (a)	**Reciprocating pump:** ▪ In reciprocating pump, the pressure energy of fluid is increased by pushing the fluid using piston/plunger that reciprocates in closed fitting cylinder. ▪ Parts of reciprocating pump: Cylinder with piston and piston rod, Crank and connecting rod, Suction pipe and delivery pipe. ▪ When electric motor is energized (switched ON), the crank rotates, transferring motion to the piston, which reciprocates (to and fro movement) inside the cylinder. ▪ I half cycle: When crank rotate from point A to C (180° rotation), piston moves towards right of the cylinder, creating partial vacuum within the cylinder. ▪ Since atmospheric pressure acting on the water in sump > than suction pressure inside the cylinder, water from sump is forced in suction pipe to move into the cylinder. ▪ The force of fluid opens the suction valve, causing it to move into the cylinder. The delivery valve remains closed during this action.	03
		02
	▪ II half cycle: When crank rotates from point C to A (180°), piston moves towards left of cylinder from extreme right side. ▪ The movement of piston towards left, increases the pressure of the fluid inside the cylinder more than atmospheric pressure. Hence suction valve closes and delivery valve opens. ▪ The liquid is forced into the delivery pipe to get discharged to required destination (tank).	03

(b) **4-s Petrol engine:**

- Works on Otto cycle (Otto cycle engines).
- Charge used: mixture of air and petrol supplied by carburettor in suitable proportions.
- The charge is ignited by spark generated by a spark plug (S.I engines).
- Uses of 4-s petrol engine: scooters, motor bikes, cars, large boats etc. 01
- Four different strokes performed :
  i. Suction stroke
  ii. Compression stroke
  iii. Power stroke/expansion stroke/working stroke
  iv. Exhaust stroke 01

Suction stroke:

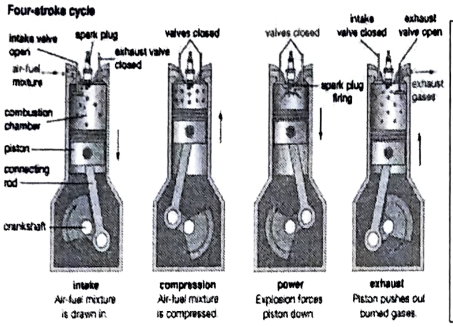
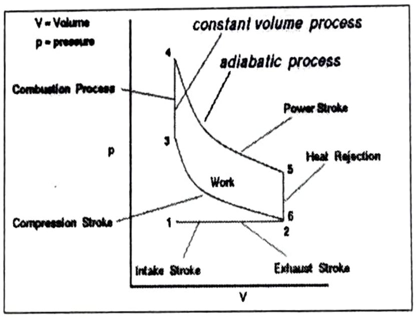
- At the beginning of suction stroke, piston is at the TDC and is about to move towards BDC [inlet valve – opened, exhaust valve – closed].
- The downwards movement of piston produces partial vacuum (suction) in the cylinder, which draws fresh air and petrol mixture through the inlet valve.
- When the piston reaches BDC, suction stroke ends and inlet valve is closed. 02
- The suction of fuel mixture takes place at atmospheric pressure [Line AB in *pv* diagram]. With this stroke, crankshaft rotates through 180° / half revolution. [The energy required for the piston movement is taken from the battery].

Compression stroke:

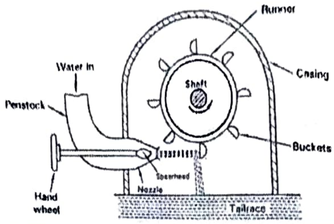
- Piston moves from BDC to TDC [both inlet and exhaust valve remains closed].
- As the piston moves upwards, air-petrol mixture gets compressed due to which p and T of mixture increases.
- The compression process is adiabatic in nature [Curve BC]
- When piston about to reach TDC, spark plug initiates spark that ignites the air-petrol mixture. 01
- Combustion of fuel mixture takes place at constant volume [Line CD](constant volume cycle engines).
- With this stroke, crankshaft rotates by another 180° / half revolution.

Power stroke:

- During this stroke, both valves will remain closed.
- As the combustion of fuel takes place, the burnt gases expands and exert a large force on the piston causing it move rapidly from TDC to BDC.
- The force/power is transmitted to the crankshaft through the connecting rod. As a result, crankshaft rotates at high speed [Clutches – gears – wheels of vehicle]
- The expansion of gases is adiabatic in nature [Curve DE].
- Power/working/expansion stroke

	Exhaust stroke: ▪ Towards the end of expansion stroke, the exhaust valve opens and inlet valve remains closed. ▪ A part of burnt gases due to their own expansion escapes out of the cylinder through exhaust valve [drop in pressure at constant volume inside the cylinder – Line EB] ▪ The exhaust stroke begins when the piston starts moving from BDC to TDC [Energy for this stroke – flywheel] ▪ As the piston moves upwards, forces remaining burnt gases to the atmosphere through exhaust valve [Line BA] ▪ When the piston reaches TDC, the exhaust valve closes and the working cycle is completed. In the next cycle, the piston starts moving from TDC to BDC, the inlet valve open allowing fresh air to enter into the cylinder and the process continues. Thus in 4-s engines, the working cycle is completed when crankshaft rotates through 720° or two revolutions.	01
	 	02
(c)	**Commonly used refrigerants** are Ammonia, sulphur dioxide, carbon dioxide, freon and HFC's	02
2 (a)	**Pelton wheel:** Tangential flow impulse turbine in which potential energy of water is converted into kinetic energy to form high speed water jet and this jet strikes the wheel tangentially to make it rotate.	01
	Parts: Nozzle with a spear head, Runner & Buckets, Turbine Casing	01
	Working: ▪ Water from the reservoir having potential energy flows through the penstock and enters the nozzle. ▪ Potential energy of water is completely converted into kinetic energy in the nozzle. The high velocity water jet from the nozzle impinge on the hemispherical blades fixed around the runner wheel. ▪ The impulse force due to the high velocity jet sets the runner wheel into rotary motion. ▪ The shaft coupled to the runner wheel also rotates thereby doing useful work.	02

- The work produced at the output shaft is used to drive a generator to produce electricity.



02

(b) **Differences between VCR and VAR (any six)**

Sl. No.	VCR system	VAR system
1.	Vapour refrigerant is compressed	Vapour refrigerant is absorbed and heated
2.	Work is performed by the compressor for the heat transfer.	System makes use of heat source such as combustion of LPG
3.	Mechanical energy required is more [refrigerant vapours are compressed to high pressure]	Energy required is less [Pump is used to circulate the refrigerant]
4.	No restriction for the type of refrigerants used	Refrigerants which are soluble in another solution are used.
5.	electric power is required to run the compressor	Not dependent on electric power.
6.	Noisy, more maintenance cost	Absence of moving parts makes the system run quiet, low maintenance cost
7.	Built in capacity = 1000 Tons	Above 1000 Tons
8.	Coefficient of performance of the system decreases with increase in load	At reduced loads, the system is almost as efficient as at full load
9.	Chances of refrigerant leakage	No chance of refrigerant leakage
10.	Domestic, commercial and industrial applications	Food storage in recreational vehicles

06

(c) **Concept of cavitation in centrifugal pump:**

- Phenomenon of formation of vapour bubble and its subsequent collapse in the low pressure region around the pump parts.
- Identified by a clear audible noise and vibrations caused by the violent collapse of vapour bubbles.
- Bubble formation: It usually occurs when a liquid is subjected to changes of pressure such that the static pressure goes lower than the liquid's vapour pressure which will cause the formation of bubbles in the liquid.
- When subjected to higher pressure, the bubbles implode. When these implosions happen near a solid material for e.g. impeller, the bubbles implode with a micro-jet hitting the material surface, causing erosion.
- Repeated bursts of micro-jets will cause further erosion which spreads and ultimately results in catastrophic equipment failure.
- The power consumption for pump operation increases and also there is a decrease flow pressure.
- Precautionary measures to avoid cavitation in pumps
  a) Ensure suitable liquid level in suction pipe
  b) Lower the water temperature

03

c) By suitable impeller design
d) Periodic checking of clogged strainers and blockages in pipes.
e) Ensures that the pressure of fluid at all points within the pump remains above saturation pressure.

Priming in centrifugal pump:

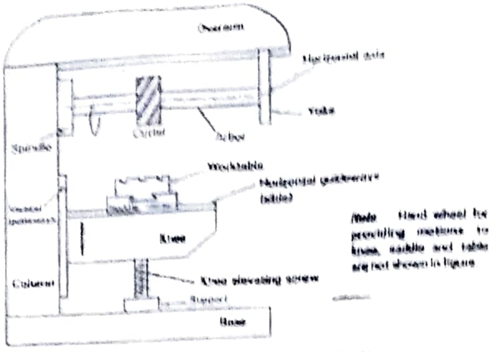
- Process of filling fluid into the casing, suction pipe and delivery pipe up to the delivery valve before starting the pump.
- Priming is required in order to remove the air entrapped in the pump, thereby reducing the risk of pump damage during start-up.
- Pressure developed inside the pump $\propto$ density of fluid in it.
- In case, if air is trapped in the pump and the impeller is allowed to rotate, pressure energy of fluid is not sufficient to lift up; because density of fluid is less [due to presence of air particle].
- The presence of air in the pump creates a small negative pressure at the suction pipe that prevents suction of fluid from sump
- In order to eliminate the trapped air, pump is filled with fluid before starting it. [when filled with fluid, the pump is said to be primed]

03

3 (a) **Horizontal spindle milling machine:**

Part	**Feature/functions**
Base	• Strong and a hollow part, which forms the foundation of the machines and upon which all other parts are mounted. • Serves as sump for cutting fluid. • A pump and filtration system can be installed in the base. • Hole provided in the center of the base, houses the support for the elevating screw that raises and lowers the knee.
Column	• A vertical hollow casting combined with base to form a single casting. • The column houses the spindle, bearings and drive units [gears, clutches, shafts and shifting mechanism] for transmitting power from the electric motor to the spindle at desired speeds. • Front face of the vertical column is provided with a square or dovetail type guideways on which the knee slides up and down.
Spindle	• Hollow shaft supported by the column with suitable bearings that absorb both radial and thrust loads. • The spindle is made hallow and tapered inside, to accept standard arbors. • Spindle obtains power from the motor and transmits it to the arbor. • The arbor carrying the cutter rotates about a horizontal axis.
Overarm	• Mounted on the vertical column, supports the yoke, which in turn supports the free end of the arbor.
Knee	• Casting that slides up and down on the vertical guideways provided on the column by means of an elevating screw. The knee supports the saddle.

03



Note: Hand wheel for providing motions to knee, saddle and table are not shown in figure.

(a) End view of a horizontal spindle column and knee milling machine

03

Part	Feature/functions
Saddle	• Mounted on the knee is provided with two guideways on its top and bottom surfaces. • The slides are machined at right angles to each other. • The lower slide fits the slide provided on the top of the knee and facilitates horizontal movement of the saddle. • The upper slide provided on the saddle accepts the slide provided on the bottom surface of the worktable.
Work table	• Larger in size and rests on the saddle. • The bottom surface of the table has a dovetail slide that fits in the slide on the top surface of saddle. This facilitates the work table to move longitudinally or at right angles to the movement of the saddle. • Work table is provided with T-slots all along its length for mounting work holding devices which enables the workpiece to be clamped rigidly on the table. • Work table may be manually controlled or power fed. • A dial graduated in thousandth of an inch is provided to allow table movement and placement.

02

(b) **Machine tool**: Machine used to remove extra material from its surface by forcing single point or multipoint cutting tool against the workpiece is termed as machine tools. 01

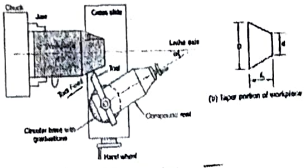
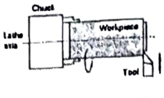
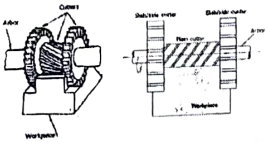
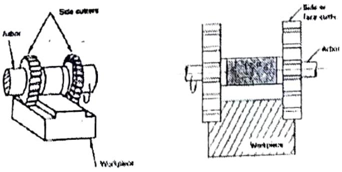
Advantages of CNC's over machine tool: (any four)

- Higher productivity, higher precision, multi operational facilities
- Does not require a skilled operator
- Improved automation
- Repeatability and reliability
- Flexibility

03

4 (a) **Industrial robot:** It is a reprogrammable, multifunctional manipulator designed to move materials, parts, tools through variable programmed motions for the performance of variety of tasks. 02

Applications of robot: Used to move materials or work parts from one location to another [pick and place application], Used to load and unload parts at the production industry, Performing a process on a work part [welding, grinding, coating etc] in automotive industries, Used to assemble the various components of a product like picking a part and inserting into another part with precise placement and orientation. 02

(b)	i. **Taper turning**: Process of producing a conical surface from a cylindrical shaped workpiece. A taper is produced when the cutting tool moves at an angle to the axis of rotation of the workpiece. Methods of producing taper, Swivelling of compound rest, Off-setting the tailstock, Taper turning attachment and form tool method  (b) Taper portion of workpiece (a) Top view of swivelled compound rest	02
	ii. **Facing:** Operation of generating a flat surface at the end of the workpiece. One end of the workpiece is held rigidly in the chuck/live center, while the other end is left un-supported. The tool is fed in a direction perpendicular to the lathe axis to produce a flat surface at the end of the workpiece. Facing is also carried out to reduce or cut the workpiece to the required length.  (a) Front view of facing operation	02
	iii. **Gang milling**: Operation in which two or more cutters are mounted on the same arbor, so that different profiles required on the workpiece can be milled simultaneously in a single pass. All the cutters used may be of the same type or of different types depending on the type of surface being milled.  	02
	iv. **Straddle milling:** Operation in which a pair of side milling cutters is used for milling two parallel vertical surfaces simultaneously. Side milling cutter has a cutting edge on one/ both sides as well as on the periphery. Straddle milling is accomplished by mounting two side milling cutters on the same arbor, set apart at an exact spacing with the help of spacers, washers and shims so that distance between the cutting teeth of each cutter is exactly equal to the width of the workpiece area being milled.  	02

Signature of Course Incharge

Head of the Department

Head of the Department
Dept. of Mechanical Engg.
K.S. Institute of Technology
Bengaluru - 560 109.

20-21 odd
1E

Visvesvaraya Technological University

K.S. INSTITUTE OF TECHNOLOGY, BANGALORE

Branch : EC Scheme : 2018 Semester : 1

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--x--	Faculty Signature									----XXXXXXX----

* - values are either optional subjects or the faculty has not yet entered the marks

HOD 21/6/2021
Seal and Signature

Head of the Department
Dept. of Science and Humanities
K.S. Institute of Technology
Bengaluru - 560 109

PRINCIPAL
Seal and Signature

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BENGALURU - 560 109.

Head of the Department
Dept. of Mechanical Engg.
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Bengaluru - 560 109.

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Kanakpura Road, Bengaluru – 560109

DEPARTMENT OF MECHANICAL ENGINEERING

CHALLEGING QUESTIONS

MODULE 1

1. Explain briefly the principle of conversion of solar energy directly into electrical energy in a solar cell.
2. Explain briefly the following; Zeroth law, first and second law of thermodynamics.
3. Explain the formation of steam with the help of Temperature-Enthalpy diagram.
4. Determine the specific volume and density of 1 kg of steam at 7 bar, when the condition of the steam is i) Wet, having dryness fraction of 0.9 ii) Dry, iii) Superheated to 250^0 C. For P_{abs}= 7 bar, assume T_{Sat}= 437.92 K and Vg=0.273341 m^3/kg.

MODULE 2

1. Explain with a neat sketch, working principle of Babcock and Wilcox boiler.
2. State the advantages, disadvantages and applications of Lancashire steam boiler.
3. With a neat sketch explain the construction and working of pelton wheel turbine.
4. What are hydraulic pumps? Explain centrifugal pump with a neat sketch.

MODULE 3

1. With a neat sketch explain the working of 4 stroke diesel engine
2. A single cylinder 4-s engine runs at 1000rpm and has a bore of 115mm and a stroke of 140mm. The brake load is 60N at 600 mm radius and the mechanical efficiency is 80%. Calculate brake power and mean effective pressure.
3. A 4-s IC engine running at 450rpm has bore diameter 100mm and stroke length 120mm. The details of the indicator diagram are as follows;
   i) Area of indicator diagram = $4cm^2$
   ii) Length of the indicator diagram = 6.5cm
   iii) Spring value of the spring = 10bar/cm.
   Calculate the indicated power of the engine.
4. Explain the working principle of VCR system

MODULE 4

1. Explain the following i) Piezoelectric materials ii) Optical fibre glass.
2. Differentiate between soldering, brazing and welding.
3. With a neat sketch, explain TIG welding process.
4. With a neat sketch, explain MIG welding process.
5. With a neat sketch explain oxy-acetylene welding process.

MODULE 5

1. Explain briefly the components of CNC machine with a neat block diagram.
2. Explain horizontal spindle milling machine with a neat sketch.
3. Define robot and explain the classification of robot based on physical configuration.
4. With a neat sketch explain the taper turning by swivelling method

K.S. INSTITUTE OF TECHNOLOGY, BANGALORE - 560109

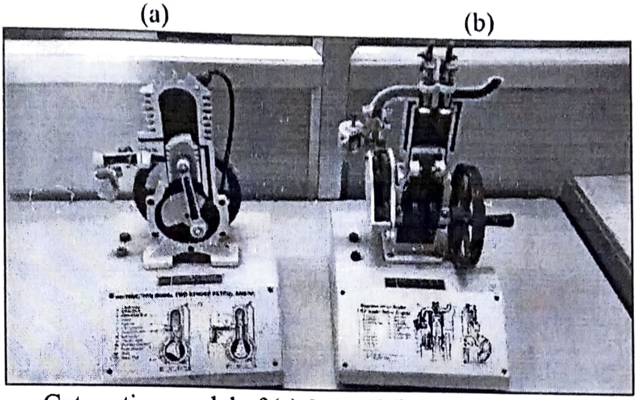
DEARTMENT OF MECHANICAL ENGINEERING

TEACHING AND LEARNING

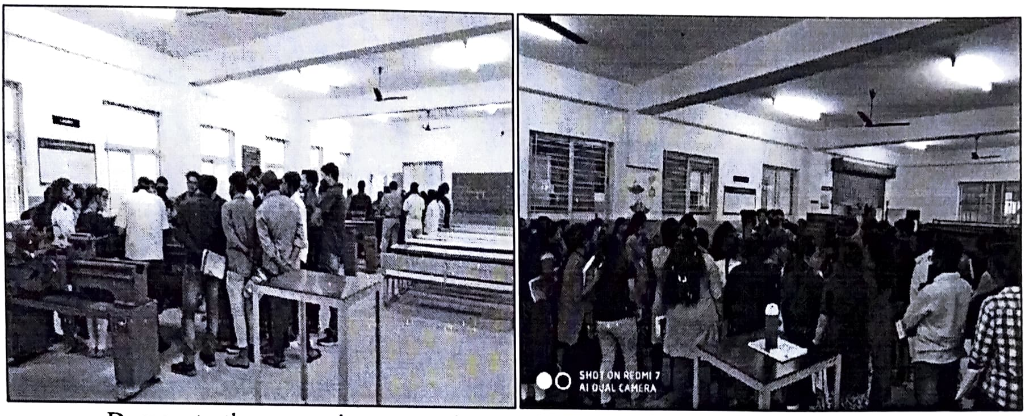
PEDAGOGY REPORT

Academic Year	2020-21_ODD Semester
Name of the Faculty	Mr. RAJESH GL
Course Name /Code	Elements of Mechanical Engineering [EME]
Semester/Section	1st / D & E
Activity Name	Demonstration on i. Working of IC engines using cut section models/Video sessions ii. Machine tools, operations performed on lathe and milling machine iii. Metal joining using electric arc welding process.
Topic Covered	Heat engines, Machine tools and Joining of engineering materials
Date	i. 15th February 2021 ii. 6th March 2021 iii. 19th March 2021
No. of Participants	118
Objectives/Goals	❖ To understand the working principle of 2 stroke & 4 stroke IC engine ❖ To discuss the various lathe and milling operations. ❖ To recognize the importance of arc generation in metal joining process.
ICT Used	PPT, videos-cut section models of IC engine, visit to machine shop and workshop.
Appropriate Method/Instructional materials/Exam Questions. ❖ Working principle of 2-s and 4-s IC engine by using cut Section model. ❖ Visit to machine shop/ live demo on lathe and milling operations. ❖ Visit to workshop/live demo on arc welding process.	
Relevant PO's	PO1,PO3,PO5,PO6,PO7,PO12
Significance of Results/Outcomes	❖ Students understood the different types of metal joining process. ❖ Students showed interest towards fabrication of IC engine parts and accessories ❖ Students came to know the specific applications of lathe operation. ❖ Students were able to distinguish machine tool with advanced manufacturing system like CNC's etc. ❖ Students came to know how gear teeth are cut using horizontal milling machine. ❖ Students understood the concept and use of tool nomenclature in manufacturing industries.
Reflective Critique	❖ Students attended few part programming courses and acquired knowledge on G and M codes. ❖ Students showed interest towards NPTEL online courses related to metal joining process. ❖ Students enquired on demonstration of CNC machine. ❖ Students gained thorough knowledge on working of 4-s and 2-s engines and its parameters. ❖ Students were able to distinguish between petrol, diesel and gas engines. ❖ Students showed interest towards developing a cut section model of IC engines. ❖ Students were able to identify different types of engineering materials and its application area.

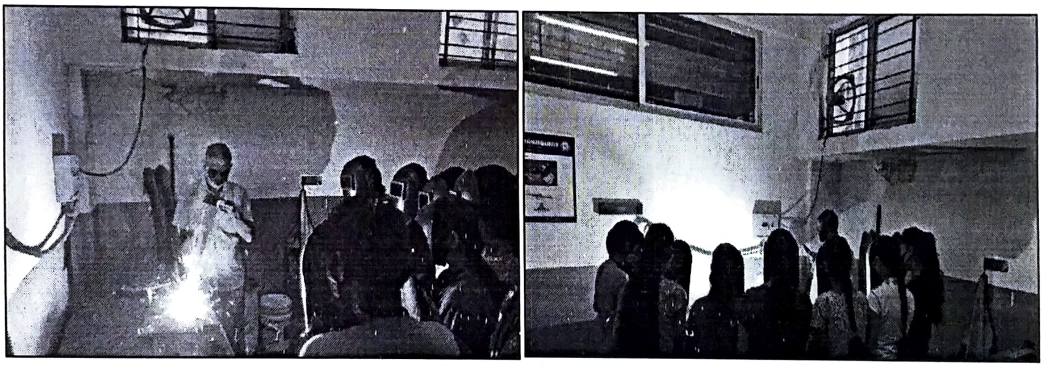
Proofs (Photographs/Videos/Reports/Charts/Models)



Cut section model of (a) 2-s and (b)4-s petrol engine



Demonstration on various operations performed on lathe and milling machine



Demonstration on arch welding process

Signature of Course In charge

Signature of HOD-ME

Head of the Department
Dept. of Mechanical Engg.
K.S. Institute of Technology
Bengaluru - 560 109.

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K.S. Group of Institutions
K. S. INSTITUTE OF TECHNOLOGY
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Kanakpura Road, Bengaluru – 560109

DEPARTMENT OF MECHANICAL ENGINEERING

MODULE WISE QUESTION BANK

MODULE 1

1. With a neat sketch explain the principle of operation of a typical wind mill.
2. Explain briefly the principle of conversion of solar energy directly into electrical energy in a solar cell.
3. Explain briefly the following; Zeroth law, first and second law of thermodynamics.
4. Explain the formation of steam with the help of Temperature-Enthalpy diagram.
5. Explain briefly i) Global Warming ii) Ozone depletion
6. Determine the specific volume and density of 1 kg of steam at 7 bar, when the condition of the steam is i) Wet, having dryness fraction of 0.9 ii) Dry, iii) Superheated to 250^0 C. For P_{abs}= 7 bar, assume T_{Sat}= 437.92 K and Vg=0.273341 m^3/kg.

MODULE 2

1. Differentiate between water tube boiler and fire tube boilers
2. Explain with a neat sketch working of Lancashire boiler.
3. Explain with a neat sketch, working principle of Babcock and Wilcox boiler.
4. State the advantages, disadvantages and applications of Lancashire steam boiler.
5. With a neat sketch explain the construction and working of pelton wheel turbine.
6. What are hydraulic pumps? Explain centrifugal pump with a neat sketch.

MODULE 3

1. With a neat sketch explain the different parts of an IC engine.
2. With a neat sketch explain the working of 4 stroke diesel engine
3. Differentiate between 2-s and 4-s engines.
4. A single cylinder 4-s engine runs at 1000rpm and has a bore of 115mm and a stroke of 140mm. The brake load is 60N at 600 mm radius and the mechanical efficiency is 80%. Calculate brake power and mean effective pressure.
5. A 4-s IC engine running at 450rpm has bore diameter 100mm and stroke length 120mm. The details of the indicator diagram are as follows;
   i) Area of indicator diagram = $4cm^2$
   ii) Length of the indicator diagram = 6.5cm
   iii) Spring value of the spring = 10bar/cm.
   Calculate the indicated power of the engine.
6. Explain the working principle of VCR system

MODULE 4

1. Classify ferrous and nonferrous metals.
2. Explain the following i) Piezoelectric materials ii) Optical fibre glass.
3. Differentiate between soldering, brazing and welding.
4. With a neat sketch, explain TIG welding process.
5. With a neat sketch, explain MIG welding process.
6. With a neat sketch explain oxy-acetylene welding process.

MODULE 5

1. Explain briefly the components of CNC machine with a neat block diagram.
2. Explain horizontal spindle milling machine with a neat sketch.
3. With sketches explain briefly the following i) Gang milling ii) Thread cutting iii) Angular milling.
4. Explain Vertical spindle milling machine with a neat sketch.
5. Define robot and explain the classification of robot based on physical configuration.
6. With a neat sketch explain the taper turning by swivelling method

First/Second Semester B.E. Degree Examination, June/July 2019

Elements of Mechanical Engineering

Time: 3 hrs. Max. Marks: 100

Note: *1. Answer FIVE full questions, choosing one full question from each module.*
2. Use of Steam table is permitted.

Module-1

1 a. List and explain any one source of energy. **(06 Marks)**

b. Explain briefly (i) Global Warming (ii) Ozone depletion **(06 Marks)**

c. Find the enthalpy of 1 kg of steam at 12 bar when
   - (i) Steam is dry saturated
   - (ii) Steam is 22% wet and
   - (iii) Super heated to 250°C

Assume the specific heat of the super heated steam as 2.25 KJ/kgK. **(08 Marks)**

OR

2 a. Explain briefly any two of the following:
   - (i) Zeroth law of thermodynamics
   - (ii) First law of thermodynamics
   - (iii) Second law of thermodynamics. **(06 Marks)**

b. Explain formation of steam with the help of Temperature-Enthalpy (T-h) diagram. **(08 Marks)**

c. Find the specific volume and enthalpy of 1 kg of steam at 0.8 MPa.
   - (i) When the dryness fraction is 0.9
   - (ii) When the steam is super heated to a temperature of 300°C

The specific heat of the super heated steam is 2.25 KJ/kgK **(06 Marks)**

Module-2

3 a. With a neat labeled diagram, explain working of Babcock and Wilcox boiler. **(08 Marks)**

b. Define prime movers and explain working of Pelton wheel turbine with a neat sketch. **(12 Marks)**

OR

4 a. Define (i) Boiler Mountings (ii) Boiler Accessories
Explain functions of any five mountings or accessories. **(12 Marks)**

b. What are hydraulic pumps? Explain centrifugal pump with a neat sketch. **(08 Marks)**

Module-3

5 a. Explain 4-s petrol engines with P-V diagram **(10 Marks)**

b. Give comparisons between petrol and diesel engines **(05 Marks)**

c. A four stroke IC engine running at 450 rpm has a bore diameter of 100 mm and stroke length 120 mm. The indicated diagram details are
   - (i) Area of the diagram 4 cm^2
   - (ii) Length of the indicated diagram 6.5 cm
   - (iii) Spring value of the spring used 10 bar/cm

Calculate the indicated power of the engine. **(05 Marks)**

OR

6 a. **Explain** with a neat sketch working of vapour compression Refrigerator (08 Marks)

b. **Define** : (i) Ton of Refrigerator (ii) COP (iii) Ice making capacity (06 Marks)

c. List commonly used refrigerants and mention the applications of air conditioners. (06 Marks)

Module-4

7 a **Classify ferrous and non ferrous metals** (05 Marks)

b **Define composites**, **explain** any two of the following (i) Piezoelectric materials
(ii) Shape memory alloys (iii) Optical fibre glass (05 Marks)

c. Classify metal joining processes, explain TIG (Tungsten Inert Gas) Welding with a neat sketch (10 Marks)

OR

8 a **Derive** an expression for **length** of the belt in open belt drive (10 Marks)

b **Mention** advantages and disadvantages of V-Belt drive (05 Marks)

c List different types of gears and explain any one with its advantages (05 Marks)

Module-5

9 a Explain briefly the following
(i) Turning
(ii) Facing
(iii) Thread cutting (06 Marks)

b. Explain the working of horizontal milling machine with a simple line diagram (08 Marks)

c. Explain briefly.
(i) Angular milling
(ii) Gang milling
(iii) Plane milling (06 Marks)

OR

10 a. **Explain** briefly the components of a CNC machine with a neat block diagram. (08 Marks)

b. **Define Robots** and mention its general applications (07 Marks)

c. Write short note on:
CNC Machining Center or Turning Center (05 Marks)

First/Second Semester B.E. Degree Examination, Dec.2019/Jan.2020

Elements of Mechanical Engineering

Time: 3 hrs.

Max. Marks: 100

Note: Answer any FIVE full questions, choosing ONE full question from each module.

Module-1

1 a. Distinguish between conventional and non-conventional sources of energy. **(08 Marks)**
b. With neat sketch, explain principle of working of Hydrostatic power plant. **(06 Marks)**
c. State and explain the Zeroth law of thermodynamics. **(06 Marks)**

OR

2 a. Distinguish between i) Open System and closed system ii) Heat and work. **(06 Marks)**
b. Define i) Sensible heat ii) Latent heat iii) Dryness fraction iv) Wet steam. **(08 Marks)**
c. Find the specific volume and enthalpy of 1kg of steam at 0.8MPa i) When the dryness fraction is 0.9 ii) When the steam is superheated to a temperature of 300°C. The specific heat of superheated steam is 2.25kJ/kg K. **(06 Marks)**

Module-2

3 a. Explain with a neat sketch, the working of Babcock and Wilcox boiler. **(12 Marks)**
b. Write a brief note on
i) Priming of pumps
ii) Cavitation in pumps. **(08 Marks)**

OR

4 a. List and explain in brief, the boiler mountings and accessories. **(10 Marks)**
b. Sketch and explain the working of Pelton wheel. **(10 Marks)**

Module-3

5 a. With help of PV diagram, explain the working of four stroke petrol engine. **(08 Marks)**
b. Mention the advantages of two stroke engine over four stroke engine. **(06 Marks)**
c. List the desirable properties of an ideal refrigerant. **(06 Marks)**

OR

6 a. With neat sketch explain the working principle of vapour absorption refrigeration system. **(08 Marks)**
b. Calculate the brake power of a single cylinder four stroke petrol engine which is running at a speed of 400rpm. The load on the brake drum is 24kg and the spring balance reads 4kg. The diameter of the brake drum is 600mm and the rope diameter is 30mm. **(06 Marks)**
c. Define: i) Refrigeration ii) COP iii) Ton of refrigeration. **(06 Marks)**

Module-4

7 a. Differentiate between ferrous and non ferrous metals. **(06 Marks)**
b. What is a composite? How are composite materials classified? List the applications of composite materials. **(08 Marks)**
c. Distinguish between soldering, brazing and welding. **(06 Marks)**

OR

8 a. **Describe the principle of arc welding with suitable welding circuit diagram.** (08 Marks)

b. **What are the advantages** and disadvantages of gear drive? (06 Marks)

c. Define slip with reference to belt drive. Why it occurs explain the phenomenon of creep in belt drives. (06 Marks)

Module-5

9 a. **Draw a neat sketch of** engine **lathe and label the parts.** (10 Marks)

b. **Explain the following** with sketches:

i) Up milling

ii) Down milling

iii) Face milling (10 Marks)

OR

10 a. **Define a robot and list the classification of robot based** on physical configuration. (08 Marks)

b. List and explain various components of CNC. What are the advantages and disadvantages of CNC? (12 Marks)

Timestamp	Name of Student	USN	Section	Branch	1. How strong are you in u	2. To what extent can you	3. How effectively have yo	4. How well can you solve	5. How confident are you i
4-7-2021 18:59:45	Sadhana srinivas	1KS20EC085	D	ECE	Very Good	Excellent	Good	Excellent	Good
4-7-2021 19:18:10	Sandeep Y H	2020054787	D	ECE	Excellent	Excellent	Excellent	Excellent	Excellent
4-7-2021 21:43:23	Shreya H	2020049792	D	ECE	Very Good	Very Good	Very Good	Very Good	Very Good
4-8-2021 8:32:56	Aditi dubey	1KS20EC002	D	ECE	Very Good	Very Good	Very Good	Very Good	Very Good
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4-8-2021 8:34:08	Sanjana t gadikar	1ks20EC091	D	ECE	Good	Good	Good	Very Good	Very Good
4-8-2021 8:34:37	Eshwar Biradar	1KS20EC026	D	ECE	Excellent	Excellent	Very Good	Very Good	Very Good
4-8-2021 8:36:15	Chaitanya k	1KS20EC012	D	ECE	Excellent	Excellent	Excellent	Excellent	Excellent
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4-8-2021 10:41:49	Sandeep Y H	1KS20EC087	D	ECE	Excellent	Excellent	Excellent	Excellent	Excellent
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4-8-2021 19:21:50	Dhamini. J	1KS20EC023	D	ECE	Excellent	Excellent	Excellent	Excellent	Excellent
4-8-2021 20:09:58	Shivareddy.ba	1KS20EC095	D	ECE	Excellent	Very Good	Satisfactory	Very Good	Satisfactory
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4-9-2021 9:54:56	Shakthi Anbazhagan M	1KS20EC092	D	ECE	Very Good	Very Good	Very Good	Excellent	Satisfactory
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4-9-2021 19:26:40	HARSHITHA N	1KS20EC036	D	ECE	Excellent	Excellent	Excellent	Excellent	Excellent
4-9-2021 19:32:26	Saksham Singh	1KS20EC086	D	ECE	Excellent	Excellent	Excellent	Excellent	Excellent
4-9-2021 22:56:15	Dhruva Kumar.S	1KS20EC024	D	ECE	Good	Good	Good	Satisfactory	Satisfactory
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4-10-2021 13:18:09	Sanjana.G	1KS20EC089	D	ECE	Very Good	Excellent	Very Good	Excellent	Excellent

K.S. INSTITUTE OF TECHNOLOGY, BANGALORE

DEPARTMENT OF ELECTRONICS AND COMMUNICATION E

YEAR / SEMESTER	I / I SEM
COURSE TITLE	Elements of Mechanical Engineering
COURSE CODE	18ME15
ACADEMIC YEAR	2020-21
BATCH	2020-24

CO Attainment Level	Significance
Level	60% and above students should have scored >= 60% of Total marks
Level	55% to 59% of students should have scored >= 60% of Total marks
Level	50% to 54% of students should have scored >= 60% of Total marks

For Direct attainment , 50% of CIE and 50% of SEE marks are considered.
For indirect attainment, Course end survey is considered.
CO attainment is 90%of direct attainment + 10% of indirect attainment.
PO attainment = CO-PO mapping strength/3 * CO attainment .

			IA1							Assignment 1							IA2										Assignment 2										IA3							Assignment 3							EXTERNAL		
Sl. NO.	USN	NAME	IA1	CO1	Score	Target	CO2	Score	Target	A1	CO1	Score	Target	CO2	Score	Target	IA2	CO2	Score	Target	CO3	Score	Target	CO4	Score	Target	A2	CO2	Score	Target	CO3	Score	Target	CO4	Score	Target	IA3	CO4	Score	Target	CO5	Score	Target	A3	CO4	Score	Target	CO5	Score	Target	SEE	Score	Target
	Maximum Marks		30	18			12			10	6			4			30	6			18			6			10	2			6			2			30	12			18			10	4			6			60		
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2	1KS20EC002	ADITI DUBEY	27	17	3	Y	10	3	Y	10	6	3	Y	4	3	Y	28	5.00	3	Y	18	3	Y	5	3	Y	10	2.00	3	Y	6	3	Y	2	3	Y	26	12.00	3	Y	14	3	Y	10	4.00	3	Y	6	3	Y	33	2	N
3	1KS20EC003	AFEEFA SHARIEFF	24	15	3	Y	9	3	Y	10	6	3	Y	4	3	Y	24	6.00	3	Y	12	3	Y	6	3	Y	10	2.00	3	Y	6	3	Y	2	3	Y	29	12.00	3	Y	17	3	Y	10	4.00	3	Y	6	3	Y	30	1	N
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8	1KS20EC008	B.S.HEMASHREE	23	14	3	Y	9	3	Y	10	6	3	Y	4	3	Y	23	4.00	3	Y	12	3	Y	5	3	Y	10	2.00	3	Y	6	3	Y	2	3	Y	23	10.00	3	Y	13	3	Y	10	4.00	3	Y	6	3	Y	21	0	N
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11	1KS20EC011	BHUVANESHWARI K	25	15	3	Y	10	3	Y	10	6	3	Y	4	3	Y	25	5.00	3	Y	15	3	Y	5	3	Y	10	2.00	3	Y	6	3	Y	2	3	Y	25	11.00	3	Y	14	3	Y	10	4.00	3	Y	6	3	Y	30	1	N
12	1KS20EC012	CHAITANYA.K	23	15	3	Y	8	3	Y	10	6	3	Y	4	3	Y	25	5.00	3	Y	14	3	Y	6	3	Y	10	2.00	3	Y	6	3	Y	2	3	Y	19	8.00	3	Y	11	3	Y	10	4.00	3	Y	6	3	Y	27	0	N
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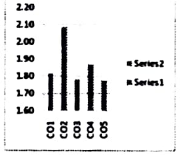
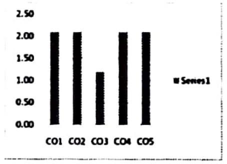
15	1KS20EC015	CHALLAGUNDLA UMA DEVI	22	12	3	Y	10	3	Y	10	6	3	Y	4	3	Y	24	6.00	3	Y	10	2	N	6	3	Y	10	2.00	3	Y	6	3	Y	2	3	Y	13	6.00	1	N	7	0	N	10	4.00	3	Y	6	3	Y	14	0	N
16	1KS20EC016	CHAYA S	23	15	3	Y	8	3	Y	10	6	3	Y	4	3	Y	22	6.00	3	Y	11	3	Y	5	3	Y	10	2.00	3	Y	6	3	Y	2	3	Y	24	12.00	3	Y	12	3	Y	10	4.00	3	Y	6	3	Y	37	3	Y
17	1KS20EC017	CHETHAN G	19	11	3	Y	8	3	Y	10	6	3	Y	4	3	Y	16	5.00	3	Y	10	2	N	4	3	Y	10	2.00	3	Y	6	3	Y	2	3	Y	13	7.00	2	N	6	0	N	10	4.00	3	Y	6	3	Y	21	0	N
18	1KS20EC018	CHETHAN KUMAR J	20	10	2	N	10	3	Y	10	6	3	Y	4	3	Y	25	5.00	3	Y	15	3	Y	5	3	Y	10	2.00	3	Y	6	3	Y	2	3	Y	18	6.00	1	N	12	3	Y	10	4.00	3	Y	6	3	Y	14	0	N
19	1KS20EC019	CHETHAN KUMAR T	19	11	3	Y	8	3	Y	10	6	3	Y	4	3	Y	22	5.00	3	Y	12	3	Y	5	3	Y	10	2.00	3	Y	6	3	Y	2	3	Y	18	8.00	3	Y	10	2	N	10	4.00	3	Y	6	3	Y	27	0	N
20	1KS20EC020	DARSHAN K	23	16	3	Y	7	2	N	10	6	3	Y	4	3	Y	21	6.00	3	Y	10	2	N	5	3	Y	10	2.00	3	Y	6	3	Y	2	3	Y	20	11.00	3	Y	9	0	N	10	4.00	3	Y	6	3	Y	26	0	N
21	1KS20EC021	DARSHAN KUMAR S	23	14	3	Y	9	3	Y	10	6	3	Y	4	3	Y	12	3.00	1	N	6	0	N	3	1	N	10	2.00	3	Y	6	3	Y	2	3	Y	24	12.00	3	Y	12	3	Y	10	4.00	3	Y	6	3	Y	36	3	Y
22	1KS20EC022	DEEPAK S	30	18	3	Y	12	3	Y	10	6	3	Y	4	3	Y	27	5.00	3	Y	14	3	Y	6	3	Y	10	2.00	3	Y	6	3	Y	2	3	Y	28	10.00	3	Y	18	3	Y	10	4.00	3	Y	6	3	Y	48	3	Y
23	1KS20EC023	DHAMINI J	23	15	3	Y	8	3	Y	10	6	3	Y	4	3	Y	25	5.00	3	Y	15	3	Y	5	3	Y	10	2.00	3	Y	6	3	Y	2	3	Y	25	11.00	3	Y	14	3	Y	10	4.00	3	Y	6	3	Y	32	1	N
24	1KS20EC024	DHRUVA KUMAR S	20	11	3	Y	9	3	Y	10	6	3	Y	4	3	Y	28	5.00	3	Y	18	3	Y	5	3	Y	10	2.00	3	Y	6	3	Y	2	3	Y	18	8.00	3	Y	10	2	N	10	4.00	3	Y	6	3	Y	24	0	N
25	1KS20EC025	DIVYA N	16	10	2	N	6	1	N	10	6	3	Y	4	3	Y	28	6.00	3	Y	16	3	Y	6	3	Y	10	2.00	3	Y	6	3	Y	2	3	Y	23	10.00	3	Y	13	3	Y	10	4.00	3	Y	6	3	Y	21	0	N
26	1KS20EC026	ESHWAR BIRADAR	18	9	1	N	10	3	Y	10	6	3	Y	4	3	Y	27	5.00	3	Y	17	3	Y	5	3	Y	10	2.00	3	Y	6	3	Y	2	3	Y	20	8.00	3	Y	12	3	Y	10	4.00	3	Y	6	3	Y	21	0	N
27	1KS20EC027	G BHAVANA PRIYADARSHINI	24	12	3	Y	12	3	Y	10	6	3	Y	4	3	Y	30	6.00	3	Y	18	3	Y	6	3	Y	10	2.00	3	Y	6	3	Y	2	3	Y	27	11.00	3	Y	16	3	Y	10	4.00	3	Y	6	3	Y	27	0	N
28	1KS20EC028	GAGAN H C	24	14	3	Y	10	3	Y	10	6	3	Y	4	3	Y	28	5.00	3	Y	18	3	Y	5	3	Y	10	2.00	3	Y	6	3	Y	2	3	Y	28	10.00	3	Y	18	3	Y	10	4.00	3	Y	6	3	Y	31	1	N
29	1KS20EC029	GAGANA B S	14	9	1	N	5	0	N	10	6	3	Y	4	3	Y	19	5.00	3	Y	10	2	N	4	3	Y	10	2.00	3	Y	6	3	Y	2	3	Y	22	12.00	3	Y	10	2	N	10	4.00	3	Y	6	3	Y	24	0	N
30	1KS20EC030	GANDHAMANI C H	28	18	3	Y	10	3	Y	10	6	3	Y	4	3	Y	21	5.00	3	Y	12	3	Y	4	3	Y	10	2.00	3	Y	6	3	Y	2	3	Y	26	10.00	3	Y	16	3	Y	10	4.00	3	Y	6	3	Y	33	2	N
31	1KS20EC031	GOMITHA R C	28	16	3	Y	12	3	Y	10	6	3	Y	4	3	Y	21	4.00	2	Y	12	3	Y	5	3	Y	10	2.00	3	Y	6	3	Y	2	3	Y	23	11.00	3	Y	12	3	Y	10	4.00	3	Y	6	3	Y	33	2	N
32	1KS20EC032	HARINI K	4	3	0	N	1	0	N	10	6	3	Y	4	3	Y	16	5.00	3	Y	10	2	N	3	1	N	10	2.00	3	Y	6	3	Y	2	3	Y	19	9.00	3	Y	10	2	N	10	4.00	3	Y	6	3	Y	14	0	N
33	1KS20EC033	HARSHITH GOWDA A R	15	9	1	N	6	1	N	10	6	3	Y	4	3	Y	25	5.00	3	Y	15	3	Y	5	3	Y	10	2.00	3	Y	6	3	Y	2	3	Y	14	6.00	1	N	8	0	N	10	4.00	3	Y	6	3	Y	27	0	N
34	1KS20EC034	HARSHITHA B L	25	15	3	Y	10	3	Y	10	6	3	Y	4	3	Y	28	5.00	3	Y	18	3	Y	5	3	Y	10	2.00	3	Y	6	3	Y	2	3	Y	29	12.00	3	Y	17	3	Y	10	4.00	3	Y	6	3	Y	24	0	N
35	1KS20EC035	HARSHITHA J	25	16	3	Y	9	3	Y	10	6	3	Y	4	3	Y	25	4.00	3	Y	16	3	Y	5	3	Y	10	2.00	3	Y	6	3	Y	2	3	Y	22	10.00	3	Y	12	3	Y	10	4.00	3	Y	6	3	Y	23	0	N
36	1KS20EC036	HARSHITHA N	22	14	3	Y	8	3	Y	10	6	3	Y	4	3	Y	30	6.00	3	Y	18	3	Y	6	3	Y	10	2.00	3	Y	6	3	Y	2	3	Y	26	9.00	3	Y	17	3	Y	10	4.00	3	Y	6	3	Y	39	3	Y
37	1KS20EC037	INCHARA P	16	10	2	N	6	1	N	10	6	3	Y	4	3	Y	20	5.00	3	Y	10	2	N	5	3	Y	10	2.00	3	Y	6	3	Y	2	3	Y	17	7.00	2	N	10	2	N	10	4.00	3	Y	6	3	Y	27	0	N
38	1KS20EC038	JAMPULA CHAITHANYA KRISHNA	12	9	1	N	3	0	N	10	6	3	Y	4	3	Y	19	4.00	3	Y	10	2	N	5	3	Y	10	2.00	3	Y	6	3	Y	2	3	Y	25	11.00	3	Y	14	3	Y	10	4.00	3	Y	6	3	Y	44	3	Y
39	1KS20EC039	JAMUNA S G	28	18	3	Y	10	3	Y	10	6	3	Y	4	3	Y	28	5.00	3	Y	18	3	Y	5	3	Y	10	2.00	3	Y	6	3	Y	2	3	Y	28	11.00	3	Y	15	3	Y	10	4.00	3	Y	6	3	Y	35	2	N
40	1KS20EC040	JANHAVI R	24	16	3	Y	8	3	Y	10	6	3	Y	4	3	Y	22	5.00	3	Y	12	3	Y	5	3	Y	10	2.00	3	Y	6	3	Y	2	3	Y	17	7.00	2	N	10	2	N	10	4.00	3	Y	6	3	Y	27	0	N
41	1KS20EC041	JAYANTH H	28	16	3	Y	12	3	Y	10	6	3	Y	4	3	Y	26	6.00	3	Y	17	3	Y	6	3	Y	10	2.00	3	Y	6	3	Y	2	3	Y	27	12.00	3	Y	15	3	Y	10	4.00	3	Y	6	3	Y	48	3	Y
42	1KS20EC042	K JEEVITHA	27	15	3	Y	12	3	Y	10	6	3	Y	4	3	Y	21	5	3	Y	12	3	Y	4	3	Y	10	2.00	3	Y	6	3	Y	2	3	Y	29	12.00	3	Y	17	3	Y	10	4.00	3	Y	6	3	Y	30	1	N
43	1KS20EC043	K M AMSHUMANTH	25	14	3	Y	11	3	Y	10	6	3	Y	4	3	Y	16	3	1	N	10	2	N	3	1	N	10	2.00	3	Y	6	3	Y	2	3	Y	27	10.00	3	Y	17	3	Y	10	4.00	3	Y	6	3	Y	42	3	Y
44	1KS20EC044	K R SAHANA	27	16	3	Y	11	3	Y	10	6	3	Y	4	3	Y	25	5	3	Y	15	3	Y	5	3	Y	10	2.00	3	Y	6	3	Y	2	3	Y	30	12.00	3	Y	18	3	Y	10	4.00	3	Y	6	3	Y	47	3	Y
45	1KS20EC045	KAVANA G S	26	15	3	Y	11	3	Y	10	6	3	Y	4	3	Y	26	5	3	Y	16	3	Y	5	3	Y	10	2.00	3	Y	6	3	Y	2	3	Y	29	12.00	3	Y	17	3	Y	10	4.00	3	Y	6	3	Y	21	0	N
46	1KS20EC046	KAVYA S M	27	18	3	Y	9	3	Y	10	6	3	Y	4	3	Y	26	5	3	Y	16	3	Y	5	3	Y	10	2.00	3	Y	6	3	Y	2	3	Y	28	11.00	3	Y	17	3	Y	10	4.00	3	Y	6	3	Y	24	0	N
47	1KS20EC047	KEERTHANA B S	20	12	3	Y	8	3	Y	10	6	3	Y	4	3	Y	14	3	1	N	8	0	N	3	1	N	10	2.00	3	Y	6	3	Y	2	3	Y	24	10.00	3	Y	14	3	Y	10	4.00	3	Y	6	3	Y	18	0	N
48	1KS20EC048	KIRAN DEV O	19	11	3	Y	8	3	Y	10	6	3	Y	4	3	Y	24	4	3	Y	16	3	Y	4	3	Y	10	2.00	3	Y	6	3	Y	2	3	Y	26	12.00	3	Y	14	3	Y	10	4.00	3	Y	6	3	Y	45	3	Y
49	1KS20EC049	KIRAN V NARAYAN	15	9	1	N	6	1	N	10	6	3	Y	4	3	Y	19	5	3	Y	10	2	N	4	3	Y	10	2.00	3	Y	6	3	Y	2	3	Y	24	11.00	3	Y	13	3	Y	10	4.00	3	Y	6	3	Y	41	3	Y
50	1KS20EC050	KODIDELA PRATHIMA	20	11	3	Y	9	3	Y	10	6	3	Y	4	3	Y	25	5	3	Y	15	3	Y	5	3	Y	10	2.00	3	Y	6	3	Y	2	3	Y	28	12.00	3	Y	16	3	Y	10	4.00	3	Y	6	3	Y	26	0	N
51	1KS20EC051	KUMAR K G	24	12	3	Y	12	3	Y	10	6	3	Y	4	3	Y	23	5	3	Y	13	3	Y	5	3	Y	10	2.00	3	Y	6	3	Y	2	3	Y	22	10.00	3	Y	12	3	Y	10	4.00	3	Y	6	3	Y	24	0	N
52	1KS20EC052	KUSUMA V R	20	11	3	Y	9	3	Y	10	6	3	Y	4	3	Y	23	5	3	Y	13	3	Y	5	3	Y	10	2.00	3	Y	6	3	Y	2	3	Y	26	10.00	3	Y	16	3	Y	10	4.00	3	Y	6	3	Y	24	0	N
53	1KS20EC053	M AROHANA	18	10	2	N	8	3	Y	10	6	3	Y	4	3	Y	19	4	3	Y	11	3	Y	4	3	Y	10	2.00	3	Y	6	3	Y	2	3	Y	20	8.00	3	Y	12	3	Y	10	4.00	3	Y	6	3	Y	9	0	N
54	1KS20EC054	MADINA	28	18	3	Y	10	3	Y	10	6	3	Y	4	3	Y	27	5	3	Y	17	3	Y	5	3	Y	10	2.00	3	Y	6	3	Y	2	3	Y	28	10.00	3	Y	18	3	Y	10	4.00	3	Y	6	3	Y	32	1	N
55	1KS20EC055	MAHESH BIRADAR	8	5	0	N	3	0	N	10	6	3	Y	4	3	Y	24	6	3	Y	13	3	Y	5	3	Y	10	2.00	3	Y	6	3	Y	2	3	Y	8	6.00	3	Y	0	0	N	10	4.00	3	Y	6	3	Y	21	0	N
56	1KS20EC056	MANASWINI K M	18	11	3	Y	7	2	N	10	6	3	Y	4	3	Y	11	3	1	N	6	0	N	2	0	N	10	2.00	3	Y	6	3	Y	2	3	Y	14	6.00	1	N	8	0	N	10	4.00	3	Y	6	3	Y	13	0	N
57	1KS20EC057	MEGHASHREE M	30	18	3	Y	12	3	Y	10	6	3	Y	4	3	Y	29	5	3	Y	18	3	Y	6	3	Y	10	2.00	3	Y	6	3	Y	2	3	Y	30	12.00	3	Y	18	3	Y	10	4.00	3	Y	6	3	Y	41	3	Y
58	1KS20EC058	MOHAN KRISHNA K	25	15	3	Y	10	3	Y	10	6	3	Y	4	3	Y	14	3	1	N	8	0	N	3	1	N	10	2.00	3	Y	6	3	Y	2	3	Y	16	6.00	1	N	10	2	N	10	4.00	3	Y	6	3	Y	21	0	N
59	1KS20EC059	N SHREYA	25	15	3	Y	10	3	Y	10	6	3	Y	4	3	Y	22	5	3	Y	12	3	Y	5	3	Y	10	2.00	3	Y	6	3	Y	2	3	Y	26	10.00	3	Y	16	3	Y	10	4.00	3	Y	6	3	Y	42	3	Y
60	1KS20EC060	NALLANI GOWTHAMI	8	8	1	N	0	0	N	10	6	3	Y	4	3	Y	10	3	1	N	5	0	N	2	0	N	10	2.00	3	Y	6	3	Y	2	3	Y	22	11.00	3	Y	11	3	Y	10	4.00	3	Y	6	3	Y	22	0	N
61	1KS20EC061	NEHA C R	30	18	3	Y	12	3	Y	10	6	3	Y	4	3	Y	28	5	3	Y	18	3	Y	5	3	Y	10	2.00	3	Y	6	3	Y	2	3	Y	26	10.00	3	Y	16	3	Y	10	4.00	3	Y	6	3	Y	32	1	N
62	1KS20EC062	NEHA NAGARAJ AIRANI	28	16	3	Y	12	3	Y	10	6	3	Y	4	3	Y	27	6	3	Y	16	3	Y	5	3	Y	10	2.00	3	Y	6	3	Y	2	3	Y	24	10.00	3	Y	14	3	Y	10	4.00	3	Y	6	3	Y	23	0	N
63	1KS20EC063	P VASANTH KUMAR	22	12	3	Y	10	3	Y	10	6	3	Y	4	3	Y	8	4	3	Y	0	0	N	4	3	Y	10	2.00	3	Y	6	3	Y	2	3	Y	19	8.00	3	Y	11	3	Y	10	4.00	3	Y	6	3	Y	16	0	N
64	1KS20EC064	PAVAN C	22	13	3	Y	9	3	Y	10	6	3	Y	4	3	Y	9	5	3	Y	1	0	N	3	1	N	10	2.00	3	Y	6	3	Y	2	3	Y	10	10.00	3	Y	0	0	N	10	4.00	3	Y	6	3	Y	9	0	N
65	1KS20EC065	PAVANI T S	30	18	3	Y	12	3	Y	10	6	3	Y	4	3	Y	25	5	3	Y	15	3	Y	5	3	Y	10	2.00	3	Y	6	3	Y	2	3	Y	26	10.00	3	Y	16	3	Y	10	4.00	3	Y	6	3	Y	21	0	N
66	1KS20EC066	PRADHYUMNA S KASHYAP	27	15	3	Y	12	3	Y	10	6	3	Y	4	3	Y	27	5	3	Y	17	3	Y	5	3	Y	10	2.00	3	Y	6	3	Y	2	3	Y	19	6.00	1	N	13	3	Y	10	4.00	3	Y	6	3	Y	23	0	N
67	1KS20EC067	PRAVEEN D B	23	14	3	Y	9	3	Y	10	6	3	Y	4	3	Y	15	5	3	Y	10	2	N	0	0	N	10	2.00	3	Y	6	3	Y	2	3	Y	22	9.00	3	Y	13	3	Y	10	4.00	3	Y	6	3	Y	14	0	N
68	1KS20EC068	PREMA G	28	14	3	Y	8	3	Y	10	6	3	Y	4	3	Y	28	5	3	Y	18	3	Y	5	3	Y	10	2.00	3	Y	6	3	Y	2	3	Y	29	12.00	3	Y	17	3	Y	10	4.00	3	Y	6	3	Y	40	3	Y
69	1KS20EC069	PRIYANKA H C	20	11	3	Y	9	3	Y	10	6	3	Y	4	3	Y	28	6	3	Y	17	3	Y	5	3	Y	10	2.00	3	Y	6	3	Y	2	3	Y	17	6.00	2	N	11	3	Y	10	4.00	3	Y	6	3	Y	24	0	N
70	1KS20EC070	PRIYANKA K	27	15	3	Y	12	3	Y	10	6	3	Y	4	3	Y	26	5	3	Y	16	3	Y	5	3	Y	10	2.00	3	Y	6	3	Y	2	3	Y	30	12.00	3	Y	18	3	Y	10	4.00	3	Y	6	3	Y	31	1	N
71	1KS20EC071	PRIYANKA M	15	9	1	N	6	1	N	10	6	3	Y	4	3	Y	21	5	3	Y	11	3	Y	5	3	Y	10	2.00	3	Y	6	3	Y	2	3	Y	22	10.00	3	Y	12	3	Y	10	4.00	3	Y	6	3	Y	29	0	N
72	1KS20EC072	PUSHPA D T	10	9	1	N	1	0	N	10	6	3	Y	4	3	Y	15	4	3	Y	9	1	N	2	0	N	10	2.00	3	Y	6	3	Y	2	3	Y	8	8.00	3	Y	0	0	N	10	4.00	3	Y	6	3	Y	21	0	N
73	1KS20EC073	RAHUL KRISHNAN V	30	18	3	Y	12	3	Y	10	6	3	Y	4	3	Y	26	5	3	Y	16	3	Y	5	3	Y	10	2.00	3	Y	6	3	Y	2	3	Y	27	12.00	3	Y	15	3	Y	10	4.00	3	Y	6	3	Y	33	2	N
74	1KS20EC074	RAHUL R	21	11	3	Y	10	3	Y	10	6	3	Y	4	3	Y	10	0	0	N	10	2	N	0	0	N	10	2.00	3	Y	6	3	Y	2	3	Y	30	12.00	3	Y	18	3	Y	10	4.00	3	Y	6	3	Y	24	0	N
75	1KS20EC075	RAJATH K ACHAR	22	12	3	Y	10	3	Y	10	6	3	Y	4	3	Y	16	3	1	N	10	2	N	3	1	N	10	2.00	3	Y	6	3	Y	2	3	Y	21	9.00	3	Y	12	3	Y	10	4.00	3	Y	6	3	Y	24	0	N

	1KS20EC077	RAKSHITH R	28	18	3	Y	10	3	Y	10	6	3	Y	4	3	Y	29	6	3	Y	18	3	Y	5	3	Y	10	2.00	3	Y	6	3	Y	2	3	Y	25	10.00	3	Y	15	3	Y	10	4.00	3	Y	6	3	Y	23	0	N
78	1KS20EC078	RAKSHITHA A	26	18	3	Y	8	3	Y	10	6	[illegible]	Y	4	3	Y	19	4	3	Y	11	3	Y	4	3	Y	10	2.00	3	Y	6	3	Y	2	3	Y	27	12.00	3	Y	15	3	Y	10	4.00	3	Y	6	3	Y	36	3	Y
79	1KS20EC079	RAMESHWAR	17	10	2	N	7	2	N	10	6	[illegible]	Y	4	3	Y	30	6	3	Y	18	3	Y	6	3	Y	10	2.00	[illegible]	[illegible]	[illegible]	3	Y	2	3	Y	17	6.00	1	N	11	3	Y	10	4.00	3	Y	6	3	Y	23	0	N
80	1KS20EC080	RAMYA T	24	14	3	Y	10	3	Y	10	6	[illegible]	Y	[illegible]	3	Y	19	5	3	Y	10	2	N	4	3	Y	10	2.00	3	[illegible]	[illegible]	3	Y	2	3	Y	30	12.00	3	Y	18	3	Y	10	4.00	3	Y	6	3	Y	21	0	N
81	1KS20EC081	RAVI VANSHI.D.N	23	14	3	Y	9	3	Y	10	6	3	Y	[illegible]	3	Y	20	5	3	Y	10	2	N	5	3	Y	10	2.00	3	Y	6	3	Y	2	3	Y	23	9.00	3	Y	14	5	Y	10	4.00	3	Y	6	3	Y	34	2	N
82	1KS20EC082	ROHITH A K	14	10	2	N	4	0	N	10	6	3	Y	[illegible]	3	Y	19	4	3	Y	11	3	Y	4	3	Y	10	2.00	3	Y	6	3	Y	2	3	Y	11	6.00	1	N	5	0	N	0	0.00	0	N	0	0	N	21	0	N
83	1KS20EC083	S ARUN KUMAR	20	12	3	Y	8	3	Y	10	6	3	Y	4	3	Y	22	5	3	Y	12	3	Y	5	3	Y	10	2.00	3	Y	6	3	Y	2	3	Y	22	10.00	3	Y	12	3	Y	10	4.00	3	Y	6	3	Y	27	0	N
84	1KS20EC084	SACHIN N M	17	10	2	N	7	2	N	10	6	3	Y	4	3	Y	18	4.00	3	Y	10	2	N	4	3	Y	10	2.00	3	Y	6	3	Y	2	3	Y	15	6.00	1	N	9	0	N	10	4.00	3	Y	6	3	Y	24	0	N
85	1KS20EC085	SADHANA SRINIVAS	26	14	3	Y	8	3	Y	10	6	3	Y	4	3	Y	22	4.00	3	Y	14	3	Y	4	3	Y	10	2.00	3	Y	6	3	Y	2	3	Y	26	12.00	3	Y	14	3	Y	10	4.00	3	Y	6	3	Y	37	3	Y
86	1KS20EC086	SAKSHAM SINGH	27	15	3	Y	12	3	Y	10	6	3	Y	4	3	Y	30	6.00	3	Y	18	3	Y	6	3	Y	10	2.00	3	Y	6	3	Y	2	3	Y	17	6.00	1	N	11	3	Y	10	4.00	3	Y	6	3	Y	30	1	N
87	1KS20EC087	SANDEEP Y H	22	12	3	Y	10	3	Y	10	6	3	Y	4	3	Y	27	5.00	3	Y	17	3	Y	5	3	Y	10	2.00	3	Y	6	3	Y	2	3	Y	25	12.00	3	Y	13	3	Y	10	4.00	3	Y	6	3	Y	35	2	N
88	1KS20EC089	SANJANA G GURUNATH	24	14	3	Y	10	3	Y	10	6	3	Y	4	3	Y	24	6.00	3	Y	12	3	Y	6	3	Y	10	2.00	3	Y	6	3	Y	2	3	Y	25	11.00	3	Y	14	3	Y	10	4.00	3	Y	6	3	Y	32	1	N
89	1KS20EC090	SANJANA.G	14	11	3	Y	3	0	N	10	6	3	Y	4	3	Y	24	5.00	3	Y	13	3	Y	4	3	Y	10	2.00	3	Y	6	3	Y	2	3	Y	20	8.00	3	Y	12	3	Y	10	4.00	3	Y	6	3	Y	38	3	Y
90	1KS20EC091	SANJANA T GADIKAR	15	9	1	N	6	1	N	10	6	3	Y	4	3	Y	15	3.00	1	N	9	1	N	3	1	N	10	2.00	3	Y	6	3	Y	2	3	Y	21	9.00	3	Y	12	3	Y	10	4.00	3	Y	6	3	Y	21	0	N
91	1KS20EC092	SHAKTHI ANBAZHAGAN M	27	17	3	Y	10	3	Y	10	6	3	Y	4	3	Y	17	4.00	3	Y	10	2	N	3	1	N	10	2.00	3	Y	6	3	Y	2	3	Y	20	6.00	1	N	12	3	Y	10	4.00	3	Y	6	3	Y	27	0	N
92	1KS20EC093	SHARATH M	11	11	3	Y	0	0	N	10	6	3	Y	4	3	Y	28	5.00	3	Y	18	3	Y	5	3	Y	10	2.00	3	Y	6	3	Y	2	3	Y	23	12.00	3	Y	11	3	Y	10	4.00	3	Y	6	3	Y	41	3	Y
93	1KS20EC094	SHASHANK S	18	10	2	N	8	3	Y	10	6	3	Y	4	3	Y	19	5.00	3	Y	9	1	N	5	3	Y	10	2.00	3	Y	6	3	Y	2	3	Y	16	8.00	3	Y	8	0	N	10	4.00	3	Y	6	3	Y	28	0	N
94	1KS20EC095	SHIVAREDDY B A	25	15	3	Y	10	3	Y	10	6	3	Y	4	3	Y	28	5.00	3	Y	18	3	Y	5	3	Y	10	2.00	3	Y	6	3	Y	2	3	Y	28	11.00	3	Y	15	3	Y	10	4.00	3	Y	6	3	Y	35	2	N
95	1KS20EC096	SHREYA H PADMANABHA	29	18	3	Y	11	3	Y	10	6	3	Y	4	3	Y	25	5.00	3	Y	15	3	Y	5	3	Y	10	2.00	3	Y	6	3	Y	2	3	Y	28	10.00	3	Y	16	3	Y	10	4.00	3	Y	6	3	Y	27	0	N
96	1KS20EC097	SHREYAS M S	23	13	3	Y	10	3	Y	10	6	3	Y	4	3	Y	24	6.00	3	Y	12	3	Y	6	3	Y	10	2.00	3	Y	6	3	Y	2	3	Y	27	11.00	3	Y	16	3	Y	10	4.00	3	Y	6	3	Y	33	2	N
97	1KS20EC098	SHREYAS P S RAO	17	10	2	N	7	2	N	10	6	3	Y	4	3	Y	24	5.00	3	Y	13	3	Y	6	3	Y	10	2.00	3	Y	6	3	Y	2	3	Y	18	8.00	3	Y	10	2	N	10	4.00	3	Y	6	3	Y	22	0	N
98	1KS20EC099	SHWETA DEEPAK K	22	12	3	Y	10	3	Y	10	6	3	Y	4	3	Y	24	6.00	3	Y	12	3	Y	6	3	Y	10	2.00	3	Y	6	3	Y	2	3	Y	26	12.00	3	Y	14	3	Y	10	4.00	3	Y	6	3	Y	24	0	N
99	1KS20EC100	SNEHA A S	26	15	3	Y	11	3	Y	10	6	3	Y	4	3	Y	27	5.00	3	Y	17	3	Y	5	3	Y	10	2.00	3	Y	6	3	Y	2	3	Y	29	12.00	3	Y	17	3	Y	10	4.00	3	Y	6	3	Y	28	0	N
100	1KS20EC101	SONIKA.R	20	11	3	Y	9	3	Y	10	6	3	Y	4	3	Y	29	6.00	3	Y	17	3	Y	6	3	Y	10	2.00	3	Y	6	3	Y	2	3	Y	26	10.00	3	Y	16	3	Y	10	4.00	3	Y	6	3	Y	21	0	N
101	1KS20EC102	SUMANA N	28	16	3	Y	12	3	Y	10	6	3	Y	4	3	Y	28	6.00	3	Y	16	3	Y	6	3	Y	10	2.00	3	Y	6	3	Y	2	3	Y	28	12.00	3	Y	16	3	Y	10	4.00	3	Y	6	3	Y	45	3	Y
102	1KS20EC103	SUMUKHA S	28	16	3	Y	12	3	Y	10	6	3	Y	4	3	Y	15	4.00	3	Y	8	0	N	3	1	N	10	2.00	3	Y	6	3	Y	2	3	Y	26	10.00	3	Y	16	3	Y	10	4.00	3	Y	6	3	Y	33	2	N
103	1KS20EC104	SURAKSHA N	29	18	3	Y	11	3	Y	10	6	3	Y	4	3	Y	22	6.00	3	Y	12	3	Y	6	3	Y	10	2.00	3	Y	6	3	Y	2	3	Y	30	12.00	3	Y	18	3	Y	10	4.00	3	Y	6	3	Y	45	3	Y
104	1KS20EC105	TARUN PRASANNA	29	17	3	Y	12	3	Y	10	6	3	Y	4	3	Y	20	5.00	3	Y	10	2	N	5	3	Y	10	2.00	3	Y	6	3	Y	2	3	Y	26	11.00	3	Y	15	3	Y	10	4.00	3	Y	6	3	Y	36	3	Y
105	1KS20EC106	TEJAS N REDDY	20	10	2	N	10	3	Y	10	6	3	Y	4	3	Y	12	2.00	0	N	8	0	N	2	0	N	10	2.00	3	Y	6	3	Y	2	3	Y	20	8.00	3	Y	12	3	Y	10	4.00	3	Y	6	3	Y	21	0	N
106	1KS20EC107	THUMMALA GIRISH CHOWDARY	21	12	3	Y	9	3	Y	10	6	3	Y	4	3	Y	6	1.00	0	N	4	0	N	1	0	N	10	2.00	3	Y	6	3	Y	2	3	Y	12	6.00	1	N	6	0	N	10	4.00	3	Y	6	3	Y	17	0	N
107	1KS20EC108	UDAY C H	29	18	3	Y	11	3	Y	10	6	3	Y	4	3	Y	27	5.00	3	Y	17	3	Y	5	3	Y	10	2.00	3	Y	6	3	Y	2	3	Y	28	12.00	3	Y	16	3	Y	10	4.00	3	Y	6	3	Y	33	2	N
108	1KS20EC109	UJJWAL NAIDU	14	10	2	N	4	0	N	10	6	3	Y	4	3	Y	19	5.00	3	Y	10	2	N	4	3	Y	10	2.00	3	Y	6	3	Y	2	3	Y	27	11.00	3	Y	16	3	Y	10	4.00	3	Y	6	3	Y	27	0	N
109	1KS20EC110	VAISHNAVI A	27	17	3	Y	10	3	Y	10	6	3	Y	4	3	Y	28	5.00	3	Y	18	3	Y	5	3	Y	10	2.00	3	Y	6	3	Y	2	3	Y	28	10.00	3	Y	18	3	Y	10	4.00	3	Y	6	3	Y	41	3	Y
110	1KS20EC111	VAISHNAVI V H	24	14	3	Y	10	3	Y	10	6	3	Y	4	3	Y	23	6.00	3	Y	12	3	Y	5	3	Y	10	2.00	3	Y	6	3	Y	2	3	Y	24	12.00	3	Y	12	3	Y	10	4.00	3	Y	6	3	Y	23	0	N
111	1KS20EC112	VARSHA N	19	10	2	N	9	3	Y	10	6	3	Y	4	3	Y	22	5.00	3	Y	13	3	Y	4	3	Y	10	2.00	3	Y	6	3	Y	2	3	Y	27	10.00	3	Y	17	3	Y	10	4.00	3	Y	6	3	Y	38	3	Y
112	1KS20EC113	VIJAYALAKSHMI K	30	18	3	Y	12	3	Y	10	6	3	Y	4	3	Y	23	6.00	3	Y	12	3	Y	5	3	Y	10	2.00	[illegible]	Y	6	3	Y	2	3	Y	26	11.00	3	Y	15	3	Y	10	4.00	3	Y	6	3	Y	42	3	Y
113	1KS20EC114	VINAY S P	29	17	3	Y	12	3	Y	10	6	3	Y	4	3	Y	25	5.00	3	Y	15	3	Y	5	3	Y	10	2.00	3	Y	6	3	Y	2	3	Y	20	8.00	3	Y	12	3	Y	10	4.00	3	Y	6	3	Y	32	1	N
114	1KS20EC115	VINAY SAGAR V ALUR	18	10	2	N	8	3	Y	10	6	3	Y	4	3	Y	9	0.00	0	N	9	1	N	0	0	N	10	2.00	3	Y	6	3	Y	2	3	Y	21	9.00	3	Y	12	3	Y	10	4.00	3	Y	6	3	Y	14	0	N
115	1KS20EC116	VINEETH M S	14	9	1	N	5	0	N	10	6	3	Y	4	3	Y	19	5.00	3	Y	10	2	N	4	3	Y	10	2.00	3	Y	6	3	Y	2	3	Y	12	8.00	3	Y	4	0	N	10	4.00	3	Y	6	3	Y	28	0	N
116	1KS20EC117	YASHILAA S	29	18	3	Y	11	3	Y	10	6	3	Y	4	3	Y	22	5.00	3	Y	12	3	Y	5	3	Y	10	2.00	3	Y	6	3	Y	2	3	Y	30	12.00	3	Y	18	3	Y	10	4.00	3	Y	6	3	Y	21	0	N
117	1KS20EC118	YASHWANTH Y	27	16	3	Y	11	3	Y	10	6	3	Y	4	3	Y	17	4.00	3	Y	10	2	N	3	1	N	10	2.00	3	Y	6	3	Y	2	3	Y	22	10.00	3	Y	12	3	Y	10	4.00	3	Y	6	3	Y	36	3	Y
	CO				CO1			CO2				CO1			CO2				CO2			CO3			CO4				CO2			CO3			CO4				CO4			CO5				CO4			CO5			SEE	
	Number of Not Attempted(NA)					0			0				0			0				0			0			0				0			0			0				0			0				0			0			0
	Score index & No of Y's				2.43	90		2.56	94			3.00	117		3.00	117			2.70	102		2.46	80		2.54	96			3.00	117		3.00	117		3.00	117			2.74	100		2.55	92			2.85	115		2.85	115		1.00	26
	No. of N's					27			23				0			0				15			37			21				0			0			0				17			25				2			2			89
	CO Attainment					76.92			80.34				100			100				87.18			68.38			82.05				100			100			100				85.47			78.63				98.29			98.29			22.61
	Level					3			3				3			3				3			3			3				3			3			3				3			3				3			3			0

CO	CIE	SEE	DIRECT ATTAINMENT	Level	T ATTA	Final Att
CO1	88.46	22.81	55.54	2.00	3.00	2.10
CO2	91.88	22.81	57.24	2.00	3.00	2.10
CO3	84.19	22.81	53.40	1.00	3.00	1.20
CO4	91.45	22.81	57.03	2.00	3.00	2.10
CO5	88.46	22.81	55.54	2.00	3.00	2.10
AVERAGE						1.92

CO	Score index out of 3
CO1	1.82
CO2	2.00
CO3	1.78
CO4	1.87
CO5	1.77





						Co-Po Mapping Table								
CO'S	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	3					2	2		1	1		2	2	3
CO2	3								1	1		2	2	3
CO3	3					1			1	1		2	2	3
CO4	3	2				2			1	1			2	3
CO5	3	1							1	1		2	2	3
AVG	3.00	1.50	-	-	-	1.67	2.00	-	1.00	1.00	-	2.00	2.00	3.00

PO Attainment

CO'S	CO Attainment	CO RESU	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
18ME15 CO1	2.10	Y	2.10					1.40	1.40		0.70	0.70		1.40	1.40	2.10
18ME15 CO2	2.10	Y	2.10								0.70	0.70		1.40	1.40	2.10
18ME15 CO3	1.20	N	1.20					0.40			0.40	0.40		0.80	0.80	1.20
18ME15 CO4	2.10	Y	2.10	1.40				1.40			0.70	0.70			1.40	2.10
18ME15 CO5	2.10	Y	2.10	0.70							0.70	0.70		0.20	1.40	2.10
Average			1.92	1.06	-	-	-	1.07	1.40	-	0.64	0.64	-	0.20	1.28	1.92

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Module – 1.1

Sources of Energy

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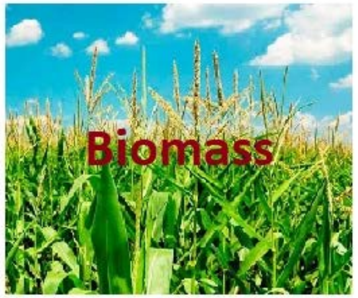
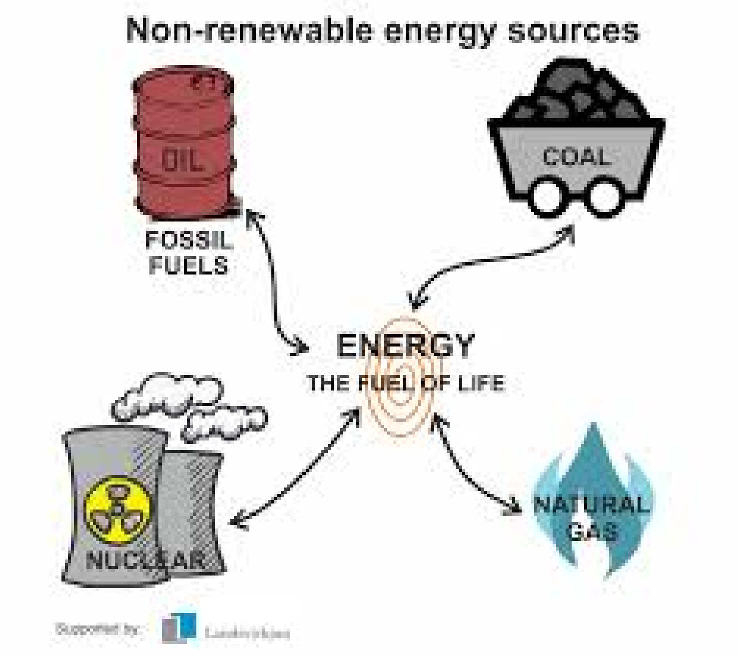
Energy Resources

- Energy is defined as the ability or the capacity to do work.
- Application/Usage of Energy: To produce electricity from which we can cook food, light our homes, make computers, televisions, move different versions of automobiles and space ships.
- Classification: *Renewable energy (Non – Conventional) and Non- Renewable (Conventional) energy resources*

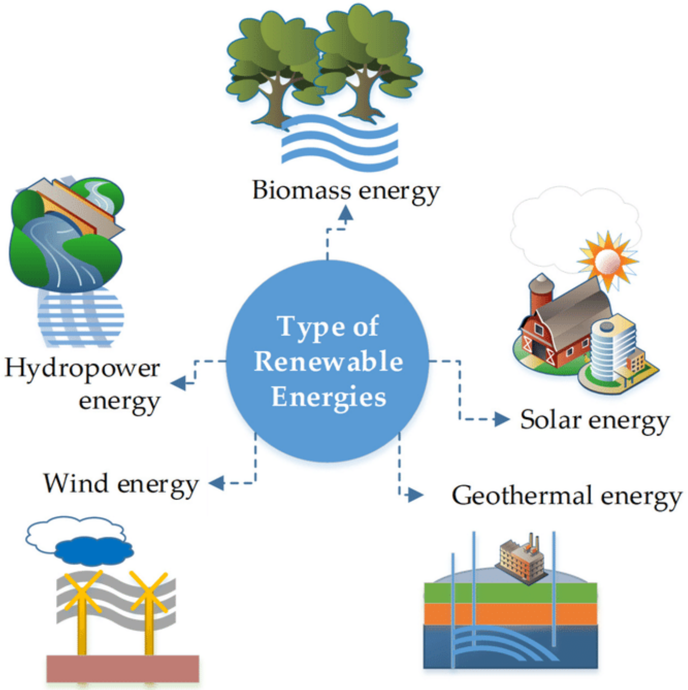




Renewable Energy sources (Non-Conventional)

- Energy resources that are produced continuously in nature and that will not get exhausted eventually in future.
- It includes;

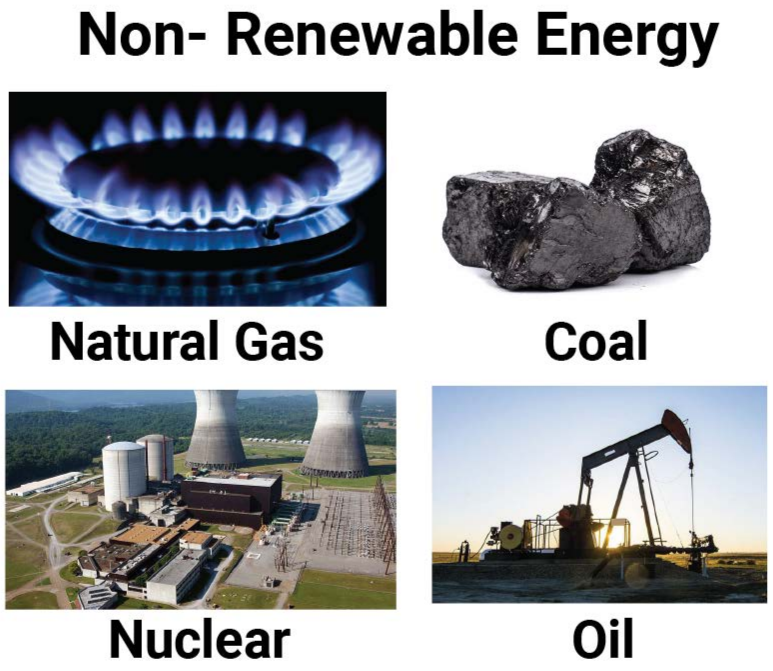
1. Solar Energy	Heat energy radiated from the sun
2. Hydel Energy	Energy obtained from water
3. Wind Energy	Energy from the flow of wind
4. Geothermal Energy	Heat energy stored deep inside the earth
5. Tidal Energy	Energy obtained from the tides in oceans
6. Ocean thermal Energy	Heat energy obtained from the surface of water in oceans
7. Biomass Energy	Energy obtained from the organic matter of plants and animals



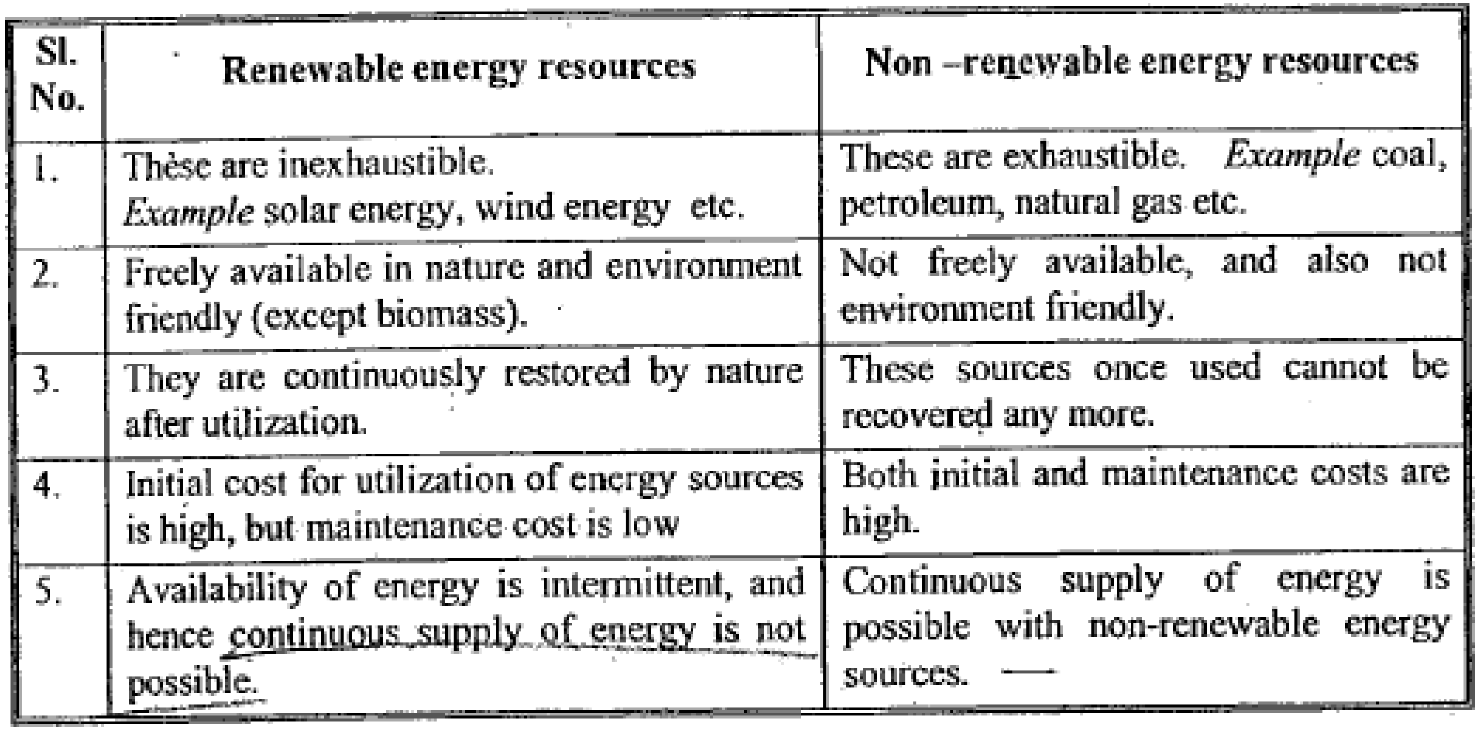
Non -Renewable Energy sources (Conventional)

- Energy resources that get exhausted eventually in future.
- It includes:

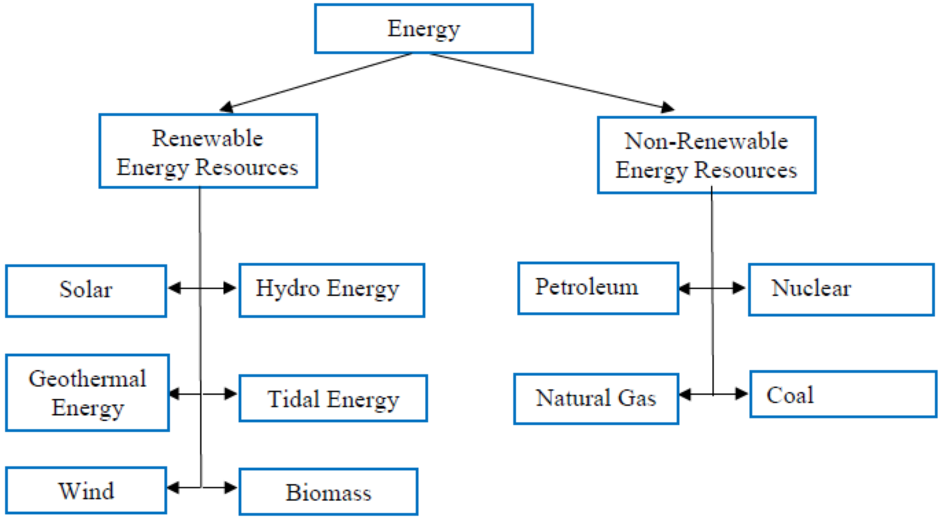
1) Fossil fuels (Coal, petroleum, coal gas and natural gas)
2) Nuclear fuels (Uranium)



Differences between Renewable and Non-renewable Energy resources



Sl. No.	**Renewable energy resources**	**Non –renewable energy resources**
1.	These are inexhaustible. *Example* solar energy, wind energy etc.	These are exhaustible. *Example* coal, petroleum, natural gas etc.
2.	Freely available in nature and environment friendly (except biomass).	Not freely available, and also not environment friendly.
3.	They are continuously restored by nature after utilization.	These sources once used cannot be recovered any more.
4.	Initial cost for utilization of energy sources is high, but maintenance cost is low	Both initial and maintenance costs are high.
5.	Availability of energy is intermittent, and hence continuous supply of energy is not possible.	Continuous supply of energy is possible with non-renewable energy sources.



Energy

Renewable Energy Resources

Non-Renewable Energy Resources

Solar

Hydro Energy

Geothermal Energy

Tidal Energy

Wind

Biomass

Petroleum

Nuclear

Natural Gas

Coal

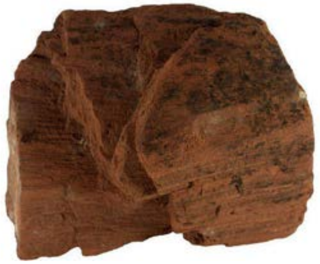
Non renewable energy - Fossil Fuels

- Formed by the action of heat from the earth’s core and pressure from the rock and soil on the remains (fossils) of dead plants and animals including micro organisms, overs millions and millions of years ago.
- Types of fossil fuels: *Coal, Oil and Natural gas*.

1. Coal

- Solid type of fossil fuel.
- Highly carbonaceous matter, dug/mined from the earth’s core.
- Most abundant fossil fuel on earth.
- How it is formed: Formed from pre-historic vegetable deposits, which have been decomposed and solidified under combined effect of great pressure and bacteria.

1.1 Forms of Coal

Lignite/sub-bituminous coal 	• Low grade brown coal. • Soft with high moisture content and ash. • Low calorific valve. • Reservoirs: TN, Assam, Kashmir & Rajasthan.	Applications: Domestic purposes and generation of electricity.
Bituminous coal 	• 75 to 90% of Carbon. • Major fuel in most of the countries • Reservoirs: Bihar, Bengal, MP and Orissa	Applications: Industrial applications: firing in furnaces, boilers and thermal power plants.
Anthracite coal 	• 92 to 98% of Carbon. • Burns slowly with great heat and releases less smoke than bituminous coal. • Very economical. • Reservoirs: Kashmir and Eastern Himalayas	Applications: Boiler fuel, metallurgical furnaces.

"Coal of all types contain sulphur to some degree, which is the worst of the pollutants to cause damage to human health and vegetation".

2. Oil (Liquid Fuel/Crude oil/Petroleum)

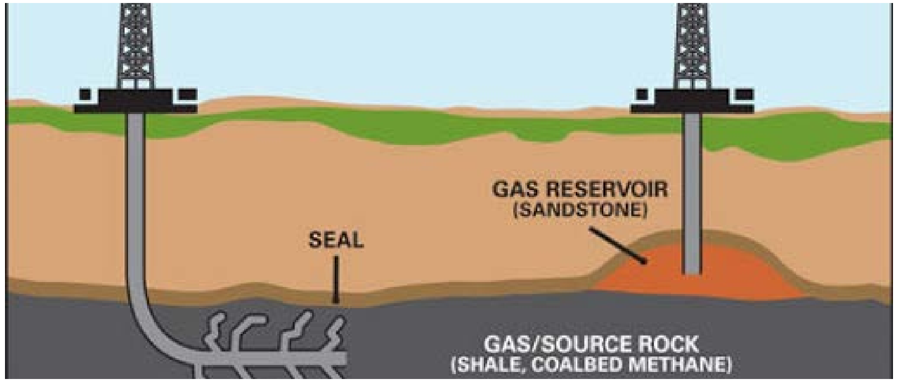
- Liquid type of fossil fuel.
- How it is formed: Formed from remains of dead plants and animals by exposure to heat and pressure in the earth’s crust.

2.1 Types of crude oil

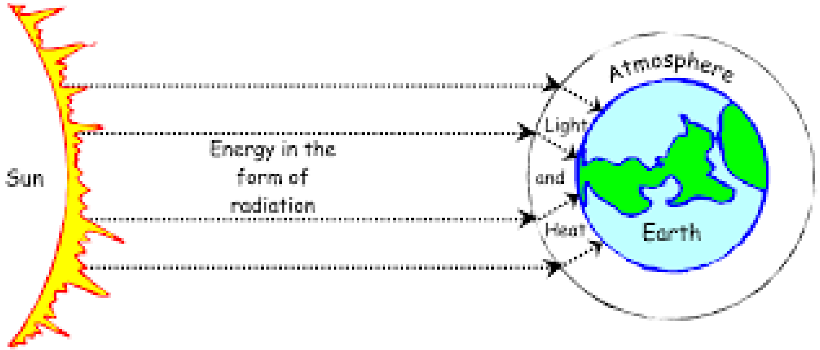
Petrol/Gasoline	• Derived from the fractional distillation of petroleum/crude oil. • Lightest fuel with specific gravity (0.71-0.76) • Volatile fuel even at room temperature.	Applications: As a fuel for the automotive vehicles as well in some small airplanes.
Diesel	• Obtained after the fractional distillation of petrol and kerosene. • Specific gravity : 0.82-0.96. • More dense than petrol. • More energy / unit volume of fuel • Calorific value of diesel is lower than petrol.	Applications: As a fuel in CI vehicles such as busses, trucks and also in airplanes.

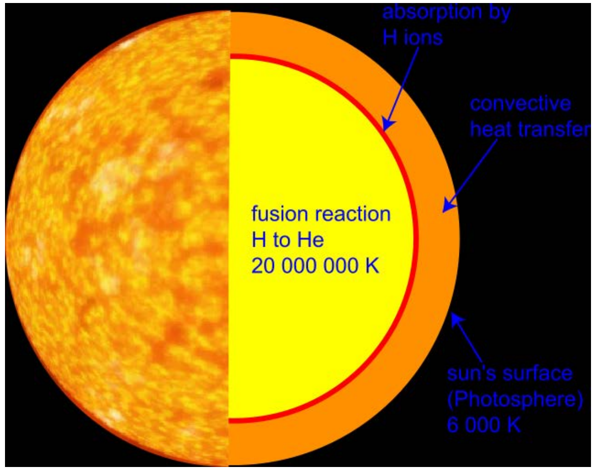
3. Natural gas

- Usually found underground near an oil source.
- Composed primarily of methane and other light hydrocarbons like ethane, propane, butane, pentane and compounds like CO_2, He, N etc.
- Cleanest burning fossil fuel: When it is burned, it gives off less CO_2 than oil and coal, no sulphur dioxide and only small amount of nitrous oxides.
- Excellent domestic fuel used for heating and cooking.
- Applications: As fuel to produce steel, glass, paper, clothing, brick, electricity; as raw material for many products like paints, fertilizers, plastics, dyes, photographic film, medicines and explosives.



Renewable energy – Solar Energy



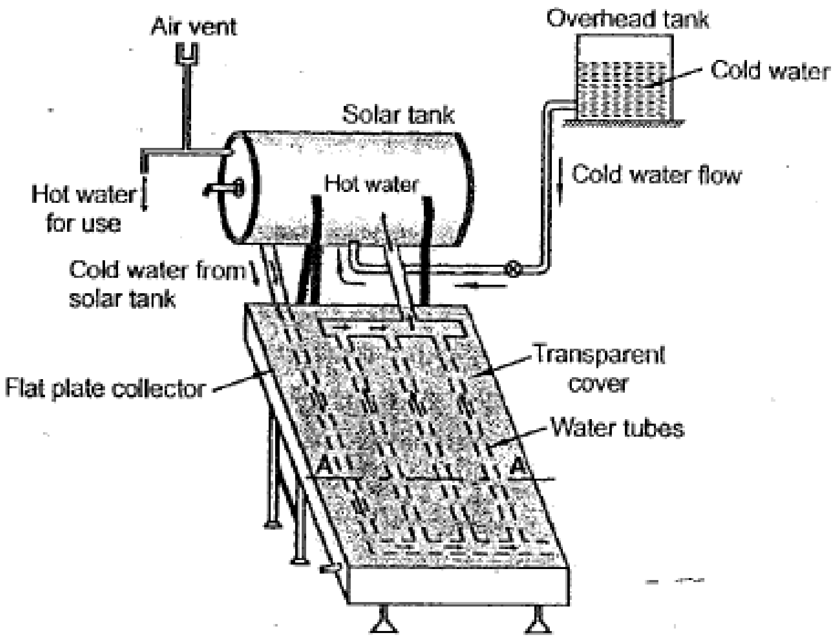


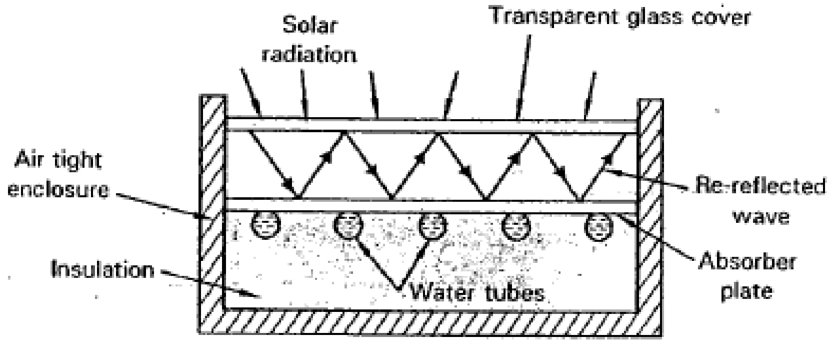
- Heat energy radiated or emitted by the sun.
- Heat energy obtained from the sun is captured, stored and utilized for various applications.
- Utilization : It is the conversion of one form of energy into another, so as to utilize it for various applications.
- Types of solar energy utilization: Flat plate collector, focusing collector, photovoltaic cell and solar pond.

2.1 Solar Energy Utilization using Flat Plate Collector

Construction

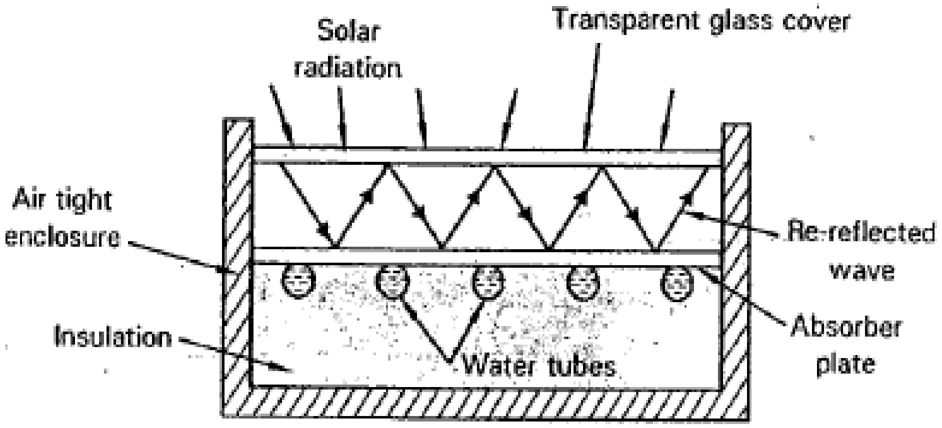
- Flat plate collector consists of the following components;
- *Absorber plate*: Usually made of copper and is coated with black to absorb the solar rays falling on it.
- *Water tubes*: Metallic tubes through which water circulates. The tubes are attached to the absorber plate.
- *Transparent cover*: Made of toughened glass (4mm thick) which helps in reflecting the incident solar energy back to the absorber plate.
- The glass cover permits the entry of solar radiation as it is transparent for incoming short wavelength, but is largely opaque to the longer infrared radiation reflected from the absorber. As a result heat remains trapped in the airspace between the absorber plate and the glass cover.
- *Insulation*: Resin bonded rock wool is provided below the absorber plate so as to prevent heat losses by conduction.





(b) Sectional view A - A

Working/operation



(b) Sectional view A - A

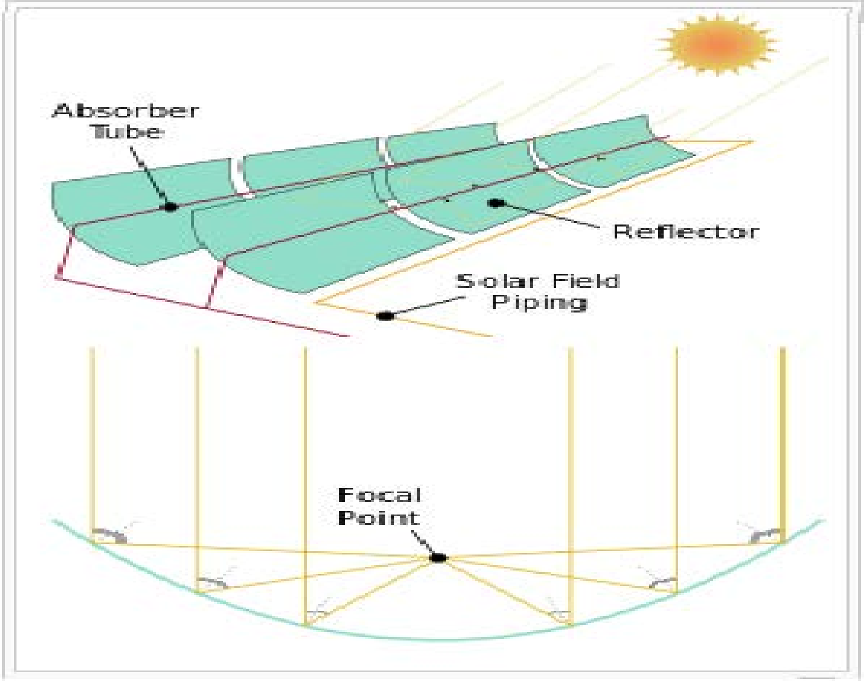
- In operation, cold water from the overhead tank is made to flow through the water tubes of the solar heater.
- When the sun rises to a certain level, it’s energy passes through the transparent cover and falls on the absorber plate.
- The heat energy absorbed by the absorber plate is transferred to the cold water flowing through the tubes.
- The heated water being lighter than the cold water, rises and flows into the top of the solar water tank.
- The heated water can be used for various purposes. The cold water from the overhead tank enters the water tubes and the process repeats.

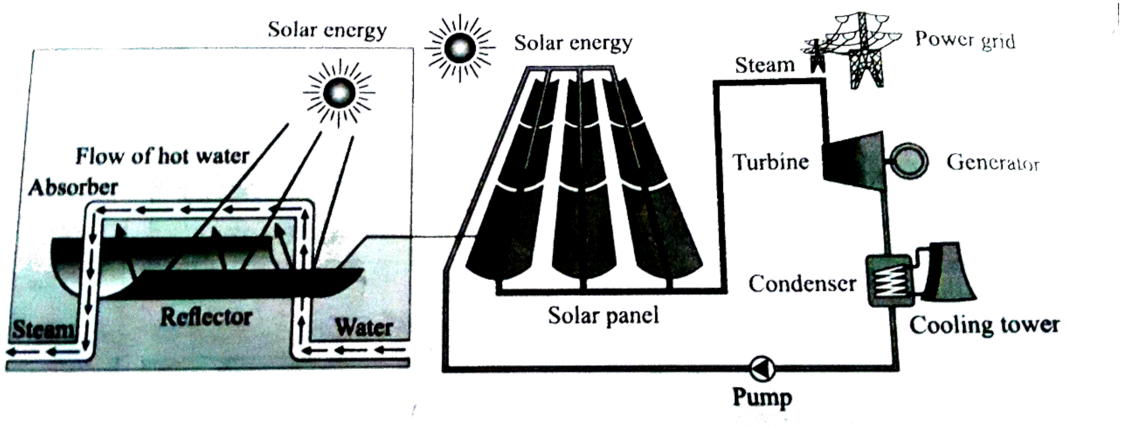
Applications

- Preferable for low temperature applications such as water heating, cooking, drying food grains and vegetables heating etc.

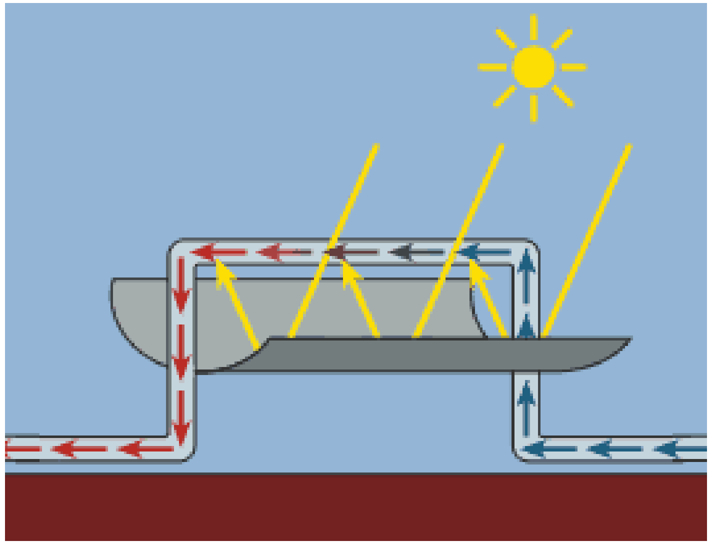
2.2 Solar Energy Utilization using Focusing Collector

- A parabolic / long rectangular U-shaped surface designed to reflect and concentrate the sun’s energy to a focal line where the absorber or receiver tube will be located.
- The absorbed heat energy raises the temperature of a special type of fluid, which is then collected at a central location to get converted into high pressure superheated steam.
- The steam is utilized for generating power in steam turbines.
- Solar thermal plant consists of many such parallel rows of solar parabolic collectors to maximize solar energy utilization.
- The largest 2000 MV solar park is set up at Pavagada, Karnataka.





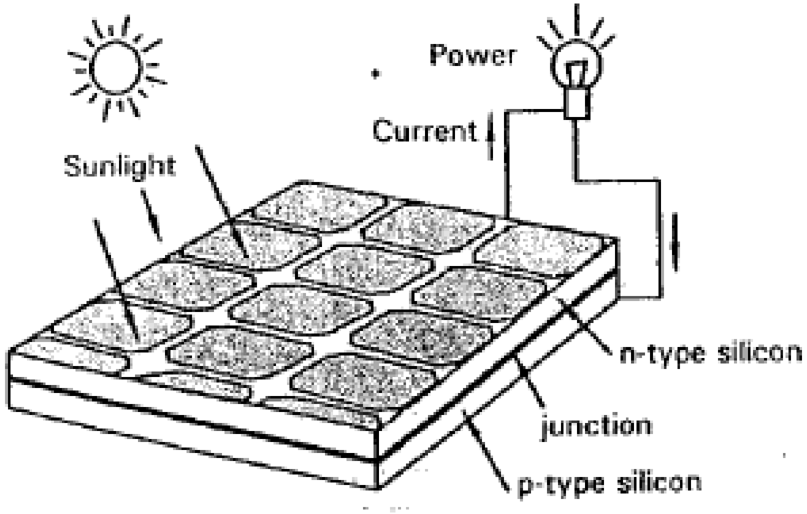
Solar thermal electric energy generation



2.3 Solar Energy Utilization using Photovoltaic Cell

Construction

- Solar cell is a device that directly converts the sun's radiation into electrical energy.
- It is made up of at least two layers of semiconductor material like silicon doped with impurities in order to increase the conductivity of the material.
- The first layer has a positive charge (p-type silicon), while the next layer a negative charge (n-type silicon).



Working

- As known, sunlight is composed of photons or particles of solar energy. When sunlight strikes the photovoltaic cell, the semiconductor material absorbs photons from the light.
- When enough photons are absorbed by the negative layer of the semiconductor material, electrons get dislodged which then moves towards positive layer. This flow of electrons constitutes an electric current.
- The electricity generated by the photovoltaic cell can be used directly or stored in batteries.
- The power output can be increased by connecting a number of photovoltaic cells together in a sealed package called a module.

Applications: Domestic lighting, railway signals, water pumping, street lighting etc.

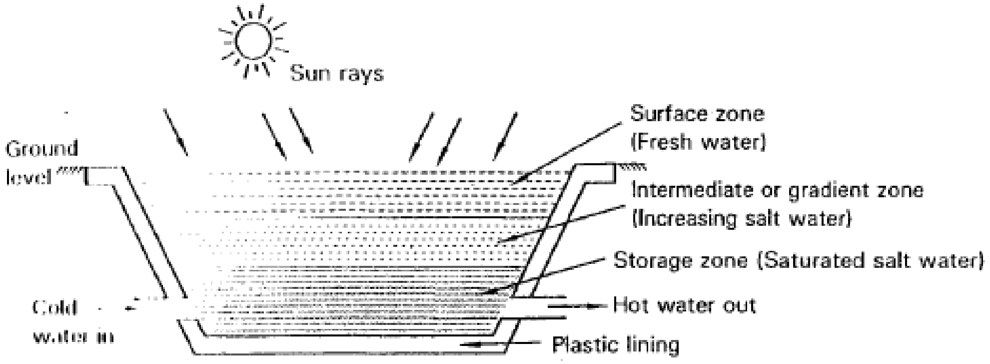
2.4 Solar Energy Utilization using Solar Pond

- A solar pond is a pool of salt water which collects and stores heat radiated from sun. This heat energy in turn can be utilized for applications like process heating, desalination, refrigeration, drying and solar power generation.

Need of solar pond

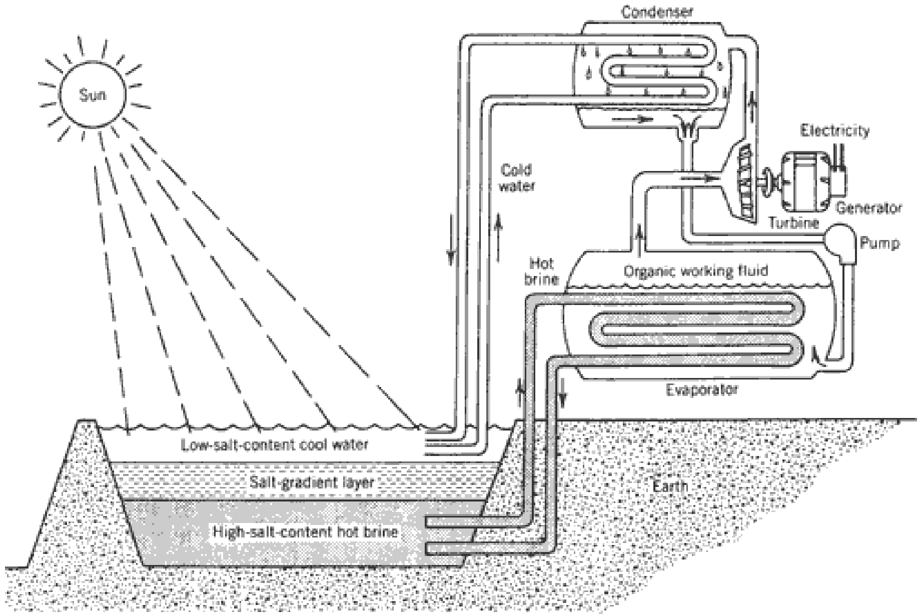
- In a natural pond, nearly about 30% solar radiation reaches to a depth of about 2 meters. The solar radiation is absorbed by the water at the bottom of the pond.
- The warm water due to its low density rises to the surface and loses its heat to the atmosphere without serving any purpose or beneficial effects.
- However, if this warm water is allowed to remain at the bottom of the pond by some mechanism, it can be piped to a boiler where it is heated further to produce steam that can drive a turbo-generator to produce electricity.
- In order to achieve this concept, artificially a pond is created over large area and salt is added at the bottom of the pond. Salt used is either sodium chloride or magnesium chloride.
- The salt dissolves in water making the water too heavy to rise to the surface of the pond. Higher salt contents (Salinity) in water will increase the density of the water allowing it to stay at the bottom of the pond. The hot water can thus be used for various applications.

Construction of solar pond



- Usually solar pond is constructed below the ground level.
- There are three distinct zones in a solar pond, with salt content increasing from top surface of the pond to its bottom.
- Storage zone: lower zone of water, rich in salt content and it is the area where solar radiation is absorbed and stored.
- Surface zone: Upper zone of water which is cold and has very low salt content.
- Intermediate zone: Separates the upper zone of cold water and the lower zone of the hot water and forms an important area in the solar pond.

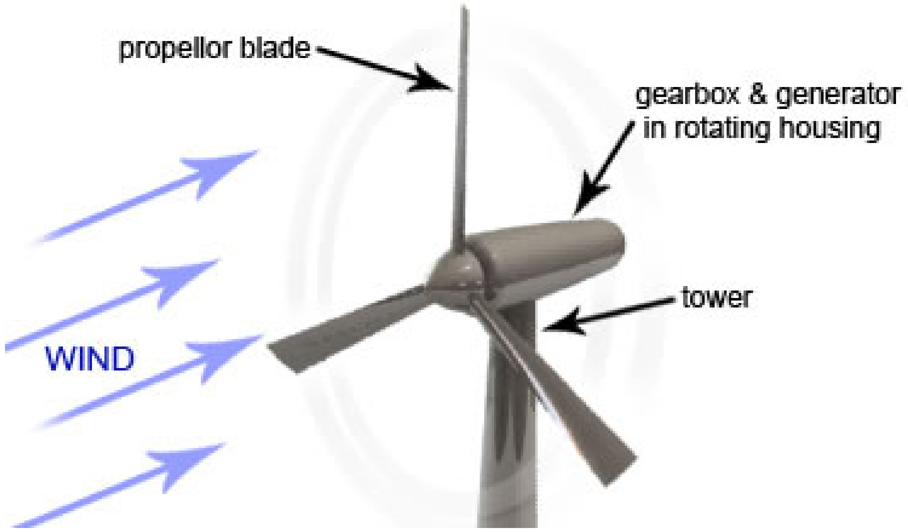
Operation of solar pond



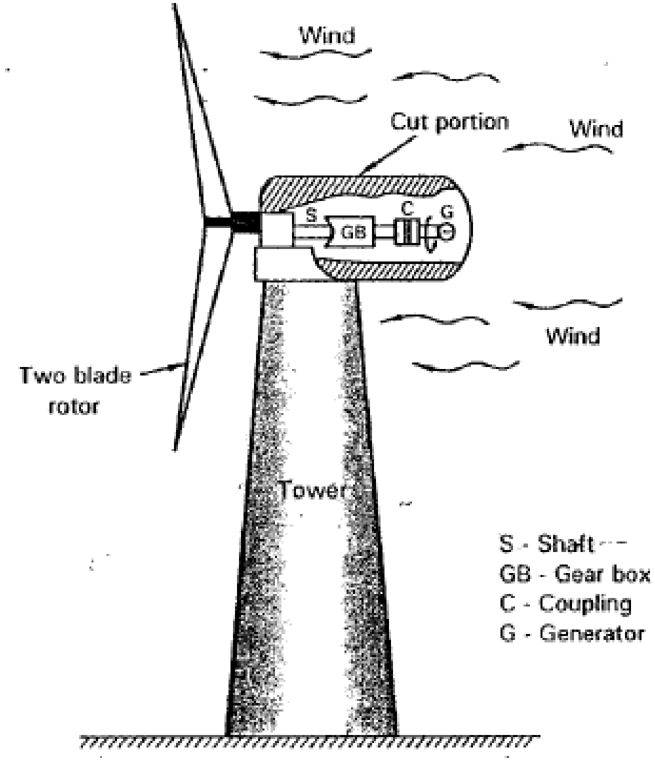
- As solar radiation is absorbed, the hot water in the storage zone cannot rise due to high salt content in it while the cold water at the surface of the pond having less salt content cannot sink, because the water below (intermediate zone) has a rich salt content and is comparatively denser.
- The hot water thus remains in the bottom layer of the pond from which useful heat may be withdrawn and used for various purpose.

Renewable energy – Wind Energy

- Wind energy is the kinetic energy of large masses of air moving over the earth's surface.
- The kinetic energy of wind can be converted into mechanical work by a wind mill or wind turbine.
- The mechanical work thus obtained can be used for specific tasks such as grinding food grains, pumping underground water, generate electricity etc.



Construction of Wind mill

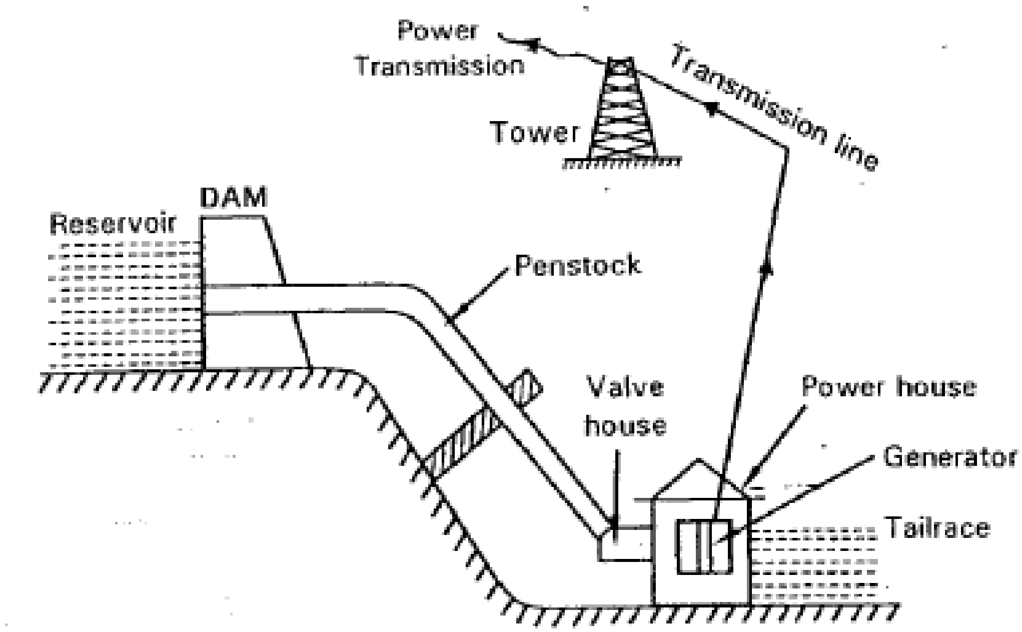


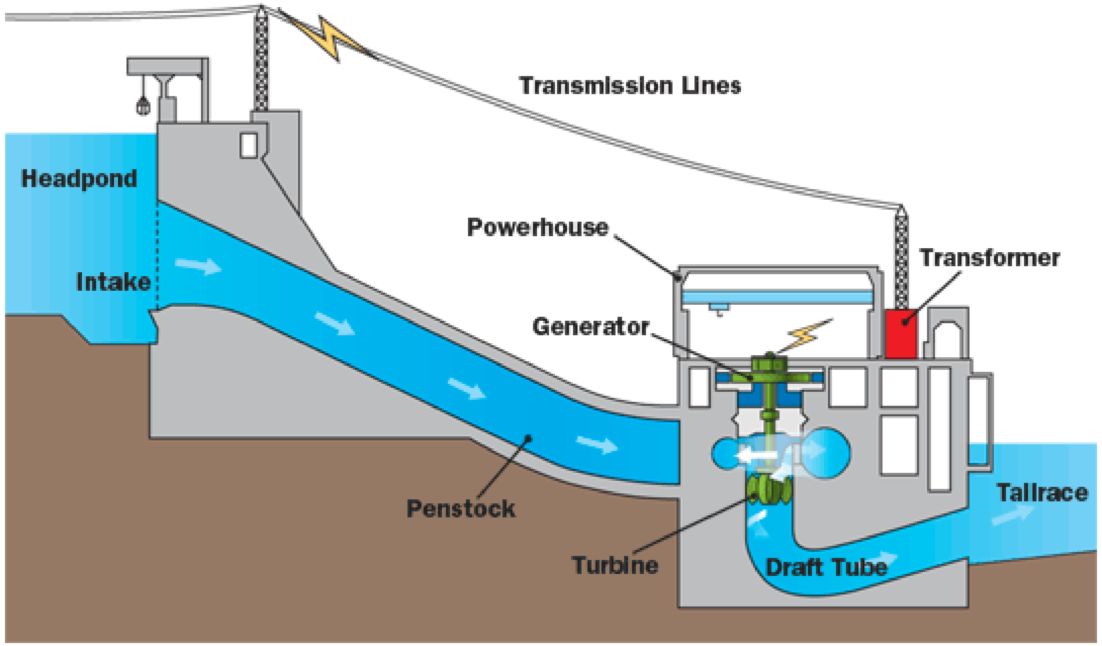
- It consists of specially designed blades that are connected to a low speed shaft. The shaft in turn is connected to a small generator fixed in the axis of the wind mill.
- Usually wind mill/turbine have either 2 or 3 blade which are designed large enough to extract energy from the largest possible volume of air.
- Since wind speed increases with height, the blades are mounted high above the ground level by means of a tower. This enables the blades to capture more energy and hence generate more electricity.

Operation of Wind mill

- The kinetic energy of the flow of wind causes the blades to rotate at slow speeds.
- The gear box comprising of many gears is used to increase the rotational speed of the shaft to that range required to produce electricity.
- The high speed of the shaft thus drives the generator to produce electricity.
- The power produced by the generator is transferred down the tower to the power grid system and then through the transmission lines.

Renewable energy – Hydro Energy





- Water power/Hydro energy is the energy obtained from the flowing water.
- A dam is built to collect the rain water in a reservoir. Gravitational potential energy is stored in the water.
- The water from the reservoir is then allowed to flow through penstock/large pipe and enter the nozzle or specially designed passages wherein the potential energy is converted to kinetic energy.
- The kinetic energy of water causes the turbine runner to rotate which in turn drives the generator to produce electricity.
- The electricity is then transmitted to a sub-station where transformers increase the voltage to that level required for residential and commercial applications.

Renewable energy – Nuclear Energy

- Nuclear power is generated utilizing the energy in the nucleus (core of an atom).
- Generation of nuclear energy:
  a) As we know, atoms are tiny particles that make up every object in the universe.
  b) There is enormous energy in the bonds that hold atoms together. The energy can be released if the atoms are split apart; the process of splitting atoms is called *nuclear fission* reaction.
  c) Enormous amount of energy can also be released when two lighter nuclei are combined to form a single heavy nucleus; the process is called *nuclear fusion* reaction.
- Generation of electricity using nuclear energy:
  a) The fuel most widely used for nuclear fission is Uranium – 235.
  b) In nuclear fission, a small particle called neutron hits the uranium atom and splits it, releasing a great amount of energy in the form of heat and light. Also more neutrons are released due to bombardment.
  c) These neutrons go on to bombard other uranium atoms and the process repeats over and over again resulting in a chain reaction.
  d) The chain reaction gives off enormous heat energy, which is used to boil water to form super heated steam.
  e) The steam thus formed is used to drive the turbine, which in turn drives the generator to produce electricity.

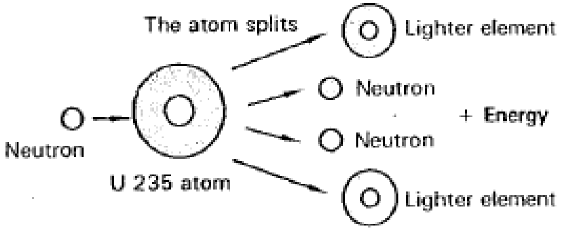


Figure 1.7 Nuclear Fission

Renewable energy – Bio Fuels

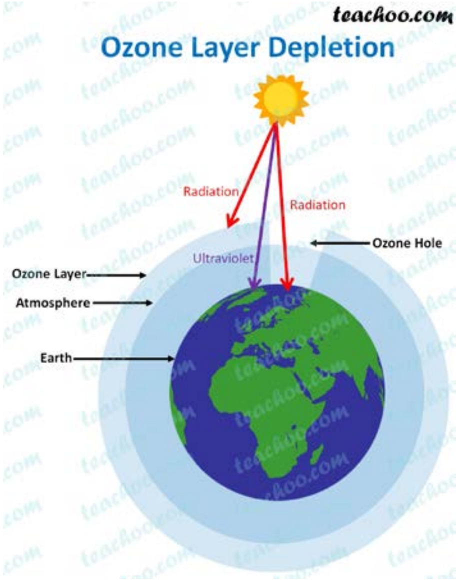
- Liquid fuels produced from biological materials or biomass such as sugarcane fiber, corn, cellulose or vegetable oils, agricultural residues, sewage and other waste.
- It is considered as an alternative to the constantly and rapidly diminishing fossil fuels.

Fuel pellets	• Made from wood chips, sawdust or agricultural wastes • Solid form of biofuels.	Applications: As a co-combustion material in coal fired power plants
Biodiesel	• Liquid form of biofuel produced from non edible oil seeds. • Oils seeds: pongamia (honge), neem, hippe, simarouba, red physic nut.	Applications: As a fuel in automotive vehicles like bus, lorry, tractor etc, heating fuel in commercial boilers
Bioethanol or ethanol	• Produced from corn, wheat, sugarcane or cellulosic material	Applications: An alternative fuel for petrol/gasoline.

However feedstocks/sources for producing biofuels in large quantities is a major problem

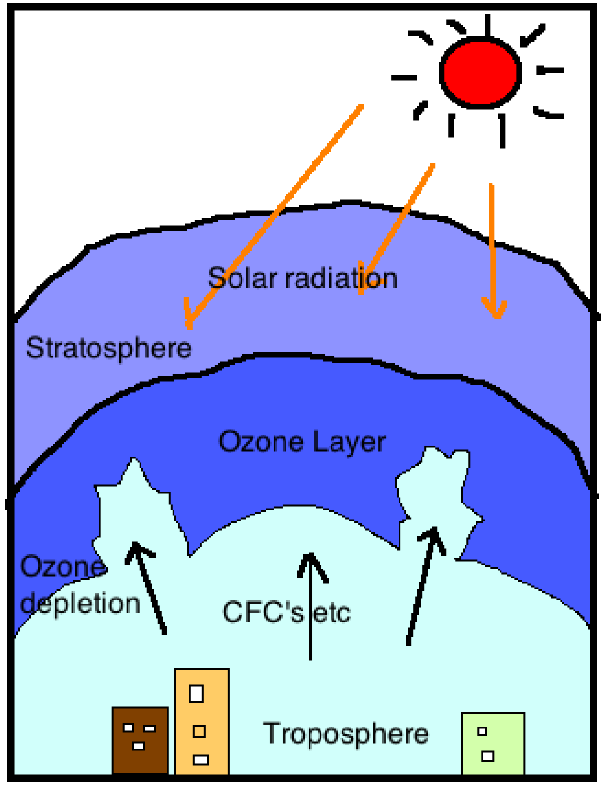
ENVIRONMENTAL ISSUES

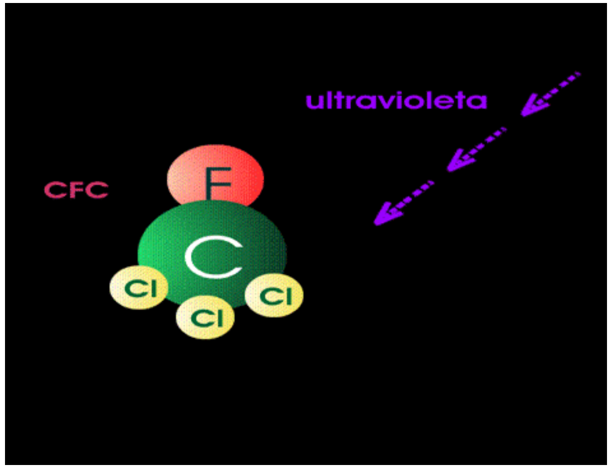
- Environmental issues refer to the harmful effects created by human beings on the living environment.
- The issues mainly relate to the climatic changes taking place in the living atmosphere.
- Increased human activity, urbanization and industrialization have led to rapid deterioration of the environment.
- Two important global environmental issues are *Ozone depletion* and *Global warming*



Ozone layer depletion

- Ozone depletion refers to the gradual thinning of the earth’s ozone layer in the upper atmosphere, caused by the release of chemical compounds containing gaseous chlorine or bromine from industries and other emissions from human activities.
- Ozone layer is a deep layer in the stratosphere encircling the earth, that has large amounts of ozone in it.
- Ozone layer shields the entire earth from the harmful UV radiation of the sun thereby protecting the living beings on the earth.
- In 1970’s it was discovered that man made chemicals called chlorofluorocarbons (CFC’s) that were released into the atmosphere gradually decompose, releasing chlorine atoms that destroy the ozone in the ozone layer.
- Each chlorine atom has the ability to destroy tens of thousands of ozone molecules.
- The depletion of ozone layer thus leads to its inability to shield the UV radiation reaching the earth’s surface thereby increasing the radiation effects like skin cancer, eye cataracts and damage to immune system.





Global warming

- A gradual increase in the average temperature of the earth's atmosphere and its oceans, a change that is believed to be permanently changing the earth's climate.
- The climatic change is due to the increased volumes of CO_2 and other green house gases (toxic gases) released by the burning of fossil fuel, land clearing, agriculture and other emissions created by human activities that have occurred over past years.
- The gases form a layer in the atmosphere and trap the sun's radiation which in turn makes the planet warmer.
- Global warming leads in rising sea levels due to the melting of the polar ice caps as well as an increase in occurrence and severity of storms, droughts and other severe weather events.

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Module – 1.2

Basic Concepts of Thermodynamics

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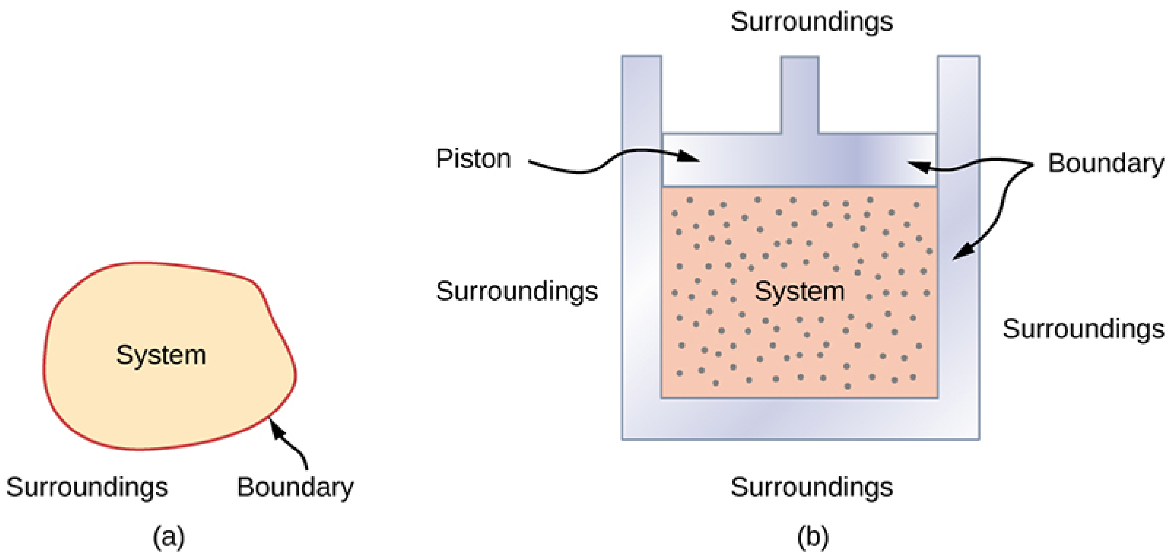
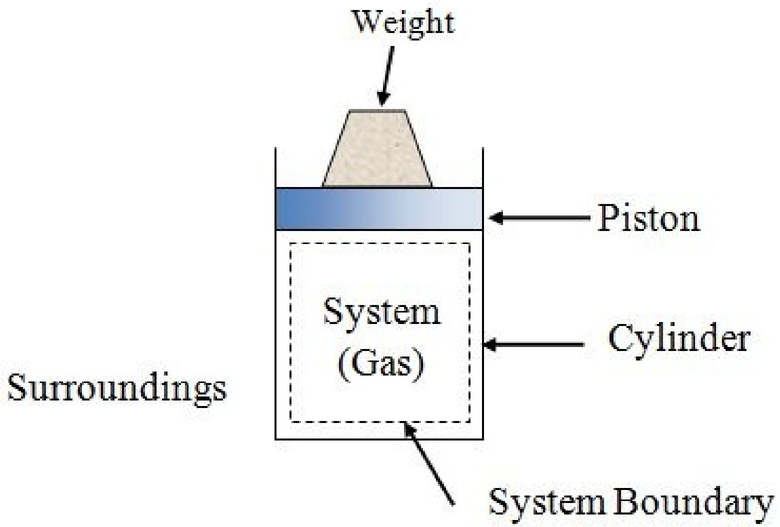
Introduction

- The word thermodynamics was first coined by William Thompson.
- Thermo – heat, dynamics means power, in other words, the capacity of hot bodies to produce work.
- Definition: A branch of science that deals with the study of energy, energy transformations and its relationship with the properties of matter.
- It provides important relationships among heat transfer, work interactions, kinetic and potential energy and properties that describe the condition of any substance.
- Applications of thermodynamics: Turbines, pumps, engines, compressors, air conditioners, solar collectors, rocket engines, fuel cells, wind and wave energy systems and all systems that transform energy from one form to another.

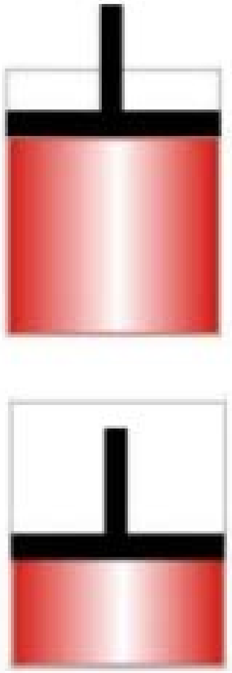
Basic concepts of Thermodynamics

1. System: A thermodynamic system is defined as a specific quantity of matter or region in space on which our attention is focussed for thermodynamic analysis.
2. Boundary: The real or imaginary surface enclosing the system through which energy and mass may enter or leave the system.
3. Surroundings: A three dimensional space outside the thermodynamic system that has a direct relationship on the behaviour of the system.

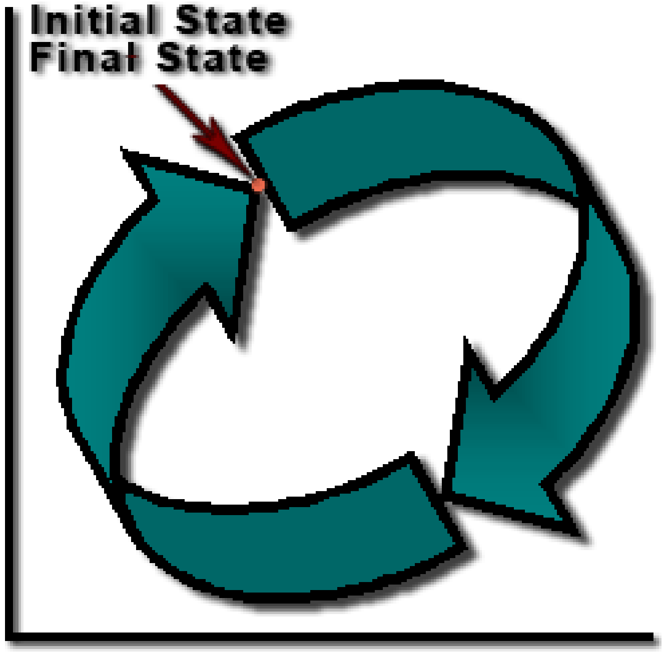


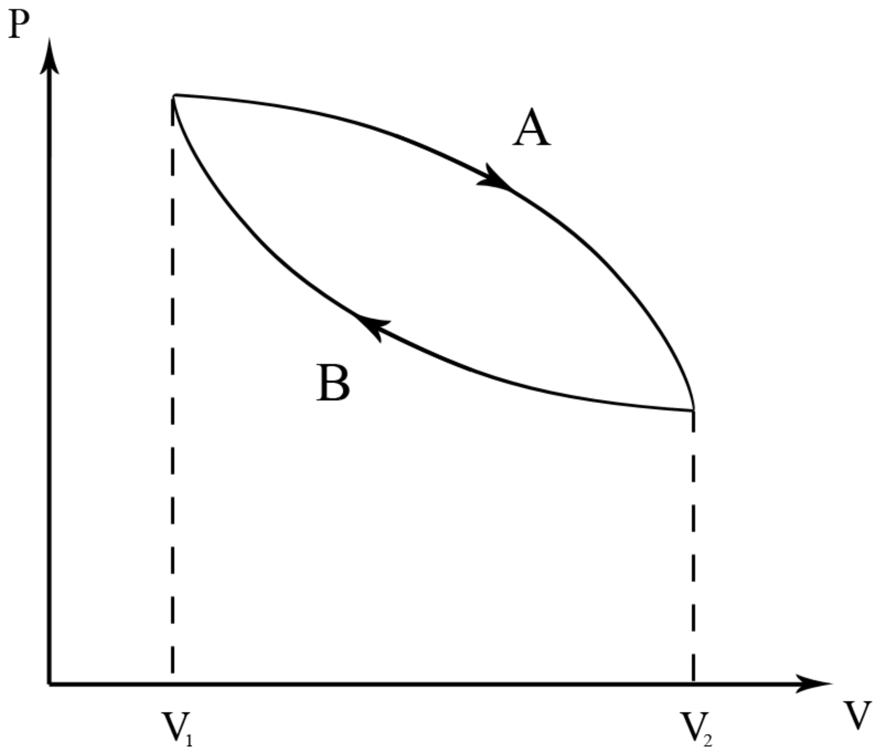


4. Thermodynamic state of system: The condition of the system at any specific time, which can be identified by values of parameters like pressure, volume, temperature, mass etc.
5. Thermodynamic cycle: A linked sequence of processes in which the working substance undergoes a series of state changes accompanying with heat and work transfer and finally returning to its initial state.



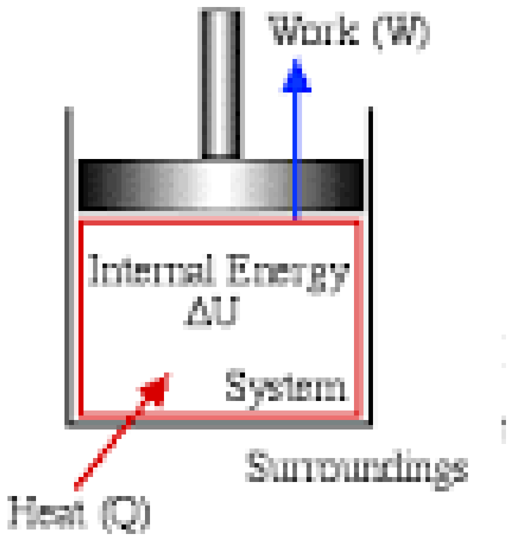
P1 x V1 = P2 x V2

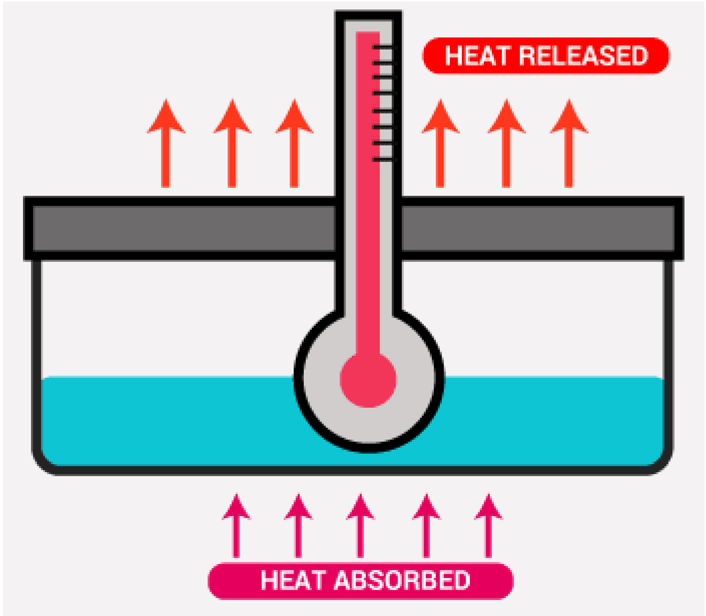




Thermodynamic cycle

6. Internal energy of a system: The energy possessed by a body or a system due to its molecular arrangement and motion of the molecule. It is the sum of potential energy (PE) and kinetic energy (KE) of the particles that form the system. Denoted by U or E, expressed in Joule (J).





7. Enthalpy of a system: Total heat content of a system. It is defined as the sum of internal energy (U) of a system and the product of the pressure (P) and volume (V) of the system.

$H = U + P.V$………kJ/kg

8. Entropy of system: It is the amount of energy that is lost to surrounding at a specific temperature. Also defined as a function of a quantity of heat which shows the possibility of conversion of that heat into work. Denoted by S and expressed in Joules/Kelvin (J/K).

- The change in entropy is given by the equation $dS = \frac{dQ}{T}$ where dQ represents change in heat and T, the temperature.

- Characteristics of entropy:
  i. Entropy increases when heat is supplied to a system irrespective of the fact whether temperature changes or not.
  ii. Entropy decreases when heat is removed from a system irrespective of the fact whether temperature changes or not.
  iii. Entropy remains unchanged for adiabatic or isentropic processes.

$$dS = C_v \ln\left(\frac{P_2}{P_1}\right) + C_p \ln\left(\frac{V_2}{V_1}\right) \text{ in terms of } \textit{pressure} \text{ and } \textit{volume}$$

$$dS = C_p \ln\left(\frac{T_2}{T_1}\right) - R \ln\left(\frac{P_2}{P_1}\right) \text{ in terms of } \textit{temperature} \text{ and } \textit{pressure}$$

$$dS = C_v \ln\left(\frac{T_2}{T_1}\right) + R \ln\left(\frac{V_2}{V_1}\right) \text{ in terms of } \textit{pressure} \text{ and } \textit{volume}$$

Temperature

- Temperature is a thermodynamic property which determines the degree of hotness or the level of heat intensity of a body/system.
- The temperature of a system is measured using a glass thermometer on Celsius scale or Fahrenheit scale.
- The relationship between the two scales is given by

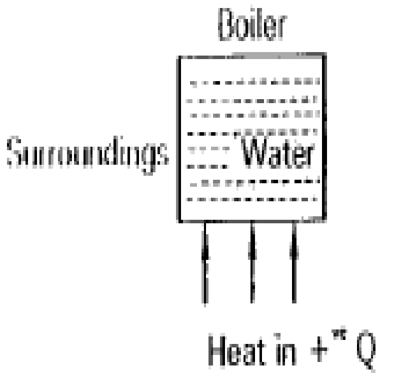
$$\frac{C}{5} = \frac{F-32}{9}$$

- Absolute zero temperature: Theoretically, gas will not occupy any volume at a certain temperature. The molecules stop moving or vibrating at all. This temperature is known as absolute zero temperature.
- The relationship between C and K scale is given as K = °C + 273.

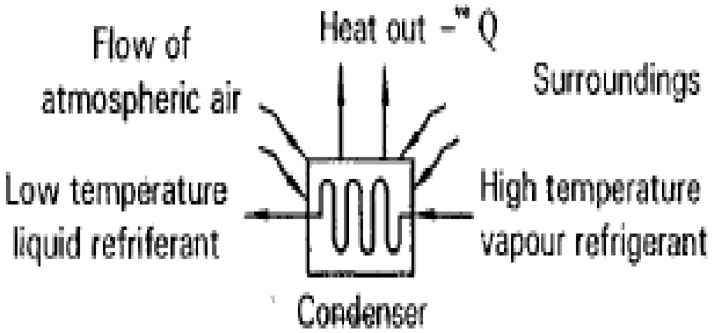
Concept of Heat & Work

Heat:

- It is defined as the transfer of energy taking place across the boundary of a system or between two different bodies due to the temperature difference between them.
- Heat is transferred naturally from a body of higher temperature to a body of lower temperature.
- Heat is denoted by Q and expressed in kJ.



(a) Heat added to convert water into steam



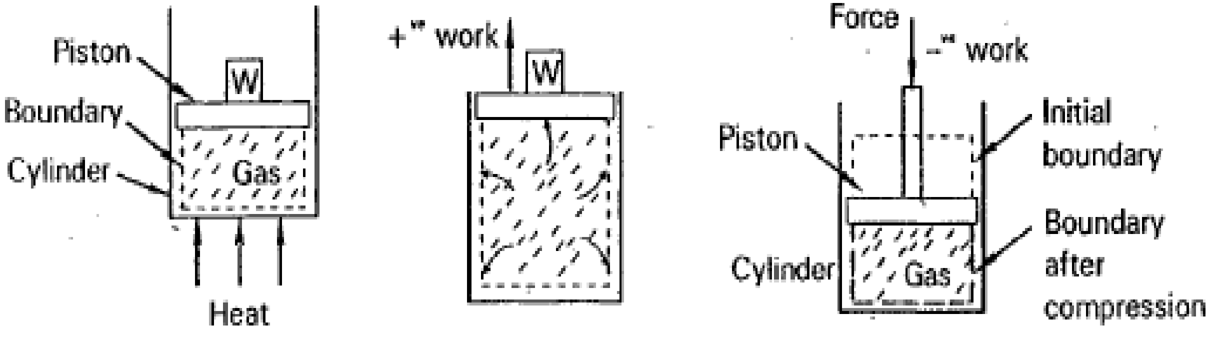
(b) Heat rejected to atmosphere by the refrigerant

Sign convention

- If heat is transferred from the surroundings to the system, it is considered as +ve.
- If heat is transferred from the system to the surroundings, it is considered as –ve.

Work:

- In thermodynamics, work refers to the energy transfer between the system and its surroundings by a mechanism through which the system can spontaneously exert macroscopic forces on its surroundings.
- In simple words, work is the energy transfer, associated with a force acting through a distance. Denoted by W and expressed in kJ.
- The displacement work from system state 1 to 2 is given by the equation $W = \int_1^2 P.dV$



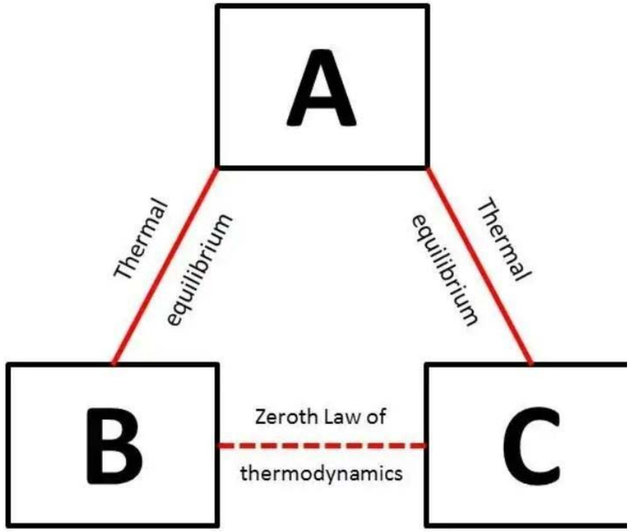
(a) Heat supplied to system (b) Work done by the system (c) Work done on the system

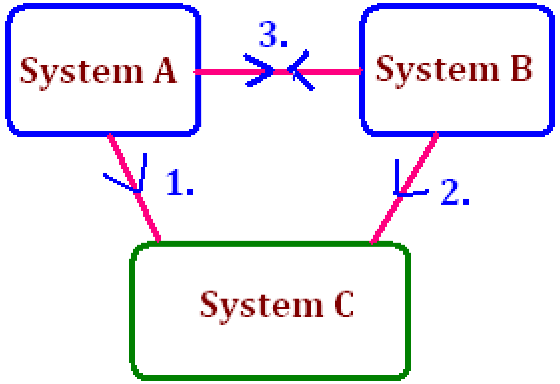
Sign convention

- If work is done by the system, it is considered as +ve.
- If work is done on the system it is considered as –ve.

Laws of Thermodynamics

I. *Zeroth law of thermodynamics*: if two thermodynamic system are each in thermal equilibrium with a third one, then they are in thermal equilibrium with each other. [Thermal equilibrium means a condition in which all parts of a system are at the same temperature]

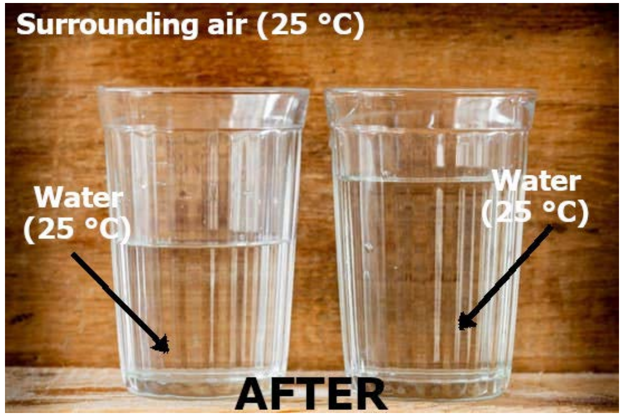




1. A & C are in thermal equilibrium
2. B & C are in thermal equilibrium

then

3. A & B are also in thermal equilibrium with each other

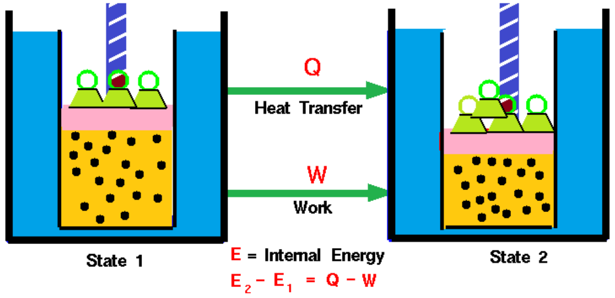


II. First law of thermodynamics:

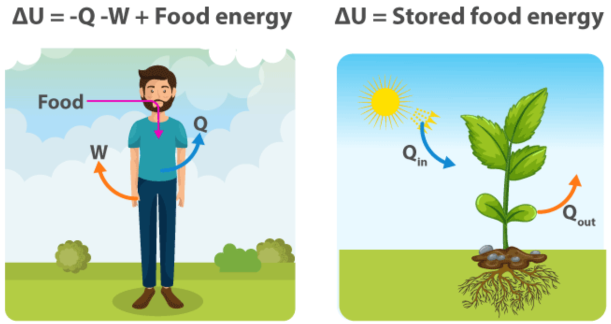
- When a closed system undergoes a thermodynamic cycle, the net heat transfer (Q) is equal to the net work transfer (W).

$$\oint \delta Q = \oint \delta W \qquad \text{where } \oint \text{ stands for cyclic integral}$$

- The first law is also known as law of conservation of energy, which states that energy can neither be created not destroyed.
- The total amount of energy and matter in the universe remains constant merely changing from one form to another.
- According to the law of conservation of energy, total energy $\Delta E = Q - W$



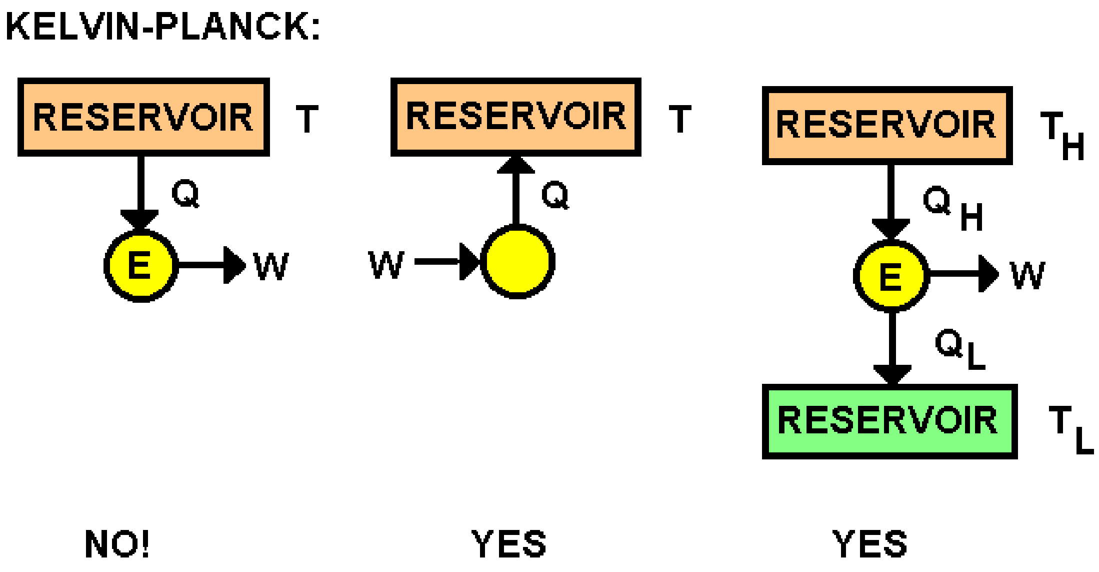
First Law of Thermodynamics

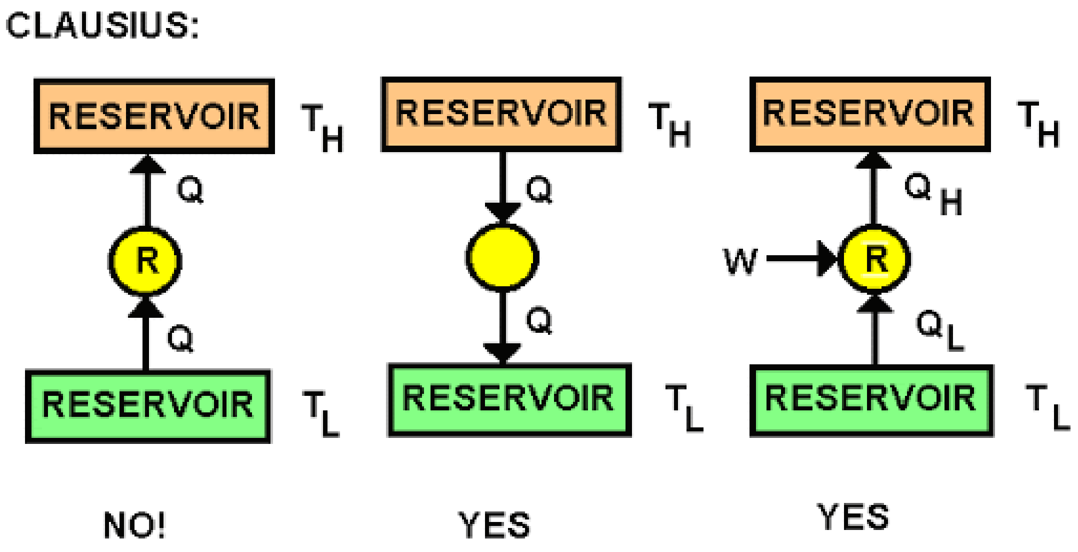


(a) (b)

III. Second law of thermodynamics:

- Kelvin-Planck statement: It is impossible for any device/machine that operates in a cycle to receive heat from a single reservoir and produce a net amount of work. There is always a degradation or loss of energy in the process of producing mechanical work from the heat supplied.
- Clausius statement: It is impossible for any device/machine working in a cyclic process to transfer heat from a body at a lower temperature to a body at a higher temperature without the aid of an external agency. [In simple words, heat cannot flow naturally from a cold body to a hot body without the help of work input]

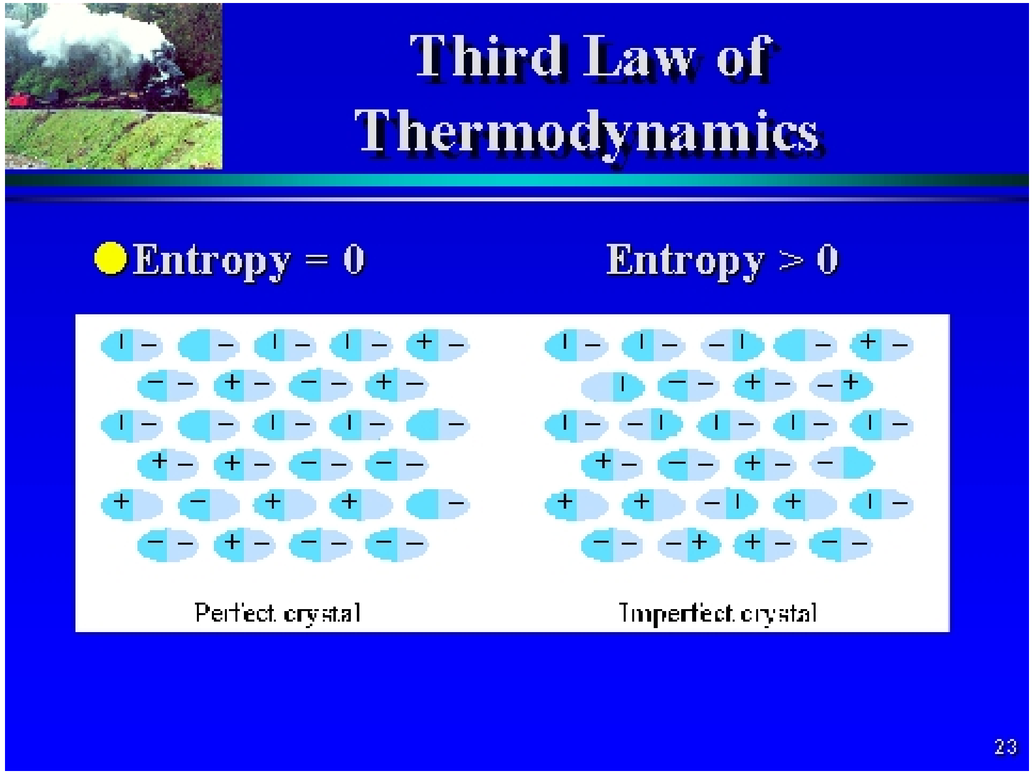




IV. *Third law of thermodynamics*:

- The entropy of a system approaches a constant value as its temperature approaches absolute zero.
- It can also be stated as “the entropy of a pure substance in thermodynamic equilibrium approaches zero as the temperature approaches zero.

$\lim_{T\to 0} S = 0$ where S = entropy (J/K) and T = absolute temperature (K)



Third Law of Thermodynamics

● Entropy = 0

Entropy > 0

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Module – 1.2.1

Basic Concepts of Thermodynamics - Numericals

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Problem 1 In an internal combustion engine, the heat rejected to cooling water during compression stroke is 50 *kJ/kg* and the work input is 100 *kJ/kg*. Calculate the change in internal energy of the working fluid stating whether it is a gain or loss.

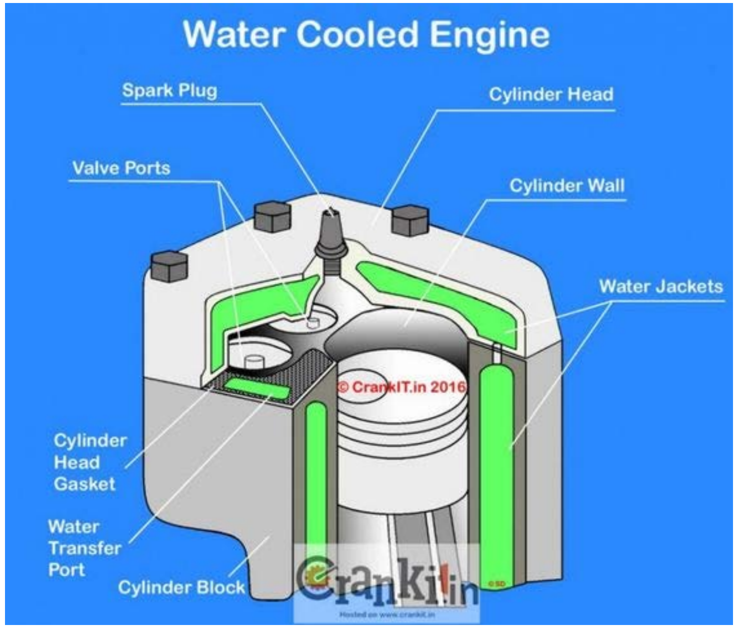
Solution : Heat rejected = $Q = -50\ kJ/kg$

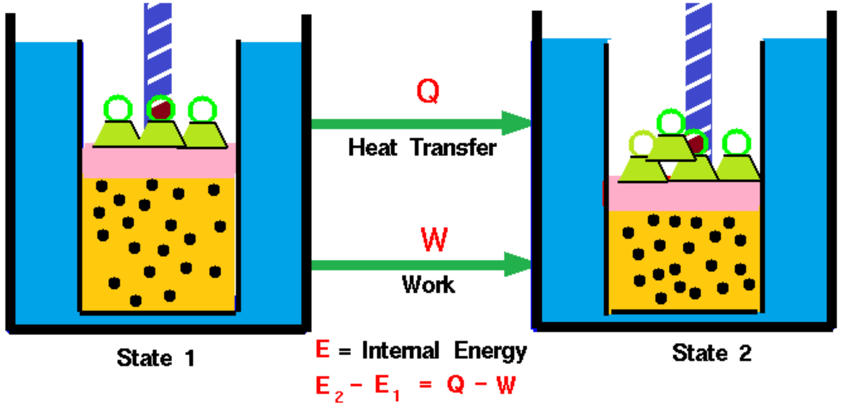
($-^{ve}$ sign indicates heat is rejected from the system to the surroundings)

Work input = $W = -100\ kJ/kg$ ($-^{ve}$ sign indicates work is done on the system)

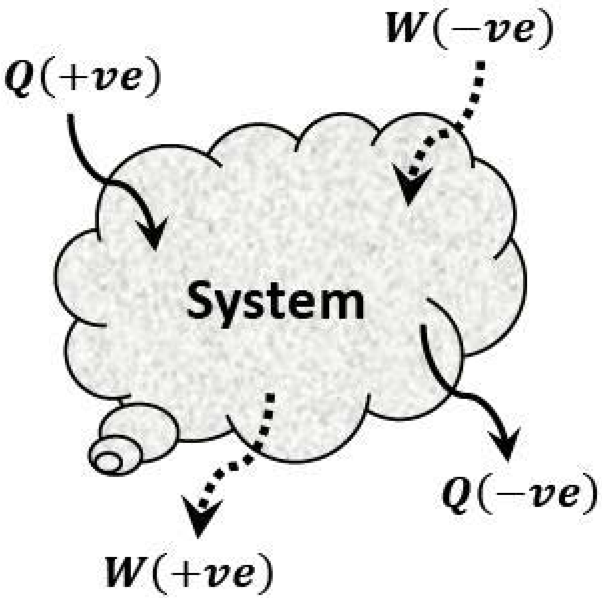
w.k.t. change in internal energy = $\Delta E = Q - W = -50 - (-100) = 50$

$\Delta E = +50\ kJ/kg$ ($+^{ve}$ sign indicates increase (gain) in internal energy of the system)





First Law of Thermodynamics



Problem 2 A closed system undergoes a change in process in which 5 kJ of heat energy is supplied to the system. Determine the change in internal energy under the following conditions. (i) 1 kJ of work is done on the system (ii) 1.25 kJ of work is done by the system.

Solution : Heat supplied $Q = 5\ kJ$

Case 1 To find ΔE for $W = -1\ kJ$

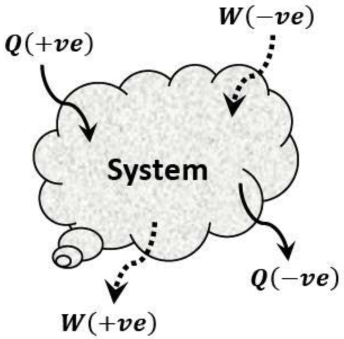
$W = -1\ kJ$ ($-^{ve}$ sign indicates work is done on the system)

From I law of Thermodynamics, Change in energy $\Delta E = Q - W = 5 - (-1) = 6\ kJ$

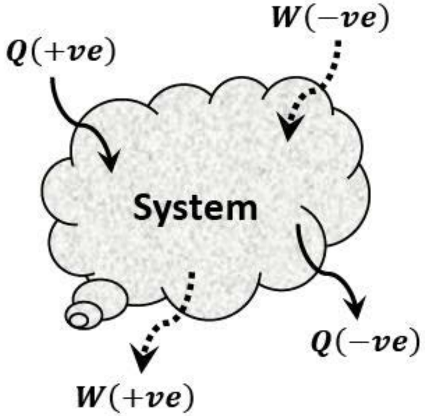
$$\therefore \Delta E = 6\ kJ$$

Case 2 To find ΔE for $W = 1.25\ kJ$

w.k.t. change in energy $\Delta E = Q - W = 5 - (1.25) = 3.75\ kJ$ $\therefore \Delta E = 3.75\ kJ$



Problem 3 A stationary mass of gas at its initial state 0.4 m^3 and 0.105 MPa was compressed at constant pressure to final state of 0.2 m^3 and 0.105 MPa. The heat transfer from the gas during the process was 42.5 kJ. Calculate the change in internal energy of the gas.



Solution : Initial condition of gas (state 1) : Volume of gas = $V_1 = 0.4\ m^3$

Pressure = $P_1 = 0.105\ MPa = 0.105 \times 10^6\ N/m^2$ ($\because$ mega = 10^6 and $Pa = N/m^2$)

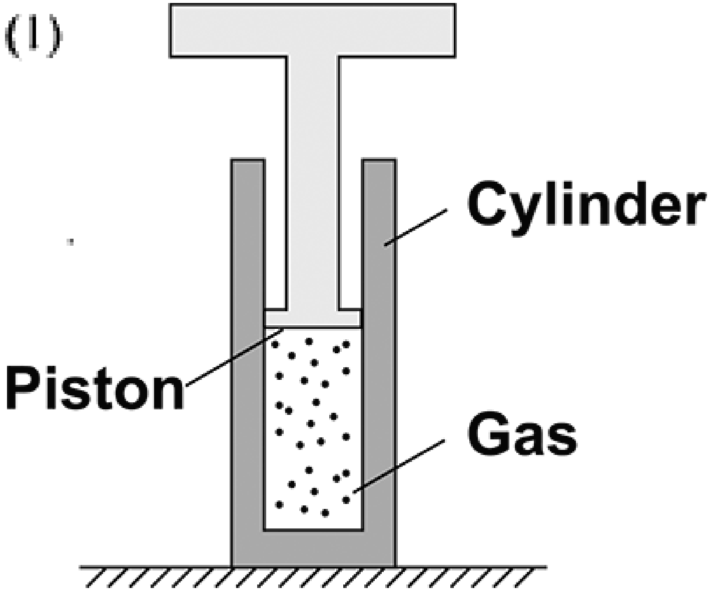
Final condition (state 2) : Volume $V_2 = 0.2\ m^3$ Pressure = $P_2 = 0.105\ MPa = 0.105 \times 10^6\ N/m^2$

Note that since $P_1 = P_2$, the compression process takes place at constant pressure.

Heat transfer from the gas = $Q = -42.5\ kJ$ ($-^{ve}$ sign indicates heat is rejected from the system)

w.k.t. change in internal energy = $\Delta E = Q - W$ ----- (1)

But work W = ?



w.k.t. displacement work = $W = \int_1^2 P.dv = P(V_2 - V_1)$

$$W = (0.105 \times 10^6)\,(0.2 - 0.4) = -21 \times 10^3\ \frac{N}{m^2} \times m^3 = -21 \times 10^3\ Nm$$

Work = $-21\ kJ$ ($\because$ kilo = 10^3 and Nm = Joule)

Now equation (1) becomes, $\Delta E = -42.5 - (-21) = -21.5$

$\therefore$ Change in internal energy = ΔE = **− 21.5 kJ**

($-^{ve}$ sign indicates decrease in internal energy of the system)

Problem 4 A gas occupies a volume of 0.1 m^3 at a temperature of 20 °*C* and a pressure of 1.5 *bar*. Find the final temperature of the gas, if it is compressed to a pressure of 7.5 *bar* and occupies a volume of 0.04 m^3.

Solution : Initial volume $V_1 = 0.1\ m^3$ Initial temperature $T_1 = 20\ °C = 20 + 273 = 293\ K$

Initial pressure $P_1 = 1.5\ bar = 1.5 \times 10^2\ kN/m^2$

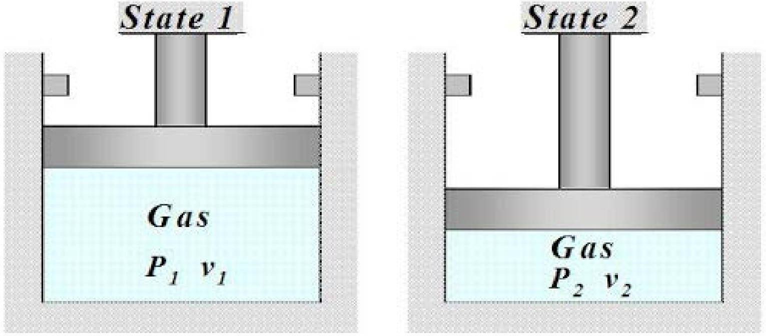
Final pressure $P_2 = 7.5\ bar = 7.5 \times 10^2\ kN/m^2$

Final volume $V_2 = 0.04\ m^3$

To find final temperature (T_2)

For a perfect gas, at condition 1 and 2, we have $\dfrac{P_1 V_1}{T_1} = \dfrac{P_2 V_2}{T_2}$

$$\frac{(1.5\times10^2)(0.1)}{293} = \frac{(7.5\times10^2)0.04}{T_2}$$



$$0.0511 = \frac{30}{T_2} \qquad \therefore\ T_2 = 587\ K$$

Problem 5 0.05 m^3 of air at a pressure of 8 bar and temperature 280°C expands to eight times its original volume and the final temperature after expansion is 25°C. Calculate the change in entropy of air during the process. Assume specific heat at constant pressure as 1.005 $kJ/kg\ K$ and specific heat at constant volume as 0.712 $kJ/kg\ K$.

$dS = C_v \ln\left(\frac{P_2}{P_1}\right) + C_p \ln\left(\frac{V_2}{V_1}\right)$ in terms of *pressure* and *volume*

$dS = C_p \ln\left(\frac{T_2}{T_1}\right) - R \ln\left(\frac{P_2}{P_1}\right)$ in terms of *temperature* and *pressure*

$dS = C_v \ln\left(\frac{T_2}{T_1}\right) + R \ln\left(\frac{V_2}{V_1}\right)$ in terms of *pressure* and *volume*

Solution :

Initial condition of air (before expansion) :

Volume $V_1 = 0.05\ m^3$ Pressure $P_1 = 8$ Bar $= 8 \times 10^5\ N/m^2$ ($\because$ 1 Bar $= 10^5\ N/m^2$)

Temperature $T_1 = 280°C = 280 + 273 = 553\ K$

Final conditions of air (after expansion) :

Volume $V_2 = 8\ V_1 = 8\ (0.05) = 0.4\ m^3$

Temperature $T_2 = 25°C = 25 + 273 = 298\ K$

$C_p = 1.005\ kJ/kg\ K$ and $C_v = 0.712\ kJ/kg\ K$

To find change in entropy (dS)

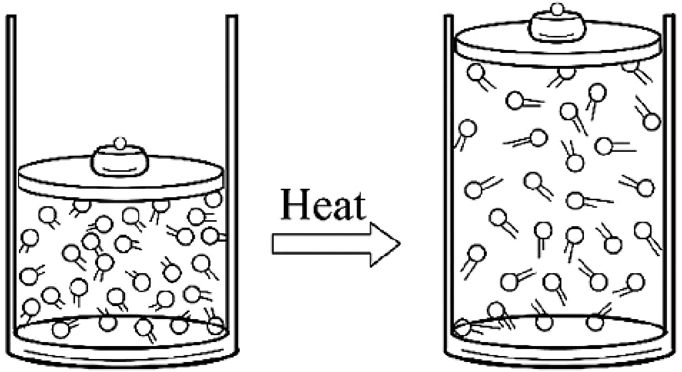
w.k.t. change in entropy $= dS = C_v \ln\left(\frac{T_2}{T_1}\right) + R \ln\left(\frac{V_2}{V_1}\right)$ ----- (1)

where R = gas constant $= C_p - C_v$

i.e., $R = 1.005 - 0.712 = 0.293\ kJ/kg\ K$

Now equation (1) becomes, $dS = 0.712 \ln\left(\frac{298}{553}\right) + 0.293 \ln\left(\frac{0.4}{0.05}\right)$

i.e., $dS = 0.169\ kJ/kg\ K$ calculated for 1 kg of air



To find mass of air (m)

w.k.t. perfect gas equation $PV = m\,R\,T$ where P is in kPa

using relation $P_1 V_1 = m\,R\,T_1$ ----- (2)

$P_1 = 8 \times 10^5\ N/m^2 = 8 \times 10^2\ kN/m^2 = 8 \times 10^2\ kPa$

$\therefore$ equation (2) becomes, $(8 \times 10^2)\ (0.05) = m\ (0.293)\ (553)$

mass $m = 0.246\ kg$

Now change in entropy $dS = 0.246\ (0.169) = 0.0415$

$dS = \mathbf{0.0415\ kJ/K}$

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Module – 1.3

Steam Formation and Properties

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Introduction

- All substances under suitable conditions of temperature and pressure can exist in one of the three states – solid, liquid and gas. But water is one of the pure substance that exists in all three phases namely, in solid phase as ice, liquid phase as water and gaseous phase as vapour.

- Water, which is liquid at normal temperature begins to boil to form steam when heated sufficiently.
- The steam thus formed is used as a working fluid in the operation of steam turbines to generate electricity.

Formation of Steam at Constant Pressure

- Consider 1kg of water at 0°C taken in a cylinder, fitted with a freely moving piston.
- A weight W is placed over the piston as shown in Figure. The weight of the piston and weight W placed over the piston exerts a constant pressure P on the water.
- Let V be the volume occupied by the water in the cylinder. The condition of water at 0°C is represented by a point A on the temperature-enthalpy (T-H) diagram.
- When water is heated at constant pressure, it is converted to steam.
- The various stages involved in the process are discussed.

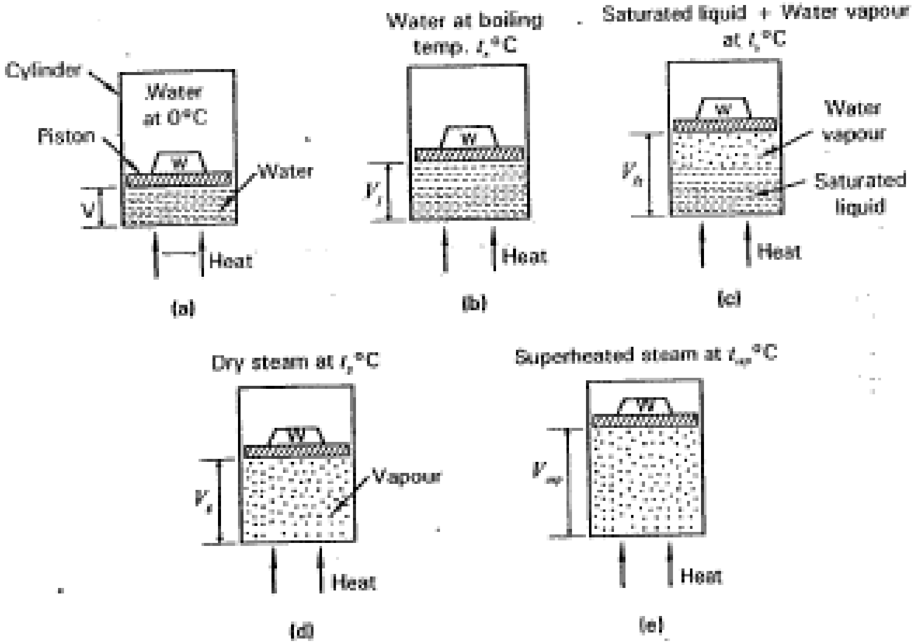
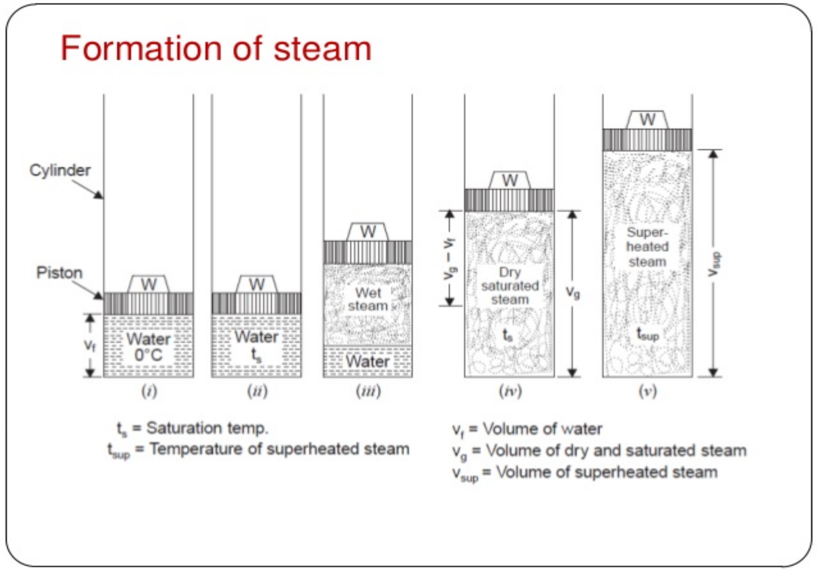


Figure 3.1 Formation of steam at constant pressure



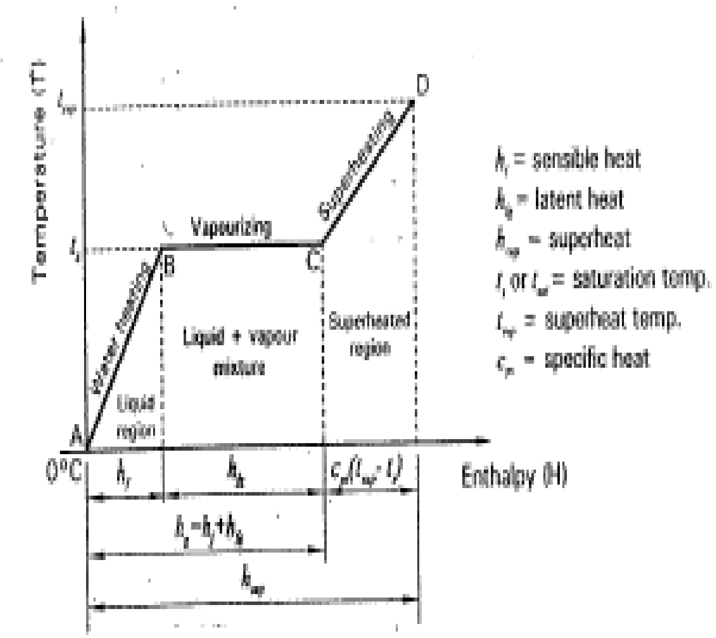


Figure 3.2 Temperature-enthalpy (TH) diagram

1. On heating, the temperature of the water rises and at a certain temperature water begins to boil/evaporate. The temperature at which water starts boiling is known as saturation temperature and is denoted by t_s. The heating of water from °C to the saturation temperature (t_s) is shown by line AB on T-H diagram. At this temperature, there is a slight increase in the volume of water (V_f) as shown in figure (previous slide).
2. When water is heated beyond the saturation temperature, there will be no rise in temperature but evaporation of water takes place (water starts converting into steam). At this stage, water exists as a two-phase mixture containing saturated liquid and water vapour occupying volume V_{fg}. The steam in this condition is called wet steam. Evaporation of water continues at the same saturation temperature until the whole of the water is completely converted into steam (Line BC on T-H diagram).
3. At point C, the steam formed does not contain water vapour and hence the steam in this state is called dry steam or dry saturated steam, occupying volume V_g.
4. If the heating is further continued at point C, the temperature of the steam increases above the saturation temperature and this temperature is called superheat temperature (t_{sup}). The steam in this condition is called superheated steam (Line CD on T-H diagram) occupying volume V_{sup}.

Types of Steam / Condition of Steam

Wet steam	• A two – phase mixture containing saturated liquid and vapour formed at the saturation temperature and at a given pressure. • Wet steam formed contains small water particles held in suspension that has not yet absorbed the latent heat and evaporated.
Dry saturated steam	• Steam that exists completely in pure vapour form at the saturation temperature and at a given pressure. • Dry steam is a pure steam that does not contain water vapours.
Superheated steam	• Steam that is heated beyond its dry saturated state to a temperature higher than its saturation temperature and at a given pressure. • The temperature at which the superheated steam is formed is called superheat temperature and is denoted by t_{sup}. • Advantages of superheated steam: a. Heat content of superheated steam is high and hence its capacity to do work is greater. b. Due to high temperature, superheated steam gives higher thermal efficiency and minimizes the specific consumption of steam. c. No moisture content; erosion/corrosion of turbine blades are minimized.

Thermodynamic properties of Steam

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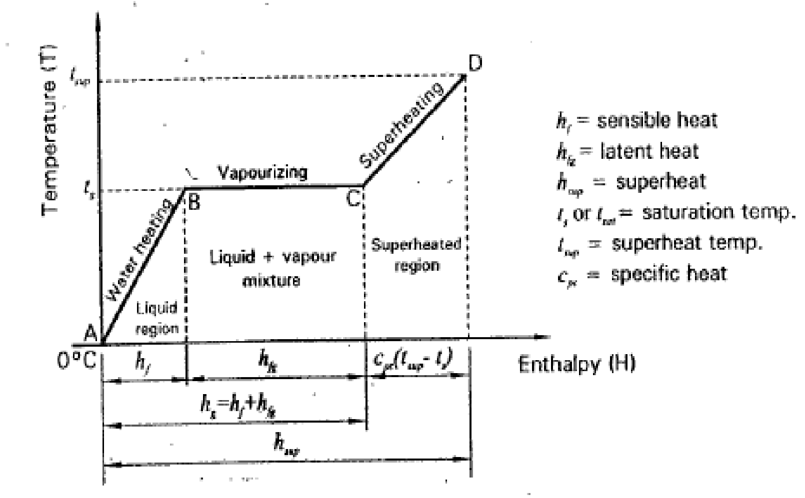
1. Dryness fraction



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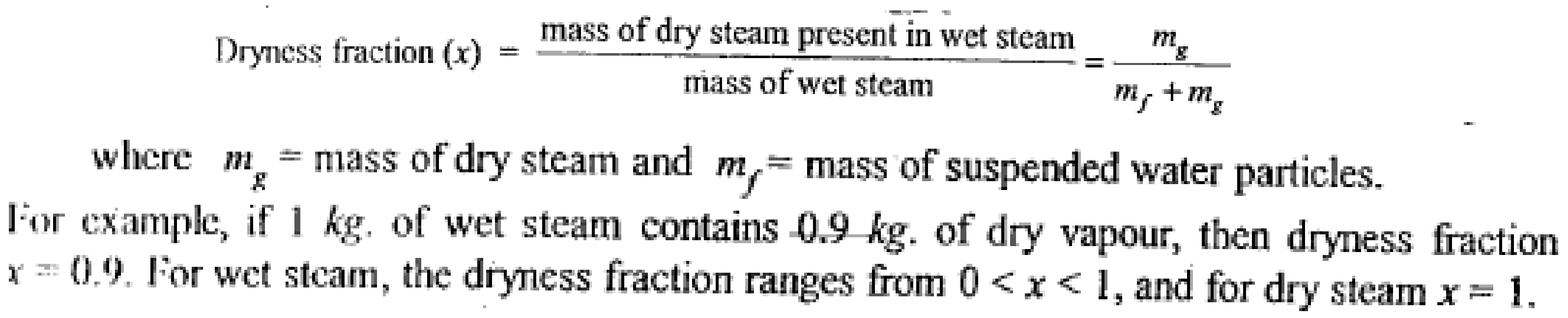
- Ratio of mass of dry steam present in a known quantity of wet steam to the total mass of wet steam.
- Dryness fraction refers to the quality of steam, or an indication of the extent of dryness of steam. It is denoted by x.



$$\text{Dryness fraction } (x) = \frac{\text{mass of dry steam present in wet steam}}{\text{mass of wet steam}} = \frac{m_g}{m_f + m_g}$$

where m_g = mass of dry steam and m_f = mass of suspended water particles.

For example, if 1 *kg*. of wet steam contains 0.9 *kg*. of dry vapour, then dryness fraction $x = 0.9$. For wet steam, the dryness fraction ranges from $0 < x < 1$, and for dry steam $x = 1$.

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2. Sensible heat/Total heat of water/Enthalpy of saturated water

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- It is the amount of heat required to raise the temperature of 1kg of water from °C to saturation temperature (t_s) at a given pressure.
- It is denoted by h_f.

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3. Latent heat of evaporation/Enthalpy of evaporation

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- It is the amount of heat required to convert 1kg of water at saturation temperature (t_s) to 1kg of dry saturated steam at the same temperature (t_s) and at a given pressure.

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4. Superheat

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- It is the amount of heat required to raise the temperature of dry saturated steam above its saturation temperature and at a given pressure. This process is called superheating.

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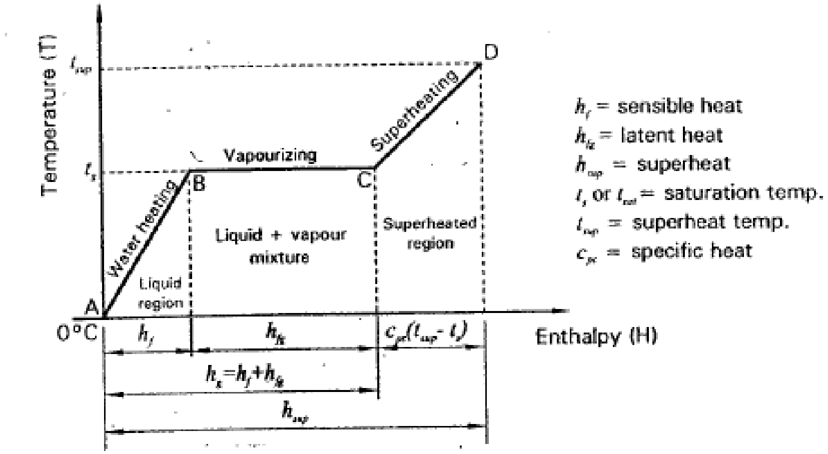
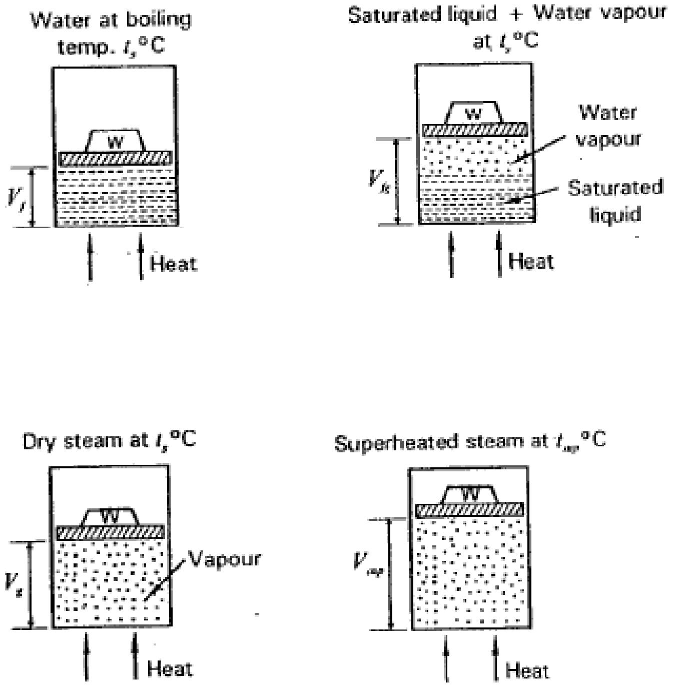
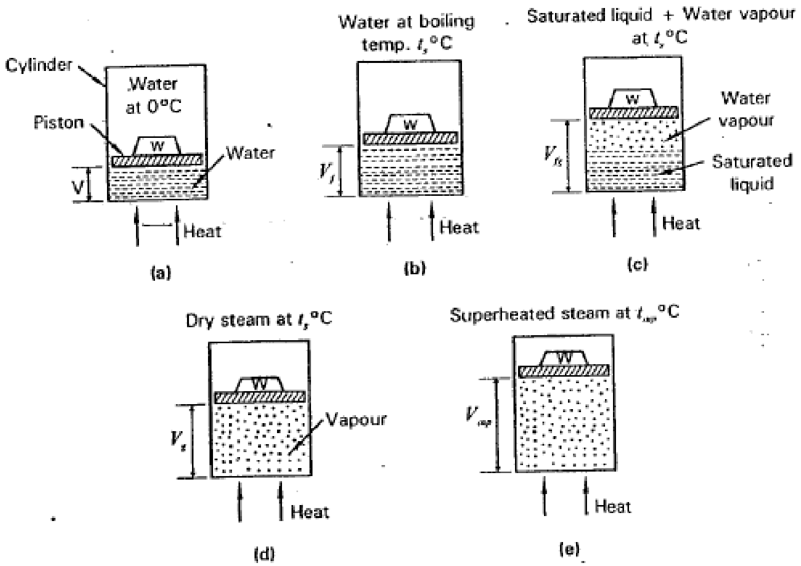
5. Degree of superheat	- It is defined as the difference between the superheat temperature (t_{sup}) and the saturation temperature (t_s). - Degrees of superheat = $t_{sup} - t_s$
6. Enthalpy of steam  	- It is the amount of heat energy contained in a unit mass of steam. - It is defined as the sum of internal energy (U) and the product of pressure (p) and volume (V), denoted by h and expressed in kJ/kg. - *Enthalpy of wet steam*: Amount of heat required at a given pressure to convert 1kg of water at 0°C to 1kg of wet steam at a given dryness fraction. Denoted by h_w . $h_w = h_f + x.h_{fg}$ kJ/kg. where h_f = sensible heat, x = dryness fraction. h_{fg} = latent heat or latent heat of evaporation - *Enthalpy of dry saturated steam*: Amount of heat required at a given pressure to convert 1kg of water at 0°C to 1kg of dry saturated steam at the saturation temperature. Denoted by h_g. $h_g = h_f + h_{fg}$. - *Enthalpy of superheated steam*: Amount of heat required at a given pressure to convert 1kg of water at 0°C to 1kg of superheated steam at the given superheat temperature. Denoted by h_{sup}. $h_{sup} = h_g + C_{ps}\,(t_{sup} - t_s)$ where h_g = enthalpy of dry steam t_{sup} = superheat temperature, t_s = saturation temperature, & C_{ps} = Specific heat* of superheated steam

7. Specific volume of steam  	• It is defined as the volume occupied by a unit mass of steam at a given temperature and pressure. It is expressed in m^3/kg. • *Specific volume of saturated water*: Volume occupied by 1kg of water at the saturation temperature and at a given pressure. Denoted by V_f. • *Specific volume of wet steam*: The volume occupied by the saturated water and vapour at a given pressure. Denoted by V_w. $V_w = x . V_g$. where x = dryness fraction of steam V_g = specific volume of dry steam • *Specific volume of dry saturated steam*: Volume occupied by 1kg of dry saturated steam at the saturation temperature and at a given pressure. Denoted by V_g. • *Specific volume of superheated steam:* Volume occupied by 1kg of superheated steam at the superheat temperature (t_{sup}) and at a given pressure. Denoted by V_{sup}. Superheated steam behaves like a perfect gas. Therefore, according to Charles law, we have $\frac{V_{sup}}{t_{sup}} = \frac{V_g}{t_s}$ ∴ $V_{sup} = \frac{V_g \cdot t_{sup}}{t_s}$ where t_{sup} and t_s are in Kelvin.
8. Density of steam	• It is the mass of steam per unit volume of steam at the given pressure and temperature. It is the reciprocal of specific volume. ∴ Density of wet steam = $\rho_w = \frac{1}{xV_g}$ and for dry steam = $\rho_g = \frac{1}{V_g}$ (∵ $x = 1$ for dry stream).

9. External work of evaporation



- When water at the saturation temperature is heated at constant pressure, it gets converted into steam by absorbing the latent heat.
- A part of this latent heat is used to move the piston due to the increase in volume of steam during evaporation.
- The work done, due to change in volume of steam from V_f to V_g is called external work of evaporation.

External work of evaporation = $W = 100.P\,(V_g - V_f)$ where P = pressure in bar.

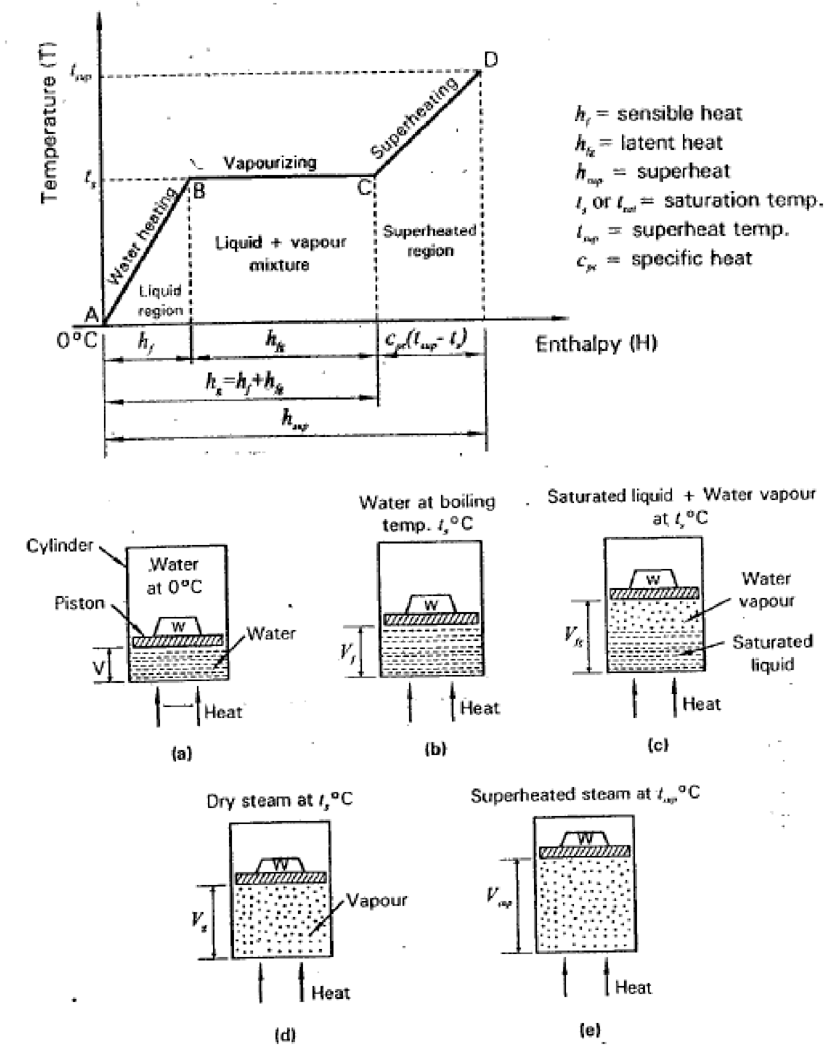
At low pressure, V_f is very small and hence can be neglected. Hence $W = 100.P.V_g$

- For *wet steam* of dryness fraction x, $W_w = 100.P.x.V_g$
- For *dry steam* $W_g = 100.P.V_g$
- For *superheated steam*, $W_{sup} = 100.P.V_{sup}$

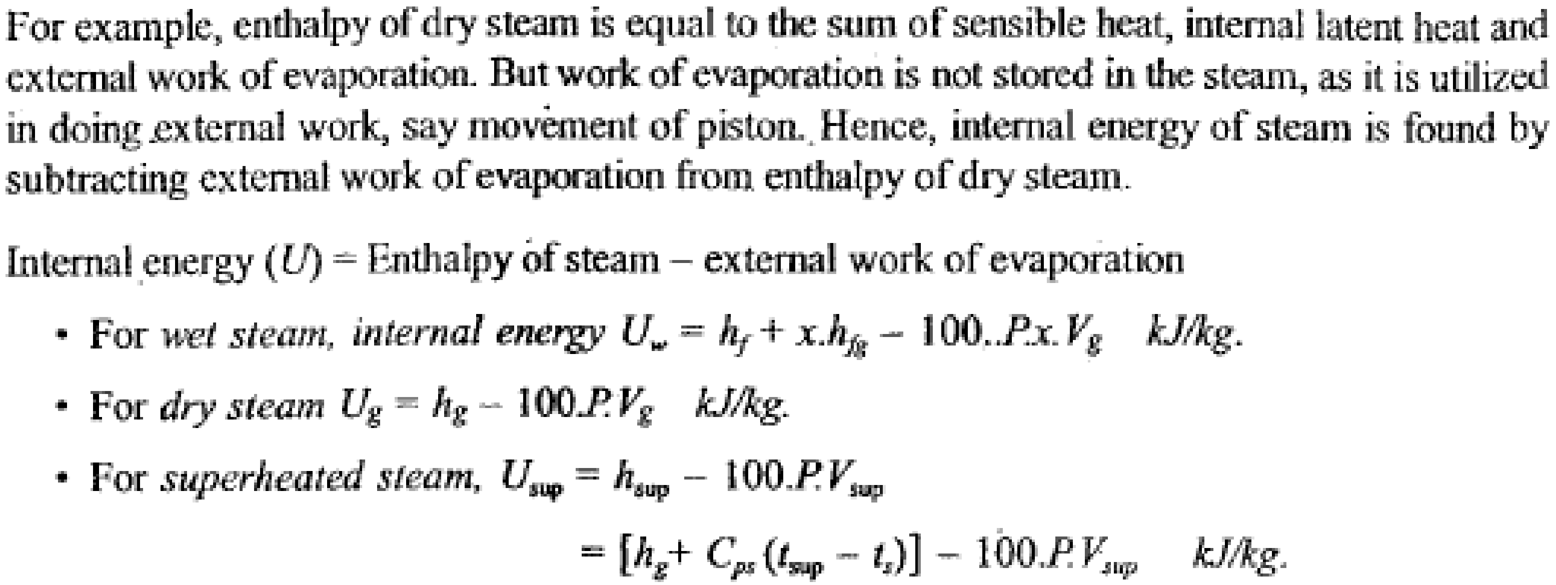
- *Internal latent heat:* The remaining part of the latent heat is used to overcome the internal resistance of water molecules to the change of phase of substance. It is called internal latent heat.
- It is obtained by subtracting the external work of evaporation from the latent heat.

$$\text{internal latent heat} = x.h_{fg} - 100.P\,x.V_g \quad kJ/kg.$$

10. Internal Energy of steam.



- Every substance has definite amount of heat energy stored in it.
- The actual heat energy stored in the steam is known as internal energy of steam.
- It can be obtained by subtracting the external work of evaporation from enthalpy of steam.



For example, enthalpy of dry steam is equal to the sum of sensible heat, internal latent heat and external work of evaporation. But work of evaporation is not stored in the steam, as it is utilized in doing external work, say movement of piston. Hence, internal energy of steam is found by subtracting external work of evaporation from enthalpy of dry steam.

Internal energy (U) = Enthalpy of steam – external work of evaporation

- For *wet steam, internal energy* $U_w = h_f + x.h_{fg} - 100..P.x.V_g$ kJ/kg.
- For *dry steam* $U_g = h_g - 100.P.V_g$ kJ/kg.
- For *superheated steam,* $U_{sup} = h_{sup} - 100.P.V_{sup}$

$$= [h_g + C_{ps}(t_{sup} - t_s)] - 100.P.V_{sup} \quad kJ/kg.$$

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Module – 1.3.1

Steam Formation and Properties- Numericals

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Problem 1 Determine the dryness fraction of steam, which has 1.5 kg of water in suspension with 50 kg of steam.

Solution :

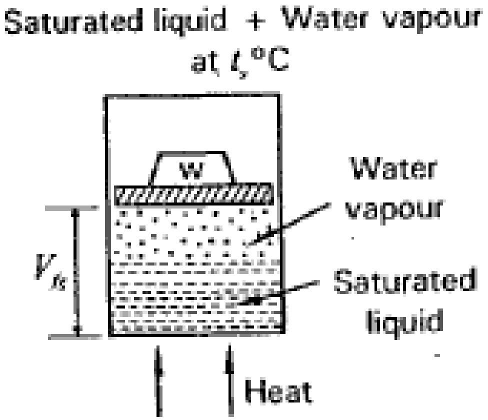
Step 1 Data

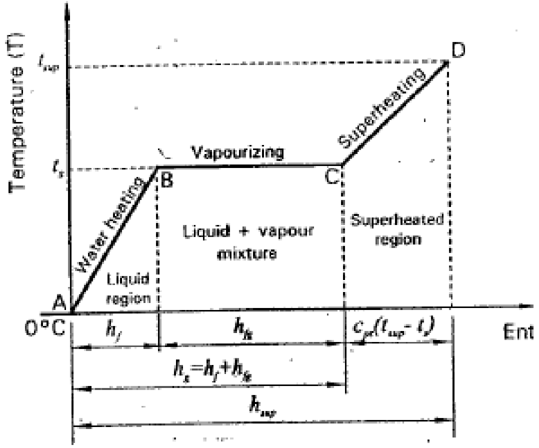
Mass of water particles $m_f = 1.5$ kg Mass of dry steam $m_g = 50$ kg

Step 2 To find dryness fraction x

$$\text{w.k.t. dryness fraction} = x = \frac{m_g}{m_f + m_g} = \frac{50}{1.5+50} = 0.97$$

$$\therefore \textbf{ dryness fraction} = x = \mathbf{0.97}$$ [97%. Dry + 3%. Wet]





Problem 2 8 kg of wet steam contains 1.56 kg of water particles in suspension. What is the dryness fraction of steam.

Solution :

Step 1 Data

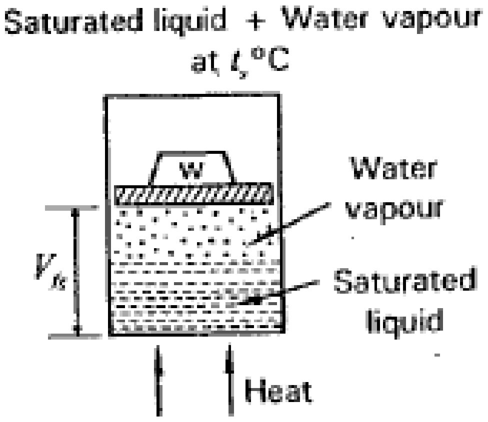
Mass of wet steam = 8 kg Mass of water particles $m_f = 1.56$ kg

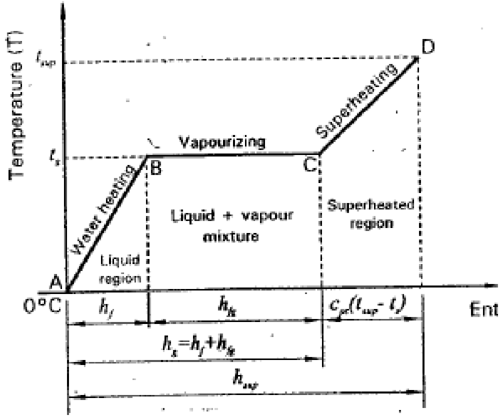
$\therefore$ Mass of dry steam present $m_g = 8 - 1.56 = 6.44$ kg

Step 2 To find dryness fraction x

$$\text{w.k.t. dryness fraction} = x = \frac{m_g}{m_f + m_g} = \frac{6.44}{1.56 + 6.44} = 0.805$$

$\therefore$ **dryness fraction = 0.805** [80.5% Dry + ·19 Swet]





Problem 3 Calculate the enthalpy of steam at a pressure of 30 bar if its dryness fraction is 0.75. ***MQP (2002 scheme) - 05 m***

Solution :

Step 1 Data

Pressure p = 30 bar Dryness fraction $x = 0.75$

Step 2 To find enthalpy of steam (h).

Since x = 0.75 is less than 1, the given steam is wet.

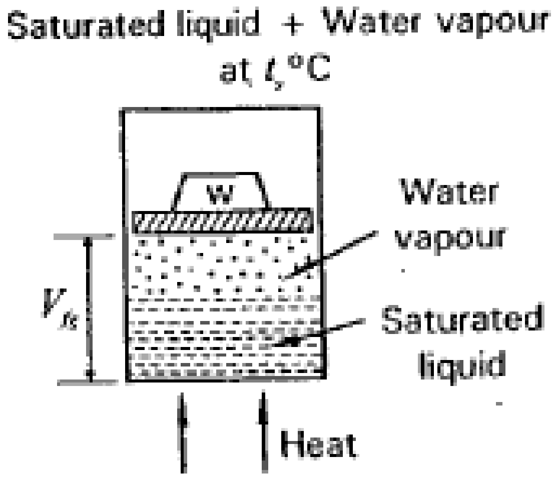
w.k.t. enthalpy of wet steam = $h_w = h_f + x\,h_{fg}$ ---- [1]

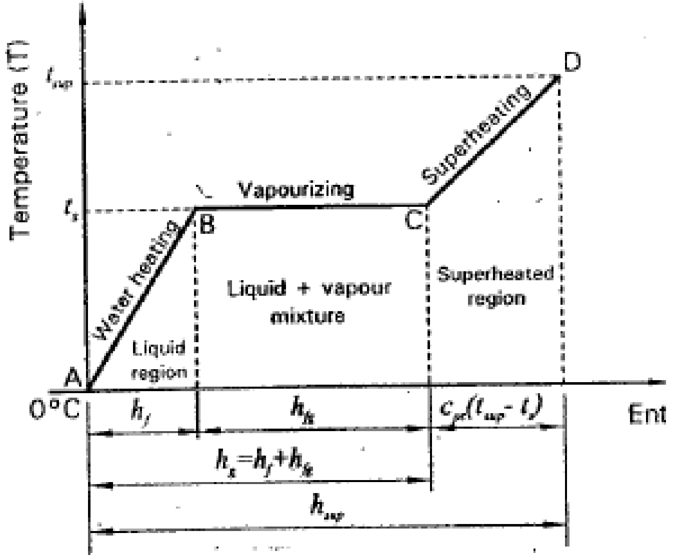
Note Since pressure (P) is given in the problem, the properties (h_f & h_{fg}) from steam tables has to read on pressure basis.

From steam tables for pressure, $P = 30$ bar, we have, $h_f = 1008.3$ kJ/kg and $h_{fg} = 1794$ kJ/kg

∴ equation (1) reduces to, $h_w = 1008.3 + [0.75 \times 1794] = 2353.8$

∴ **enthalpy of wet steam h_w = 2353.8 kJ/kg**





Problem 4 Find the enthalpy of 1 kg of steam at 12 bar when steam is (i) dry saturated (ii) 22% wet, and (iii) superheated to 250°C. Assume specific heat of the superheated steam as 2.25 kJ/kg K. ***July 2003 - 08m & Jan 2010***

Solution :

Step 1 Data

Mass of steam $= m = 1$ kg Pressure $P = 12$ bar

From steam tables, corresponding to a pressure of 12 bar, we have

$t_{sat} = t_s = 188^\circ\text{C}$, $h_f = 798.4$ kJ/kg, $h_{fg} = 1984.3$ kJ/kg, and $h_g = 2782.7$ kJ/kg

Step 2 To find enthalpy of dry saturated steam (h_g)

w.k.t. for dry saturated steam, enthalpy $= h_g = h_f + h_{fg} = 798.4 + 1984.3 = 2782.7$

$$\therefore \; \boldsymbol{h_g = 2782.7} \textbf{ kJ/kg of steam}$$

Step 3 To find enthalpy (h) when steam is 22% wet

w.k.t. enthalpy of wet steam $= h_w = h_f + x\,h_{fg}$ ---- [1]

but $x = ?$

If steam is 22% wet, then it is 100 – 22 = 78% dry.

i.e., $x = 0.78$

$\therefore$ equation (1) reduces to, $h_w = 798.4 + [0.78 \times 1984.3] = 2346.15$

$$\boldsymbol{h_w = 2346.15} \textbf{ kJ/kg}$$

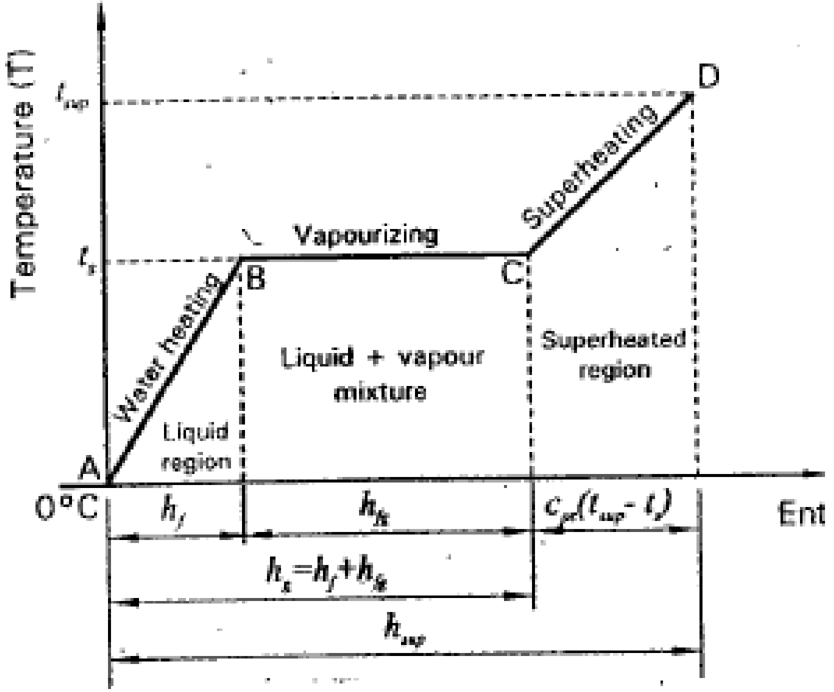
Step 4 To find enthalpy when steam is superheated to 250°C.

w.k.t. enthalpy of superheated steam $= h_{sup} = h_g + C_{ps}\,(t_{sup} - t_{sat})$

where $C_{ps} = 2.25$ kJ/kg K, and $t_{sup} = 250^\circ\text{C}$

$\therefore h_{sup} = 2782.7 + 2.25\,(250 - 188) = 2922.2$

$$\boldsymbol{h_{sup} = 2922.2} \textbf{ kJ/kg of steam}$$



Problem 5 Find the enthalpy of 0.5 kg of steam at a pressure of 10 bar absolute for the following conditions. (i) it is 1.5% wet, (ii) it is dry saturated, (iii) it is at a temperature of 200°C. Assume specific heat as 2.3 kJ/kg K. ***Jan 2007 - 06 m***

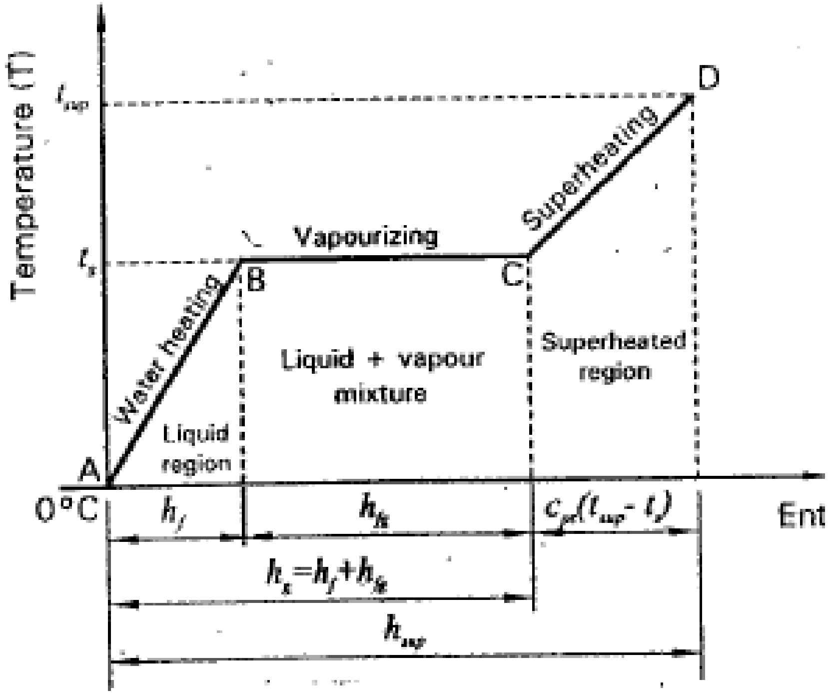
Solution :

Step 1 Data

Mass of steam $m = 0.5$ kg Pressure $P = 10$ bar

From steam tables, corresponding to $P = 10$ bar, we have

$t_{sat} = 179.9°C$, $h_f = 762.6$ kJ/kg, $h_{fg} = 2013.6$ kJ/kg and $h_g = 2776.2$ kJ/kg



Step 2 To find enthalpy when steam is 1.5% wet.

w.k.t. for wet steam, $h_w = h_f + x\, h_{fg}$ ----[1]

but $x = ?$

If steam is 1.5% wet, then it will be 100 – 1.5 = 98.5% dry

$\therefore$ dryness fraction $= x = 0.985$

equation (1) reduces to, $h_w = 762.6 + (0.985 \times 2013.6) = 2746$ kJ/kg

$\therefore$ for 0.5 kg of steam $h_w = 0.5 \times 2746$

$\mathbf{h_w = 1373}$ **kJ**

Step 3 To find enthalpy of dry steam

w.k.t. for dry saturated steam, enthalpy $h_g = h_f + h_{fg} = 762.6 + 2013.6 = 2776.2$

$h_g = 2776.2$ kJ/kg of steam

$\therefore$ for 0.5 kg of steam, $h_g = 0.5 \times 2776.2 = 1388.1$

$\mathbf{h_g = 1388.1}$

Step 4 To find enthalpy of superheated steam at 200°C.

w.k.t. for superheated steam, $h_{sup} = h_g + C_{ps}(t_{sup} - t_{sat})$ where $t_{sup} = 200°C$

$h_{sup} = 2776.2 + 2.3\,(200 - 179.9) = 2822.43$ kJ/kg of steam

$\therefore$ for 0.5 kg of steam, $h_{sup} = 0.5 \times 2822.43 = 1411.21$

$\mathbf{h_{sup} = 1411.21}$ **kJ**

Problem 6 What is the enthalpy of 5 kg steam under the following condition : (i) 0.8 bar absolute and 90% dry, and (ii) 20 bar absolute and at 300°C. Specific heat of superheated steam is 2.25 kJ/kg K. ***Feb. 04 - 04 m***

Solution :

Step 1 Data

Mass of steam $m = 5$ kg $\qquad C_{ps} = 2.25$ kJ/kg K

Step 2 To find enthalpy when $P = 0.8$ bar and 90% dry

Steam is 90% dry, i.e., $x = 0.9$ dryness fraction of steam

Since $x < 1$, the steam is in wet condition

$\therefore$ enthalpy of wet steam = $h_w = h_f + x\,h_{fg}$

From steam tables, at P = 0.8 bar, we have, $h_f = 391.7$ kJ/kg & $h_{fg} = 2274.1$ kJ/kg

$\therefore$ equation (1) reduces to, $h_w = 391.7 + (0.9 \times 2274.1) = 2438.4$ kJ/kg of steam

$\therefore$ For 5 kg of steam, enthalpy = $h_w = 2438.4 \times 5$

h_w = **12192 kJ**

Step 3 To find enthalpy h when $P = 20$ bar & temperature 300°C

From steam tables, at $P = 20$ bar, we have, $t_{sat} = 212.4$°C, and $h_g = 2797.2$ kJ/kg

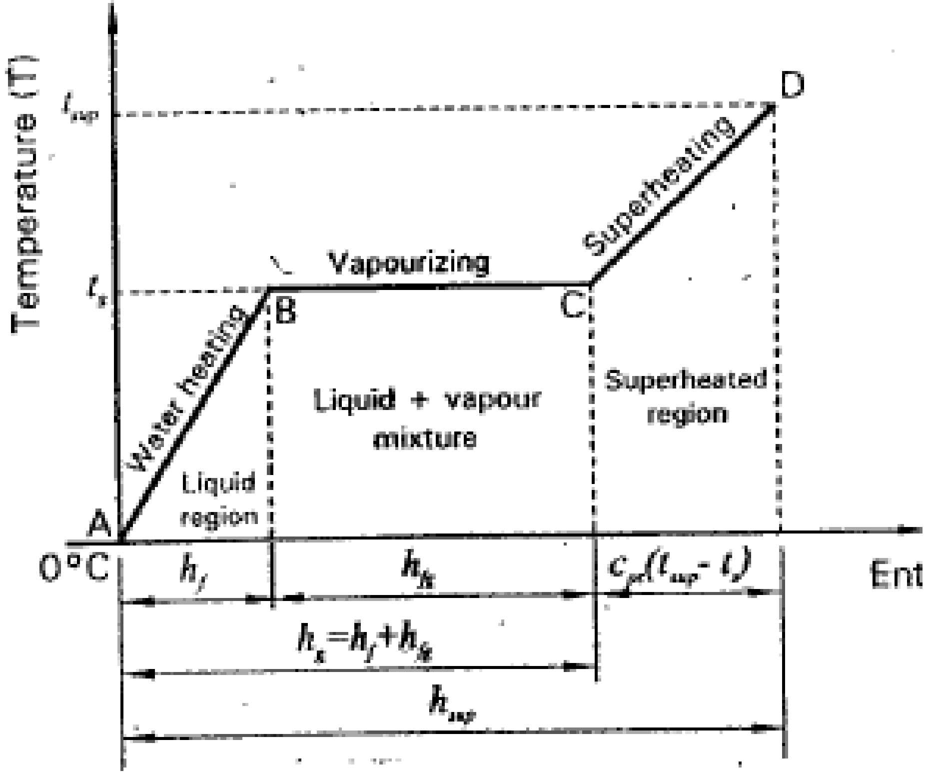
Since the temperature 300°C is greater than $t_{sat} = 212.4$°C, the given steam is in superheated state.

w.k.t. for superheated steam, $h_{sup} = h_g + C_{ps}\,(t_{sup} - t_{sat})$ ---- [1]

$\therefore h_{sup} = 2797.2 + 2.25\,(300 - 212.4) = 2994.3$ kJ/kg

$\therefore$ for 5 kg of steam, $h_{sup} = 2994.3 \times 5 = 14971.5$

h_{sup} = **14971.5 kJ**



Problem 7 By actual measurement, the enthalpy of saturated steam at 190°C is 2500 kJ/kg. What is the quality of steam.

Solution :

Step 1: Data

Saturation temperature t_{sat} = 190°C Enthalpy of saturated steam = h_w = 2500 kJ/kg

Since saturation temperature (t_{sat}) is given in the problem, the properties of steam from steam tables hand book has to be read on temperature basis. Note that in previous problems, the properties of steam was recorded on pressure basis.

From steam tables, corresponding to t_{sat} = 190°C, we have,

$P = 12.551$ bar, $h_f = 807.5$ kJ/kg, $h_{fg} = 1976.8$ kJ/kg & $h_g = 2784.3$ kJ/kg

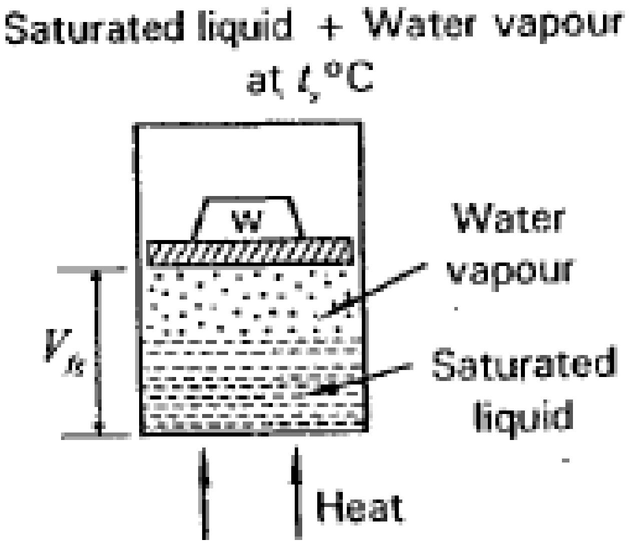
w.k.t. enthalpy of steam= $h = h_f + x\, h_{fg}$

$$2500 = 807.5 + x(1976.8)$$

$$\mathbf{x = 0.8561}$$

∴ Quality of steam= 0.8561 × 100 = 85.61%

i.e., the steam is 85.61% dry and 14.39 % wet.



Problem 8 A mixture of wet steam at a pressure of 10 bar is found to have a quality of 85%. Determine its enthalpy, internal energy, specific volume and density.

Solution :

Step 1 Data

State of steam = WET, Pressure = $P = 10$ bar

Quality of steam = 85% ∴ Dryness fraction = $x = 0.85$

From steam tables, corresponding to P = 10 bar, we have,

$t_{sat} = 179.9°C$, $h_f = 762.6$ kJ/kg, $h_{fg} = 2013.6$ kJ/kg, $h_g = 2776.2$ kJ/kg, & $V_g = 0.19430$

Step 2 To find enthalpy of wet steam

w.k.t. for wet steam, $h_w = h_f + x\, h_{fg} = 762.6 + (0.85 \times 2013.6)$

Enthalpy = $\boldsymbol{h_w}$ = **2474.16 kJ/kg**

Step 3 To find internal energy $U_w = ?$

w.k.t. Internal energy for wet steam = $U_w = [h_f + x\, h_{fg}] - 100\, P \cdot x \cdot V_g$ kJ/kg

$$U_w = (2474.16) - [100 \times 10 \times 0.85 \times 0.19430]$$

Internal energy of wet steam = $\boldsymbol{U_w}$ = **2309 kJ/kg**

Step 4 To find specific volume of wet steam $V_w = ?$

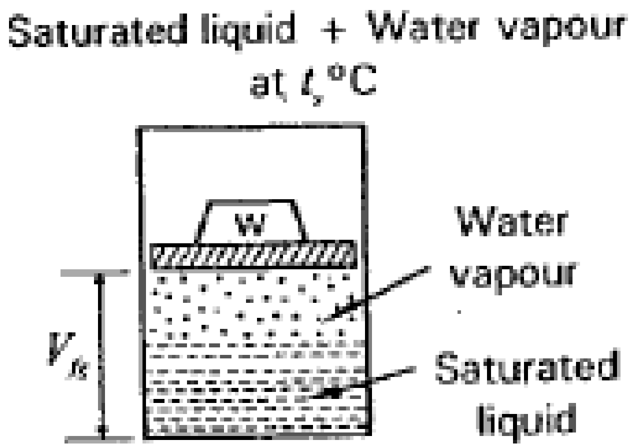
w.k.t. specific volume of wet steam = $V_w = x\, V_g$ m³/kg

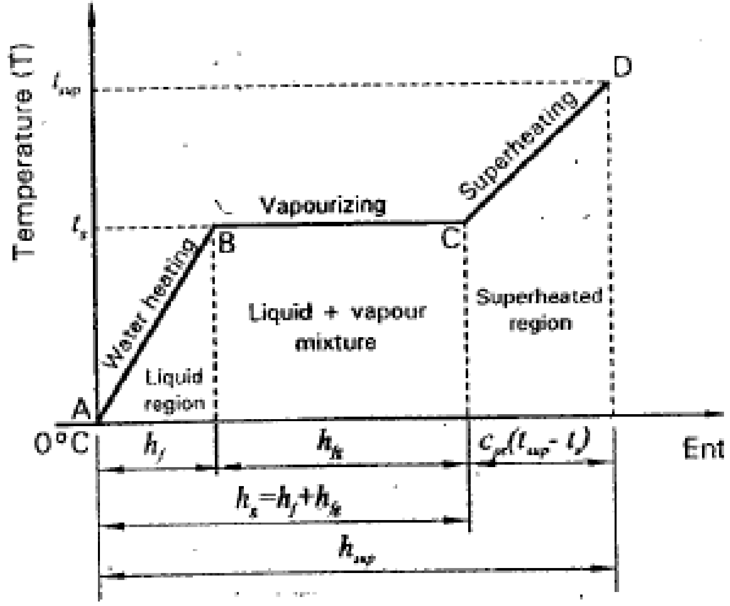
$$V_w = 0.85 \times 0.19430$$

$$V_w = \mathbf{0.1651\ m^3/kg}$$

Step 5 Density of wet steam = $\rho_w = ?$

w.k.t. density of wet steam = $\rho_w = \dfrac{1}{x\, V_g} = \dfrac{1}{(0.85 \times 0.19430)} = 6.057$ ρ_w = **6.057 kg/m³**





Problem 9 Steam at a pressure of 8 bar has temperature of 200°C. What is the specific enthalpy? What is its specific volume. Assume specific heat of steam to be 2.25 kJ/kg K

July 2006 - 08 m

P (bar)	t (°C)	V_f m³/kg	V_g m³/kg	h_f kJ/kg	h_{fg} kJ/kg	h_g kJ/kg
8.0	170.4	0.001115	0.24026	720.9	2046.5	2767.4

Solution :

Step 1: Data

Pressure = P = 8 bar $\quad C_{ps}$ = 2.25 kJ/kg K

Since the saturation temperature t_{sat} = 170.4°C is less than the given temperature of steam (200°C), the steam is in superheated state. $\therefore t_{sup} = 200°C$

Step 2 To find specific volume of superheated steam (V_{sup})

w.k.t. Specific volume of superheated steam = $V_{sup} = \frac{t_{sup}}{t_{sat}} \times V_g$ where t_{sup} & t_{sat} must be in Kelvin.

$$\therefore V_{sup} = \left(\frac{200+273}{170.4+273}\right) \times 0.24026$$

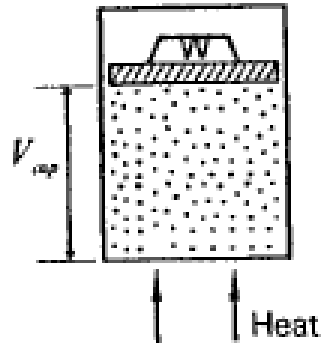
Specific volume V_{sup} = 0.2563 m³/kg

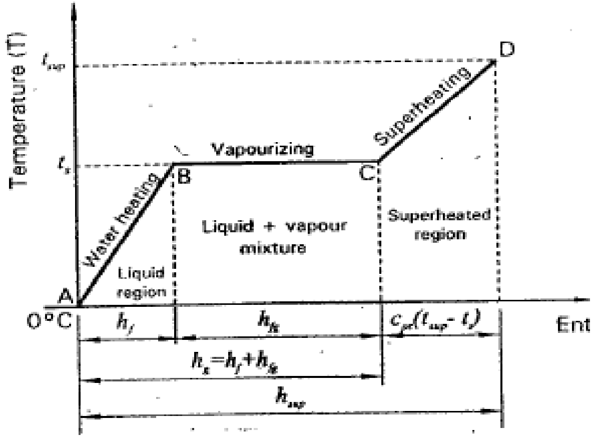
Step 3 To find specific enthalpy of superheated steam (h_{sup})

w.k.t. for superheated steam, enthalpy, $h_{sup} = h_g + C_{ps}(t_{sup} - t_{sat}) = 2767.4 + 2.25\,(200 - 170.4)$

Enthalpy = h_{sup} = 2834 kJ/kg

Superheated steam at t_{sup}°C





Problem 10 Calculate the specific volume and enthalpy of 8 kg of steam at 1.2 MPa (i) when the steam is 12% wet (ii) when the steam is superheated at 300°C. *MQP (2002 scheme) - 08 m*

Assume C_{ps} = 2.25 kJ/kg K [illegible]

Solution :

Step 1 Data

Mass of steam = m = 8 kg Pressure = P = 1.2 MPa

P = 1.2 × 10^6 N/m² (Mega = 10^6 & 1 Pa = 1 N/m²)

P = 12 bar (∵ 1 Bar = 10^5 N/m²)

From steam tables, at P = 12 bar, we have

t_{sat} = 188°C, h_f = 798.4 kJ/kg, h_{fg}= 1984.3 kJ/kg, h_g = 2782.7 kJ/kg, and V_g = 0.16321 m³/kg

Step 2 When steam is 12% wet

when steam is 12% wet, it will be 88% dry. ∴ dryness fraction = x = 0.88

w.k.t. specific volume of wet steam = $V_w = x\ V_g$ = 0.88 × 0.16321

V_w = 0.14362 m³/kg of steam

∴ For 8 kg of steam, specific volume = 8 × 0.14362

$\mathbf{V_w = 1.149\ m^3}$

w.k.t. Enthalpy of wet steam = $h_w = h_f + x\ h_{fg}$ = 798.4 + (0.88 × 1984.3)

h_w = 2544.58 kJ/kg of steam

∴ For 8 kg of steam, enthalpy = 2544.58 × 8

$\mathbf{h_w = 20356.67\ kJ}$

Step 3 When steam is superheated at 300°C

$$\text{w.k.t. Specific volume of superheated steam } V_{sup} = \frac{t_{sup}}{t_{sat}} \times V_g = \left(\frac{300+273}{188+273}\right) \times 0.16321 = 0.20286$$

V_{sup} = 0.20286 m³/kg of steam

∴ For 8 kg of steam, V_{sup}= 8 × 0.20286 = 1.622

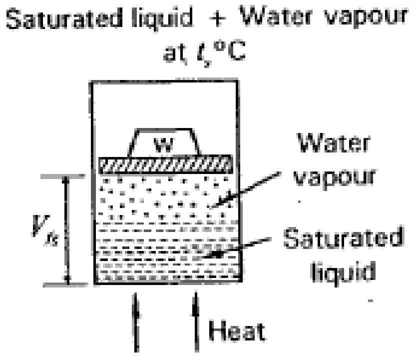
$\mathbf{V_{sup} = 1.622\ m^3}$

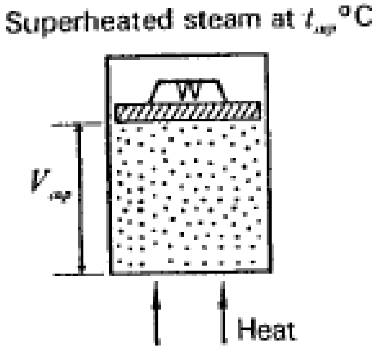
w.k.t. enthalpy of superheated steam = $h_{sup} = h_g + C_{ps}\ (t_{sup} - t_{sat})$

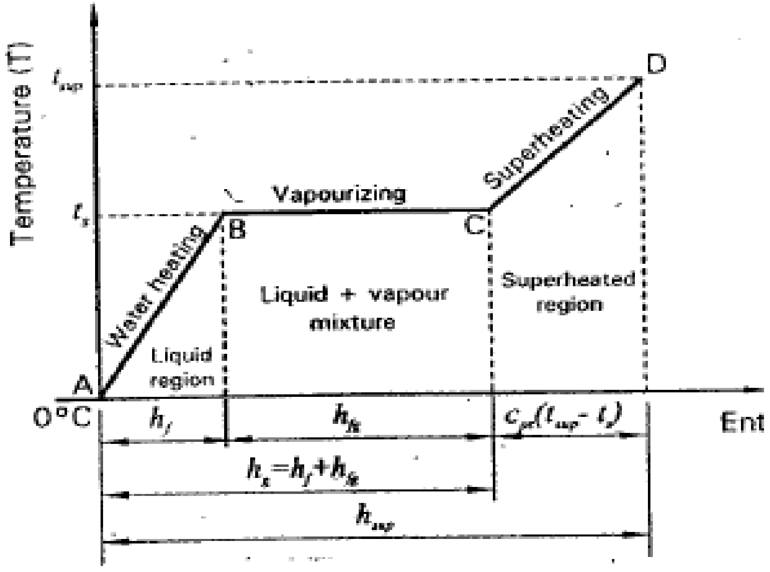
Assume C_{ps} = 2.25 kJ/kg K when not specified in the problem

h_{sup} = 2782.7 + 2.25 (300 – 188) = 3034.7 kJ/kg of steam

∴ For 8 kg of steam, h_{sup}= 8 × 3034.7 = 24277.6 $\mathbf{h_{sup} = 24277.6\ kJ}$







Problem 11 Determine the specific volume & density of 1 kg of steam at a pressure of 7×10^5 Pa when the condition of steam is, (i) wet, having dryness fractions 0.9, (ii) dry, and (iii) superheated at 250°C. If required, use the extract of the steam table provided below: ***July 2009 – 09 m***

P	t_s	V_g
7 bar	437.92 K	0.273341 m³/kg

Solution :

Step 1 Data

Mass of steam = m = 1 kg

Pressure = $P = 7 \times 10^5$ Pa $= 7 \times 10^5$ N/m² (1Pa = 1 N/m²)

P = 7 bar (1 Bar = 10^5 N/m²)

Step 2 When steam is wet with $x = 0.9$

w.k.t. specific volume of wet steam = $V_w = x\ V_g = 0.9 \times 0.273341$

$$V_w = \mathbf{0.246}\ \ \mathbf{m^3/kg}$$

$$\text{Density of wet steam} = \rho_w = \frac{1}{x\ V_g} = \frac{1}{(0.9 \times 0.273341)} = 4.065$$

$$\rho_w = \mathbf{4.065}\ \ \mathbf{kg/m^3}$$

Step 3 When steam is dry

w.k.t. Specific volume of wet steam = $V_g = x\ V_g$. But, for dry steam $x = 1$

∴ Specific volume of dry steam = $V_g = 0.273341$ m³/kg (from extract of steam tables)

$$\text{density of dry steam} = \rho_g = \frac{1}{x\ V_g} = \frac{1}{V_g} = \frac{1}{0.273341} = 3.658$$

$$\rho_g = \mathbf{3.658}\ \ \mathbf{kg/m^3}$$

Step 4 When steam is superheated to 250°C

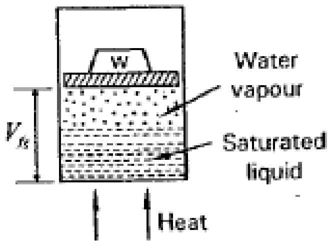
$$\text{w.k.t. Specific volume of superheated steam} = V_{sup} = \frac{t_{sup}}{t_{sat}} \times V_g = \left(\frac{250+273}{437.92}\right) \times 0.273341$$

$$V_{sup} = \mathbf{0.3264}\ \ \mathbf{m^3/kg}$$

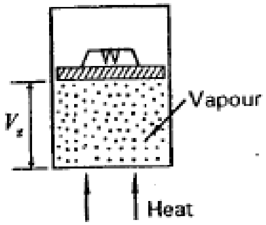
$$\text{Density of superheated steam} = \rho_{sup} = \frac{1}{V_{sup}} = \frac{1}{0.3264} = 3.063$$

$$\rho_{sup} = \mathbf{3.063}\ \ \mathbf{kg/m^3}$$

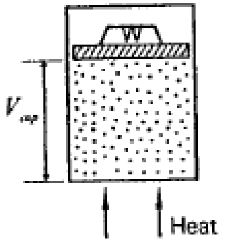
Saturated liquid + Water vapour at t_s°C



Dry steam at t_s°C



Superheated steam at t_{sup}°C



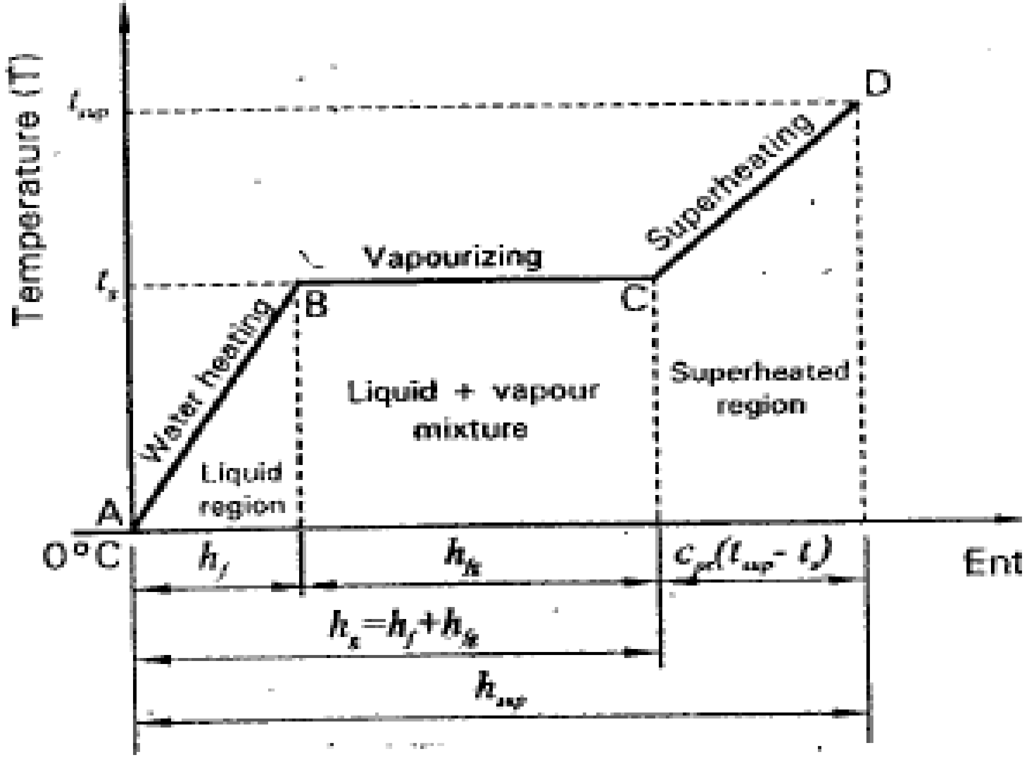
Problem 12 Determine the condition of steam in the following cases

(a) at a pressure of 5 Bar, the total heat is 2654 kJ/kg

(b) at a pressure of 10 bar, the total heat is 2832 kJ/kg

(c) at a pressure of 20 bar and temperature 222°C.

(d) at a pressure of 10 bar & specific volume 0.23 m³/kg



Solution :

Step 1 When $P = 5$ bar

Total heat or enthalpy $= h = 2654$ kJ/kg

From steam tables, at $P = 5$ bar, we have, $h_g = 2747.5$ kJ/kg (enthalpy of dry steam)

Since the given total heat or enthalpy of steam (h) is less than the enthalpy of dry steam (h_g), the steam is in WET condition.

Step 2 When $P = 10$ bar

Total heat or enthalpy $= h = 2832$ kJ/kg

From steam tables, at $P = 10$ bar, we have, $h_g = 2776.2$ kJ/kg

Since the given total heat $h > h_g$, the steam is in superheated state.

Step 3 When $P = 20$ bar and temperature $= 222$°C

From steam tables, at $P = 20$ bar, we have, $t_{sat} = 212.4$°C

Since the temperature of the given steam (222°C) is greater than the saturation temperature (212.4°C), the steam is in the superheated state.

Step 4 When $P = 10$ bar & specific volume 0.23 m³/kg

From steam table, at $P = 10$ bar, specific volume of dry steam $= V_g = 0.19430$ m³/kg

Since the specific volume of the given steam ($V = 0.23$ m³/kg) is greater than the specific volume of dry steam ($V_g = 0.19430$ m³/kg), the steam is in the superheated state.

Problem 13 By actual measurement, the enthalpy of saturated steam at 190°C is 2500 kJ/kg. What is the quality of steam. If 500 kJ of heat is added at constant pressure, what is the final state of steam. Also determine its final temperature. ***Aug 2001***

Solution :

Step 1 To determine quality of steam

Saturation temperature = t_{sat} = 190°C Enthalpy = $h = 2500$ kJ/kg

From steam tables, corresponding to $t_{sat} = 190°C$, we have, $h_g = 2784.3$ kJ/kg

Since the enthalpy of given steam $h < h_g$, the steam is in WET condition.

WKT, for wet steam $h_w = h_f + x\, h_{fg}$ ----[1]

From tables, at $t_{sat} = 190°C$, $h_f = 807.5$ kJ/kg & $h_{fg} = 1976.8$ kJ/kg

∴ equation (1) becomes, $2500 = 807.5 + (x \times 1976.8)$ or $\mathbf{x = 0.856}$

∴ **Quality of steam = 85.6%**

Step 2 Heat addition process

If 500 kJ of heat is added, then total enthalpy = 2500 + 500 = 3000 kJ/kg

Since 3000 kJ/kg is greater than h_g (2784.3 kJ/kg), the steam after heat addition becomes SUPERHEATED.

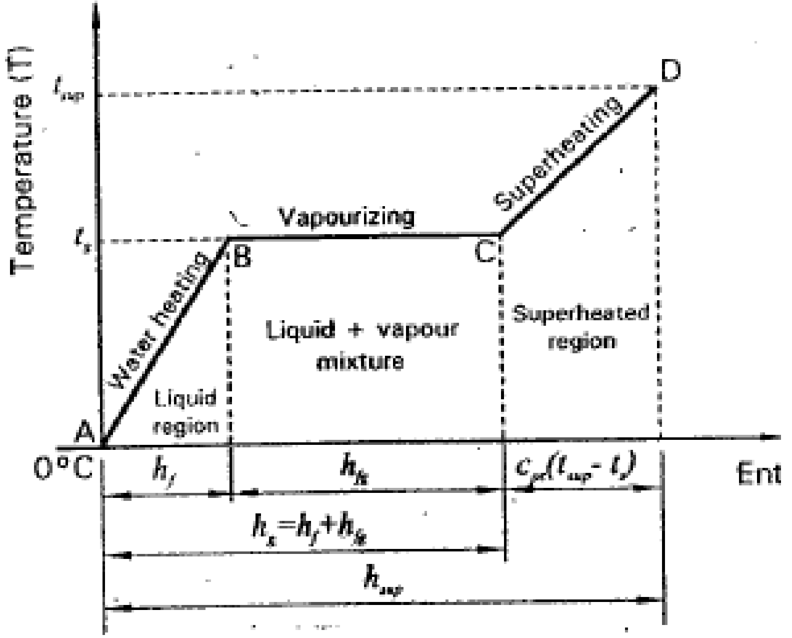
To find temperature of superheated steam (t_{sup}) = ?

w.k.t. for superheated steam, $h_{sup} = h_g + C_{ps}\,(t_{sup} - t_{sat})$

Assume $C_{ps} = 2.25$ kJ/kg k

$$\therefore 3000 = 2784.3 + 2.25\,(t_{sup} - 190)$$

$$t_{sup} = \mathbf{285.86°C}$$



Problem 14 A steam initially will be at 9 bar and dryness fraction 0.98. Find the final quality and temperature of the steam at each of the following operations. (a) when steam loses 50 kJ/kg at constant pressure (b) when steam receives 150 kJ/kg at constant pressure ***Jan 2000 & July 05***

Solution :

Step 1 Data

$$\text{Pressure} = P = 9 \text{ bar, Dryness fraction} = x = 0.98$$

From steam tables, at $P = 9$ bar, we have,

$t_{sat} = 175.4^\circ C$, $h_f = 742.6$ kJ/kg, $h_{fg} = 2029.5$ kJ/kg and $h_g = 2772.1$ kJ/kg

Step 2 To find the enthalpy of given steam

Since $x = 0.98$ is less than 1, the given steam is WET

w.k.t. for wet steam, enthalpy $= h_w = h_f + x\, h_{fg} = 742.6 + (0.98 \times 2029.5)$

$$\boldsymbol{h_w = 2731.51 \text{ kJ/kg}}$$

Step 3 When steam loses 50 kJ/kg of heat

Let h_1 be the enthalpy in this condition

When steam loses 50 kJ of heat, the total enthalpy is $h_1 = h_w - 50$

$$h_1 = 2731.51 - 50 = 2681.51$$

$$\therefore \boldsymbol{h_1 = 2681.51 \text{ kJ/kg}}$$

Since $h_1 < h_g$, the steam is wet.

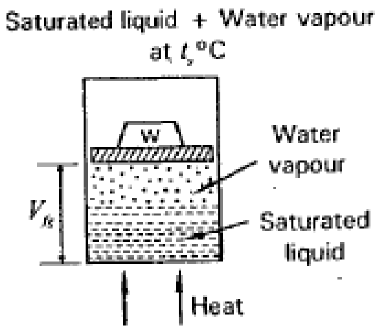
To find quality of steam:

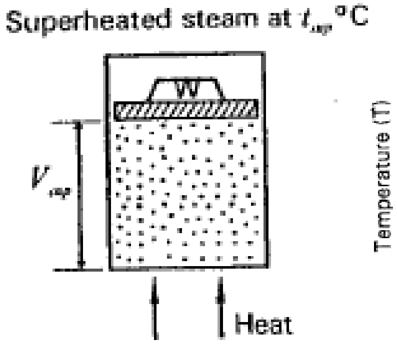
For wet steam $h = h_f + x\, h_{fg}$ where $h = h_1 = 2681.5$ kJ/kg

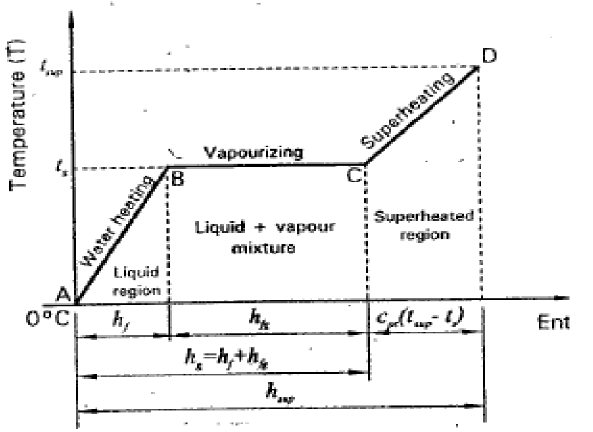
$$2681.51 = 742.6 + (x \times 2029.5)$$

$$x = 0.955$$

$\therefore$ **Quality of steam = 95.5%**







Step 4 When steam receives 150 kJ/kg of heat

Let h_2 be the enthalpy in this condition. $\therefore$ $h_2 = h_w + 150$

$$h_2 = 2731.51 + 150 = 2881.51$$

$$\therefore h_2 = 2881.51 \text{ kJ/kg}$$

Since $h_2 > h_g$, the steam is superheated

$$\text{To find } t_{sup} = ?$$

$$\text{w.k.t. } h_{sup} = h_g + C_{ps}(t_{sup} - t_{sat})$$

$$\text{Assume } C_{ps} = 2.25 \text{ kJ/kg } \mathbf{K}$$

$$h_{sup} = h_2 = 2881.51 \text{ kJ/kg}$$

$\therefore$ equation (1) becomes, $2881.51 = 2772.1 + 2.25\,(t_{sup} - 175.4)$

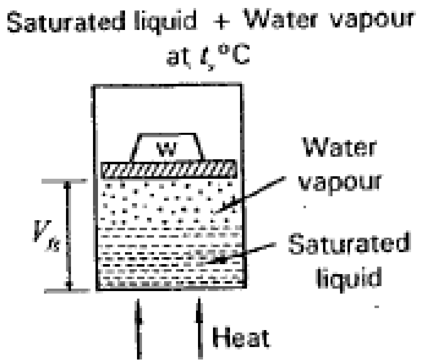
$$\boldsymbol{t_{sup} = 224^\circ C}$$

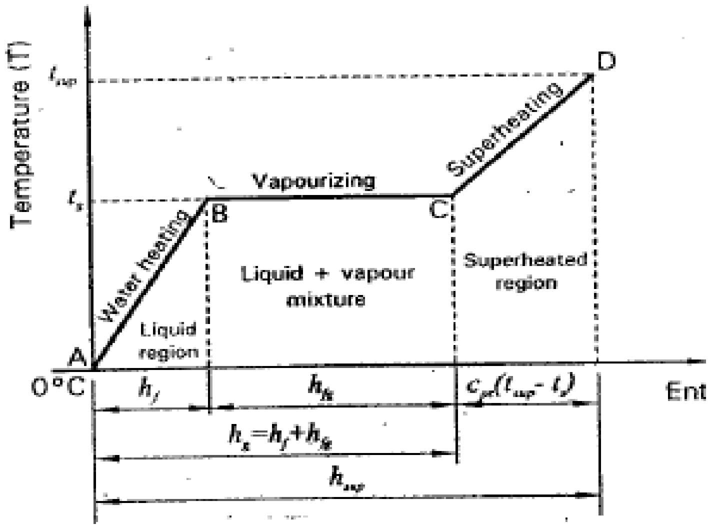
Problem 15 2 kg of wet steam is heated at a constant pressure of 2 bar until its temperature increases to 150°C. The heat transferred is 2100 kJ. Find the initial dryness fraction of steam.

Assume C_{steam} = 2.1 kJ/kg K. If required use the extract of the steam table provided below.

Jan 2006 - 08 m

P (bar)	t (°C)	V_f (m³/kg)	V_g (m³/kg)	h_f (kJ/kg)	h_g (kJ/kg)
2.0	120.23	0.001061	0.8857	504.5	2706.5





Solution : In the present problem, the enthalpy of wet steam has to be calculated, which in turn helps us to obtain the dryness fraction of steam.

Step 1 Data

Mass of wet steam = 2 kg

t_{sup} = 150°C (∵ given temperature > t_{sat} 120.23°C)

Pressure = P = 2 bar

Heat transfered = enthalpy= 2100 kJ for 2 kg of steam

$$\therefore \text{ for 1 kg of steam } = \frac{2100}{2} = 1050 \text{ kJ/kg}$$

$$C_{steam} = C_{ps} = 2.1 \text{ kJ/kg K}$$

Step 2 To find initial dryness fraction of steam

$$\text{w.k.t. } h_{sup} = h_g + C_{ps}(t_{sup} - t_{sat}) = 2706.5 + 2.1\,(150 - 120.23)$$

$$\therefore h_{sup} = 2769.01 \text{ kJ/kg}$$

Heat supplied for 1 kg of wet steam = 1050 kJ

∴ Heat initially present in wet steam = 2769.01 – 1050 = 1719.01 kJ/kg

i.e., enthalpy of wet steam = h_w = 1719.01 kJ/kg

$$\text{w.k.t. } h_w = h_f + x\,h_{fg} \qquad \text{---- [1]}$$

Note Value of h_{fg} is not provided in the extract of steam tables. However h_{fg} can be obtained by using $h_{fg} = h_g - h_f$ (∵ $h_g = h_f + h_{fg}$)

$$\text{i.e., } h_{fg} = 2706.5 - 504.5 = 2202 \text{ kJ/k}$$

∴ equation (1) becomes, 1719.01 = 504.5 + (x × 2202)

$$x = 0.55$$

∴ initial dryness fraction of steam was **$x = 0.55$**

Problem 16 3 kg of steam is generated at 5 bar from water at 34°C. Determine the quantity of heat required when, (a) steam is wet, having dryness fraction 0.8, (b) steam is dry saturated, and (c) steam is superheated to 240°C. Assume $C_{ps} = 2.25$ kJ/kg K and $C_{pw} = 4.187$ kJ/kg K

Solution :

Step 1 Data

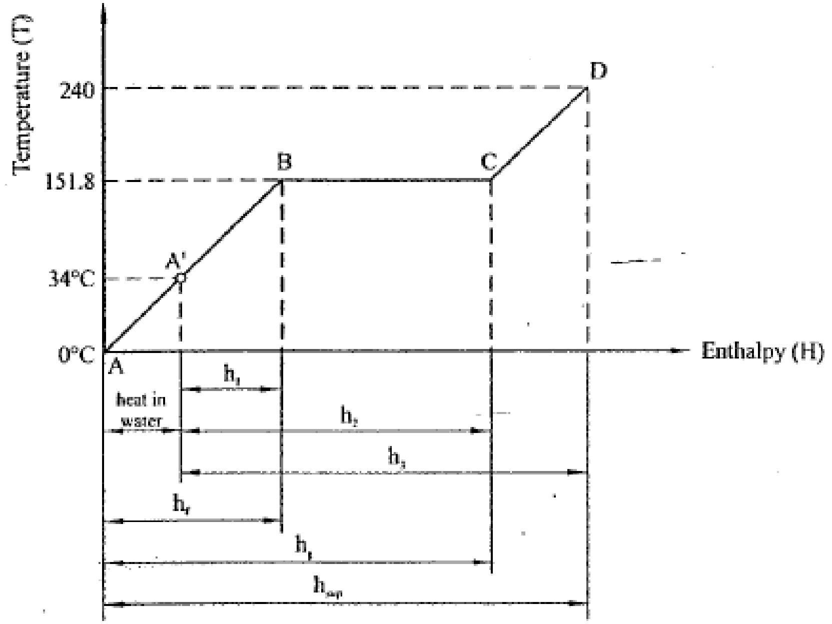
Mass of steam = 3 kg, Pressure = $P = 5$ bar Initial temperature of water = 34°C

$C_{ps} = 2.25$ kJ/kg K, C_{pw} = Specific heat of water = 4.187 kJ/kg K

From steam tables, at $P = 5$ bar, we have

$t_{sat} = 151.8$°C, $h_f = 640.1$ kJ/kg. $h_{fg} = 2107.4$ kJ/kg and $h_g = 2747.5$ kJ/kg

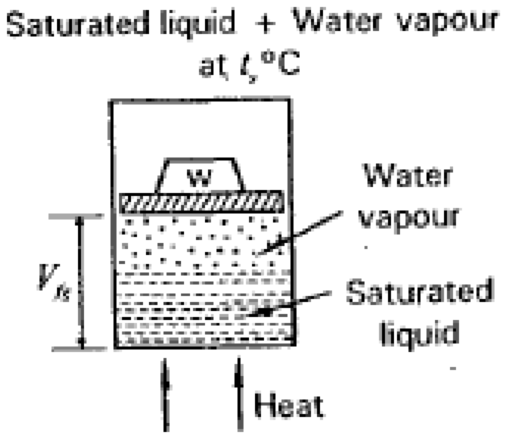
Note In all the previous problems, the properties of steam were determined for water at 0°C. However, in the present problem, the initial temperature of water is 34°C, which means that there is some amount of heat already present in water. The problem can be best understood by plotting the T-H diagram as shown in figure. P.16 below.

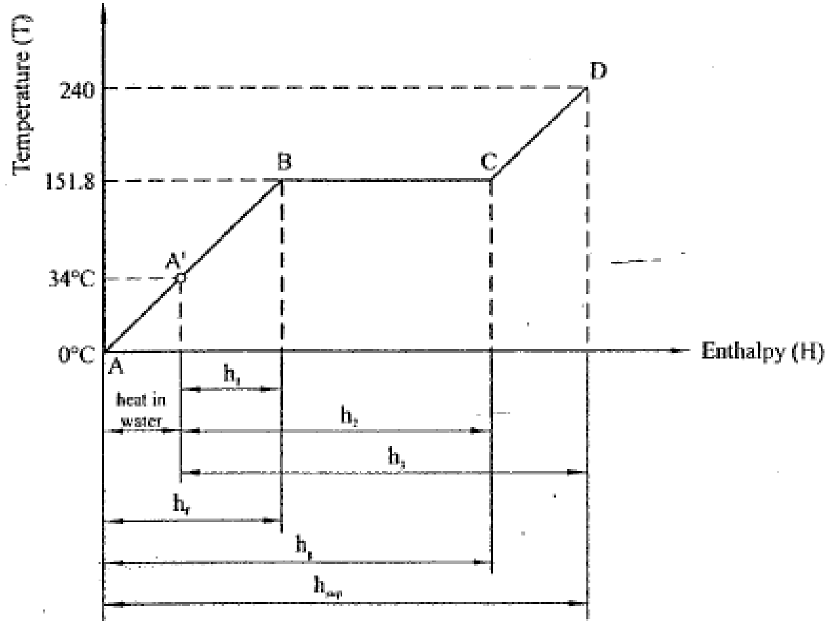


∴ Heat already in water (portion AA') = $m\, C_{pw}\, \Delta T$ (m = Mass of water = 1 kg)

ΔT = change in temperature= 34°C – 0°C = 34°C

∴ Heat already in water = 1 × 4.187 × 34 = 142.35 kJ/kg





Step 2 When steam is wet with $x = 0.8$

Let H_w = heat required to convert 1 kg of water at 0°C into wet steam

w.k.t. enthalpy of wet steam (between points A & B) = $h_w = h_f + x\,h_{fg}$ = 640.1+ (0.8×2107.4)

$$H_w = 2326.02 \text{ kJ/kg}$$

Let h_1 = actual quantity of heat supplied to produce 1 kg of wet steam from water whose initial temperature is 34°C

$$\therefore h_1 = h_w - \text{heat already in water}$$
$$= 2326.02 - 142.35$$
$$h_1 = 2183.67 \text{ kJ/kg of steam}$$

∴ to produce 3 kg of steam, heat required = h_1 = 3×2183.67

$$\mathbf{h_1 = 6551.01 \text{ kJ} \quad \text{for 3 kg of steam}}$$

Thus 6551.01 kJ of heat is required to produce 3 kg wet steam from water at 34°C.

Step 3 When steam is dry saturated

Let h_g = heat required to convert 1 kg of water at 0°C into dry steam

Let h_2= actual heat required to produce 1 kg of dry steam from water at 34°C

$$\therefore\ h_2 = h_g - \text{heat already in water}$$

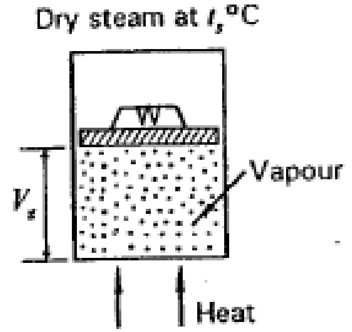
$$= 2747.5 - 142.35$$

$$h_2 = 2605.15 \text{ kJ/kg of steam}$$

∴ To produce 3 kg of steam, heat required = 3×2605.15

$$\boldsymbol{h_2 = 7815.45 \text{ kJ} \quad \text{for 3 kg of steam}}$$

Thus 7815.45 kJ of heat is required to produce 3 kg of dry steam from water at 34°C.

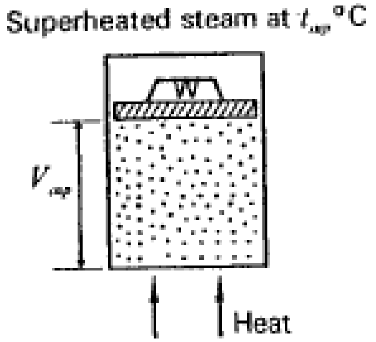


Step 4 When steam is superheated to 240°C.

Let h_{sup}= heat required to convert 1 kg of water at 0°C to superheated steam

$$\text{w.k.t.}\ h_{sup} = h_g + C_{ps}(t_{sup} - t_{sat}) = 2747.5 + 2.25(240 - 151.8)$$

$$h_{sup} = 2945.95 \text{ kJ/kg of steam}$$



Let h_3 = actual heat required to produce 1 kg of superheated steam from water at 34°C.

$$\therefore\ h_3 = h_{sup} - \text{heat already in water}$$

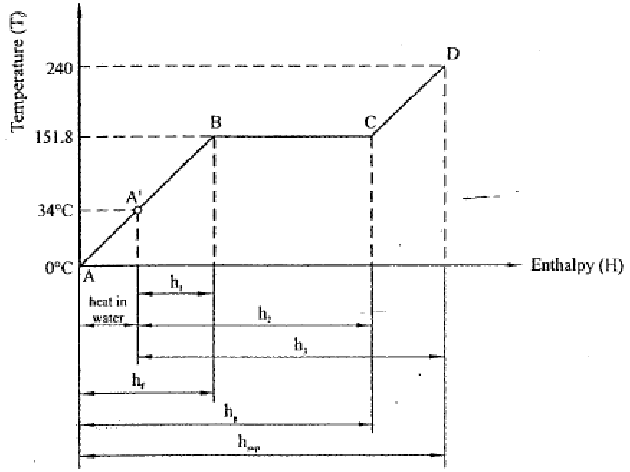
$$= 2945.95 - 142.35$$

$$h_3 = 2803.6 \text{ kJ/kg of steam}$$

∴ To produce 3 kg of steam, heat required = 3 × 2803.6 = 8410.8 kJ.

Thus 8410.8 kJ of heat is required to produce 3 kg of superheated steam from water at 34°C.

$$\boldsymbol{h_3 = 8410.8 \text{ kJ}}$$



Problem 17 How much heat energy is required to generate 2 kg of dry saturated steam at 7 bar from feed water at 25°C.

Jan 07 - 05 m

Solution :

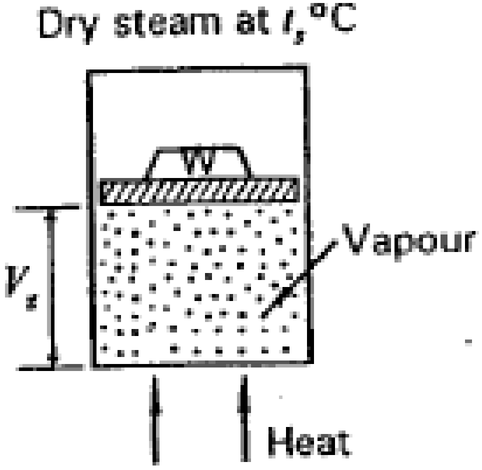
Step 1 Data

Mass of dry steam = m = 2 kg, Pressure = 7 bar Initial temperature of water = 25°C.

From steam tables, at P = 7 bar, we have,

t_{sat} = 165°C, h_f = 697.1 kJ/kg; h_{fg} = 2064.9 kJ/kg & h_g = 2762 kJ/kg

The details are plotted on the T-H diagram as shown in figure P.17



Step 2 To find h_l

Heat initially present in water (AA') = $m\ C_{pw}\ \Delta T$ (m = 1 kg of water & C_{pw} = 4.18 kJ/kg K)

= 1× 4.18 × (25 – 0) = 104.5 kJ/kg

Let h_g = heat required to convert 1 kg of water at 0°C into dry saturated steam.

w.k.t. enthalpy of dry steam = $h_g = h_f + h_{fg}$

From steam tables, at P = 7 bar, we have, h_g = 2762 kJ/kg

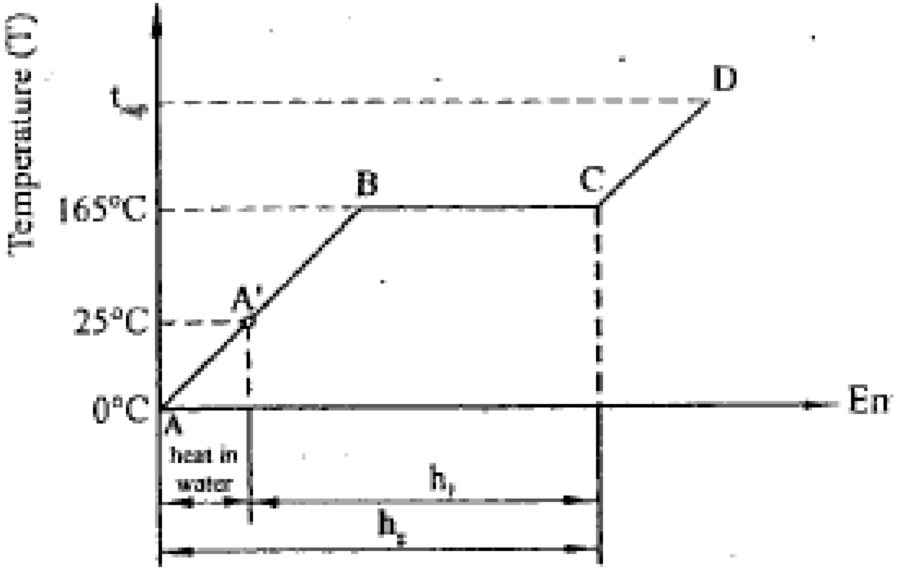
Let h_l = actual heat required to produce 1 kg of dry steam from water at 25°C

∴ $h_l = h_g$ – heat already in water = 2762 – 104.5

h_l = 2657.5 kJ/kg of steam

∴ to generate 2 kg of dry steam, heat required, h_l = 2 × 2657.5 = 5315

h_l = 5315 kJ for 2 kg of dry steam



Problem 18 What amount of heat would be required to produce 4 kg of steam at a pressure of 6 bar and temperature of 250°C from water at 30°C. Take C_{pg} = 2.2 kJ/kg K, specific heat of water = 4.18 kJ/kg K. At 6 bar h_f = 670.4 kJ/kg, h_{fg} = 2085 kJ/kg, T_s = 158.8°C. ***Jan 2009 - 06 m***

Solution :

Step 1 Data

Mass of steam = m = 4 kg, Pressure = 6 bar

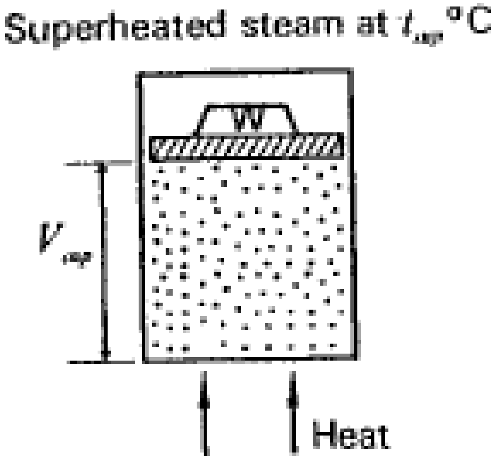
Since 250°C > T_{sat} (158.8°C), the steam is in the superheated state

$\therefore t_{sup} = 250^\circ C$

Temperature of water = 30°C

$C_{pg} = C_{ps}$ = 2.2 kJ/kg K, h_f = 670.4 kJ/kg, h_{fg} = 2085 kJ/kg, t_{sat} = 158.8°C, & C_{pw} = 4.18 kJ/kg K

The details are plotted on the TH diagram as shown in figure.P.18.



Step 2 To find h_1

Heat already present in water (AA') = $m\ C_{pw}\ \Delta T$

$= 1 \times 4.18 \times (30 - 0)$ (m = 1 kg of water)

$= 125.4$ kJ/kg

Let h_{sup} heat required to convert 1 kg of water at 0°C into superheated steam

w.k.t. for superheated steam= $h_{sup} = h_g + C_{ps}\ (t_{sup} - t_{sat})$

$h_g = h_f + h_{fg} = 670.4 + 2085$ (from data)

$h_g = 2755.4$ kJ/kg

$\therefore\ h_{sup} = 2755.4 + 2.2\ (250 - 158.8) = 2956.04$ kJ/kg of steam

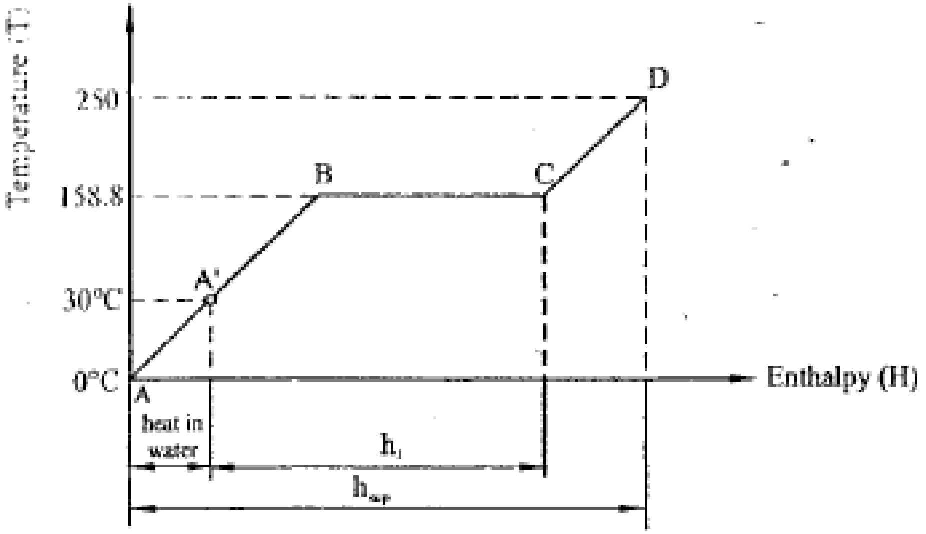
Let h_1 = actual heat required to produce 1 kg of superheated steam from water at 30°C.

$\therefore\ h_1 = h_{sup}$ – heat already in water = 2956.04 – 125.4

$h_1 = 2830.64$ kJ/kg of steam

$\therefore$ to generate 4 kg of steam; heat required = $h_1 = 4 \times 2830.64$

h_1 = 11322.56 kJ for 4 kg of steam



Problem 19 Find the internal energy of 2.5 kg of steam at 20 bar, when (i) it is wet, its dryness fraction being 0.9, (ii) it is superheated, its temperature being 350°C. (take the specific heat of steam as 2.3 kJ/kg K). ***Feb 2005 - 06 m***

Solution :

Step 1 Data

Mass of steam = m = 2.5 kg, Pressure = 20 bar

From steam tables, at P = 20 bar, we have,

t_{sat} 212.4°C, $h_f = 908.5$ kJ/kg, $h_{fg} = 1888.7$ kJ/kg, $h_g = 2797.2$ kJ/kg, & $V_g = 0.09955$ m³/kg

Step 2 To find internal energy of wet steam (U_w).

Given, dryness fraction = $x = 0.9$

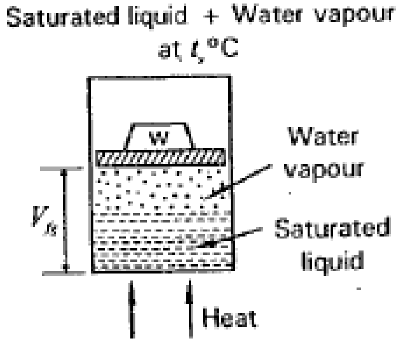
w.k.t. for wet steam, internal energy, $U_w = h_w - 100\ P.x.V_g$ kJ/kg ---- [1]

but $h_w = ?$

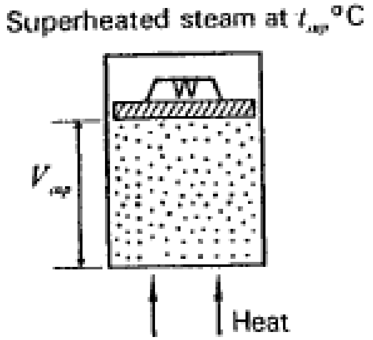
for wet steam $h_w = h_f + x\, h_{fg} = 908.5 + (0.9 \times 1888.7) = 2608.33$

∴ equation (1) becomes, $U_w = 2608.33 - (100 \times 20 \times 0.9 \times 0.09955) = 2429.14$ kJ/kg of steam

Saturated liquid + Water vapour at t_s°C



Superheated steam at t_{sup}°C



∴ for 2.5 kg of steam, $U_w = 2.5 \times 2429.14 = 6072.85$

∴ U_w **= 6072.85 kJ** **for 2.5 kg of steam**

Step 3 Internal energy of superheated steam = U_{sup} = ?

w.k.t. for superheated steam, internal energy = $U_{sup} = h_{sup} - (100.P.V_{sup})$ kJ/kg ---- [2]

but $h_{sup} = ? = V_{sup}$

w.k.t. $h_{sup} = h_g + C_{ps}\,(t_{sup} - t_{sat}) = 2797.2 + 2.3\,(350 - 212.4)$

$h_{sup} = 3113.68$ kJ/kg

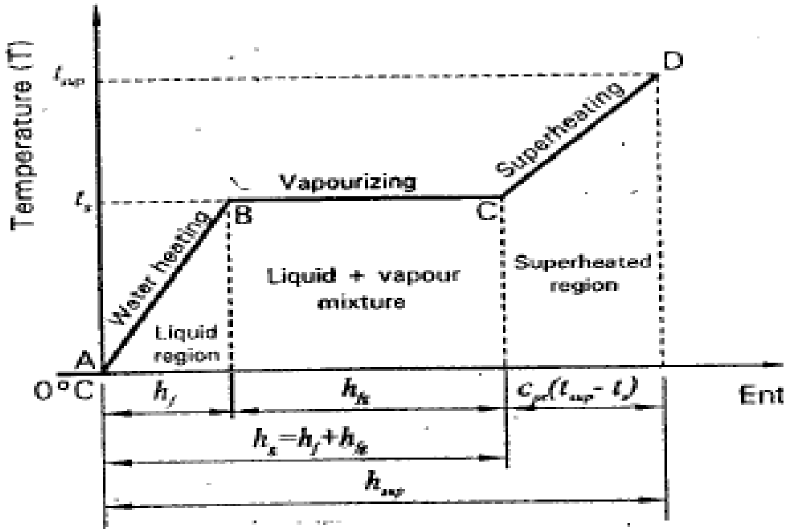
$$\text{w.k.t.}\quad V_{sup} = \frac{t_{sup}}{t_{sat}} \times V_g = \left(\frac{350+273}{212.4+273}\right) \times 0.09955$$

$V_{sup} = 0.1277$ m³/kg of steam

∴ equation (2) becomes, $U_{sup} = 3113.68 - (100 \times 20 \times 0.1277) = 2858.28$ kJ/kg of steam

∴ for 2.5 kg of steam, $U_{sup} = 2858.28 \times 2.5$

U_{sup} **= 7145.7 kJ** **for 2.5 kg of steam**



Problem 20 Determine the density of 1 kg of steam initially at a pressure of 10 bar absolute, having a dryness fraction of 0.78. If 500 kJ of heat is added at constant pressure, determine the condition and internal energy for the final state of steam. Take specific heat of superheated steam = 2.1 kJ/kg K. ***Jan 2003 - 10 m***

Solution :

Step 1 Data

Mass of steam = m = 1 kg, Pressure = 10 bar, Dryness fraction = x = 0.78

Heat added to steam = 500 kJ, C_{ps} = 2.1 kJ/kg K

From steam tables, at P = 10 bar, we have,

$t_{sat} = 179.9^\circ\text{C}$, $h_f = 762.6$ kJ/kg, $h_{fg} = 2013.6$ kJ/kg, $h_g = 2776.2$ kJ/kg, & $V_g = 0.19430\ \text{m}^3/\text{kg}$

Step 2 To find density of steam

Since $x < 1$, the steam is WET

$$\text{w.k.t. for wet steam, density } = \rho_w = \frac{1}{x\,V_g} = \frac{1}{(0.78\times 0.19430)} = 6.598$$

$$\text{Approximately } \rho_w = 6.6\ \text{kg/m}^3$$

Step 3 Condition of steam on heat addition

By data, 500 kJ of heat was added to wet steam

w.k.t. Enthalpy of wet steam = $h_w = h_f + x\,h_{fg} = 762.6 + (0.78 \times 2013.6) = 2333.2$ kJ/kg

Let h_1 be the enthalpy after heat addition

$$\therefore\ h_1 = 500 + 2333.2$$

$$h_1 = 2833.2\ \text{kJ/kg}$$

Since $h_1 > h_g$ (2776.2 kJ/kg), the steam is superheated after heat addition

$$\therefore\ h_1 = h_{sup} = 2833.2\ \text{kJ/kg}$$

To find internal energy of superheated steam

$$\text{w.k.t. } U_{sup} = h_{sup} - 100\,P.V_{sup}$$

$$\text{but } V_{sup} = ?$$

$$\text{w.k.t. } V_{sup} = \frac{t_{sup}}{t_{sat}} \times V_g$$

$$\text{But } t_{sup} = ?$$

$$\text{using } h_{sup} = h_g + C_{ps}\,(t_{sup} - t_{sat}),\text{ we have,}$$

$$2833.2 = 2776.2 + 2.1\,(t_{sup} - 179.9)$$

$$t_{sup} = 207.04^\circ\text{C}$$

$$\therefore\ \text{equation (2) becomes, } V_{sup} = \left(\frac{207.04+273}{179.9+273}\right) \times 0.19430$$

$$V_{sup} = 0.2059\ \text{m}^3/\text{kg}$$

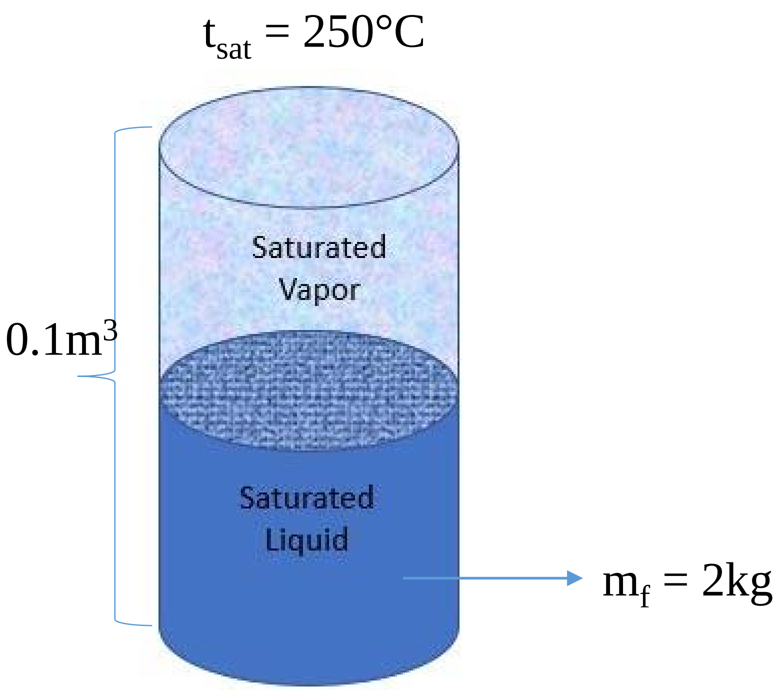
Substituting V_{sup} in equation (1) we have, $U_{sup} = 2833.2 - (100\times 10\times 0.2059)$

$$\mathbf{U_{sup} = 2627.3\ \ kJ/kg}$$

Problem 21 A mixture of saturated water and saturated steam at a temperature of 250°C is contained in a closed vessel of 0.1 m^3 capacity. If the mass of saturated water is 2 kg, find the mass of steam in the vessel. Also find the pressure, specific volume, dryness fraction and the enthalpy of the mixture. Use the properties of the steam given the table below.

July 08 - 10 m

Saturation temperature °C	Saturation pressure bar	Specific enthalpy of saturated Liquid kJ/kg	Specific enthalpy of saturated Vapour kJ/kg	Specific volume of saturated Liquid m^3/kg	Specific volume of saturated Vapour m^3/kg
250	39.77	1085.8	2800.4	0.0012513	0.05004



Solution :

Step 1 Data collection

Saturation temperature = t_{sat} = 250°C

Volume of vessel = 0.1 m^3

Mass of saturated water = 2 kg

Step 2 To find mass of steam in the vessel

The vessel contains a mixture of *saturated water* and *saturated steam* (dry steam).

$$\therefore \text{Total volume} = \underbrace{m_f\ v_f}_{\text{saturated water}} + \underbrace{m_g\ V_g}_{\text{Saturated vapour}} \qquad \text{----[1]}$$

where m_f = mass of saturated water = 2 kg

v_f = volume of saturated water = 0.0012513 m^3/kg (by data)

m_g = mass of saturated steam = ?

V_g = volume of saturated steam = 0.05004 m^3/kg (by data)

$\therefore$ equation (1) becomes, $0.1 = (2\times0.0012513) + (m_g \times 0.05004)$

mass of saturated steam in the vessel m_g = 1.948 kg

$\therefore$ Total mass of mixture $= m_f + m_g = 2+1.948$

mass of mixture = 3.948 kg

Step 3 To find pressure P

From the extract of steam tables provided in the problem, we have,

at t_{sat} = 250°C, pressure = P = 39.77 ~~bar~~

Step 4 To find specific volume of mixture

Specific volume of the mxiture is the volume of unit mass of mixture at the given temperature and pressure

$$\therefore \text{Specific volume of mixture} = \frac{0.1}{3.948} = 0.02532$$

Specific volume of mixture = 0.02532 m³/kg

Step 5 To find dryness fraction of the mixture

$$\text{w.k.t. dryness fraction} = x = \frac{m_g}{m_f + m_g} = \frac{1.948}{2+1.948} = 0.4934$$

dryness fraction of mixture = x = 0.4934

Step 6 Enthalpy of mixture

enthalpy of mixture = enthalpy of saturated water + enthalpy of saturated steam

$$= m_f h_f + m_g h_g$$

$$= (2\times1085.8) + (1.948\times2800.4)$$

enthalpy of mixture = 7626.78 kJ

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Module – 2.1

Steam Boilers

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STEAM BOILERS

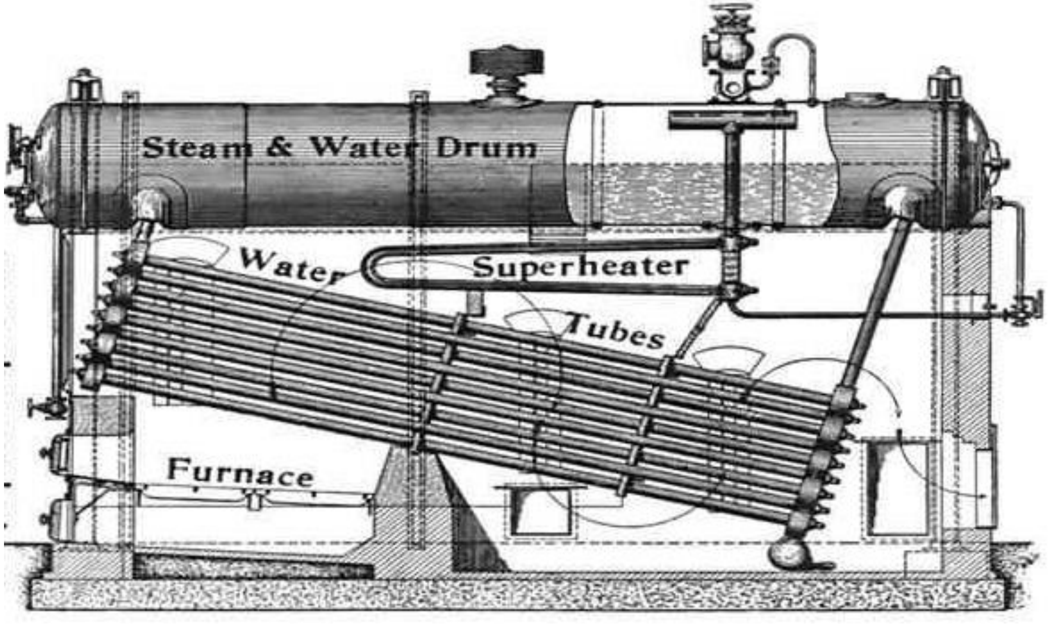
- A closed metallic vessel in which steam at the desired pressure and temperature can be generated from water under the application of heat.
- Applications: Generation of electricity, industrial purpose like sugar factories, breweries.
- Also called as “Steam generators”

Classification of steam boilers

- *According to the circulation of hot gases*
  1. Fire tube boilers – ***Lancashire boiler***, locomotive boiler, Cochran boiler, scotch marine boiler
  2. Water tube boilers – ***Babcock and Wilcox boiler***, stirling boiler, Yarrow boiler
- *According to the location of furnace*
  1. Internally fired boiler – All fire tube boilers
  2. Externally fired boiler – Water tube boilers
- *According to the circulation of water*
  1. Natural circulation boiler – All low capacity boilers
  2. Forced circulation boiler- High pressure and high capacity boilers
- *According to the axis of the shell*
  1. Vertical boilers – Cochran boiler
  2. Horizontal boilers – Babcock and wilcox boiler, Lancashire boiler
- *According to their uses*

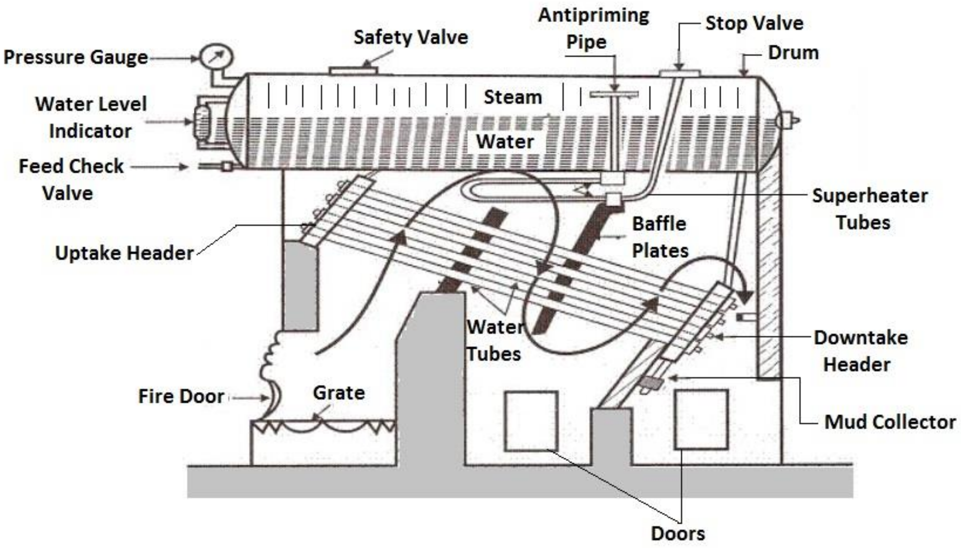
  Stationary boiler, locomotive boiler and marine boiler.

Babcock & Wilcox boiler



- It was discovered by George Herman Babcock and Stephen Wilcox in the year 1967.
- Horizontal, externally fired, stationary, natural circulation water tube boiler.
- Steam pressure of 12-18bars (Range of pressure)
- Evaporation capacity 20,000-40,000 kg/hour.
- Application: generation of high pressure steam in thermal power plants.

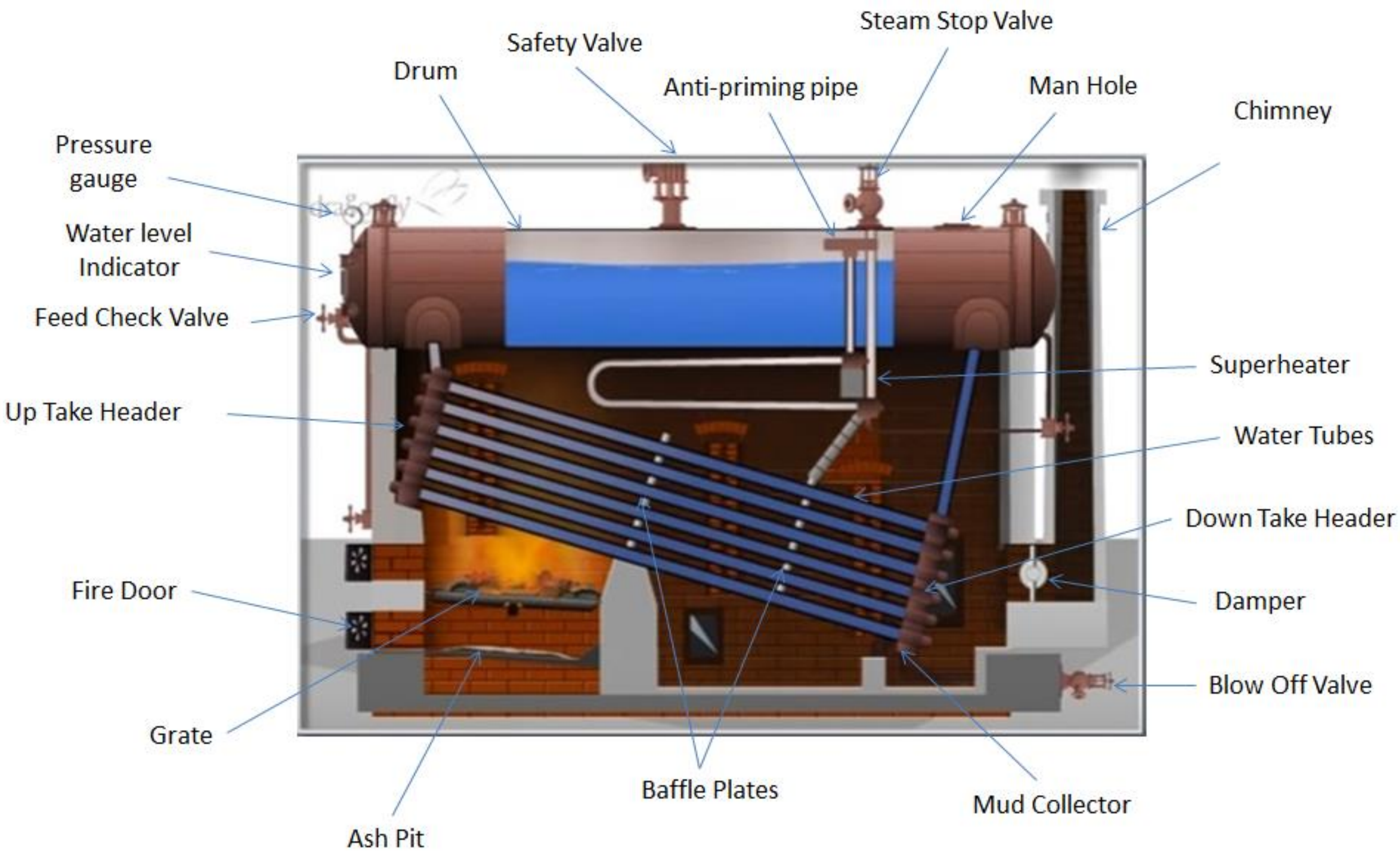
Construction



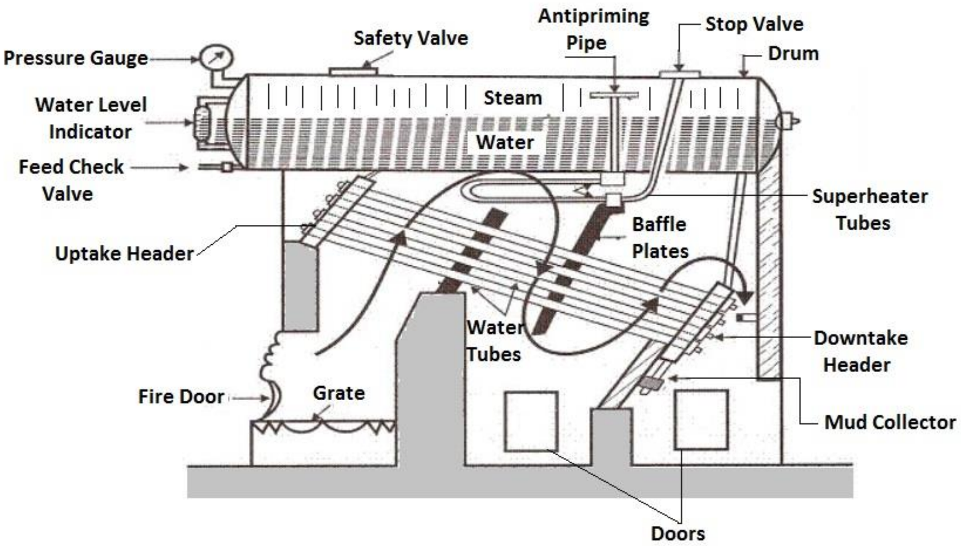
Babcock and Wilcox Boiler

1. *Steam drum*: Horizontal axis drum which contains water and steam.
2. *Down Take Header*: It is present at rear end of the boiler which connects the water tubes to the rear end of the drum. It receives water from the drum.
3. *Up Take Header*: It is present at front end of the boiler and connected to the front end of the drum. It transports the steam from the water tubes to the drum.
4. *Water Tubes*: Tubes in which water flows and gets converted into steam. It exchanges the heat from the hot flue gases to the water. It is inclined at angle of 10-15 degree with the horizontal direction. Due to its inclination the water tubes do not completely filled with water and the water & steam can be separated out easily.
5. *Baffle Plates*: Placed in between the water tubes and it allows the zigzag motion of hot flue gases from the furnace.
6. *Mud Collector*: Placed at the bottom of down take header used to collect the mud present in the water.

7. *Superheater*: It increases the temperature of saturated steam to the required temperature before discharging it from steam stop valve.
8. *Safety Valve*: It is a valve which acts when the pressure of steam within the boiler drum increase above the safety level. It opens and releases the extra steam in the environment to maintain the desired pressure within the boiler.



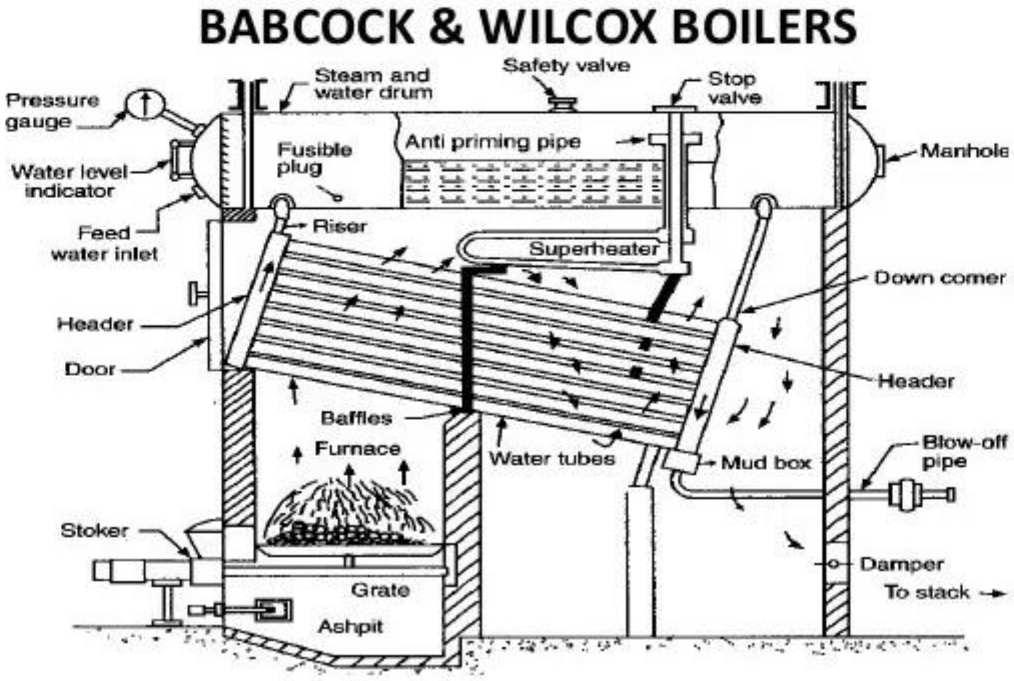
Working of Babcock and Wilcox boiler



Babcock and Wilcox Boiler

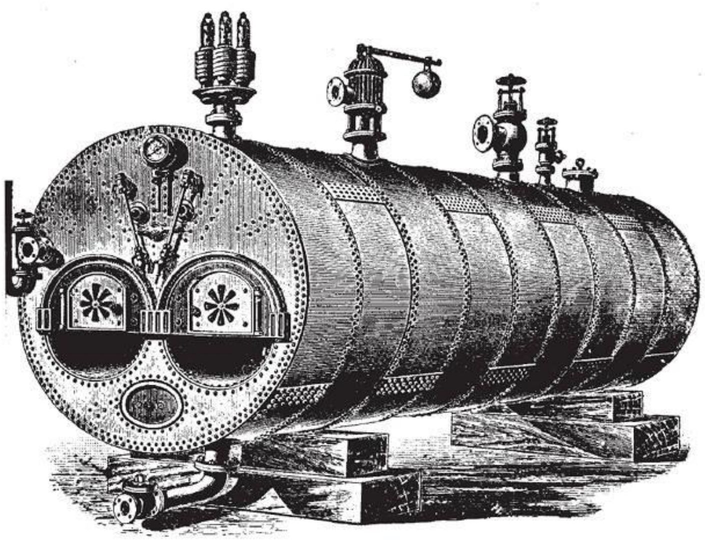
- First water starts to flow into the water tubes from drum through down take header.
- The water present in the inclined water tubes gets heated up by the hot flue gases. The coal burning on the grate produces hot flue gases and it is forced to move in zigzag way with the help of baffle plates.
- As the hot flue gases come in contact with water tubes, it exchanges the heat with water and converts it into steam.
- The steam generated is moved upward through up take header which gets collected at upper side in the boiler drum.
- T-tube is provided in the drum. This anti-priming pipe filters the water content from the steam and allows only dry steam to enter into superheater.
- The superheater receives the water free steam from the T-tube. It increases the temperature of steam to desired level and transfers it to the steam stop valve.
- The superheated steam from the steam stop valve is either collected in a steam drum or made to strike on the steam turbine for electricity generation.

Advantage	Disadvantage
1. It occupies less space.	1. High maintenance cost.
2. Replacement of defective tubes is easy.	2. It is not much suitable for impure and sedimentary water.
3. Inspection of boiler can be done anytime during its working.	3. Continuously supply of feed water is required for the working.

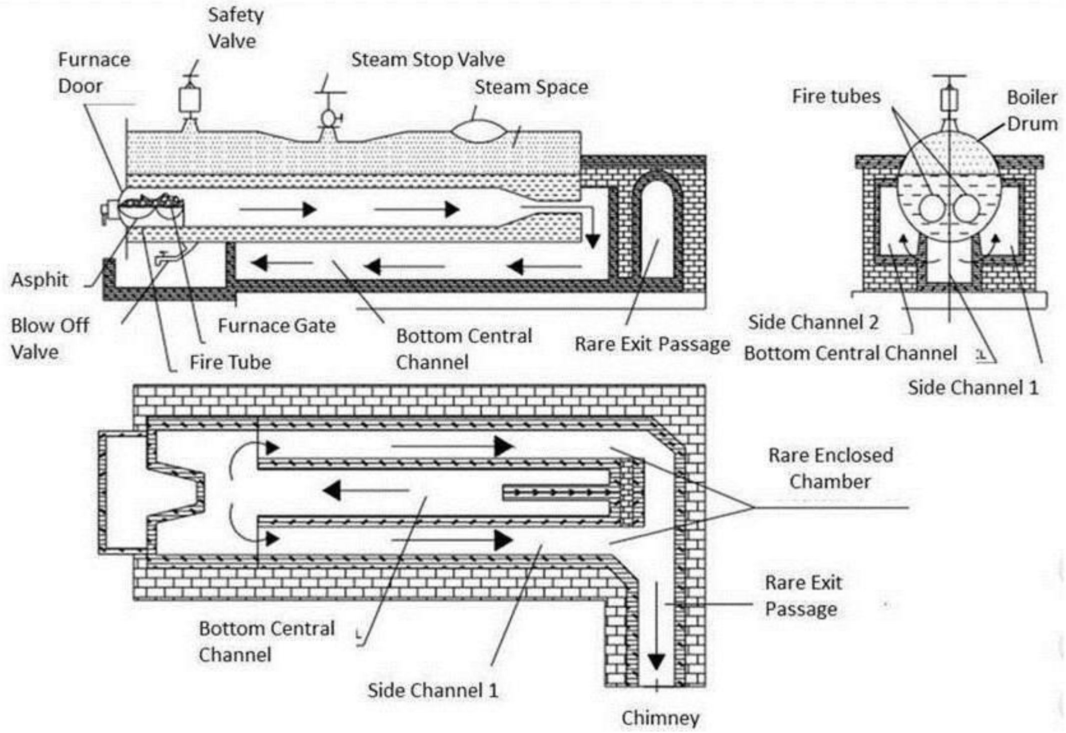


Lancashire boiler

- Lancashire Boiler was invented in the year 1844, by William Fairbairn.
- Horizontal, internally fired, stationary, natural circulation fire tube boiler.
- Steam pressure of 14bars (moderate pressure)
- Evaporation capacity 9,000 kg/hour.
- Application: Employed in sugar mills, textile and paper industries.

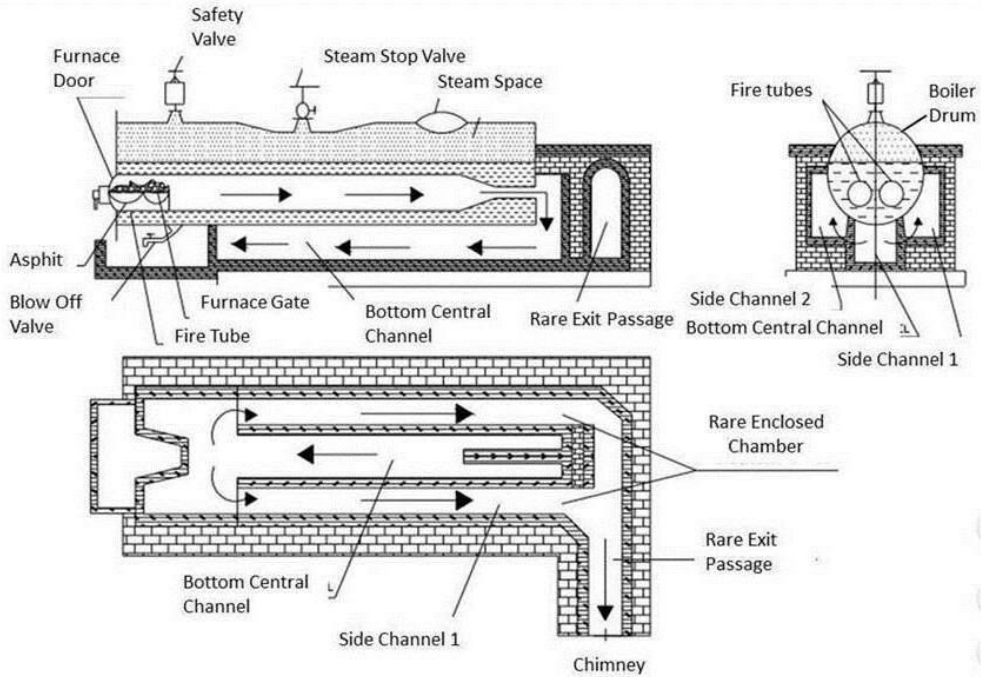


Construction of Lancashire boiler



- It consists of a horizontal cylindrical shell placed on a brick work set-up.
- Two flue tubes having dia 0.4 times that of boiler shell are placed inside the boiler shell and in each of these tubes, two furnace grates are provided.
- At the rear end of the boiler shell, the flue tubes are enclosed by brick work. While designing brick work, some narrow space is left underneath the boiler shell, which is termed as bottom channel. (Side channel 1 & 2)

Working

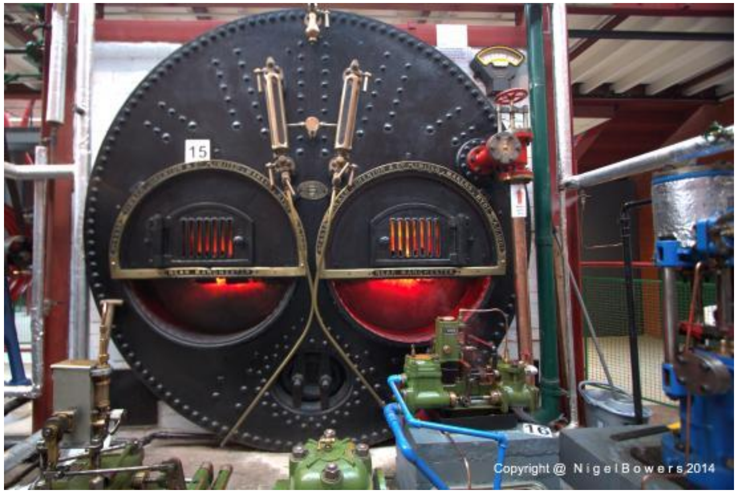


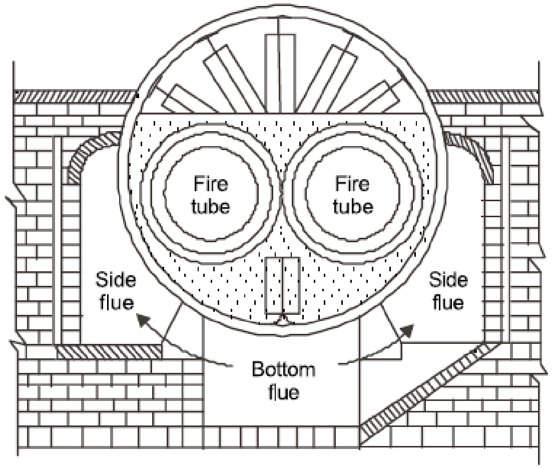
- Boiler shell is filled with water upto 75% of its volume so that the flue tubes get fully submerged in it.

  Coal is charged into the grate through furnace door. The hot gases pass through the flue tubes from front to the rear end of boiler shell. Water surrounding the flue tubes gets heated.

- From the side channels, the hot gases pass to the rear end of the boiler shell and pass out through the chimney.
- The steam thus formed gets separated from the surface of the water and collects in the steam space.
- The steam from the steam space is taken out through the steam stop valve and then used for various applications.

Advantage	Disadvantage
1. It has high thermal efficiency; the thermal efficiency is about 80 to 90%. 2. It is easy to operate. 3. Easy to maintain. 4. Generate a large amount of steam and hence more reliable.	1. It has a limited grate area due to the small diameter of the flue tubes. 2. The steam production rate is low. 3. Low-pressure type boiler, so high-pressure steam is not produced. 4. Tedious maintenance of brickwork.

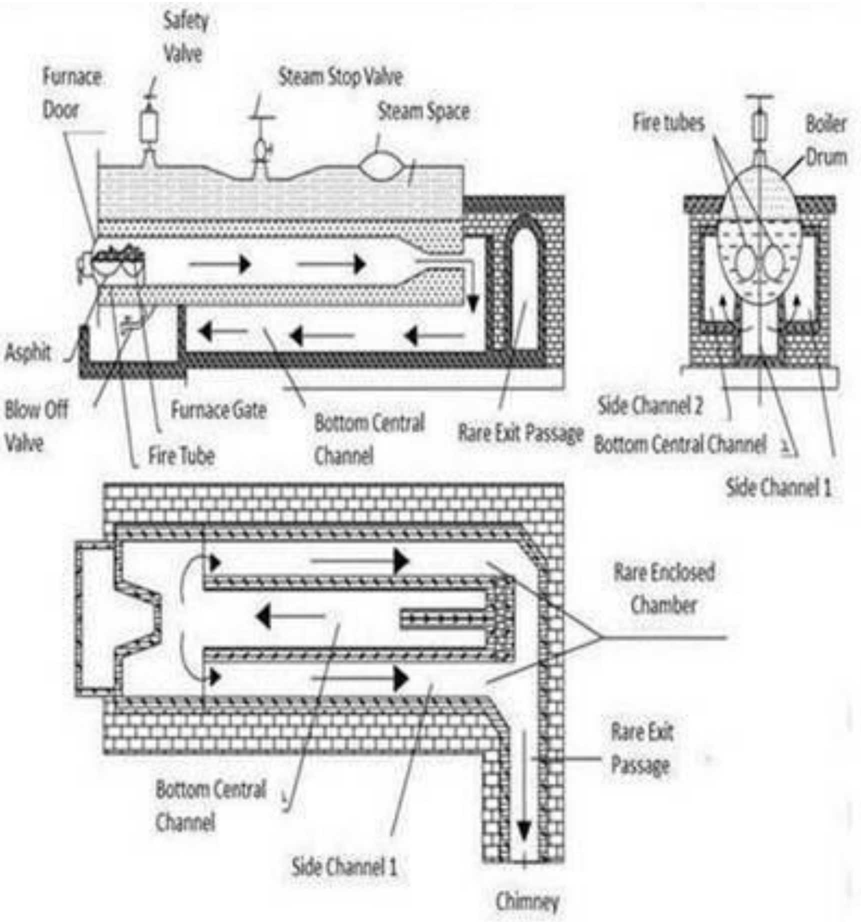




(c) Side view of Lancashire boiler

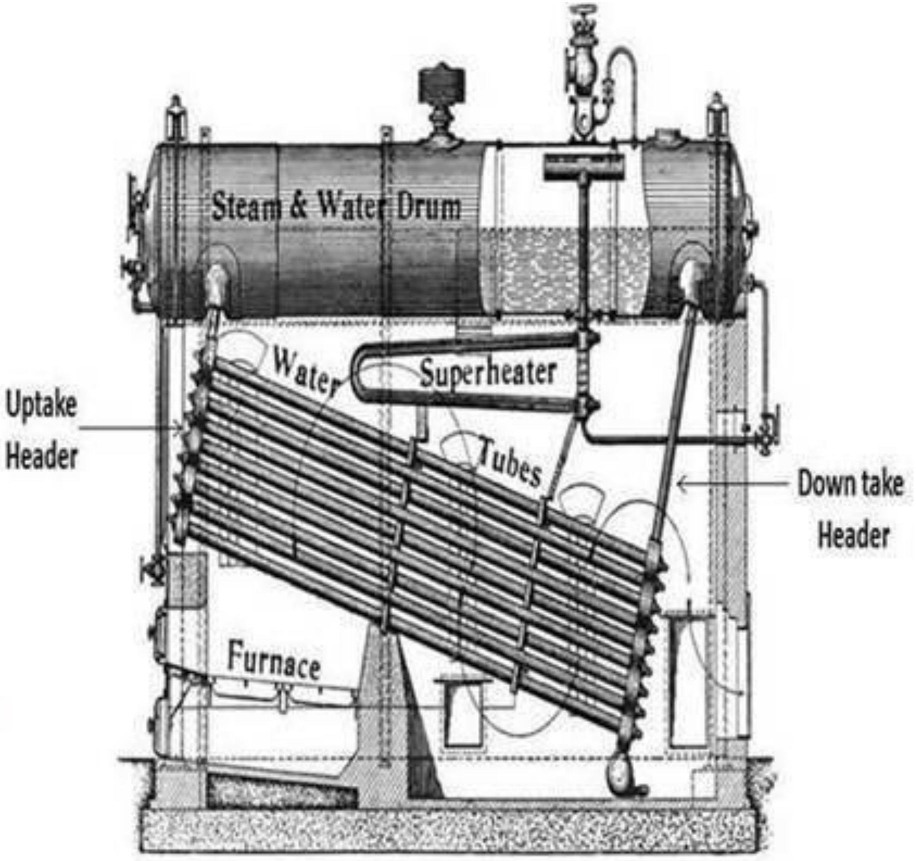
Differences between water tube and fire tube boilers

Water tube boilers (Babcock and Wilcox)	Fire tube boilers (Lancashire)
1. Water circulates inside the tubes and the hot gases surround the water tubes	1. Hot gases pass inside the tubes and water surrounds the tube.
2. Furnace is situated outside the boiler shell	2. Furnace is situated inside the boiler shell
3. Combustion space is large, 100% combustion of fuel	3. Combustion takes place in a small space within the boiler shell.
4. Water circulates between the drum and the tubes maintaining a closed circuit.	4. Water circulates within the boiler drum only.
5. Steam generation rate is fast	5. Slow steam generation rate
6. Rate of evaporation is high	6. Evaporating capacity is slow
7. High thermal efficiency	7. Thermal efficiency is low
8. Parts are easily accessible for cleaning, inspection and repair.	8. Inspection and repairing is difficult
9. Capital investment is high	9. Low cost of investment
10. High pressure steam at a very fast rate; used in power plants	10. Used in process industries or industrial plants



Fire Tube Boiler

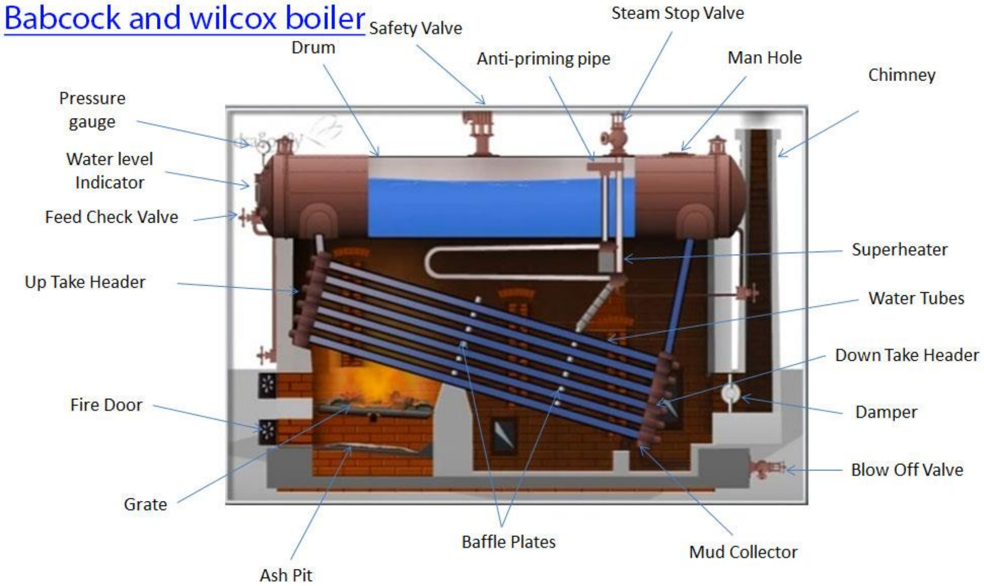
VS

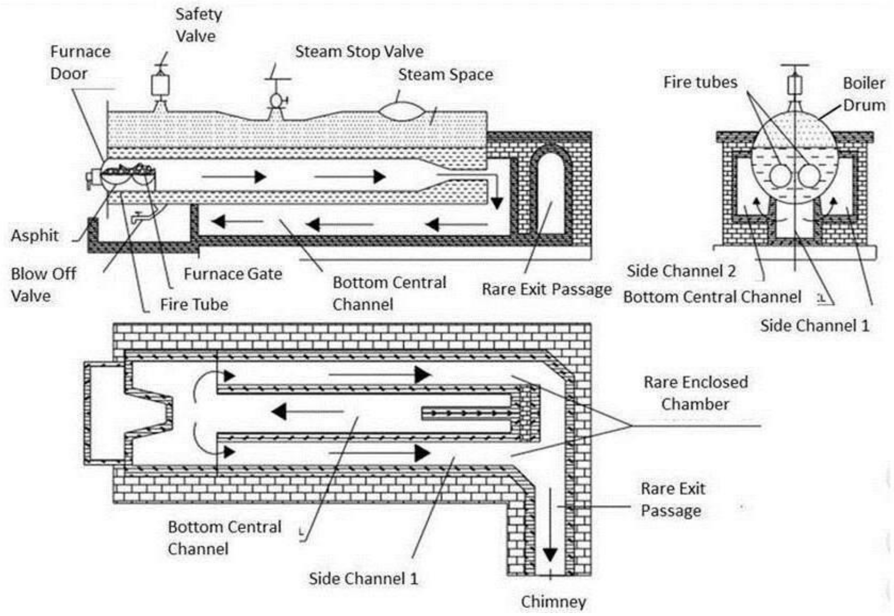


Water Tube Boiler

Boiler Mountings (Boiler Fittings)

- Purpose: To ensure
  - Safe operation
  - Efficient working
  - Controlled steam generation
  - Easy maintenance


Babcock and wilcox boiler

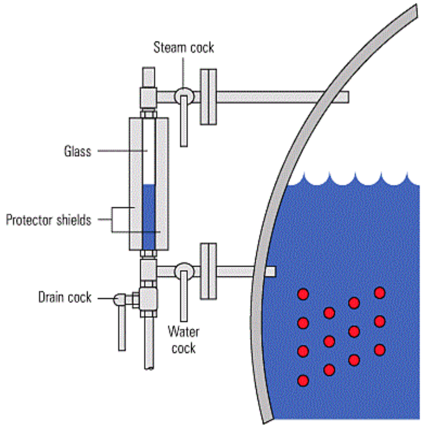


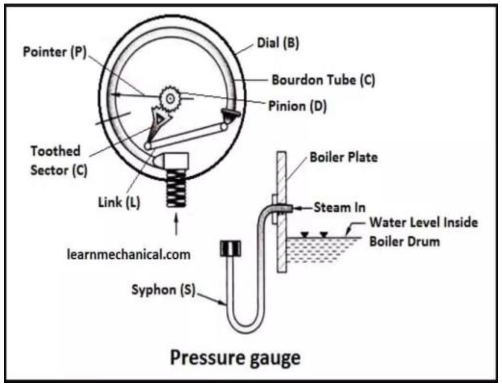
- <u>List of boiler mountings</u>
  1. *Water level indicators*
  2. *Pressure gauge*
  3. *Safety valve and Feed valve*
  4. *Blow-off cock*
  5. *Fusible plug*

Boiler mountings	**Functions/Features**
Water level Indicator (Two in numbers)	• To indicate the level of water inside the water drum. • Enables the operator to control the flow of water as when required.
Pressure gauge	• It indicates the pressure of the steam developed within the boiler. • Usually mounted in the front end and at top of the boiler shell.
Safety valve	• To maintain a constant safe pressure inside the boiler. • When pressure of steam within the boiler exceeds the critical pressure, safety valve opens and discharges the excess steam to atmosphere. • Placed on the top of boiler shell

Boiler mountings	**Functions/Features**
Steam stop valve or Junction valve	• To control the flow of steam from the boiler to the steam pipe or form one steam pipe to other pipe. • If valve is placed directly over the boiler – Junction valve. • If valve is placed in between the steam pipes – stop valve.
Feed valve or feed check valve	• To control the supply of water into the boiler • To prevent water escaping back from the boiler in case of feed pump failure. • Fitted over the shell below the water level of the boiler.
Blow-off cock	• To empty the boiler, during cleaning or inspection. • To remove sediments periodically which are collected at the bottom of the boiler.

Boiler mountings	**Functions/Features**
Fusible plug	• To ensure safety of boiler from being damaged by overheating due to decreased water level in the boiler. • Fitted over the combustion chamber





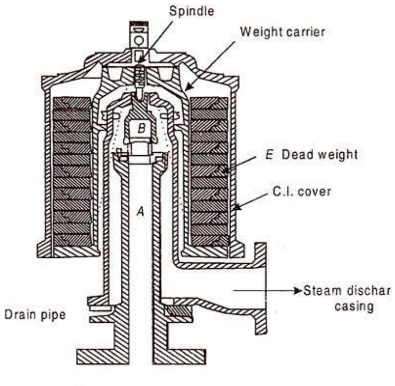
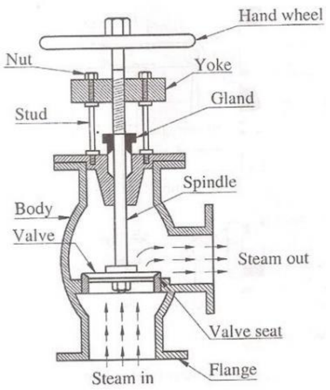
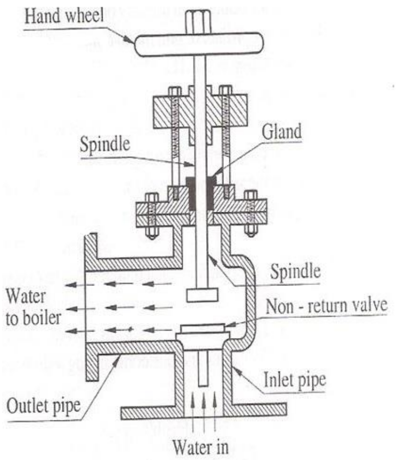
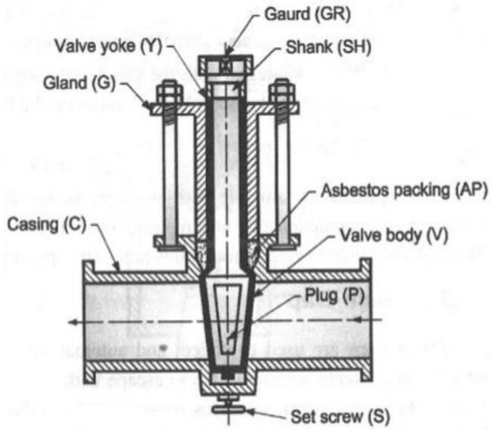
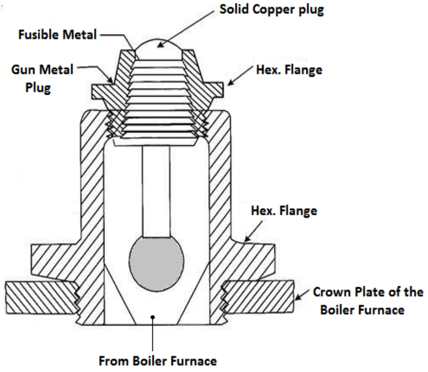


Fig. 11.13. *Dead-weight safety valve*









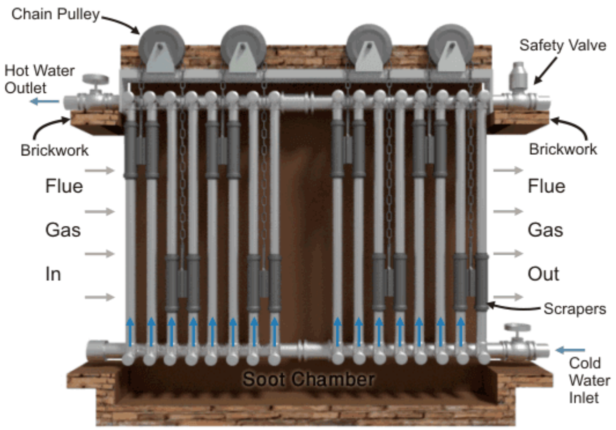
Fusible Plug

Boiler Accessories

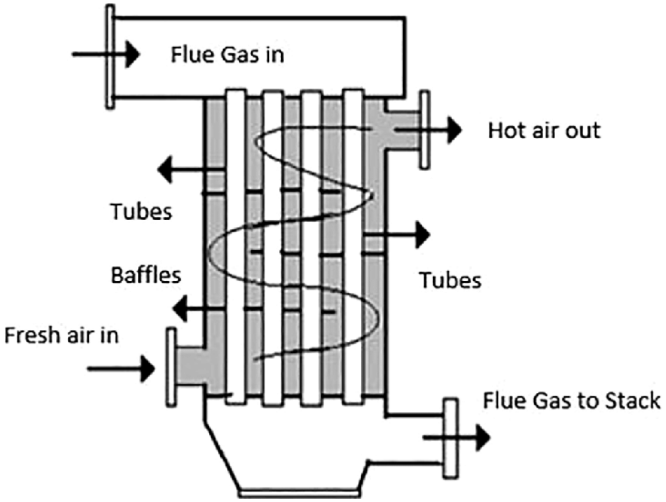
- Auxiliary/supplementary/additional parts of steam boiler.
- Purpose:
    - Smooth functioning
    - To increase overall efficiency of the boiler
- List of boiler accessories

1. *Economizer*
2. *Air-preheater*
3. *Superheater*
4. *Steam separator*
5. *Steam trap*
6. *Feed pump*

- **Economizer**
  a. Device used to heat the feed water by extracting the heat from the gases that are passing out of the chimney.
  b. Placed in between the boiler exit and the chimney entrance.



- **Air-preheater**
  a. Extracts the heat from the gases passing out of the chimney and is utilized for heating the air supplied for combustion of fuel in the furnace.
  b. Placed in between the economizer and the chimney entrance.



- **Superheater**
  a. Increase the temperature of steam above its saturation temperature (dry steam to superheated steam)
  b. Placed below the boiler drum and is exposed directly to the hot gases coming from the furnace.

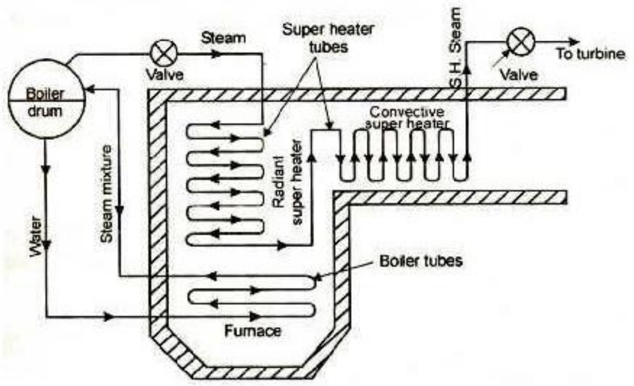


Fig Super heater (radiant and convective)

- **Steam separator**
  a. Device which separates the water vapours present in steam before it enters the engine or turbine.
  b. Placed closer to the engines or turbines.

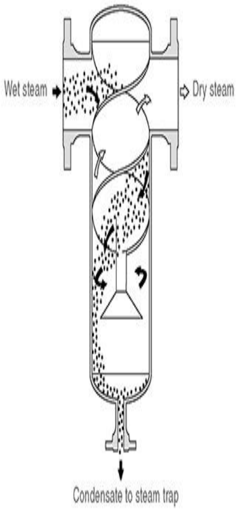
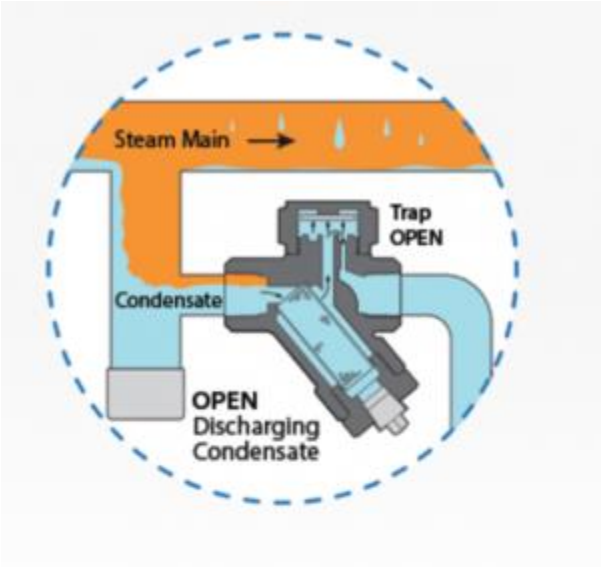
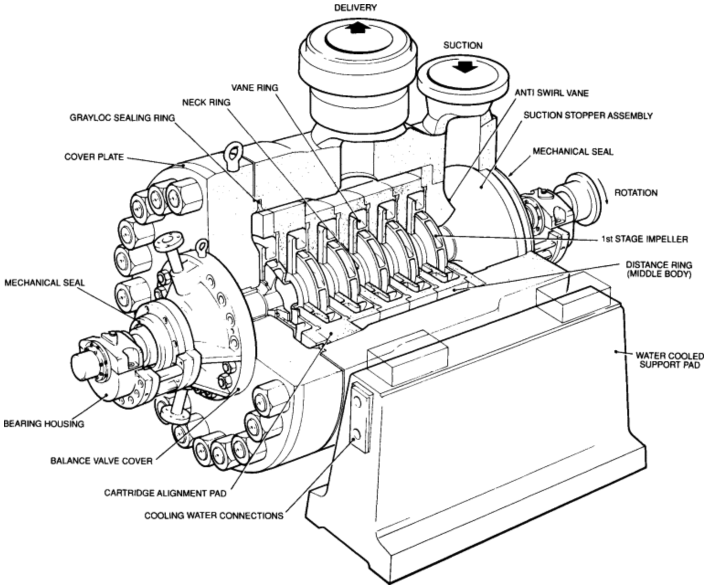


Fig. 12.5.3 A cyclonic type separator

- **Steam trap**
  a. Automatic valve used to drain off the condensed water accumulated in steam pipes and steam separator.
  b. Hinders the escape of high pressure steam from steam separator.



- **Feed pump**
  a. Pump the water at high pressure into the boiler drum.
  b. Reciprocating pump and centrifugal pumps



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Module – 2.2

Hydraulic Turbines

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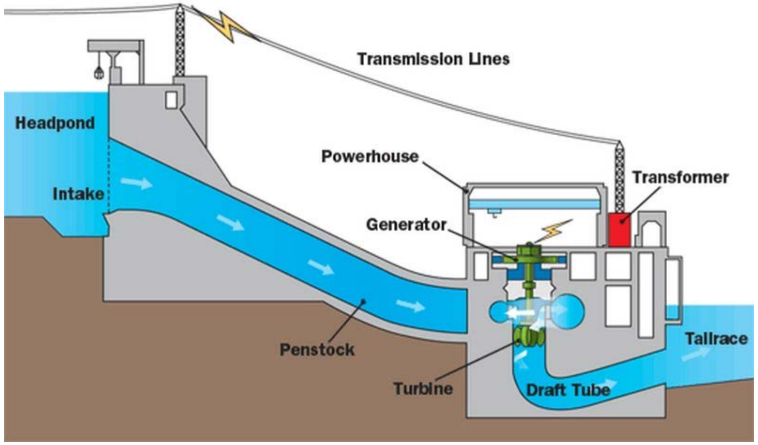
WATER TURBINE

- A device/machine that converts kinetic energy of flowing water into mechanical energy, which in turn converted into electrical energy by means of electric generator.



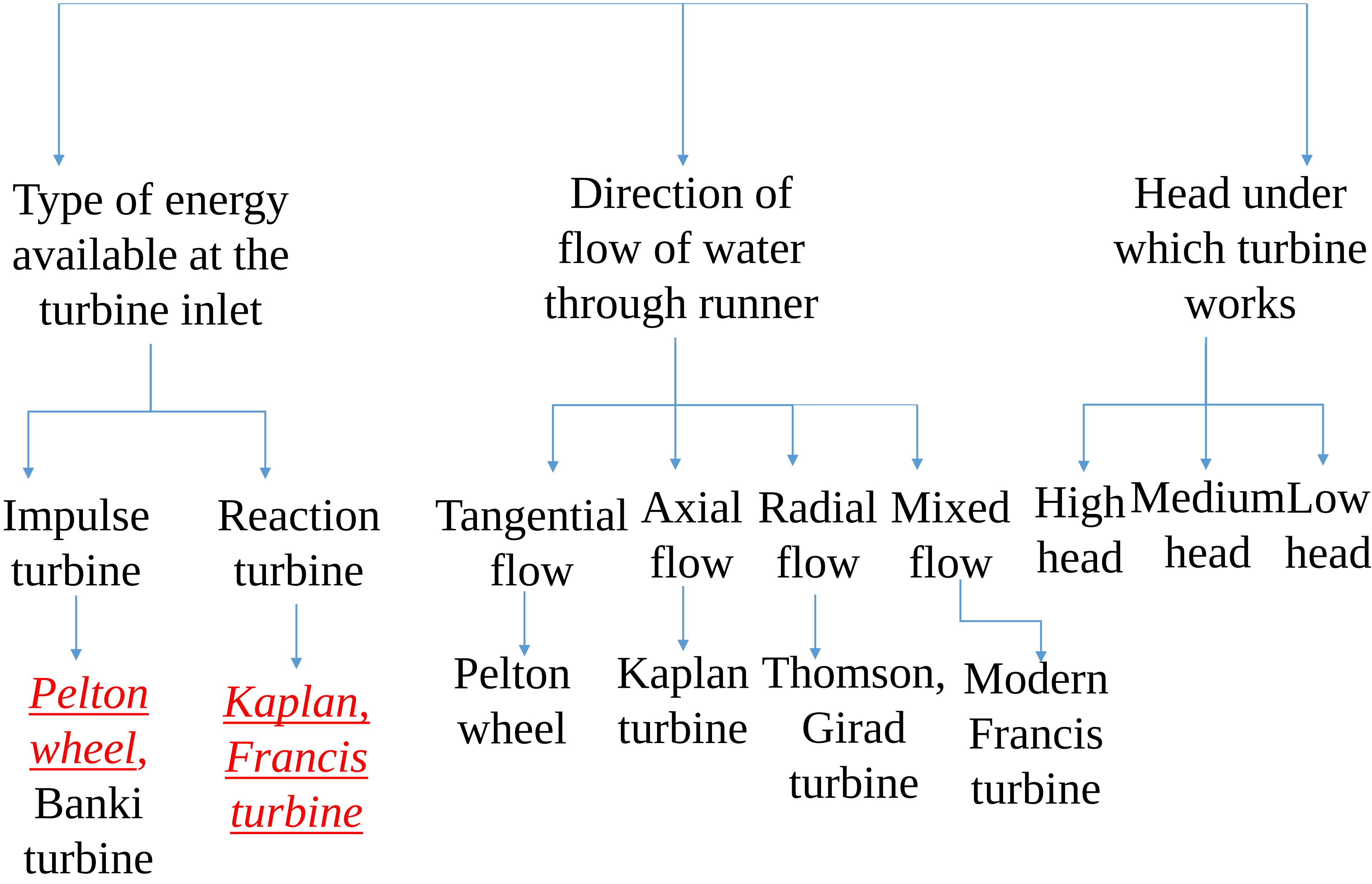
- *General principle:*

a. Force ∝ change in momentum (Newton II law)

b. Turbine blades are placed against the flow of water, which changes the momentum in it.

c. If there is any change in momentum of fluid, a force is generated. This force is used for rotation of shaft coupled with electric generator.

Classification of hydraulic turbines



Type of energy available at the turbine inlet

Impulse turbine

Pelton wheel, Banki turbine

Reaction turbine

Kaplan, Francis turbine

Direction of flow of water through runner

Tangential flow

Pelton wheel

Axial flow

Kaplan turbine

Radial flow

Thomson, Girad turbine

Mixed flow

Modern Francis turbine

Head under which turbine works

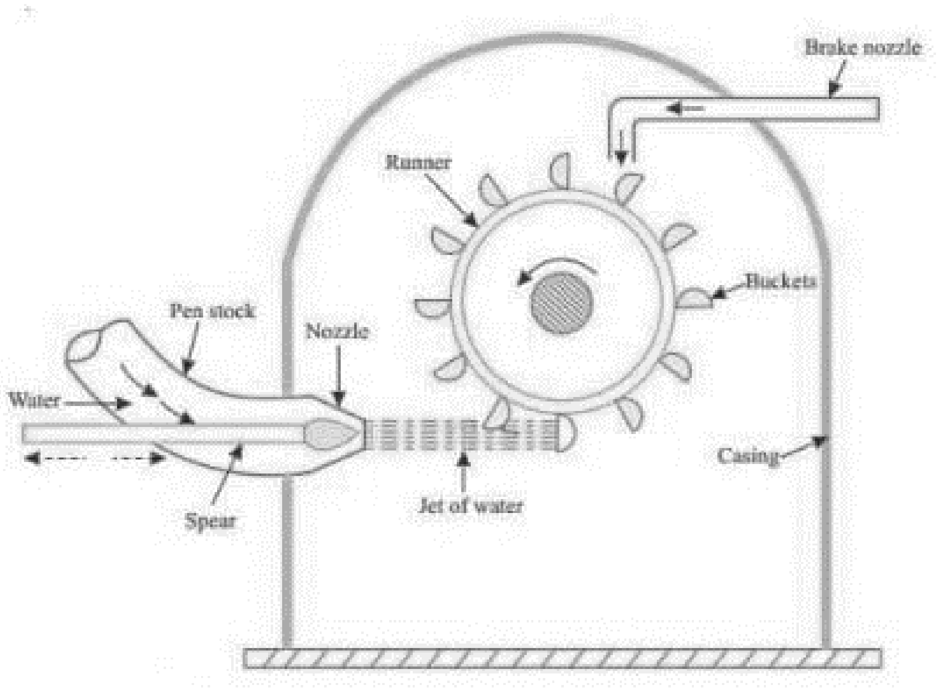
High head

Medium head

Low head

Pelton Wheel

- Tangential flow impulse turbine in which potential energy of water is converted into kinetic energy to form high speed water jet and this jet strikes the wheel tangentially to make it rotate.

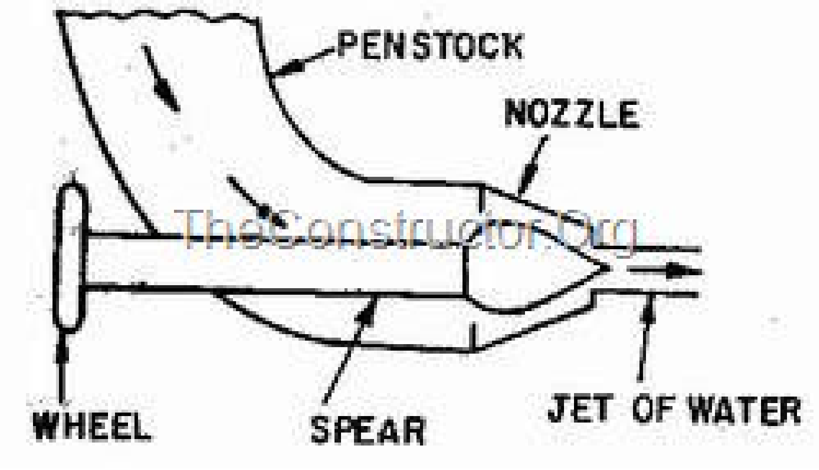


***Parts*:**

1. Nozzle with a spear head
2. Runner & Buckets
3. Turbine Casing

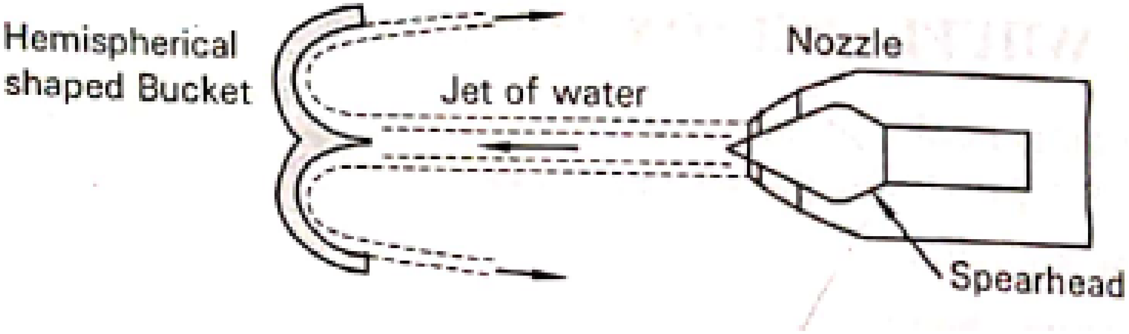
1. Nozzle with a spear head

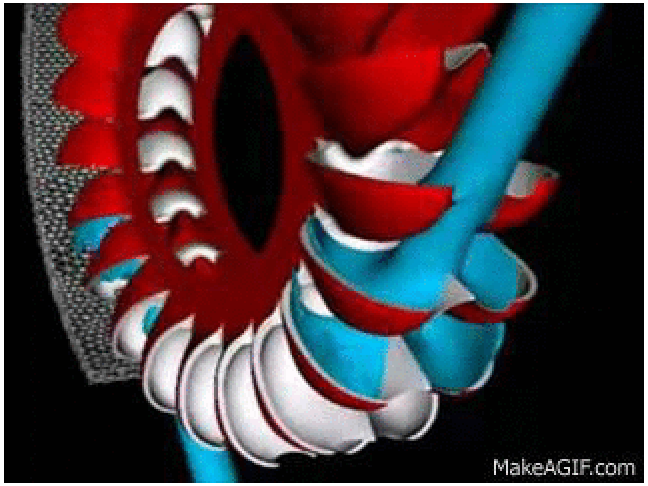
- Pipe/tube of varying cross sectional area attached to the penstock.
- Arranged around the runner wheel such that water jet emerging from a nozzle is tangential to the circumference of the runner wheel.
- Flow of water through the nozzle is controlled by a spear head, which is operated by means of hand wheel.
- Smooth flow of water with negligible energy losses.



2. Runner and buckets

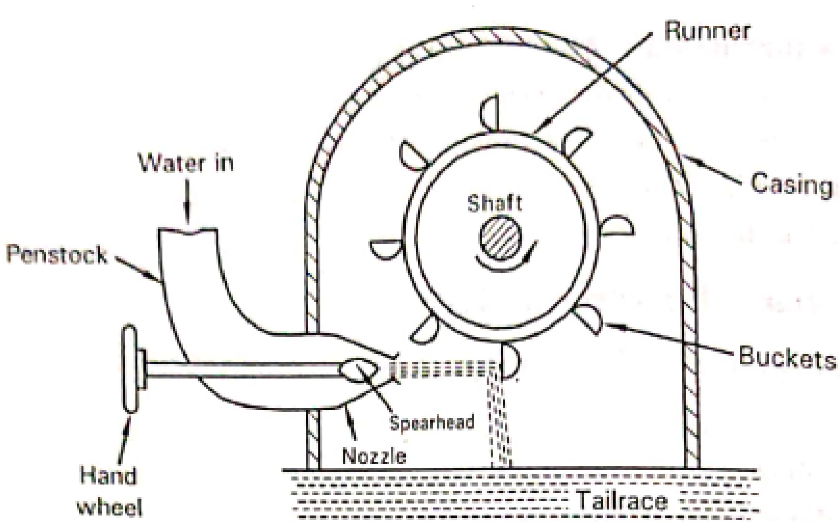
- Circular disc on the periphery of which a number of buckets are mounted with equal spacing between them. The runner is coupled to the rotating shaft as shown in the figure.
- The buckets mounted are either double hemispherical or double ellipsoidal shaped.
- Advantage of double hemispherical buckets:
  a) Water jet splits and leaves symmetrically on both sides of the bucket
  b) Eliminate the end thrust/axial thrust on the bearing and the shaft.





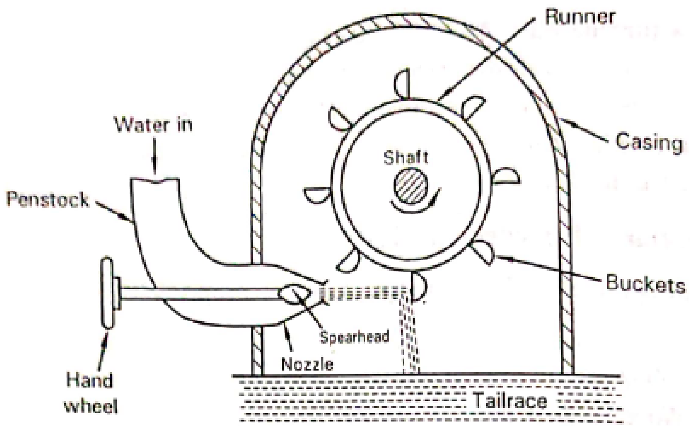
3. Turbine casing

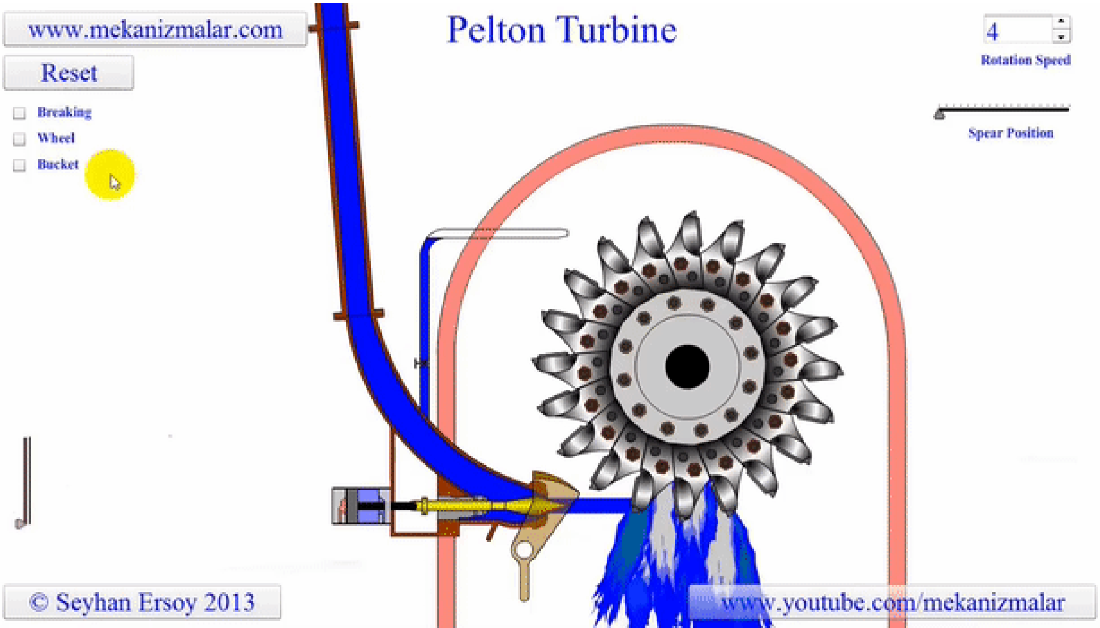
- The whole arrangement of runner and buckets, inlet and braking jets are covered by the Casing.
- Prevents the splashing of water and also helps to discharge the water into the tailrace.



Working of Pelton wheel

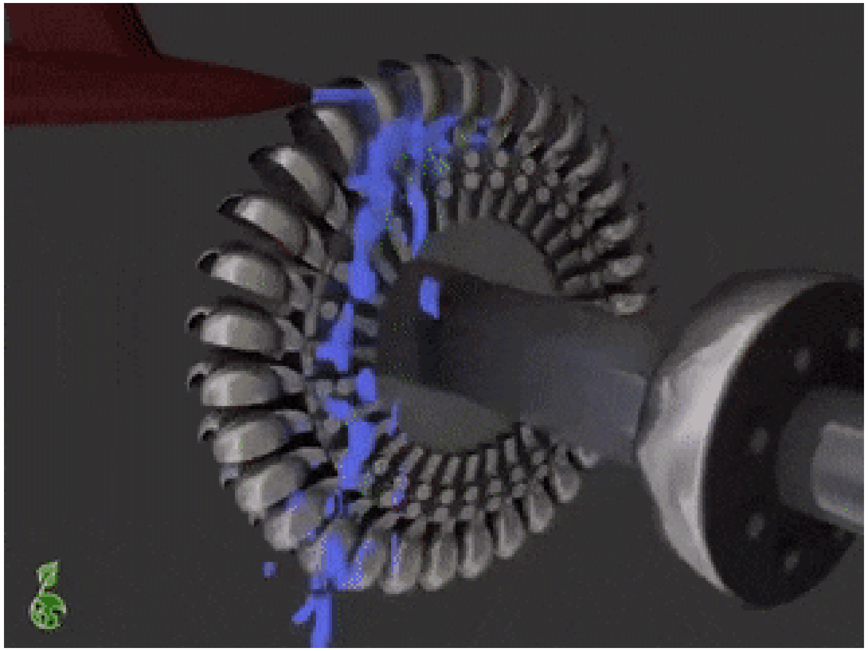
- Water from the reservoir having potential energy flows through the penstock and enters the nozzle.
- Potential energy of water is completely converted into kinetic energy in the nozzle. The high velocity water jet from the nozzle impinge on the hemispherical blades fixed around the runner wheel.
- The impulse force due to the high velocity jet sets the runner wheel into rotary motion.



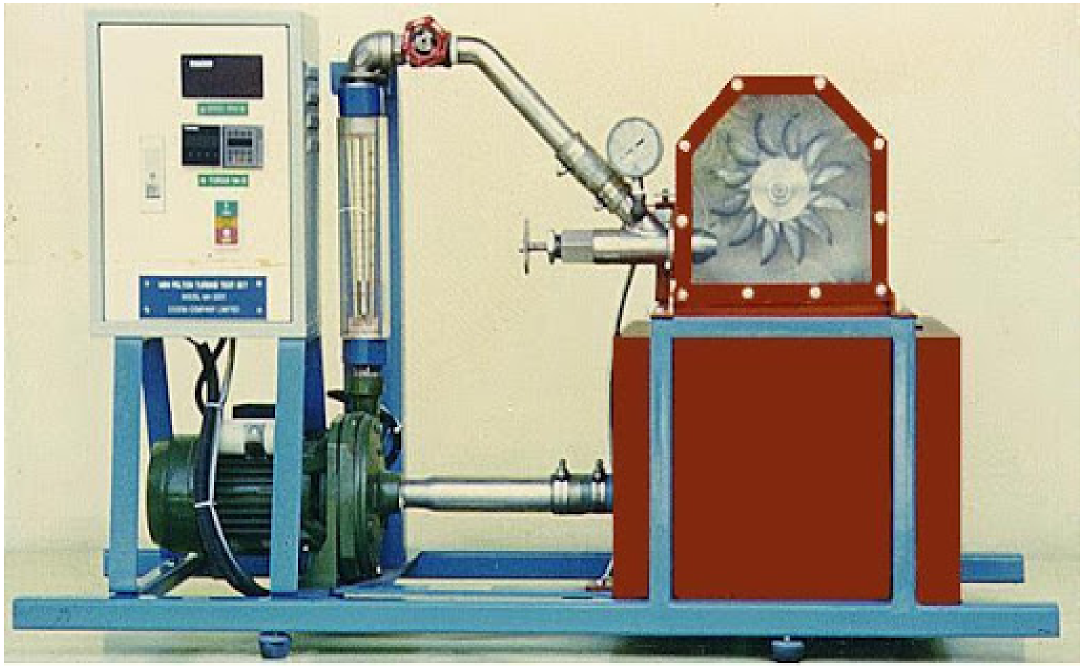


- The shaft coupled to the runner wheel also rotates thereby doing useful work.

  (Kinetic energy of water → Mechanical work)
- The work produced at the output shaft is used to drive a generator to produce electricity.

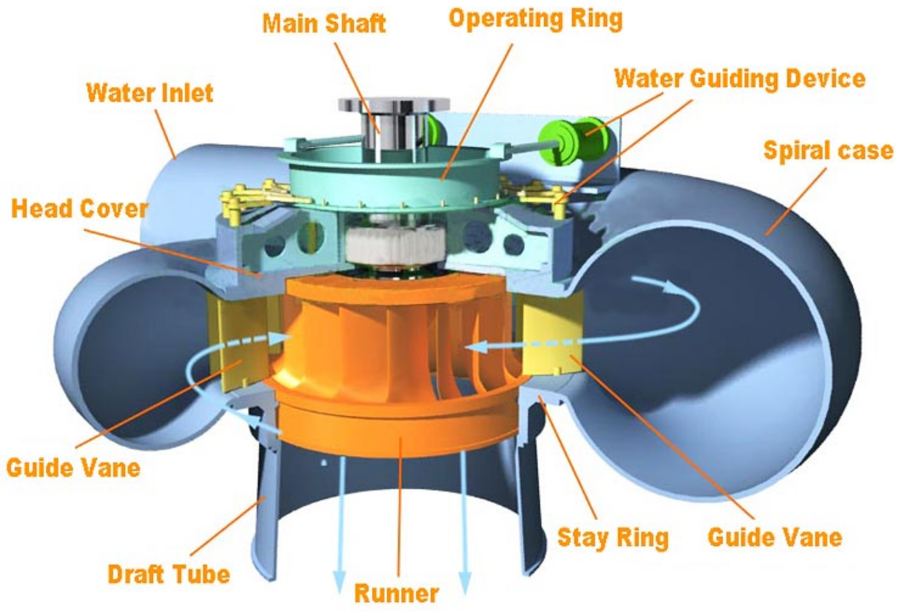


Advantage	Disadvantage
1. No cavitation problem 2. Overall efficiency is high 3. Intake and exhaust of water takes place at atmospheric pressure hence no draft tube is required 4. It can work on low discharge	1. Requires high head of operation 2. Turbine size is generally large



Francis Turbine

- Reaction turbine, combines radial and axial flow, operating head range 10m to several 100m.
- Used widely in hydro power stations.



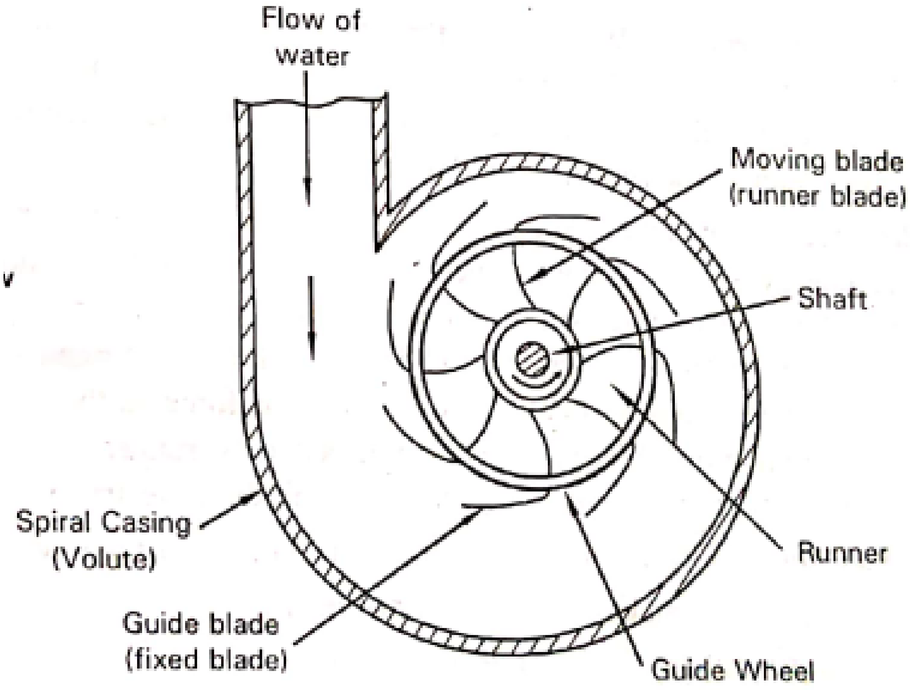
Francis Turbine

Parts:

1. Runner
2. Guide Wheel
3. Spiral casing
4. Draft tube

1. Runner

- Circular wheel on which series of curved blades are fixed.
- The number of blades usually varies between 16-24.
- The runner in turn coupled to a rotating vertical shaft.



2. Guide wheel

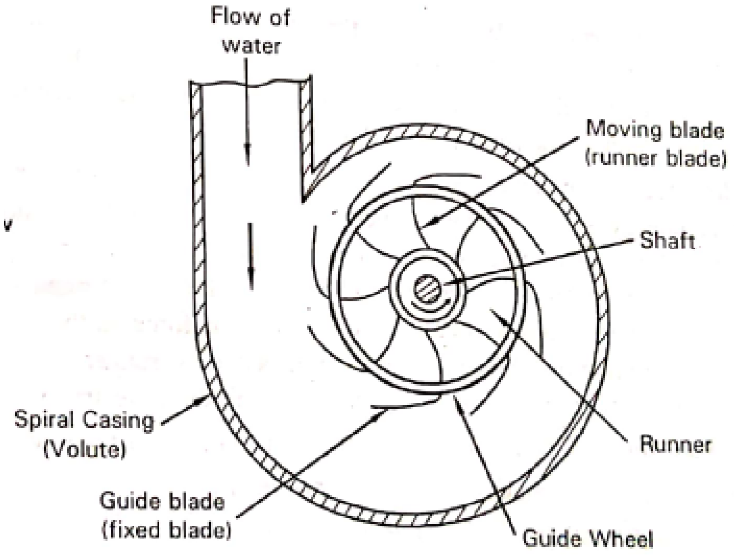
- Stationary wheel around the runner of the turbine.
- A number of blades are fixed around the circumference of the guide wheel (guide blades).
- Guide blades allow the water to strike at a certain angle on to the moving blades.
- The blades are designed in such a manner that the water while flowing through the blades will be subjected to nozzle effect (potential energy to kinetic energy)

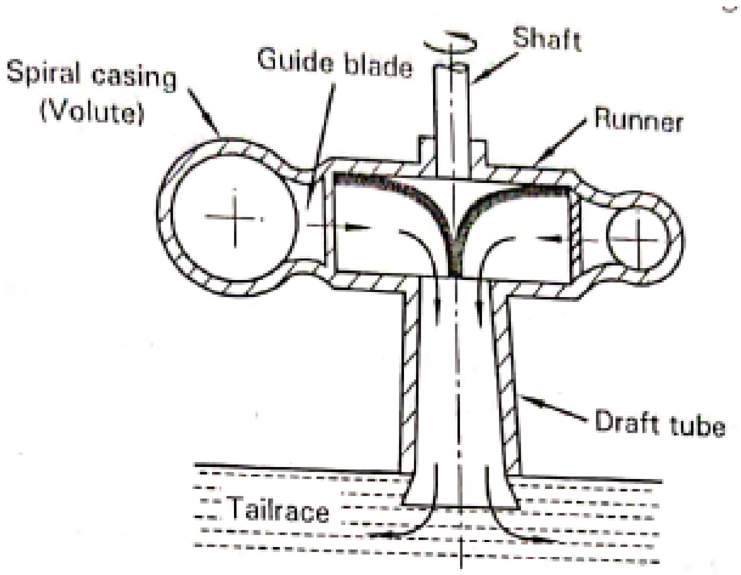
3. Spiral casing (Scroll/volute casing)

- Closed passage surrounding the guide blades.
- The cross section area of the spiral casing gradually decreases along the flow direction in order to distribute water uniformly around the entire perimeter of the runner.

4. Draft tube

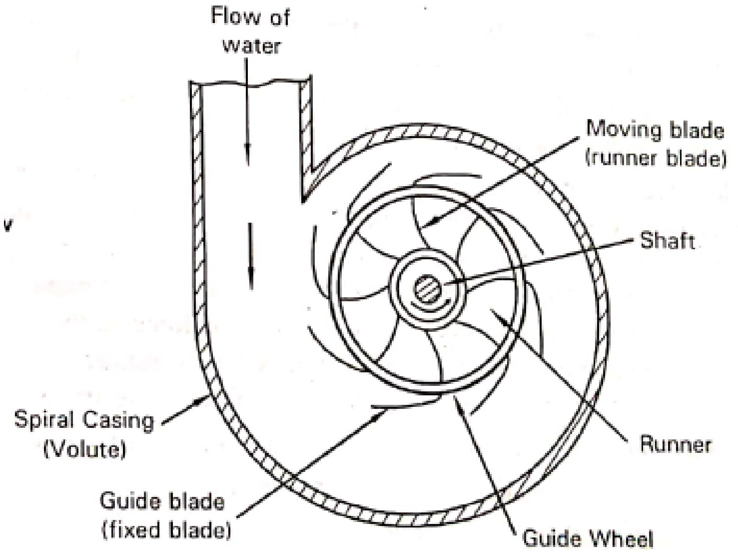
- Tube or pipe of gradually increasing area used for discharging of water from the exit of the turbine to the tailrace at low pressure.
- It does not allow water to fall freely to tailrace as in case of Pelton wheel.

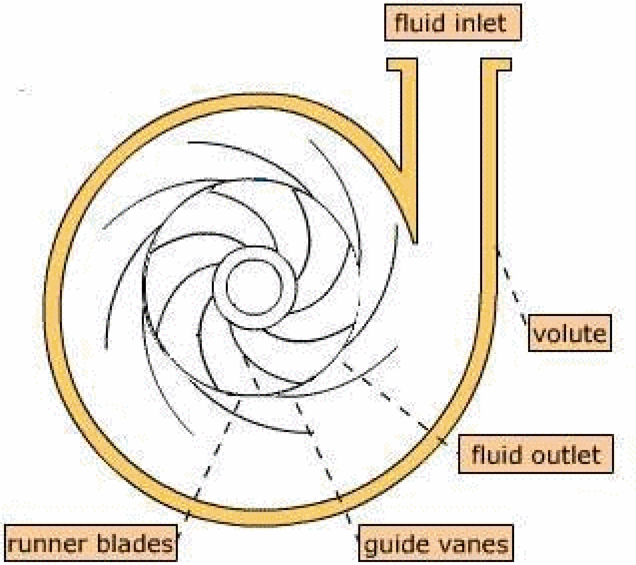




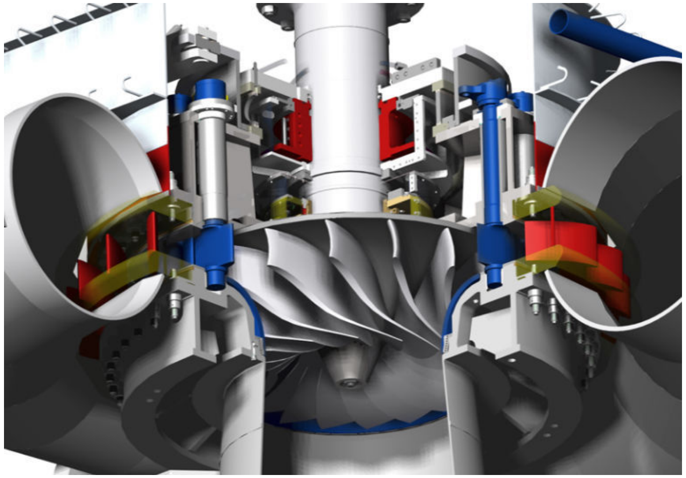
Working of Francis turbine

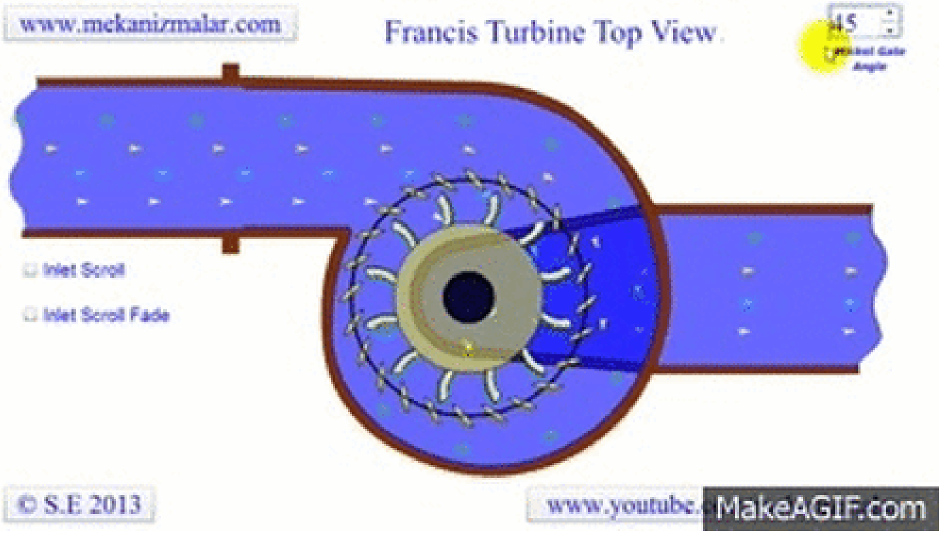
- Water from the reservoir flows through the penstock and enters the spiral casing.
- As the water flows through the tapered spiral casing, a part of its potential energy is converted into kinetic energy.
- Water flows through the guide blades, gets deflected and then flows radially inwards to the outer diameter of the runner.
- During its flow over the runner blades, the blade passage acts a nozzle and the remaining part of the potential energy is converted into kinetic energy.



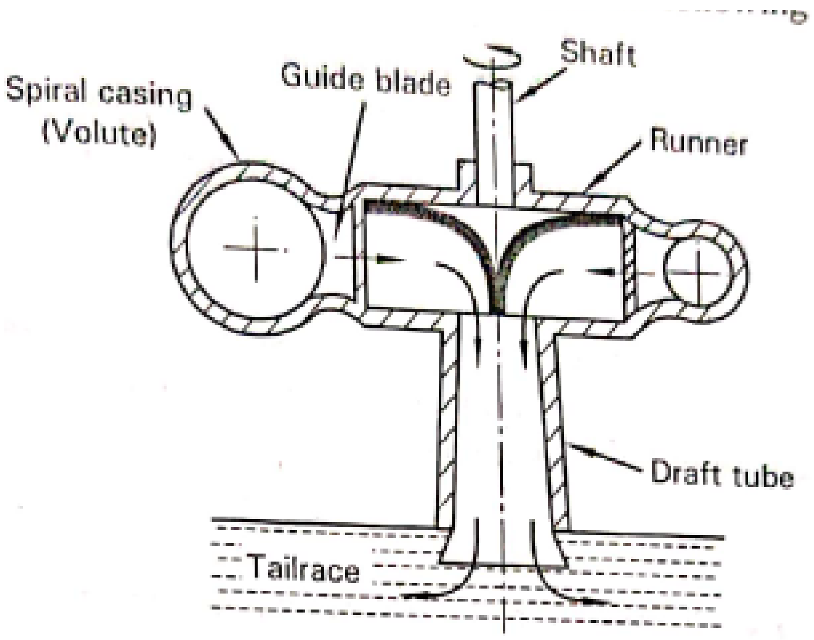


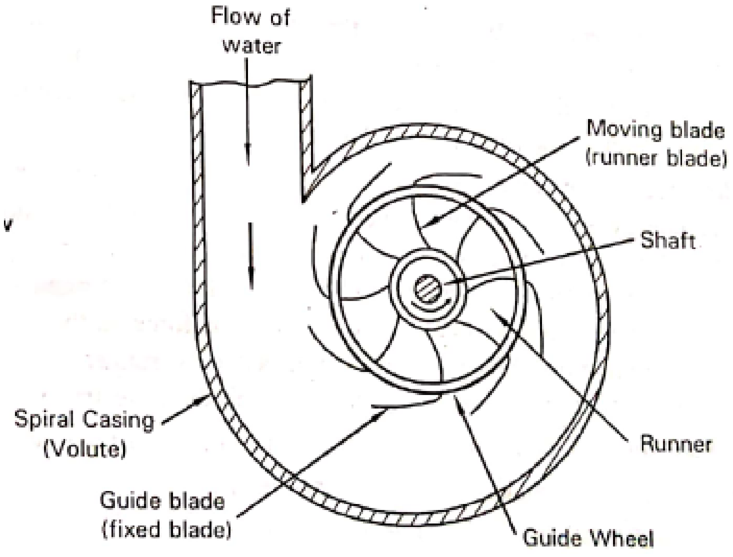
- It is important to note that, the jet of water does not impinge on the runner, in fact water leaves the runner at very high velocity. Hence there is a reaction force on the runner which set runner to rotary motion.
- The shaft connected to the runner also rotates thereby doing using work. The shaft in turn drives the generator to produce electricity.





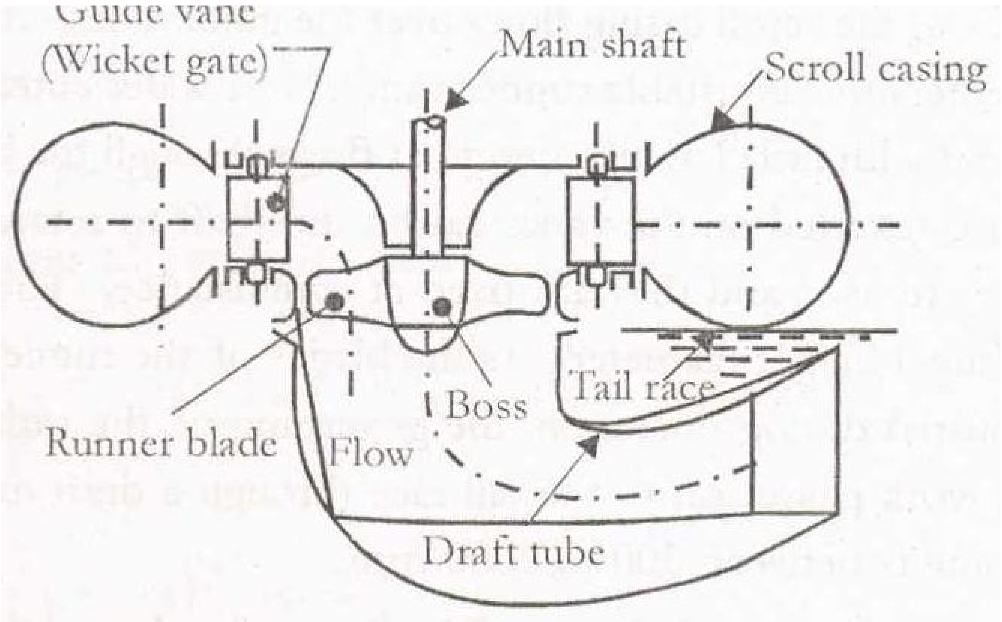
Advantage	Disadvantage
1. Variation in the operating head can be easily controlled. 2. Mechanical efficiency of turbine in high 3. Runner size is small.	1. Water which is not dirt free, can cause extremely rapid wear of turbine parts. 2. Cavitation is ever-present hazard. 3. Repair and inspection is difficult.

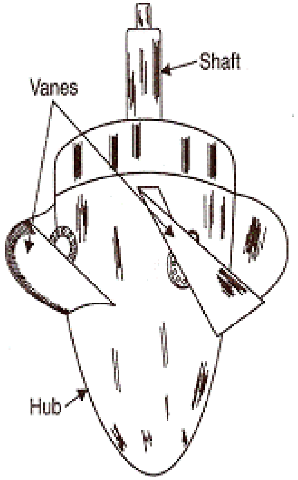


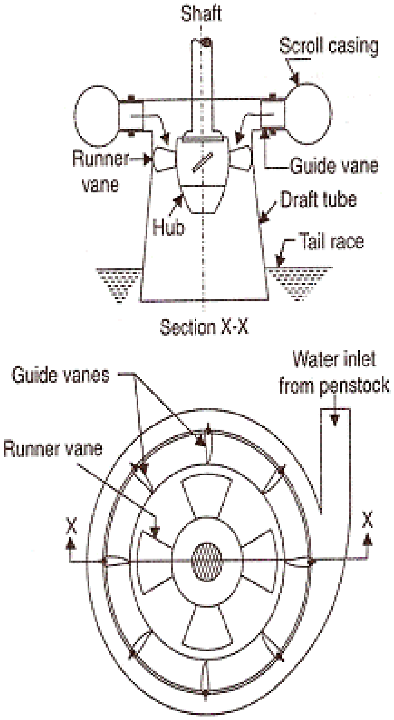


Kaplan Turbine/Axial flow turbine

- propeller type, axial flow reaction turbine with adjustable blades.
- It is suitable for low head (10m) and high flow applications. It is an evolution of Francis turbine.







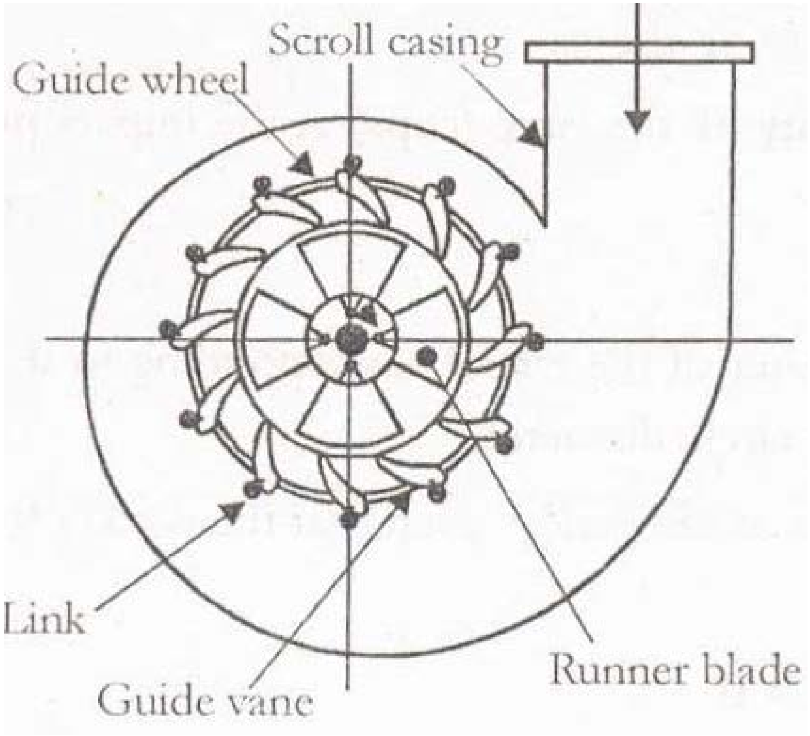
Main parts of Kaplan turbine

1. Scroll casing

- Spiral type of casing with decreasing cross sectional area.
- Scroll casing protects the runner, runner blades, guide vanes and other internal parts of the turbine from external damage.

2. Guide vanes

- It is the controlling part of turbine which opens and closes depending upon the power requirement.
- From guide vanes, water turns through 90° and flows axially through runner.
- Mechanism: High power requirement – opens wider to allow more water to hit the runner blades. Low power requirement – closes to cease the flow of water.

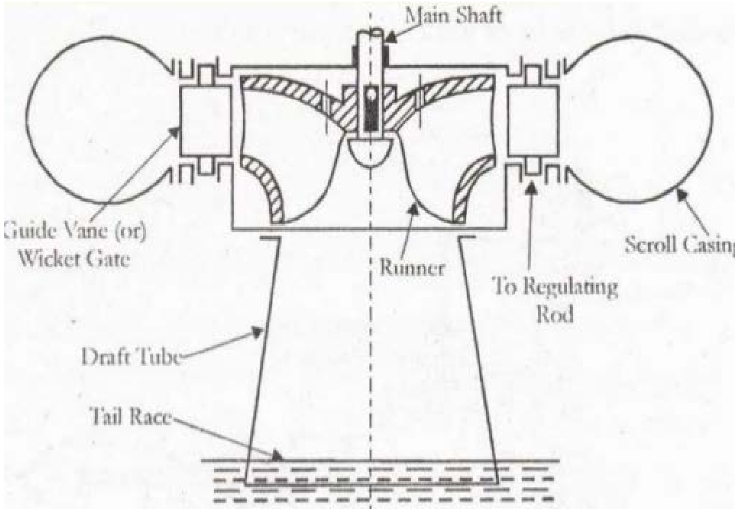


3. Hub or boss with vanes

- Hub/boss: Part on which blades/vanes are attached.
- Vanes have twist along its length. (To achieve greater efficiency of turbine)
- Vanes of the hub are adjustable to an optimum angle of attack of water for maximum power output. (For all cross sections of vanes/blades)

4. Draft tube

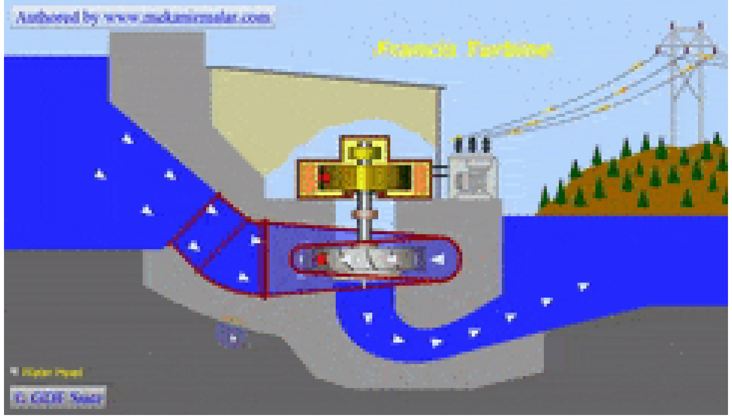
- Used only in reaction type turbines.
- At the exit of the hub, the pressure available is generally less than atmospheric pressure, so water cannot be directly discharged to tailrace.
- One end of the tube is connected to the outlet of hub while the other end is sub-merged below the level of water in the tail-race.



Working of Kaplan/Axial flow turbine

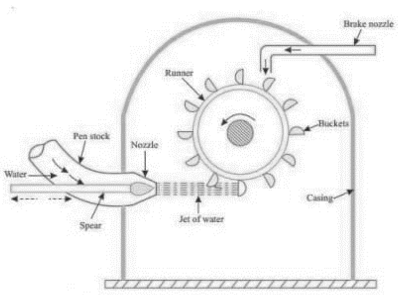
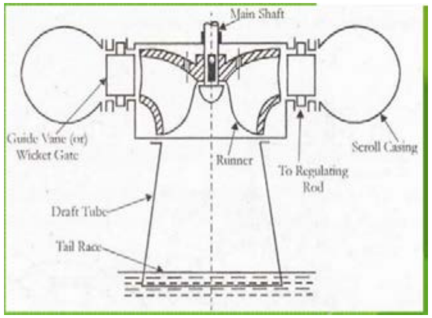
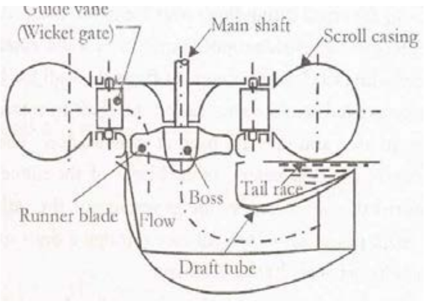
- Water from the pen-stock enters into the scroll casing. The water moves into scroll casing and the guide vanes directs the water from casing to the vanes of hub (through 90° and water flows axially to hub).
- As the water moves over the vanes it starts rotating due to reaction force of the water. (Potential energy & kinetic energy of water → rotation of hub → Useful work).

- From the hub blades, the water enters into the draft tube where its pressure energy and kinetic energy decreases. Here the K.E. gets converted into pressure energy results in increased pressure of the water. Finally the water discharged to the trail race.
- Rotation of the hub with vanes rotates the shaft of generator for electricity production.



Advantage	Disadvantage
1. It can works at low head. 2. Less number of blades and adjustable vanes. 3. Less construction space.	1. Cavitation is a problem. 2. Water flow rate is low. 3. Expensive to design, manufacture and install.

Specification of water turbines

Hydraulic Turbine	Specification
	- Power generation – 400MW - Speed rate of runner wheel – 65 to 800rpm - Efficiency – greater than 90% - Runner diameter – 0.8 to 6.0m - Operational Head – 15 to 1800m
	- Power generation – 800MW - Speed rate of turbine – 75 to 1000rpm - Efficiency – 90% - Runner diameter – 0.91 to 10.6m - Operational Head – 40m
	- Power generation – 5 to 200MW - Speed rate of hub – 69.2 to 429rpm - Efficiency – 85% - Runner diameter – 2 to 11m - Operational Head – minimum 10m

Differences between impulse turbine and reaction turbine

Sl. No.	Impulse turbine	Reaction turbine
1	All hydraulic energy (potential & pressure energy) is converted to kinetic energy by a nozzle	Only some amount of energy (pressure energy) is converted to kinetic energy
2	Operates at high hydraulic head (greater than 100m)	Operates at medium and low head (less than 100m)
3	Water flow regulation is done by means spear head fitted in nozzle	Water flow regulation is carried out by means of guide vane assembly
4	Water flows in tangential direction to runner wheel	Water flows in radial and axial direction to runner wheel
5	Hydraulic efficiency is more (>90%)	Relatively less efficiency (<90%)
6	Always installed above the tailrace. Hence no draft tube used	Generally connected to tailrace through a draft tube
7	Requires low discharge of water	Medium to high discharge of water
8	Water strikes the surface of blades only in the form of high velocity jet	Water is admitted over the entire circumference of the runner
9	No cavitation problem	Cavitation is ever-present hazard.
10	Requires less maintenance	Repair and inspection is difficult.

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Module – 2.3

Hydraulic Pumps

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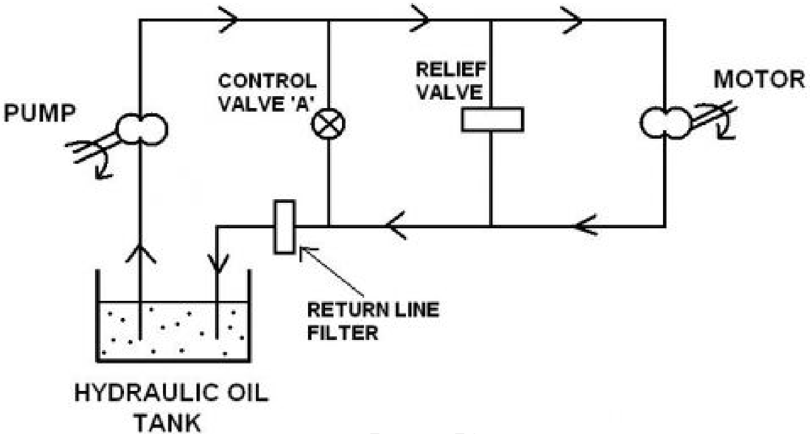
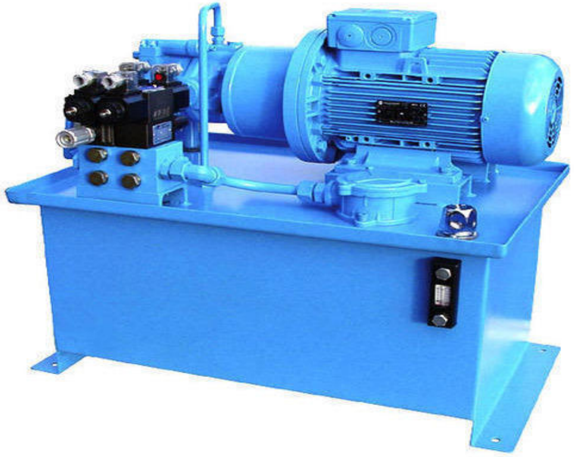
Hydraulic pump

- Device that transfer energy to raise liquid from lower level to a higher level or circulate a liquid in a closed system. (Mechanical energy to hydraulic energy)
- Examples of pump : pumping of water from sump to an overhead tank, circulation of lubricating oil/coolant to various moving parts of machine.



Hydraulic System

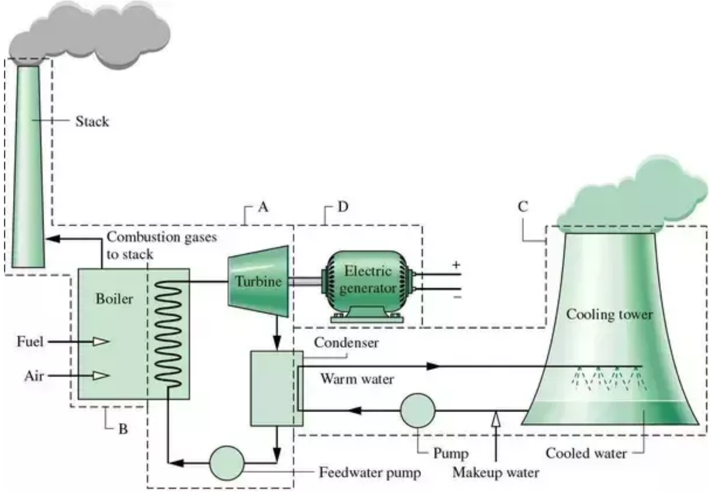


Hydraulic pump unit

Hydraulic pump

- General Applications of pumps:
  - Agriculture and irrigation works
  - In steam power plants for condensing water
  - Feed water to the boiler drum (steam boilers)
  - Circulate water in machine tools
  - In drainage system.

Irrigation works

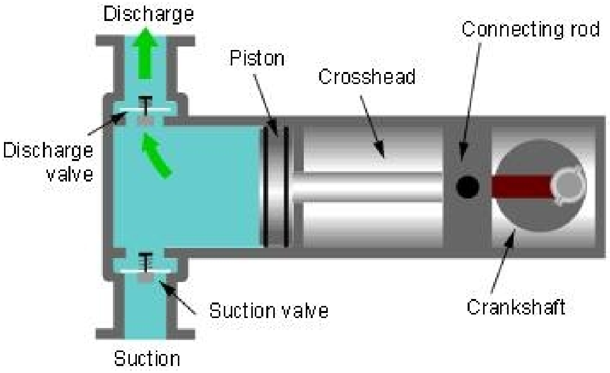


Steam power plant

Coolant in machine tool

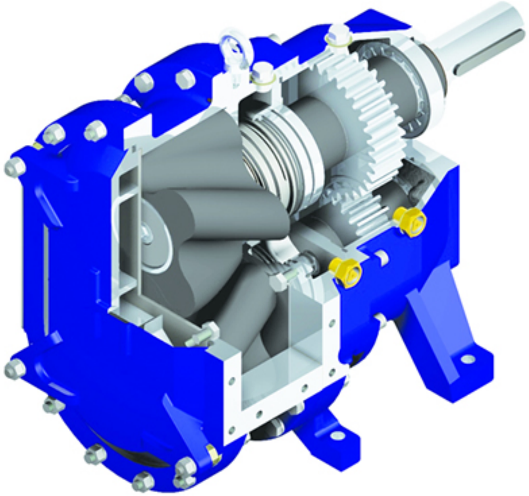
Classification of pumps

- *Centrifugal pump*: Pump which uses the centrifugal force of a rotary element/impeller to impart energy to the liquid.



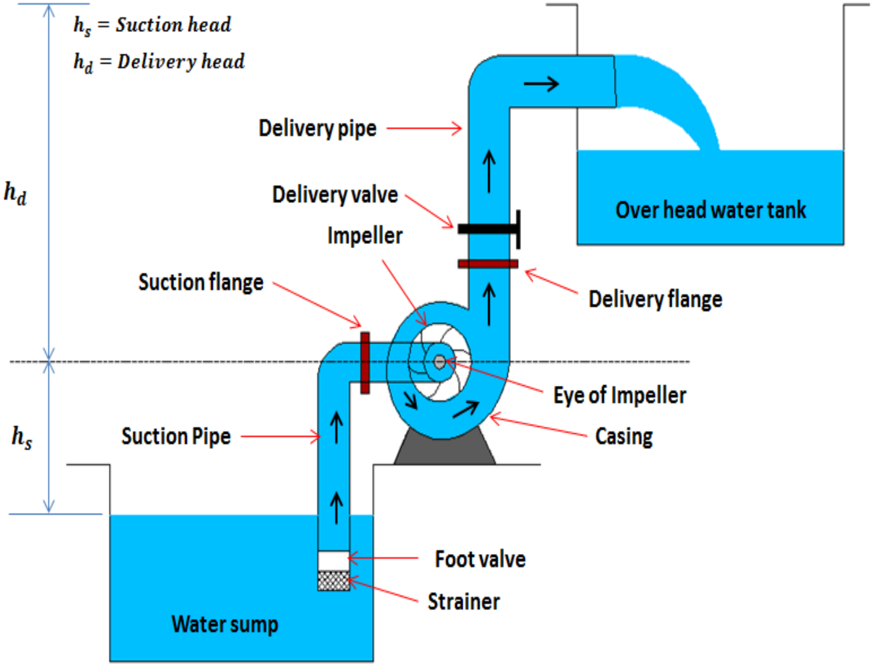
- *Reciprocating pump*: Pump which imparts energy to the liquid by the reciprocating action of a piston inside the cylinder.

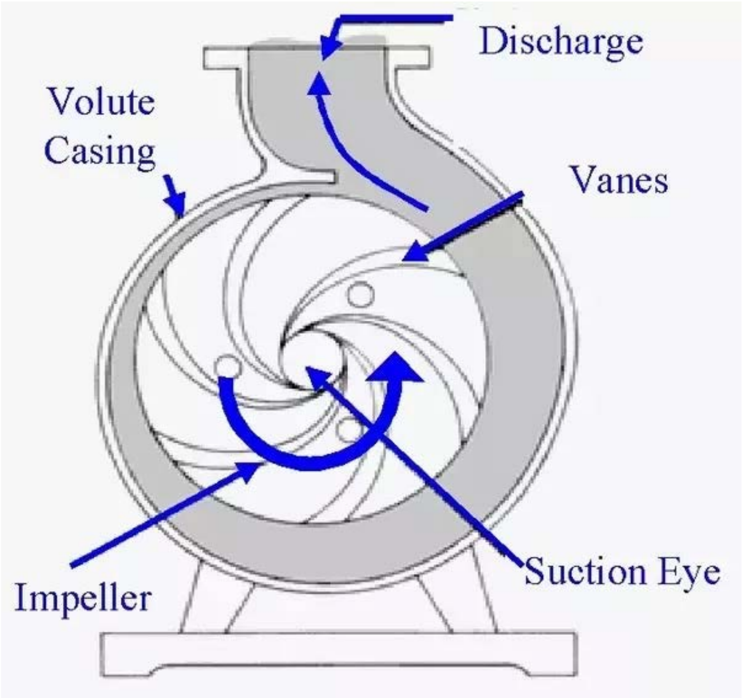
- *Rotary pump*: Pump which uses rotating members like gears, vanes or screws to impart energy to the liquid.



Centrifugal pump

- Centrifugal pump make use of centrifugal force of a rotary element (Impeller) to impart energy to the fluid.
- Applications: Agriculture, water and wastewater plants, power generation plants and automobile industries.

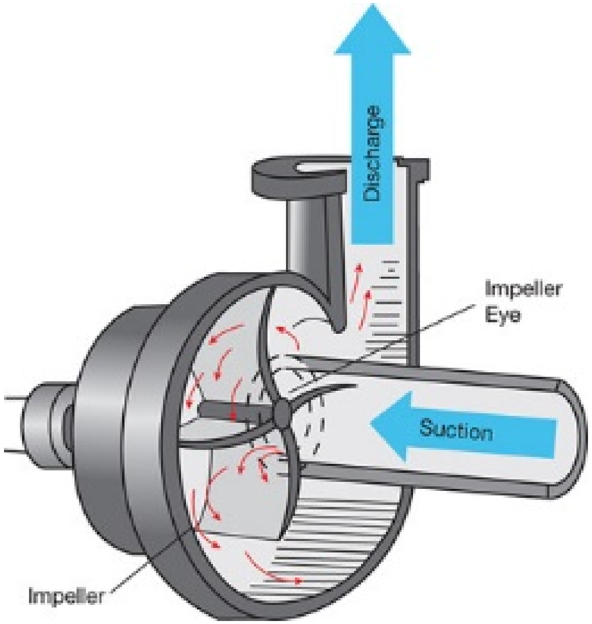




Parts of centrifugal pump

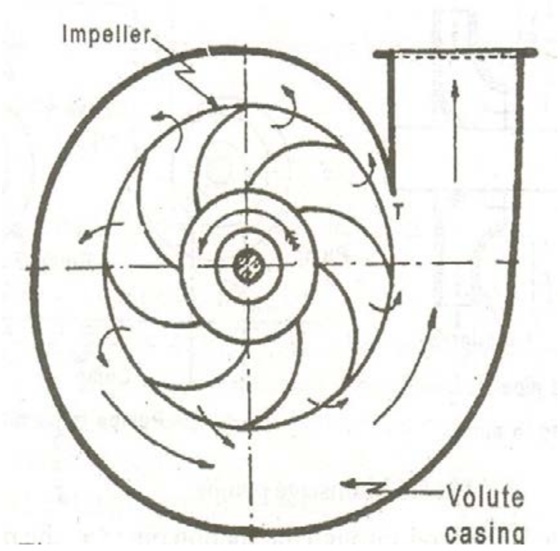
1. Impeller

- Principal rotating part of pump. It is a wheel (rotary element) with a series of backward curved blades/vanes.
- Mounted on a shaft, which is connected to the shaft of motor.



2. Volute casing

- Air tight chamber surrounding the impeller.
- Designed with its cross sectional area gradually increasing (velocity of flow decreases – increase in the fluid pressure)

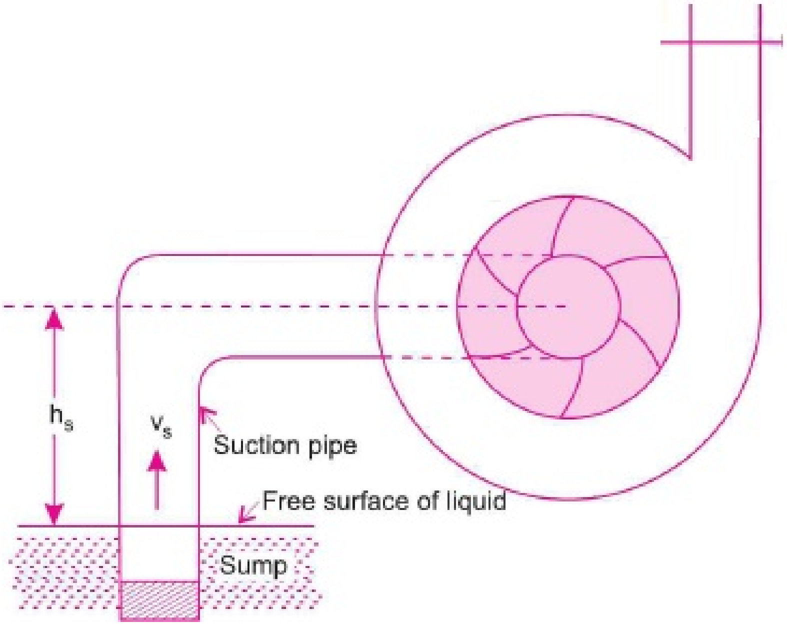


3. Suction pipe

- Circular pipe with its upper end connected to the centre of impeller (Eye of impeller).
- Lower end of pipe immersed in the sump/reservoir from where the fluid is to be lifted up.
- Lower end of suction pipe is fitted with a foot valve and strainer.

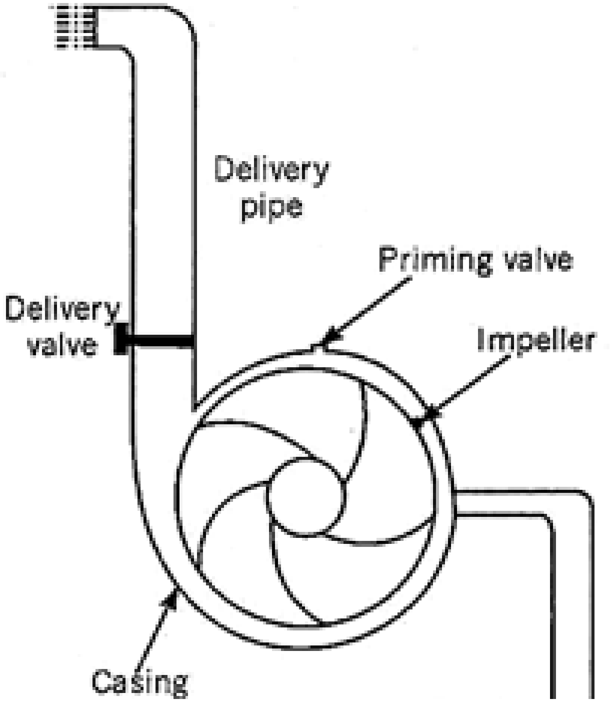
i. Strainer: Avoids the entry of any foreign matters into the suction pipe.

ii. Foot valve: one way valve or non-return valve, opens only in the upward direction, to prevent draining out in suction pipe when pump is stopped.



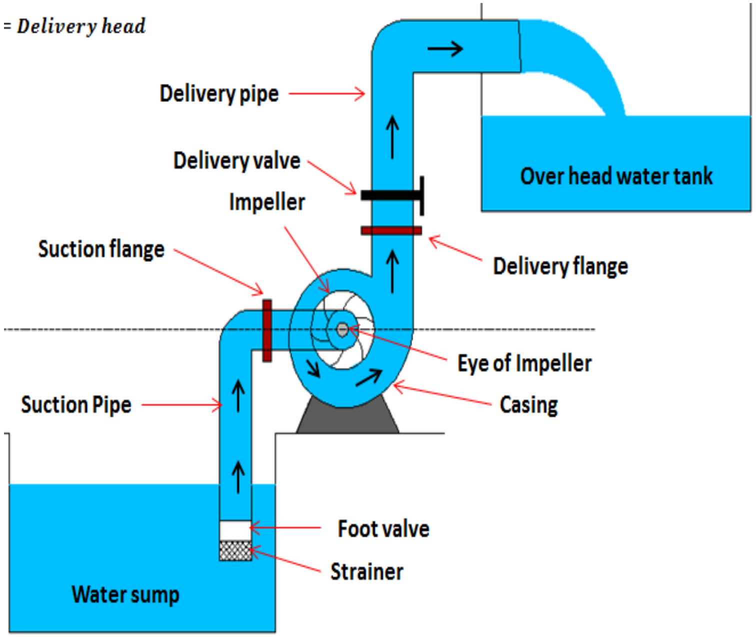
4. Delivery pipe

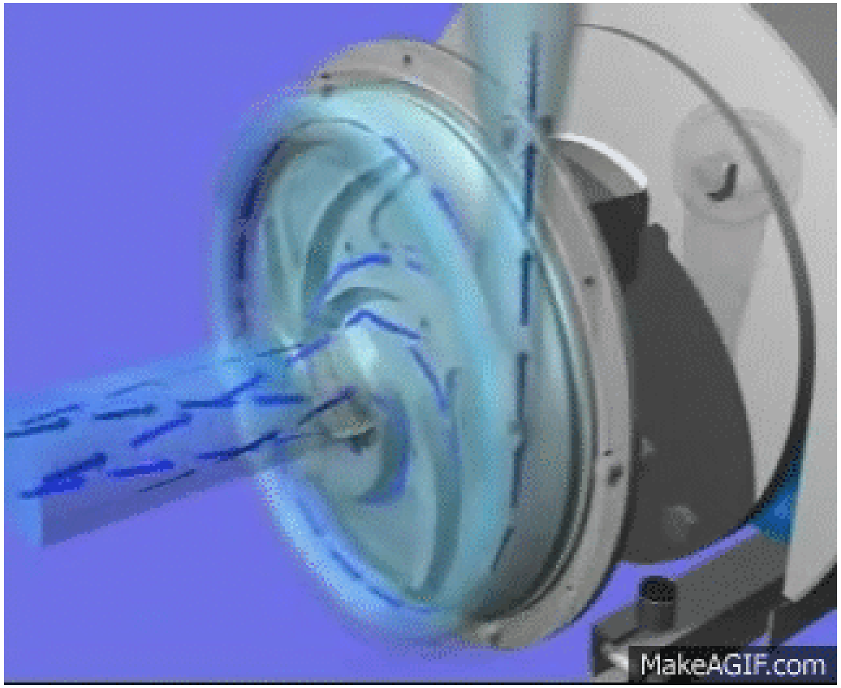
- Circular pipe with its lower end connected to the outlet of the pump (casing).
- Upper end is connected to the tank where the fluid is to be pumped or stored.
- Delivery valve : provided for regulating the fluid flow. The valve is closed prior to starting and stopping of pump; to prevent any possible backflow from delivery pipe and consequent damage to pump assembly.



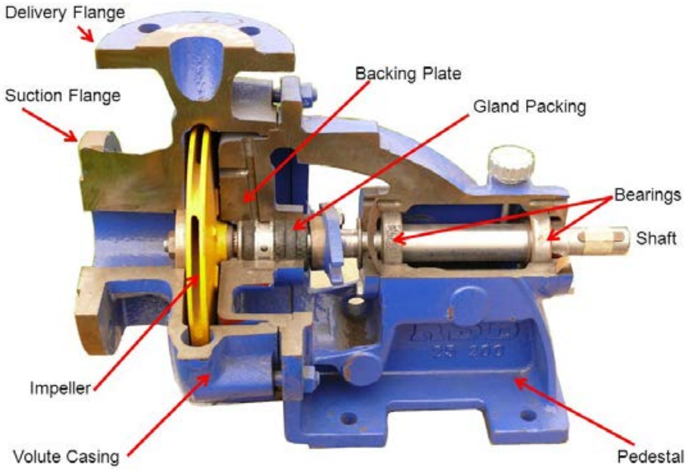
Working of centrifugal pump

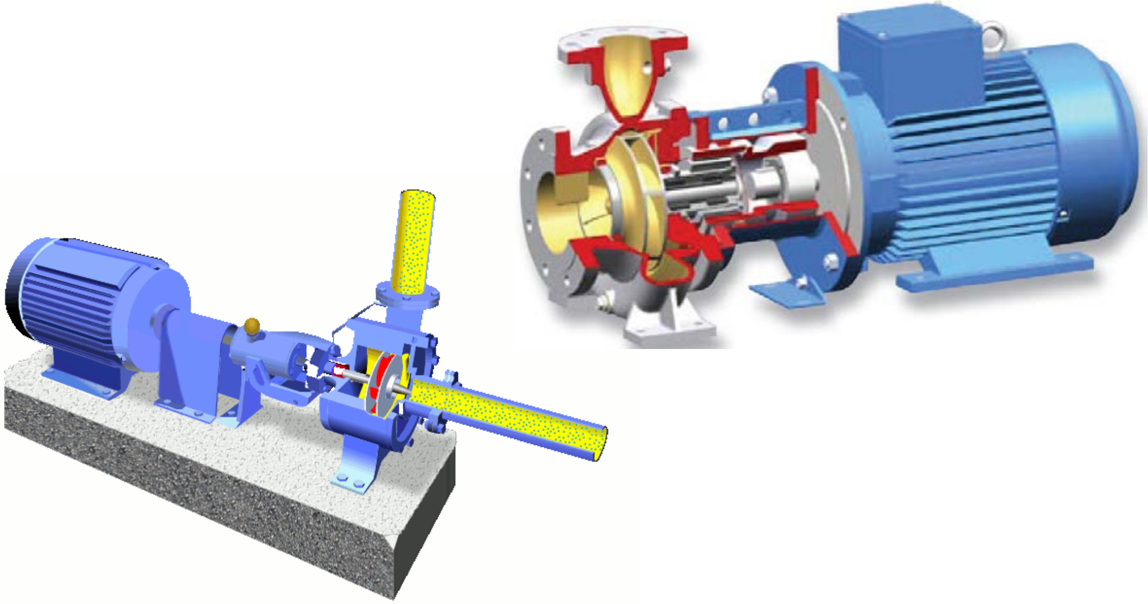
- When electric motor is energized (switched ON), the impeller rotates creating suction at the suction pipe. Due to suction created, the water from the sump/reservoir starts flowing into the casing through the impeller eye.
- The centrifugal force created by the rotating impeller acts on water causing it to flow radially outward and towards the outlet of the casing.



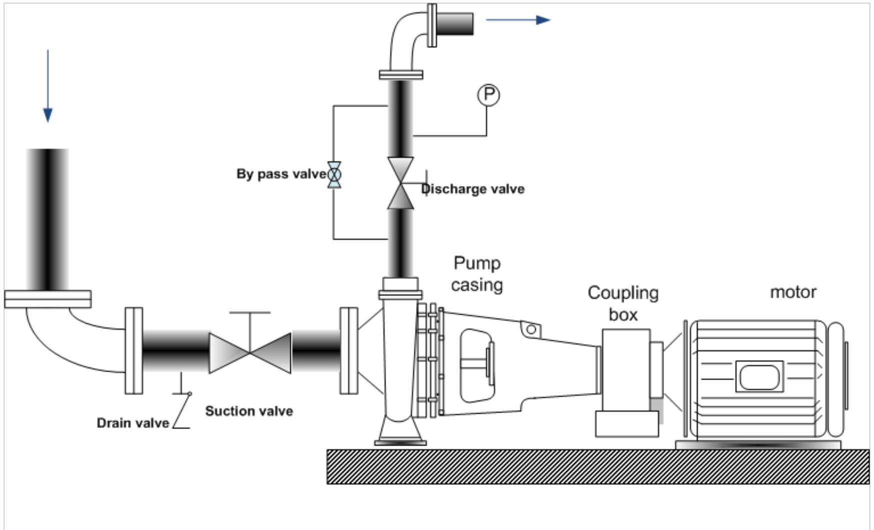


- As the water flows through the casing, its velocity decreases due to increasing cross sectional area of casing.
- The decrease in the velocity increases the pressure of water and reaches to maximum at the outlet of the casing.
- The water flows through the delivery pipe into the overhead tank.
- When the fluid is discharged to the delivery pipe, a partial vacuum is created near impeller eye, which causes the fluid in sump (at atmospheric pressure) to rush through suction pipe to replace the fluid that is being discharged.
- Thus the water is pumped continuously from sump to overhead tank through delivery pipe.





Advantages	Disadvantages
1. All types of fluids can be used	1. Pump must be primed before pumping can begin
2. Output flow is steady and consistent	2. Develops cavitation resulting in failure of parts
3. Can be mounted vertically or horizontally	3. Not suitable for gases
4. Simple and compact design	4. Loss of energy due to magnetic resonance

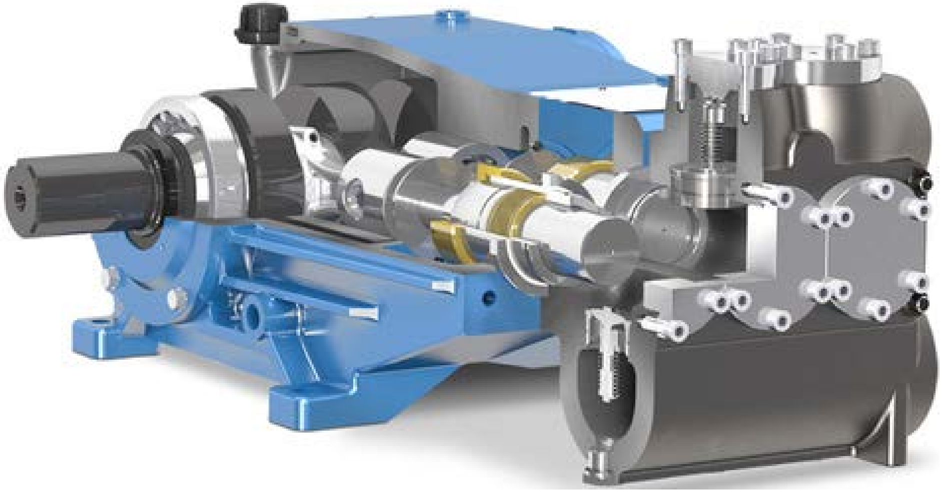


Centrifugal pump system

Reciprocating pump

- In reciprocating pump, the pressure energy of fluid is increased by pushing the fluid using piston/plunger that reciprocates in closed fitting cylinder. (Reciprocating motion of piston/plunger – flow pressure of fluid)
- Applications: (low discharge rate with high pressure) water jet cutting, salt water disposal, well services, descaling, hydraulic fracturing, inflating tyres etc.

Reciprocating Pump

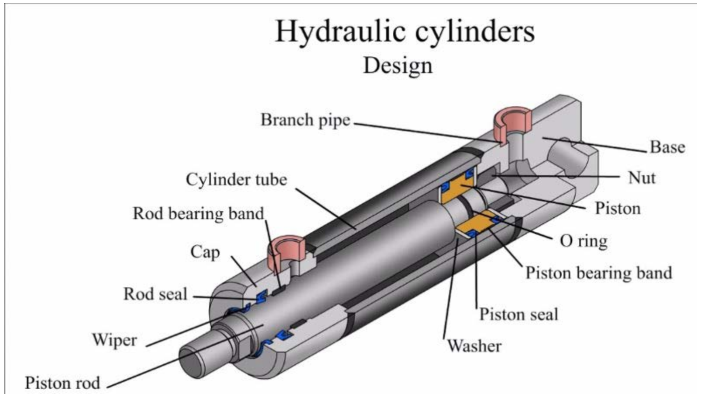


Parts of reciprocating pump

1. Cylinder with piston and piston rod

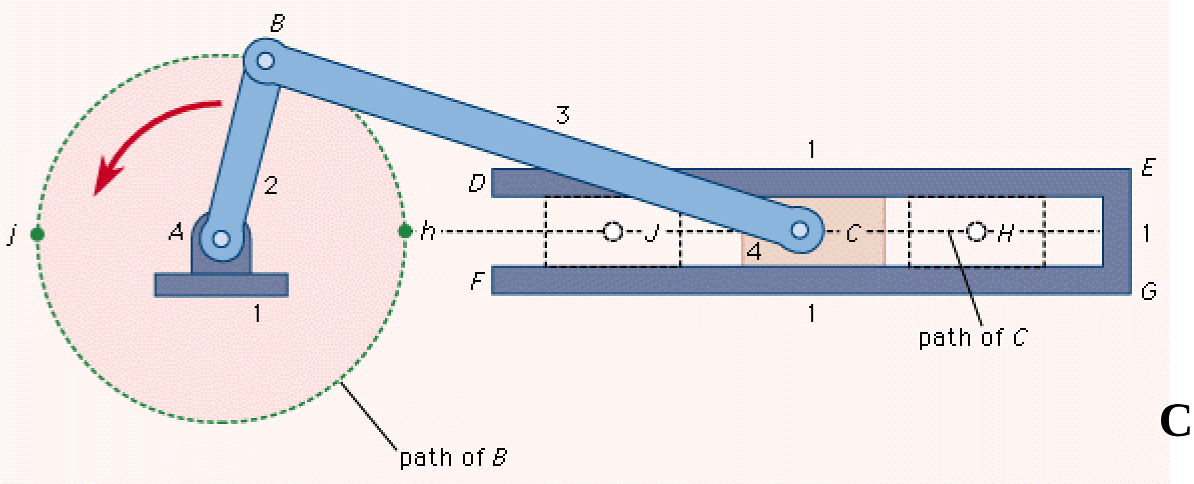
- A hollow cylinder made of steel alloy or cast iron. Arrangement of piston and piston rod is inside this cylinder.
- Both suction and delivery pipes along with valves are connected to the cylinder.
- Piston is a solid type cylinder part which moves backward and forward inside the hollow cylinder to perform suction and deliverance of liquid. Piston rod helps the piston to move in linear motion.

Piston



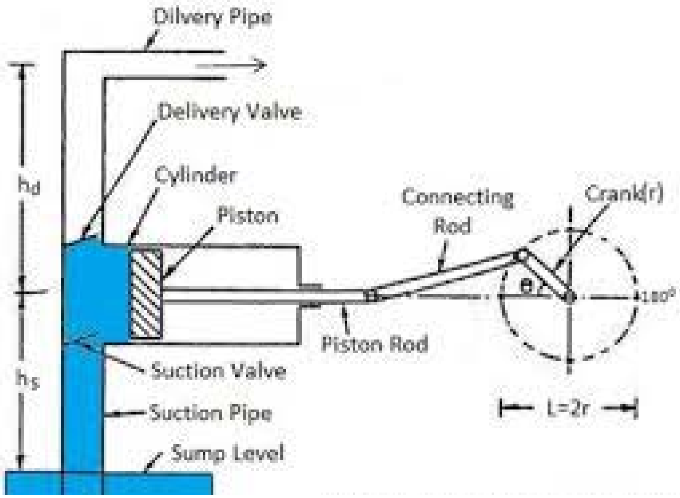
2. Crank and connecting rod

- Crank is a solid circular disc which is connected to power source (motor, engine) for its rotation.
- Connecting rod connects the crank to the piston. The rotational motion of crank gets converted into linear motion of the piston by means of connecting rod.



Crank – connecting rod assembly

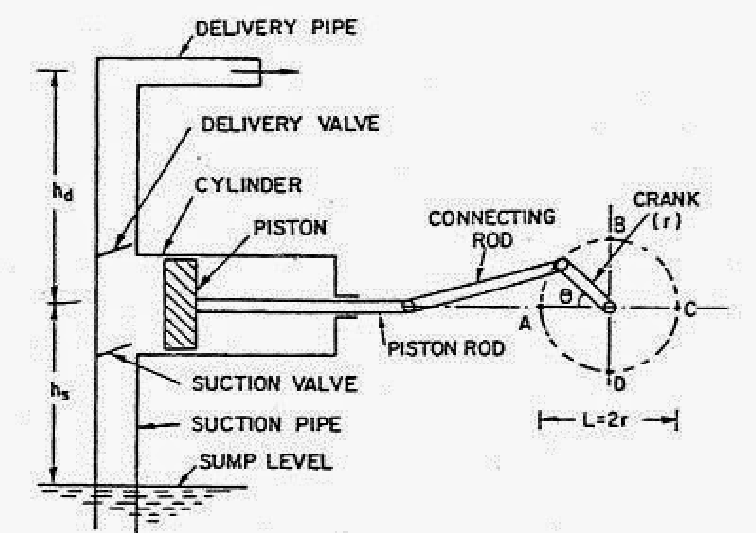
3. Suction pipe and delivery pipe



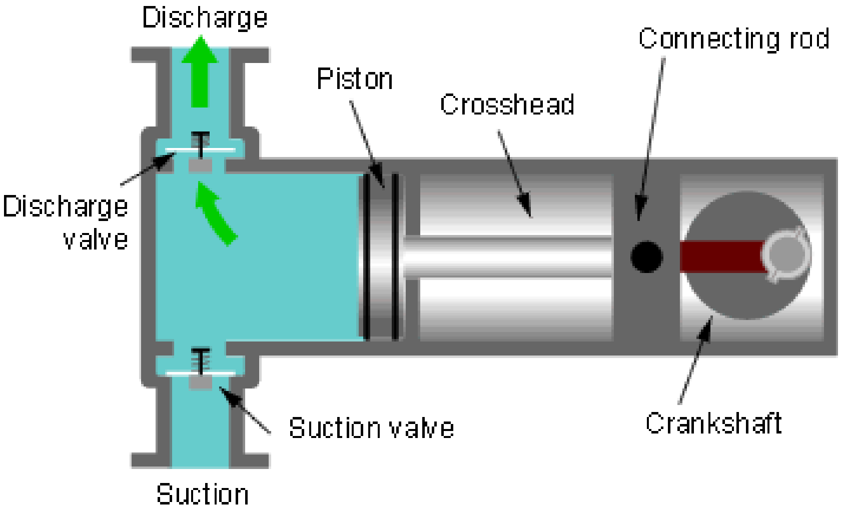
- The lower end of suction pipe is immersed in sump/reservoir from where the fluid is to be lifted up while the upper end of the pipe links to the cylinder inlet.
- Lower end of the delivery pipe is connected to the cylinder outlet while the upper end is connected to the discharge point or where the fluid is to be pumped.
- Both the pipes are provided with control valves i.e. suction valve and delivery valve which are non-return/one-way valves allowing water to flow in single direction only.

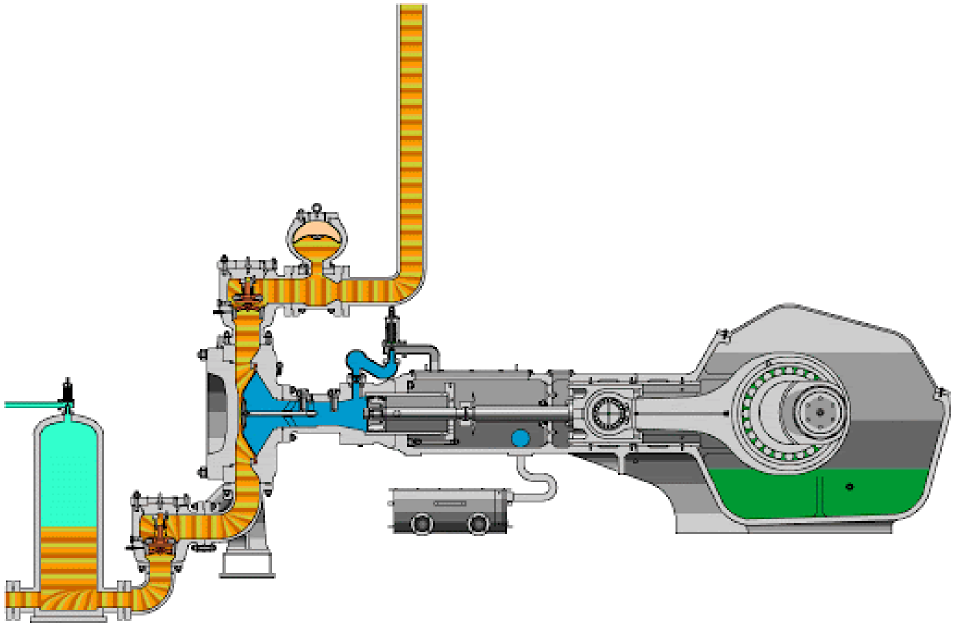
Working of reciprocating pump

- When electric motor is energized (switched ON), the crank rotates, transferring motion to the piston, which reciprocates (to and fro movement) inside the cylinder.
- I half cycle: When crank rotate from point A to C (180° rotation), piston moves towards right of the cylinder, creating partial vacuum within the cylinder.
- Since atmospheric pressure acting on the water in sump > than suction pressure inside the cylinder, water from sump is forced in suction pipe to move into the cylinder.
- The force of fluid opens the suction valve, causing it to move into the cylinder. The delivery valve remains closed during this action.

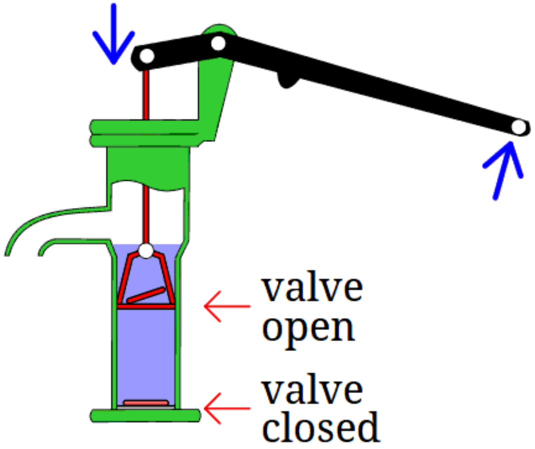


- II half cycle: When crank rotates from point C to A (180°), piston moves towards left of cylinder from extreme right side.
- The movement of piston towards left, increases the pressure of the fluid inside the cylinder more than atmospheric pressure. Hence suction valve closes and delivery valve opens.
- The liquid is forced into the delivery pipe to get discharged to required destination (tank).



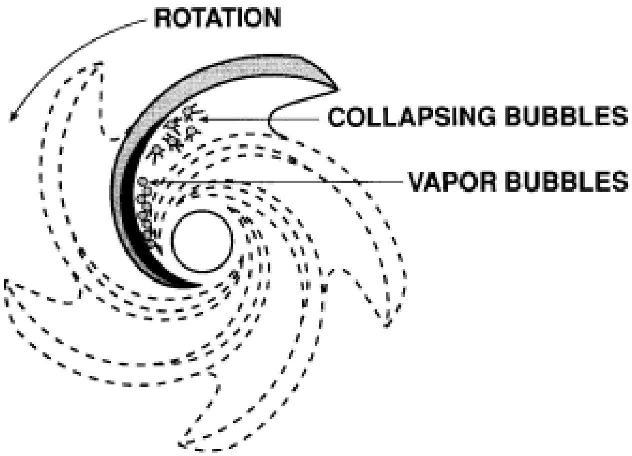


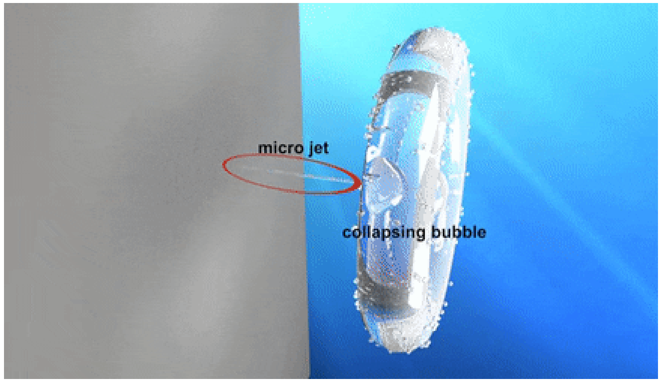
Advantages	Disadvantages
1. High discharge pressure can be obtained 2. High suction lift 3. Priming is not required 4. Air/Gases can be pumped.	1. Low flow rate 2. Heavy and bulky in size 3. Wear and tear of reciprocating parts. (High maintenance) 4. High investment cost.



Cavitation in centrifugal pumps

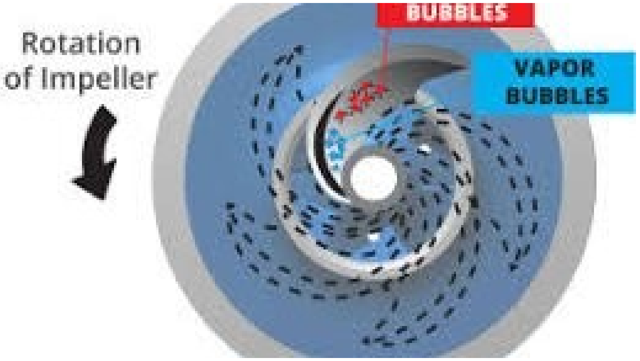
- Phenomenon of formation of vapour bubble and its subsequent collapse in the low pressure region around the pump parts.
- Identified by a clear audible noise and vibrations caused by the violent collapse of vapour bubbles.
- Bubble formation: It usually occurs when a liquid is subjected to changes of pressure such that the static pressure goes lower than the liquid's vapour pressure which will cause the formation of bubbles in the liquid.
- When subjected to higher pressure, the bubbles implode. When these implosions happen near a solid material for e.g. impeller, the bubbles implode with a micro-jet hitting the material surface, causing erosion.





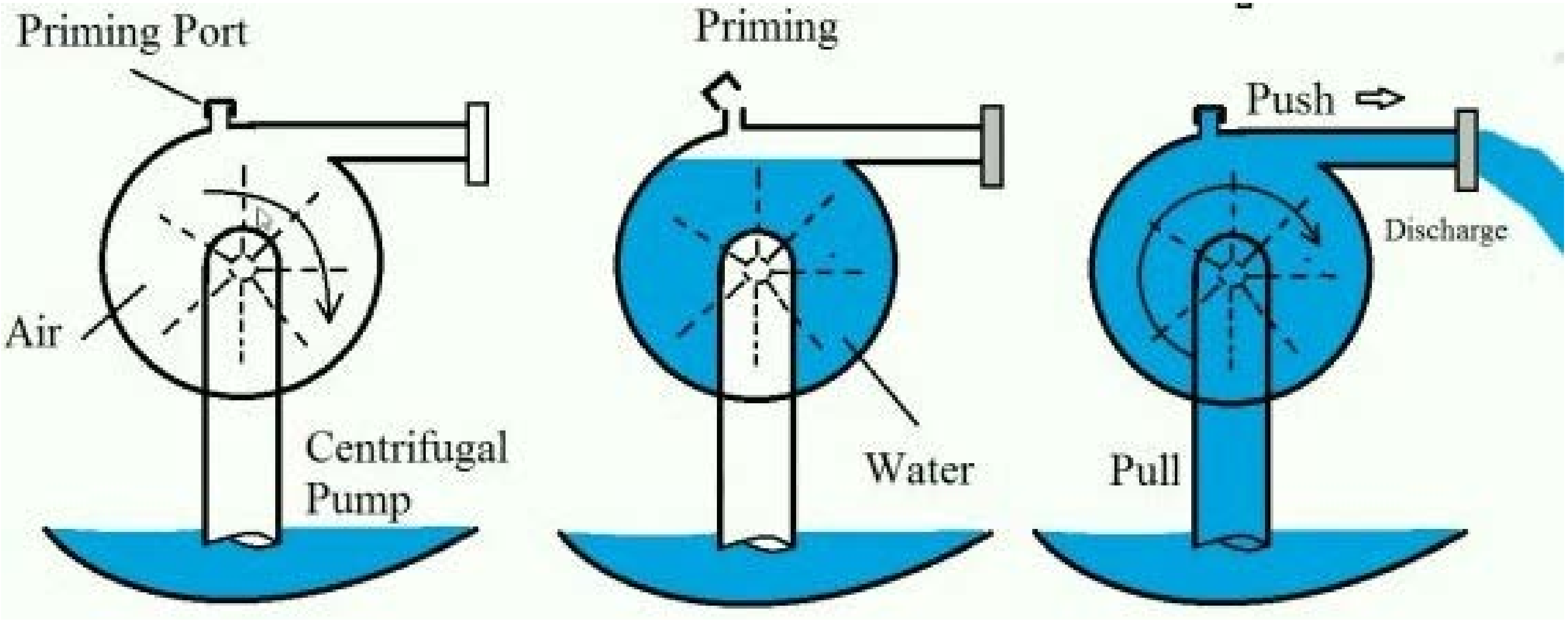
- Repeated bursts of micro-jets will cause further erosion which spreads and ultimately results in catastrophic equipment failure.
- The power consumption for pump operation increases and also there is a decrease flow pressure.
- Precautionary measures to avoid cavitation in pumps

i. Ensure suitable liquid level in suction pipe
ii. Lower the water temperature
iii. By suitable impeller design
iv. Periodic checking of clogged strainers and blockages in pipes.
v. Ensures that the pressure of fluid at all points within the pump remains above saturation pressure.



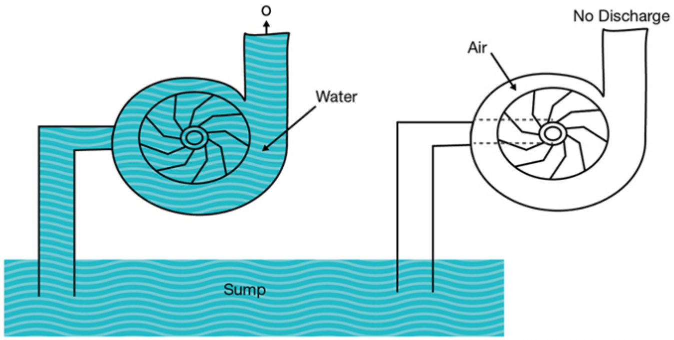
Priming of Centrifugal pumps

- Process of filling fluid into the casing, suction pipe and delivery pipe up to the delivery valve before starting the pump.
- Priming is required in order to remove the air entrapped in the pump, thereby reducing the risk of pump damage during start-up.



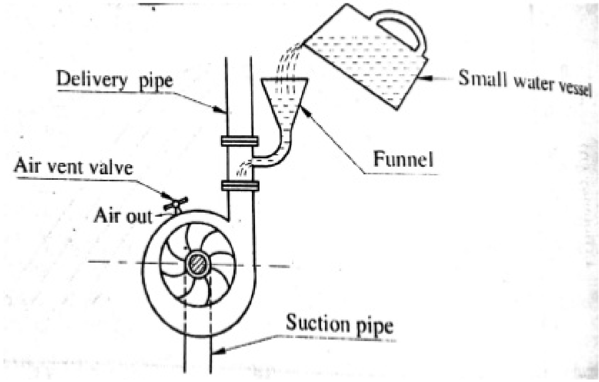
Need for priming

- Pressure developed inside the pump ∝ density of fluid in it.
- In case, if air is trapped in the pump and the impeller is allowed to rotate, pressure energy of fluid is not sufficient to lift up; because density of fluid is less [due to presence of air particle].
- The presence of air in the pump creates a small negative pressure at the suction pipe that prevents suction of fluid from sump
- In order to eliminate the trapped air, pump is filled with fluid before starting it. [when filled with fluid, the pump is said to be primed]



No need of priming as impeller is running in water

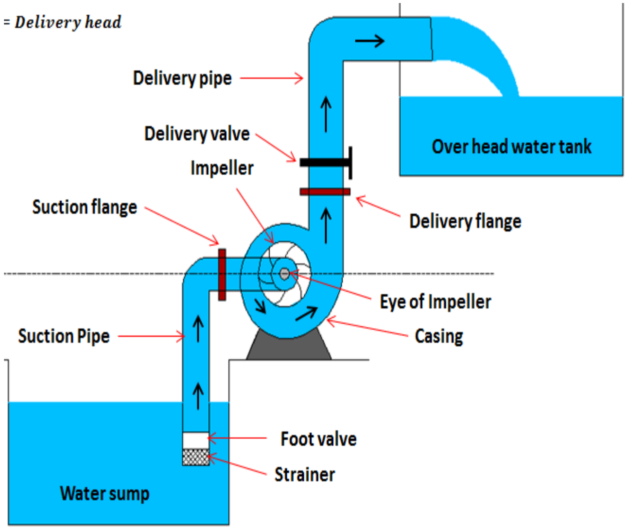
Priming is required as impeller is running in air

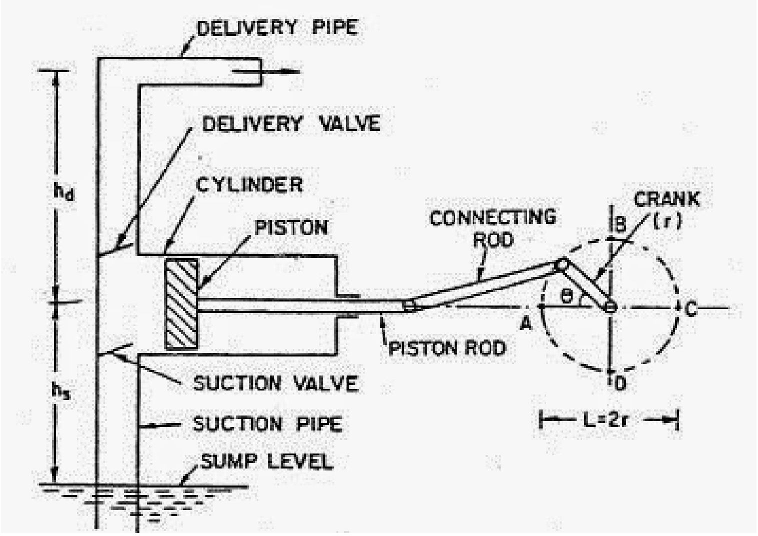


Specification of hydraulic pumps

Hydraulic pumps are generally specified by the following criteria;

- Maximum discharge pressure – the maximum pressure that the pump is designed to generate
- Maximum discharge flow – the maximum flow that the pump is designed to generate
- Discharge size – size of pump discharge or outlet connection
- Pump type and its features – reciprocating or centrifugal pump
- Power source – AC/DC
- HP (horse power) – rate at which mechanical energy is expended
- Housing material – Al, cast iron, stainless steel etc.





Differences between centrifugal pump and reciprocating pump

Sl. No	Centrifugal pump	Reciprocating pump
1	Pumps which uses mechanical energy of impeller to transfer fluid	Pump which uses force exerted by piston to transfer fluid
2	Flow rate decreases with increase in the pressure of fluid	The pressure does not affect flow rate in reciprocating pumps.
3	Discharge is inversely promotional to the viscosity of fluid.	viscosity of fluid does not affect the discharge rate.
4	Efficiency of these pumps are low compare to reciprocating pump.	Efficiency is high
5	Discharge of fluid is continuous	It does not discharge the fluid continuously.
6	Centrifugal pump have problem of priming.	It does not have any problem of priming
7	Easy to install, requires less floor space	Difficult to install, more floor space required
8	Requires less maintenance (low cost)	More maintenance (High cost)

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Module – 3.1

Internal Combustion Engines

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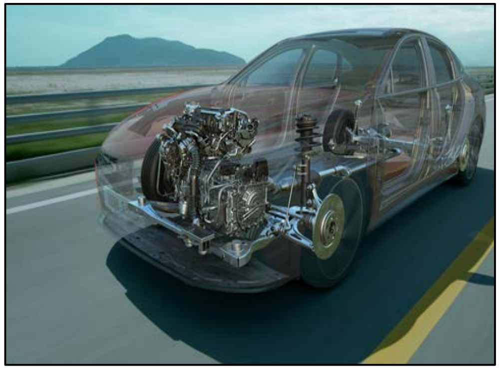
I.C Engines

- An engine or heat engine: Device/machine that converts chemical energy of a fuel into heat energy by combustion of fuel and utilizes developed heat energy to perform useful mechanical work

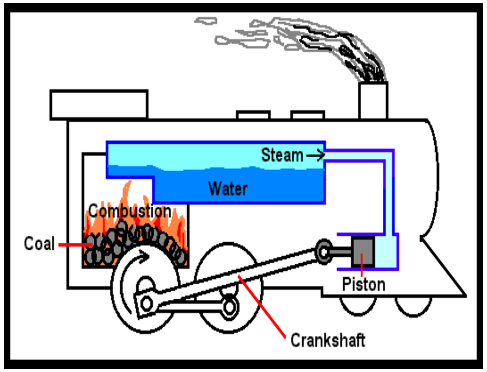
[*Chemical energy* $\xrightarrow{\textit{Combustion}}$ *Heat energy* $\xrightarrow{\hspace{6em}}$ *Mechanical work*]

- Examples : Vehicle engines (Petrol / Diesel), steam engines, gas engines, steam turbines, gas turbine engines etc.



4-wheeler Engine (Diesel engine)

2-wheeler Engine (petrol engine)



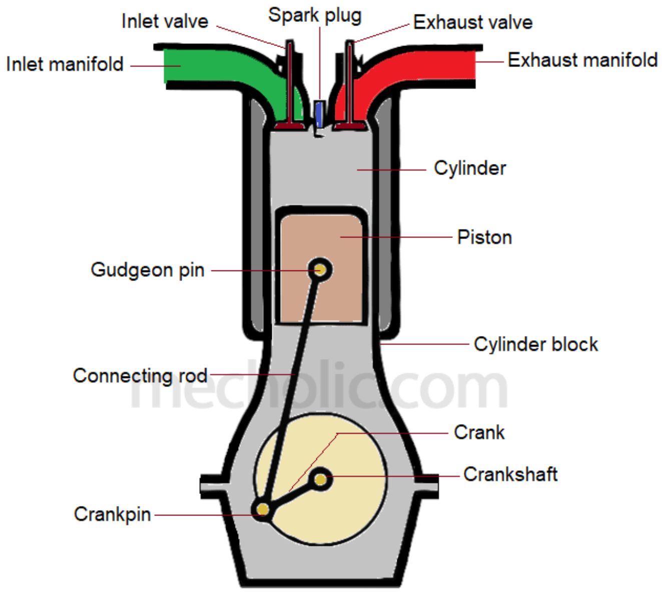
Steam engines used in trains

Aircraft engine

Types of heat engine:

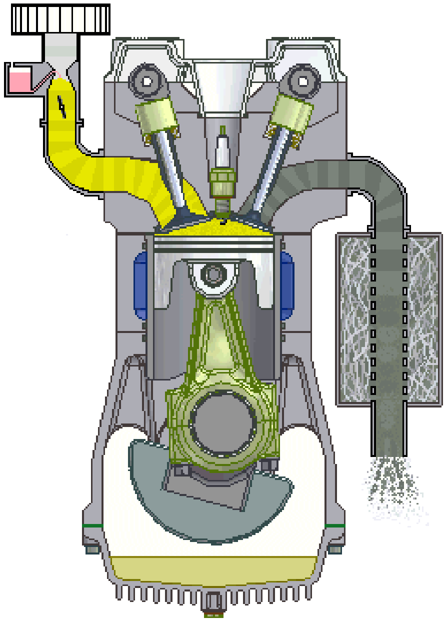
i. **Internal combustion engine (IC engine)**

ii. **External combustion engine (EC engine)**

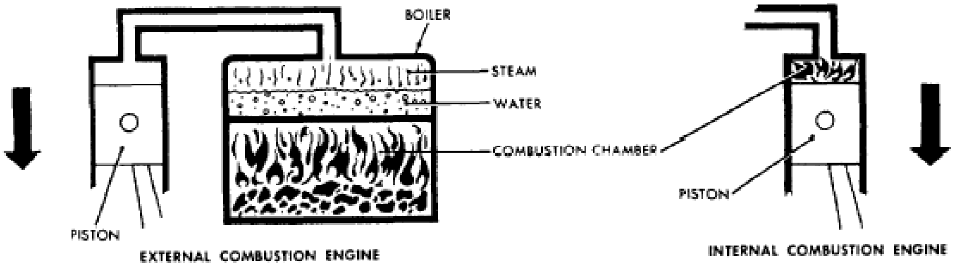


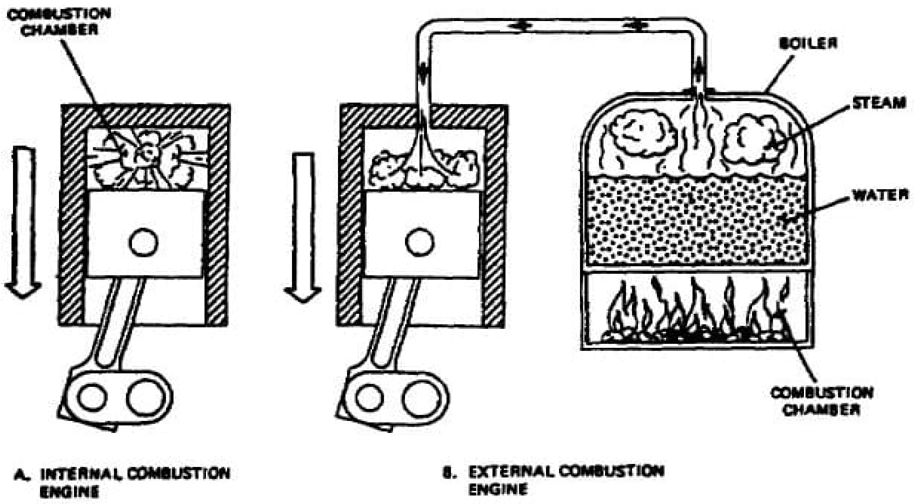
Internal combustion engine

- If the combustion of the fuel takes place inside the engine cylinder, the engine is called internal combustion engine. (petrol/diesel engine and gas engine)
- In IC engines, burning gas inside the engine cylinder expands and exerts force to the movable part called piston.
- The linear motion from the piston is converted into rotary motion of crankshaft by means of connecting rod and crank.
- The motion at the crankshaft can be used to drive any machines or devices or perform other useful work.



External combustion engine





- If the combustion of the fuel takes place outside the engine cylinder, the engine is called external combustion engine. (steam engine, steam turbines and closed cycle gas turbines)
- In EC engines, heat obtained by burning the fuel outside the engine cylinder is used to convert water into steam.
- The steam expands within the cylinder which produces linear motion of piston.
- Further, linear motion of piston is converted into rotary motion of crankshaft which drives a machine or perform useful work.

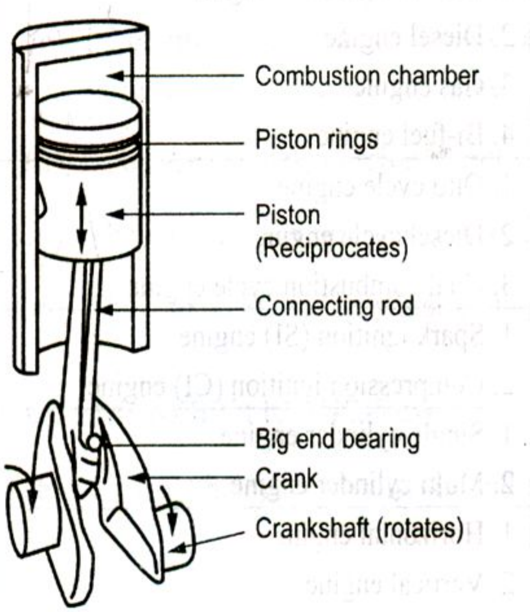
Classification of IC engines

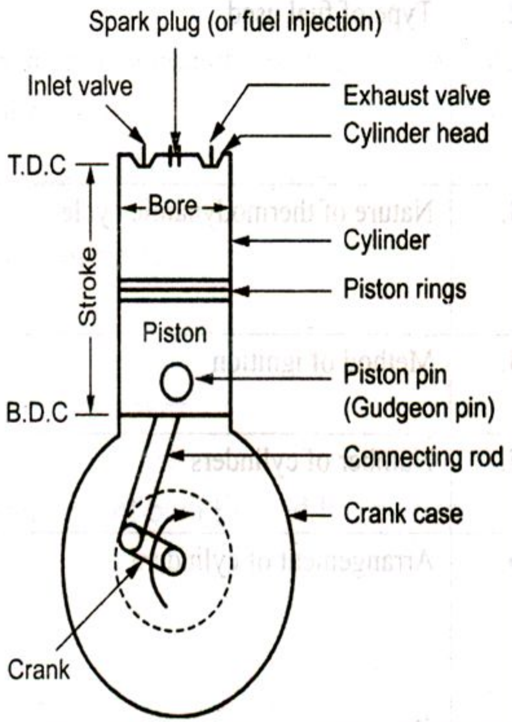
Sl. No.	Categories	Types
1	Type of fuel used	1. Petrol engine 2. Diesel engine 3. Gas engine 4. Bi-fuel engine
2	Method of ignition	1. Spark ignition engine (SI engines) 2. Compression ignition engine (CI engines)
3	No. of strokes/cycle	1. 4-stroke engine 2. 2-stroke engine
4	Cycle of combustion	1. Otto cycle engine (constant volume cycle) 2. Diesel cycle engine (constant pressure cycle) 3. Dual combustion cycle engine (initially constant V and finally at constant P)
5	No. of cylinders used	1. Single cylinder engine (one cylinder) 2. Multi cylinder engine (2 to maximum of 12 cylinders)
6	Arrangement of cylinder	1. Vertical engine 2. Horizontal engine 3. Inline engine 4. Radial engine 5. V-engines 6. Opposed type engine

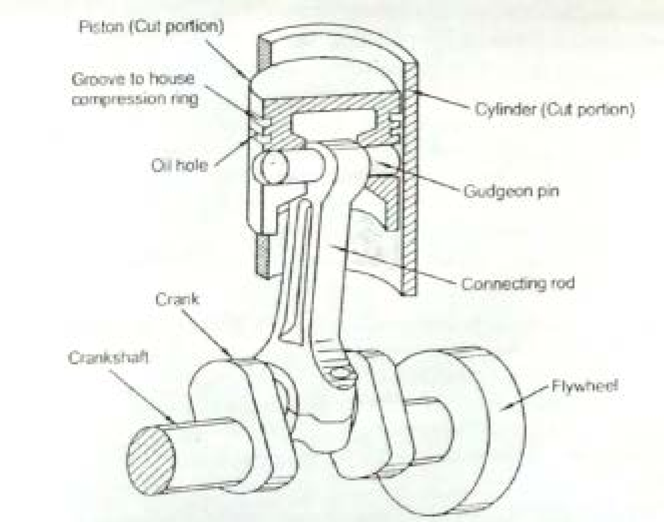
Sl. No.	**Categories**	**Types**
7	Method of cooling	1. Air cooled engines 2. Water cooled engines
8	Uses	1. Stationary engines 2. Automobile engines 3. Marine engines 4. Aircraft engines

Parts of IC engines

1. Cylinder (cylinder block)
2. Cylinder head
3. Piston
4. Piston rings (compression rings & oil rings)
5. Connecting rod
6. Crank
7. Crankshaft
8. Crankcase
9. Flywheel
10. Inlet & exhaust valve

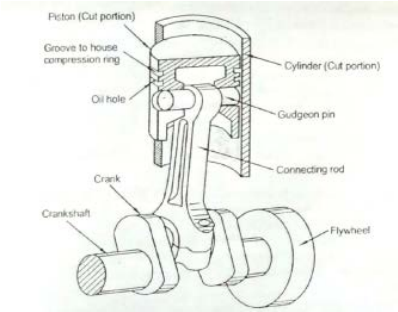




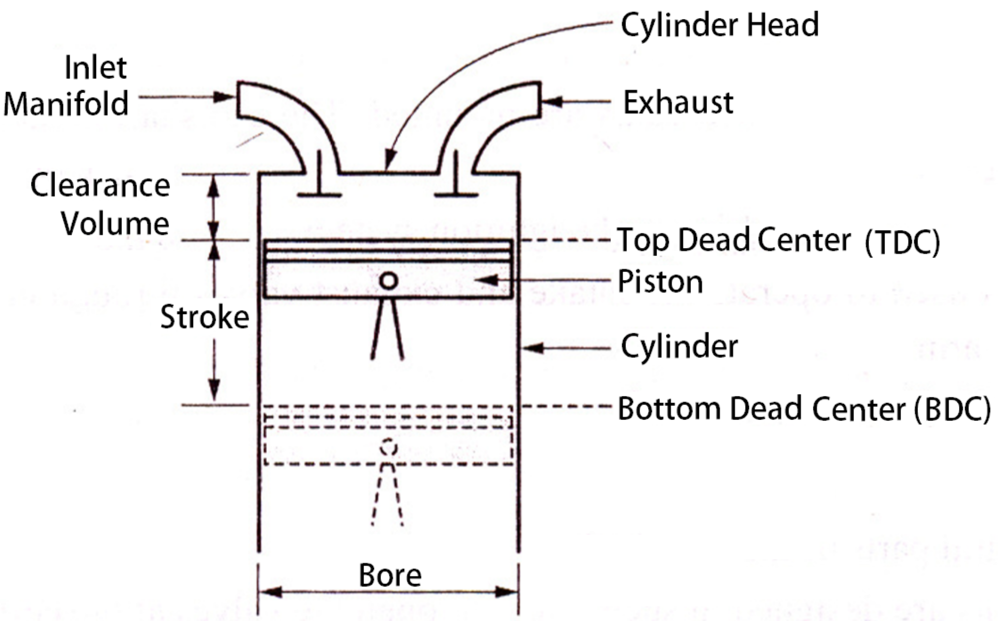


Part of IC engine	**Features/Functions**
Cylinder	• Cylinder shaped component in which combustion of fuel takes place. (Gray cast or steel alloy – to withstand high pressure and temperature). • Functions : i. To contain working fuel under pressure. ii. To guide the piston while reciprocating inside cylinder.
Cylinder head	• Top portion of the cylinder is covered by a removable component called cylinder head. • Designed to incorporate inlet and exhaust valves, spark plug
Piston	• Cylindrical shaped component placed inside the cylinder (cast iron and aluminium alloys). • Functions: i. To receive the force/impulse produced by combustion of fuel and to transmit force to crankshaft through connecting rod. ii. Acts as a supporting member for upper end of connecting rod. iii. To compress the fuel during working cycle. iv. Serves as a carrier for the piston rings.

Part of IC engine	**Features/Functions**
Piston rings 	• Metallic split rings that are attached to the outer diameter of a piston. • Types : Compression rings & oil rings • Compression rings : Usually 2 in numbers. These rings press hard with the cylinder walls maintaining a tight seal between piston and cylinder (Prevents escaping of high pressure gases into crankcase). • Oil rings: Extracts excess of lubricating oil from the cylinder walls and send it back to oil source through the holes (oil holes) provided on the piston.
Connecting rod	• A link between piston and crankshaft. • Upper end of the connecting rod is connected to the piston by piston pin while lower end is connected to the crankshaft through crank. • Converts the reciprocating motion of the piston into rotary motion of crankshaft.
Crank	• An arm attached at a right angle to a rotating shaft. • One end connected to lower end of connecting rod and other end connected to crankshaft.

Part of IC engine	Features/Functions
Crankshaft 	• Rotating shaft which converts reciprocating motion of piston into rotational motion. • Transmits the power developed by engine through flywheel, clutch, transmission and differential to drive the vehicle. • Usually made of steel and nickel alloys
Crankcase	• Case or covering that encloses the crankshaft • Provides a reservoir for lubricating oil
Flywheel	• Large disc or a wheel mounted on the crankshaft • Provides an inertial mass that stores rotational energy and supplies the same for the piston to reciprocate during subsequent strokes.
Inlet and exhaust valve	• Fresh air and/or fuel mixture enters the engine cylinder through the inlet valve • Burnt gases are discharged outside the cylinder through exhaust valve • Both the valves are opened and closed by means of cams driven by the camshaft through a timing gear/chain so that charge enters or discharges at the right time.

IC Engine Terminology



1. **Bore:** It is the inner diameter of the cylinder. Denoted by ‘d’.
2. **Top dead center (TDC):** The extreme position of the piston near to the cylinder head is called TDC.
3. **Bottom dead center (BDC):** The extreme position of the piston near to the crankshaft is called BDC.
4. **Stroke or stroke length:** The linear distance travelled by the piston when it moves from BDC to TDC is called stroke or stroke length. Denoted by ‘L’.
5. **Stroke volume/swept volume/piston displacement:** The volume swept by the piston when it moves from BDC to TDC is called stroke volume (V_s).
6. **Clearance volume:** The volume of the cylinder above the top of the piston when the piston is at TDC is called clearance volume (V_c)

7. **Compression ratio:** Ratio of total cylinder volume to the clearance volume.

Total cylinder volume = stroke volume (V_s) + clearance volume (V_c)

Therefore, compression ratio = $R_c = \frac{V_s + V_c}{V_c}$

"Higher the compression ratio – more powerful the engine and higher the efficiency"

- *Example:* The R_c of petrol engine is 8:1. It means fuel mixture is compressed inside the engine cylinder to about 1/8th of its original volume. In case of diesel engine R_c is 16:1. Thus diesel engines are capable of producing more power than petrol engine and hence more efficient.
- However, the compression ratio should not exceed the limit in order to avoid pre-ignition of the fuel mixture, which causes engine knocking resulting in damage to the engine.

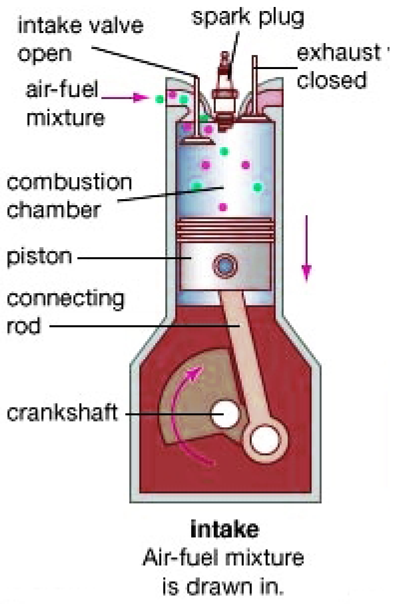
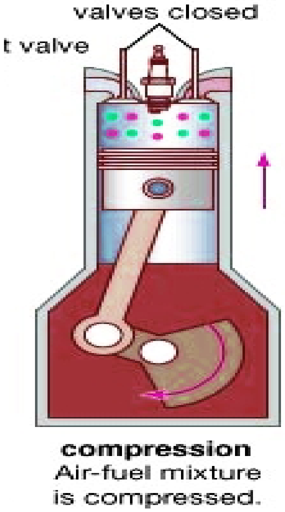
8. **Piston speed:** The average speed of the piston as it moves from BDC to TDC is called piston speed. *Piston speed = 2.L.N* ………(m/min) where L – stroke length in meters, N – engine speed in revolutions per minute (rpm)

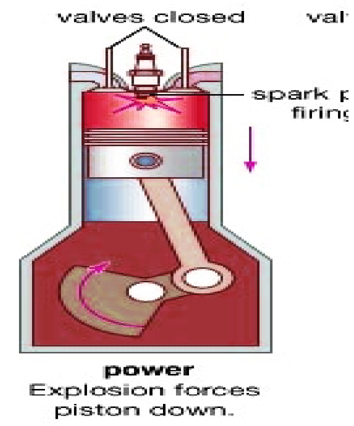
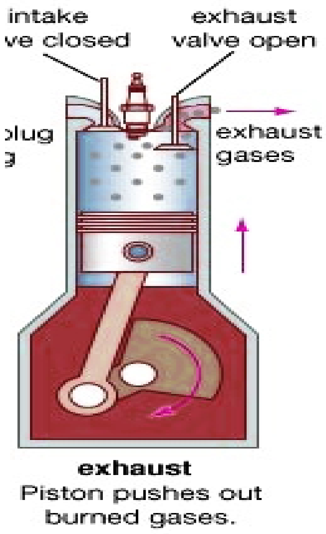
Four stroke (4-s) engines

- Working cycle is completed in four different strokes of the piston or two revolution of crankshaft
- Four different strokes performed :
  1. Suction stroke
  2. Compression stroke
  3. Power stroke/expansion stroke/working stroke
  4. Exhaust stroke
- Types of 4-s engines: *4-stroke petrol engine* and *4-stroke diesel engine*

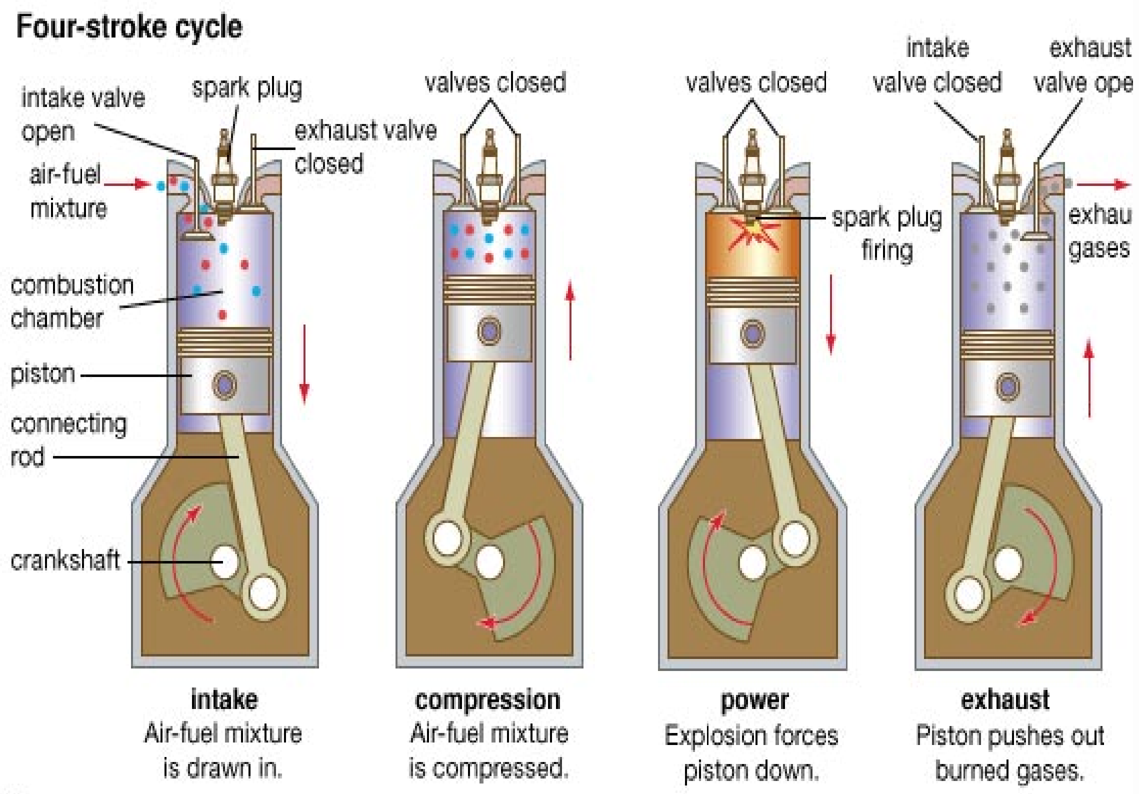
4-stroke petrol engine:

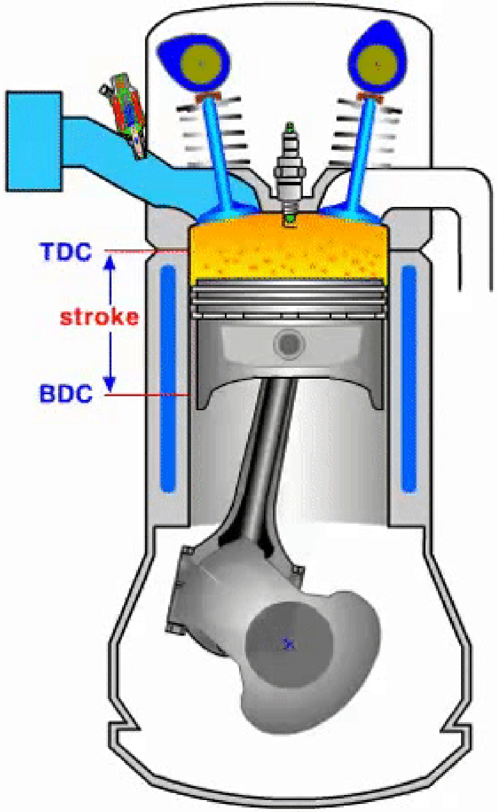
- Works on Otto cycle (Otto cycle engines).
- Charge used: mixture of air and petrol supplied by carburettor in suitable proportions.
- The charge is ignited by spark generated by a spark plug (S.I engines).
- Uses of 4-s petrol engine: scooters, motor bikes, cars, large boats etc.

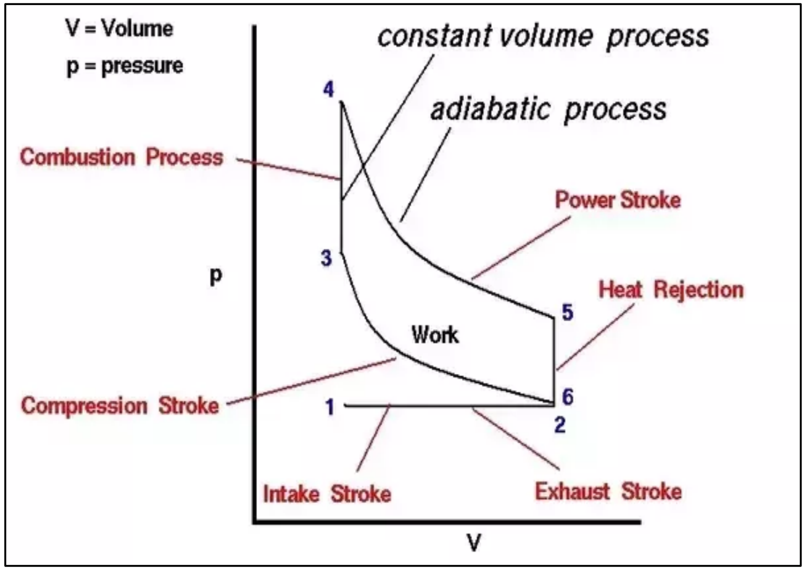
 ***Suction stroke***	• At the beginning of suction stroke, piston is at the TDC and is about to move towards BDC [inlet valve – opened, exhaust valve – closed]. • The downwards movement of piston produces partial vacuum (suction) in the cylinder, which draws fresh air and petrol mixture through the inlet valve. • When the piston reaches BDC, suction stroke ends and inlet valve is closed. • The suction of fuel mixture takes place at atmospheric pressure [Line AB in *pv* diagram] • With this stroke, crankshaft rotates through 180° / half revolution. [The energy required for the piston movement is taken from the battery].
 ***Compression stroke***	• Piston moves from BDC to TDC [both inlet and exhaust valve remains closed]. • As the piston moves upwards, air-petrol mixture gets compressed due to which p and T of mixture increases. • The compression process is adiabatic in nature [Curve BC] • When piston about to reach TDC, spark plug initiates spark that ignites the air-petrol mixture. • Combustion of fuel mixture takes place at constant volume [Line CD](constant volume cycle engines). • With this stroke, crankshaft rotates by another 180° / half revolution.

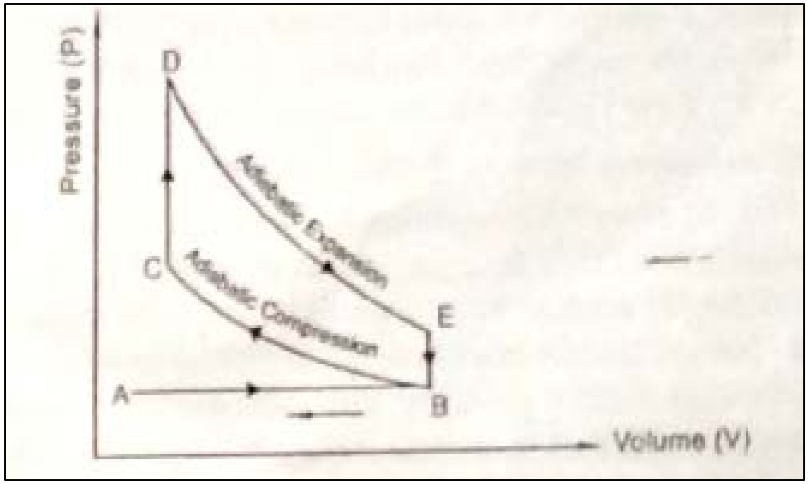
 ***Power stroke***	• During this stroke, both valves will remain closed. • As the combustion of fuel mixture takes place, the burnt gases expands and exert a large force on the piston causing it move rapidly from TDC to BDC. • The force/power is transmitted to the crankshaft through the connecting rod. As a result, crankshaft rotates at high speed [Clutches – gears – wheels of vehicle] • The expansion of gases is adiabatic in nature [Curve DE]. • Power/working/expansion stroke
 ***Exhaust stroke***	• Towards the end of expansion stroke, the exhaust valve opens and inlet valve remains closed. • A part of burnt gases due to their own expansion escapes out of the cylinder through exhaust valve [drop in pressure at constant volume inside the cylinder – Line EB] • The exhaust stroke begins when the piston starts moving from BDC to TDC [Energy for this stroke – flywheel] • As the piston moves upwards, forces remaining burnt gases to the atmosphere through exhaust valve [Line BA] • When the piston reaches TDC, the exhaust valve closes and the working cycle is completed.

- In the next cycle, the piston starts moving from TDC to BDC, the inlet valve open allowing fresh charge to enter into the cylinder and the process continues.
- Thus in 4-s engines, the working cycle is completed when crankshaft rotates through 720° or two revolutions.





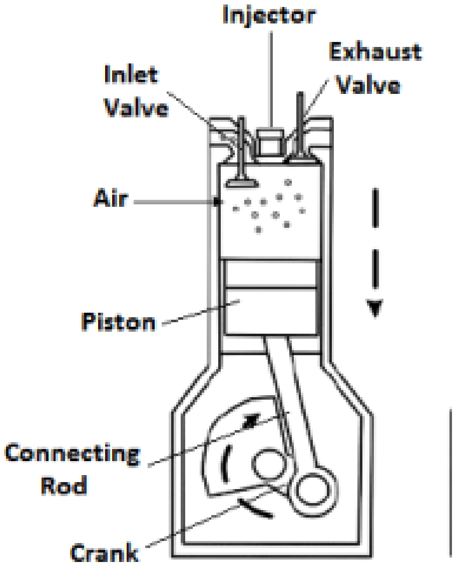
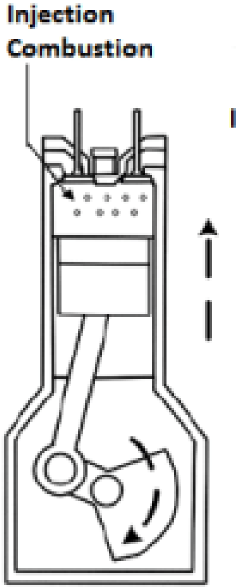


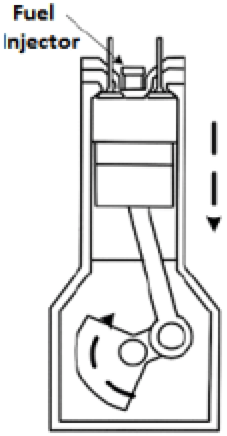
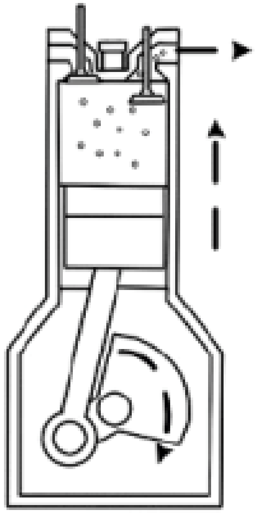


p-v diagram of 4-s petrol engine

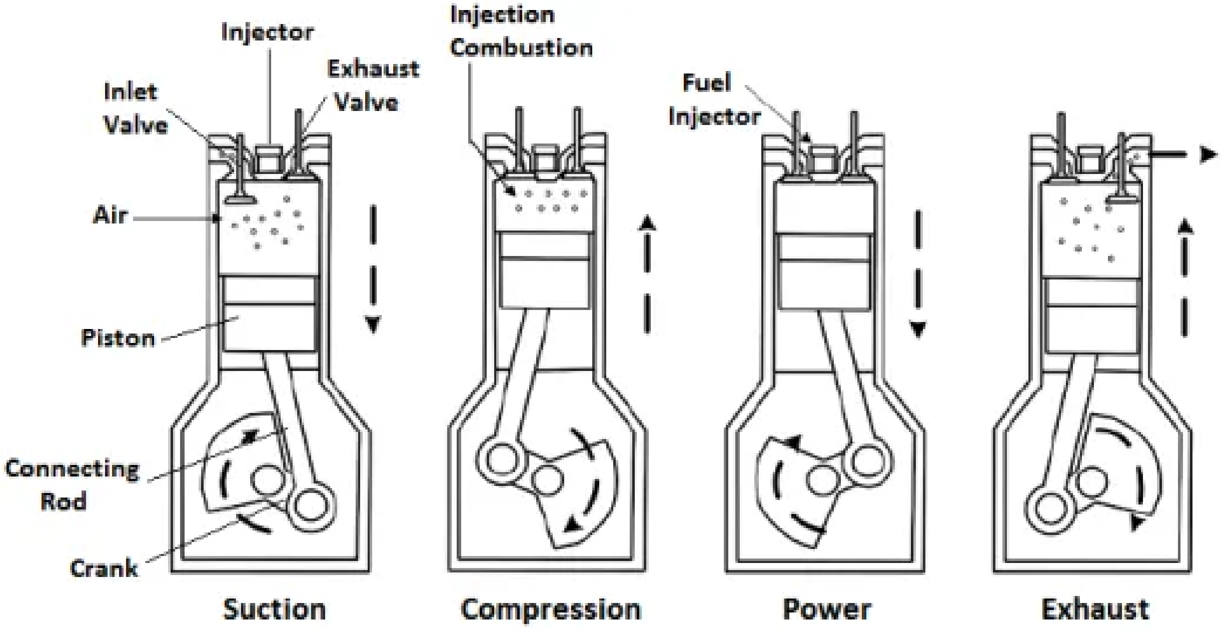
4-stroke diesel engine

- Works on diesel cycle [diesel cycle engines]
- Working principle is similar to that of 4-s petrol engine, except a fuel injector is used in place of spark plug.
- Only air enter the cylinder during suction stroke and gets compressed in compression stroke [compression ignition engines].
- Four different strokes performed :
  1. Suction stroke
  2. Compression stroke
  3. Power stroke/expansion stroke/working stroke
  4. Exhaust stroke
- Used for heavy duty applications such as in buses, trucks, tractors, bulldozers, marine and industrial applications.

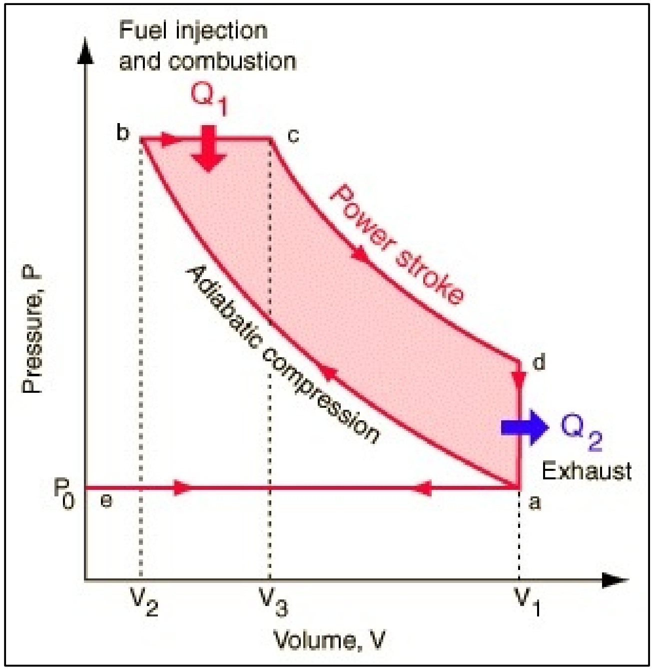
 ***Suction stroke***	• At the beginning of suction stroke, piston is at the TDC and is about to move towards BDC [inlet valve – opened, exhaust valve – closed]. • The downwards movement of piston produces partial vacuum (suction) in the cylinder, which draws fresh air through the inlet valve. • When the piston reaches BDC, suction stroke ends and inlet valve is closed. • The suction of fuel mixture takes place at atmospheric pressure [Line AB in *pv* diagram] • With this stroke, crankshaft rotates through 180° / half revolution. [The energy required for the piston movement is taken from the battery].
 ***Compression stroke***	• Piston moves from BDC to TDC [both inlet and exhaust valve remains closed]. • As the piston moves upwards, air in the cylinder gets compressed due to which p and T of air increases. • The compression process is adiabatic in nature [Curve BC] • When piston about to reach TDC, metered quantity of diesel fuel is injected in the form of fine spray into the hot compressed air by a fuel injector. • Combustion of fuel takes place at constant pressure [Line CD](constant pressure cycle engines). With this stroke, crankshaft rotates by another 180° / half revolution.

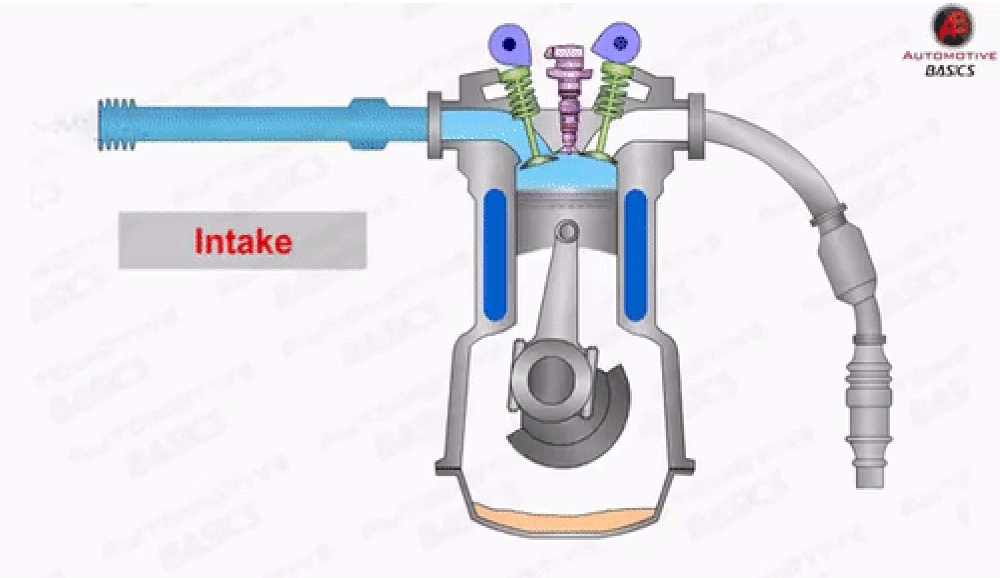
 ***Power stroke***	• During this stroke, both valves will remain closed. • As the combustion of fuel takes place, the burnt gases expands and exert a large force on the piston causing it move rapidly from TDC to BDC. • The force/power is transmitted to the crankshaft through the connecting rod. As a result, crankshaft rotates at high speed [Clutches – gears – wheels of vehicle] • The expansion of gases is adiabatic in nature [Curve DE]. • Power/working/expansion stroke
 ***Exhaust stroke***	• Towards the end of expansion stroke, the exhaust valve opens and inlet valve remains closed. • A part of burnt gases due to their own expansion escapes out of the cylinder through exhaust valve [drop in pressure at constant volume inside the cylinder – Line EB] • The exhaust stroke begins when the piston starts moving from BDC to TDC [Energy for this stroke – flywheel] • As the piston moves upwards, forces remaining burnt gases to the atmosphere through exhaust valve [Line BA] • When the piston reaches TDC, the exhaust valve closes and the working cycle is completed.

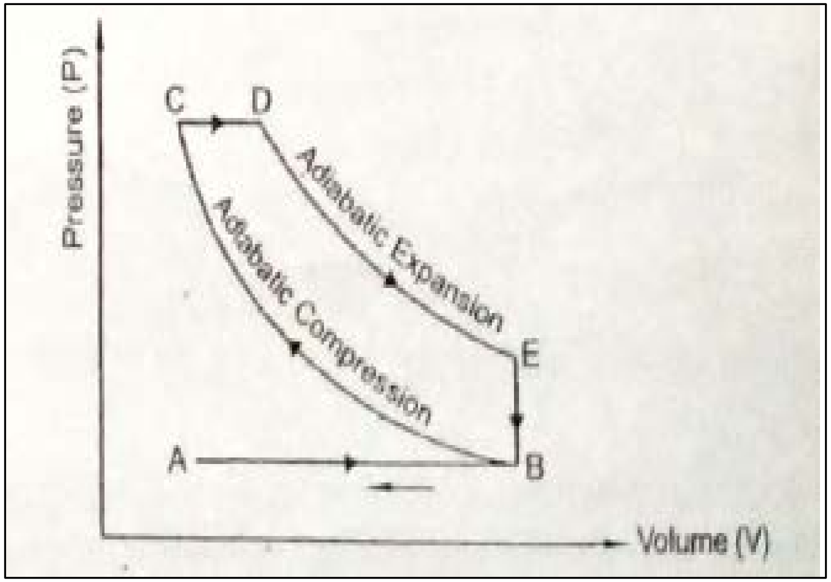
- In the next cycle, the piston starts moving from TDC to BDC, the inlet valve open allowing fresh air to enter into the cylinder and the process continues.
- Thus in 4-s engines, the working cycle is completed when crankshaft rotates through 720° or two revolutions.



Four-Stroke Diesel Cycle, Compression Ignition Engine







p-v diagram of 4-s diesel engine

Two stroke (2-s) engines

- Introduced by Dugald clerk in 1878.
- Working cycle will be completed in 360° or one revolution of crankshaft.
- In 2-s engines there are no separate suction and exhaust strokes, instead they are performed while the compression and power strokes are in progress.

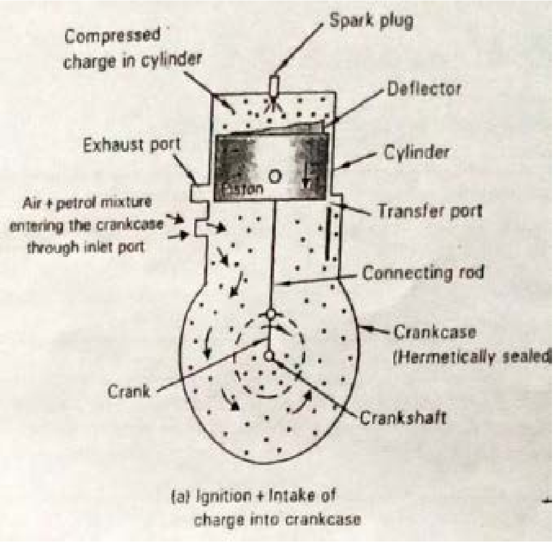
- Two different strokes performed:

  1. Downward stroke
  2. Upward stroke

- Cylinders are provided with openings called ports (acts as valves)

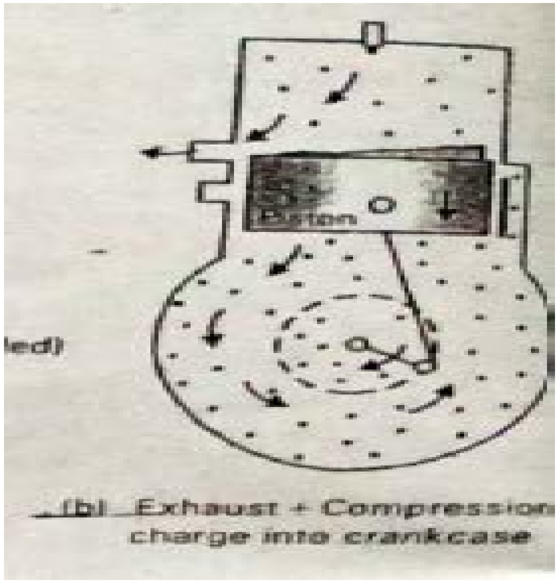
  1. Inlet port – through which charge enters the crankcase
  2. Exhaust port – through which burnt gases are discharged out of the cylinder.
  3. Transfer port – through which charge is transferred from crankcase to cylinder.
- Used in light duty vehicles – mopeds, some motor cycles

Two stroke (2-s) petrol engine



(a) Ignition + Intake of charge into crankcase

(a)

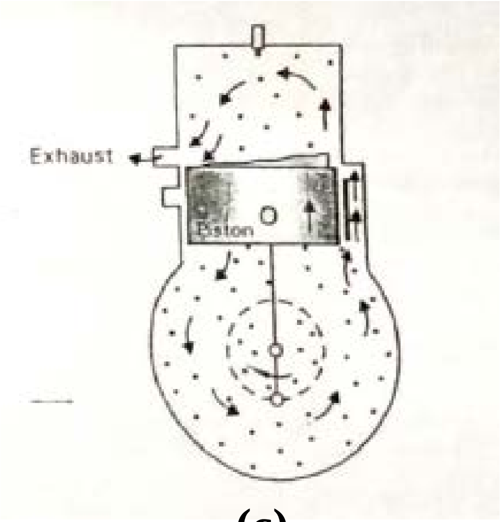
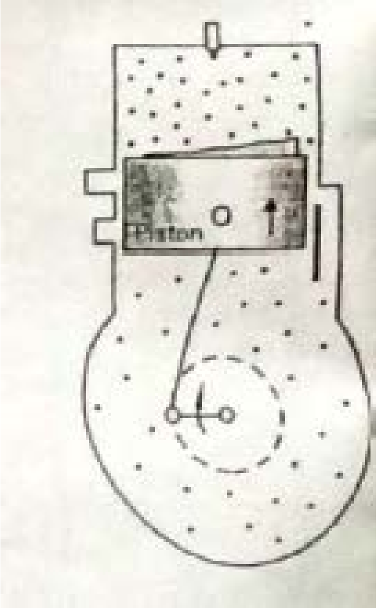


(b) Exhaust + Compression charge into crankcase

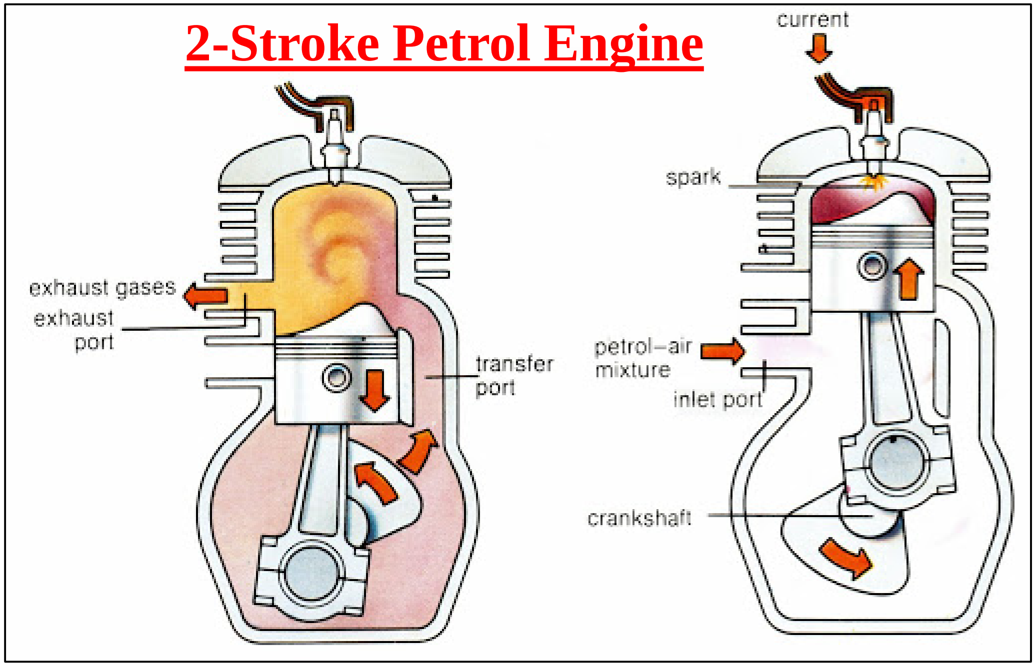
(b)

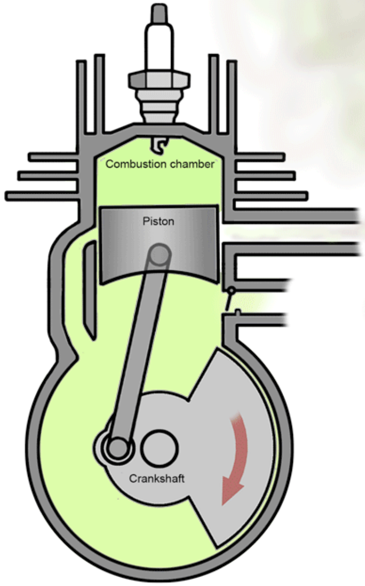
1. Downward stroke

- To begin with the working cycle , let us assume piston is at TDC [figure (a)]
- The air + fuel mixture that has entered the cylinder in the previous cycle is compressed to high pressure and temperature.
- Inlet port will be opened , fresh charge of air – fuel mixture enters the crankcase. The exhaust port and the transfer port will be closed. [figure (a)]
- The compressed charge in the cylinder (above the piston head) is ignited by means of an electric spark by the spark plug.
- As the combustion takes place, burnt gases expands and exerts a large force on the piston causing it move rapidly from TDC to BDC.
- The force/power is transmitted to the crankshaft through the connecting rod. As a result, crankshaft rotates at high speed [Clutches – gears – wheels of vehicle]
- Meanwhile , when the piston is pushed downwards by the expanding gases, the movement of piston from TDC to BDC uncovers the exhaust port [figure (b)]
- A part of burnt gases due to their own expansion escapes out of the cylinder through exhaust port to the atmosphere. Further downward movement of the piston uncovers the transfer port.

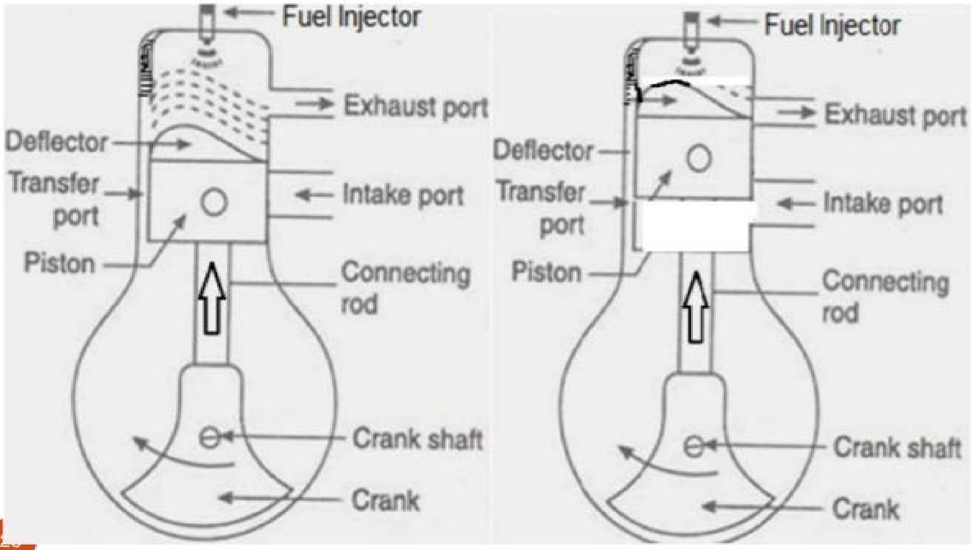
 **(c)**	• During the downward movement of the piston, the air + petrol mixture present in the crankcase is compressed by the underside of the piston. • The pressure exerted causes the charge from crankcase to rush into the cylinder through transfer port [Figure (c)] • The fresh charge enters the cylinder and drives away the remaining burnt gases through the exhaust port [exhaust stroke takes place when power stroke is in progress]. • When piston reaches BDC, downward stroke is completed and crankshaft rotates by 180° or half revolution.
 **(d)**	**2. Upward stroke** • During upward stroke, the piston moves from BDC to TDC, as the piston moves upwards, covers the transfer port thereby stopping the flow of fresh charge from crankcase to cylinder. • Further movement of piston covers the exhaust port and actual compression of charge begins [Figure (d)] • In the mean time, inlet port opens and the upward moving piston creates suction in crankcase due to which fresh charge from carburettor is drawn into crankcase. • Thus the intake of fresh charge takes place when compression stroke is in progress [Figure (a)] • When the piston reaches TDC, the upward stroke is completed and crankshaft completes 360° or one revolution.

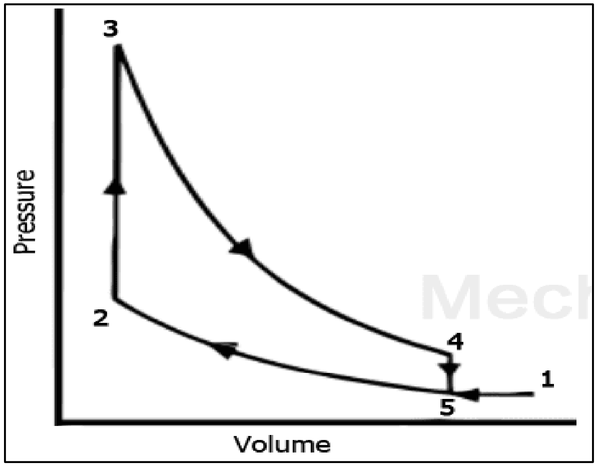
2-Stroke Petrol Engine





2-Stroke Diesel (CI) Engine

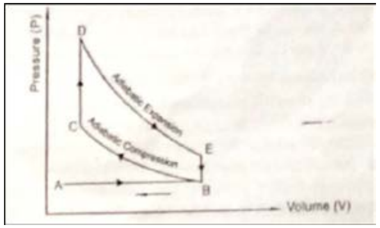
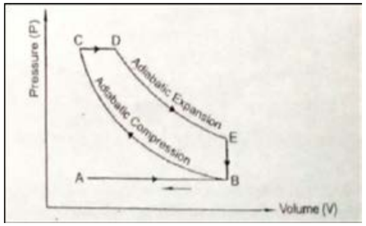




p-v diagram of 2-s petrol engine

Differences between 4-s petrol engine and 4-s diesel engine

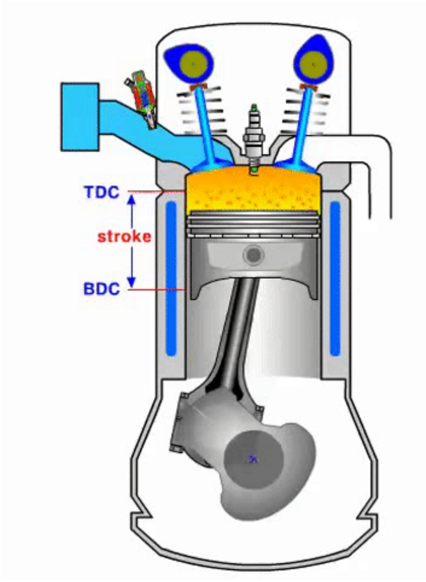
Sl. No.	Description	Petrol engine	Diesel engine
1.	Cycle of operation	Otto cycle or constant volume cycle	Diesel cycle or constant pressure cycle
2.	Fuel used	Petrol or Gasoline	Diesel
3.	Admission of charge	Air + fuel mixture enters the cylinder during suction stroke	Only air enters the cylinder during suction stroke. Diesel is injected at the end of compression stroke
4.	Compression ratio (R_c)	Ranges from 6:1 to 10:1	16:1 to 22:1
5.	Ignition of fuel	Fuel is ignited by spark plug (Generation of spark)	Heat of compressed air ignites the fuel
6.	Power	Less (low R_c)	Comparatively high
7.	Fuel consumption	More	Comparatively less
8.	Weight / space occupied	Light weight and also occupies less space	Heavier and stronger [To sustain high T and P during compression stroke]. More space
9.	Speed	Runs at high speed	Low to medium speed
10.	Torque	Low torque	High torque [can pull heavy loads]

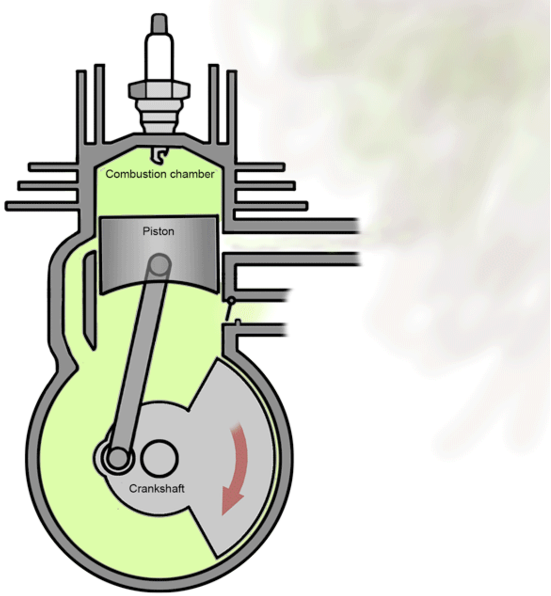
Sl. No.	Description	Petrol engine	Diesel engine
11	Running/operating cost	Running cost is high [cost of petrol is high]	Low running cost
12.	Maintenance cost	Low [Repair and service cost]	More maintenance
13.	Engine life	Comparatively low [Petrol destroys lubrication]	Diesel has better lubrication properties, improves engine life
14.	Noise & vibration	Negligible due to low operating pressures	Noise and vibrations are high
15.	Starting of engine	Easily started even in cold conditions	Difficult to start in cold conditions
16.	Governing	Quantitative method	Qualitative method
17.	Pollution	Exhaust pollution is more	Comparatively less pollution
18.	Uses	Scooters, motorbikes, cars, large boats	Heavy duty application such as bus, trucks, tractors, bulldozers, marine and industrial applications
19.	pv diagram		

Differences between 4-s and 2-s engine

Sl. No.	Description	4-s engine	2-s engine
1.	Working cycle	4 different strokes of piston or two revolution of crankshaft	2 different strokes of piston or one revolution of crankshaft
2.	Valves	Valves [inlet and exhaust valves]	Consists of ports / openings [opened and closed by piston]
3.	Admission of charge	Charge directly enters the cylinder through inlet valve	Charge enters the crankcase first and is then discharged into the cylinder
4.	Discharge of burnt gases	Pushed out during the exhaust stroke by piston movement	Fresh charge from the crankcase pushes burnt gas through exhaust port
5.	Suction and exhaust	Takes place in separate strokes of piston	Takes place while compression and power stroke is in progress
6.	Power	Developed for every two revolution of crankshaft	One revolution of crankshaft
7.	Fuel consumption	Low fuel consumption	More fuel consumption [charge mixes with the exhaust gas during scavenging]
8.	Weight	Comparatively heavy and bulky	Light and compact

Sl. No.	Description	4-s engine	2-s engine
9.	Mechanical efficiency	Low [4- strokes/ cycle, valve mechanism]	Comparatively high [2-strokes / cycle, no valves]
10.	Pollution	Less pollution	More [Fresh charge escapes with the exhaust gas]
11.	Flywheel	Heavy flywheel is required [since power is produced in alternative revolutions, torque will not be uniform]	Lighter flywheel is used [Power is produced in every revolution of crankshaft, torque will be more uniform]
12.	Uses	Bikes, cars, trucks, aircraft etc.	Mopeds, motorcycle, lawn movers, marine engines etc.

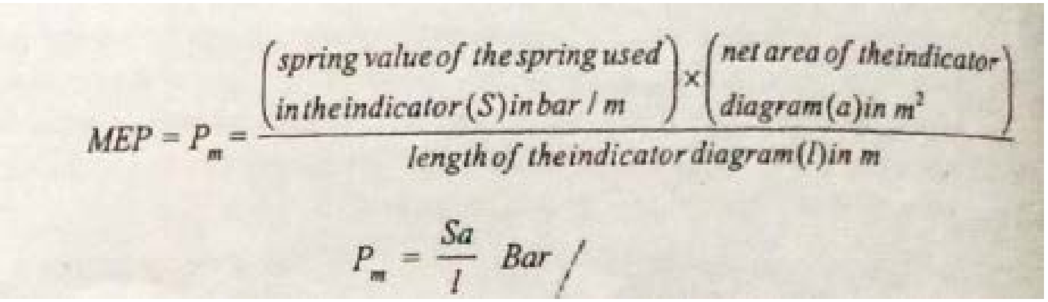




IC engine parameters

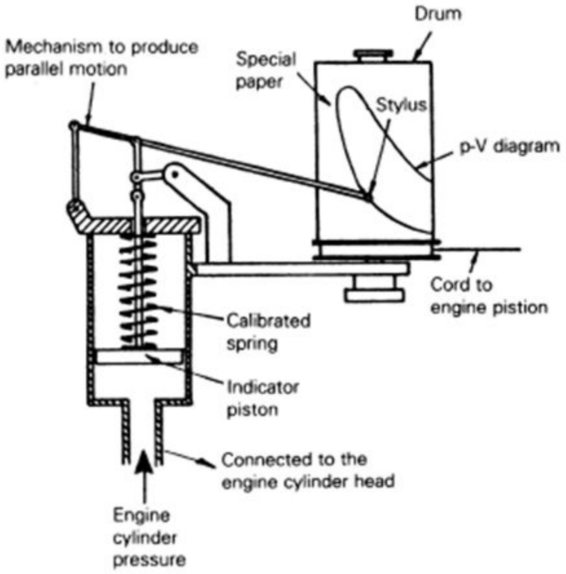
1. Mean effective pressure (MEP) – P_m

- Defined as mean or average pressure acting on the piston throughout the power stroke
- Also defined as average power developed inside the engine cylinder of an IC engine.
- Expressed in Bar
- MEP of an engine is obtained from the *indicator diagram*.
- Indicator diagram : p-v diagram for one cycle at that load, drawn with the help of an mechanical indicator on the engine.
- Indicated mean effective pressure is calculated using the formula



$$MEP = P_m = \frac{\begin{pmatrix}\text{spring value of the spring used}\\ \text{in the indicator }(S)\text{ in bar / m}\end{pmatrix} \times \begin{pmatrix}\text{net area of the indicator}\\ \text{diagram }(a)\text{ in m}^2\end{pmatrix}}{\text{length of the indicator diagram }(l)\text{ in m}}$$

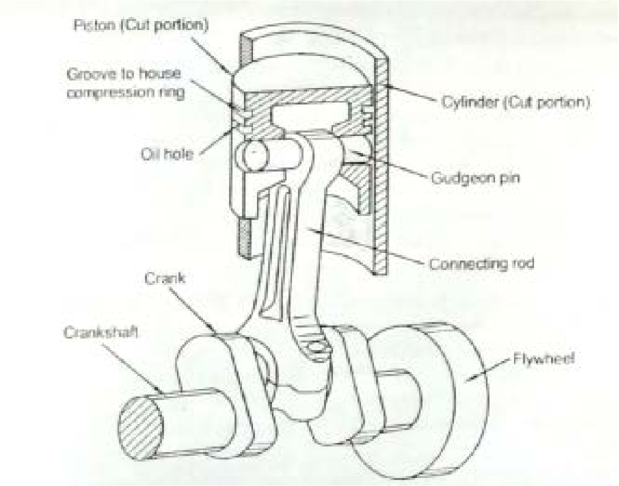
$$P_m = \frac{Sa}{l}\ Bar$$

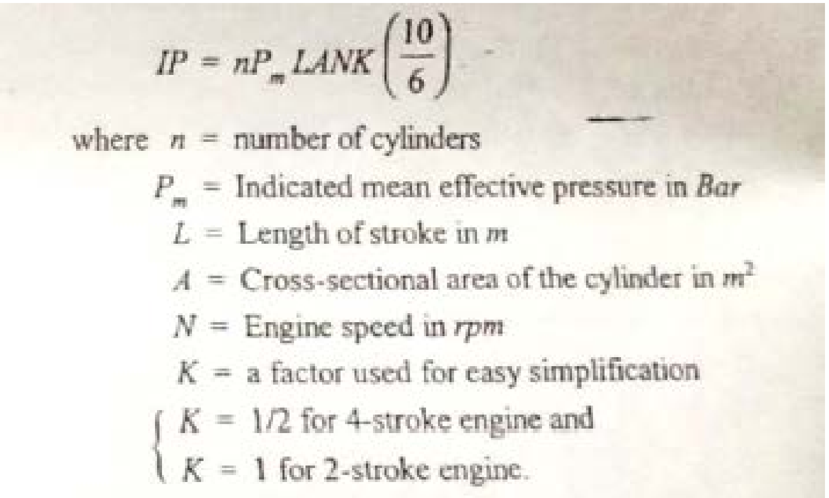


Indicator

2. Indicated power (IP)

- Defined as total power developed inside the cylinder during combustion of fuel.
- Denoted as IP and expressed in kW [kilo watts]





$$IP = nP_m LANK \left(\frac{10}{6}\right)$$

where n = number of cylinders

P_m = Indicated mean effective pressure in *Bar*

L = Length of stroke in m

A = Cross-sectional area of the cylinder in m^2

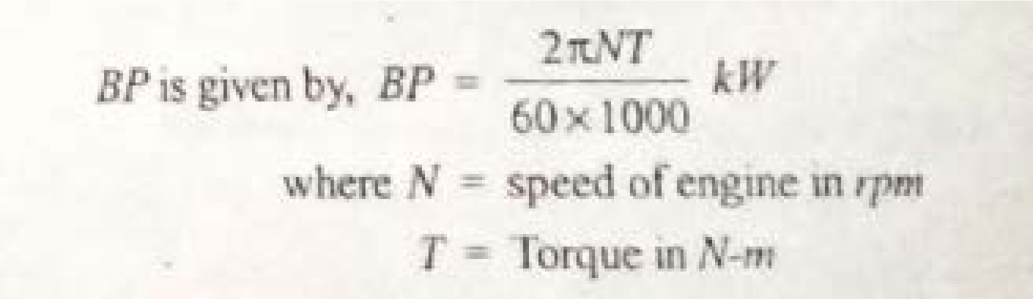
N = Engine speed in *rpm*

K = a factor used for easy simplification

$\begin{cases} K = 1/2 \text{ for 4-stroke engine and} \\ K = 1 \text{ for 2-stroke engine.} \end{cases}$

3. Brake power (BP)

- Net power available at the crankshaft of the engine for performing useful work.
- Denoted as BP, expressed in kW



BP is given by, $BP = \frac{2\pi NT}{60 \times 1000}\ kW$

where N = speed of engine in *rpm*

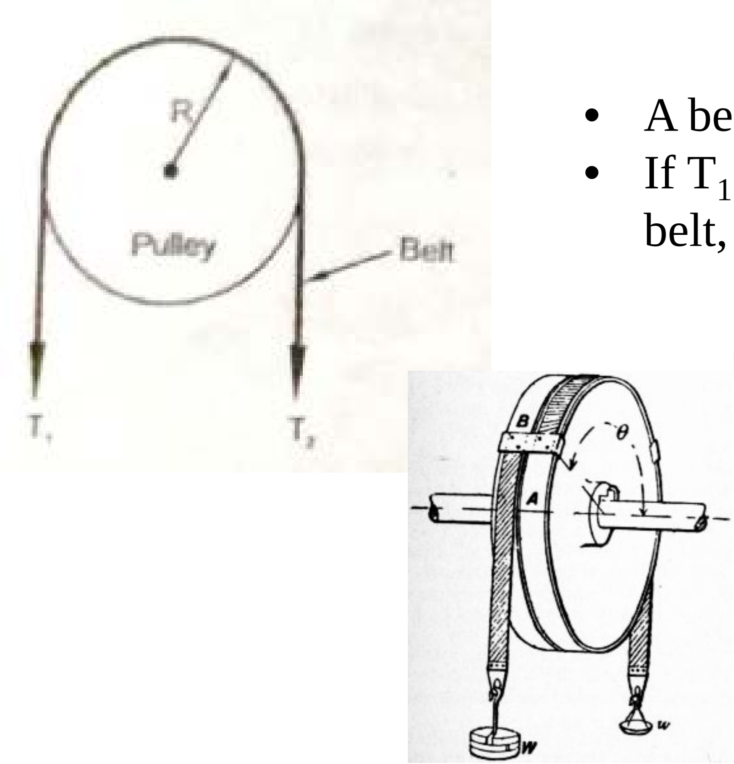
T = Torque in $N\text{-}m$

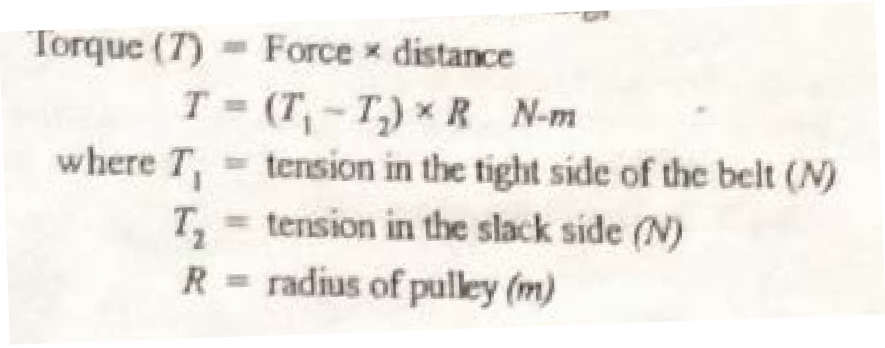
Note

- Power developed inside the engine cylinder is transmitted to the crankshaft through piston, connecting rod and crank. Hence a fraction of indicated power [actual power] developed is lost due to friction experienced by the moving parts.
- Thus the net power available at the crankshaft is the true output of the engine.
- The power available at the crankshaft is measured by applying brakes of some kind to the pulley attached to engine, and is therefore called brake power.

3.1 Measurement of torque (T) by belt dynamometer

- A belt wound around a pulley of radius R.
- If T_1 and T_2 be the tight side and loose side tensions of the belt, then engine torque is calculated using





Torque (T) = Force × distance

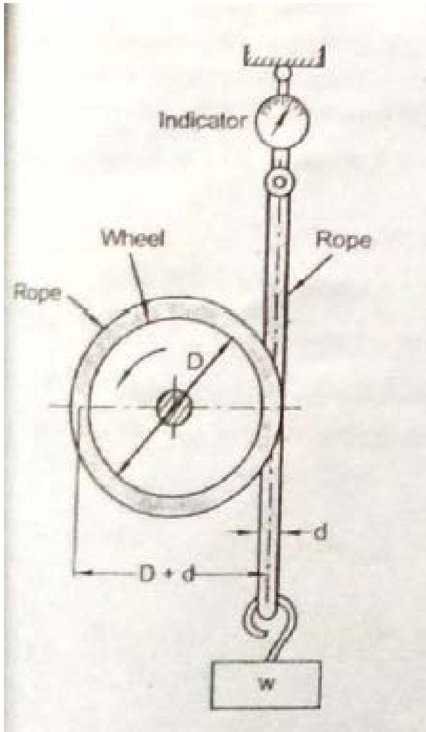
$$T = (T_1 - T_2) \times R \quad N\text{-}m$$

where T_1 = tension in the tight side of the belt (N)

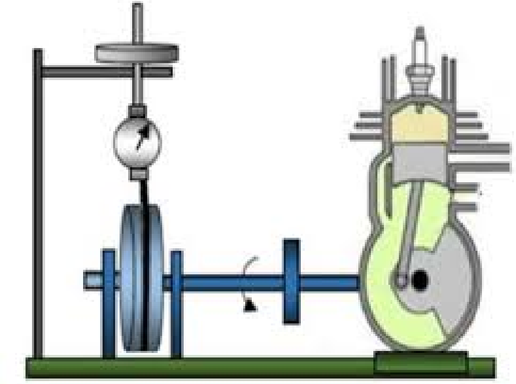
T_2 = tension in the slack side (N)

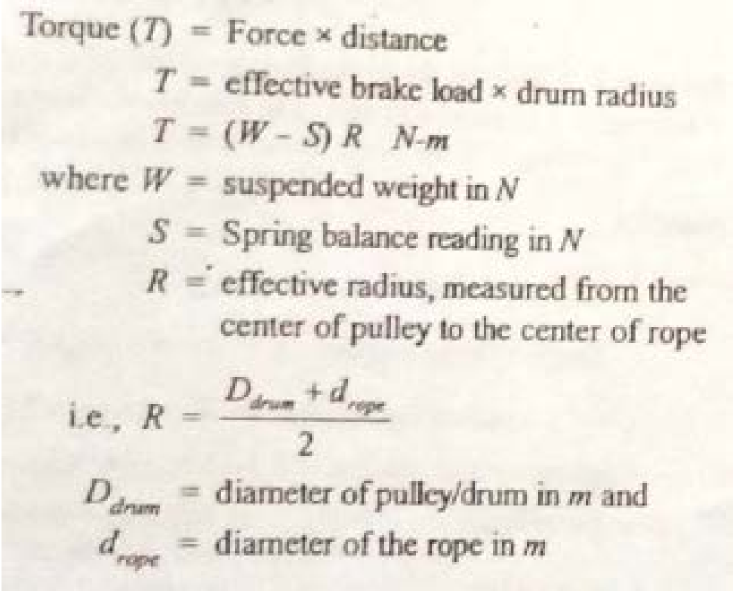
R = radius of pulley (m)

3.2 Measurement of torque (T) by rope brake dynamometer



- A rope wound around the circumference of the wheel/drum/pulley.
- One end of the rope is attached to a spring balance reading, while the other end carries dead load (W).
- The torque is calculated by using





Torque (T) = Force × distance

T = effective brake load × drum radius

$T = (W - S)\,R$ N-m

where W = suspended weight in N

S = Spring balance reading in N

R = effective radius, measured from the center of pulley to the center of rope

i.e., $R = \frac{D_{drum} + d_{rope}}{2}$

D_{drum} = diameter of pulley/drum in m and

d_{rope} = diameter of the rope in m

4. Friction power (FP)

- The amount of power lost due to friction of the various moving parts such as piston, connecting rod, crank etc., is called friction power.
- Difference between the indicated power and brake power. Expressed in kW
- FP = IP – BP………(kW)

5. Mechanical Efficiency (η_{mech})

- Ratio of brake power to the indicated power.
- Expressed in percentage.
- η_{mech} denotes the efficiency with which the moving parts of the engine can transmit the power developed inside the cylinder to useful motive power.

$$\eta_{mech} = \frac{BP}{IP} \times 100$$

6. Thermal Efficiency (η_{th})

- Ratio of power output to the heat supplied by burning fuel.
- Expressed in percentage.
- Power output in the formula may be BP or IP

$$\eta_{th} = \frac{\text{power output}}{\text{heat supplied}} \times 100$$

w.k.t. Heat supplied = $(m_f) \times CV$

where m_f = mass of fuel in kg/sec.

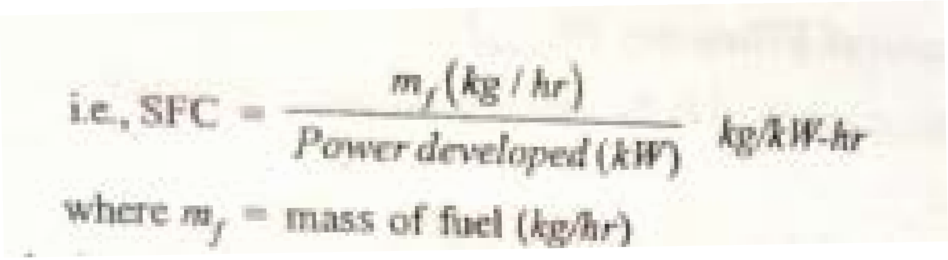
CV = calorific value^ of fuel in kJ/kg.

$$\text{Indicated thermal effiiciency} = \eta_{ITH} = \frac{IP}{m_f \times CV} \times 100$$

$$\text{Brake thermal efficiency} = \eta_{BTH} = \frac{BP}{m_f \times CV} \times 100$$

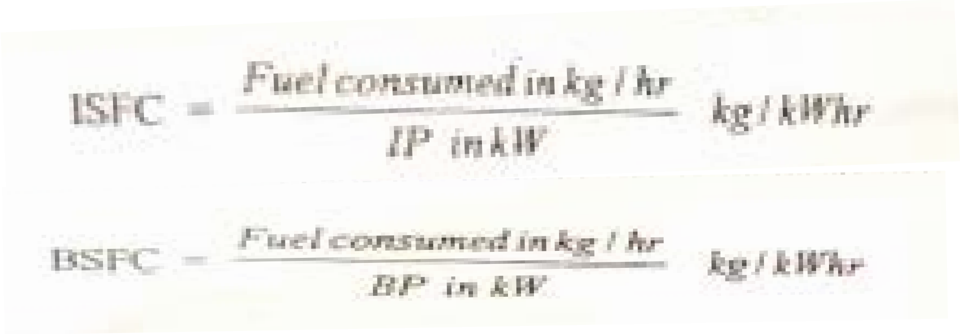
7. Specific fuel consumption(SFC)

- Term used to describe the fuel efficiency of an engine.
- It measures the amount of fuel needed to provide a given power for a given time period.
- Ratio of mass of the fuel consumed per kW power developed per hour.
- Power developed can be based on BP or IP



$$\text{i.e., SFC} = \frac{m_f\,(kg/hr)}{\text{Power developed}\,(kW)}\ \text{kg/kW-hr}$$

where m_f = mass of fuel (kg/hr)



$$\text{ISFC} = \frac{\text{Fuel consumed in kg / hr}}{\text{IP in kW}}\ \text{kg / kWhr}$$

$$\text{BSFC} = \frac{\text{Fuel consumed in kg / hr}}{\text{BP in kW}}\ \text{kg / kWhr}$$

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Module – 3.1.1

IC Engines-Numericals

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Problem 1 A four stroke diesel engine has a piston diameter 250 mm and stroke 400 mm. The mean effective pressure is 4 bar and speed is 500 rpm. The diameter of the brake drum is 1000 mm and the effective brake load is 400 N. Find IP, BP & FP. ***June 2010 & Jan. 2015 - 10 m***

Given:

Engine type = 4-s diesel engine. $\therefore K = \frac{1}{2}$.

Approximately Piston diameter = Cylinder diameter = d = 250 mm = 0.25 m

$\therefore$ Area = $A = \frac{\pi}{4} d^2 = \frac{\pi}{4}(0.25)^2 = 0.049 \text{ m}^2$

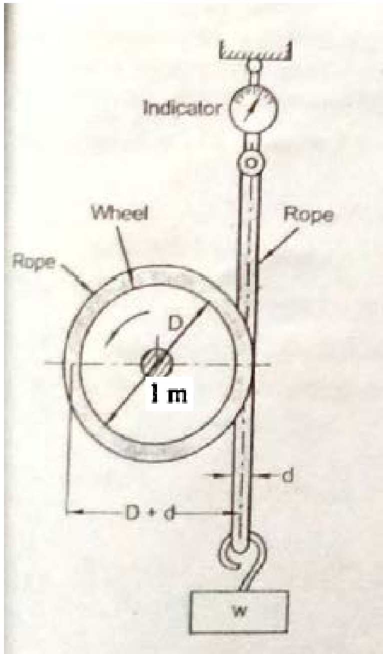
Stroke = L = 400 mm = 0.4 m MEP = P_m = 4 bar, Speed = N = 500 rpm

Diameter of brake drum = D = 1000 mm = 1 m

$\therefore$ Radius of brake drum = $R = \frac{1}{2} = 0.5$ m.

Effective brake load = (W – S) = 400 N.

Assume single cylinder engine. $\therefore n = 1$



To find Indicated power (*IP*)

$$\text{w.k.t. } IP = n\,P_m L\,A\,N\,K\left(\frac{10}{6}\right) = 1 \times 4 \times 0.4 \times 0.049 \times 500 \times \frac{1}{2} \times \frac{10}{6}$$

$$IP = 32.66 \text{ kW}$$

To find Brake power (*BP*)

$$\text{w.k.t. } BP = \frac{2\pi NT}{60 \times 1000} \text{ kW}$$

$$\text{Torque } T = (W - S)R = (400)\,0.5 = 200 \text{ } N\text{-}m$$

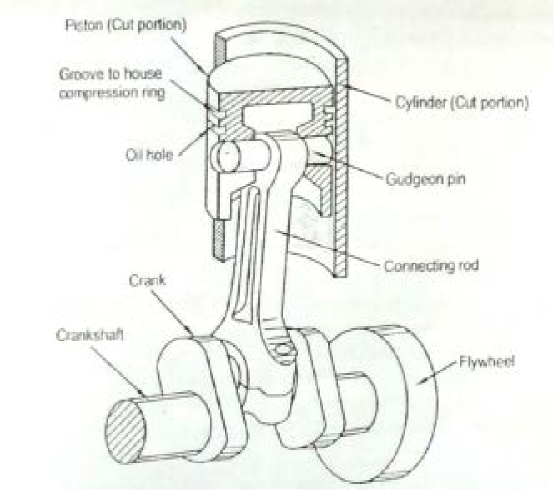
$$\therefore BP = \frac{2 \times \pi \times 500 \times 200}{60 \times 1000} = 10.47 \text{ kW}$$

$$BP = 10.47 \text{ kW}$$

To find frictional power (FP)

$$\text{w.k.t. } FP = IP - BP = 32.66 - 10.47$$

$$FP = 22.19 \text{ kW}$$



Problem 2 Calculate the Brake Power output of a single cylinder four stroke petrol engine which is running at a speed of 400 rpm. The load on the brake drum is 24 kg and the spring balance reads 4 kg. The diameter of the brake drum is 600 mm & the rope diameter is 30 mm. ***Feb 2007 - 05 m***

<u>*Given:*</u>

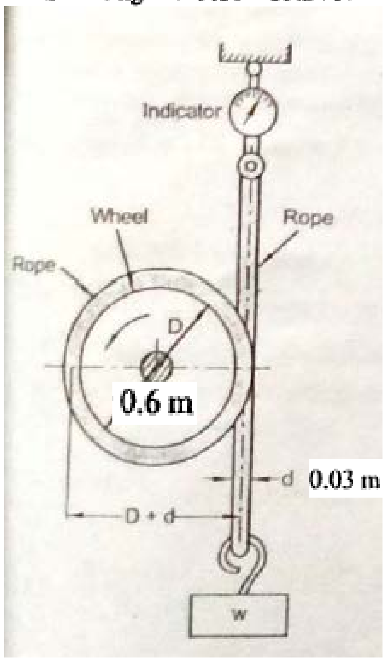
Single cylinder engine = n = 1, 4-s engine = $K = \frac{1}{2}$, Speed = N = 400 rpm

Load on brake drum = $W = 24\text{ kg} = 24\times9.81 = 235.44\text{ N}$

Spring balance reading = S = $4\text{ kg} = 4\times9.81 = 39.24\text{ N}$

Diameter of brake drum = D_{drum} = 600 mm = 0.6 m Rope diameter = $d_{rope} = 30\text{ mm} = 0.03\text{ m}$

$S = 4\text{ kg} = 4\times9.81 = 39.24\text{ N}$



$W = 24\text{ kg} = 24\times9.81 = 235.44\text{ N}$

To find BP

$$\text{w.k.t. } BP = \frac{2\pi NT}{60\times1000}\text{ kW} \qquad \text{- - - - [1]}$$

$$T = (W - S)R \quad \text{where } R = \frac{D_{drum} + d_{rope}}{2} = \frac{0.6+0.03}{2} = 0.315\text{ m}$$

$$\therefore\ T = (235.44 - 39.24)\,0.315 = 61.8\text{ Nm}$$

$$\therefore\ BP = \frac{2\times\pi\times400\times61.8}{60\times1000} = 2.58\text{ kW}$$

$$BP = 2.58\text{ kW}$$

Problem 3 A single cylinder 4-s engine runs at 1000 rpm and has a bore of 115 mm and a stroke of 140 mm. The Brake load is 60 N at 600 mm radius and the mechanical efficiency is 80%. Calculate brake power and mean effective pressure. ***Dec. 2010 - 6 m***

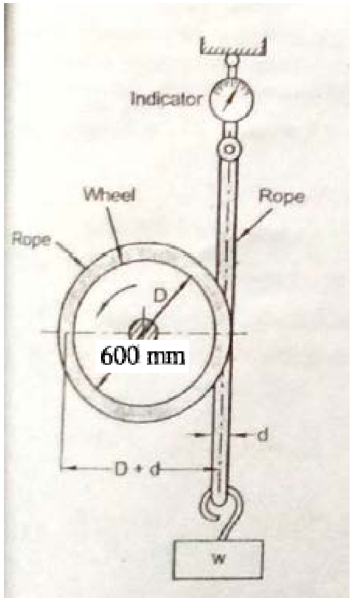
Given:

Engine type = 4-s $\therefore K = \frac{1}{2}$, Single cylinder = n = 1, Speed = N = 1000 rpm

Bore = d = 115 mm = 0.115 m. $\therefore A = \frac{\pi}{4}(0.115)^2 = 0.010\ \text{m}^2$

Stroke = L = 140 mm = 0.14 m, Brake load = W = 60 N

Radius of brake drum = R = 600 mm = 0.6 m, mechanical efficiency = η_{mech} = 80% = 0.8



W = 60 N

To find *BP*

w.k.t. $BP = \frac{2\pi NT}{60\times1000}$ kW

T = (W − S) R. Nm.

Neglecting value of S, we have, T = (60 − 0) 0.6 = 36 Nm

$\therefore BP = \frac{2\times\pi\times1000\times36}{60000} = 3.77$ **BP = 3.77 kW**

To find MEP (P_m)

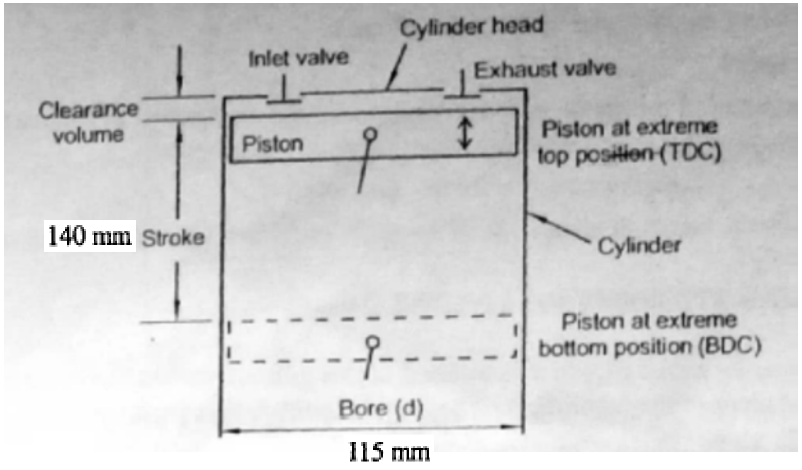
w.k.t. $IP = n\,P_m L\,A\,N\,K\left(\frac{10}{6}\right)$

but IP = ? & P_m = ?, But $\eta_{mech} = 0.8$

We have $\eta_{mech} = \frac{BP}{IP}$

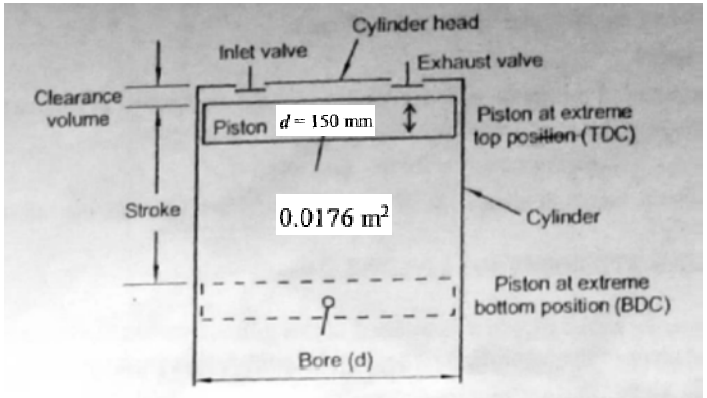
$\therefore$ IP $= \frac{BP}{\eta_{mech}} = \frac{3.77}{0.8} = 4.71$ kW

$4.71 = 1\times P_m\times0.14\times0.01\times1000\times\frac{1}{2}\times\frac{10}{6}$ **$P_m \approx$ 4 Bar**



Problem 4 The average piston speed of a 4-stroke petrol engine having piston diameter of 150 mm is 3.5 m/sec. The mean effective pressure acting on the piston is 0.786 MPa. Determine the power developed inside the engine cylinder.

Given:



Engine type = 4-stroke. $\therefore K = \frac{1}{2}$

Diameter $= d = 150$ mm $= 0.15$ m, $\therefore$ area $= A = \frac{\pi}{4}d^2 = \frac{\pi}{4}(0.15)^2 = 0.0176\ \text{m}^2$

Average piston speed $= 3.5$ m/sec $= 3.5 \times 60$ m/min $= 210$ m/min

w.k.t. average piston speed $= 2\,L\,N$ m/min

i.e., $2\,L\,N = 210$ m/min or $L\,N = 105$ m/min

$MEP = P_m = 0.786$ MPa $= 0.786 \times 10^6\ \text{N/m}^2$ (1 Pa = 1 N/m²)

$P_m = 7.86$ Bar (1 Bar = 10^5 N/m²) Assume n = 1 (number of cylinder)

To find power developed in the cylinder.

$$\text{w.k.t.}\quad IP = n\,P_m L\,A\,N\,K\left(\frac{10}{6}\right) = 1\times 7.86\times 105\times 0.0176\times\frac{1}{2}\times\frac{10}{6}$$

$$IP = 12.10\ \text{kW}$$

Problem 5 A 4-stroke IC engine running at 450 rpm has bore diameter 100 mm and stroke length 120 mm. The details of the indicator diagram are as follows. Area of indicator diagram = 4 cm². Length of the indicator diagram = 6.5 cm, and the spring value of the spring used is 10 Bar/cm. Calculate the indicated power of the engine. ***August 1999 - 05 m***

Given:

Engine type = 4-s. $\therefore$ K = $\frac{1}{2}$ Speed = N = 450 rpm

Bore = cylinder diameter = d = 100 mm = 0.1 m

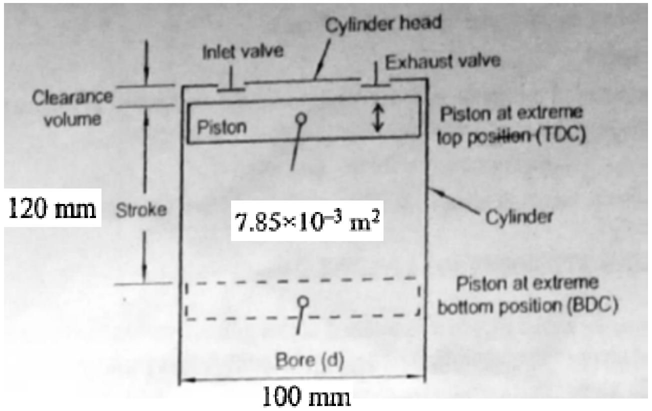
$$\therefore \text{ Area} = A = \frac{\pi}{4}d^2 = \frac{\pi}{4}(0.1)^2 = 7.85\times10^{-3}\text{ m}^2$$

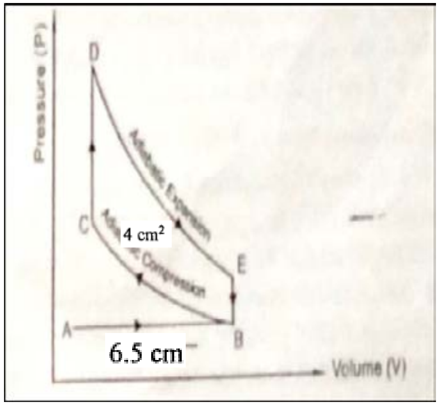
Stroke = L = 120 mm = 0.12 m

Area of indicator diagram = a = 4 cm² Length of the indicator diagram = l = 6.5 cm

Spring value = s = 10 Bar/cm, Assume single cylinder = n = 1

Note: An engine indicator is an instrument for graphically recording the pressure versus piston displacement through an engine stroke cycle. A mechanical indicator consists of a piston, spring, stylus, and recording system. The pressure of the cylinder deflects the piston and pushes against the spring, creating a linear relationship between the gas pressure and the deflection of the piston against the spring. The deflection is recorded by the stylus on a rotating drum that is connected to the piston.





To find IP

$$\text{w.k.t. } IP = n\,P_m\,L\,A\,N\,K\left(\frac{10}{6}\right)$$

But P_m = ?

$$\text{w.k.t. } P_m = \frac{s.a}{l} = \frac{10\times4}{6.5} = 6.15 \text{ Bar}$$

$$\therefore\ IP = 1\times6.15\times0.12\times(7.85\times10^{-3})\times450\times\frac{1}{2}\times\frac{10}{6}$$

$$\boldsymbol{IP = 2.17 \text{ kW}}$$

Problem 6 Following data are collected from a 4-stroke single cylinder oil engine at full load. Bore = 200 mm, stroke = 280 mm, speed = 300 rpm, indicated mean effective pressure = 5.6 bar, torque on the brake drum = 250 Nm, oil consumed = 4.2 kg/hour and calorific value of oil 41,000 kJ/kg. Determine mechanical efficiency, indicated thermal efficiency and brake thermal efficiency.

Given:

Engine type = 4-S $\therefore$ $K = \frac{1}{2}$ Single cylinder = n = 1

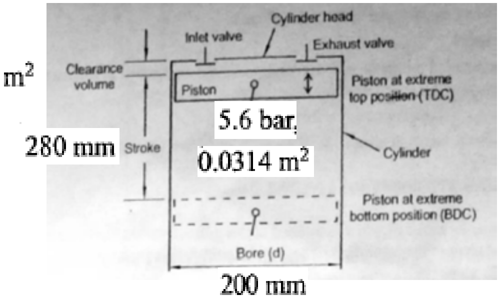
Bore = cylinder diameter = d = 200 mm = 0.2 m $\therefore$ Area = $A = \frac{\pi}{4}d^2 = \frac{\pi}{4}(0.2)^2 = 0.0314\ \text{m}^2$

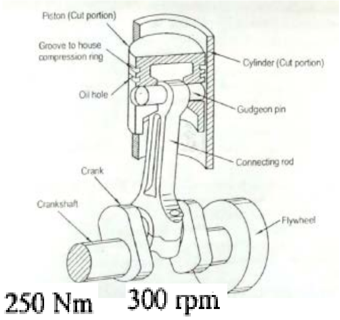
Stroke = L = 280 mm = 0.28 m, Speed = N = 300 rpm

MEP = P_m = 5.6 bar, Torque = T = 250 Nm

Oil consumed = m_f = 4.2 kg/hour = $\frac{4.2}{3600} = 1.167\times10^{-3}$ kg/sec

C.V. of fuel = cv = 41,000 kJ/kg





To find mechanical efficiency η_{mech}

$$\text{w.k.t. } \eta_{mech} = \frac{BP}{IP}$$

But $BP = IP = ?$

$$IP = n P_m L A N K\left(\frac{10}{6}\right) = 1\times5.6\times0.28\times0.0314\times300\times\frac{1}{2}\times\frac{10}{6}$$

IP = 12.3 kW

$$BP = \frac{2\pi NT}{60\times1000} = \frac{2\times\pi\times300\times250}{60000} = 7.85\ \text{kW}$$

$$\eta_{mech} = \frac{BP}{IP} = \frac{7.85}{12.3} = 0.638 \text{ or } 0.638\times100 = 63.8\%$$

To find indicated thermal efficiency (η_{ITH})

$$\text{w.k.t. } \eta_{ITH} = \frac{IP}{m_f\times cv} = \frac{12.3}{\left(1.167\times10^{-3}\right)\times41000} = 0.257\times100 = 25.7\%$$

$$\eta_{ITH} = 25.7\%$$

To find brake thermal efficiency (η_{BTH})

$$\eta_{BTH} = \frac{BP}{m_f\times cv} = \frac{7.85}{\left(1.167\times10^{-3}\right)\times41000} = 0.164 \text{ or } 0.164\times100 = 16.4\%$$

$$\therefore \quad \eta_{BTH} = 16.4\%$$

Problem 7 A person conducted a test on a single cylinder two stroke petrol engine and found that the mechanical and brake thermal efficiencies of the engine were 0.7 and 0.2 respectively. The engine with a mean effective pressure of 6 bar ran at 300 rev/min, consuming fuel at a rate of 2.2 kg/h. Given that the calorific value of the fuel is 42500 kJ/kg and that the stroke to bore ratio of the engine cylinder is 1.2. Find the bore and stroke of the engine in cm. *Feb. 2006 - 10 m*

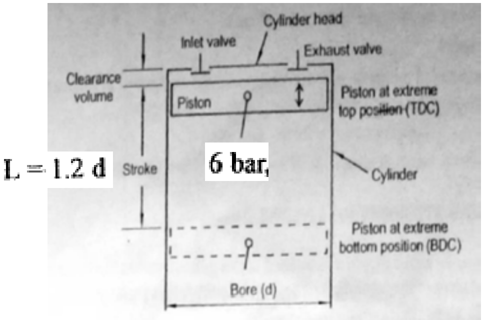
Given:

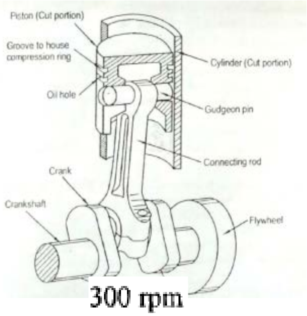
Single cylinder = $n = 1$, Engine type = 2-S $\therefore$ K = 1

$\eta_{mech} = 0.7$ & $\eta_{BTH} = 0.2$ MEP = $P_m = 6$ bar, Speed = $N = 300$ rpm

$$m_f = 2.2 \text{ kg/hour} = \frac{2.2}{3600} = 6.11\times10^{-4} \text{ kg/sec}$$

C.V. of fuel = $cv = 42{,}500$ kJ/kg, Stroke to bore ratio = $\frac{L}{d} = 1.2$





To find bore (d) & stroke (L)

$$\eta_{BTH} = \frac{BP}{m_f \times cv}$$

$$BP = \eta_{BTH} \times m_f \times cv = 0.2(6.11\times10^{-4}) \times (42500) = 5.19 \text{ kW}$$

w.k.t. $\eta_{mech} = \frac{BP}{IP}$

$$\therefore \quad IP = \frac{BP}{\eta_{mech}} = \frac{5.19}{0.7} = 7.42 \text{ kW}$$

w.k.t. $IP = n\, P_m L\, A\, N\, K \left(\frac{10}{6}\right)$ kW

$$7.42 = 1\times6\times\text{L}\times\left(\frac{\pi}{4}\cdot d^2\right)\times300\times1\times\frac{10}{6}$$

$$3.15\times10^{-3} = \text{L}\cdot\text{d}^2$$

But $\frac{L}{d} = 1.2$ or L = 1.2 d

$$3.15\times10^{-3} = (1.2\text{ d})\text{ d}^2$$

$$d = 0.138 \text{ m or } 13.8 \text{ cm}$$

$$L = 1.2\text{ d} = 1.2\,(13.8) = 16.58 \text{ cm}$$

Thus $d = 13.8$ cm and $L = 16.58$ cm

Problem 8 A 4-cylinder two-stroke petrol engine develops 30 kW at 2500 rpm. The mean effective pressure on each piston is 8 bar & mechanical efficiency is 80%. Calculate the diameter and stroke of each cylinder, stroke to bore ratio is 1.5. Also calculate the fuel consumption if brake thermal efficiency is 28%. The calorific value of the fuel is 43900 kJ/kg. ***Jan. 2013 - 10 m***

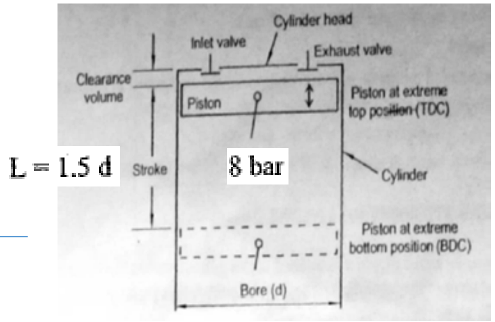
Given:

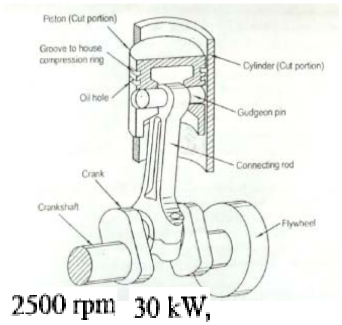
4 cylinder engine = $n = 4$, 2-stroke engine = K = 1

Power developed = $BP = 30$ kW, Speed = $N = 2500$ rpm, MEP = $P_m = 8$ bar

$\eta_{mech} = 80\% = 0.8$ Stroke to bore ratio = $\frac{L}{d} = 1.5$

$\eta_{BTH} = 28\% = 0.28$, $cv = 43900$ kJ/kg





To find L & d

w.k.t. $\eta_{mech} = \frac{BP}{IP}$

$$\therefore \quad IP = \frac{BP}{\eta_{mech}} = \frac{30}{0.8} = 37.5 \text{ kW}$$

Also $IP = n\,P_m\,L\,A\,N\,K\left(\frac{10}{6}\right)$ kW

$$37.5 = 4\times8\times\text{L}\times\left(\frac{\pi}{4}\cdot d^2\right)\times2500\times1\times\frac{10}{6}$$

$$3.58\times10^{-4} = \text{Ld}^2$$

from data, $\frac{L}{d} = 1.5$ or L = 1.5 d

$\therefore$ $3.58\times10^{-4} = (1.5\text{ d})\,\text{d}^2$ or $d = 0.062$ m or **d = 62 mm**

and $L = 1.5\text{ d} = 1.5\,(62)$, or **$L$ = 93 mm**

Fuel consumption (m_f)

w.k.t. $\eta_{BTH} = \frac{BP}{m_f \times cv}$, $0.28 = \frac{30}{m_f\times43900}$

$m_f = 2.44\times10^{-3}$ kg/sec. or m_f = **8.78 kg/hr**

Problem 9 A single cylinder 4-s IC engine has a swept volume of 6 litres and runs at a rated speed of 300 rpm. At full load, the torque developed was measured with a belt dynamometer whose pulley diameter is 1 m. The tension in the tight side and slack side of the belt is 700 N & 300 N respectively. 4 kg of fuel was consumed in one hour. The indicated mean effective pressure is 6 bar and the CV of the fuel is 42000 kJ/kg. Calculate the BP, IP, mechanical efficiency, indicated thermal efficiency, brake thermal efficiency & brake specific fuel consumption. ***Aug. 2009 – 12 m***

Given:

Single cylinder $= n = 1$, 4-S engine $= K = \frac{1}{2}$

Swept volume* $= L \cdot A = 6$ litres $= 6\times10^{-3}$ m^3 (1 m^3 = 1000 litres)

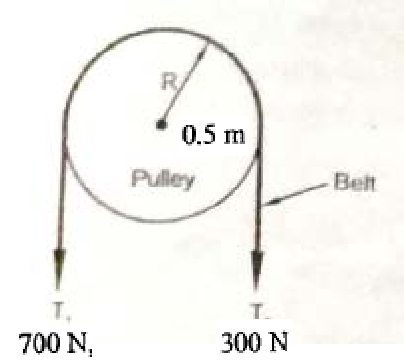
Speed $N = 300$ rpm

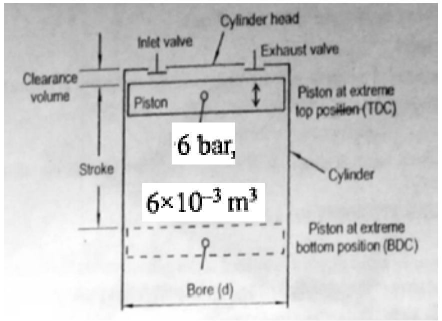
Pulley diameter = 1 m ∴ Radius $= R = 0.5$ m

Tight side tension $= T_1 = 700$ N, Slack side tension $= T_2 = 300$ N

Mass of fuel $= m_f = 4$ kg/hr $= \frac{4}{3600} = 1.11\times10^{-3}$ kg/sec

MEP $= P_m = 6$ bar, $cv = 42000$ kJ/kg





To find BP

$$\text{w.k.t. } BP = \frac{2\pi NT}{60\times1000}\text{ kW}$$

$$\text{Torque } T = (T_1 - T_2)R = (700 - 300)0.5 = 200 \quad \text{N-m}$$

$$\therefore \ BP = \frac{2\times\pi\times300\times200}{60\times1000} = \mathbf{6.28 kW}$$

To find IP

$$\text{w.k.t. } IP = nP_mLANK\left(\frac{10}{6}\right) = 1\times6\times(6\times10^{-3})\times(300)\times\frac{1}{2}\times\frac{10}{6} = 9\text{ kW}$$

To find η_{mech}

$$\text{w.k.t. } \eta_{mech} = \frac{BP}{IP} = \frac{6.28}{9} = 0.697 = 69.7\%$$

To find η_{ITH}

$$\text{w.k.t. } \eta_{ITH} = \frac{IP}{m_f\times cv} = \frac{9}{(1.11\times10^{-3})\times(42000)} = 0.193$$

$$\eta_{ITH} = 19.3\%$$

To find η_{BTH}

$$\text{w.k.t. } \eta_{BTH} = \frac{BP}{m_f\times cv} = \frac{6.28}{(1.11\times10^{-3})\times(42000)} = 0.134$$

$$\eta_{BTH} = 13.4\%$$

To find brake specific fuel consumption (BSFC)

$$\text{w.k.t. } BSFC = \frac{Fuel\ consumed\ in\ kg/hr}{BP} = \frac{4\ kg/hr}{6.28}$$

$$BSFC = \mathbf{0.63\ kg/kW\text{-}hr}$$

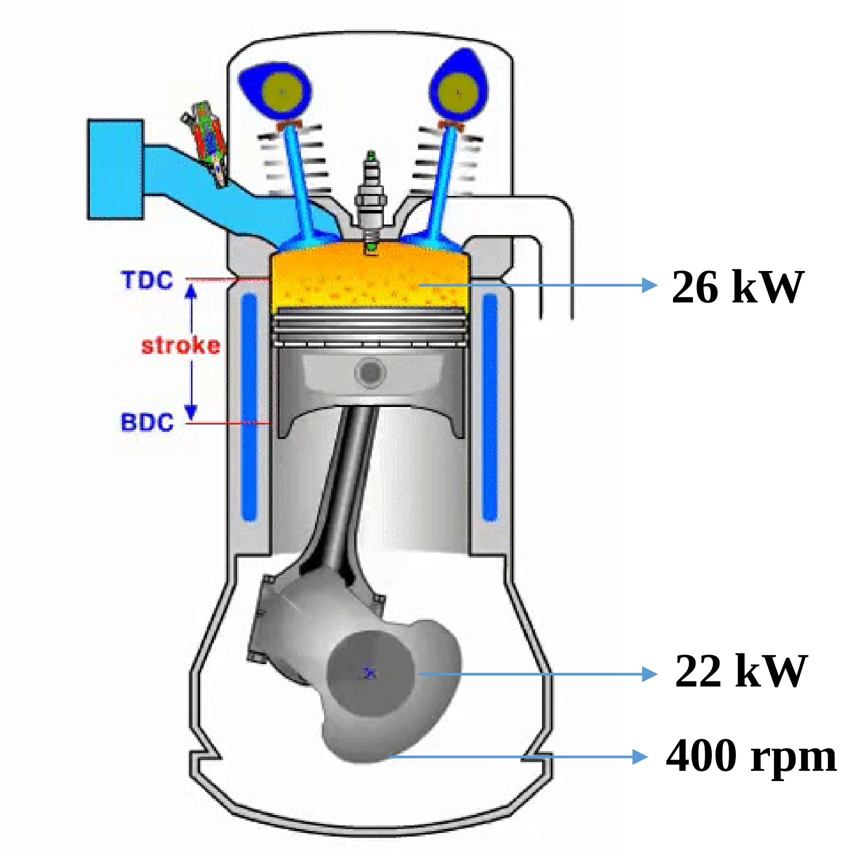
Problem 10 During a trial on a 4-S petrol engine, the following results were obtained: Indicated power = 26 kW, Brake power = 22 kW, engine speed = 400 rpm, Fuel/BP hour = 0.33 kg, CV of petrol = 44300 kJ/kg. Determine the following parameters: (a) mechanical efficiency, (b) Indicated thermal efficiency, and (c) Brake thermal efficiency

Given:

Engine type = 4-S, $\therefore K = \frac{1}{2}$, $IP = 26$ kW, $BP = 22$ kW, $N = 400$ rpm, Fuel/BP hour = 0.33 kg

Fuel consumed in kg/hr = $m_f = BSFC \times BP = 0.33 \times 22 = 7.26$ kg/hr

or $m_f = 2.016 \times 10^{-3}$ kg/sec cv of fuel = 44300 kJ/kg



To find η_{mech}

$$\text{w.k.t. } \eta_{mech} = \frac{BP}{IP} = \frac{22}{26} = 0.846 \qquad \eta_{mech} = 84.6\%$$

To find η_{ITH}

$$\text{w.k.t. } \eta_{ITH} = \frac{IP}{m_f \times cv} = \frac{26}{(2.016\times10^{-3})\times(44300)} = 0.2911$$

$$\eta_{ITH} = 29.11\%$$

To find η_{BTH}

$$\text{w.k.t. } \eta_{BTH} = \frac{BP}{m_f \times cv} = \frac{22}{(2.016\times10^{-3})\times(44300)} = 0.2463$$

$$\eta_{BTH} = 24.63\%$$

Problem 11 A diesel engine develops 5 kW. Its indicated thermal efficiency is 30% and mechanical efficiency 75%. Estimate the fuel consumption of the engine in (a) kg/hr and (b) litres/hr. Also find (a) ISFC and (b) BSFC. Take cv of fuel = 42000 kJ/kg and specific gravity of fuel = 0.87.

Given:

$BP = 5$ kW, $\eta_{ITH} = 30\% = 0.3$, $\eta_{mech} = 75\% = 0.75$, cv of fuel = 42000 kJ/kg

Specific gravity of fuel = 0.87

Case (a) Fuel consumption (m_f) in kg/hr

$$\text{w.k.t. } \eta_{ITH} = \frac{IP}{m_f \times cv}$$

$$\therefore \quad m_f = \frac{IP}{\eta_{ITH} \times cv}$$

But IP = ?

$$\text{Using } \quad \eta_{mech} = \frac{BP}{IP}\text{, we have, } IP = \frac{BP}{\eta_{mech}} = \frac{5}{0.75} = 6.67 \text{ kW}$$

$$m_f = \frac{6.67}{0.3 \times 42000} = 5.293 \times 10^{-4} \text{ kg/sec}$$

$$\mathbf{m_f = 1.905 \text{ kg/hr}}$$

Case (b) To find fuel consumption m_f in litres/hr

Divide m_f by specific gravity to obtain mass of fuel m_f in litres/hr, i.e., $m_f = \frac{1.905}{0.87} = 2.189\ Lt/hr$

$$\mathbf{m_f = 2.189 \text{ Lt/hr}}$$

Note Method to obtain m_f in Lt/hr

$$\text{w.k.t. specific gravity of fuel} = \frac{Density\ of\ fuel}{Density\ of\ water}$$

$$\text{i.e., } 0.87 = \frac{Density\ of\ fuel}{1000} \quad \text{(density of water = 1000 kg/m}^3\text{)}$$

Density of fuel = 870 kg/m^3

$$\text{w.k.t. Density of fuel} = \frac{mass\ of\ fuel\ (m_f)}{volume\ of\ fuel}$$

$$\therefore \text{ Volume of fuel or fuel consumption} = \frac{m_f}{Density\ of\ fuel} = \frac{1.905\ kg/hr}{870\ kg/m^3} = 2.189 \times 10^{-3} \text{ m}^3\text{/hr}$$

∴ **Fuel consumption = 2.189 litres/hr** (1 m^3 = 1000 litres)

To find ISFC

$$\text{w.k.t. } ISFC = \frac{Fuel\ consumed\ in\ kg/hr\ (m_f)}{IP} = \frac{1.905}{6.67} = \mathbf{0.285 \text{ kg/kW hr}}$$

To find BSFC

$$\text{w.k.t. } BSFC = \frac{Fuel\ consumed\ in\ kg/hr\ (m_f)}{BP} = \frac{1.905}{5} = \mathbf{0.381 \text{ kg/kW hr}}$$

Problem 12 A single cylinder 4-S petrol engine has bore 200 mm, stroke 400 mm & runs at 400 rpm. The indicated MEP is 7 bar and the fuel consumption is 10 litres/hour. Taking cv of petrol 45000 kJ/kg and specific gravity of petrol 0.8, determine the indicated thermal efficiency.

Given:

Single cylinder = n = 1, 4-S engine = K = $\frac{1}{2}$

Bore = d = 200 mm = 0.2 m $\therefore$ $A = \frac{\pi}{4}d^2 = \frac{\pi}{4}(0.2)^2 = 0.0314\ m^2$

Stroke L = 400 mm = 0.4 m, Speed N = 400 rpm

MEP = P_m = 7 bar, cv of petrol = 45000 kJ/kg

Fuel consumption = 10 litres/hour, Specific gravity of petrol = 0.8

fuel consumption is given in litres/hr. It should be expressed in kg/sec.

Muliply fuel consumption by specific gravity to obtain mass of fuel m_f in kg/sec,

i.e., Mass of fuel $m_f = 10\times0.8 = 2.22\times10^{-3}$ kg/sec.

To find η_{ITH}

$$\text{w.k.t. } \eta_{ITH} = \frac{IP}{m_f \times cv} \qquad \text{But } IP = ?$$

$$IP = n\,P_m\,LANK\left(\frac{10}{6}\right) = 1\times7\times0.4\times0.0314\times400\times\frac{1}{2}\times\frac{10}{6} = 29.3\text{ kW}$$

$$\therefore \eta_{ITH} = \frac{29.3}{\left(2.22\times10^{-3}\right)\times(45000)} = 0.2932 = 0.2932\times100 = 29.32\%$$

$$\eta_{ITH} = \mathbf{29.32\%}$$

$$\text{w.k.t. Specific gravity} = \frac{\textit{Density of fuel}}{\textit{Desnity of water}}$$

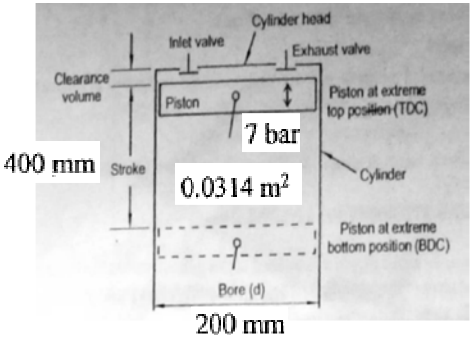
$\therefore$ Density of fuel = 0.8 × 1000 = 800 kg/m^3 (Density of water = 1000 kg/m^3

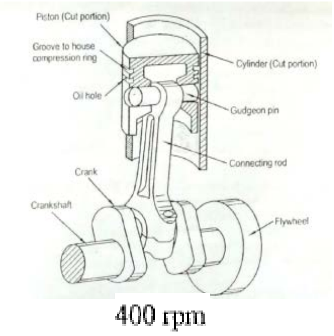
Multiplying fuel consumption by density of fuel, we have

$$\frac{10\ \textit{litres}}{\textit{hour}} \times 800\ \frac{kg}{m^3} = \frac{10\ \cancel{litres}}{hour} \times \frac{800\ kg}{1000\ \cancel{litres}}\ (1\ m^3 = 1000\ \text{litres})$$

$$= 8\ \frac{kg}{hr} = \frac{8}{3600}\ \frac{kg}{sec}$$

$\therefore$ Fuel consumption = mass of fuel = m_f = 2.22×10^{-3} kg/sec





Problem 13 Following observations are taken during a trail on four stroke diesel engine. Cylinder diameter = 25 cm, stroke = 40 cm, speed = 250 rpm, brake load = 70 kg, brake drum diameter = 2 m, mean effective pressure = 6 bar, diesel oil consumption = 0.1 Lt/min, specific gravity of fuel = 0.78, cv of fuel = 43900 kJ/kg. Determine (i) IP (ii) BP (iii) FP (iv) Mechanical efficiency (v) Brake thermal efficiency (vi) Indicated thermal efficiency. ***Feb. 2009 - 08 m***

Given:

4-S engine $= K = \frac{1}{2}$, Cylinder diameter = 25 cm = 0.25 m

$\therefore$ Area $= A = \frac{\pi}{4}d^2 = \frac{\pi}{4}(0.25)^2 = 0.049\ \text{m}^2$

Stroke $= L$ = 40 cm = 0.4 m, Speed $N = 250$ rpm

Brake load $= W = 70\ \text{kg} = 70\times9.81 = 686.7$ N

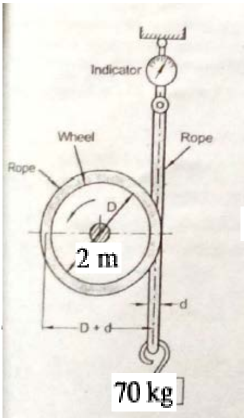
Brake drum diameter $= D$ = 2 m $\therefore$ Radius $R = 1$m

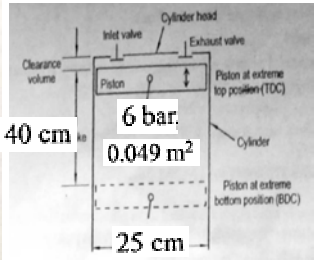
MEP $= P_m$ = 6 bar, Oil consumption = 0.1 Lt/min

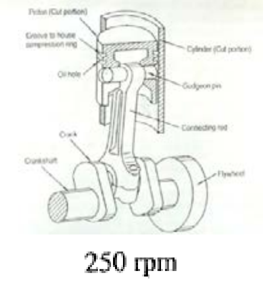
Specific gravity of fuel = 0.78

Mass of fuel $= m_f = \frac{0.1\times0.78}{60} = 1.3\times10^{-3}$ kg/sec

cv of fuel = 43900 kJ/kg







To find IP

$$\text{w.k.t.}\quad IP = n\,P_m LANK\left(\frac{10}{6}\right)\ \text{kW} = 1\times6\times0.4\times0.049\times250\times\frac{1}{2}\times\frac{10}{6}$$

$$\boldsymbol{IP = 24.5\ \text{kW}}$$

To find BP

$$\text{w.k.t.}\quad BP = \frac{2\pi NT}{60\times1000}\ \text{kW}\quad \text{and}\ T = (W - S)R$$

neglecting spring value S, we have, torque $T = (686.7)1 = 686.7$ Nm

$$\therefore\quad BP = \frac{2\times\pi\times250\times686.7}{60000} = 17.97$$

$$\boldsymbol{BP = 17.97\ \text{kW}}$$

To find FP

Friction power $FP = IP - BP = 24.5 - 17.97 = 6.53$

$$\boldsymbol{FP = 6.53\ \text{kW}}$$

To find η_{mech}

$$\text{w.k.t.}\ \eta_{mech} = \frac{BP}{IP} = \frac{17.97}{24.5} = \mathbf{0.733} \qquad \eta_{mech} = \mathbf{73.3\%}$$

To find η_{BTH}

$$\text{w.k.t.}\ \eta_{BTH} = \frac{BP}{m_f\times cv} = \frac{17.97}{\left(1.3\times10^{-3}\right)\times(43900)} = 0.314$$

$$\eta_{BTH} = \mathbf{31.4\%}$$

To find η_{ITH}

$$\text{w.k.t.}\ \eta_{ITH} = \frac{IP}{m_f\times cv} = \frac{24.5}{\left(1.3\times10^{-3}\right)\times(43900)}$$

$$\therefore\ \eta_{ITH} = \mathbf{42.9\%}$$

Problem 14 The following observations were recorded during a test on a 4-S engine: Bore = 25 cm, stroke = 40 cm, crank speed = 250 rpm, Net load on brake drum = 700 N, Diameter of brake drum = 2 m, Indicated MEP = 6 bar, Fuel consumption = 0.0013 kg/sec., specific gravity of fuel = 0.78, cv of fuel = 43900 kJ/kg. Determine (a) BP (b) IP (c) FP (d) Mechanical efficiency (e) Indicated thermal efficiency (f) Brake thermal efficiency.

Feb. 2003 - 12 m

Given:

d = 25cm = 0.25m, stroke = 40cm = 0.4m , N = 250rpm W = 700N D_{drum} = 2m, P_m = 6bar
m_f = 0.0013kg/sec, specific gravity of fuel = 0.78, CV = 43900kJ/kg

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To find BP

w.k.t. $BP = \frac{2\pi NT}{60\times1000}$ kW and $T = (W - S)R$

BP = 18.32 kW

To find IP

w.k.t. $IP = n\, P_m LANK\left(\frac{10}{6}\right)$ kW $= 1\times6\times0.4\times0.049\times250\times\frac{1}{2}\times\frac{10}{6}$

IP = **24.5 kW**

To find FP

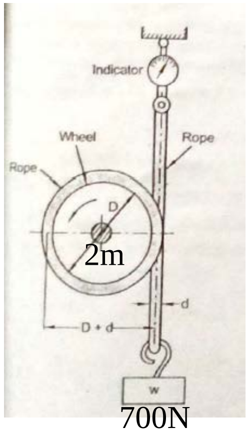
Friction power $FP = IP - BP =$ 24.5-18.32 = 6.18 kW

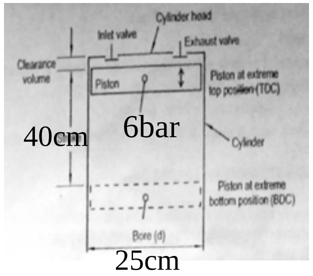
To find η_{mech}

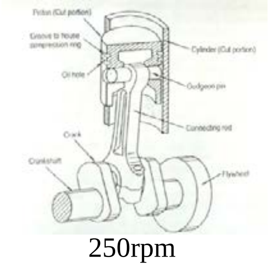
w.k.t. $\eta_{mech} = \frac{BP}{IP} =$ 74.7%

$$\eta_{ITH} = \frac{IP}{m_f\times cv} = \frac{24.5}{(0.0013)\times(43900)} = 42.9\%$$

$$\eta_{BTH} = \frac{BP}{m_f\times cv} = \frac{18.32}{(0.0013)\times(43900)} = 32.1\%$$

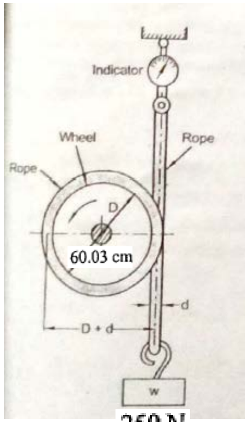


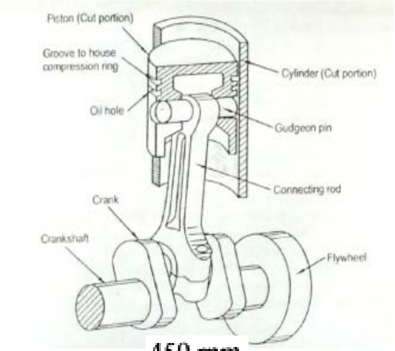




Problem 15 The following are the details of a 4-S petrol engine. Diameter of brake drum - 60.03 cm, Full brake load on drum = 250 N, Brake drum speed = 450 rpm, Calorific value of petrol - 40 MJ/kg, Brake thermal efficiency = 32%, mechanical efficiency = 80%, specific gravity of petrol = 0.82. Determine (i)Brake power, (ii) Indicated power, (iii) Full consumption in litres per second, and (iv) Indicated thermal efficiency

Feb. 2004 - 12 m





Given:

4-S petrol engine = $K = \frac{1}{2}$

Brake drum diameter = D = 60.03 cm = 0.6003m $\therefore$ Radius $R = 0.3$ m

Brake load = W = 250 N, Speed = N = 450 rpm

cv = 40 MJ/kg

$cv = 40\times10^6$ J/kg = 40×10^3 kJ/kg (kilo = 10^3)

$\eta_{BTH} = 32\% = 0.32$, $\eta_{mech} = 80\% = 0.8$ Specific gravity of petrol = 0.82

To find BP

w.k.t. $BP = \frac{2\pi NT}{60\times1000}$ kW

$T = (W - S)R$

neglecting S, we have, $T = (250)\times0.3 = 75$ Nm

$\therefore \quad BP = \frac{2\times\pi\times450\times75}{60000} = 3.53$ **BP = 3.53 kW**

To find IP

use η_{mech} to find IP. $\eta_{mech} = \frac{BP}{IP}$

$\therefore \quad IP = \frac{BP}{\eta_{mech}} = \frac{3.53}{0.8} = 4.41$ **IP = 4.41 kW**

Fuel consumption in lt./sec.

w.k.t. = $\eta_{BTH} = \frac{BP}{m_f \times cv}$

$\therefore \quad m_f = \frac{BP}{\eta_{BTH}\times cv} = \frac{3.53}{0.32\times40\times10^3} = 2.75\times10^{-4}$ kg/sec

To convert kg/sec to litres/sec, divide m_f by specific gravity.

i.e., $\frac{2.75\times10^{-4}}{0.82} = 3.363 \times 10^{-4}$ lt./sec.

$\therefore$ **Fuel consumption = 3.363×10^{-4} litres/sec.**

To find η_{ITH}

w.k.t. = $\eta_{ITH} = \frac{IP}{m_f \times cv} = \frac{4.41}{\left(2.75\times10^{-4}\right)\times40\times10^3} = 0.4$

η_{ITH} = **40%**

Problem 16 A 4-S petrol engine delivers a power of 35 kW with a mechanical efficiency of 80%. The fuel consumed by the engine is 0.4 kg per kW/hr of the power developed. Calculate, indicated power, friction power, Brake thermal efficiency, indicated thermal efficiency, & fuel consumption per hour. If the air-fuel ratio is 14:1, Calculate the air consumption per hour. The heating value of the fuel is 43000 kJ/kg.

Given:

4-S engine = $K = \frac{1}{2}$, $BP = 35$ kW, $\eta_{mech} = 80\% = 0.8$

Fuel consumption/kW-hr = BSFC = 0.4 kg/kW hr

$$\text{Air-fuel ratio (A/F ratio)} = \frac{mass\ of\ air\ (m_a)}{mass\ of\ fuel\ (m_f)} = 14:1$$

cv of fuel = 43000 kJ/kg, Assume single cylinder engine = $n = 1$

To find IP

$$\eta_{mech} = \frac{BP}{IP}$$

$$0.8 = \frac{35}{IP} \qquad \therefore\ IP = 43.75 \text{ kW}$$

To find FP

w.k.t. $FP = IP - BP = 43.75 - 35$ $\qquad FP = 8.75$ kW

To find η_{BTH}

$$\eta_{BTH} = \frac{BP}{m_f \times cv}$$

But $m_f = ?$

$$\text{w.k.t.}\quad BSFC = \frac{Fuel\ consumed\ /\ hr}{BP\ in\ kW}$$

$$0.4 = \frac{m_f}{35}$$

m_f = fuel consumption per hour = 14 kg/hr or 3.88×10^{-3} kg/sec

$$\eta_{BTH} = \frac{35}{(3.88 \times 10^{-3}) \times 43000} = 0.2094$$

$$\eta_{BTH} = \mathbf{20.97\%}$$

To find η_{ITH}

$$\text{w.k.t.}\ \eta_{mech} = \frac{\eta_{BTH}}{\eta_{ITH}}$$

$$\therefore\ \eta_{ITH} = \frac{\eta_{BTH}}{\eta_{mech}} = \frac{0.2097}{0.8} = 0.2621$$

$$\eta_{ITH} = \mathbf{26.21\%}$$

To find air consumption/hour

$$\text{w.k.t. A/F ratio} = \frac{m_a}{m_f}$$

$$\frac{14}{1} = \frac{m_a}{m_f}$$

$$\therefore\ m_a = 14 \times m_f = 14 \times 14 = 196$$

Air consumed per hour = m_a = **196 kg/hr**

Problem 17 A large diesel engine runs on four-stroke-cycle at 2000 rpm. The engine has a displacement of 25 litres and a brake mean effective pressure of 0.6 MN/m². It consumes 0.018 kg/s of fuel. (Calorific value = 42000 kJ/kg). Determine the brake power and brake thermal efficiency.

Given:

4-S engine = $K = \frac{1}{2}$, N = 2000 rpm

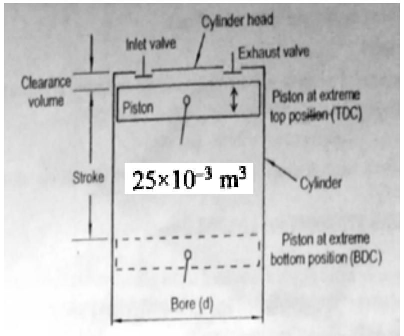
Engine displacement = $V_s = \frac{\pi}{4} d^2 \times L = 25$ litres

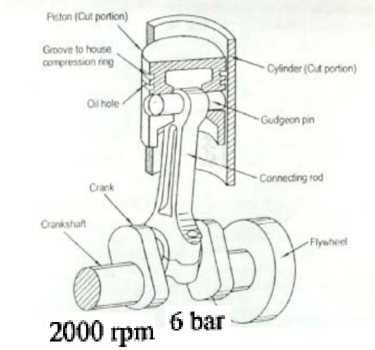
$\therefore \; V_s = 25 \times 10^{-3}$ m³ (1 m³ = 1000 litres)

Brake MEP = *BMEP* = $P_{mb} = 0.6$ MN/m² $= 0.6 \times 10^6$ N/m² $= 6 \times 10^5$ N/m²

or $P_{mb} = 6$ bar

$m_f = 0.018$ kg/sec, $cv = 42000$ kJ/kg, Assume single cylinder = $n = 1$





To find BP

When BMEP is given, use equation of IP for expressing BP, i.e., $BP = IP$

$$\text{i.e., } BP = n\, P_{mb}\, L\, A\, N\, K \left(\frac{10}{6}\right) = 1 \times 6 \times \mathrm{L} \times \frac{\pi}{4} \times d^2 \times 2000 \times \frac{1}{2} \times \frac{10}{6}$$

$$BP = \left(\frac{\pi}{4} \cdot d^2 L\right) \times 10000$$

$$\text{But } \frac{\pi}{4} d^2 = V_S = 25 \times 10^{-3} \text{ m}^3$$

$$BP = 25 \times 10^{-3} \times 10000 = 250 \text{ kW}$$

To find η_{BTH}

$$\text{w.k.t. } \eta_{BTH} = \frac{BP}{m_f \times cv} = \frac{250}{0.018 \times 42000} = 0.3306$$

$$\eta_{BTH} = 33.06\%$$

Problem 18 A 4 cylinder, 4-stroke spark ignition engine develops a maximum brake torque of 160 Nm at 3000 rpm. Calculate the engine displacement, bore ~~and~~ stroke. The brake mean effective pressure at the maximum engine torque point is 960 kPa. Assume bore is equal to stroke.

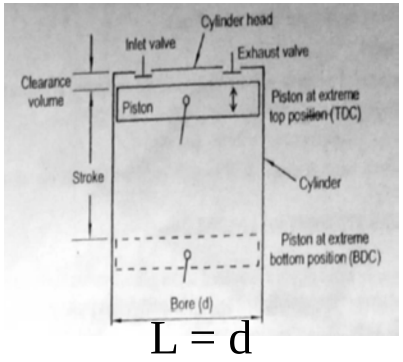
Given:

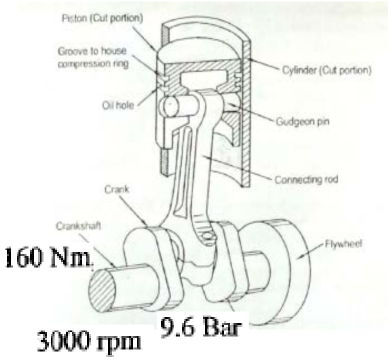
4-cylinder engine = n = 4, 4-stroke engine. = K = $\frac{1}{2}$

Torque = T = 160 Nm, Speed N = 3000 rpm

$BMEP = P_{mb}$ = 960 kPa = 960 × 10^3 N/m² = 9.6 Bar

Bore d = stroke L





To find V_S, d & L

Power developed = BP = IP (for BMEP)

$$\frac{2\pi NT}{60\times1000} = n\,P_{mb}\,LANK\left(\frac{10}{6}\right)$$

For 4-cylinders, $4\times\frac{2\pi NT}{60\times1000} = n\,P_m\,LANK\left(\frac{10}{6}\right)$

$$\frac{4\times2\times\pi\times3000\times160}{60\times1000} = 4\times9.6\times L\times\frac{\pi}{4}d^2\times3000\times\frac{1}{2}\times\frac{10}{6}$$

$$2.667\times10^{-3} = Ld^2$$

But L = d

$$\therefore\; d^3 = 2.667\times10^{-3}$$

$$\mathbf{d = 0.1386\ m = L}$$

To find Engine displacement V_S

Note Engine displacement = stroke volume

$$= \text{Area}\times\text{length} = \frac{\pi}{4}d^2\times L$$

w.k.t. stroke volume = $V_S = \frac{\pi}{4}d^2\times L = \frac{\pi}{4}d^3 = \frac{\pi}{4}\times(0.1386)^3$

$$\mathbf{V_S = 2.09\times10^{-3}\ m}$$

Problem 19 Calculate the brake specific fuel consumption of a diesel engine having a brake thermal efficiency of 28%. The calorific value of the fuel used is 42500 kJ/kg.

Given: $\eta_{BTH} = 28\% = 0.28,\ cv = 42500\ \text{kJ/kg}$

To find BSFC

$$\text{w.k.t. BSFC} = \frac{\textit{Fuel consumed in kg/hr}}{BP}$$

$$\text{BSFC} = \frac{m_f \ \ kg/hr}{BP \ \ KW}$$

But $m_f = BP = ?$

$$\text{w.k.t. } \eta_{BTH} = \frac{BP}{m_f \times cv} \quad m_f \text{ is in kg/sec.}$$

$$0.28 = \frac{BP \times 3600}{m_f \times cv} \quad (m_f \text{ is converted to kg/hr})$$

$$m_f = \frac{BP \times 3600}{0.28 \times 42500}$$

$$\text{, we have, } BSFC = \frac{\frac{BP \times 3600}{0.28 \times 42500}}{BP} = \frac{3600}{0.28 \times 42500} = 0.3025$$

$$\boldsymbol{BSFC = 0.3025 \text{ kg/kW-hr}}$$

Problem 20 A single cylinder 4-stroke diesel engine gave the following results while running at full load. Area of indicator card 300 mm², length of diagram 40 mm, spring constant 1 bar/mm, speed of the engine 400 rpm, load on the brake 370 N, spring balance reading 50 N, diameter of brake drum 1.2 m, fuel consumption 2.8 kg/hr, CV of fuel 41800 kJ/kg, diameter of the cylinder 160 mm, stroke of the piston 200 mm. Determine the following: (a) IMEP (b) BMEP (c) BP (d) BSFC (e) brake thermal & indicated thermal efficiencies.

Given:

single cylinder = $n = 1$, 4-S engine $= K = \frac{1}{2}$

area of indicator card $= 300$ mm², length of diagram $= l = 40$ mm

spring constant $= s = 1$ bar/mm, engine speed $= 400$ rpm

brake load $= W = 370$ N, spring reading $= S = 50$ N

Drum diameter $= D = 1.2$ m $\therefore$ Drum radius $= \frac{D}{2} = 0.6$ m

Fuel consumption $= m_f = 2.8$ kg/hr $= 7.77 \times 10^{-4}$ kg/sec

cv of fuel $= 41800$ kJ/kg

diameter of cylinder $= d = 160$ mm $= 0.16$ m $\therefore$ $A = \frac{\pi}{4} d^2 = 0.020$ m²

stroke $= L = 200$ m $= 0.2$m

To find IMEP

$$\text{w.k.t. IMEP} = P_m = \frac{s.a}{l} = \frac{1 \times 300}{40} = 7.5 \text{ Bar}$$

$$P_m = \textbf{IMEP = 7.5 Bar}$$

When BMEP (P_{mb}) is asked, use, $BP = n\, P_{mb}\, L\, A\, N\, K \left(\frac{10}{6}\right)$

But $BP = ?$

$$\text{w.k.t. } BP = \frac{2\pi NT}{60 \times 1000} \text{ kW}$$

$$T = (W - S)\, R$$

$$T = (370{-}50) \times 0.6 = 192 \text{ Nm}$$

$$\therefore\ BP = \frac{2 \times \pi \times 400 \times 192}{60 \times 1000} = 8.04 \qquad BP = 8.04 \text{ kW}$$

$$8.04 = 1 \times P_{mb} \times 0.2 \times 0.02 \times 400 \times \frac{1}{2} \times \frac{10}{6} \qquad BMEP = P_{mb} = \textbf{6.03 Bar}$$

To find BSFC

$$\text{w.k.t. } BSFC = \frac{\text{Fuel consumed in kg/hr}}{BP} = \frac{2.8}{8.04} = 0.348$$

$$BSFC = \textbf{0.348 kg/kW-hr}$$

To find η_{BTH} & η_{ITH}

$$\text{w.k.t. } \eta_{BTH} = \frac{BP}{m_f \times cv} = \frac{8.04}{7.77 \times 10^{-4} \times 41800} = 0.247$$

$$\eta_{BTH} = \textbf{24.7\%}$$

$$\text{and, } \eta_{ITH} = \frac{IP}{m_f \times cv}$$

But IP $= ?$

t. $IP = n\, P_m\, L\, A\, N\, K \left(\frac{10}{6}\right) = 1 \times 7.5 \times 0.2 \times 0.02 \times 400 \times \frac{1}{2} \times \frac{10}{6} = 10$ kW

$$\eta_{ITH} = \frac{10}{7.77 \times 10^{-4} \times 41800}$$

$$\eta_{ITH} = \textbf{30.79\%}$$

Problem 21 A single cylinder, four-stroke engine develops indicated power of 30 kW at 300 rpm. The indicated mean effective pressure is 6.5 bar. The piston speed is 180 m/min. Determine the stroke and diameter of the cylinder. Also find brake specific fuel consumption, if the mechanical efficiency is 80% and indicated thermal efficiency is 30%. Take the calorific value of diesel as 40,000 kJ/kg. ***Jan 2008 - 08 m***

Given: number of cylinders $= n = 1$; 4-stroke engine $= K = \frac{1}{2}$

$$IP = 30 \text{ kW}, \text{ speed } N = 300 \text{ rpm}$$

$$\text{IMEP} = P_m = 6.5 \text{ bar}, \text{ Piston speed} = 3\,LN = 180 \text{ m/min}$$

$$\eta_{mech} = 80\% = 0.8 \quad ; \quad \eta_{ITH} = 30\% = 0.3 \qquad CV = 40000 \text{ kJ/kg}$$

To find stroke (L) and diameter (d) of cylinder

By data, piston speed $2\,LN = 180$ m/min

$$\therefore L = \frac{180}{2N} = \frac{180}{2(300)} = 0.3\ m \qquad \therefore \text{ stroke } L = \mathbf{0.3}\ m$$

To find d w.k.t. $IP = n\,P_m\,LANK\left(\frac{10}{6}\right)$

$$30 = 1\,(6.5)\,0.3\left[\frac{\pi}{4}(d^2)\right]300\left(\frac{1}{2}\right)\left(\frac{10}{6}\right)$$

$\therefore$ diameter of cylinder $= d = \mathbf{0.28}\ m$

To find BSFC

$$\text{w.k.t. BSFC} = \frac{\text{Fuel consumed in kg / hr}\,(m_f)}{BP}$$

To find m_f and BP

w.k.t. $\eta_{ITH} = \dfrac{IP}{m_f \times CV}$ Note that m_f is in kg/sec.

$$\therefore m_f = \frac{IP}{\eta_{ITH} \times CV} = \frac{30}{0.3(40000)} = 2.5 \times 10^{-3} \text{ kg/sec} = 9 \text{ kg/hr}$$

w.k.t. $\eta_{mech} = \dfrac{BP}{IP}$ or $BP = \eta_{mech}(IP) = 0.8\ (30) = 24$ kW

$$\text{BSFC} = \frac{9}{24} = 0.375$$

BSFC **= 0.375 kg/kW-hr**

Problem 22 A gas engine working on a four stroke cycle has a cylinder diameter of 0.25 *m* and length of stroke of 0.45 *m* and running at 180 *r/min*. Its mechanical efficiency is 80% when mean effective pressure is 6.5 bar. Find indicated power, brake power, and friction power. What is the fuel consumption rate (kg/hour) and brake specific fuel consumption (kg/kWh) if the energy content of the fuel used is 42000 kJ/kg and brake thermal efficiency is 25%. ***July 2008 - 10 m***

Given:

4-stroke engine = $K = \frac{1}{2}$, diameter d = 0.25 m, stroke length = L = 0.45 m, speed N = 180 rpm

η_{mech} = 80% = 0.8 ; P_m = 6.5 bar, CV of fuel = 42000 kJ/kg ; η_{BTH} = 25% = 0.25

To find IP, BP and FP

w.k.t. indicated power $IP = nP_mLANK\left(\frac{10}{6}\right) = 1\,(6.5)\,(0.45)\left[\frac{\pi}{4}(0.25)^2\right]180\left(\frac{1}{2}\right)\left(\frac{10}{6}\right)$

IP = **21.53 kW**

w.k.t. $\eta_{mech} = \frac{BP}{IP}$

Brake power BP = η_{mech}(IP) = 0.8 (21.53) = 17.22

BP = 17.22 kW

w.k.t. Friction power FP = IP – BP = 2153 – 17.22 = 4.31

FP = 4.31 kW

To find fuel consumption rate m_f in kg/hr

w.k.t. $\eta_{BTH} = \frac{BP}{m_f \times CV}$ whre m_f is in kg/sec.

$\therefore\ m_f = \frac{BP}{\eta_{BTH}(CV)} = \frac{17.22}{0.25(42000)} = 1.64 \times 10^{-3}$

$m_f = 1.64 \times 10^{-3}$ kg/sec or 1.64×10^{-3} (3600) kg/hr

Fuel consumption rate m_f = **5.904 kg/hr**

To find BSFC

w.k.t. $BSFC = \frac{m_f\ in\ kg\,/\,hr}{BP\ in\ kW} = \frac{5.904}{17.22}$

$BSFC$ = **0.342 kg/kW-hr**

Problem 23 A six-cylinder 4-stroke IC engine develops 50 kW of indicated power at MEP of 700 kPa. The bore and stroke length are 70 mm and 100 mm respectively. If the engine speed is 3700 rpm. Find the average misfires per unit time.

July 2013 - 06 m

Given:

number of cylinders $= n = 6$; 4-stroke engine $= K = \frac{1}{2}$; $IP = 50$ kW

$MEP = P_m = 700\ kPa = 700 \times 10^3\ N/m^2$ (1 Pa = 1 N/m^2)

bore $d = 70\ mm = 0.07\ m$; stroke $L = 100\ mm = 0.1\ m$

Actual engine speed $N' = 3700$ rpm

To find average number of misfires/unit time

Misfire – one or more cylinders are not igniting the fuel mixture at the right time. This occurs due to malfunctioning of the fuel injector/spark plug or due to insufficient compression in the cylinder

$$\text{w.k.t.} \quad IP = n P_m LANK \left(\frac{10}{6}\right)$$

$$\text{Theoretical engine speed} \quad N = \frac{IP.(6)}{n P_m LAK(10)} = \frac{50(6)}{6(10)(0.1)\left[\frac{\pi}{4}(0.07)^2\right]\frac{1}{2}(10)}$$

Theoretical speed $N = 3712$ rpm

For a 4-S engine, number of cycles/min or number of explosions / min $= \frac{N}{2} = \frac{3712}{2} = 1856$

Actual explosions / min $= \frac{N'}{2} = \frac{3700}{2} = 1850$

$\therefore$ Number of misfires $= 1856 - 1850 = 6$

Approximately number of misfire / min = 6

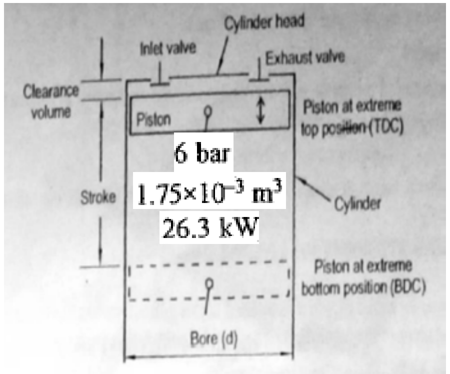
Problem 24 A 6-cylinder, 4-stroke IC engine with a stroke volume of 1.75 litres, develops 26.3 kW of indicated power while running at 504 rpm. The MEP is found to be 6 bar. Calculate the average number of times each cylinder misfires in one minute.

Given:

$$n = 6 \text{ , and 4-S engine } K = \frac{1}{2}$$

$$\text{stroke volume} = V_S = \text{L.A} = 1.75 \text{ litres} = 1.75\times10^{-3}\ \text{m}^3\ (1\ \text{m}^3 = 1000\ \text{lt})$$

$$IP = 26.3\ \text{kW}, \text{ Actual speed} = N' = 504\ \text{rpm} \qquad MEP = P_m = 6\ \text{bar}$$



To find number of misfires per minute/cylinder

$$\text{w.k.t. } IP = n\, P_m\, L\, A\, N\, K \left(\frac{10}{6}\right)$$

$$\therefore \text{ Engine speed } = N = \frac{IP\times6}{n\cdot Pm\cdot L\cdot A\,K\times10} = \frac{26.3\times6}{6\times6\times1.75\times10^{-3}\times\frac{1}{2}\times10} = 500.95\ \text{rpm}$$

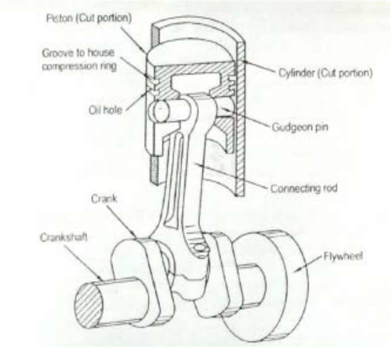
$$N = 500.95\ \text{rpm}$$

For a 4-S engine, number of cycles/min or number of explosions/min $= \frac{N}{2} = \frac{500.95}{2} = 250.47$

$$\therefore \text{ Actual explosions/min } = \frac{N'}{2} = \frac{504}{2} = 252$$

$$\therefore \text{ Number of misfires } = 252 - 250.47 = 1.53$$

Approximately number of misfire/min = 2



504 rpm

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Module – 3.2

Refrigeration & Air conditioning

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Refrigeration

- The process of cooling or reducing the temperature of a substance below that of the surrounding atmosphere and maintaining lower temperature within the boundary of a given space is called refrigeration.
- The machine or device employed to produce refrigeration effect is called refrigeration machine or refrigerator.
- Need of refrigeration:

i. Food stuff, medical supplies and other important products have to be kept cool to stay fresh and usable.

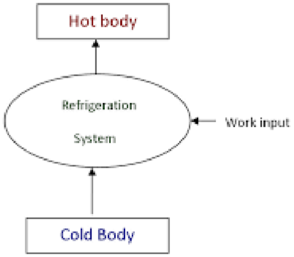
ii. By cooling or reducing the temperature, the growth of bacteria and enzymatic activity can be reduced which helps to preserve the products for longer time.

Commercial refrigeration

Industrial refrigeration

Principle of refrigeration

- The primary purpose of refrigeration is to keep the substance cold. In order to keep the substance cold, heat must be continuously removed from it.
- According to the law of thermodynamics, heat naturally flows from a hot substance to a cold substance. But if heat has to flow from cold to hot substance, some form of work has to be performed.
- Principle of refrigeration: Heat is continuously extracted from the low temperature substance by performing mechanical work and rejecting this heat to the surrounding atmosphere or high temperature substance.
- A carrier substance is used to extract the heat known as refrigerant (chemical substance which includes ammonia, CO_2 , methyl chloride etc.)
- The refrigerant in the liquid state is made to circulate in a cycle, through a series of events where it undergoes a change of phase from liquid to vapour and again back to the liquid state.
- During its change of phase (L → Vapour) it absorbs heat from the substance & a change from vapour → L phase helps in rejection of heat to the surroundings.
- The process repeats again and again thereby maintaining low temperature in the given space or substance.



Types of refrigerators

1. Vapour compression refrigerator (VCR)
2. Vapour absorption refrigerator (VAR)

1. Vapour compression refrigerator

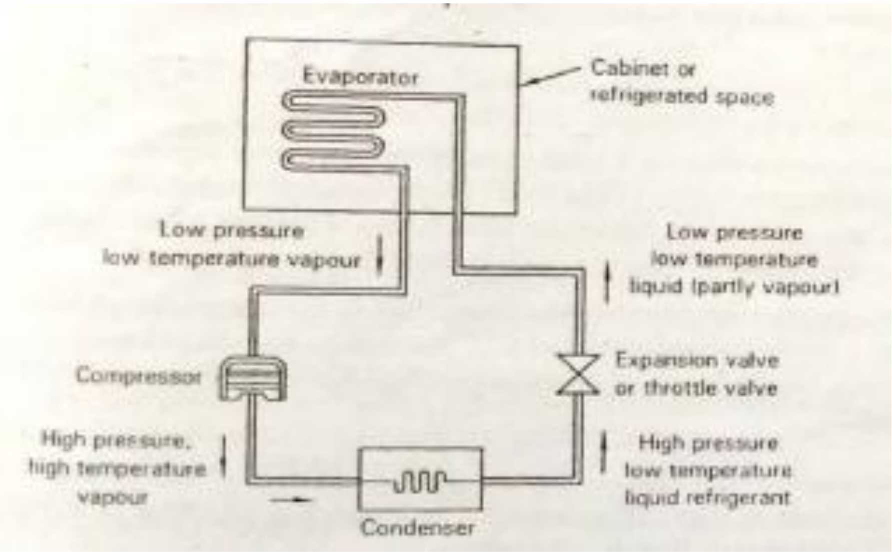
- Works on vapour compression cycle.
- Uses: Domestic/ household purpose, large commercial and industrial refrigeration.
- Basic components:

  i. Evaporator

  ii. Compressor

  iii. Condenser

  iv. Expansion valve



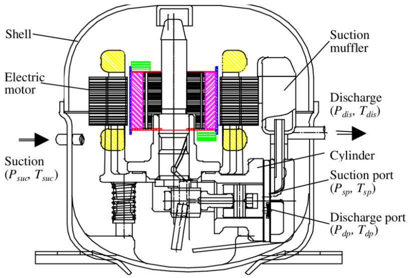
Vapour compression refrigeration cycle

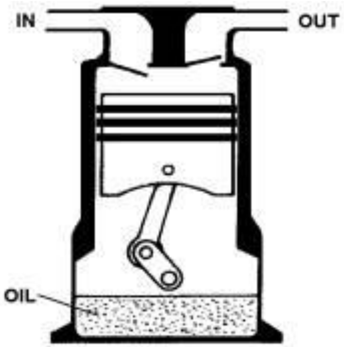
Construction of VCR

i. Evaporator: A component located inside the cabinet in which the substance has to be cooled. It consists of serpentine or coiled set of pipes through which the refrigerant flows.

ii. Compressor:

- A reciprocating compressor with a piston - cylinder arrangement is placed at the bottom portion of the refrigerator.
- The compressor is driven by an electric motor from an AC power supply.
- Functions:
  1) compress the vapour refrigerant to high pressures and temperatures
  2) Circulate the refrigerant in a circuit – refrigerant can perform heat absorbing function again and again.



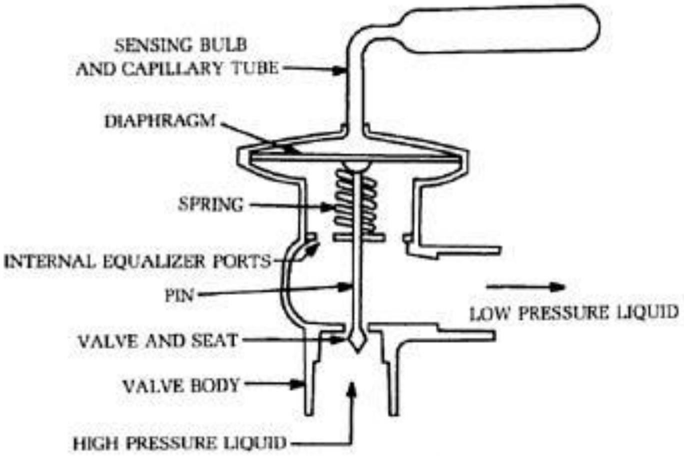


iii. Condenser

- Similar in appearance to the evaporator, usually placed at the back of the refrigerator.
- Acts like a heat exchanger – vapour refrigerant while flowing through it gives away heat to the cooling medium [air or water] circulating around the coils.
- The vapour refrigerant after rejecting heat gets condensed to liquid state.

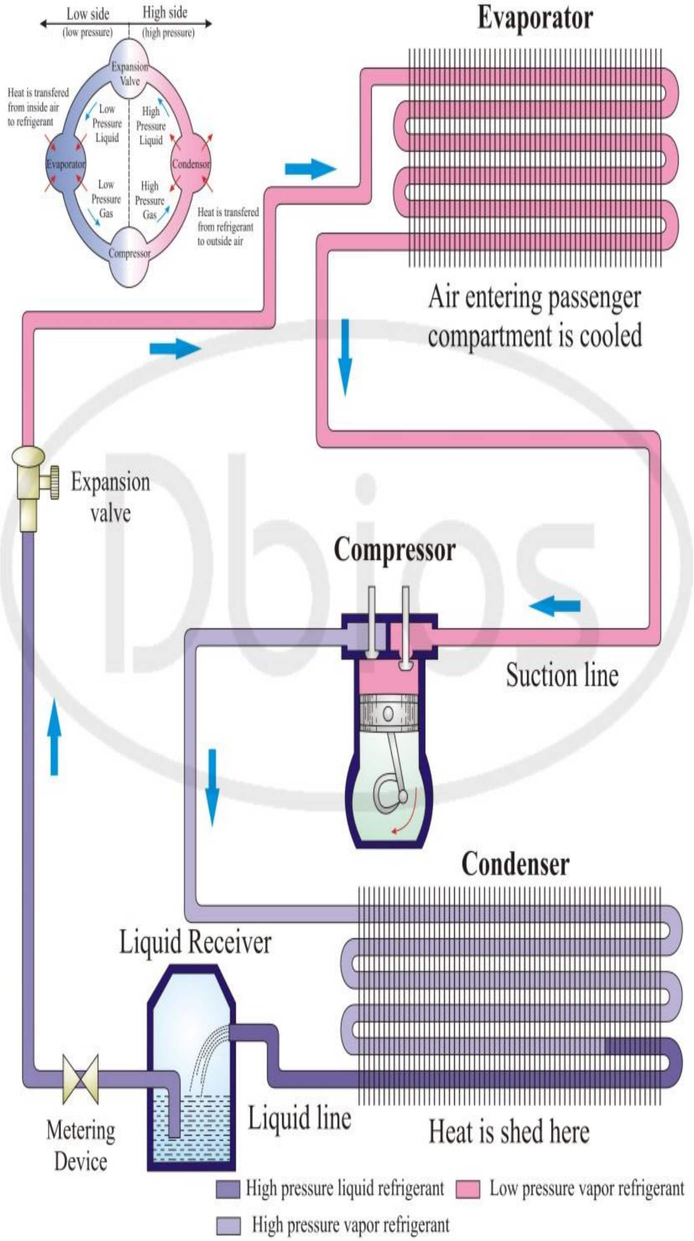
iv. Expansion valve

- Small orifice/tiny openings.
- Functions:
  1) Reduce the pressure of the refrigerant as it flows through it.
  2) Regulate the flow of refrigerant to the evaporator.

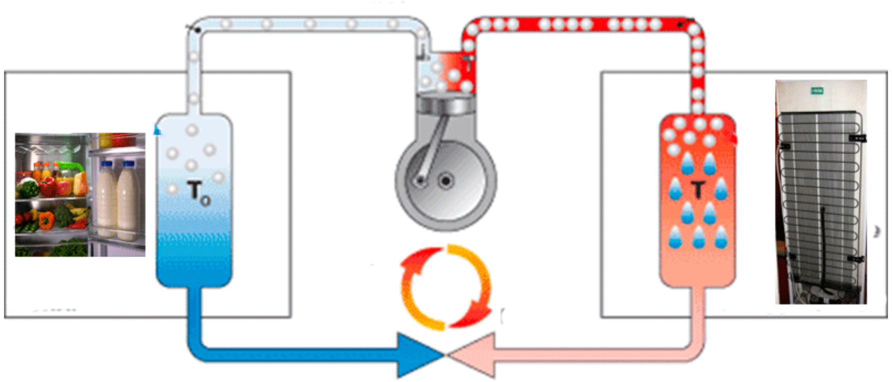


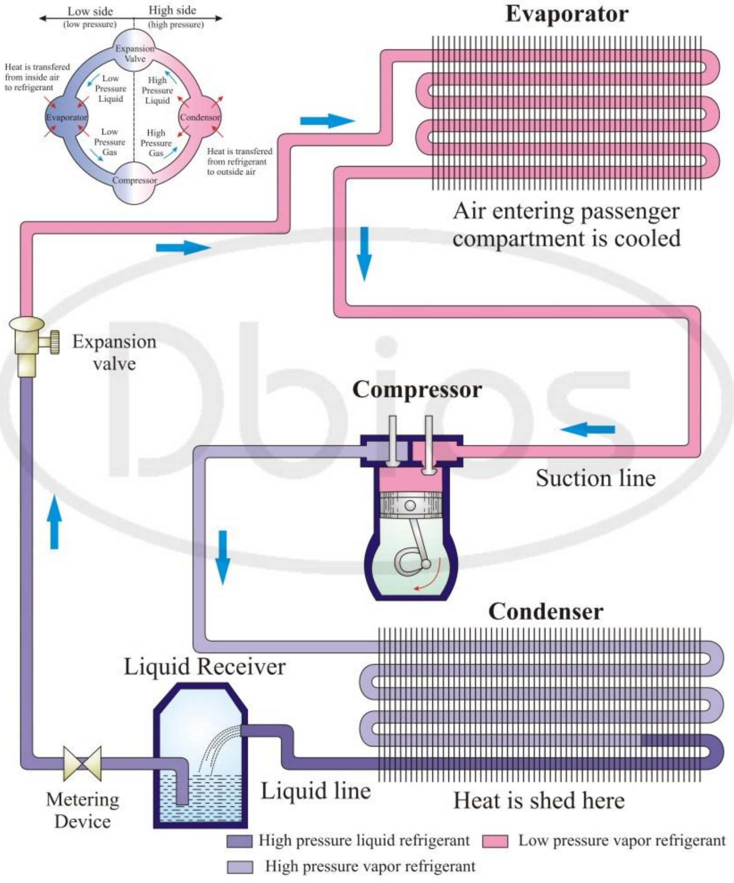
Working of VCR

- Let us assume that the low pressure and low temperature liquid refrigerant (partly vapour) in the evaporator absorbs the heat from the inside of the cabinet and undergoes a change in phase from L ⟶ Vapour.
- The vapour at low temperature and pressure is drawn into the compressor, where it is compressed/squeezed to high pressure and temperature.
- The compressor compresses the vapour to such high pressures, than its saturation temperature will be higher than the temperature of the cooling medium [work is performed by the compressor for the heat transfer to take place].
- The high temperature and pressure refrigerant flows through the condenser, gives away its latent heat to the cooling medium [either air / water flowing around the condenser] (Vapour refrigerant L). The temperature of the refrigerant decreases, but its pressure remains same.



- The high pressure and low temperature liquid refrigerant coming from the condenser passes through the expansion valve, where it is expanded to low pressure and temperature.
- The low pressure, low temperature liquid refrigerant now enters the evaporator where it absorbs heat from the cabinet and changes to vapour phase. The low pressure, low temperature vapour refrigerant is drawn into compressor and the cycle repeats.
- Thus heat is continuously extracted from the cabinet thereby keeping the substance at the required low temperature.



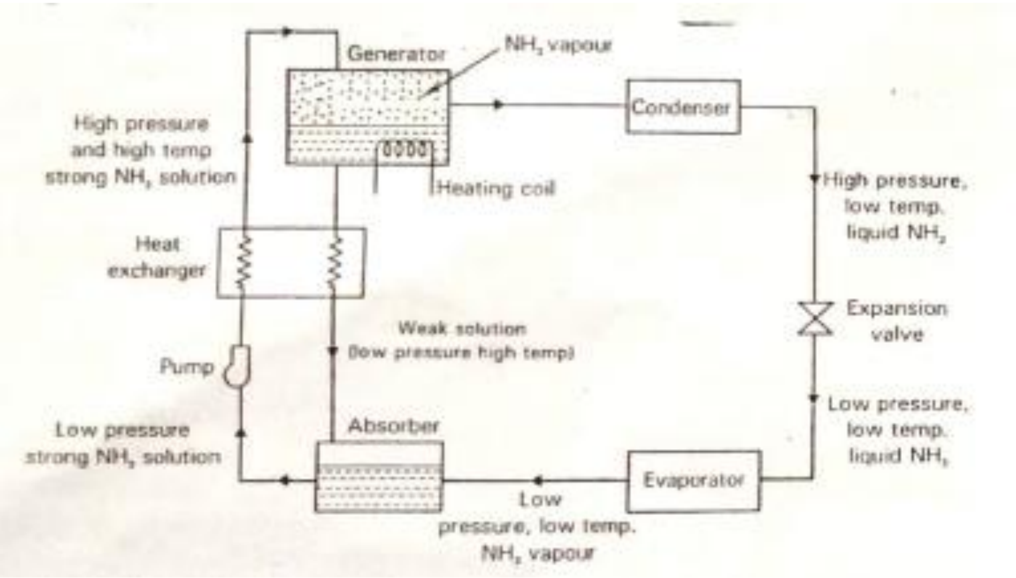


2. Vapour absorption refrigerator

- Similar in working to the vapour compression system except for the method of raising the pressure of the refrigerant vapour.
- Uses: Recreational vehicles that carry LP gas, industrial environments where exhaust waste heat can be used to provide the energy needed to drive the cooling system, as chiller in office buildings and in hospitals to chill a brine solution.
- Basic components

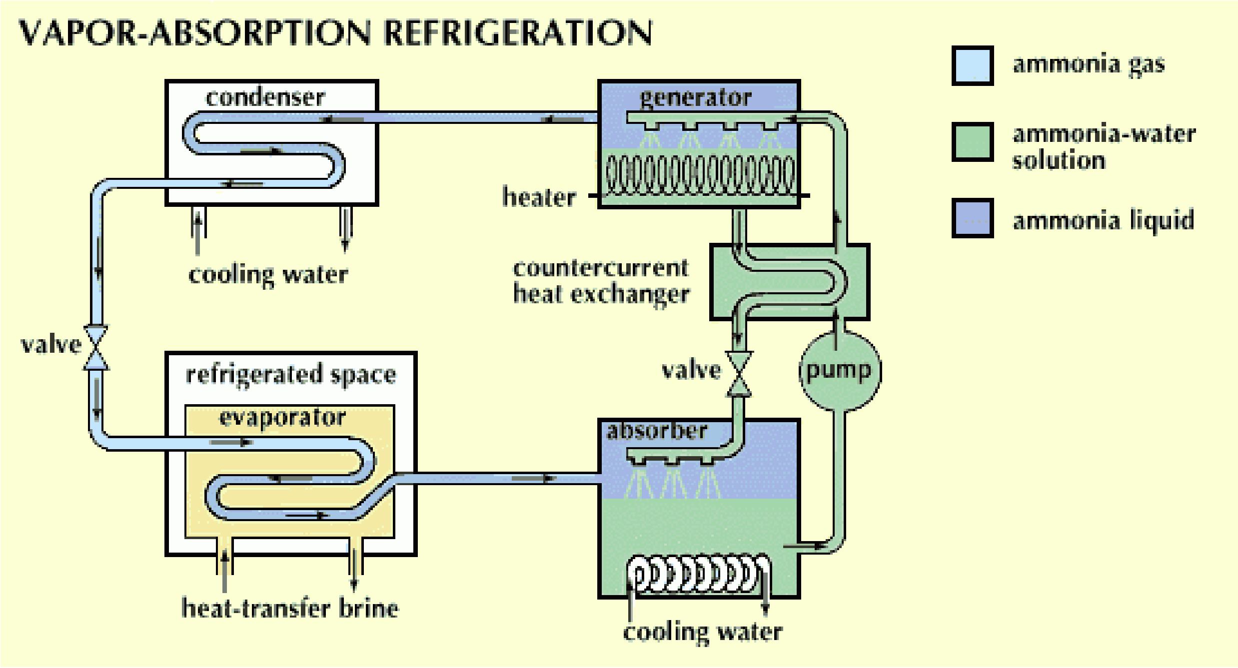
i. Evaporator
ii. Absorber
iii. Pump
iv. Generator
v. Condenser
vi. Expansion valve

Absorption system



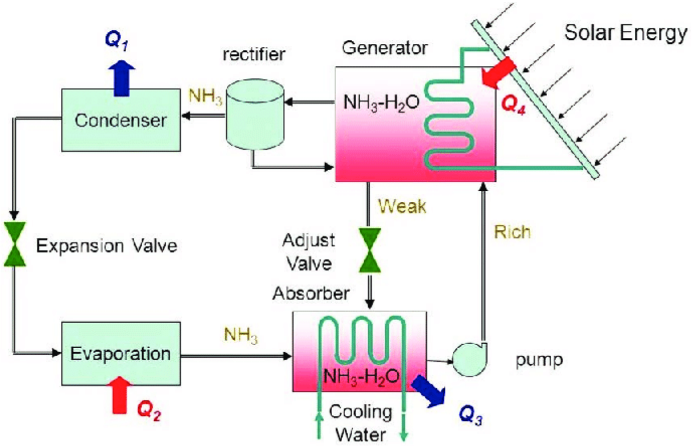
Construction of VAR

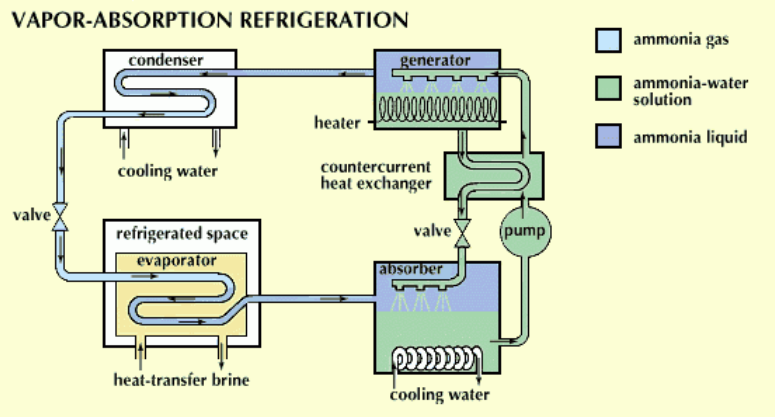
- In the absorption system, the compressor (VCR) is replaced by an absorber, generator and a pump.
- Absorber: consists of refrigerant which is highly soluble in liquid (absorbent). The most common combinations are ammonia (refrigerant) & water (absorbent), water (refrigerant) & lithium bromide (absorbent).
- Generator: The system makes use of heat source such as combustion of LPG, kerosene-fuelled flame, solar energy or an electric heating element. These heat sources make the system work smoothly and quietly.
- Pump: Circulates the refrigerant – absorbent solution from the low pressure absorber to high pressure generator.



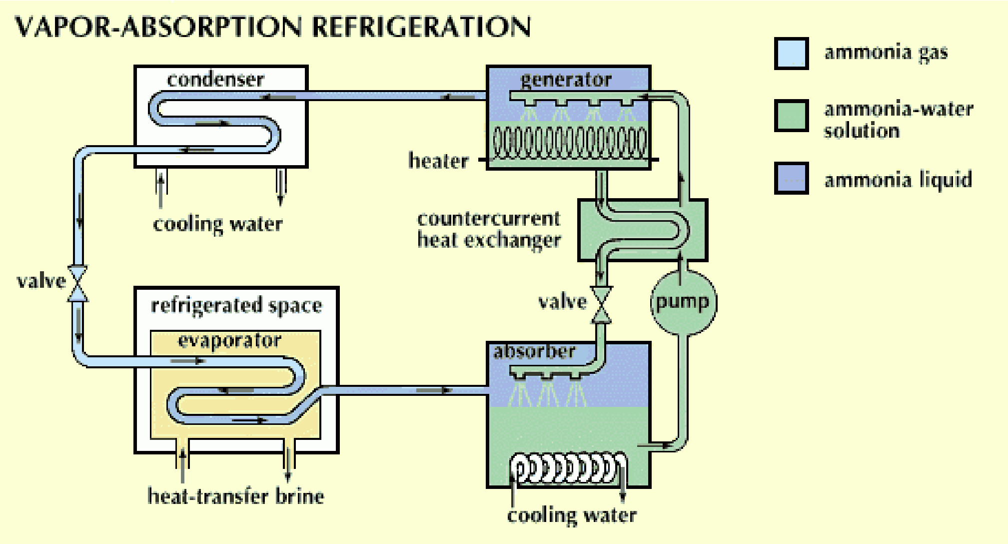
Working of VAR

- Let us assume that the liquid ammonia refrigerant in the evaporator absorbs heat from the cabinet and undergoes a change of phase from liquid to vapour [L → Vap].
- This low pressure and low temperature NH_3 vapour is passed to the absorber, which contains weak solution of $NH_3 + H_2O$.
- Since water has the capacity to absorb ammonia vapour, low pressure ammonia is dissolved in $NH_3 + H_2O$ resulting in a strong ammonia solution.
- The strong ammonia solution is then pumped to a generator through the heat exchanger at high pressure [using pump].
- While passing through the heat exchanger, the strong ammonia solution is warmed up by the hot weak ammonia solution flowing from the generator to the absorber.





- The ammonia solution from the heat exchanger enters the generator, where it is heated by an external source. Due to heating, the vapour gets separated from the solution.
- The ammonia solution (hot and weak solution) flows through the heat exchanger to the absorber.
- The high pressure and high temperature ammonia vapours from the generator enters the condenser, where it gives away its heat to the circulating cooling medium. The vapour refrigerant gets condensed to liquid state.
- The high pressure and low temperature ammonia liquid refrigerant enters the expansion valve where it is expanded to low pressure and temperature.
- The low pressure and low temperature liquid refrigerant enters the evaporator where it absorbs heat from the cabinet and evaporates.
- The ammonia vapours now enters the absorber and the cycle repeats again and again.



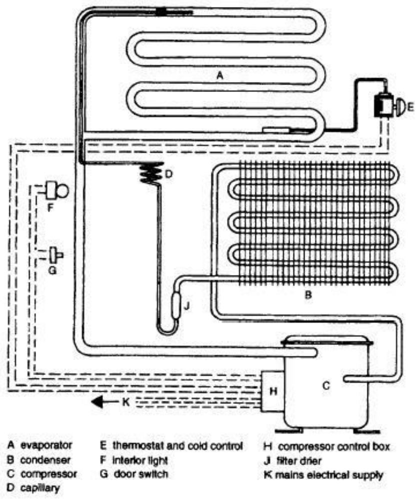
3. Domestic refrigeration

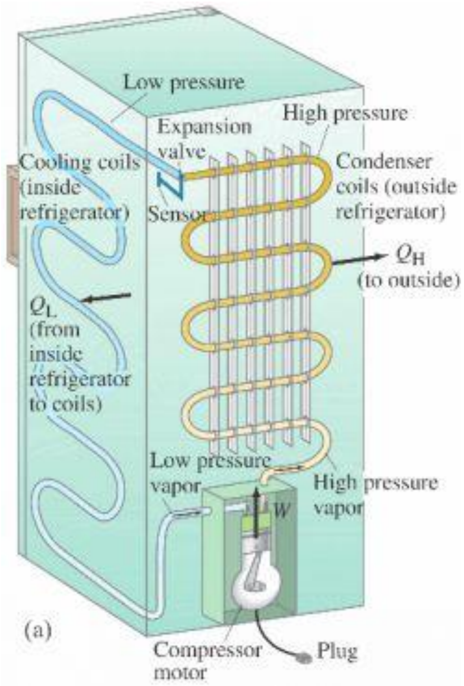
- A house hold or domestic refrigerator works on vapour compression refrigeration cycle.

Construction of DR

- Compressor used – reciprocating type, hermetically sealed [compressor and the electric motor are a single unit enclosed in a container].
- Condenser – natural air convention type [small refrigerators], forced air convention type [large refrigerators]
- Expansion valves – small capillary tube made from copper with very less diameter and longer length [increases friction , high pressure liquid refrigerant → low pressure , due to pressure drop in capillary itself].

Working of DR – *same as the working of VCR*



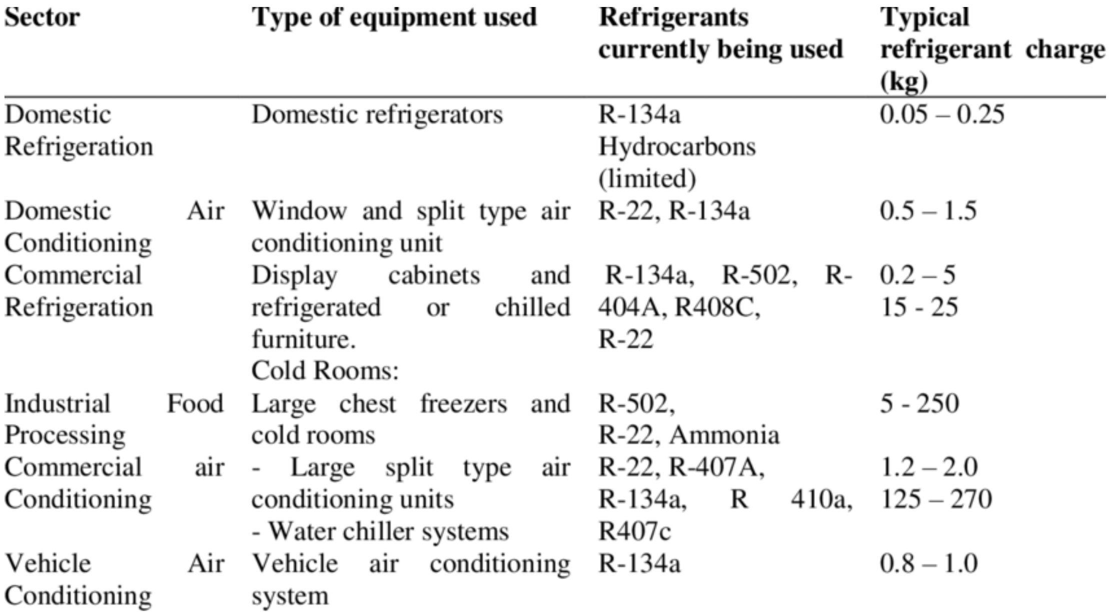


Difference between vapour compression system and vapour absorption system

Sl. No.	VCR system	VAR system
1.	Vapour refrigerant is compressed	Vapour refrigerant is absorbed and heated
2.	Work is performed by the compressor for the heat transfer.	System makes use of heat source such as combustion of LPG
3.	Mechanical energy required is more [refrigerant vapours are compressed to high pressure]	Energy required is less [Pump is used to circulate the refrigerant]
4.	No restriction for the type of refrigerants used	Refrigerants which are soluble in another solution are used.
5.	electric power is required to run the compressor	Not dependent on electric power.
6.	Noisy, more maintenance cost	Absence of moving parts makes the system run quiet, low maintenance cost
7.	Built in capacity = 1000 Tons	Above 1000 Tons
8.	Coefficient of performance of the system decreases with increase in load	At reduced loads, the system is almost as efficient as at full load
9.	Chances of refrigerant leakage	No chance of refrigerant leakage
10.	Domestic, commercial and industrial applications	Food storage in recreational vehicles

Refrigerants

- A chemical substance that absorbs heat from a substance or given space by evaporating at a low temperature and pressure, and rejecting the heat by condensing at a high temperature and pressure.
- Refrigerant does not undergo chemical change during the process, instead undergoes a change of phase from liquid to vapour by absorbing heat and vapour to liquid phase by rejecting heat.
- Different types of refrigerant: NH_3, sulphur dioxide, carbon dioxide, methyl chloride, Freon etc.



Sector	Type of equipment used	Refrigerants currently being used	Typical refrigerant charge (kg)
Domestic Refrigeration	Domestic refrigerators	R-134a Hydrocarbons (limited)	0.05 – 0.25
Domestic Air Conditioning	Window and split type air conditioning unit	R-22, R-134a	0.5 – 1.5
Commercial Refrigeration	Display cabinets and refrigerated or chilled furniture. Cold Rooms:	R-134a, R-502, R-404A, R408C, R-22	0.2 – 5 15 - 25
Industrial Food Processing	Large chest freezers and cold rooms	R-502, R-22, Ammonia	5 - 250
Commercial air Conditioning	- Large split type air conditioning units - Water chiller systems	R-22, R-407A, R-134a, R 410a, R407c	1.2 – 2.0 125 – 270
Vehicle Air Conditioning	Vehicle air conditioning system	R-134a	0.8 – 1.0

Properties/characteristics of refrigerants

Sl. No	Properties	Description
1.	Thermodynamic properties	• Low boiling point • Low freezing point • High latent heat of vaporization • High critical temperature
2.	Physical properties	• Low viscosity • Low liquid specific heat • Low specific volume • High thermal conductivity • High electric insulation
3.	Chemical properties	• Non toxic • Non flammable and non explosive • Non corrosive • Good chemical stability • Miscible with lubricating oil
4.	Other properties	• Availability • Low cost • Ease of handling • No impact on the ozone layer

Types of refrigerants

Type	Properties	Applications
Ammonia	• Oldest and widely used refrigerant • Boiling temperature of -33.3°C • Soluble in water, produce high refrigeration effect • Cost less, hazards free • Highly toxic, not miscible, explosive • Moderately flammable, irritating and corrosive • Not suitable for domestic refrigerators	• Ice manufacturing plants, packaging plants, cold storage etc.
Sulphur dioxide	• Non flammable, non corrosive • Absorbs a lot of heat in evaporation. • High boiling point of -10°C • Low refrigerating effect • Suffocating and irritating odour • In presence of moisture, it forms sulphuric acid.	• In domestic refrigerators in olden days, but now no longer used
Carbon dioxide	• Non toxic, non flammable, inexpensive odourless gas and low specific volume • Boiling point of -77.6°C. • 1.53 times heavier than air [high operating pressures – low efficiency]	• Large ships, theatre AC systems [where space consideration is more important]

Type	Properties	Applications
Freon	• Highly efficient • Two types of Freon refrigerant i. Freon -12 (R-12) ii. Freon – 22 (R-22)	
	i. Freon – 12(R12) • Chemical formula – CCl_2F_2 – dichloro difluromethane • Non flammable, non expensive, non-corrosive and odourless • Boiling point of -29.8°C	• Small capacity equipment such as domestic refrigerators, water coolers, AC etc
	ii. Freon – 22(R22) • Chemical formula $CHClF_2$ – chloro difluoromethane • Boiling point of -40.8°C • High pressure refrigerant	• Large capacity plants like packaged AC units • Low and medium temperature refrigeration
HFC (Hydro fluoro carbon)	• Family of hydrocarbons containing one or several fluorine atoms • Favourable thermodynamic, health and safety properties. • R134A – tetra fluoromethane (CH_2FCF_3) – no chlorine content. (BP = -15°C) i. Non corrosive, non toxic, non flammable	• Medium temperature applications such as AC and commercial refrigeration. • Modern car AC • R407C, R410A – variants of HFC

Terms used in refrigeration

Sl. No.	Terms	Description
1.	Refrigeration	• The process of reducing the temperature of the given space, below that of the surrounding atmosphere and maintaining lower temperature within the boundary of the given space.
2.	Refrigerating effect (RE)	• The amount of cooling produced by the refrigeration process in known as refrigerating effect. • Rate at which heat is removed from the system in one cycle of operation. • Also called as capacity of refrigerator • Expressed in kJ/sec or kW
3.	Ton of refrigeration (TOR)	• Unit of refrigeration. • The capacity of a refrigerator can be expressed in terms of TOR. • Definition – Amount of heat absorbed in order to produce 1 ton of ice in 24 hours from water whose initial temperature is 0°C. • In SI unit, 1TOR = 210kJ/min = 3.5kJ/sec or 3.5kW • TOR is a measurement of the rate of heat transfer and not a unit of mass, i.e., one TOR will not produce 1 ton of ice. • The rate of removal of heat in a cooling operation was expressed in terms of tons of ice required per unit time (24hr)
4.	Ice making capacity	• The capacity of a refrigeration system to remove heat from water to make ice.

Sl. No.	Terms	Description
5.	Refrigeration cycle	• Describes the changes that take place in the refrigerant as it alternately absorbs and rejects heat while circulating through a refrigerator.
6.	Co-efficient of performance (COP)	• Ratio of the amount of heat removed from a given space to the work supplied for the heat removal. • COP = $\frac{amount\ of\ heat\ removed/absorbed}{Work\ supplied} = \frac{Q}{W}$ ………kJ/sec or kW • Basic parameter used to measure energy efficiency of heating / cooling and refrigeration appliances. • Higher the COP, the more efficient is the device.
7.	Relative COP	• Ratio of actual COP to theoretical COP of a refrigerator. • Relative COP = $\frac{actual\ COP}{Theoretical\ COP}$; Actual COP = $\frac{Q}{W}$, where Q and W are measured during a test Theoretical COP = $\frac{Q_{th}}{W_{th}}$, where Q_{th} and W_{th} are obtained by applying theoretical equations (laws of thermodynamics) to the refrigeration cycle.

Applications of refrigeration

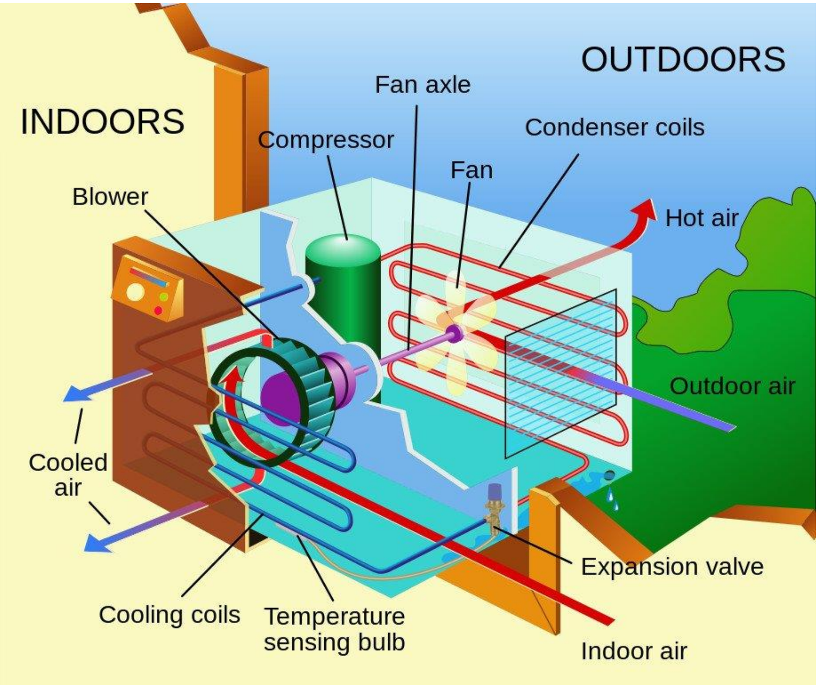
Sl. No.	**Area**	**Applications**
1.	Food processing, preservation and distribution	• Storage of raw fruits, vegetables, fish, meat and poultry. • Storage of dairy products like milk, butter, ice creams • Production and cooling of liquor and concentrated fruit juices • Processing and distribution of frozen food.
2.	Chemical and process industries	• Used in petroleum refineries, petrochemical plants, paper pulp industries etc [very large cooling capacities]
3.	Special applications	• Ice manufacturing • Cold treatment of metals • Manufacturing and preservation of medicines, chemicals • Medical laboratories for storing test samples • Desalination of sea water
4.	Air conditioning	• Indoor cooling • Vehicular AC • Laboratories, printing, textile, pharmaceutical and mechanical industries. • Power plants

Air conditioning (AC)

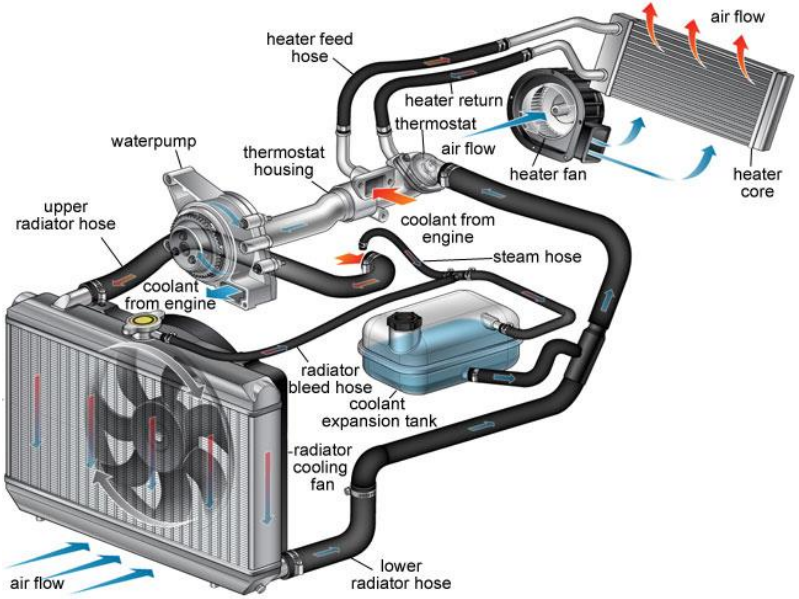
- The process of simultaneous control of temperature, humidity, cleanliness and air motion of the confined space.
- Introduced by Stuart Cramer in 1905 [father of air conditioning]

Principle of AC

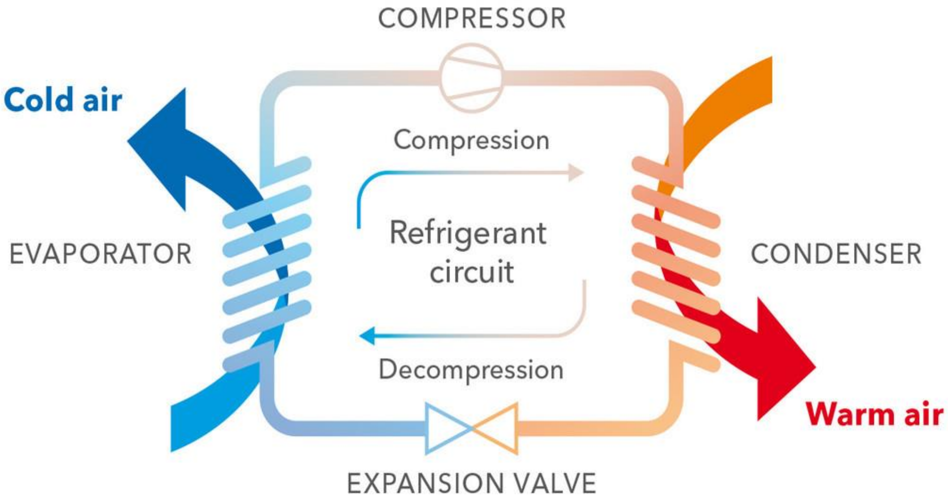
- Similar to that of refrigeration, except without an insulated box.
- Cooling is achieved using a *vapour compression refrigeration cycle (VCR)*.
- A refrigerant is made to circulate through evaporator, compressor, condenser and expansion valve to complete the working cycle.
- During the flow of refrigerant through the evaporator coils, it absorbs heat from the warm air, which is drawn from the inside the room and undergoes a change of phase from liquid to vapour state.
- The heat absorbed by the refrigerant is discharged to the atmosphere during its flow through the condenser coils and gets condensed back to liquid state.
- Thus heat is continuously drawn from the room and dissipated to the atmosphere thereby maintaining relatively low temperature inside the room.

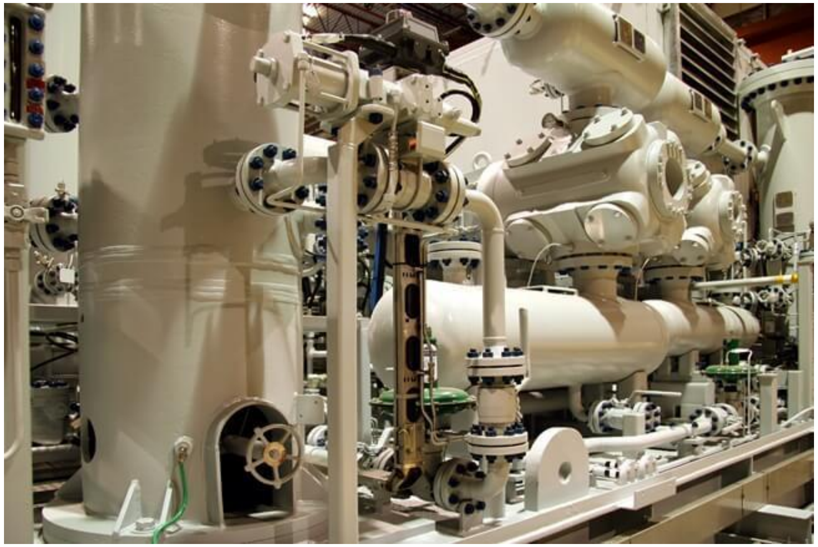


Domestic AC /Indoor cooling



Vehicular AC

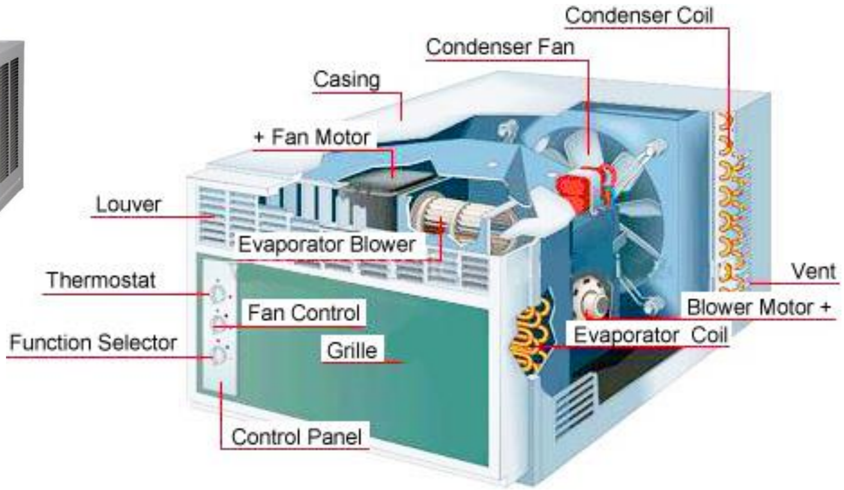




AC used in Ship refrigeration plant

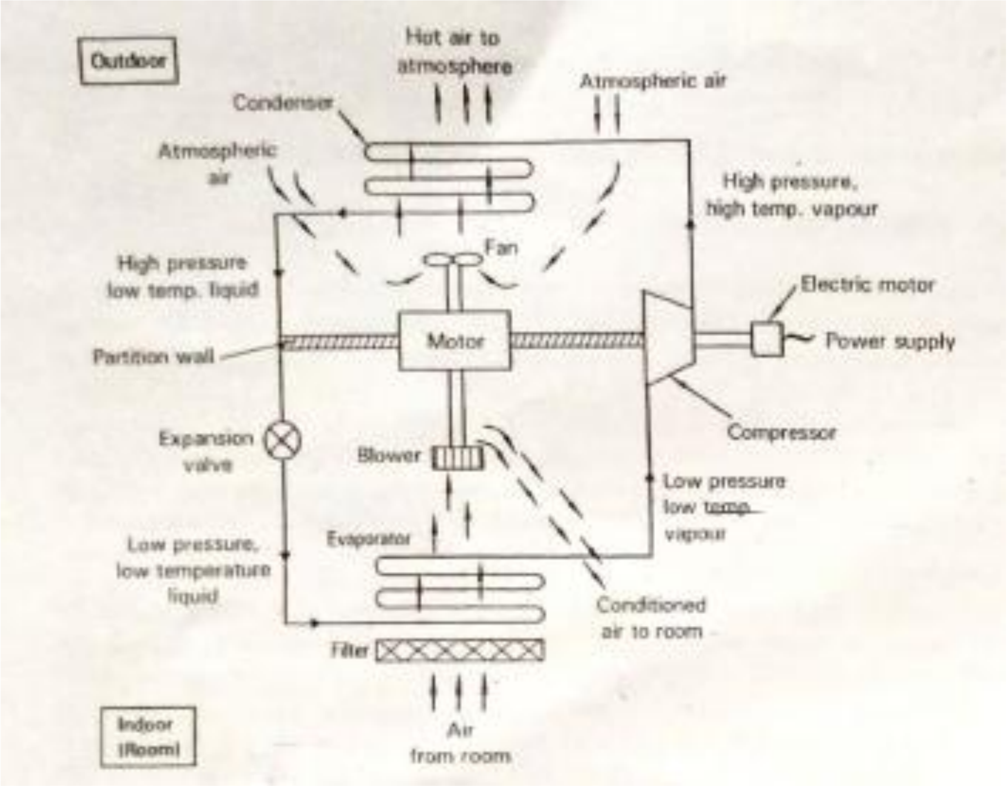
Types of AC

1. Room AC/window units
2. Split AC



1. Room AC/ Window units

- Simplest form of AC designed to cool a single room.
- Basic components :
  i. Compressor
  ii. Condenser
  iii. Expansion valve
  iv. Evaporator
  v. Air filter
  vi. Control panel
  vii. Double shaft motor.



Construction of room AC

- The evaporator and expansion valve are located at the room side (indoor) while the compressor and condenser are located at the outdoor side.
- The room side and the outdoor side of the unit are separated by an insulated partition wall within the casing of the AC.
- A double shaft motor is used to drive a fan at one end and a blower at the other end.

Working of room AC

- The blower draws the warm air from the room through the air filter and over the evaporator coils.
- The low pressure and low temperature liquid refrigerant (partially vapour) flowing through the evaporator coils absorb heat from the warm air and undergoes a change of phase from liquid to vapour.
- The low temperature and low pressure vapour refrigerant from evaporator is drawn by the suction of the compressor, which compresses it to high pressure and temperature.
- The high pressure, high temperature vapour refrigerant now flows through the condenser coils. The heat contained in the refrigerant is dissipated to the atmosphere [Vapour → Liquid].
- The high pressure, low temperature liquid refrigerant enters the expansion valve where its is expanded to low pressure and temperature.

- The low pressure , low temperature liquid refrigerant enters the evaporator coils, absorbs heat from the warm air and the cycle repeats until the desired temperature inside the room is achieved.
- After the desired room temperature has been achieved, the thermostat in the AC unit cuts the power supply to turn the compressor OFF.
- As the room warms up, the thermostat initiates the power supply and the cycle repeats till the desired temperature in the room is achieved.

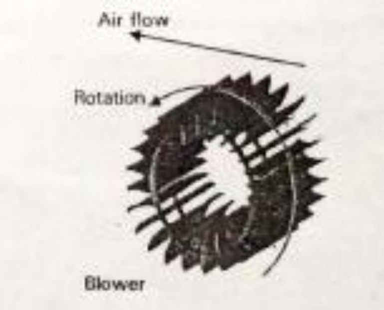
Note:

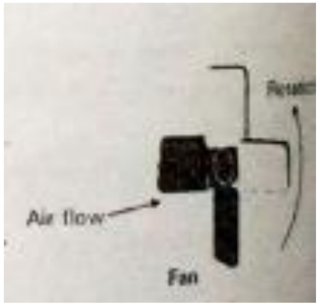
- Thermostat - a component which senses the temperature of a physical system and performs actions so that the system's temperature is maintained near a desired set points.
- Blowers and fan

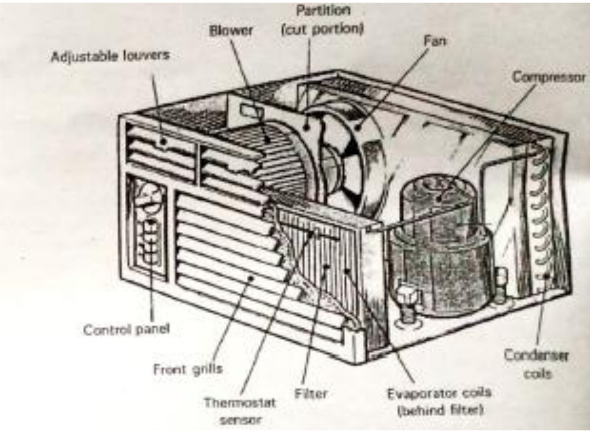
  i. Blowers have the same function as a fan, differs in construction.

  ii.Fans are normally located at the outdoor side while blowers are located at the indoor side.

  iii.Fans operate by displacing air perpendicular to its rotation while blower operate by displacing air parallel to its rotation.





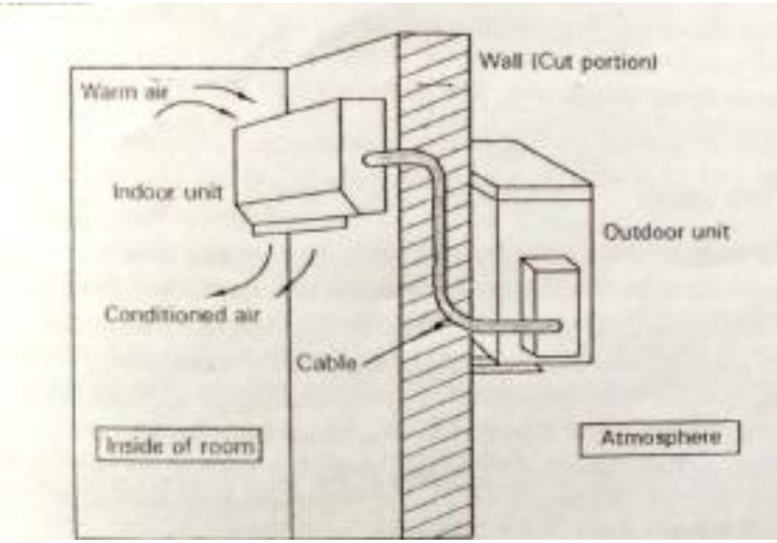


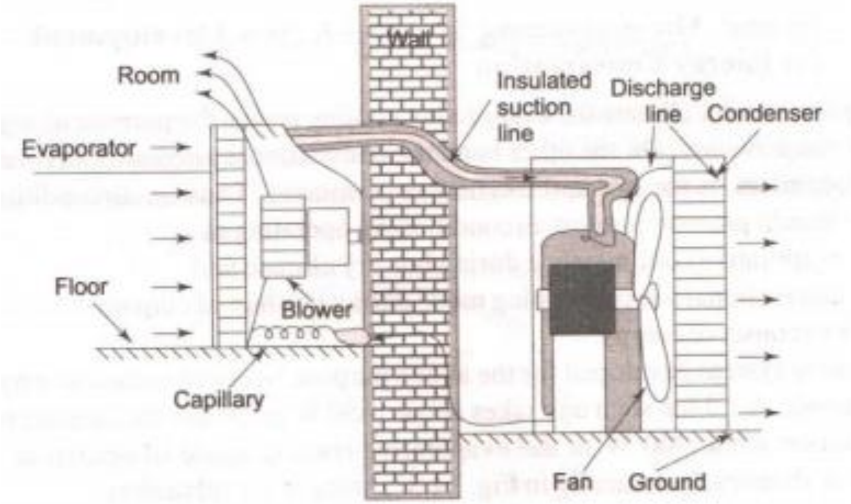
2. Split /ductless AC

- Similar in operation to a window /room AC system except the components are split into two separate units instead of being entirely enclosed in a single unit.

Construction of split AC

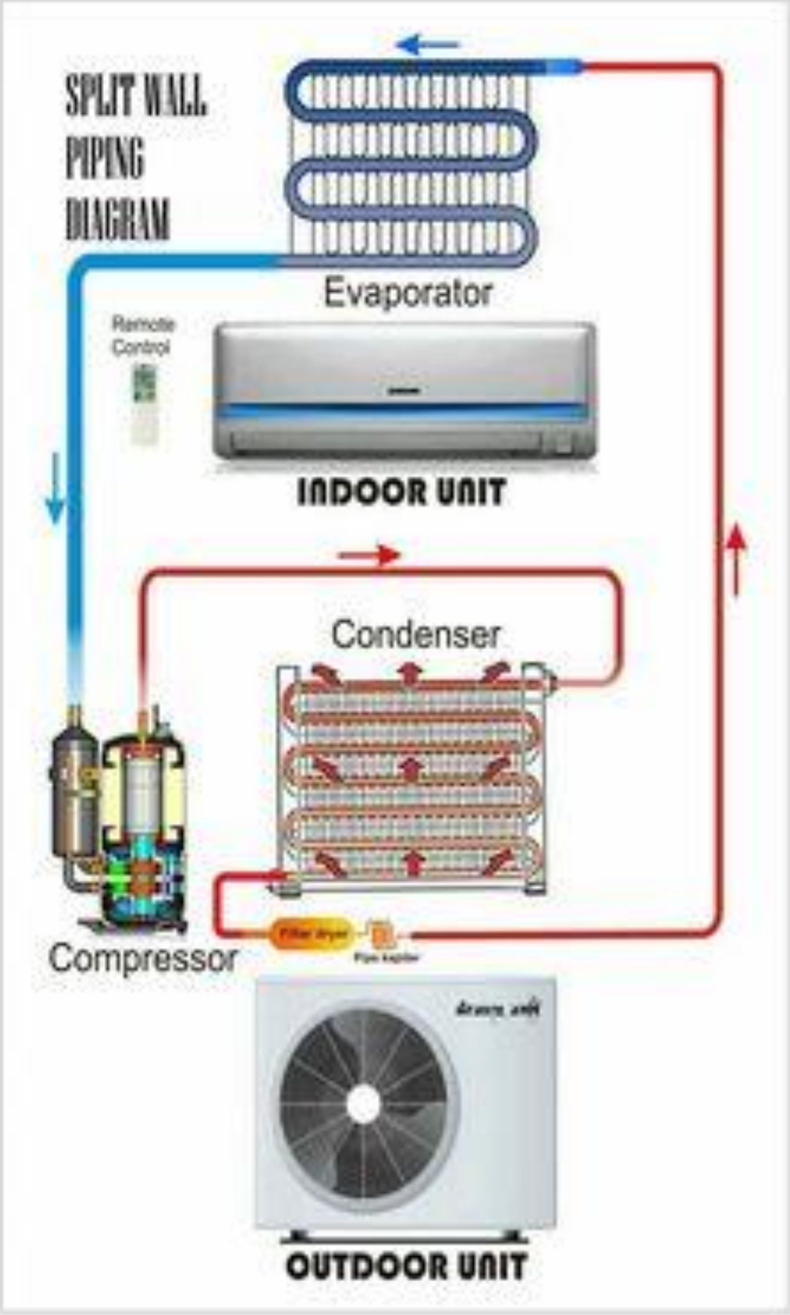
- Split AC consists of two self contained units namely indoor unit and outdoor unit.
- Indoor unit is located inside the room and outdoor unit located outside the room.
- The indoor unit encloses the evaporator and blower, while the outdoor unit encloses the compressor, condenser and fan.
- The two units are connected with a set of electrical wires and tubing(lines) used to transport air between the two units.

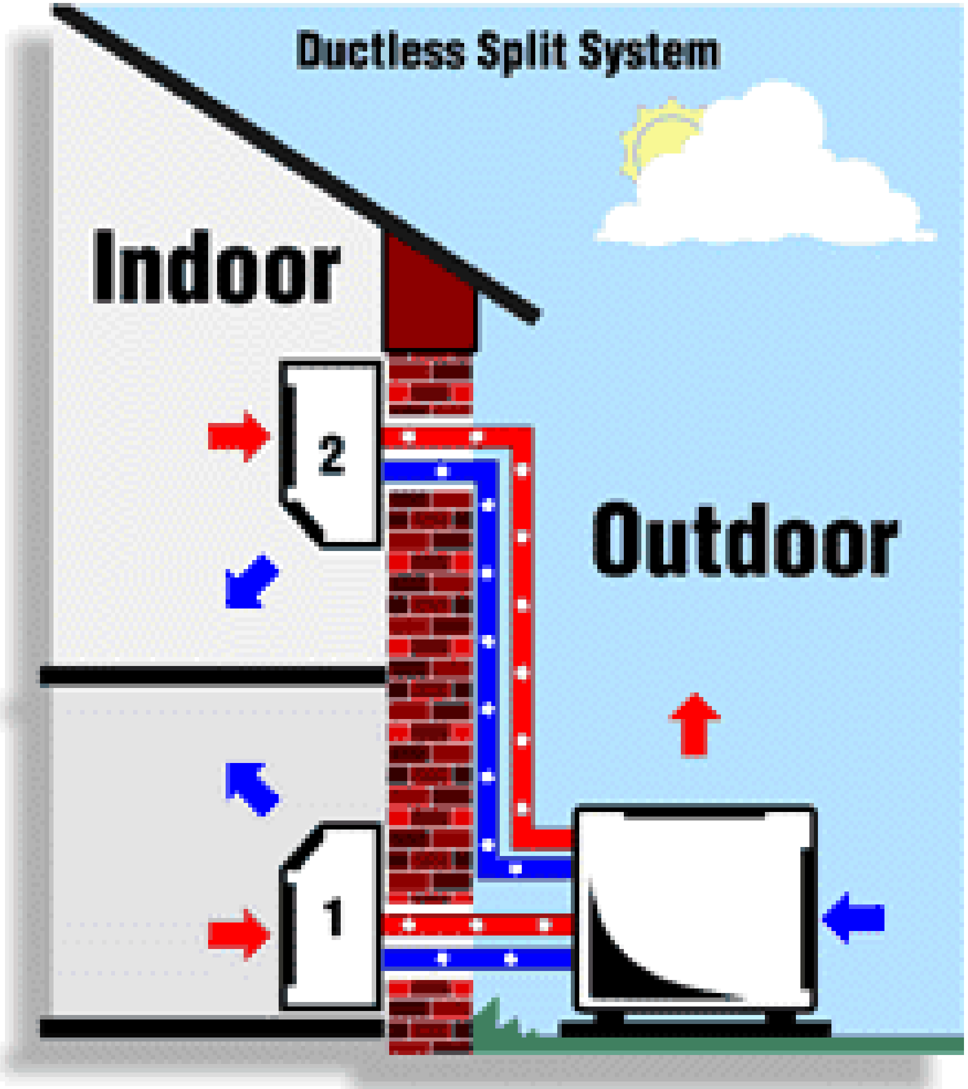




Working of Split AC

- The thermostat detects warm air inside the room and activates the compressor enclosed in the outdoor unit.
- The compressor which has received the vapour refrigerant from the evaporator in the previous cycle, compresses the refrigerant thereby raising its pressure and temperature.
- The refrigerant then pass through the condenser coils where it gives away its heat to the air drawn from the atmosphere by the fan. The temperature of the refrigerant reduces causing the vapour refrigerant to change its phase to liquid state.
- The liquid refrigerant is pushed through the tubing indoors where its pressure reduce (due to expansion process) and in turn passes through the evaporator coils.
- The low pressure, low temperature liquid refrigerant now circulates through the evaporator coils.
- Inside the room, the blower draws the warm air and passes it through the evaporator coils where it gives away the heat to the circulating low pressure low temperature refrigerant.
- The cold air is forced into the room by the blower. The refrigerant after absorbing heat changes its phase from liquid to vapour state. If the thermostat still detects air that is warmer than desirable, the process continues.





Available in 1,2,3, & 4 Zones (2 Zone Shown)
Cooling Shown, also Available as Heat Pump

Applications of AC

Categories	Applications
Comfort application (comfort for human beings)	• In residential buildings, including family houses, duplexes and apartments • Institutional buildings – hospitals, computer laboratories etc. • Commercial buildings – malls, shopping centres, restaurants, office etc. • Transportation – in cars, buses, ships, aircraft and space craft
Process application(controlled environment for industrial activities)	• Hospitals – in operation theatres • Production of integrated chips, microprocessors, computers, aircraft parts, nano material fabrication • Breeding laboratory animals • Nuclear power plants • Pharmaceuticals, chemical & biological laboratories • Textile, printing factories, mines • Food processing centres

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Module – 4.1

Engineering materials

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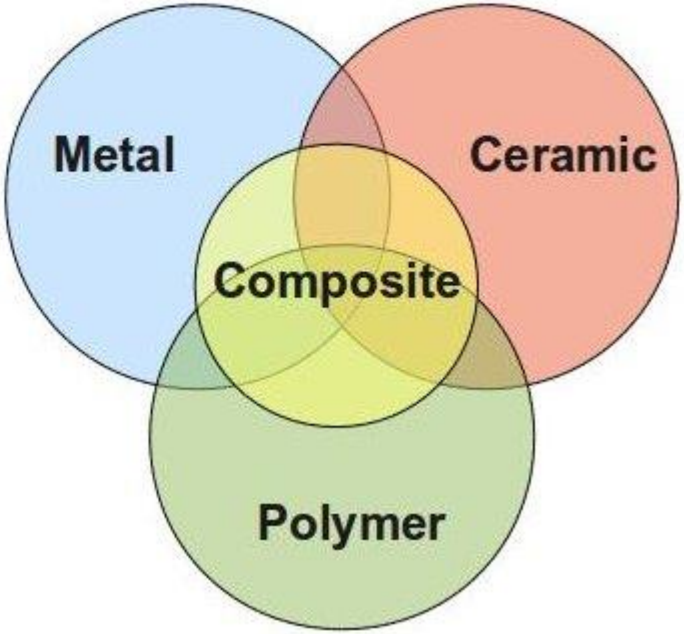
Engineering materials

- Solid substances which are manufactured and used for various engineering applications.
- Selection of material for a specific application depends on the set of properties possessed by the material.

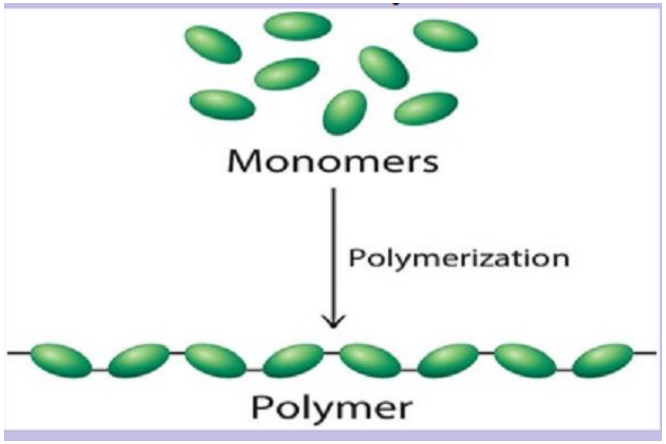
Classification of engineering materials

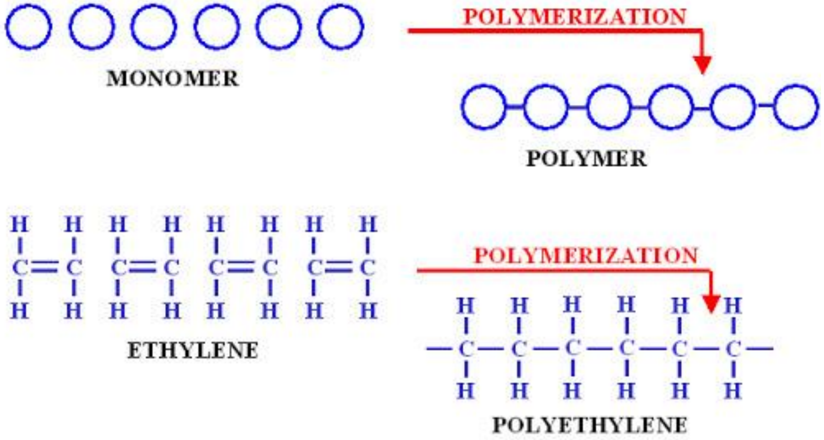
- Polymers – thermoset and thermoplastics
- Metals – Ferrous and non ferrous metals
- Ceramics – glasses, cermets
- Composites – PMC, MMC, CMC
- Smart materials – piezoelectric, shape memory
- Insulators and semi-conductors



1. Plastics/polymers

- Group of polymers that are built from relatively simple units called monomers through a chemical polymerization process.
- Polymerization process - The process of reacting monomer molecules together in a chemical reaction to form polymer chains or three-dimensional networks.



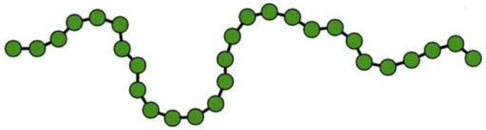


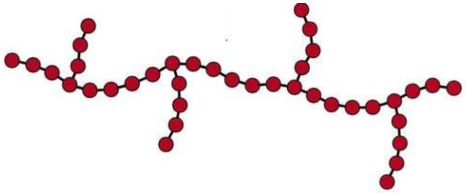
Types of plastics

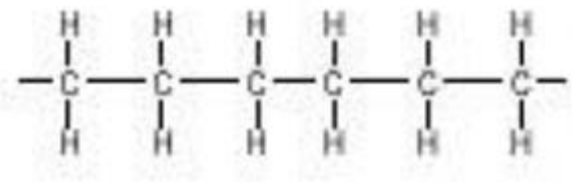
- Thermoplastics – Polyethylene, polystyrene, PVC, polypropylene, nylon, Teflon etc.
- Thermosetting plastics – Epoxy, polyester, phenol formaldehyde etc.

Thermoplastics

- Linear or branched structure where carbon atoms in the material are connected to molecules of H, O, N, Cl and S in a continuous long chain of molecules.
- Thermoplastics are meltable [soften on heating and harden upon cooling]
- Uses – Telephone, receivers, electric plugs, TV cabinets, switch panels, aircraft and automotive parts etc.


Linear Structure

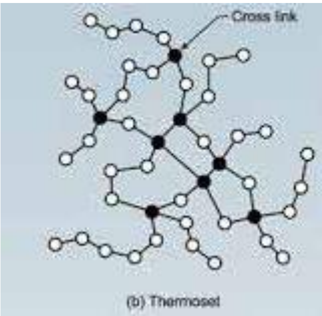

Branched Structure

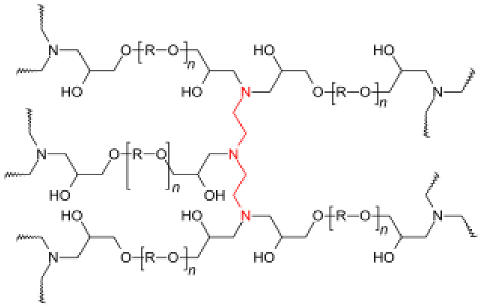


Polyethylene structure

Thermoset

- Cross – linked structures of long chain molecules to form two and three dimensional networks.
- Not being meltable [permanently hard when heated and do not soften upon subsequent heating]
- Uses – Toys, photographic films, insulating tapes, electric insulation etc.





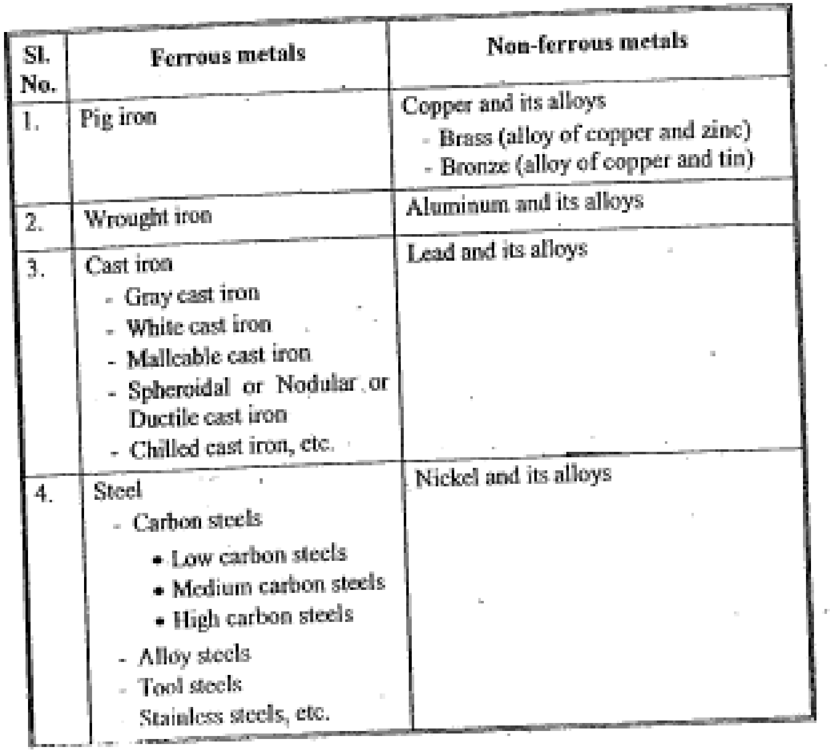
Epoxy structure

Difference between thermoplastics and thermoset plastics

Sl. No.	Thermoplastics	Thermoset plastics
1.	Exhibits linear and branched structures	Cross-linked molecular structure
2.	Atoms are held together by weak Vander Waal’s bond	Strong primary covalent bond
3.	Soften on heating and harden when cooled. [processed any number of times]	Permanently hard when heated and do not soften upon subsequent heating.
4.	Suitable only at low temperature	Low and high temperature
5.	Soft and flexible	Harder, stronger and brittle
6.	High strains to failure	Low strains to failure
7.	Poor resistance to fluids and solvents	Good resistance to fluids and solvents
8.	Low electrical resistance and dimensional stability	Better electrical resistance and dimensional stability
9.	High material cost	Low cost
10.	Indefinite shelf life	Definite shelf life
11.	Recycled [Hence economical]	Cannot be recycled
12.	Short cure cycle	Long cure cycles
13.	Toys, photographic films, etc.	Electric plugs, automobile parts etc.

2. Metals

- Opaque, lustrous elements that are used in engineering applications.
- Types of metals
  - i. Ferrous metals – Fe as chief constituent
  - ii. Non-ferrous metals – very negligible or absence of Fe content



Sl. No.	Ferrous metals	Non-ferrous metals
1.	Pig iron	Copper and its alloys - Brass (alloy of copper and zinc) - Bronze (alloy of copper and tin)
2.	Wrought iron	Aluminum and its alloys
3.	Cast iron - Gray cast iron - White cast iron - Malleable cast iron - Spheroidal or Nodular or Ductile cast iron - Chilled cast iron, etc.	Lead and its alloys
4.	Steel - Carbon steels • Low carbon steels • Medium carbon steels • High carbon steels - Alloy steels - Tool steels Stainless steels, etc.	Nickel and its alloys

Table 9.1 Brief classification of metals

Ferrous materials

Cast iron

Composition	Properties	Applications
90-92% Fe, 2-4.5% C, 1-3% Si, S, Mn, P	Low T_m , good fluidity, castability and machinability, resistance to deformation and wear resistance	Hard tools, pipe fittings electrical fittings

Gray Cast iron

Composition	Properties	Applications
3.2-3.5% C, 1.3-2.3%Si, S, P, Mn	Excellent castability, machinability, vibration damping characteristics, wear resistant, brittle, low tensile strength and shock resistance, good fatigue resistance	Automotive engine parts, gears, flywheel, brake discs, frames, as a base in machines

White Cast iron

Composition	Properties	Applications
1.8 – 3.6% C, 0.5-2.0% Si, S, P, and Mn	Extremely hard, brittle, wear resistant, cannot be machined easily, high tensile strength and low compressive strength	Mill liners, hot-blasting nozzles, car wheels, brick making equipment, crushers, sprockets etc

Malleable Cast iron

Composition	Properties	Applications
2-3% C, 0.6-1.3% Si, S, Mn, P	Malleable, easily machined, good castability, moderate strength, toughness, corrosion resistant	Connecting rods, transmission gears, compressors, crankshaft, marine, heavy duty applications

Spheroidal/nodular Cast iron

Composition	Properties	Applications
3.2-4.2% C, 1.1-3.5% Si, S, Mn, P	Good fluidity, castability, machinability, wear resistance, shock resistance	Crankshaft, punches, dies used in sheet metal work, heavy duty gears, automobile door hinges

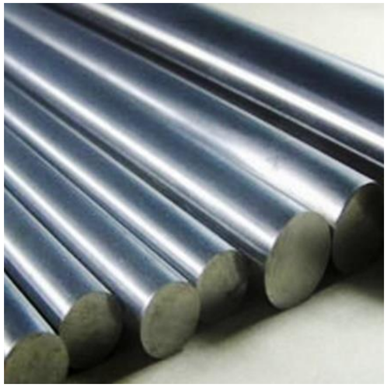
Tool steels

- Primarily used to make tools in manufacturing process [for machining metals, wood, plastics]
- Capable of withstanding high loads and remain stable at elevated temperatures
- Types of tool steels
  - i. High speed steel(HSS)
  - ii. Stainless steels

High speed steels

Composition	Properties	Applications
Alloy of steel consisting of W, Mo, Cr, V [Co- improves hardness] *Types of HSS* • T-type: 12-18% W, 4% Cr, 1% V, 0.7%C • M-type: 6%Mo, 6%W, 4%Cr, 2%V, 0.7%C	Excellent hardenability [600°C], shaped easily, relatively tough, hot hardness 	Manufacturing drill bits, reamers, counter bore, milling cutters, single point cutting tools 

Stainless steels

Composition	Properties	Applications
Fe-C alloy with 11.5% - 25% Cr. [resist corrosion]	Good corrosion resistance 	Manufacturing of kitchen sinks, food processing equipment, architectural applications, chemical plant, knife blades, surgical equipment, shafts, spindles, marine applications, desalination plants, heat exchanger

Non-ferrous materials

Copper and its alloys

- Malleable, corrosion resistant, good conductor of heat and electricity.
- Pure copper is ductile and very weak.
- Alloys of copper – Brass and Bronze

Brass

Composition	Properties	Applications
Cu + 5-45% Zn, Pb, Sn, Si	Good strength, ductility, machinability, formability, electrical and thermal conductivities, wear and corrosion resistance, spark resistance, non-magnetic	Manufacturing nuts, bolts, threaded parts, taps, injectors, valve bodies, condensers and heat exchangers tubes, pump bodies, pump fittings

Bronze

Composition	Properties	Applications
88% Cu + 11% Sn, P, Al, Si, Be	Soft, corrosion resistant, better hardness and fatigue properties, better heat and electrical conductivity, good ductility and malleability	Manufacturing springs, electrical contacts, clutch disc, marine pumps, condenser tubes, valve parts etc

Aluminum and its alloys

Composition	Properties	Applications
Silverish white metal extracted from bauxite material, Alloyed with Cu, Si, Mg, Sn	Light metal, easily machinable highly reflective to heat and light, good heat and electrical conductivity, can be cast, rolled, extruded, forged, excellent corrosion resistance, very ductile material	Aircraft, automotive vehicles, marine applications, electric wires, windings of motor, generators, transformers, house hold utensils

Classification of Al alloys

- Cast alloys
  - i. 1xx.x series are minimum 99% aluminium
  - ii. 2xx.x series copper
  - iii. 3xx.x series silicon, with added copper and/or magnesium
  - iv. 4xx.x series silicon
  - v. 5xx.x series magnesium
  - vi. 6xx.x unused series
  - vii. 7xx.x series zinc
  - viii. 8xx.x series tin
  - ix. 9xx.x other elements

- Wrought alloys - 1xxx, 2xxx, 3xxx, 4xxx, 5xxx, 6xxx, 7xxx, 8xxx series alloys

3. Ceramics

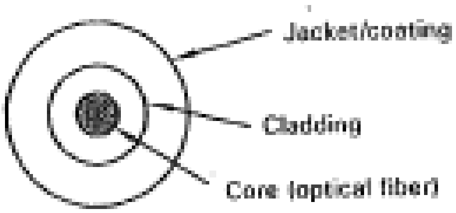
- Inorganic solid materials containing compounds of metals and non metallic elements such as oxides, nitrides and carbides
- Examples –Al_2O_3, Zirconium oxide, Tungsten carbide, B_4C, SiC, SiN_3 etc.
- Ceramic materials may be in crystalline state [atoms bonded together in a regular pattern] or amorphous/glassy state [atoms having no regular arrangement]

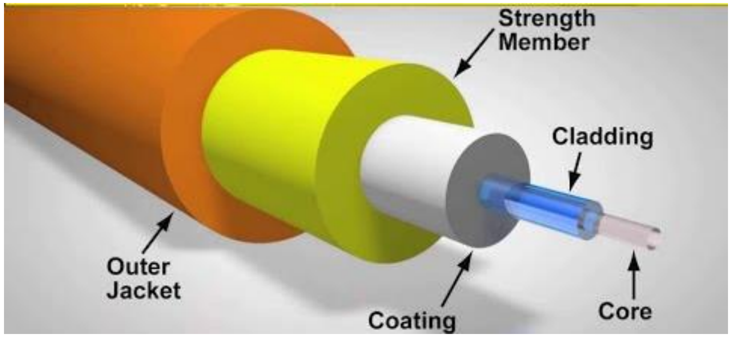
Properties	**Applications**
High compressive strength	Structural and building applications – pipes, bricks, roof and floor tiles etc.
High hardness	Cutting tool applications
Excellent wear resistance	Brakes, clutches, bearings etc.
High melting point	Heat resisting components for automobile, aerospace, heat sinks for electronic packages, furnace linings etc.
Low electrical and thermal conductivity	Electrical and electronics applications
Chemical inertness	Biomedical applications like orthopaedic prostheses and dental implants

- Major demerit – extremely brittle in nature

Optical fiber glass

- A flexible, transparent fiber made by drawing (forming process) silica glass or plastic to a diameter slightly thicker than that of a human hair.
- Used most often as a means to transmit light between two ends of the fiber and fiber optic communications, field of telecommunication, automobile, aviation, medical and in industries.
- Basic elements of optical fiber transmission system
  i. Transmitter – converts electrical energy into optical energy
  ii. Optical fiber – through which light is transmitted
  iii. Photo-diode – converts back the light energy to electrical energy





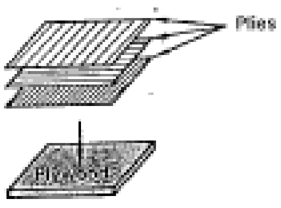
- It consists of silica glass core surrounded by a similar material called cladding, but with low refractive index and in turn the cladding is enclosed in a plastic jacket or a coating.
- Glass material used in optical fiber: fluoro-zirconate, fluoro-aluminate, chalcogenide glass, sapphire.

Cermets

- Combination of ceramics (Cer) and metals (met).
- Ceramic materials used are either oxides, carbide or boride.
- Metallic materials used is usually cobalt.
- Most widely used cermet is tungsten carbide (WC) or cemented carbides [6% Co]
- The ceramic constitute imparts high hardness to the material [wear resistance, chemical and temperature resistance]
- The metallic constituent imparts ductility to the material to undergo plastic deformation.
- Other cermets – Titanium carbide [Co + Ni]
- Applications :
  i. Fabrication of cutting tools
  ii. Components of airplane jet engines, space rockets
  iii. Manufacturing of resistors, potentiometers, capacitors
  iv. Used as insulators
  v. Material for fillings and prosthesis [dentistry]

4. Composites

- A combination of two or more constituent materials having different physical/chemical properties separated by a boundary (interface) is called a composite material.
- It possesses properties that are superior to those of the individual materials.
- Example: plywood – wood product manufactured out of many sheets of wood veneer (plies), pressed together and glued [Very sturdy and durable wood].



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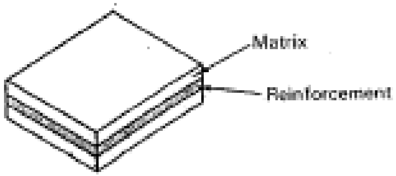

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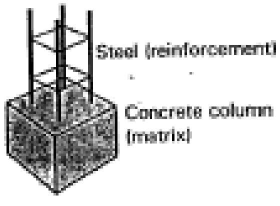

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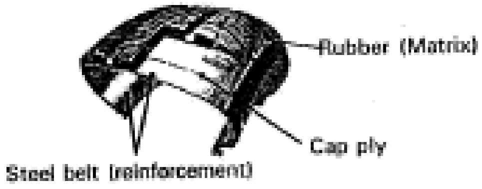
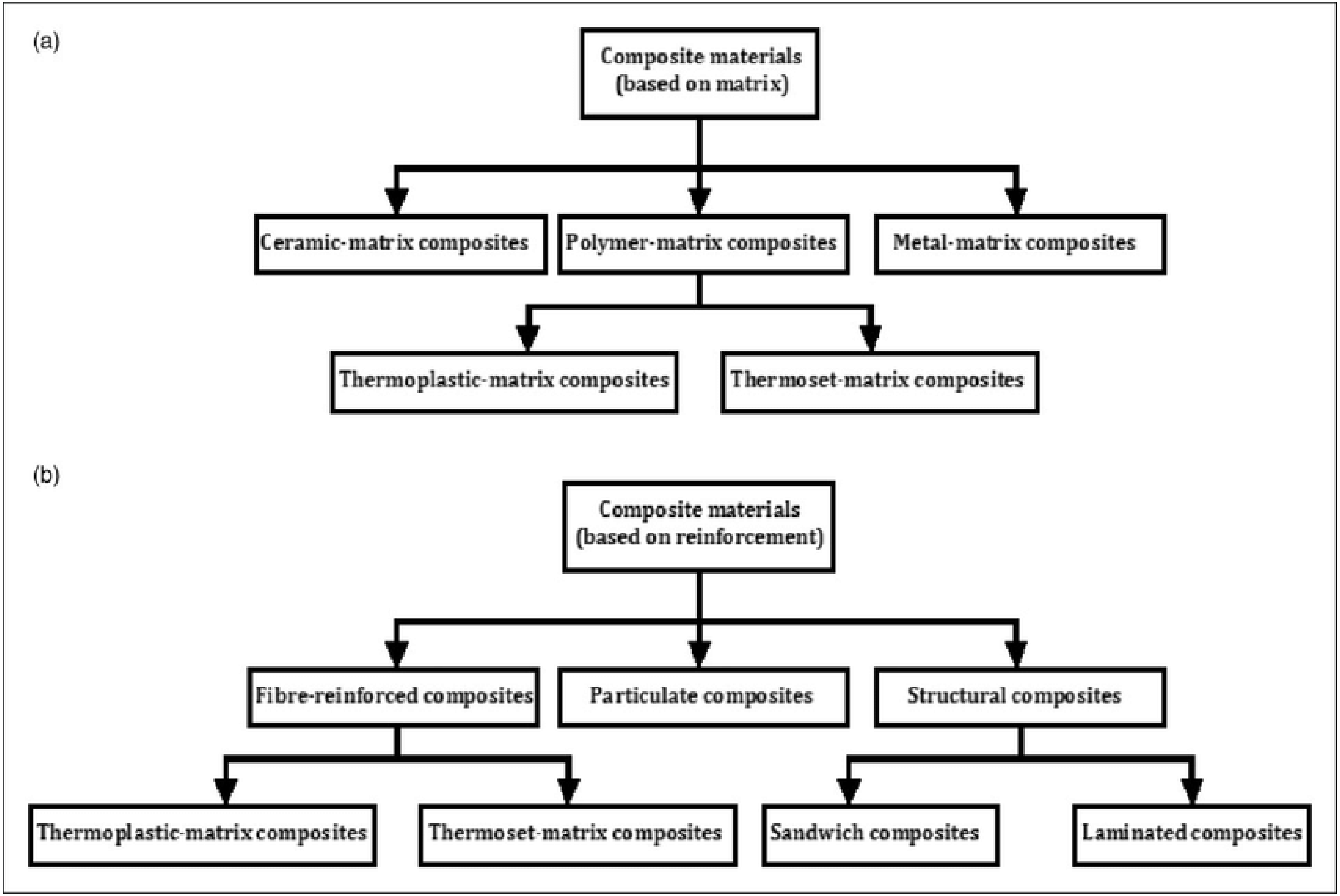


(b)

- Composites are made up of two materials – matrix(binder) and reinforcement(dispersed phase).
- Matrix surrounds and binds a cluster of fibers, particles or fragments called reinforcement. It holds the fibers together and keep them aligned in predetermined direction.
- The reinforcement carry load along the length of the fiber to provide strength and stiffness to the composite.
- Example: concrete = cement + sand + stones; steel reinforced concrete; radial car rubber tyre = rubber + steel.

Classification of composite material



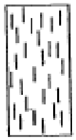
Metal matrix composites

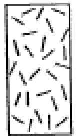
Composition	Properties	Applications
Matrix – metal alloys, reinforcement – fibers, particulates made of ceramics Metal alloys – Ti, Al, Mg, light metals	Low density, high strength, fracture toughness and stiffness, low coefficient of thermal expansion	Aircraft, automotive parts like piston, push rods, brake components, shafts, electrical and electronic components etc.

Fiber reinforced composites

Composition	Properties	Applications
Reinforcement – form of fibers [elongated thread like structure] Types – glass fibers, carbon fibers and aramid fibers Matrix - polymers	Circular in cross section in the form of tubular, rectangle or hexagonal [0.0001inch – 0.005inch] Continuous fiber reinforced composites – L > d Discontinuous fiber reinforced composites – L<d	Manufacturing of doors, windows, bathtubs, boats, pipes, tanks and vessels, internal parts of rail, automotive and aerospace applications


(a) Continuous fibers


(b) Discontinuous fibers


(c)Discontinuous & randomly oriented

5. Smart materials

- Designed materials having one or more properties that can be significantly changed in a controlled fashion by stress, temperature, moisture, pH, electric or magnetic field.
- The change in properties is reversible and can be repeated any number of times.
- Example: plastic material, an insulator at normal condition can be made to behave as a conductor by applying compressive force. Upon removal of the force, the plastic material returns to its insulating state.
- Example: a photosensitive glass, darkens when exposed to sunlight and returns back to initial state when protected from sunlight.

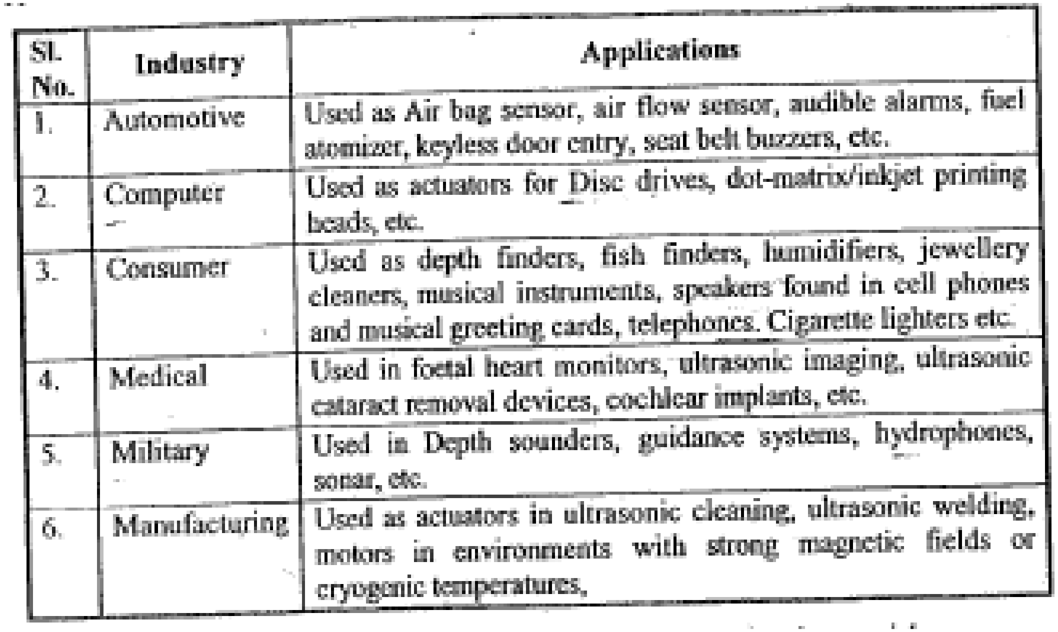
- Types of materials used in smart materials

  i. Piezoelectric materials

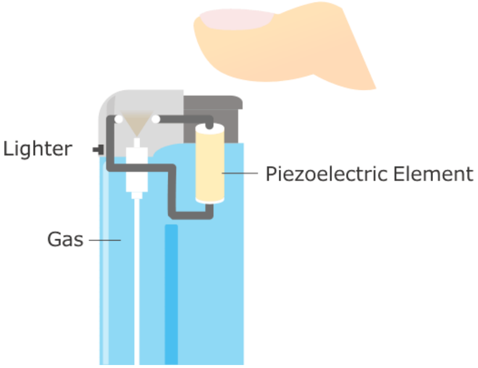
  ii. Shape memory alloys

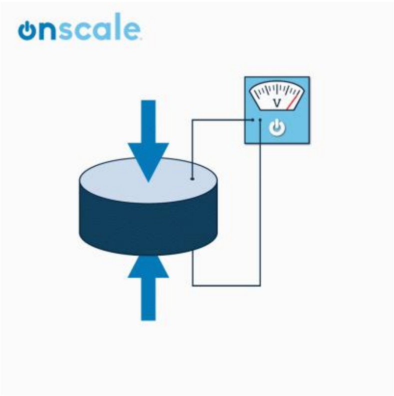
Piezoelectric materials

- Materials that produce an electric current when they are subjected to mechanical stress.
- When a piezoelectric material is deformed by applying stress, it gives off a small electrical discharge. Alternately, when an electrical current is passed through a piezoelectric material it experiences a significant deformation.
- Common piezoelectric material – lead zirconium titanate (PZT), Barium titanate, lead zirconate titanate, lead zirconate, potassium niobate, polyvinylidene fluoride.



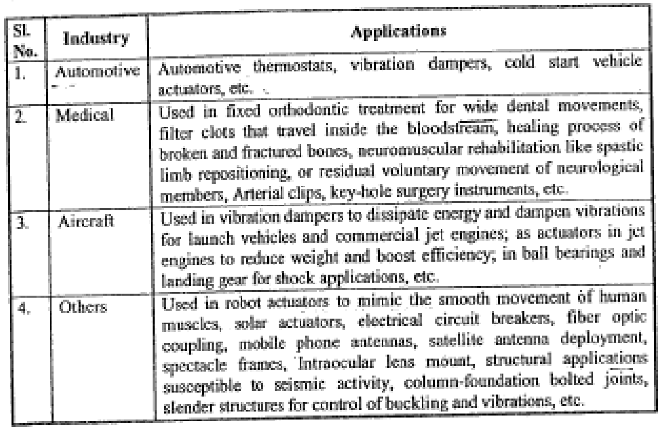
Sl. No.	Industry	Applications
1.	Automotive	Used as Air bag sensor, air flow sensor, audible alarms, fuel atomizer, keyless door entry, seat belt buzzers, etc.
2.	Computer	Used as actuators for Disc drives, dot-matrix/inkjet printing heads, etc.
3.	Consumer	Used as depth finders, fish finders, humidifiers, jewellery cleaners, musical instruments, speakers found in cell phones and musical greeting cards, telephones. Cigarette lighters etc.
4.	Medical	Used in foetal heart monitors, ultrasonic imaging, ultrasonic cataract removal devices, cochlear implants, etc.
5.	Military	Used in Depth sounders, guidance systems, hydrophones, sonar, etc.
6.	Manufacturing	Used as actuators in ultrasonic cleaning, ultrasonic welding, motors in environments with strong magnetic fields or cryogenic temperatures,





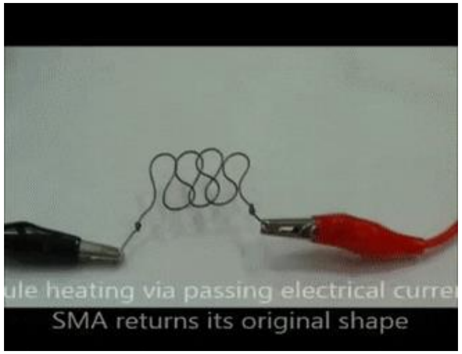
Shape memory alloy

- Unique class of metal alloys which exhibit two properties; shape memory effect and pseudo-elasticity/super-elasticity, based on change in internal stress
- *Shape memory effect*:
  1. when a shape memory alloy is in its cold state, the metal can be bent or stretched and will hold those shape until heated above the transition temperature of the alloy.
  2. Upon heating, the metal changes to its original shape. When the metal cools, it will remain in the original shape until deformed again [alloy appears to have a memory of returning to its original shape]
- *Pseudo-elasticity/super-elasticity*:
  1. A mechanical type of shape memory. A force induces deformation in the alloy, but when the force is removed, the material automatically recovers its original shape without the need for heating.
  2. Observed when alloy are strained just above their transition temperature.



Sl. No.	Industry	Applications
1.	Automotive	Automotive thermostats, vibration dampers, cold start vehicle actuators, etc.
2.	Medical	Used in fixed orthodontic treatment for wide dental movements, filter clots that travel inside the bloodstream, healing process of broken and fractured bones, neuromuscular rehabilitation like spastic limb repositioning, or residual voluntary movement of neurological members, Arterial clips, key-hole surgery instruments, etc.
3.	Aircraft	Used in vibration dampers to dissipate energy and dampen vibrations for launch vehicles and commercial jet engines; as actuators in jet engines to reduce weight and boost efficiency; in ball bearings and landing gear for shock applications, etc.
4.	Others	Used in robot actuators to mimic the smooth movement of human muscles, solar actuators, electrical circuit breakers, fiber optic coupling, mobile phone antennas, satellite antenna deployment, spectacle frames, Intraocular lens mount, structural applications susceptible to seismic activity, column-foundation bolted joints, slender structures for control of buckling and vibrations, etc.

Shape memory alloys: Cu-Zn-Al, Cu-Ni-Al, Cu-Be-Al, Fe-Mn-Si, Ni-Al, Ti-Pd, Au-Cd, Ni-Ti alloys



6. Insulators

- Material which is a poor conductor of heat and electricity.
- Examples: wood, plastics, ceramic materials like glass, porcelain and plastics
- It possess high resistivity [charges do not flow freely as in case of conductor and semiconductor]
- It works as electrical protectors.
- Applications:

i. Electric wires and cables are often coated with insulated materials

ii. Printed circuit boards are made from epoxy plastic and fiberglass

iii. Power distribution or transmission lines make use of glass, porcelain to protect living beings from dangerous effects of electricity.

iv. Prevent the passage of sound from one location to another [Fiber glass, plastic foam, mineral wool, cellulose etc]

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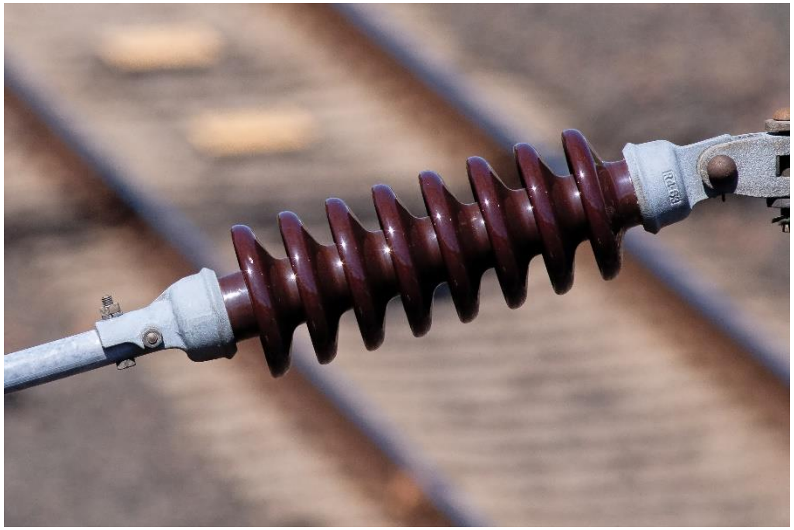
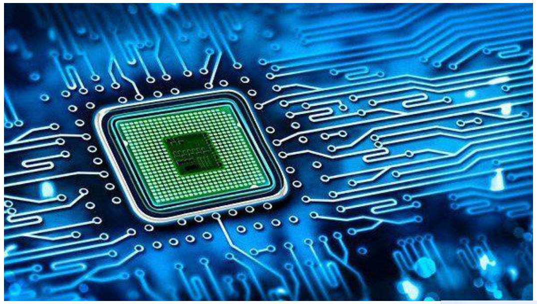
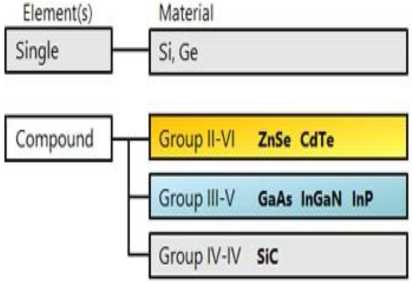


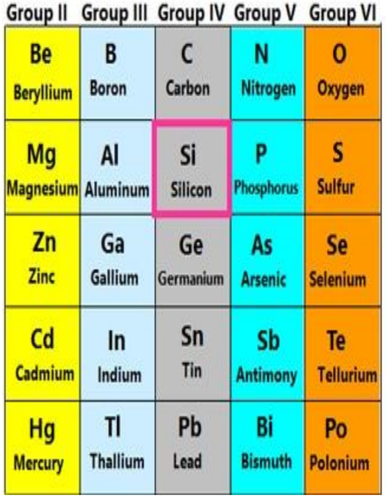
7. Semiconductors

- Materials having electrical conductivity between that of conductors and insulators.
- Examples: Si, germanium, gallium arsenide, cadmium selenide.
- The conducting properties of a semiconductor can be altered by the inclusion of impurities in to the crystal structure called doping.
- Doping greatly increases the number of charge carriers within the crystal causing electricity to pass through them easily.
- Applications:

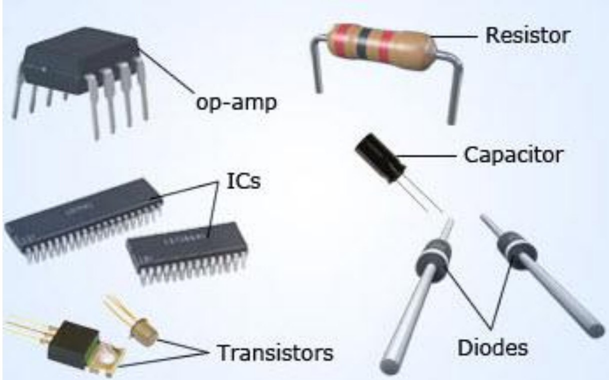
i. Used for amplification, switching and energy conversion
ii. Used for making integrated circuits (IC), diagnostic equipments
iii. Refrigerators, AC, programmable machines and robots etc.







Group II	Group III	Group IV	Group V	Group VI
Be Beryllium	B Boron	C Carbon	N Nitrogen	O Oxygen
Mg Magnesium	Al Aluminum	Si Silicon	P Phosphorus	S Sulfur
Zn Zinc	Ga Gallium	Ge Germanium	As Arsenic	Se Selenium
Cd Cadmium	In Indium	Sn Tin	Sb Antimony	Te Tellurium
Hg Mercury	Tl Thallium	Pb Lead	Bi Bismuth	Po Polonium



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Module – 4.2

Joining of materials

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Joining processes

- Processes by which two or more parts/materials can be joined together.
- Joints obtained by these processes may be temporary or permanent.
- Temporary joint – brazing, soldering, bolts and nuts, screw etc
- Permanent joint – Welding, riveting etc.

Soldering

Brazing

Welding

Nut and bolt

Studs and nut

Soldering

1. Principle of soldering

i. Joining process used for joining similar or dissimilar metals by means of a filler metal whose T_m is below 450°C.

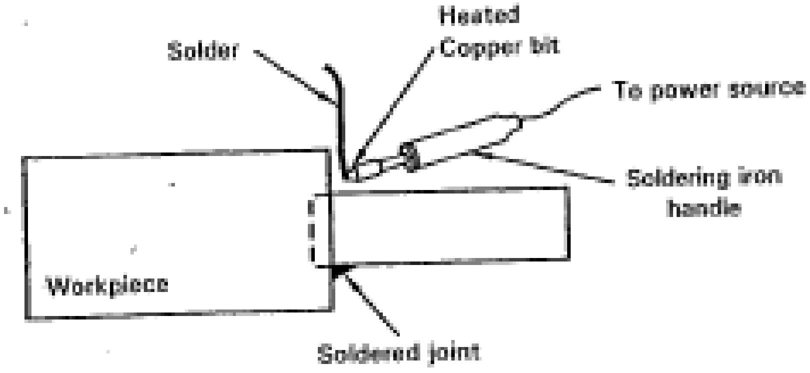
ii. Filler metal: Solder – an alloy of tin and lead

iii. Soldering involves melting of filler metals/solder and allowing it to flow into the gap between the two workpieces/materials.

iv. The solder cools down and solidifies forming a joint.

v. The principle by which the filler metal is drawn throughout the joint is by capillary action [A pulling force draws the molten filler between the surfaces of the metals to be joined]

vi. Solder joints has adequate strength, electrical conductivity and water tightness.



2. Surface preparation in soldering

i. It includes thoroughly cleaning the workpiece surfaces to remove contaminants like oil, rust, scale, paint and other impurities either mechanically or chemically.
ii. Mechanical method – wire brushing, abrasion techniques.
iii. Chemical method – Soaking, cleaning or acid etching.
iv. Once the contaminants are removed the next step is to apply a suitable flux.
v. Flux – A substance either in a liquid or semiliquid state.
vi. Functions of Flux:
    - ❖ Helps base metal from oxidizing while they are being heated to the soldering temperature.
    - ❖ Acts as a wetting agent in the soldering process, reducing the surface tension of the molten solder and causing it to better wet out the parts to be joined.
    - ❖ Cleans the surface, dissolving the metal oxides.

vii. Types of flux: rosin-alcohol, zinc chloride, aniline phosphate etc.
viii. The flux may be applied on the metal surface by brushing, dipping, spraying

3. Types of solder

- Solder - An alloy which melts at low temperatures (less than 450°C).
- Types :
    i. Soft solder
    ii. Hard solder

Soft solder

Composition	Properties	Applications
An alloy of tin and lead; lead = 37%, Tin = 63%	Low melting points [150°C - 190°C], Addition of antimony <0.5% improves the mechanical properties.	Low load and temperature applications

Hard solder

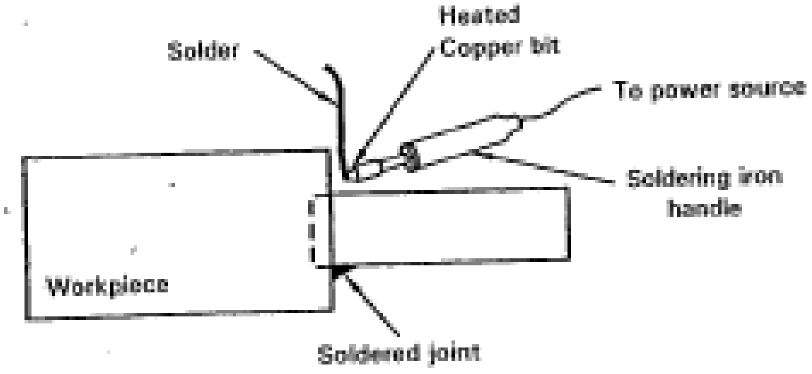
Composition	Properties	Applications
An alloy of silver and lead; lead = 97.5%, silver= 2.5% *Or* Silver = 50%, Cu=34%, Zn = 16%	melting points ranges between 300°C - 600°C	To make strong joints that can resist high temperature

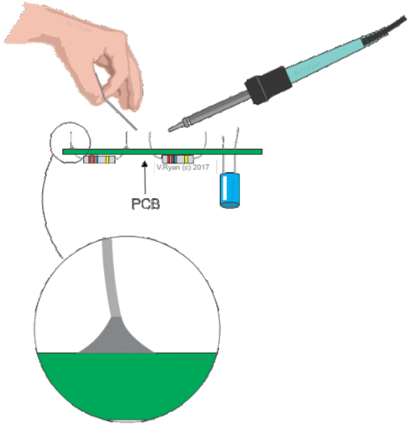
4. Types of soldering

- Soldering methods are classified based on the mode of heat application.
- Heat supplied should be such that it should melt the solder and permit the molten solder to flow quickly into the joint.
- Soldering method:
  i. Soldering iron method
  ii. Torch soldering
  iii. Wave soldering

a) Soldering iron method

- Most common and widely used method of soldering.
- Tool – soldering iron with a Cu coated tip which may be heated electrically or by oil/gas flame.
- The tip of the soldering iron stores and conduct heat from heat source [electrical energy] to the components being joined.
- Surface preparation:
  - ❖ Cleaned thoroughly to remove the contaminants.
  - ❖ Flux used are Zinc chloride, HCl and alcohol-rosin
- Joining processes:
  - ❖ Soldering iron is heated to a suitable temperature, solder melts at the tip of the soldering iron[bit].
  - ❖ Then bit is brought at the joint and the molten solder is deposited.
  - ❖The molten solder flows into the joint by the capillary force.
  - ❖The solder cools down and solidifies forming a joint.
  - ❖The joint is cleaned to remove flux residues in order to prevent corrosion.



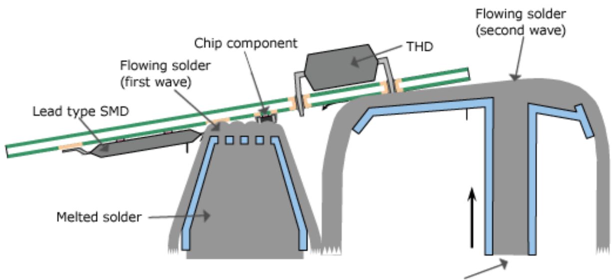


b) *Torch soldering*

- Utilizes the heat of a flame issued from an oxy-fuel gas torch.
- The torch mixes a fuel gas like acetylene with oxygen in suitable proportions and burn the mixture at its tip.
- The flame generated at the torch tip is directed at the workpiece with a flux applied on their surfaces.
- When the workpieces are heated to a suitable temperature, the solder is fed into the joint region to melt and flow into the gap between the two workpieces.
- The solder cools down and solidifies forming a joint.

c) *Wave soldering*

- Very popular approach for soldering through-hole components on printed circuit boards.
- Method used a tank filled with molten solder.
- The solder is pumped and flow in a form of wave of predetermined height.
- The printed circuit boards pass over the wave touching it with their lower sides.



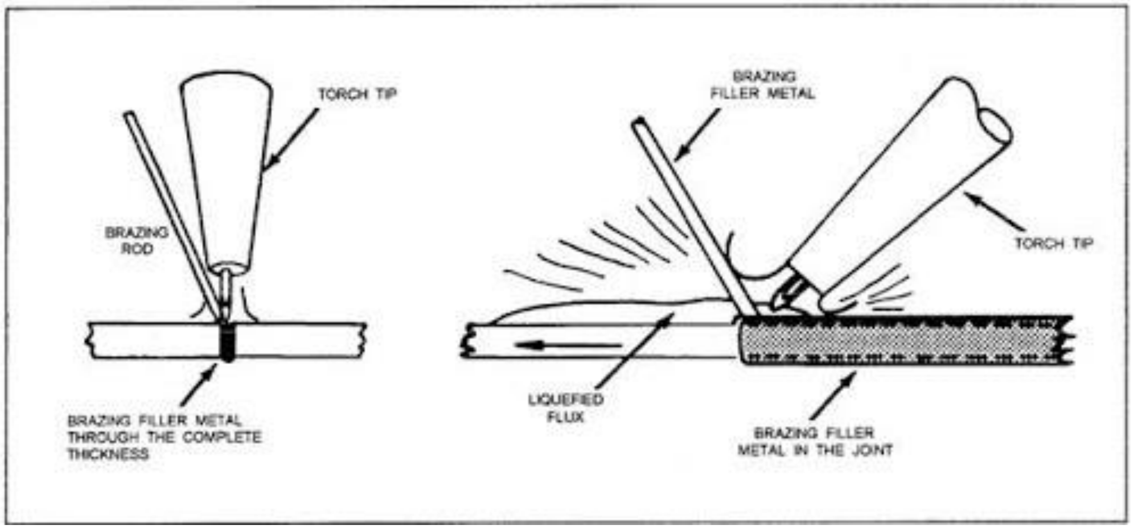
5. Advantages, disadvantages and applications of soldering

Advantages	Disadvantages	Applications
• Low power requirement • Low temperature process • No thermal distortions and residual stresses in joints • Dissimilar parts can be easily soldered • Thin parts can be joined easily.	• Flux residues should be removed after soldering [causes corrosion] • Thick parts can be efficiently joined. • Solder joint cannot be used in high temperature applications • Strength of the joint is low.	• Assembling electronic components to printed circuit boards • making connections between copper pipes in plumbing system, • Joining of sheet metal objects like food cans, metal containers, • Used as a semi-permanent patch for a leak in a container or cooking vessel.

Brazing

1. Principle of brazing

i. Method of joining similar or dissimilar metals by means of a filler metal whose T_m is above 450°C, but below the T_m of workpiece to be joined.
ii. Filler metal: Spelter – an alloy non-ferrous metal or alloy [Cu, Al and its alloys]
iii. The flow of molten filler material into the gap between the two workpiece is driven by the capillary force.
iv. The filler material cools down and solidifies forming a strong metallurgical joint.



2. Flux used in brazing

i. Performs its usual function as in soldering, i.e., it melts during the preheating stage and spreads over the joint area, wetting it and protecting the surface from oxidation.

ii. Also cleans the surface, dissolving the metal oxides.

iii. The flux used in brazing is available in powder, liquid and paste form.

iv. Method of applying the flux:

- ❖ Powered form- The heated end of the filler rod is dipped into the container of powdered flux and allowing the flux to stick to the filler rod.
- ❖ Liquid form – The base metal is heated slightly and powdered flux is sprinkled over the joint, allowing the flux to partly melt and stick to the base metal.
- ❖ Paste form – Powdered flux is mixed with clean distilled water and applied over the joint.

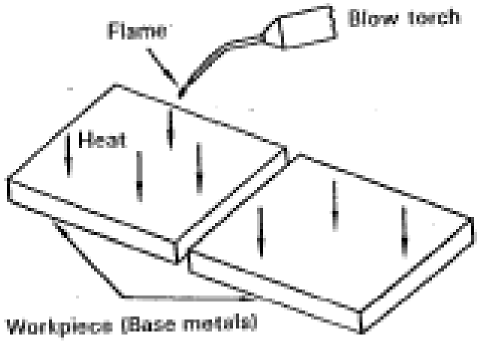
v. Flux in either the paste or liquid form can be applied with a brush to the joint.

vi. Types of flux used: borax, borax with small amounts of P, halogen salts of iodine, bromine, fluorine, chlorine, astatine etc.

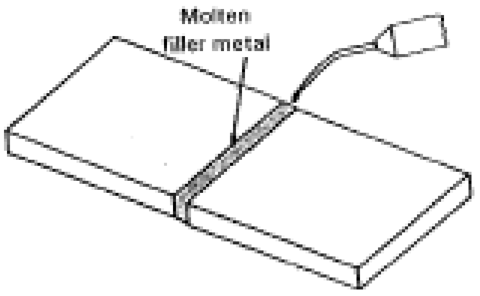
3. Types of brazing

a) Torch brazing

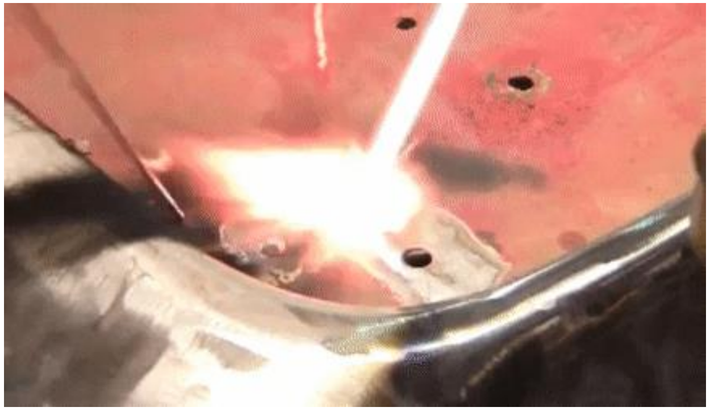
- Most commonly used brazing process wherein the two metals are joined by the heat obtained from a gas flame and by using a non-ferrous filler metal [T_m >450°C], but below the melting temperature of the workpiece to be joined.
- Surface preparation:
  - ❖ Surface to be joined are cleaned thoroughly in order to remove dirt, grease and other oxides.
  - ❖ After cleaning, flux is applied at the joint [Borax, boric acid, fluorides or chlorides].
- The workpiece to be joined are broadly heated by an oxy-acetylene welding torch.
- The filler metal is then placed at the joint and is heated with a carburizing flame [type of flame obtained by supplying excess acetylene with oxygen in the torch].
- The filler metal melts and flows through the joint by capillary action.
- The workpiece is allowed to cool for sometime and the joint is then cleaned to remove flux residues in order to prevent corrosion.



(a) Broad heat to base metals

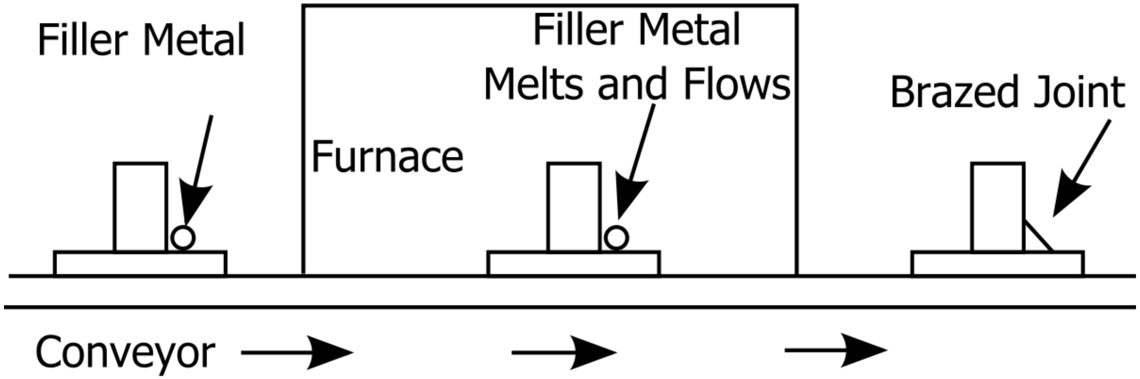


(b) Filler metal placed at the joint & melted



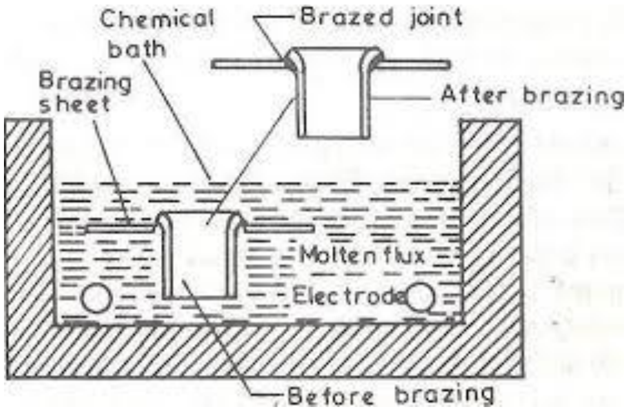
b) Furnace brazing

- The process in which bonding [joint] is produced by using the furnace heat and a non ferrous filler metal [T_m >450°C], but below the melting temperature of the workpiece to be joined.
- The filler metal is distributed in the joint by capillary attraction.
- Suited for fabricating complete brazements and does not require a highly skilled operator.
- Pre-fluxed/pre-cleaned parts with filler metal pre-placed at the joints are heated in furnaces.
- Brazing can be done in an air furnace with a flux, though a protective atmosphere usually is needed.
- The type of atmosphere required depends on the materials being brazed and the filler metals being used.
- Base metals with readily reducible oxides can be brazed in an atmosphere of combusted natural gas or cracked ammonia.
- Dry hydrogen, a powerful reducing agent can be used for brazing stainless steels, nickel, cobalt and iron-base alloys



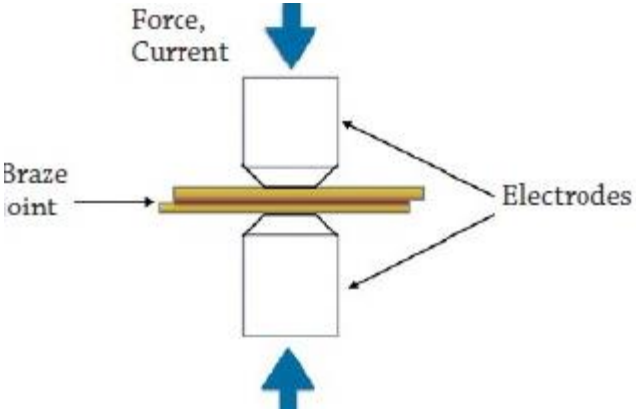
c) Dip brazing

- The temperature of the molten flux bath can be controlled [used on aluminium assemblies].
- The molten bath serves as both heating medium and fluxing agent.
- Uniform heating to brazing temperature is achieved rapidly.
- Parts are cleaned, assembled and held together in fixtures during brazing.
- Parts are normally preheated before immersion and residues are removed after brazing in order to prevent corrosion.

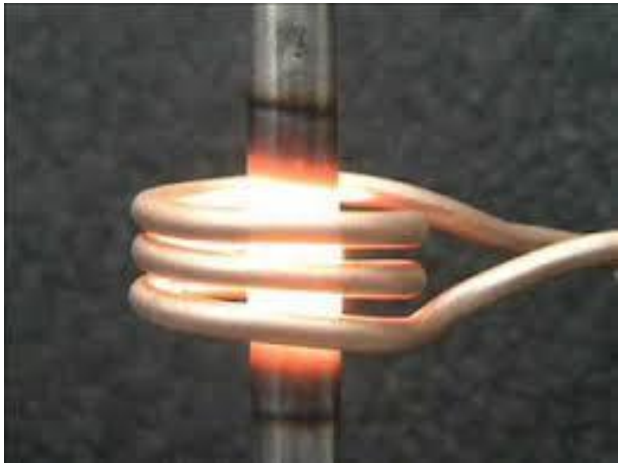


d) Resistance brazing

- Suited for special joints where heat must be restricted to a localized area without overheating surrounding parts.
- The required for brazing is produced due to the electrical resistance offered by the joint members to the flow of current through them.



e) Induction brazing



- Utilizes alternating electromagnetic field of high frequency for heating the workpiece together with the flux and the filler metal placed in the joint region.
- The technique is used only in those applications, where the entire assembly would be adversely affected by heat.
- Induction brazing reduces unwanted part distortion or annealing since the workpiece is heated selectively by the coil.
- Induction heating brings the joint rapidly to brazing temperatures.

4. Advantages, disadvantages and applications of brazing

Advantages	Disadvantages	Applications
• Low thermal distortions and residual stresses in the joints. • Easily automated process • Dissimilar parts can be joined.	• Flux residues must be removed after brazing[causes corrosion]. • Large and thick sections cannot be brazed effectively. • Relatively expensive filler materials	• Automotive, aerospace and tool industries, fastening pipe fittings, tanks, carbide tips on tools, radiators, heat exchangers, electrical parts, bicycle frames, rims.

Differences between soldering and brazing

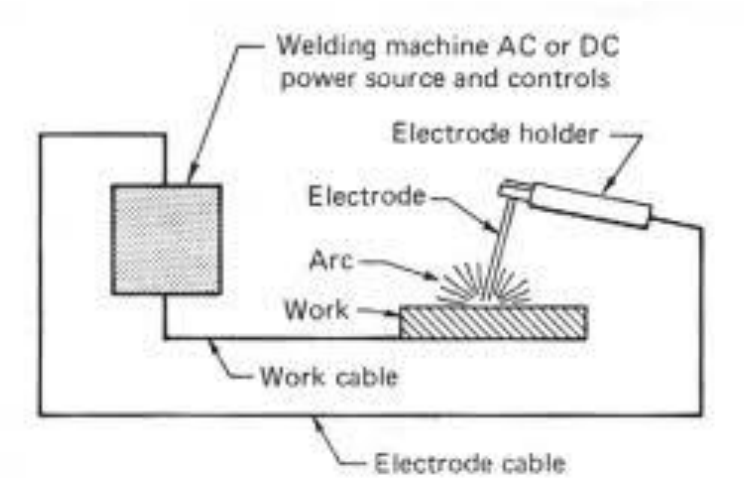
Sl. No.	*Soldering*	*Brazing*
1.	Filler metal used is solder	Filler metal used is spelter
2.	T_m of filler metal is below 450°C	T_m of filler metal is above 450°C, but below the melting point of the workpiece
3.	Strength of the joint obtained in soldering is comparatively low	Stronger joints can be obtained in brazing
4.	Soldered joints does not exhibits resistance to corrosion	Brazed joints resist corrosion
5.	Soldering equipments are economical	Slightly costlier

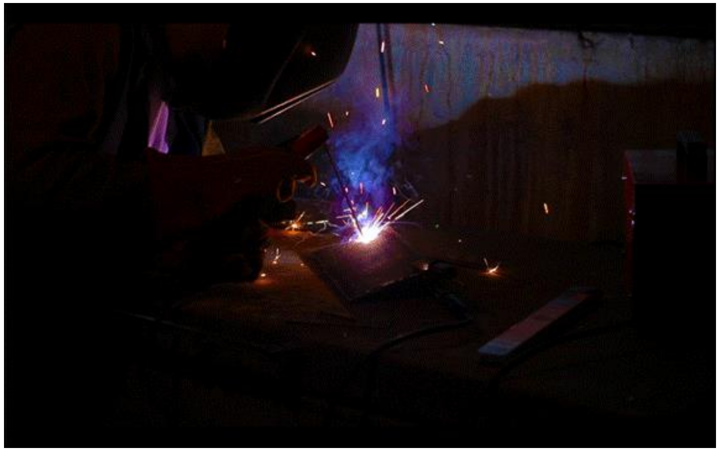
Welding

- Fabrication process in which two or more workpiece [metals or even thermoplastics] are joined permanently to form a single component.

1. Principle of welding

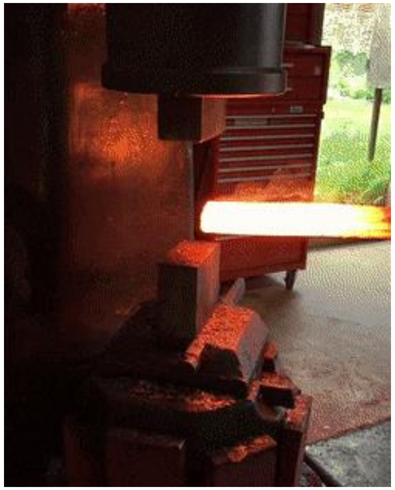
- Welding process is carried out by heating the edges of the workpiece to a suitable temperature and then fused [combine] together with or without the application of pressure.
- A slight gap usually exist between the edges of the workpiece, a filler metal is used to supply additional material to fill the gap.
- However, welding can also be carried out without the use of filler metal.
- Filler metal is melted in the gap, combines with the molten metal of the workpiece and upon solidification forms an integral part of the weld.



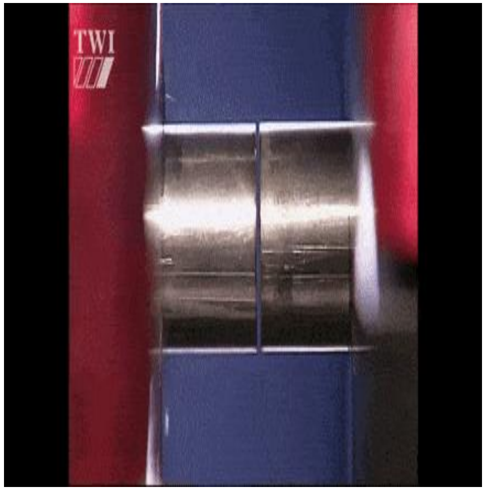


2. Classification of welding

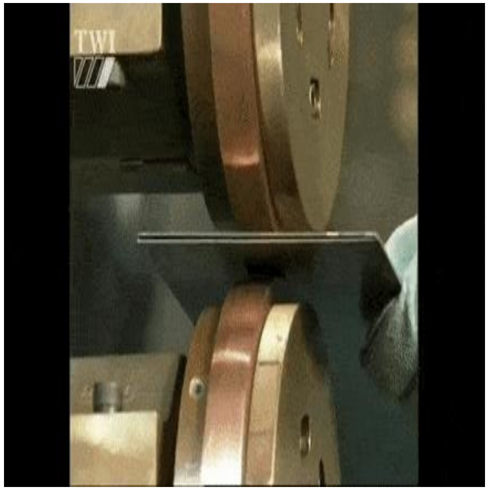
- *Plastic welding:*
  i. The metal parts to be joined are heated to the plastic state or slightly above and then fused together by applying external pressure.
  ii.No filler metal is used in this process.
  iii.Examples – Forge welding, friction welding, resistance welding etc.
  iv.Also called as pressure welding process.
- *Fusion welding:*
  i. The metal parts to be joined are heated above their melting temperature and then allowed to solidify by cooling.
  ii. A filler metal may or may not by used during the welding process.
  iii. Examples – Arc welding, gas welding, laser welding etc.



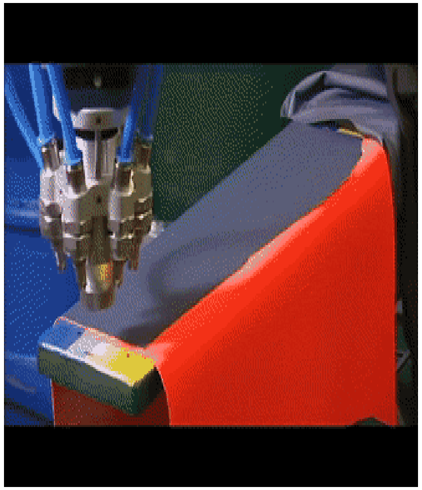
Forge welding



Friction welding



Resistance welding



Laser welding

3. Edge preparation in welding

- Before starting the welding process, the edges of the two workpiece to be welded should be prepared well to obtain a good weld.
- Edge preparation in welding process involves two operations

i. Joint preparation

❖ Involves cutting or bevelling the edges of the two workpieces to suitable shapes so that the heat would be able to penetrate to the entire depth of the workpiece.

❖ Types of joint: square/straight joint, V-joint, U-joint, double V and U symmetrical joints.

ii. Cleaning of joint

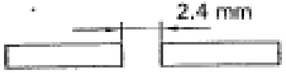
❖ Workpiece surfaces are often chemically contaminated by dirt, grease, oxides etc.

❖ Most metals are very reactive and in presence of air they forms an oxide layer on the workpiece.

❖ This layer prevents intimate contact from being made between the two metal surfaces.

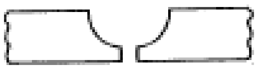
❖ Hence the edges of the workpiece and the area adjoining them should be cleaned thoroughly to remove the contaminants.

❖ Cleaning in done either chemically [acetone, carbon tetrachloride solution] or mechanically [wire brush, hand files, grinding].



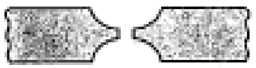
(a) Straight /Square joint used for workpiece with thickness < 5mm

(b) Single – V for thickness 8 – 16 mm



(c) Single - U joint for thickness > 20mm

(d) Double - V symmetrical for thickness > 16 mm



(e) Double - U symmetrical for thickness > 20 mm

Arc welding process

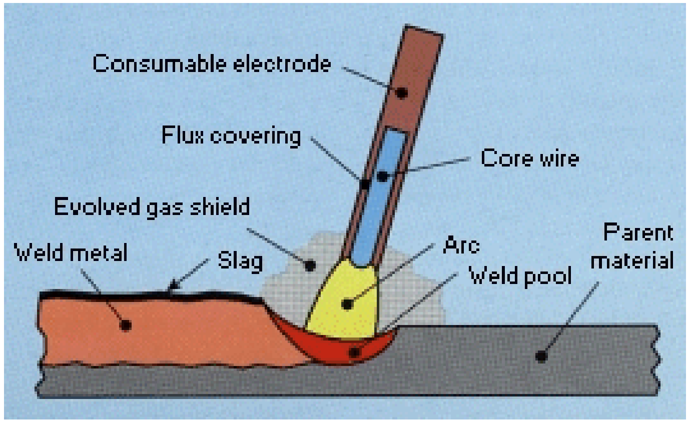
- Principle: A fusion method of welding that utilizes the high intensity of an electric arc to melt the workpiece metals. A solid continuous joint is formed upon cooling. Either AC or DC can be used to supply the required current for welding.
- Construction details:

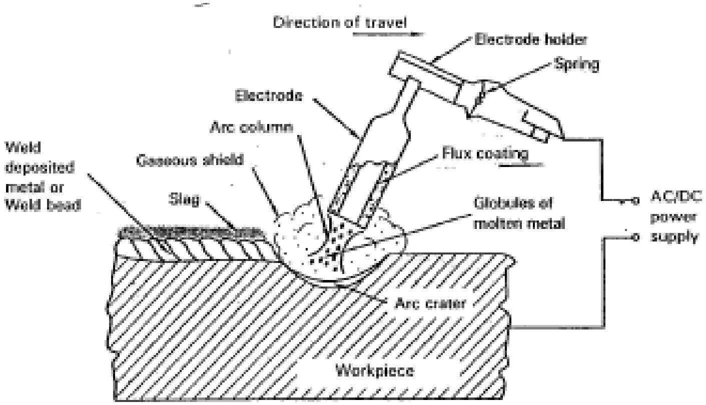
  ❖In this process, the electrode holder holding the electrode firmly forms one pole of the electric circuit while the workpiece to be welded forms the other pole.

  ❖The electrode serves both to carry the arc and also acts as a filler rod to deposit the molten metal into the joint.

  ❖The electrode used in arch welding process is metallic wire which is made of the same material or nearly the same chemical composition as that of the workpiece material.

  ❖The metallic wire is coated with a suitable flux material like titania, calcium fluoride, cellulose, iron oxide etc., which gives off gases as it decomposes thereby preventing oxidation of the molten metal during welding process.





- Operation:

❖ An arc is struck by touching the tip of the electrode on the workpiece and instantaneously with electrode separated by a small distance of 2-4mm.

❖ The temperature of the arc ranges from 5000°C - 6000°C.

❖ The high heat at the tip of the arc melts the workpiece metal forming a small molten metal pool.

❖ At the same time, the tip of the electrode also melts. The molten metal of the electrode is transferred into the molten metal of the workpiece in the form of globules of metal.

❖ The deposited metal fills the joint and bonds the joint to form a single piece of metal

❖ The electrode is moved along the surface to be welded to complete the joint.

❖ The arc is extinguished by increasing the arc length i.e., by widening the gap between the workpiece and the electrode.

- Advantages, disadvantages and applications of arc welding

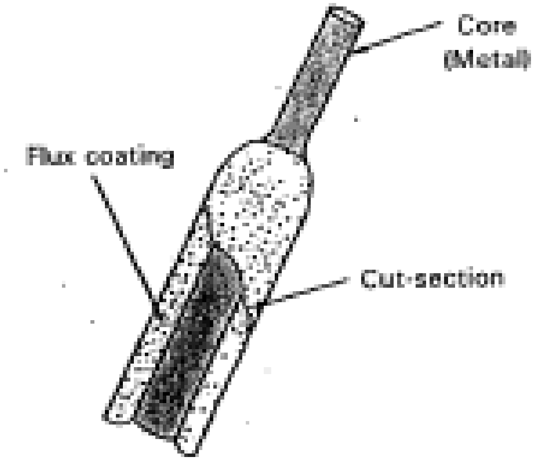
Advantages	Disadvantage	Applications
• Simple and inexpensive • Skilled labour not required • Low maintenance • Can weld Fe and non Fe metals	• Slow process, weld spatter, poor fusion, shallow penetration, cracking were observed.	• Building and bridge construction, ship building, boiler and pressure vessel fabrication, joining of large pipes, penstock etc

Electrodes used in arc welding

I. Consumable electrodes – Electrodes which get consumed during the welding process. These electrodes help to establish the arc and also act as a filler metal to deposit additional material to fill the gap between the workpieces.

a) Coated electrodes:

- The metallic wire, called core is coated with a flux. Coating is done by dipping the heated end of the metal rod in the constituents of flux.
- Flux materials used: titanium oxide, cellulose, manganese oxide, calcium carbonates, mica, iron oxide etc.
- Functions of flux coated over core:
  1) Stabilizes the arc
  2) Prevents oxidation of molten metal
  3) Helps in removing the oxides from the surface of the workpiece
  4) Chemically reacts with the oxides and forms a slag
  5) Eliminates weld metal porosity
  6) Helps to produce minimum spatter adjacent to the weld.



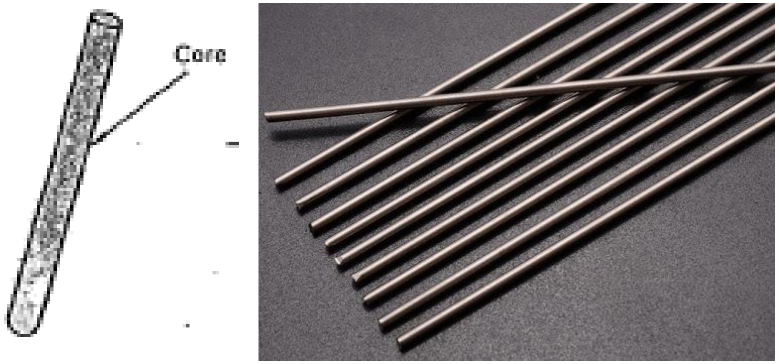
b) *Plain or bare electrodes*:

- The core wire is left plain or uncoated with flux.
- These electrodes do not prevent oxidation of the weld and hence joint obtained is weak.
- Welding processes that makes use of plain electrodes utilizes inert gases for shielding of weld metal from atmospheric oxidation.

c) *Tubular electrodes:*

- Hollow materials containing flux constituents inside the core wire.
- Used in flux-cored arc welding process.
- It consist of a wire made of low carbon steel sheet surrounding a core of flux and alloying materials.

II. Non-consumable electrode: Electrodes which are not consumed during welding process. Usually made of carbon, tungsten, graphite. They serve only to strike and maintain the arc during the welding process.



Bare electrodes

Tubular electrodes

Tungsten inert gas welding process

- Principle: Type of welding process in which the workpiece are joined by the heat obtained from an electric arc struck between a non-consumable tungsten electrode and the workpiece, in presence of an inert gas atmosphere.
- Construction details:

❖ It consists of a welding torch in which a non-consumable tungsten alloy electrode[0.5-6.4mm diameter] is held rigidly in the collet.

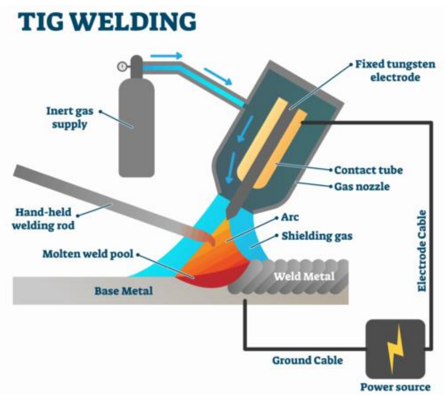
❖ Various alloy like Zr, thorium, lanthanum etc., are alloyed with tungsten to improve arc stability, better current carrying capacity, resistance to contamination.

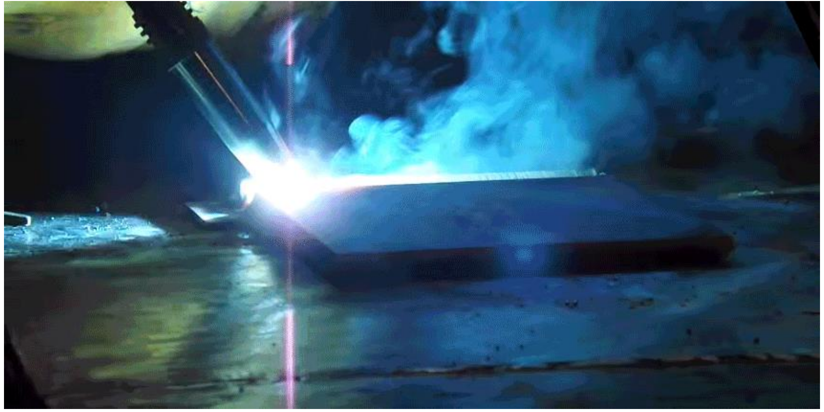
❖ TIG welding makes use of inert gas like argon or helium to protect the welding area from atmospheric gasses [O, N] which cause fusion defects and porosity in the weld metal.

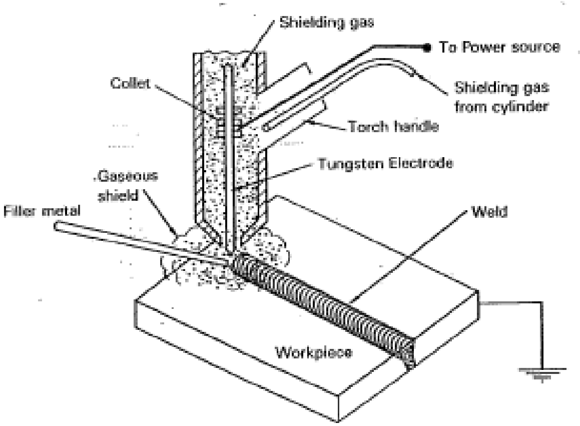
❖ The shielding gas flow from the cylinder through the passage in the electrode holder and then impinges on the workpiece.

❖ Pressure regulator and flow meters are used to regulate the pressure and flow of gas from the cylinder.

❖ Either AC or DC can be used to supply the required current







- Operation:

❖ The workpieces to be joined are cleaned to remove dirt, grease and other oxides chemically or mechanically to obtain good weld.

❖ The welding current and inert gas supply are turned ON. An arc is struck by touching the tip of the tungsten electrode with the workpiece and instantaneously the electrode is separated from the workpiece by a small distance of 1.5-3mm .

❖ The high intensity of the arc melts the workpiece metal forming a small metal pool.

❖ Filler metal in the form of a rod is added manually to the front end of the weld pool.

❖ The deposited filler metal fills and bonds the joint to form a single piece of metal.

❖ The arc is extinguished by widening the gap between the workpiece and the electrode.

❖ The shielding gas is allowed to impinge on the solidifying weld pool for a few seconds even after the arc is extinguished [increases the strength of weld joint].

- Advantages, disadvantages and applications of TIG welding

Advantages	Disadvantage	Applications
• Suitable for thin metals • Clear visibility of the arc, greater control over the weld • Strong and high quality joint • No flux is used. No slag formation, clean weld joints.	• Difficult process, short arc length, Chances of tungsten inclusion in weld joint • Skilled operator required. • Slower process, not suitable for thick metals	• To weld SS and non Fe metals • Aerospace, refrigerators, AC, chemical plants

Metal inert gas (MIG) welding process

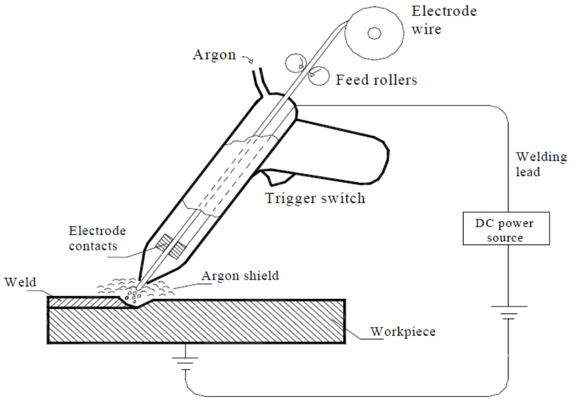
- Principle: Type of welding process in which the workpiece are joined by the heat obtained from an electric arc struck between a bare (uncoated) consumable electrode and the workpiece, in presence of an inert gas atmosphere. The consumable electrode acts as filler metal to fill the gap between the two workpiece.
- Construction details:

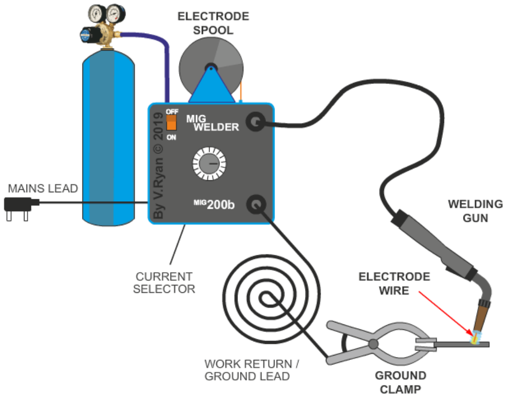
❖ It consists of a welding torch in which a bare (uncoated) electrode in the form of wire [0.7-2.4mm diameter] is held and guided by a guide tube [electrode material is of the same material as that of the base metal]. The electrode is fed continuously at a constant rate through feed rollers driven by an electric motor.

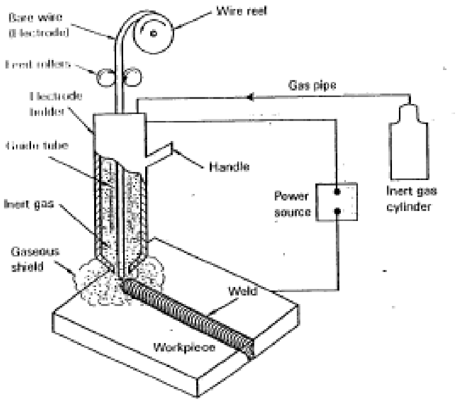
❖ MIG welding makes use of shielding gas like [argon + carbon dioxide = 75-80% + 25-20%] to protect the molten weld pool from atmospheric contamination.

❖ The shielding gas flow from the cylinder through the passage in the electrode holder and then impinges on the workpiece.

❖ MIG makes use of DC power source [electrode – positive pole of the power source] resulting in faster melting of the electrode, greater weld penetration and welding speed.







- Operation:

- ❖ The workpieces to be joined are cleaned to remove dirt, grease and other oxides chemically or mechanically to obtain good weld. The tip of the workpiece is also cleaned with a wire brush.
- ❖ The control switch provided in the welding torch is switched ON to initiate the electric power, shielding gas and the electrode feed.
- ❖ An arc is struck by touching the tip of the electrode with the workpiece and instantaneously the electrode is separated from the workpiece by a small distance of 1.5-3mm .
- ❖ The high intensity of the arc melts the workpiece metal forming a small metal pool.
- ❖ At the same time, the tip of the electrode also melts and combines with the molten metal of the workpiece thereby filling the gap between the two workpiece.
- ❖ The deposited metal upon solidification bonds the joint to form a single piece of metal.

- Advantages, disadvantages and applications of MIG welding

Advantages	Disadvantage	Applications
• Fast and economical. • Electrode and inert gas are automatically fed. • Weld deposition rate is high • No flux is used, Thin and thick metals can be welded. Automated process.	• Equipment is costlier • Gas entrapment in the weld pool	• Sheet metal industries and automobile sectors.

Gas welding process

- <u>Principle</u>:

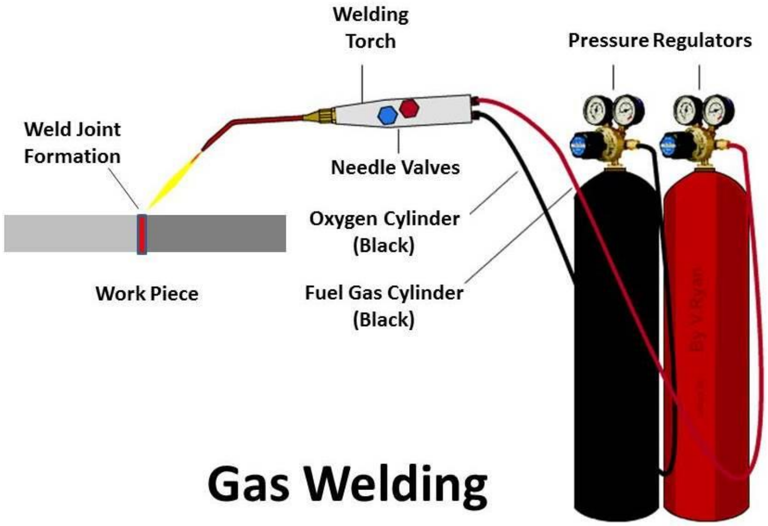
❖ A fusion welding process in which the workpieces are joined by the heat of a strong flame generated by the combustion of a fuel gas and oxygen.

❖ When the fuel gas and oxygen are mixed in suitable proportions in a welding torch and ignited, the flame resulting at the tip of the torch is sufficient enough to melt the edges of the workpiece metals. A solid continuous joint is formed upon cooling.

❖ Fuel gas used – acetylene, hydrogen, propane or butane.

- <u>Types of gas welding process:</u>
  a) Oxy-acetylene welding process – mixture of oxygen and acetylene gas
  b) Oxy-hydrogen welding process – mixture of oxygen and hydrogen gas

- Oxy-acetylene welding is the most versatile and widely used gas welding process due to its high flame temperature [3500°C] when compared to that of oxy-hydrogen process [2500°C]



Oxy-acetylene welding

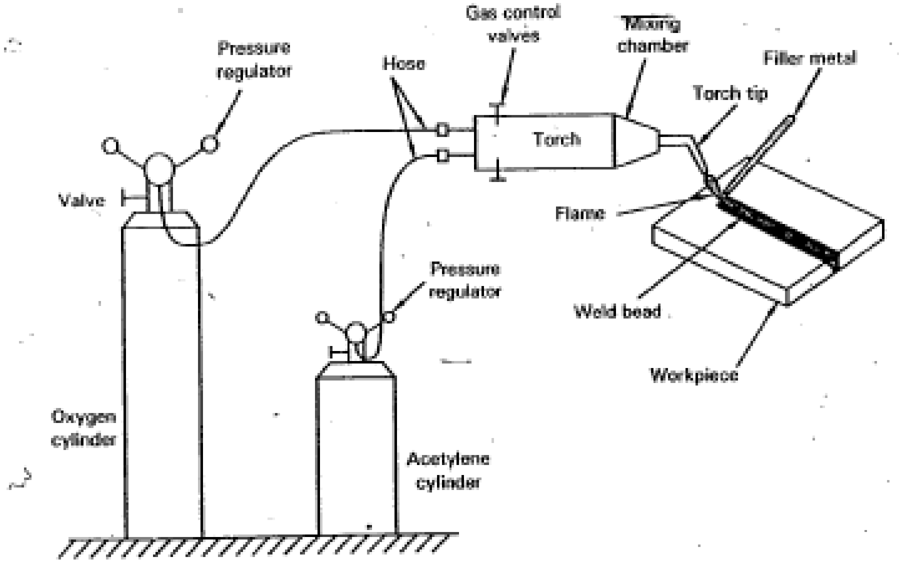
- Principle: When oxygen and acetylene are mixed in suitable proportions in a welding torch and ignited, the flame resulting at the tip of the torch has a temperature ranging from 3100°C-3500°C which is sufficient enough to melt and fuse the workpiece metals. Filler metal may or may not be used during the process.
- Construction details:

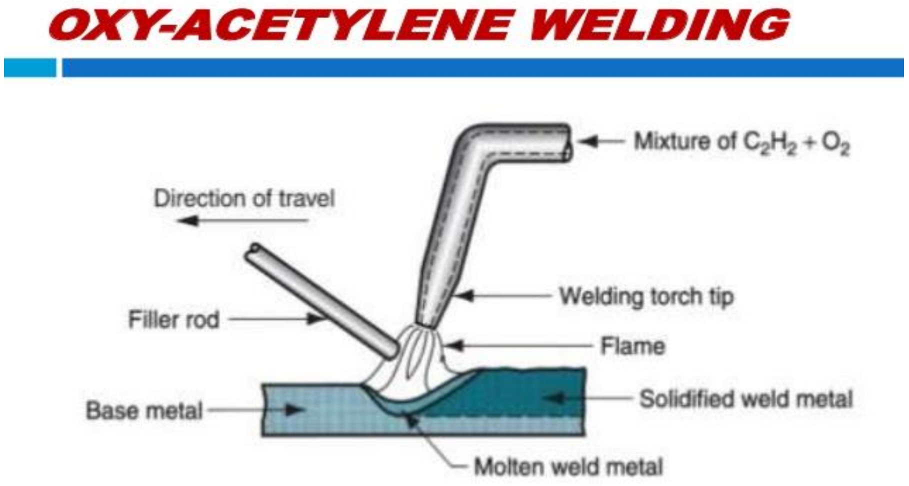
❖ Two large cylinders: one containing oxygen at high pressure and the other containing acetylene gas.

❖ Two pressure regulators fitted on the respective cylinders to regulate or control the pressure of the gas flowing from the cylinders to the welding torch as per requirements.

❖ Welding torch: Used to mix oxygen and acetylene gas in proper proportions and burn the mixture at its tip.

❖ A match stick or a may be used to ignite the mixture at the torch tip.





- Operation:

- ❖ By adjusting the pressure regulators, suitable proportions of oxygen and acetylene gases enter into the welding torch.
- ❖ The gases get mixed in the torch and are issued from the torch to burn in the atmosphere.
- ❖ A match stick is used to ignite the gas at the torch tip. The resulting flame at the torch tip has a temperature ranging from 3100-3500°C and this heat is sufficient enough to melt the workpiece metals.
- ❖ Since a slight gap usually exists between the two workpieces, a filler metal may be used to supply the additional material to fill the gap.
- ❖ The molten metal of the filler metal combines with the molten metal of the workpiece and upon solidification form a single piece of metal.

- Advantages, disadvantages and applications of Oxy-acetylene gas welding

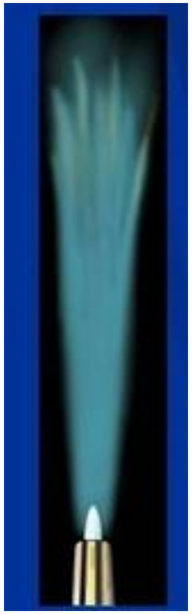
Advantages	Disadvantage	Applications
• Simple and inexpensive. • Eliminates skilled operator • Flame temperature can be controlled depending on the thickness of material being welded.	• Acetylene gas is slightly costlier. • Not suitable for thick and high T_m metals • Refractories metals can not be welded. • Acetylene is highly explosive.	• Joining of thin Fe and Non-Fe metals, automotive, aerospace and manufacturing industries. • Fabrication of sheet metal parts.

Flames produced in Oxy-acetylene welding

a) Neutral flame:

- Produced when approximately equal volumes of oxygen and acetylene are burnt at the torch tip.
- All the carbon supplied by C_2H_2 is being consumed resulting in complete combustion.
- The flame has a nicely defined inner whitish cone surrounded by a sharp blue flame.
- The temperature of the neutral flame is around 3260°C.
- Applications: welding mild steel, cast iron, Al, Cu, metal cutting.
- It has least chemical effect on the heated metal.

b) Oxidizing flame:



- If the supply of oxygen is further increased after the neutral flame has been established, the result will be an oxidizing flame.
- It is a flame in which there is excess oxygen than the required for complete combustion.
- It appears similar to neutral flame but with a shorter inner white cone and the outer envelope being narrow and brighter in colour.
- The temperature of the oxidizing flame is around 3500°C.
- Applications: Welding Cu-base metals, Zn-base metals etc.
- It should not be used for welding steels [burns some of the metal being welded].

c) Reducing flame:

- If the volume of oxygen supplied to the neutral flame is reduced, the resulting flame will be carburizing or reducing flame [rich in acetylene].
- Combustion is incomplete with unconsumed carbon being present in the flame.
- The flame has an acetylene feather which exists between the inner cone and outer envelope. The outer flame envelope is longer than that of the neutral flame and much brighter in colour.
- The temperature of the reducing flame is around 3066°C.
- Applications: welding hard surfacing, Ni-Cu alloy, few non-Fe metals.
- It should not be employed for welding steel, as unconsumed carbon may be introduced into the weld to produce hard and brittle deposit.

Underwater welding

- Wet welding: It entails the welder to perform the weld directly in the water using a specially designed welding rod.
- Dry welding: A chamber is sealed around the structure that is to be welded. It is then filled with a gas[He+O], which then forces the water outside of the hyperbaric sphere which allows a dry environment for performing the weld.
- Very risky and dangerous for welder.

Difference between soldering, brazing and welding process

Sl. No.	Soldering	Brazing	Welding
1.	Low temperature process. Base metals are not melted	Base metals are not melted, but heated to suitable temperature	High temperature process wherein base metals are heated above their T_m
2.	Filler metal is not same as that of base metal	Filler metal is not same as that of base metal	Filler material used is of the same material as that of base metal
3.	Joint is formed by diffusion of the filler metal into the base metal	Diffusion of filler metal into the base metal associated with surface alloying	Solidification of the molten filler metal with the molten base metal
4.	Strength of the joint is comparatively low	Strength lies between that of welded and soldered joint	Much stronger than the base metal
5.	No heat effected zone	Heat affected zone is not too much when compared to welding	Heat affected zone is affected to a large extent
6.	Finishing operations are not required	Sometimes brazed joints require finishing	Requires finishing operations like grinding, filing etc
7.	Sheet metal work and electronic industries	Arts, jewellery works	Fabrication and structural works

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Module – 4.3

<u>Belt drives</u>

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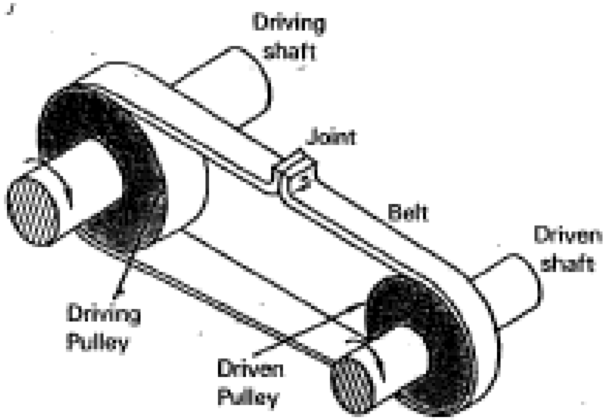
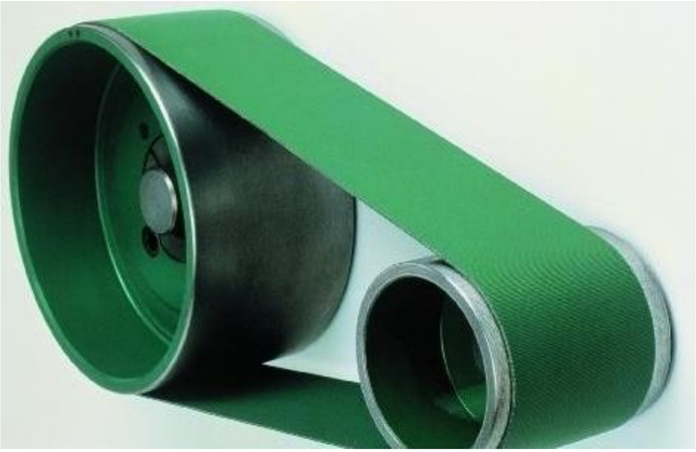
Belt drives

- Belt drives are used to transmit power or motion from one shaft to the other by means of a thin inextensible belt running over two pulleys.

Mechanism of belt drives

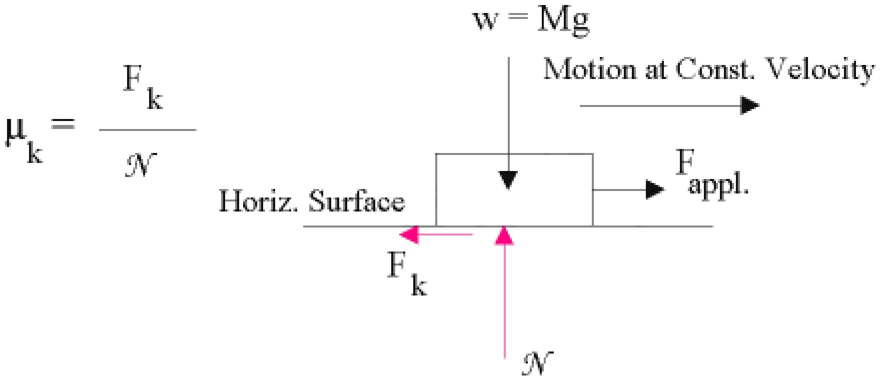
- Belt drive arrangement consists of two pulleys mounted on two different shafts.
- One shaft called the driving shaft receives power from the mains and transmits it to another shaft called driven shaft.
- The pulley mounted on the driving shaft is called driving pulley or driver.
- The other pulley mounted on a shaft to which the power is to be transmitted is called the driven pulley or follower.
- The belt passing over the two pulleys is kept in tension so as to avoid slip over the pulleys.
- This helps in transmitting power effectively from one shaft to another.





Materials used for belts

- Properties of belt material: Strong, flexible and durable. It must have a high coefficient of friction
- *COF*: Dimensionless value, ratio of frictional force between two bodies and the force pressing them together, denoted by μ.



- Types of belts:
  i. Leather belts – cut from the back bone of steer hides [animal skin]
  ii. Cotton/fabric belts – folding canvass to three or more layers and stitching together
  iii. Rubber belt- layers of fabric impregnated with rubber.
  iv. Balata belt - similar to rubber belt except that balata gum is used in place of rubber

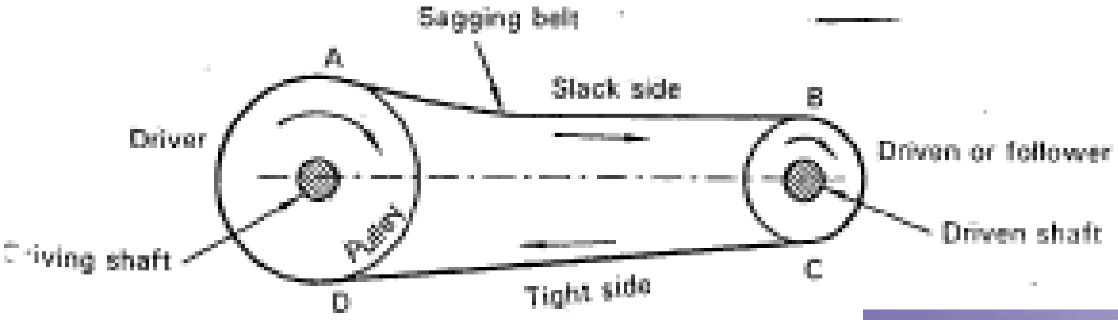
Types of belt drives

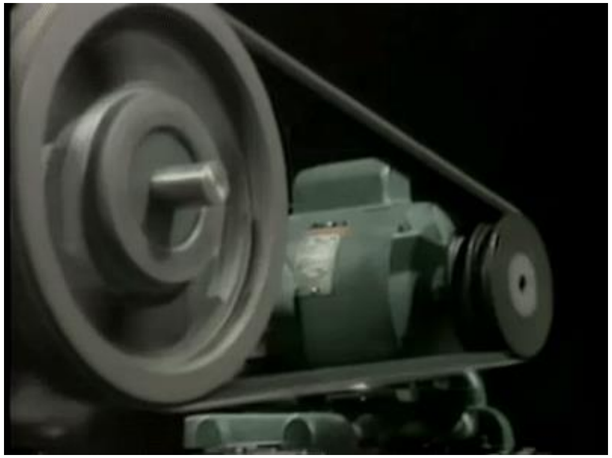
i. Open belt drive

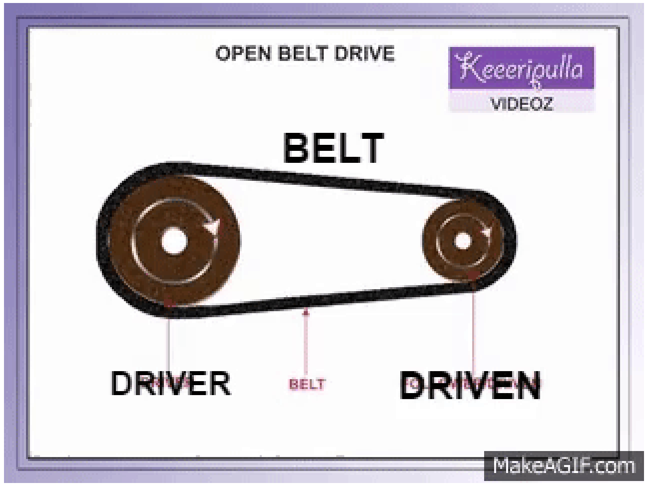
ii. Closed belt drive

i. Open belt drive

- Open belt drive are used to connect two shafts that are parallel and rotating in the same direction.
- The driver pulls the belt from the lower side CD and delivers it to the upper side AB.
- Therefore *“tension in the lower side belt CD will be more than the tension in the upper side belt AB”*.
- The lower side, because of more tension, it is known as tight side whereas the upper side belt, because of low tension, it is known as slack side
- Limitation: Due to the lesser tension on the slack side, the belt sags due to its own weight.

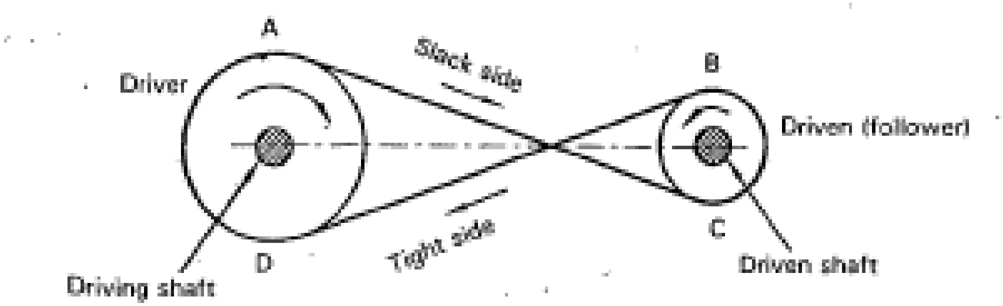


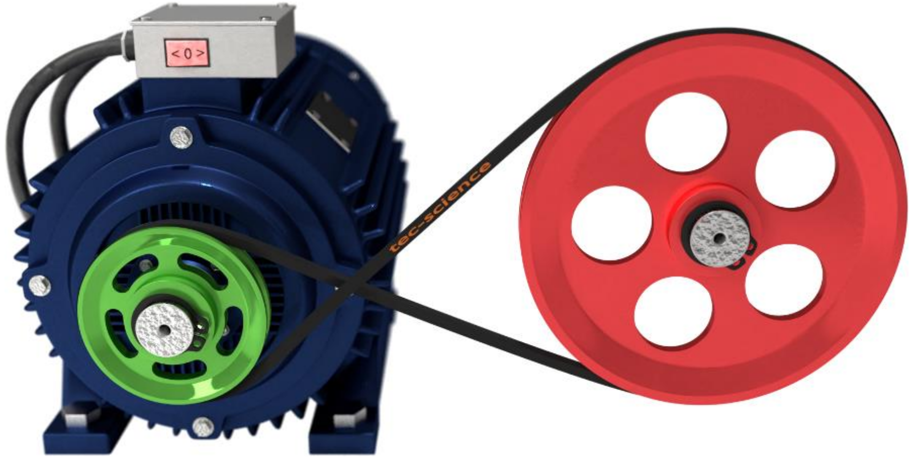


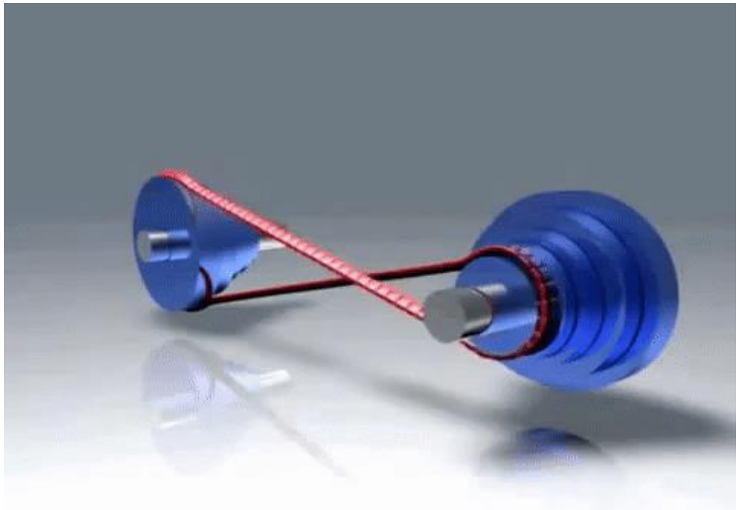


ii. Cross belt drive

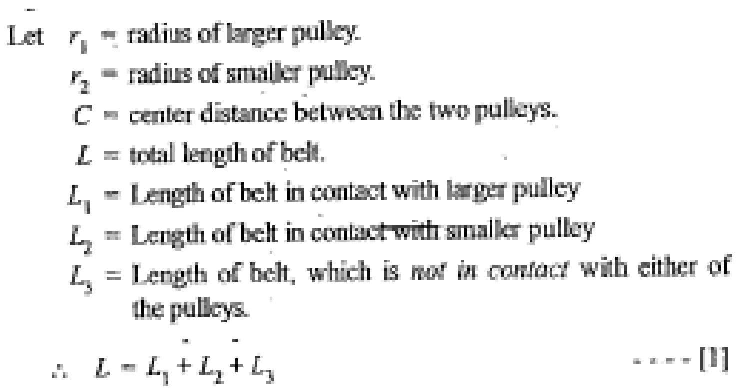
- Cross belt drive are used to connect two shafts that are parallel and rotating in the opposite direction.
- The driver pulls the belt from the lower side BD and delivers it to the other side AC.
- Therefore *“tension in the belt side BD will be more than the tension in the belt side AC”*.
- The belt side BD, because of more tension, it is known as tight side whereas the belt side AC, because of low tension, it is known as slack side.







Length of belt for open belt drive



Let r_1 = radius of larger pulley.

r_2 = radius of smaller pulley.

C = center distance between the two pulleys.

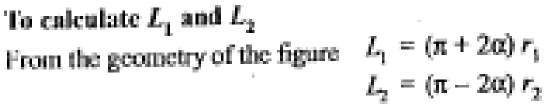
L = total length of belt.

L_1 = Length of belt in contact with larger pulley

L_2 = Length of belt in contact with smaller pulley

L_3 = Length of belt, which is *not in contact* with either of the pulleys.

$$\therefore \quad L = L_1 + L_2 + L_3 \qquad \text{- - - - [1]}$$



To calculate L_1 and L_2

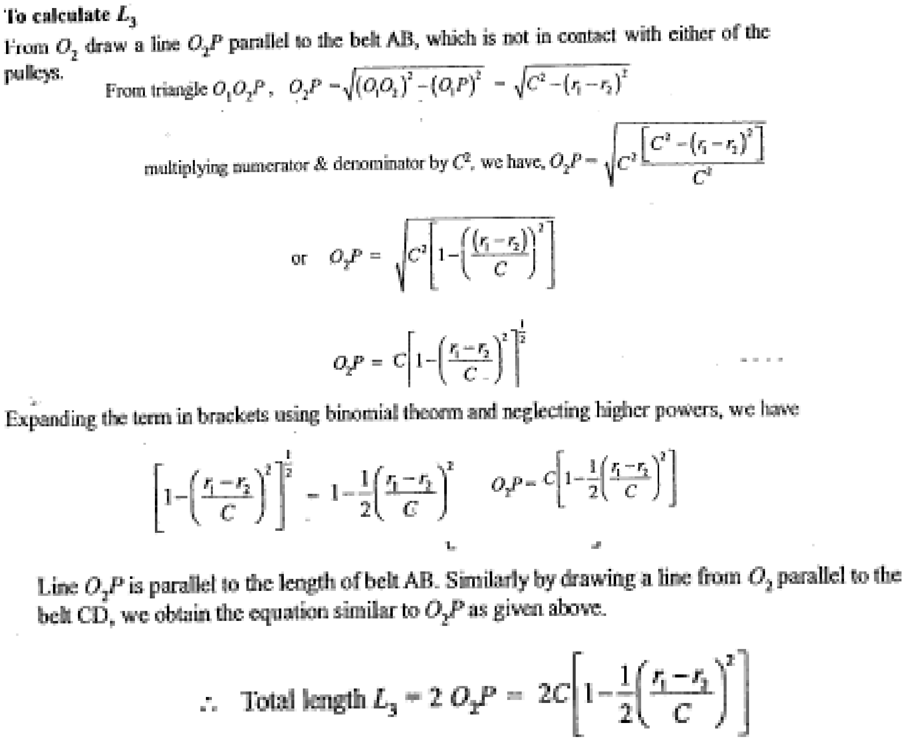
From the geometry of the figure $L_1 = (\pi + 2\alpha)\, r_1$

$L_2 = (\pi - 2\alpha)\, r_2$

Arc length = r× (central angle)

= r_1 (180° + 2α)

L_1 = r_1 (π+ 2α)



To calculate L_3

From O_2 draw a line O_2P parallel to the belt AB, which is not in contact with either of the pulleys.

From triangle O_1O_2P, $O_2P = \sqrt{(O_1O_2)^2 - (O_1P)^2} = \sqrt{C^2 - (r_1 - r_2)^2}$

multiplying numerator & denominator by C^2, we have, $O_2P = \sqrt{C^2 \frac{\left[C^2 - (r_1 - r_2)^2\right]}{C^2}}$

$$\text{or} \quad O_2P = \sqrt{C^2\left[1 - \left(\frac{(r_1 - r_2)}{C}\right)^2\right]}$$

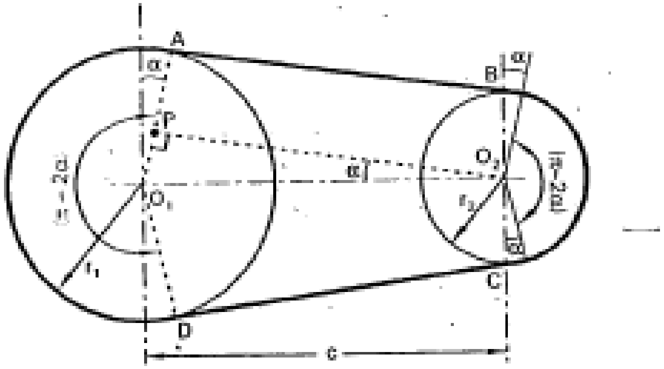
$$O_2P = C\left[1 - \left(\frac{r_1 - r_2}{C}\right)^2\right]^{\frac{1}{2}} \qquad \text{- - - -}$$

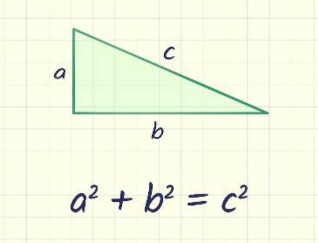
Expanding the term in brackets using binomial theorm and neglecting higher powers, we have

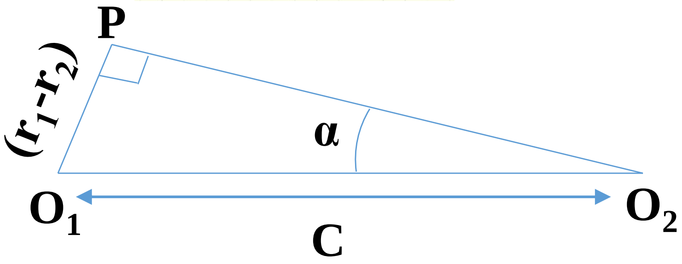
$$\left[1 - \left(\frac{r_1 - r_2}{C}\right)^2\right]^{\frac{1}{2}} = 1 - \frac{1}{2}\left(\frac{r_1 - r_2}{C}\right)^2 \qquad O_2P = C\left[1 - \frac{1}{2}\left(\frac{r_1 - r_2}{C}\right)^2\right]$$

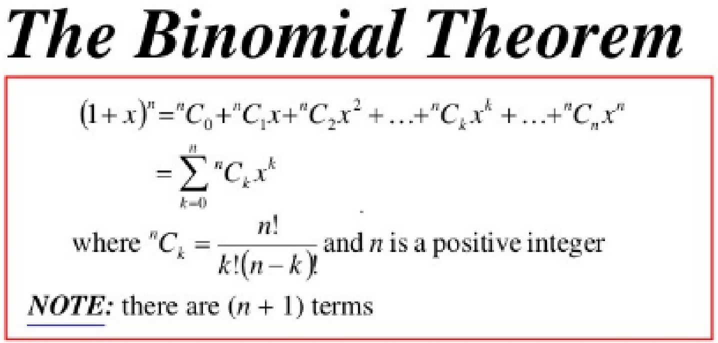
Line O_2P is parallel to the length of belt AB. Similarly by drawing a line from O_2 parallel to the belt CD, we obtain the equation similar to O_2P as given above.

$$\therefore \quad \text{Total length } L_3 = 2\,O_2P = 2C\left[1 - \frac{1}{2}\left(\frac{r_1 - r_2}{C}\right)^2\right]$$









The Binomial Theorem

$$(1+x)^n = {}^nC_0 + {}^nC_1x + {}^nC_2x^2 + \ldots + {}^nC_kx^k + \ldots + {}^nC_nx^n$$
$$= \sum_{k=0}^{n} {}^nC_kx^k$$

where ${}^nC_k = \dfrac{n!}{k!(n-k)!}$ and n is a positive integer

NOTE: there are $(n + 1)$ terms

$$L = [(\pi + 2\alpha)\, r_1] + [(\pi - 2\alpha)\, r_2] + 2C\left[1-\frac{1}{2}\left(\frac{r_1-r_2}{C}\right)^2\right]$$

$$L = \pi r_1 + 2\alpha r_1 + \pi r_2 - 2\alpha r_2 + 2C\left[1-\frac{1}{2}\left(\frac{r_1-r_2}{C}\right)^2\right]$$

$$L = \pi\,(r_1 + r_2) + 2\alpha\,(r_1 - r_2) + 2C - \frac{(r_1-r_2)^2}{C} \quad - - - -$$

But $\alpha = ?$

From triangle O_1O_2P $\sin\alpha = \dfrac{O_1P}{O_1O_2} = \dfrac{r_1-r_2}{C}$

For small values of α, $\sin\alpha = \alpha$

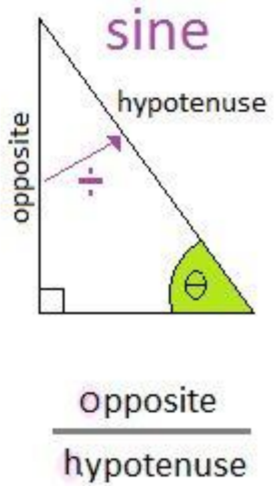
$\therefore$ equation (7) becomes $\alpha = \dfrac{r_1-r_2}{C}$

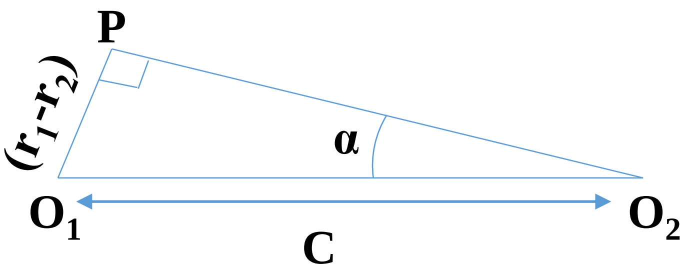
Substituting (8) in (6), $L = \pi\,(r_1 + r_2) + 2\dfrac{(r_1-r_2)^2}{C} + 2C - \dfrac{(r_1-r_2)^2}{C}$

$$L = \pi\,(r_1 + r_2) + \frac{(r_1-r_2)^2}{C} + 2C$$

Re-arranging $L = 2C + \pi(r_1 + r_2) + \dfrac{(r_1-r_2)^2}{C}$

Length of open belt drive = $2C + \pi(r_1+r_2) + \dfrac{(r_1-r_2)^2}{C}$

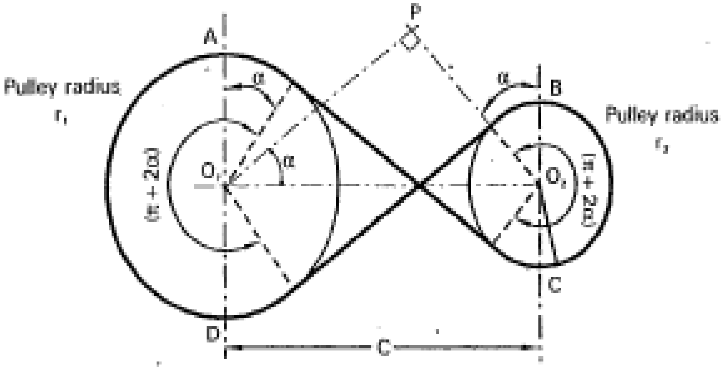




Length of belt for cross belt drive

Let r_1 = radius of larger pulley.
r_2 = radius of smaller pulley.
C = center distance between the two pulleys.
L = total length of belt.
L_1 = Length of belt in contact with larger pulley
L_2 = Length of belt in contact with smaller pulley
L_3 = Length of belt, which is *not in contact* with either of the pulleys.

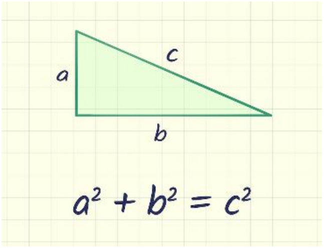
$$\therefore \quad L = L_1 + L_2 + L_3 \qquad \text{- - - - [1]}$$



To calculate L_1 and L_2

From the geometry of the figure
$$L_1 = (\pi + 2\alpha)\, r_1$$
$$L_2 = (\pi + 2\alpha)\, r_2$$

Arc length = r× (central angle)
= r_1 (180° + 2α)
$L_1 = r_1\,(\pi + 2\alpha)$



To calculate L_3

From O_1 draw a line O_1P parallel to the belt BD as shown in the figure.

From triangle O_1O_2P, $O_1P = \sqrt{(O_1O_2)^2 - (O_2P)^2} = \sqrt{(C^2) - (\overline{r_1 + r_2})^2}$

multiplying numerator & denominator by C^2, we have,

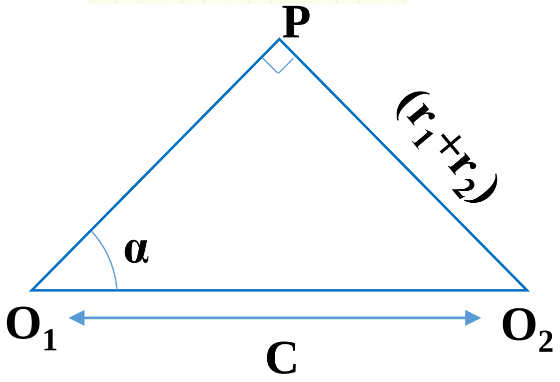
$$O_1P = \sqrt{C^2\,\frac{\left[C^2 - (r_1 + r_2)^2\right]}{C^2}} = \sqrt{C^2\left[1 - \left(\frac{r_1 + r_2}{C}\right)^2\right]}$$

$$\text{or} \quad O_1P = C\left[1 - \left(\frac{r_1 + r_2}{C}\right)^2\right]^{\frac{1}{2}} \qquad \text{- - -}$$

Expanding the term within the brackets by using binomial theorem and neglecting higher powers,

we have, $\left[1 - \left(\frac{r_1 + r_2}{C}\right)^2\right]^{\frac{1}{2}} = 1 - \frac{1}{2}\left(\frac{r_1 + r_2}{C}\right)^2$ $\qquad O_1P = C\left[1 - \frac{1}{2}\left(\frac{r_1 + r_2}{C}\right)^2\right]$

$$\text{Total length } L_3 = 2O_1P = 2C\left[1 - \frac{1}{2}\left(\frac{r_1 + r_2}{C}\right)^2\right]$$



The Binomial Theorem

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$$= \sum_{k=0}^{n} {}^nC_kx^k$$

where ${}^nC_k = \dfrac{n!}{k!(n-k)!}$ and n is a positive integer

NOTE: there are $(n + 1)$ terms

$$L = [(\pi + 2\alpha)\, r_1] + [(\pi + 2\alpha)\, r_2] + 2C\left[1 - \frac{1}{2}\left(\frac{r_1 + r_2}{C}\right)^2\right]$$

$$L = [(\pi + 2\alpha)r_1] + [(\pi + 2\alpha)r_2] + 2C - \frac{(r_1 + r_2)^2}{C}$$

$$L = \pi r_1 + 2\alpha r_1 + \pi r_2 + 2\alpha r_2 + 2C - \frac{(r_1 + r_2)^2}{C}$$

$$L = \pi\,(r_1 + r_2) + 2\alpha\,(r_1 + r_2) + 2C - \frac{(r_1 + r_2)^2}{C}$$

But $\alpha = ?$

From triangle O_1O_2P, $\sin\alpha = \frac{O_2P}{O_1O_2}$

$$\sin\alpha = \frac{r_1 + r_2}{C}$$

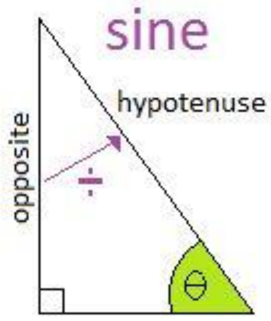
For small values of α, $\sin\alpha = \alpha$

∴ equation (7) becomes, $\alpha = \frac{r_1 + r_2}{C}$

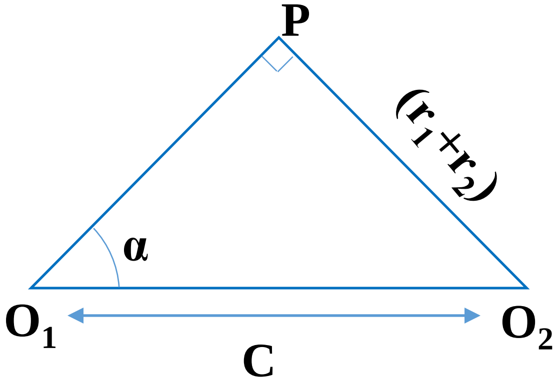
$$L = \pi\,(r_1 + r_2) + \frac{2(r_1 + r_2)^2}{C} + 2C - \frac{(r_1 + r_2)^2}{C}$$

$$L = \pi\,(r_1 + r_2) + \frac{(r_1 + r_2)^2}{C} + 2C$$

Re-arranging $L = 2C + \pi(r_1 + r_2) + \frac{(r_1 + r_2)^2}{C}$



$$\frac{\text{opposite}}{\text{hypotenuse}}$$



Length of cross belt drive = $2C + \pi(r_1 + r_2) + \frac{(r_1 + r_2)^2}{C}$

Velocity ratio in belt drive

- Ratio between the speed of the driven pulley [follower] and the speed of the driving pulley [driver].

Let d_1 = Diameter of driving pulley (driver).

d_2 = Diameter of driven pulley (follower / driven).

n_1 = Speed of the driving pulley and n_2 = Speed of driven pulley

Assuming that there is no slip between the belt and the pulley rim, the linear speed at every point on the belt must be the same. Hence, $\pi d_1 n_1 = \pi d_2 n_2$

$$\text{or } d_1 n_1 = d_2 n_2$$

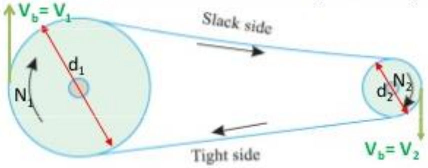
$$\text{or } \frac{n_2}{n_1} = \frac{d_1}{d_2}$$

$$\text{i.e.,} \quad \frac{\text{speed of driven}}{\text{speed of driver}} = \frac{\text{diameter of driver}}{\text{diameter of driven}}$$

Let d_1, d_2 -Diameters, m

N_1, N_2 - Speeds, rpm

V_1, V_2, V_b -Velocities, m/min



For no slip

$$\left\{\begin{matrix}\text{Length of the belt}\\ \text{passing over driver pulley}\\ \text{in one minute}\end{matrix}\right\} = \left\{\begin{matrix}\text{length covered}\\ \text{by a point on driver pulley}\\ \text{in one minute}\end{matrix}\right\}$$

$$V_b = \pi d_1 N_1$$

$$\left\{\begin{matrix}\text{Length of the belt}\\ \text{passing over driven pulley}\\ \text{in one minute}\end{matrix}\right\} = \left\{\begin{matrix}\text{length covered}\\ \text{by a point on driven pulley}\\ \text{in one minute}\end{matrix}\right\}$$

$$V_b = \pi d_2 N_2$$

The ratio $\frac{n_2}{n_1} = \frac{d_1}{d_2}$ is called *velocity ratio* or *speed ratio* or *transmission ratio* of belt drives.

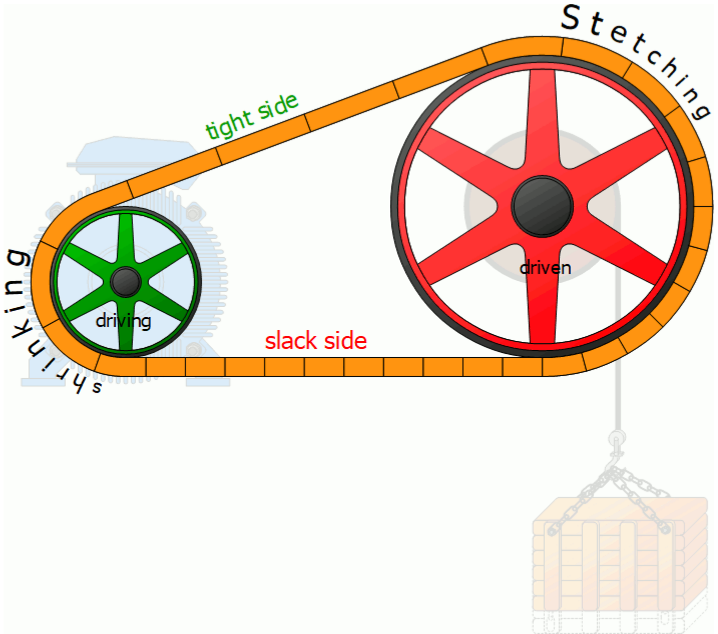
Thus, in belt drives, the speeds are inversely proportional to the diameter of pulleys.

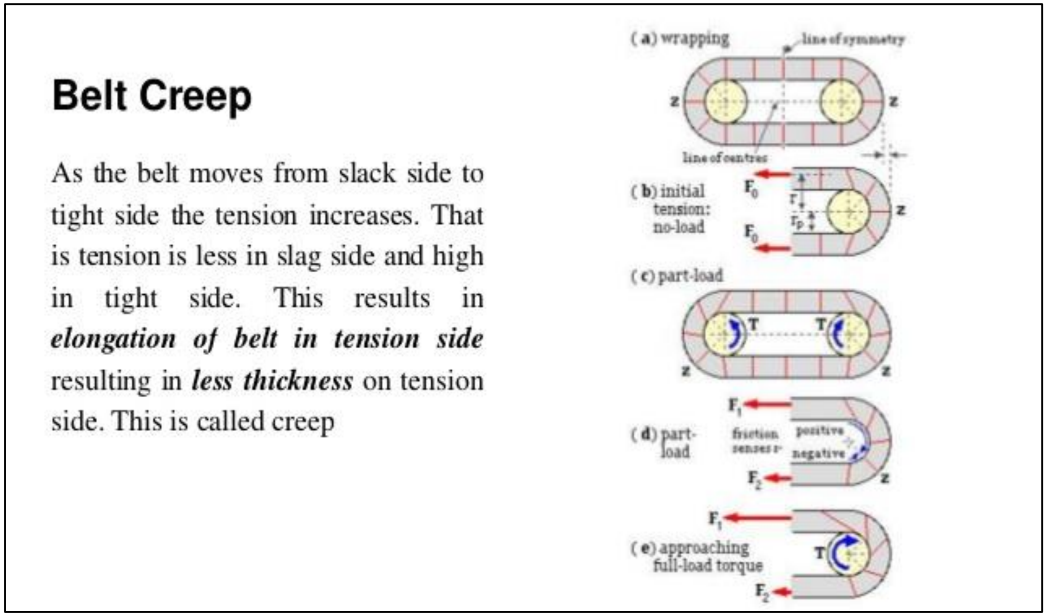
Note When thickness (t) of the belt is considered, then, velocity ~~ratio~~ is given by

$$\frac{n_2}{n_1} = \frac{d_1 + t}{d_2 + t}$$

Creep in belt drive

- In belt drives, the driver pulls the belt from the driven and hence receives more length of the belt [The belts gets stretched as it comes out of the driven pulley]
- The driven pulley receives less length of the belt as it comes out from the driving pulley and hence there is a contraction in the belt.
- The belt being an elastic material stretches out more compared to contraction and hence the increase in the length of the belt results in a relative motion of the belt on the pulley surface.
- This relative motion is called creep in the belt.
- Effects of creep in belt drive: Increases with load, reduces the speed of the driven pulley, which in turn results in loss of power transmitted.





Belt Creep

As the belt moves from slack side to tight side the tension increases. That is tension is less in slag side and high in tight side. This results in ***elongation of belt in tension side*** resulting in ***less thickness*** on tension side. This is called creep

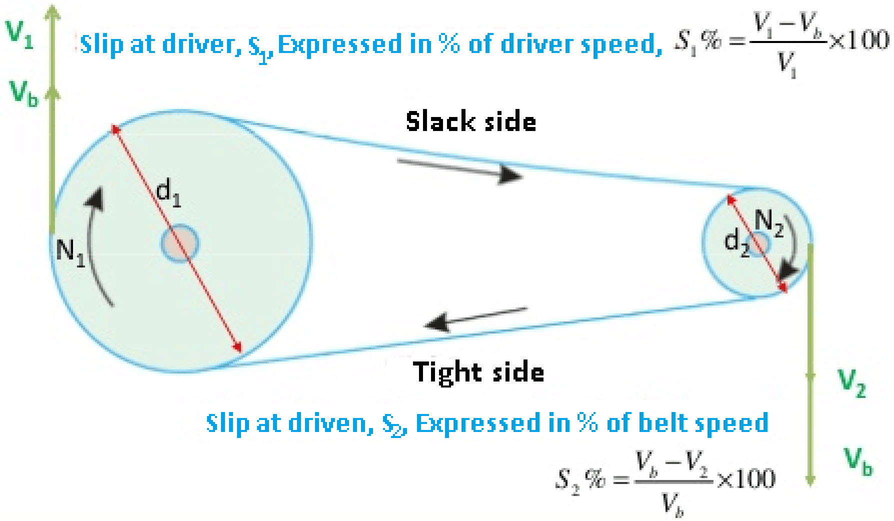
Slip in belt drive

- The power transmitted from one shaft to the other depends on the frictional grip between the belt and the pulley rim.
- There is always some amount of slip between the belt and the pulley rim that results in a slight reduction in the velocity ration of the belt drive.
- Definition: Relative motion between the pulley and the belt passing over it.
- Expressed as a percentage.

velocity ratio (when slip is considered) $\frac{n_2}{n_1} = \frac{d_1}{d_2}\left(\frac{100-S}{100}\right)$

where S = % slip.

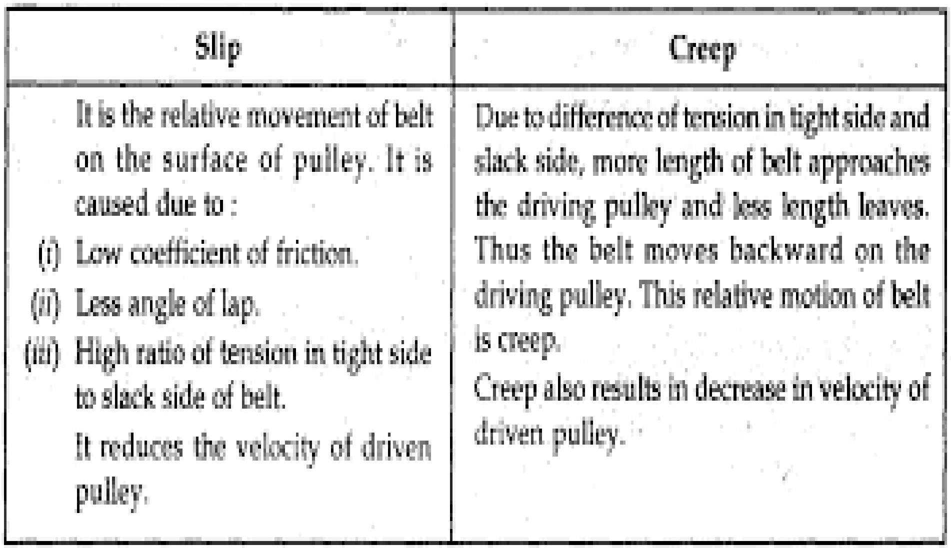
When thickness of belt is considered, velocity ratio $\frac{n_2}{n_1} = \frac{d_1+t}{d_2+t}\left(\frac{100-S}{100}\right)$



Slip at driver, S_1, Expressed in % of driver speed, $S_1\% = \frac{V_1 - V_b}{V_1} \times 100$

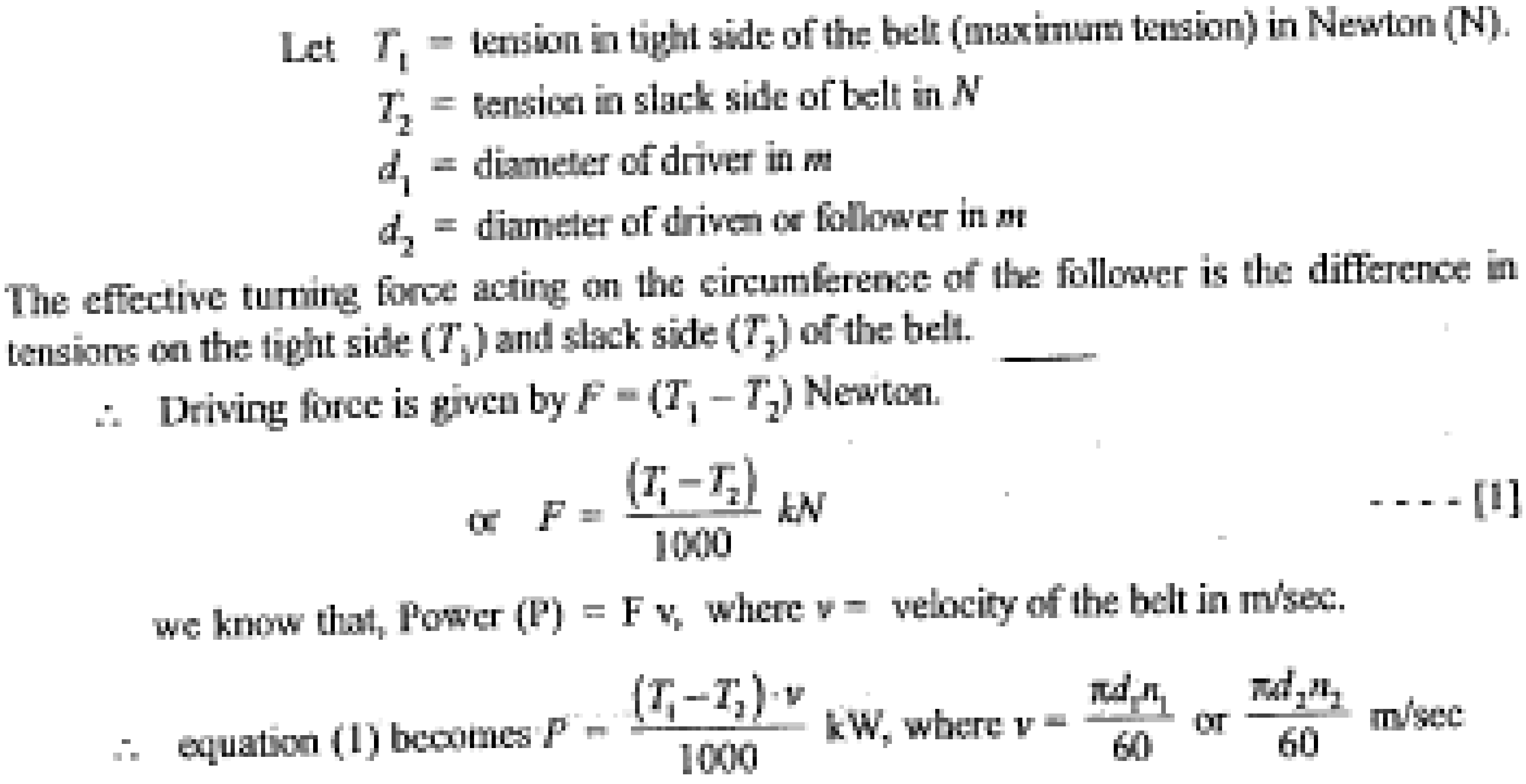
Slip at driven, S_2, Expressed in % of belt speed

$S_2\% = \frac{V_b - V_2}{V_b} \times 100$



Slip	Creep
It is the relative movement of belt on the surface of pulley. It is caused due to : (i) Low coefficient of friction. (ii) Less angle of lap. (iii) High ratio of tension in tight side to slack side of belt. It reduces the velocity of driven pulley.	Due to difference of tension in tight side and slack side, more length of belt approaches the driving pulley and less length leaves. Thus the belt moves backward on the driving pulley. This relative motion of belt is creep. Creep also results in decrease in velocity of driven pulley.

Power transmitted in a belt drive



Let T_1 = tension in tight side of the belt (maximum tension) in Newton (N).

T_2 = tension in slack side of belt in N

d_1 = diameter of driver in m

d_2 = diameter of driven or follower in m

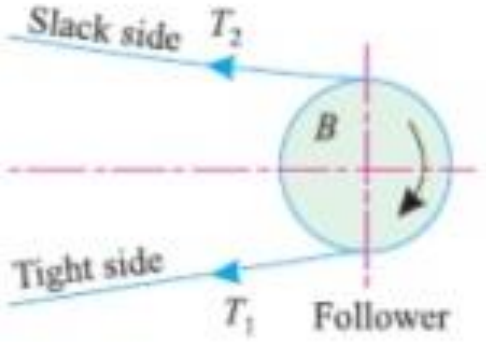
The effective turning force acting on the circumference of the follower is the difference in tensions on the tight side (T_1) and slack side (T_2) of the belt.

$\therefore$ Driving force is given by $F = (T_1 - T_2)$ Newton.

$$\text{or} \quad F = \frac{(T_1 - T_2)}{1000} \; kN \qquad \text{- - - - [1]}$$

we know that, Power (P) = F v, where v = velocity of the belt in m/sec.

$$\therefore \text{ equation (1) becomes } P = \frac{(T_1 - T_2)\cdot v}{1000} \text{ kW, where } v = \frac{\pi d_1 n_1}{60} \text{ or } \frac{\pi d_2 n_2}{60} \text{ m/sec}$$



Ratio of belt tensions for flat belt drive

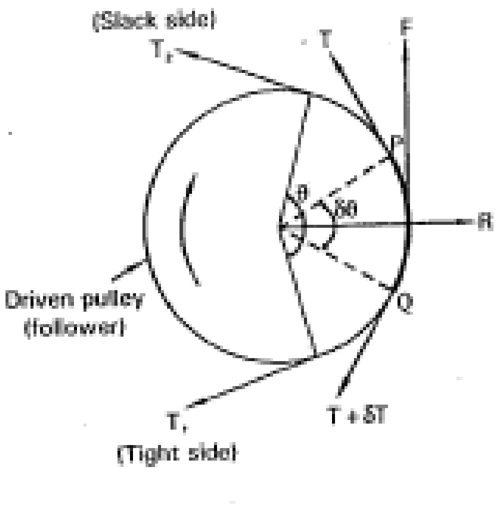
- Consider a flat belt wound around a driven pulley as shown in figure.
- Let the driven pulley rotate in clockwise direction.
- Let T_1= tension on tight side of the belt, T_2 = tension on slack side of the belt, θ = arc of contact between the belt and pulley.
- Consider a small element PQ of the belt. Let δθ be the angle subtended by the element PQ. The element PQ is in equilibrium under the action of the following forces

  i. Slack side tension (T) acting at P

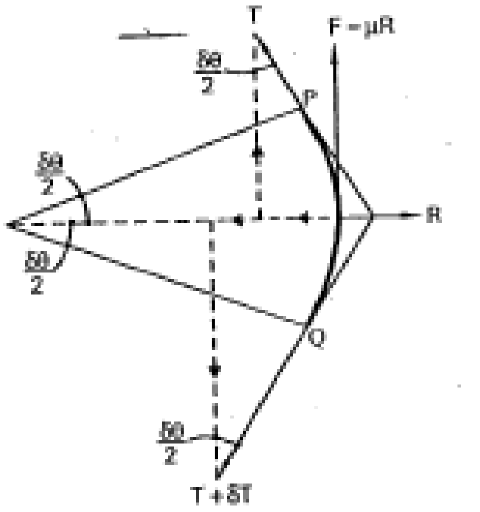
  ii. Tight side tension (T+δT) at Q

  iii. Normal reaction (R) exerted by the pulley on the belt element PQ

  iv. Frictional force (F=μR) acting perpendicular to the normal reaction (R)



(a) Flat belt wound around driven pulley



(b) Forces acting on belt element PQ

I. Resolving all forces horizontally

$$T\sin\frac{\delta\theta}{2}+(T+\delta T)\sin\frac{\delta\theta}{2}=R$$

$$T\sin\frac{\delta\theta}{2}+T\sin\frac{\delta\theta}{2}+\delta T\sin\frac{\delta\theta}{2}=R$$

Since the angle $\frac{\delta\theta}{2}$ is very small, $\sin\frac{\delta\theta}{2}=\frac{\delta\theta}{2}$

∴ equation (1) becomes, $T\frac{\delta\theta}{2}+T\frac{\delta\theta}{2}+\delta T\frac{\delta\theta}{2}=R$

$$R=2T\frac{\delta\theta}{2}+\delta T\frac{\delta\theta}{2}$$

Neglecting $\delta T\cdot\frac{\delta\theta}{2}$ for small angles, we get $R=T\delta\theta$

II. Resolving all forces vertically

$$T\cos\frac{\delta\theta}{2}+\mu R=(T+\delta T)\cos\frac{\delta\theta}{2}$$

$$T\cos\frac{\delta\theta}{2}+\mu R=T\cos\frac{\delta\theta}{2}+\delta T\cos\frac{\delta\theta}{2}$$

$$\mu R=\delta T\cos\frac{\delta\theta}{2}$$

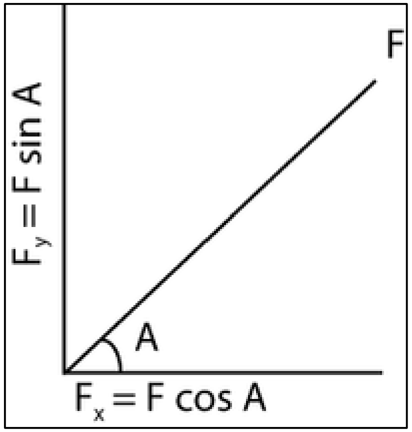
since $\frac{\delta\theta}{2}$ is small, $\cos\frac{\delta\theta}{2}=1$

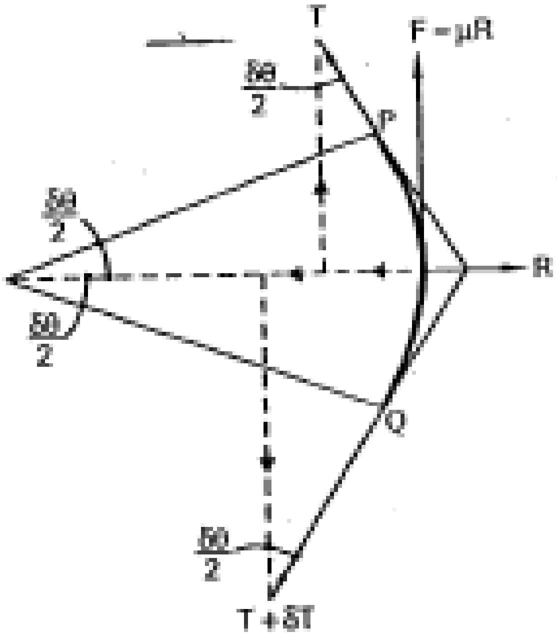
$$\mu R=\delta T\quad\text{or}\quad R=\frac{\delta T}{\mu}$$

$$T\delta\theta=\frac{\delta T}{\mu}\quad\text{or}\quad\frac{\delta T}{T}=\mu\delta\theta$$

Integrating between limits T_2 and T_1 and from 0 to θ respectively, we have, $\int_{T_2}^{T_1}\frac{\delta T}{T}=\int_0^{\theta}\mu\delta\theta$

$$\log_e\left(\frac{T_1}{T_2}\right)=\mu\theta\quad\text{or}\quad\frac{T_1}{T_2}=e^{\mu\theta}$$





Angle of contact for flat belt drive

a) Open belt drive

- When power is transmitted between two pulleys of different diameters, then the angle of contact at the smaller pulley must be taken into consideration.
- The belt will slip first on the pulley having smaller angle of contact i.e., on the smaller pulley.

$$\theta = \left(180 - 2\sin^{-1}\frac{(r_1 - r_2)}{C}\right)\frac{\pi}{180} \text{ radians.}$$

where r_1 = radius of larger pulley.
r_2 = radius of smaller pulley
C = center distance between two pulleys.

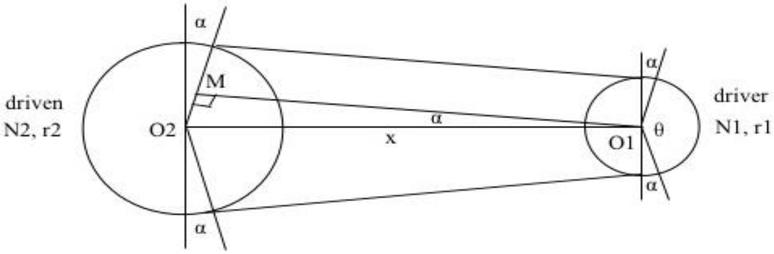
b) Cross belt drive

- When two pulleys of different diameters are connected by means of a cross-belt drive, the angle of contact on both the pulley will be same.

$$\theta = \left(180 + 2\sin^{-1}\frac{(r_1 + r_2)}{C}\right)\frac{\pi}{180} \text{ radians}$$

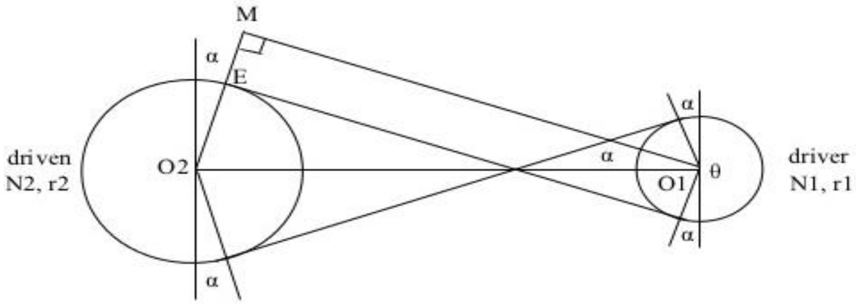
where r_1 = radius of larger pulley, r_2 = radius of smaller pulley
C = center distance between two pulleys.

For open drive:



Note: always measure angle of contact from smaller pulley

For cross drive:



Initial tension in belt drive

- When the belt is wound around the two pulleys, the two ends of the belt are joined together tightly and are fixed over the pulleys so as to maintain a tight grip between the belt and the pulley rim.
- Thus even when the pulleys are stationary, the belt is subjected to some tension and this tension is called initial belt tension.
- Denoted by T_0

$$T_0 = \frac{T_1 + T_2}{2}$$

where T_0 = Initial belt tension, T_1 = Tight side tension, and T_2 = Slack side tension

Advantages and disadvantages of flat belt drive

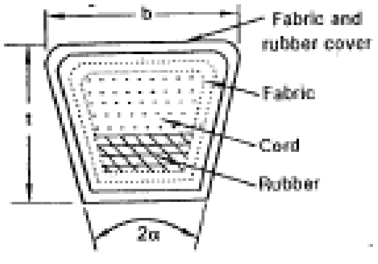
Sl. No.	Advantages	Disadvantages
1.	Used when the center distance between the two shafts is large	Not efficient when center distance between the two shafts is small
2.	Speed can be varied by varying the diameter of the pulley	Due to slip in belt drives, exact velocity ratio cannot be maintained
3.	Simple in construction and operation	Moderate power transmission
4.	Low operating costs	Due to slip, driven pulley rotate at a lower speed
5.	Smoothness of operation and ability to absorb shocks.	Used for transmitting power only between parallel shaft

V-Belt drives

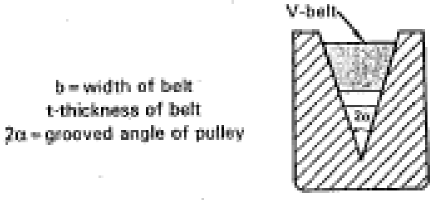
- V-belts are used to transmit power between two shafts when the center distance between the shafts is relatively small.
- Usually endless and trapezoidal in cross section.
- The included angle for the belt is usually 30°-40°.
- The belts are made from fabric and cords moulded in rubber and covered with fabric and rubber.
- In case of flat belt drive, the belt runs over the pulley whereas in V-belt drive, the rim of the pulley is grooved so as to accommodate the V-belt.
- The effect of the groove is to increase the grip of the V-belt on the pulley, thereby reducing chances of slipping.
- For a V- belt drive, ratio of tensions is given by : $\frac{T_1}{T_2} = e^{\frac{\mu\theta}{\sin\alpha}}$, where α = semi-groove angle

Advantages: transmits more power, negligible slip, can transmit power for short center distance, high velocity ratio can be obtained, smooth operation, shaft axis may be horizontal/vertical/inclined, no joint trouble.

Disadvantages: Not suitable for large center distance, construction of belt and pulley are complicated.



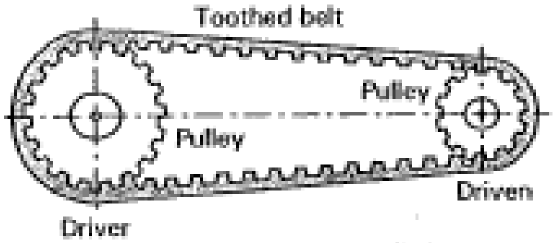
(a) Cross-section of v-belt



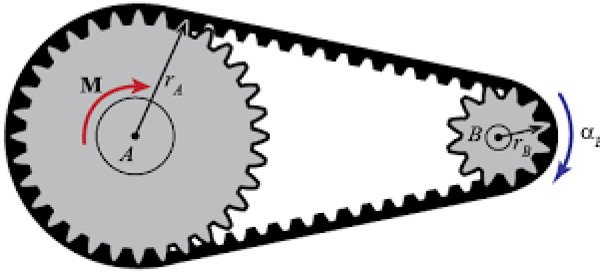
(b) Cross-section of v-grooved pulley

Timing or toothed belt drives

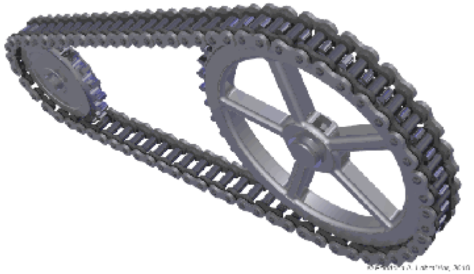
- It consists of a flexible belt having a flat outer surface and evenly spaced teeth moulded on its inner surface designed to run over matching toothed pulleys or sprockets.
- The toothed pulley looks like a spur gear, but the tooth profile is not involute.
- The belt being jointless is used made form rubberized fabric reinforce with steel wires to take the load during operation.
- When correctly tensioned between the pulleys, this type of belt has no slippage [used to transfer motion for indexing or timing purpose]
- Applications: automobile or motorcycle engines to coordinate the rotational motion of the engine crankshaft with cam shaft, sewing machines, photocopiers, treadmills etc.



Advantages: compact and synchronous transmission, no slippage, high torque carrying capacity[gripping power], power transmission at constant speed, no creep effect in belt, low noise and vibration, no lubrication required, less weight of belt and pulley.



Disadvantages: Complex design of belt and pulley, high cost, requires accurate alignment of the belt with the pulleys for efficient operation.



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Module – 4.3.1

Belt drives-Numericals

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Problem 1 In a belt drive, the velocity ratio is 3. The driving pulley runs at 400 rpm. The diameter of the driven pulley is 300 mm. Find the speed of the driven pulley and the diameter of the driving pulley.

Jan 06 - 06 m

Given:

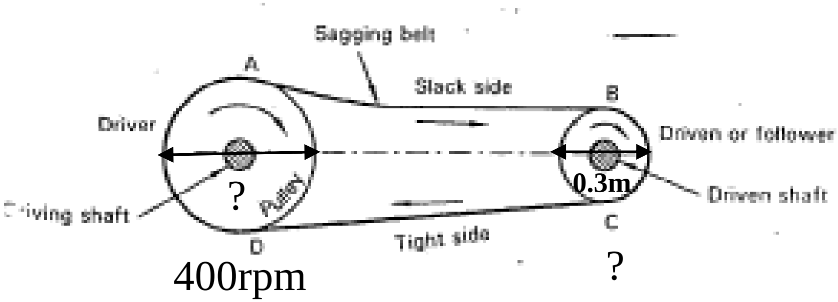
$$\text{velocity ratio} = \frac{n_2}{n_1} = 3$$

Driving	**Driven**
$n_1 = 400$ rpm $d_1 = ?$	$n_2 = ?$ $d_2 = 300$ mm $= 0.3$ m

Speed of driven $n_2 = ?$

$$\text{From data, } \frac{n_2}{n_1} = 3$$

$$\frac{n_2}{400} = 3 \qquad \therefore \boldsymbol{n_2 = 1200 \text{ rpm}}$$



Diameter of driving pulley $d_1 = ?$

$$\text{w.k.t. velocity ratio} = \frac{n_2}{n_1} = \frac{d_1}{d_2}$$

$$\therefore d_1 = \frac{n_2 d_2}{n_1} = \frac{1200 \times 0.3}{400} = 0.9 \text{ m} \qquad \boldsymbol{d_1 = 0.9 \text{ m or } 900 \text{ mm}}$$

Problem 2 It is required to drive a shaft A at 600 rpm by a belt using a pulley of 150 mm diameter on another parallel shaft B running at 240 rpm. What would be the diameter of the pulley on the shaft A. Find also the velocity ratio. ***Jan 2008 - 08 m***

Given:

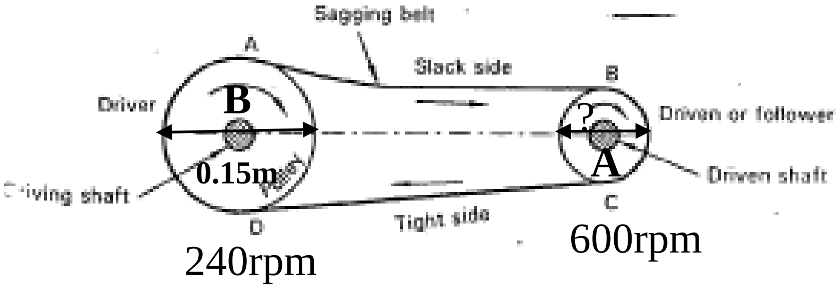
Shaft B (driver)	Shaft A (driven)
$n_B = 240$ rpm $d_B = 150$ mm $= 0.15$m	$n_A = 600$ rpm $d_A = ?$

Diameter of pulley on shaft A = d_A = ?

k.t. velocity ratio= $\frac{n_A}{n_B} = \frac{d_B}{d_A}$

$$\therefore d_A = \frac{n_B \cdot d_B}{n_A} = \frac{240 \times 0.15}{600}$$

$$\boldsymbol{d_A = 0.06 \text{ m or } 60 \text{ mm}}$$



Velocity ratio = ?

w.k.t. velocity.ratio $= \frac{n_A}{n_B} = \frac{600}{240} = \frac{5}{2}$

velocity ratio $= \frac{n_A}{n_B} = 5:2$

Problem 3 Two pulleys are connected by a cross belt, the velocity ratio of the drive being 3. The driver runs at 1000 rpm and has a diameter of 120 cm. Find the speed and diameter of the driven pulley.

July 05 - 06 m

Given: Drive - cross belt type, velocity ratio = $\frac{n_2}{n_1} = 3$

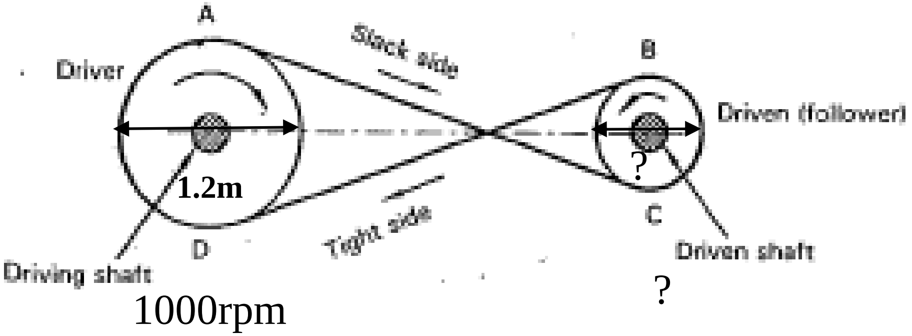
Driver	**Driven**
$n_1 = 1000$ rpm	$n_2 = ?$
$d_1 = 120$ cm $= 1.2$ m	$d_1 = ?$

To find $d_2 = ?$

w.k.t. velocity ratio $\frac{n_2}{n_1} = \frac{d_1}{d_2}$

$$3 = \frac{1.2}{d_2}$$

$$\mathbf{d_2 = 0.4\ m = 400\ mm}$$



$n_2 = ?$

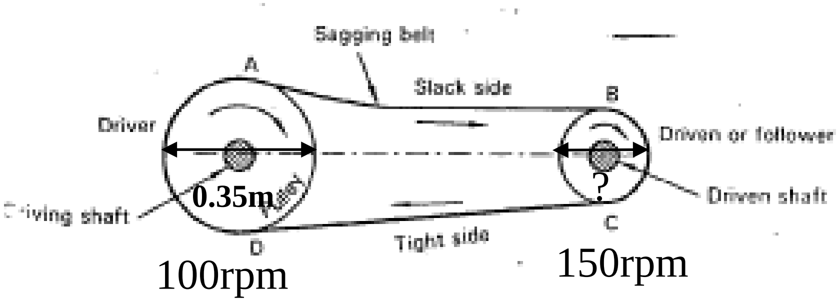
w.k.t. $\frac{n_2}{n_1} = 3$

$$\frac{n_2}{1000} = 3 \qquad \therefore n_2 = 3000 \text{ rpm}$$

Problem 4 A shaft running at 100 rpm is to drive a parallel shaft at 150 rpm. The pulley on the driving shaft is 35 cm in diameter. Find the diameter of the driven pulley. Calculate the linear velocity of the belt and also the velocity ratio. ***Jan 10 - 06 m***

Given:

Driver	Driven
$n_1 = 100$ rpm $d_1 = 35$ cm $= 0.35$ m	$n_2 = 150$ rpm $d_2 = ?$



$d_2 = ?$

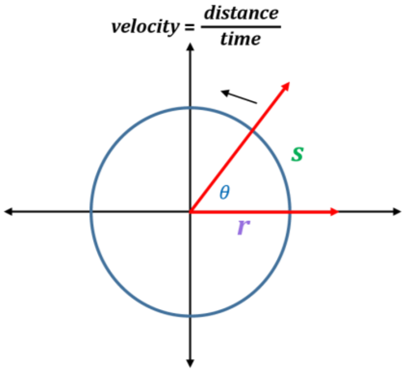
$$\text{w.k.t. velocity ratio} = \frac{n_2}{n_1} = \frac{d_1}{d_2}$$

$$\frac{150}{100} = \frac{0.35}{d_2}$$

$$\therefore\ d_2 = \frac{100 \times 0.35}{150} = 0.233 \text{ m}$$

$d_2 = 0.233$ **m or 23.3 cm**

Angular Velocity	Linear Velocity
$\omega = \frac{\theta}{t}$ ω in radians per unit time θ in radians	$v = \frac{s}{t}$ $v = \frac{r\theta}{t}$ $v = r\omega$



velocity ratio = ?

$$\text{w.k.t. velocity ratio} = \frac{n_2}{n_1} = \frac{150}{100} = \frac{3}{2}$$

$$\text{velocity ratio} = \frac{n_2}{n_1} = 3:2$$

w.k.t. Linear velocity at every point on the belt is same. Hence, $V = \pi d_1 n_1 = \pi d_2 n_2$

$$\text{Taking } V = \pi d_1 n_1 = \pi(0.35)(100) = 109.95$$

$$V = 109.95 \text{ m/min} \quad \text{or} \quad \mathbf{V = 1.83 \text{ m/sec}}$$

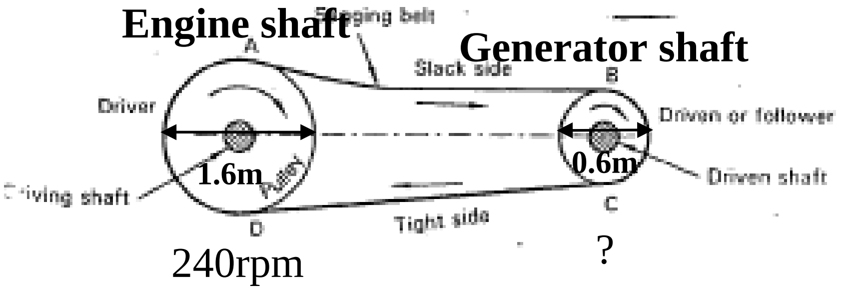
Problem 5 An engine shaft running at 240 revolutions per minute is required to drive a generator by means of a flat belt drive. Pulley on an engine shaft has 160 cm diameter & on the generator shaft 60 cm diameter. Determine the speed of the generator shaft in the following cases.

(a) Neglecting thickness of belt,
(b) When belt thickness is 6 mm
(c) Considering thickness 6 mm & a slip 3%.
(d) Velocity of belt with thickness 6 mm.

Given:

Driver (Engine shaft)	Driven (Generator)
$n_1 = 240$ rpm $d_1 = 160$ cm $= 1.6$ m	$n_2 = ?$ $d_2 = 60$ cm $= 0.6$ m

$t = 6$ mm $= 6 \times 10^{-3}$m, and slip $= S = 3\%$



a): To find n_2 by neglecting belt thickness

$$\text{w.k.t. velocity ratio} = \frac{n_2}{n_1} = \frac{d_1}{d_2}$$

$$n_2 = \frac{d_1 \cdot n_1}{d_2} = \frac{1.6 \times 240}{0.6}$$

$$\mathbf{n_2 = 640\ rpm}$$

b): To find n_2 by when belt thickness = t = 6 mm

$$\text{In this case, velocity ratio} = \frac{n_2}{n_1} = \frac{(d_1+t)}{(d_2+t)}$$

$$\therefore\ n_2 = \frac{(d_1+t) \cdot n_1}{(d_2+t)} = \frac{\left[1.6+\left(6\times10^{-3}\right)\right]\times 240}{\left[0.6+\left(6\times10^{-3}\right)\right]} \quad n_2 = 636.04\ \text{rpm}$$

c): To find n_2 when t = 6 mm and S = 3%.

$$\text{w.k.t. velocity ratio} = \frac{n_2}{n_1} = \frac{(d_1+t)}{(d_2+t)} \times \left[\frac{100-5}{100}\right]$$

$$\frac{n_2}{240} = \frac{\left[1.6+\left(6\times10^{-3}\right)\right]}{\left[0.6+\left(6\times10^{-3}\right)\right]} \times \left[\frac{100-3}{100}\right]$$

$$\mathbf{n_2 = 616.9\ rpm}$$

d): To find velocity of belt with t = 6 mm

Linear velocity of belt at any point remains same

i.e., $V = \pi d_1 n_1 = \pi d_2 n_2$

n thickness is considered, $V = \pi(d_1+t)n_1 = \pi(d_2+t)n_2$

Taking $V = \pi(d_1+t)n_1$ we have,

$V = \pi[1.6+(6\times10^{-3})]240$

$V = 1210.89$ m/min

or **V = 20.18 m/sec**

Problem 6 The sum of diameter of two pulleys is 1000 mm and the pulleys are connected by a belt. If the pulleys rotate at 600 rpm & 1800 rpm, find the diameter of each pulley. *Aug 99 - 04 m*

Given: d_1 (driver) + d_2 (driven) = 1000 mm or $d_1 + d_2 = 1\text{m}$

Note Since the speeds of driver & driven are not specifically mentioned in the given problem, one can assume speeds in 2 different combinations resulting in 2 different belt drive arrangements.

i.e., if $n_1 = 600$ rpm (driving), and $n_2 = 1800$ rpm (driven), then diameter of driving pulley (d_1) will be greater than that of driven pulley (d_2) resulting in speed reducing arrangement of belt drive (Speeds are inversely proportional to diameters according to velocity ratio).

Case 1 Assuming $n_1 = 600$ rpm & $n_2 = 1800$ rpm

$$\text{w.k.t. velocity ratio } = \frac{n_2}{n_1} = \frac{d_1}{d_2}$$

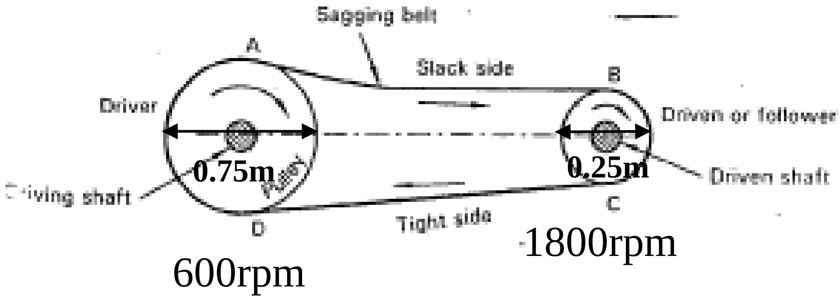
$$\frac{1800}{600} = \frac{(1-d_2)}{d_2} \qquad (\because d_1 + d_2 = 1 \text{ m})$$

$$1800\, d_2 = (1 - d_2)\, 600 \quad \text{or} \quad d_2 = 0.25 \text{ m}$$

$$\text{and, } d_1 = 1 - d_2 = 1 - 0.25 = 0.75 \quad \text{or} \quad d_1 = 0.75 \text{ m}$$

Thus when $n_1 = 600$ rpm & $n_2 = 1800$ rpm, we have,

$d_1 = 0.75$ m & $d_2 = 0.25$ m for speed increasing arrangement,



Case 2 Assuming $n_1 = 1800$ rpm & $n_2 = 600$ rpm

$$\text{w.k.t. velocity ratio } = \frac{n_2}{n_1} = \frac{d_1}{d_2}$$

$$\frac{600}{1800} = \frac{(1-d_2)}{d_2} \qquad (\because d_1 + d_2 = 1 \text{ m})$$

$$600\, d_2 = 1800 - 1800\, d_2$$

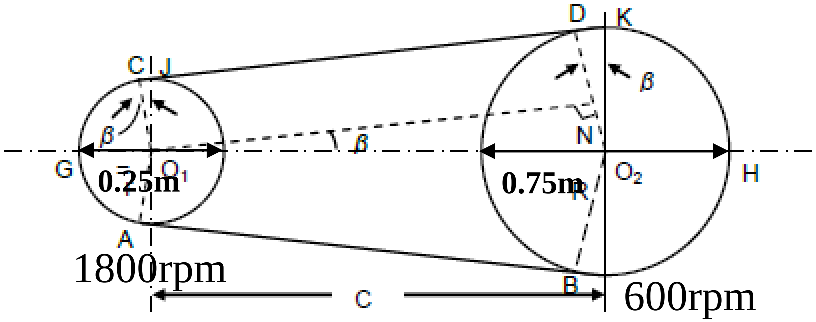
$$\therefore d_2 = 0.75 \text{ m}$$

$$\text{and, } d_1 = 1 - d_2 = 1 - 0.75 = 0.25$$

$$d_1 = 0.25 \text{ m}$$

Thus when $n_1 = 1800$ rpm & $n_2 = 600$ rpm, we have,

$d_1 = 0.25$ m & $d_2 = 0.75$ m for speed reducing arrangement.



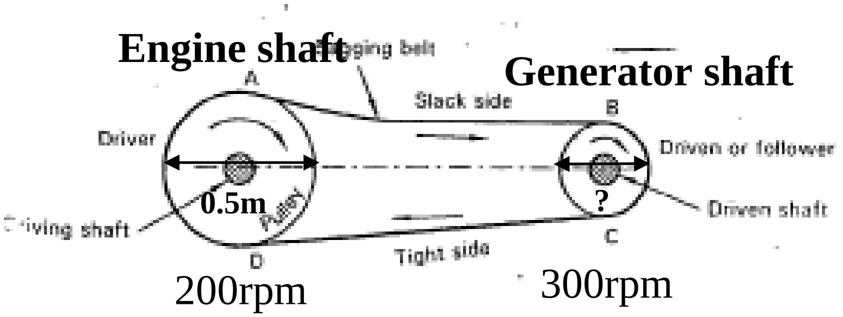
Problem 7 An engine shaft running at 200 rpm is required to drive a generator at 300 rpm by means of a flat belt drive. Pulley on the driving shaft has 500 mm diameter. Determine the diameter of the pulley on the generator shaft if the belt thickness is 8 mm & slip is 4 percent.

March 1999 - 10 m

Given:

Driver	Driven
$n_1 = 200$ rpm	$n_2 = 300$ rpm
$d_1 = 500$ mm $= 0.5$ m	$d_2 = ?$

Belt thickness $= t = 8$ mm $= 8\times10^{-3}$m, and slip $= S = 4\%$



To find d_2 when t = 8×10^{-3}m and S = 4%

$$\text{w.k.t. velocity ratio} = \frac{n_2}{n_1} = \frac{(d_1+t)}{(d_2+t)} \times \left[\frac{100-S}{100}\right]$$

$$\frac{300}{200} = \frac{\left[0.5+\left(8\times10^{-3}\right)\right]}{\left[d_2+\left(8\times10^{-3}\right)\right]} \times \left[\frac{100-4}{100}\right]$$

$$d_2 + (8\times10^{-3}) = 0.325$$

$$d_2 = 0.317 \text{ m} \qquad \text{or} \quad \mathbf{d_2 = 317\ mm}$$

Problem 8 In a cross belt drive the difference in tension between tight and slack sides is 1200 N. If the angle of contact is 160° and the co-efficient of friction is 0.28, find the tension between slack and tight sides.

Jan 04 - 06 m

$$\text{Radians} = \left(\frac{\pi}{180^0}\right) \times \text{degrees}$$

$$\text{Degrees} = \left(\frac{180^0}{\pi}\right) \times \text{radians}$$

Given:

Tight side (T_1) – Slack side (T_2) = 1200 N

angle of contact $= \theta = 160^\circ = \frac{160 \times \pi}{180} = 2.792$ radians $(180^\circ = \pi \text{ radians})$

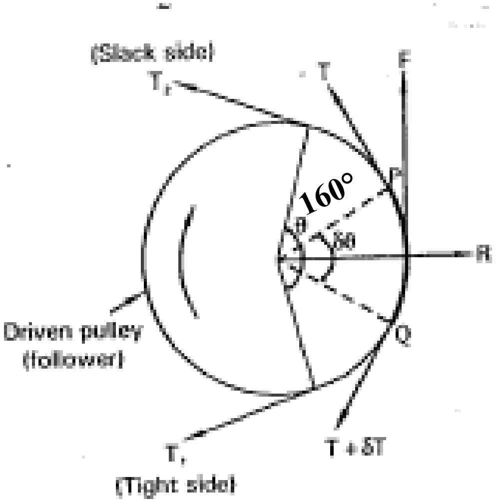
co-officient of friction $= \mu = 0.28$

To find T_1 & T_2

w.k.t. $$\frac{T_1}{T_2} = e^{\mu\theta}$$

$$\frac{T_1}{T_2} = e^{(0.28 \times 2.792)}$$

$$T_1 = 2.185\, T_2$$



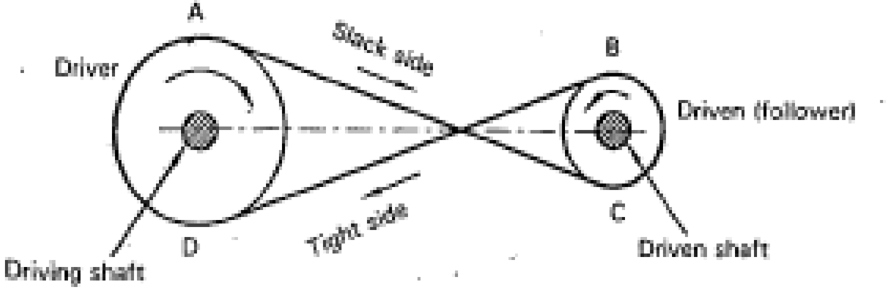
$2.185T_2$

we have $1200 + T_2 = 2.185\, T_2$

$T_2 = 1012.65$ **N slack side tension**

$T_1 = 1200 + 1012.65 = 2212.65$ N

$T_1 =$ **2212.65N tight side tension**



Problem 9 In a belt drive, the angle of lap on a driven pulley is 160° and the coefficient of friction is 0.3. If the maximum tension in the belt is 10000 N, find the initial tension in the belt drive.

Given:

$$\text{angle of lap} = \theta = 160^\circ = \frac{160 \times \pi}{180} = 2.792 \text{ radians}$$

$$\mu = 0.3, \text{ Maximum tension} = T_1 = 10000 \text{ N}$$

To find initial tension (T_0)

$$\text{w.k.t. } T_0 = \frac{T_1 + T_2}{2} \text{ N}$$

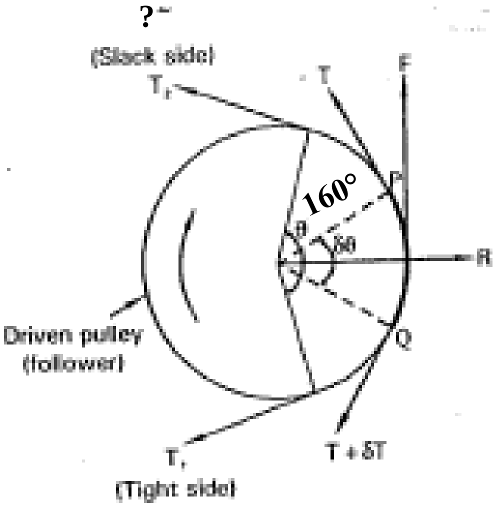
$$\text{but } T_2 = ?$$

$$\text{Using } \frac{T_1}{T_2} = e^{\mu\theta}, \quad \text{we have } \frac{10000}{T_2} = e^{(0.3 \times 2.792)}$$

$$T_2 = 4327.47 \text{ N}$$

$$\therefore T_0 = \frac{10000 + 4327.47}{2} = 7163.73 \text{ N}$$

$$\therefore \textbf{Initial tension} = T_0 = 7163.73 \text{ N}$$



10000N

Problem 10 In a belt drive the ratio of tensions is 2, and the slack side tension is 500 N. If the speed and diameter of the driven pulley are 200 rpm and 120 cm respectively, find the power transmitted.

Jan 03 - 06 m

Given:

$$\frac{T_1}{T_2} = 2$$

$$T_2 = 500\text{ N}$$

$$n_2 = 200\text{ rpm, and } d_2 = 120\text{ cm} = 1.2\text{ m}$$

To find power transmitted (P)

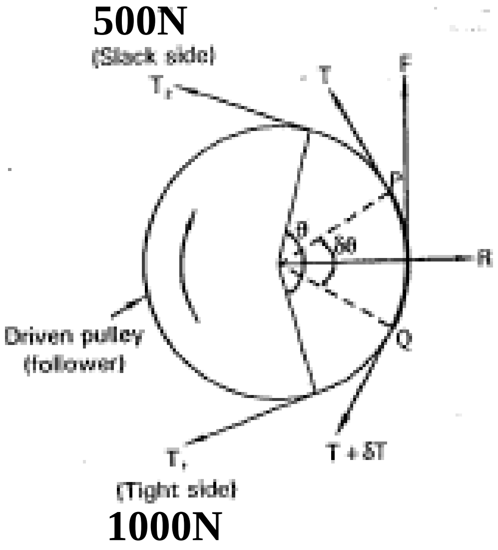
$$\text{w.k.t. Power P} = \frac{(T_1 - T_2)\cdot v}{1000}\text{ kW}$$

From equation (1) & (2), $T_1 = 1000\text{ N}$; But V = ?

$$\text{w.k.t. } V = \pi d_1 n_1 = \pi d_2 n_2 \quad \text{m/min}$$

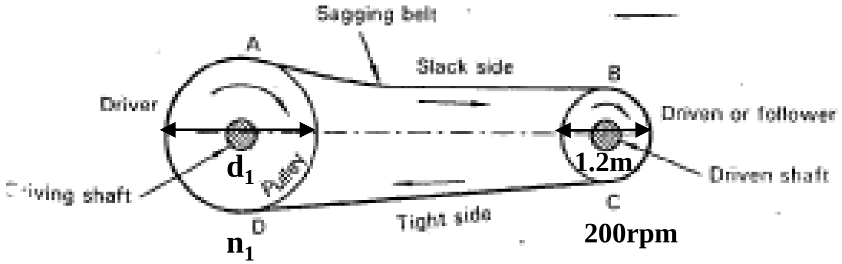
$$\text{Taking } V = \pi d_2 n_2 \quad \text{we have, } V = \pi\times1.2\times200$$

$$V = 753.98\text{ m/min,} \qquad \text{or} \quad V = 12.56\text{ m/sec}$$



$$\therefore \quad P = \frac{(1000-500)\times12.56}{1000} = 6.28$$

Power transmitted = P = 6.28 kW



Problem 11 Two pulleys of 50 cm and 25 cm diameter are to be coupled by a belt drive. If the distance between their axis is 1.5 m, find the lengths of the belt for (a) open and (b) cross drives.

Given: Assuming diameter of larger pulley $d_1 = 50\text{ cm} = 0.5\text{ m}$ ∴ radius $r_1 = 0.25\text{ m}$

$d_2 = 25\text{ cm} = 0.25\text{ m}$ ∴ radius $r_2 = 0.125\text{ m}$

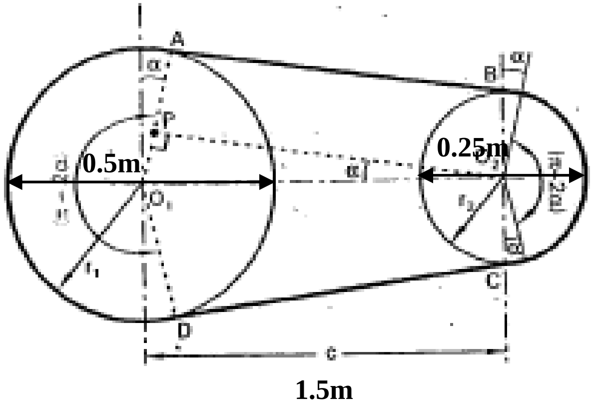
center distance $= c = 1.5\text{ m}$

To find L for open belt drive

ength of belt for open belt drive $= L = 2c + \pi(r_1+r_2) + \dfrac{(r_1-r_2)^2}{c}$

$$\therefore L = 2(1.5) + \pi(0.25+0.125) + \frac{(0.25-0.125)^2}{1.5} = 4.188$$

Length of open belt = L = 4.188 m

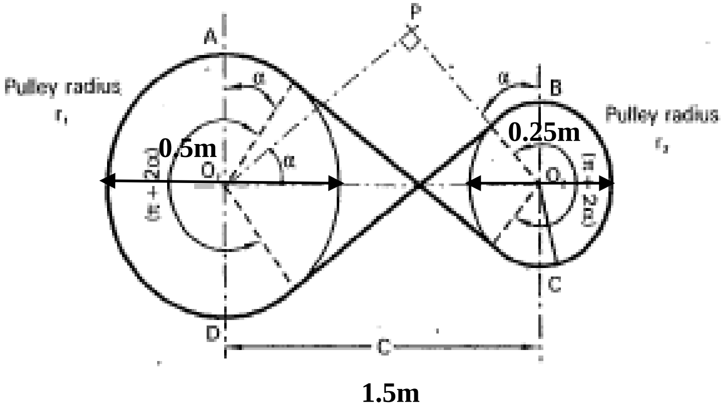


To find L for cross belt drive

length of belt for cross-belt drive $= L = 2c + \pi(r_1+r_2) + \dfrac{(r_1+r_2)^2}{c}$

$$= 2(1.5) + \pi(0.25+0.125) + \frac{(0.25+0.125)^2}{1.5} = 4.271$$

Length of cross belt = 4.271 m



Problem 12 Two parallel shafts 6m apart are provided with 300 mm & 400 mm diameter pulleys & are connected by a cross-belt. The direction of rotation of the follower pulley is to be reversed by changing over to an open belt drive. How much length of the belt should be changed.

Given:

Type of drive = cross belt type assuming larger diameter d_1= 400 mm = 0.4 m ; ∴ radius r_1 = 0.2 m

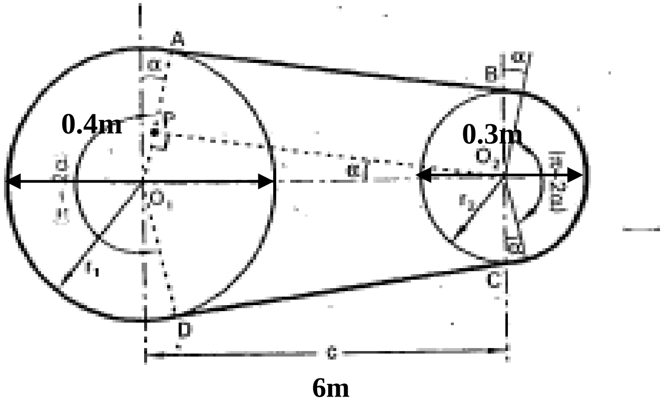
c = 6 m smaller diameter = d_2 = 300 mm = 0.3 m ∴ radius r_2 = 0.15 m

To find L for cross belt drive

w.k.t. $L = 2c + \pi(r_1+r_2) + \frac{(r_1+r_2)^2}{c}$ for cross-belt drive

$$L = 2(6) + \pi(0.2+0.15) + \frac{(0.2+0.15)^2}{6} = 13.12$$

L = 13.12 m for cross belt drive

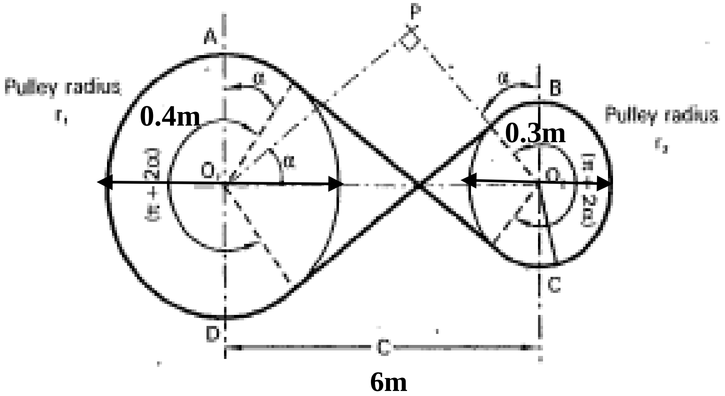


To find L for open belt drive

w.k.t. $L = 2c + \pi(r_1+r_2) + \frac{(r_1-r_2)^2}{c}$ for open-belt drive

$$L = 2(6) + \pi(0.2+0.15) + \frac{(0.2-0.15)^2}{6} = 13.1$$

L = 13.1 m for open belt drive



Change in length of belt (ΔL)

∴ change in length of belt = ΔL = 13.12 – 13.10 = 0.02 m = 20 mm

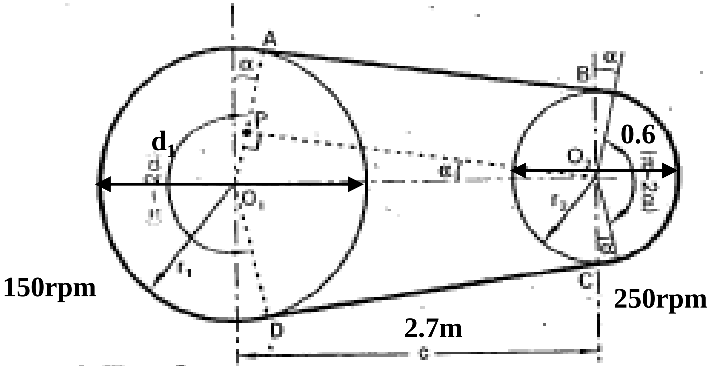
change in length of belt = ΔL = 20 mm

Problem 13 It is desired to transmit a power of 20 kW between 2 parallel shafts by means of belt drive arrangement. The driving shaft rotates at 150 rpm, while the driven shaft at 250 rpm. The distance between the centers of the two shafts is 2.7 m. and the pulley mounted on the driven shaft has 60 cm diameter. Assuming the co-efficient of friction between the belt & the pulley rim as 0.25, determine the length of the belt and belt tensions for open belt drive & cross-belt drive.

Given:

Power = P = 20 kW   c = 2.7 m $\mu = 0.25$

Driving	Driven
$n_1 = 150$ rpm $d_1 = ?$	$n_2 = 250$ rpm $d_2 = 60$ cm $= 0.6$ m



To find length of belt

$$\text{for open belt drive, } L = 2c + \pi(r_1 + r_2) + \frac{(r_1 - r_2)^2}{c}$$

$$r_2 = \frac{d_2}{2} = \frac{0.6}{2} = 0.3 \text{ m} \quad \text{But } r_1 = ?$$

$$\text{w.k.t. velocity ratio} = \frac{n_2}{n_1} = \frac{d_1}{d_2}$$

$$\therefore d_1 = \frac{n_2 \cdot d_2}{n_1} = \frac{250 \times 0.6}{150} = 1 \text{ m} \quad \text{or } r_1 = \frac{d_1}{2} = \frac{1}{2} = 0.5 \text{ m}$$

$$L = 2(2.7) + \pi(0.5 + 0.3) + \frac{(0.5 - 0.3)^2}{2.7}$$

L $\doteq$ 7.92 m for open belt drive

To find belt tensions, T_1 & $T_2 = ?$

$$\frac{T_1}{T_2} = e^{(0.25 \times 2.993)} \qquad \theta = \left[180 - 2\sin^{-1}\left(\frac{0.5 - 0.3}{2.7}\right)\right]\frac{\pi}{180} = 2.993 \text{ radians}$$

$$T_1 = 2.113\, T_2$$

$$\text{Power} = P = \frac{(T_1 - T_2)\cdot v}{1000} \text{ kW}$$

$$V = \pi d_1 n_1 = \pi d_2 n_2 \quad \text{m/min}$$

$$V = \pi d_2 n_2 = \pi \times 0.6 \times 250 = 471.23 \text{ m/min or } V = 7.85 \text{ m/sec.}$$

$$20 = \frac{(T_1 - T_2) \times 7.85}{1000}$$

$$20 = \frac{(2.113\, T_2 - T_2) \times 7.85}{1000}$$

$$1.113\, T_2 = 2547.77$$

$$\therefore \mathbf{T_2 = 2289.1 \text{ N}}$$

$$T_1 = 2.113\, T_2 = 2.113 \times 2289.1 = 4836.8 \text{ N}$$

$$\mathbf{T_1 = 4836.8 \text{ N}}$$

To find length of belt

w.k.t. for a cross belt drive, $L = 2c + \pi(r_1+r_2) + \frac{(r_1+r_2)^2}{c} = 2\,(2.7) + \pi\,(0.5+0.3) + \frac{(0.5+0.3)^2}{2.7}$

L = 8.15 m for cross belt drive.

To find belt tensions T_1 & T_2 = ?

$$\frac{T_1}{T_2} = e^{(0.25\times 3.743)} \qquad \theta = \left[180 + 2\sin^{-1}\left(\frac{0.5+0.3}{2.7}\right)\right]\frac{\cancel{\pi}}{180} = 3.743 \text{ radians}$$

$$T_1 = 2.549\,T_2$$

$$P = \frac{(T_1 - T_2)\cdot v}{1000} \text{ kW}$$

$$20 = \frac{(T_1 - T_2)\times 7.85}{1000}$$

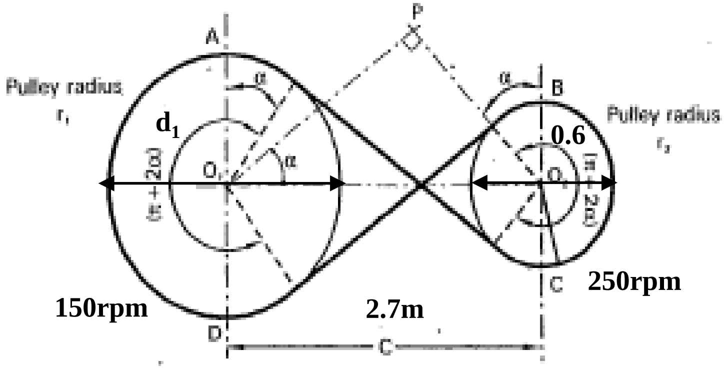
Note Velocity 7.85 m/s remains same for both open belt and cross belt drive.

$$20 = \left(\frac{2.549\ T_2 - T_2}{1000}\right)\times 7.85$$

$1.549\,T_2 = 2547.77$ or T_2 **= 1644.7 N**

and $T_1 = 2.549\,T_2 = 2.549 \times 1644.7 = 4192.3$ N

T_1 **= 4192.3 N**



Open Belt drive	Cross Belt drive
L = 7.92 m	L = 8.15 m
T_1 = 4836.8 N	T_1 = 4192.3 N
T_2 = 2289.1 N	T_2 = 1644.7 N

Problem 14 Two pulleys of diameter 300 mm and 750 mm mounted on two parallel shafts 1.5 mts apart are connected by leather belt 150 mm width. If maximum safe tension of belt is 14 N per mm width, determine maximum power transmitted in case of (i) open belt drive, and (ii) cross belt drive. Assume speed of the belt as 540 m/min & μ = 0.25 ***Jan 09 - 08 m***

Given:

Assuming larger diameter = d_1 = 750 mm = 0.75 m ∴ $r_1 = 0.375$ m

$d_2 = 300$ mm = 0.3 m ∴ $r_2 = 0.15$ m C = 1.5 m, width of belt = W = 150 mm

Maximum safe tension = $T_1 = 14$ N/mm width.

∴ For 150 mm width = $T_1 = 14 \times 150 = 2100$ N $v = 540$ m/min & μ = 0.25

Power P for open belt-drive

$$\text{k.t. Power} = P = \frac{(T_1 - T_2) \cdot v}{1000} \text{ kW} \quad \text{where } v = 540 \text{ m/min} = \frac{540}{60} = 9 \text{ m/sec}$$

$$\therefore P = \frac{(2100 - T_2) \times 9}{1000} \text{ kW}$$

but $T_2 = ?$

$$\text{w.k.t. } \frac{T_1}{T_2} = e^{\mu\theta}$$

But θ = ?

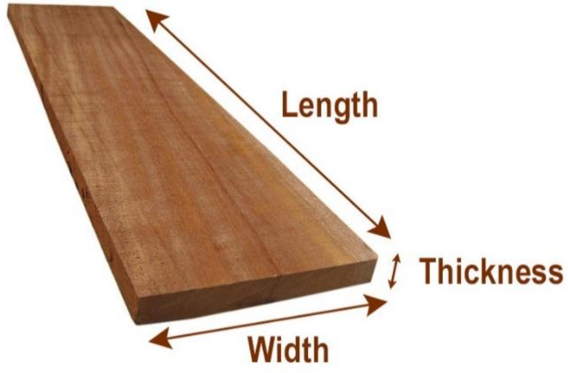
$$\text{for open belt drive, } \theta = \left[180 - 2\sin^{-1}\left(\frac{r_1 - r_2}{c}\right)\right]\frac{\pi}{180} = \left[180 - 2\sin^{-1}\left(\frac{0.375 - 0.15}{1.5}\right)\right]\frac{\pi}{180}$$

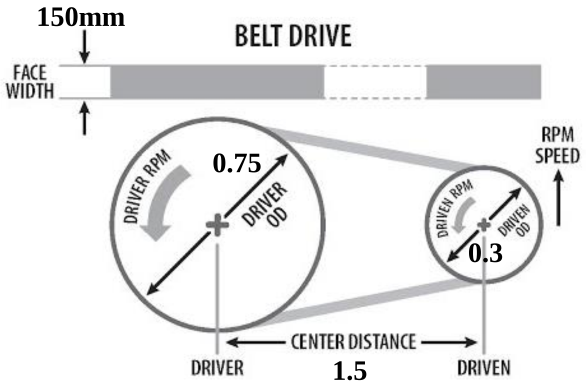
θ = 2.84 radians

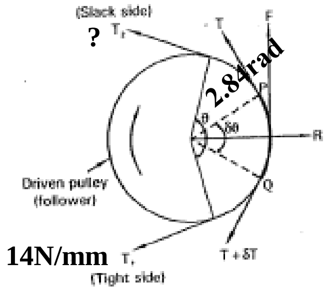
$$\frac{2100}{T_2} = e^{(0.25 \times 2.84)} \qquad \text{or} \quad T_2 = 1032.4 \text{ N}$$

$$P = \frac{(2100 - 1032.4) \times 9}{1000} = 9.6 \text{ kW}$$

P = 9.6 kW for open belt drive







Power P for cross belt drive

Arc of contact will be different for open and cross belt drive.

$$\text{w.k.t.}\quad \frac{T_1}{T_2} = e^{\mu\theta}$$

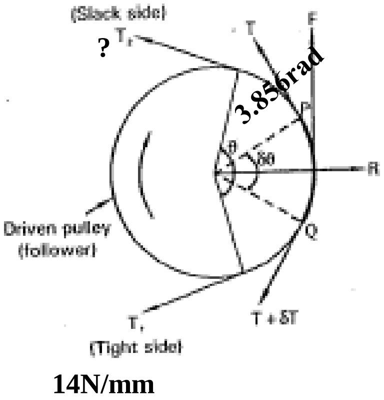
$$\text{For cross belt drive, } \theta = \left[180 + 2\sin^{-1}\left(\frac{r_1 + r_2}{c}\right)\right]\frac{\pi}{180} = \left[180 + 2\sin^{-1}\left(\frac{0.375 + 0.15}{1.5}\right)\right]\frac{\pi}{180} = 3.856$$

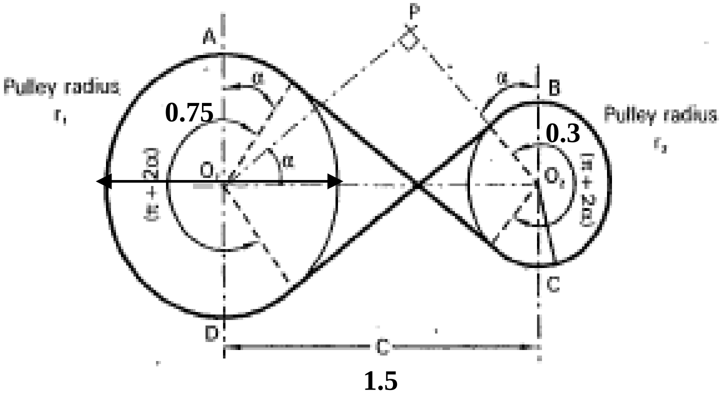
$$\theta = 3.856 \text{ radians}$$

$$\frac{2100}{T_2} = e^{(0.25\times3.856)} \qquad \text{or} \quad T_2 = 800.86 \text{ N}$$

$$P = \frac{(2100 - 800.86)\times 9}{1000} = 11.69 \text{ kW}$$

P = 11.69 kW for cross-belt drive.





Problem 15 A v-belt drive transmits 10 kW power at 200 rpm. The grooved pulley has a mean diameter of 1.2m and the groove angle is 45°. Taking the co-efficient of friction as 0.25, and the angle of lap as 190°, determine the tension on each side of the belt.

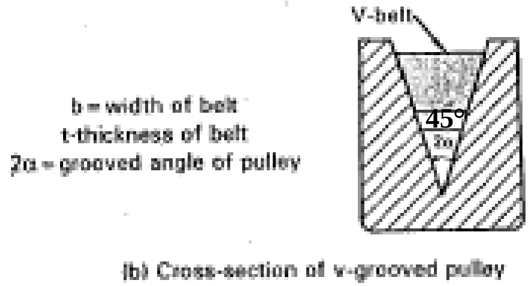
Given: Type of drive - V-belt drive, Power = P = 10 kW speed n = 200 rpm

mean diameter of pulley = d = 1.2 m ; groove angle = $2\alpha = 45^\circ$ $\therefore$ semi-groove angle = $\alpha = 22.5^\circ$

$$\mu = 0.25, \quad \theta = 190^\circ = \frac{190 \times \pi}{180} = 3.316 \text{ radians}$$

To find belt tensions T_1 & T_2

a V-belt drive, belt tensions $= \dfrac{T_1}{T_2} = e^{(\mu\theta/\sin\alpha)}$ or $\dfrac{T_1}{T_2} = e^{\left(\frac{0.25 \times 3.316}{\sin 22.5}\right)}$



(b) Cross-section of v-grooved pulley

$$\frac{T_1}{T_2} = 2.166 \quad \text{or} \quad T_1 = 8.72\ T_2$$

But $T_1 = T_2 = ?$

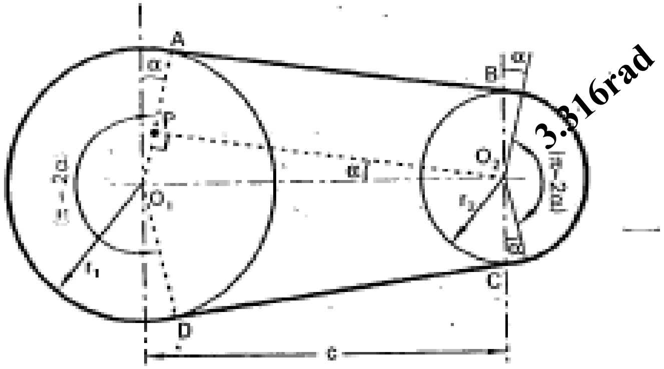
w.k.t. Power $= P = \dfrac{(T_1 - T_2) \cdot v}{1000}$ kW

$V = \pi d n$ (general equation)

$V = \pi \times 1.2 \times 200 = 753.98$ m/min or $V = 12.56$ m/sec.

$$10 = \frac{(T_1 - T_2) \times 12.56}{1000}$$

$$10 = \frac{(8.72\ T_2 - T_2) \times 12.56}{1000} \text{ from equation (1)}$$



$\mathbf{T_2} = \mathbf{103.13\ N}$

$T_1 = 8.72\ T_2 = 8.72 \times 103.13 = 899.31$

$\mathbf{T_1} = \mathbf{899.31\ N}$

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Module – 4.4

Gear drives

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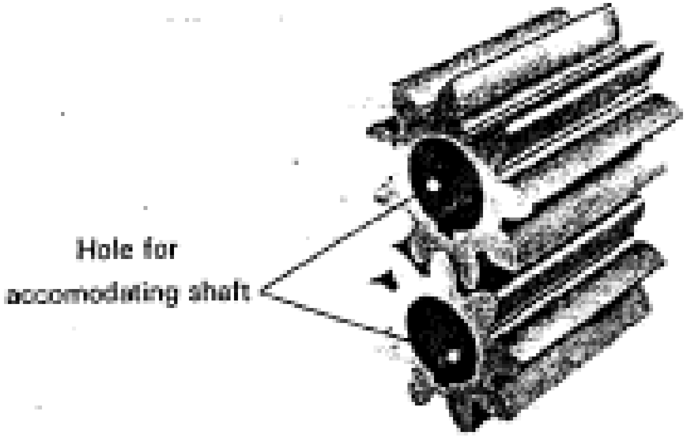
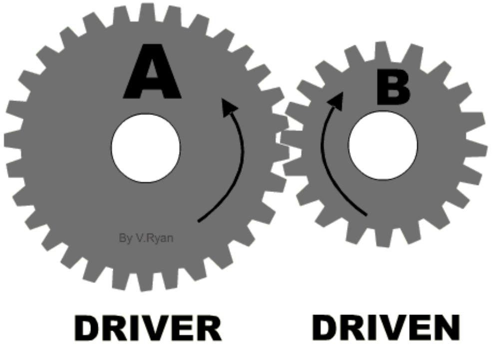
Gear drives

- Transmission of power or motion from one shaft to another by means of gears is called gear drive.
- Gears are toothed wheels mounted on shafts.



Mechanism of gear drives

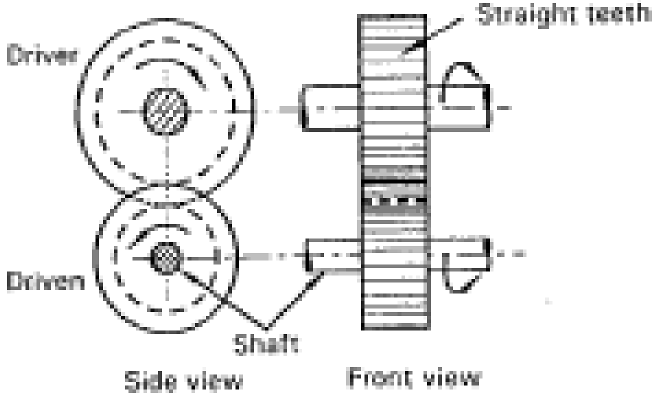
- The gear mounted on the shaft to which power source is connected is called driver gear.
- The gear which is driven by the driver gear is called driven gear.
- Apart from transmitting power from one shaft to another, gears are also used for following reasons:
  i. To reverse the direction of rotation
  ii. To increase or decrease the speed of rotation
  iii. To move rotational motion to a different axis
  iv. To keep the rotation of two axes synchronized

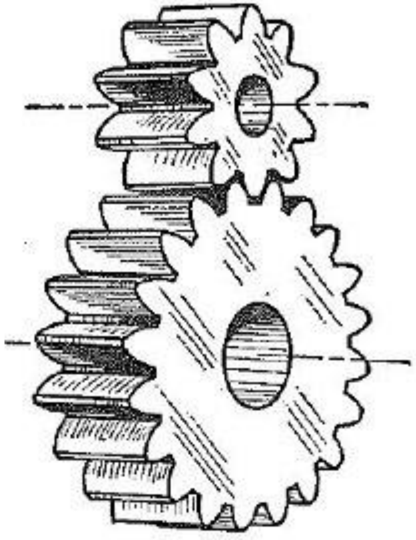


Types of gears

a) Spur gear

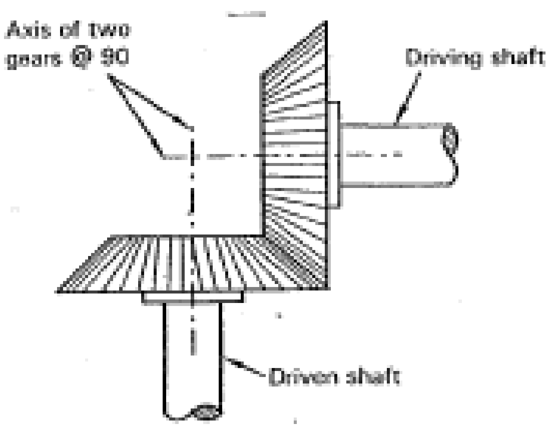
- Simplest and most commonly used gears designed to transmit motion between two parallel shafts.
- The axis of driving shaft and driven shaft are parallel to each other.
- The teeth are cut straight on the periphery of the wheel and they are parallel to the axis of wheel.
- Applications: Machine tools, gearboxes, wind-up alarm clock, watches, precision measuring instruments.
- Limitation: Not used in automobiles [vibration and noise]

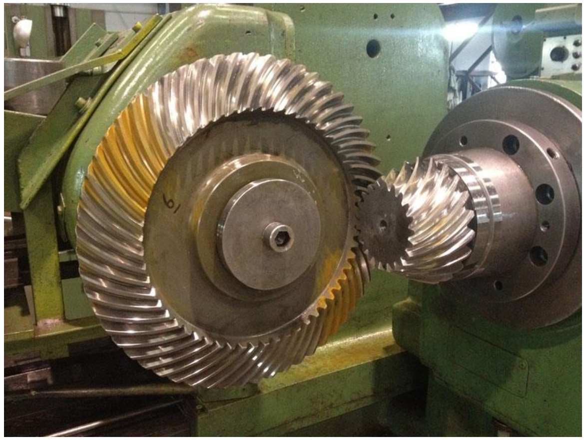




b) Bevel gear

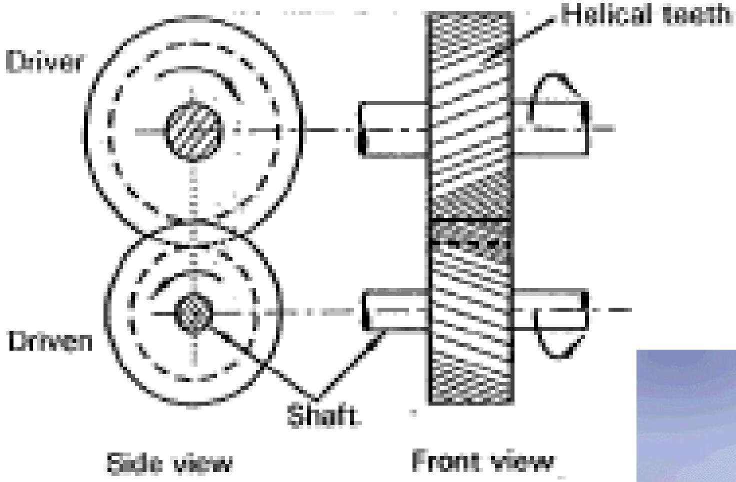
- Designed for transmitting power between two intersecting shafts.
- They are usually mounted on shafts that are 90° apart, but can be designed to work at other angles as well.
- The teeth are cut on the outside of the conical surface and vary in cross section throughout their length.
- The teeth will be thicker at the base, since the diameter of the cone is greatest at its base.
- The teeth on bevel gear can be straight, spiral or hypoid.
- Spiral bevel gear: If straight teeth is used in bevel gear, as each tooth engages, it imparts the corresponding tooth all at once. In order to overcome this, gear teeth are made slightly curved and such gears are called spiral bevel gears.

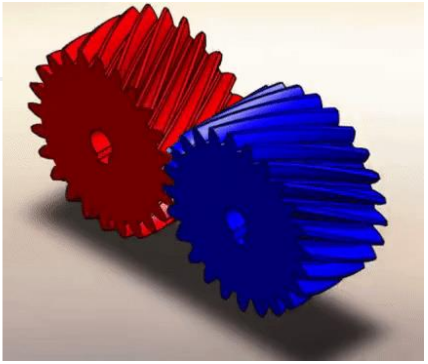


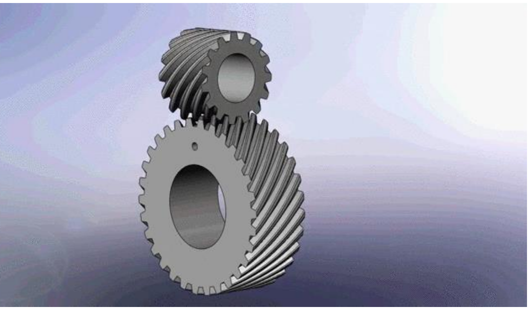


c) Helical gear

- Designed to transmit power or motion between two parallel or non parallel, non intersecting shafts.
- The teeth are curved and helical in shape.
- When two teeth on a helical gear engage, the contact starts at one end of the teeth and gradually spreads as the gears rotates until the two teeth are in full engagement.
- This gradual engagement makes helical gears run much smoothly and quietly than spur gears.
- Application: Automobile power transmission systems

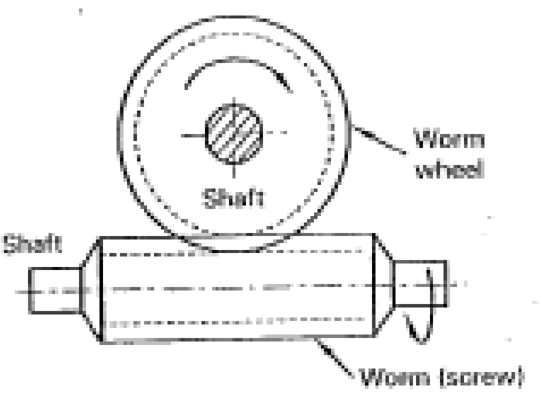


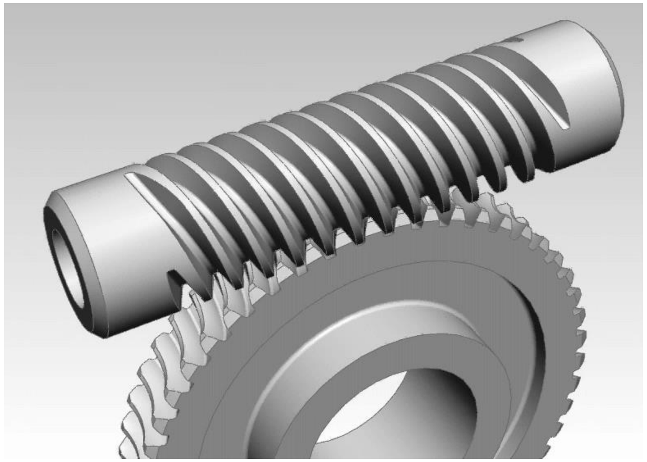




d) Worm gear

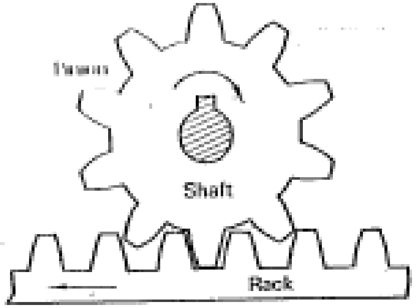
- Designed to transmit power or motion between two shafts having their axis at right angles and non intersecting.
- Type of screw gearing that consists of a screw meshing with a spur gear.
- The screw is called worm and the gear wheel meshing with the screw is called worm wheel.
- Uses: When large gear reductions are needed, steering mechanism, lifts, conveyors

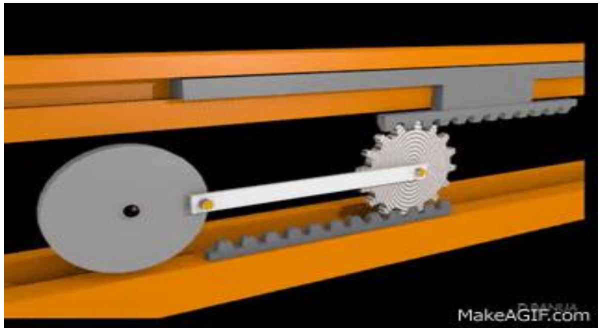


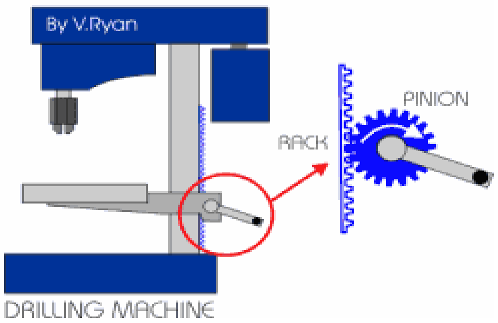


e) Rack and pinion gear

- A rack is a gear having teeth cut along a straight line, while a pinion is a gear with teeth cut along its periphery.
- With help of rack and pinion rotary motion can be converted into linear motion.





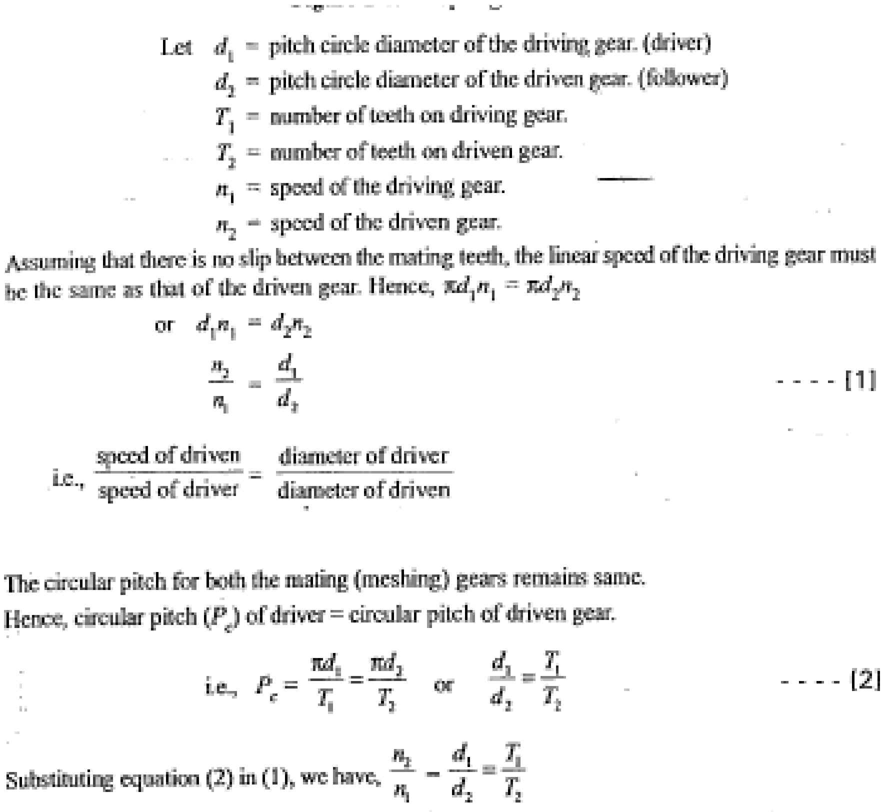


Advantages and disadvantages of gear drives

Sl. No.	Advantages	Disadvantages
1.	Can transmit power or motion between parallel, non-parallel, intersecting and non intersecting shafts	Not efficient when center distance between the two shafts is large
2.	Centre distance between two shafts is small	Requires some kind of lubrication
3.	Power can be transmitted with a constant speed ratio	Production cost of gears is high.
4.	Higher power transmission efficiency	Noise and vibration is a major problem
5.	Low, medium and high power transmission	Damage to the single teeth affects the whole arrangement

Velocity ratio of gear drives

- Ratio between the speed of the driven gear and the speed of the driving gear.
- Consider the spur gear drive arrangement as shown in figure.



Let d_1 = pitch circle diameter of the driving gear. (driver)
d_2 = pitch circle diameter of the driven gear. (follower)
T_1 = number of teeth on driving gear.
T_2 = number of teeth on driven gear.
n_1 = speed of the driving gear.
n_2 = speed of the driven gear.

Assuming that there is no slip between the mating teeth, the linear speed of the driving gear must be the same as that of the driven gear. Hence, $\pi d_1 n_1 = \pi d_2 n_2$

or $d_1 n_1 = d_2 n_2$

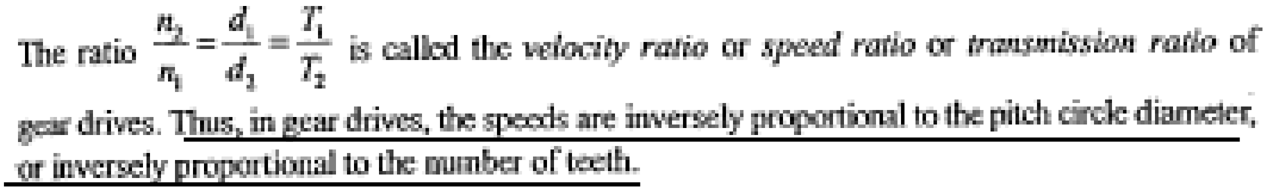
$$\frac{n_2}{n_1} = \frac{d_1}{d_2} \qquad \text{---- [1]}$$

$$\text{i.e., } \frac{\text{speed of driven}}{\text{speed of driver}} = \frac{\text{diameter of driver}}{\text{diameter of driven}}$$

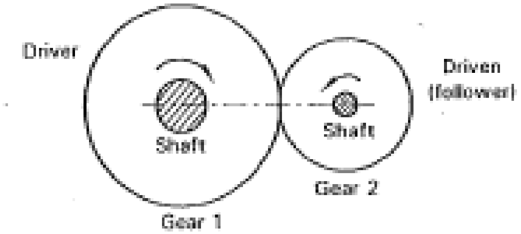
The circular pitch for both the mating (meshing) gears remains same.
Hence, circular pitch (P_c) of driver = circular pitch of driven gear.

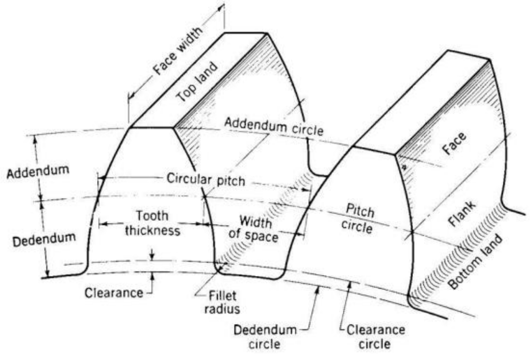
$$\text{i.e., } P_c = \frac{\pi d_1}{T_1} = \frac{\pi d_2}{T_2} \quad \text{or} \quad \frac{d_1}{d_2} = \frac{T_1}{T_2} \qquad \text{---- [2]}$$

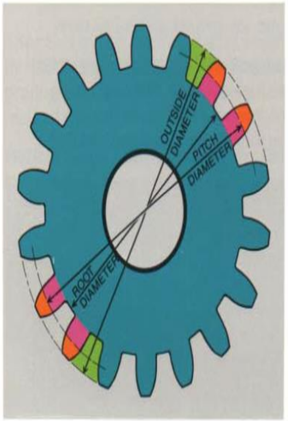
Substituting equation (2) in (1), we have, $\frac{n_2}{n_1} = \frac{d_1}{d_2} = \frac{T_1}{T_2}$

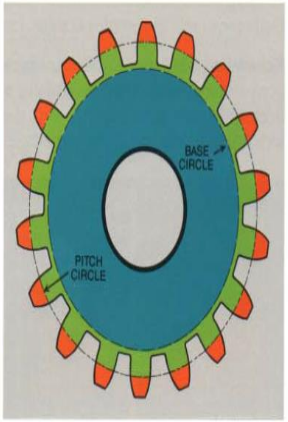


The ratio $\frac{n_2}{n_1} = \frac{d_1}{d_2} = \frac{T_1}{T_2}$ is called the *velocity ratio* or *speed ratio* or *transmission ratio* of gear drives. Thus, in gear drives, the speeds are inversely proportional to the pitch circle diameter, or inversely proportional to the number of teeth.



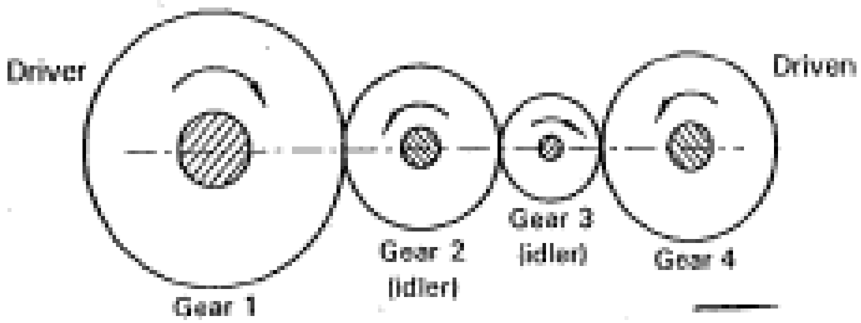


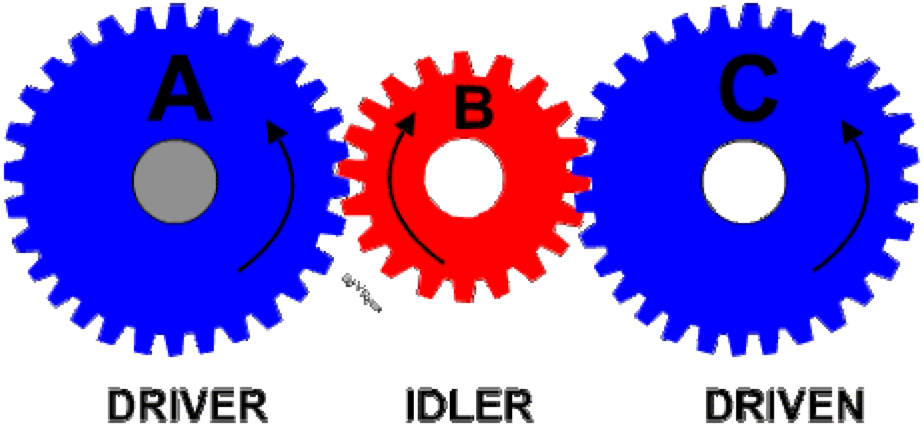


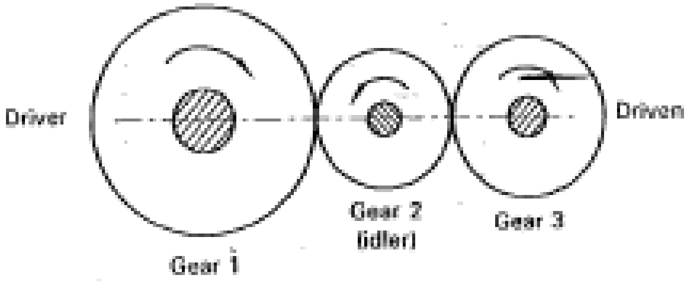


Velocity ratio for simple gear trains

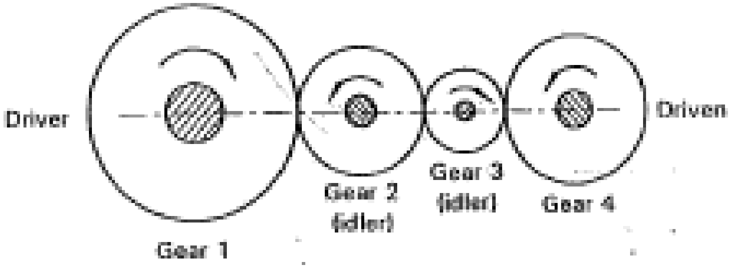
- An arrangement of gears in which each gears is mounted on its own shaft.
- Used to transmit power between the driver and driven shaft that are at large distance.
- In the figure, gear 2 and gear 3 are called intermediate or idler gears.
- The idler gears do not affect the velocity ratio of the gear drive, instead serve to fill the gap between the driver and driven shaft.
- Also helps in achieving the desired direction of rotation for the driven shaft.



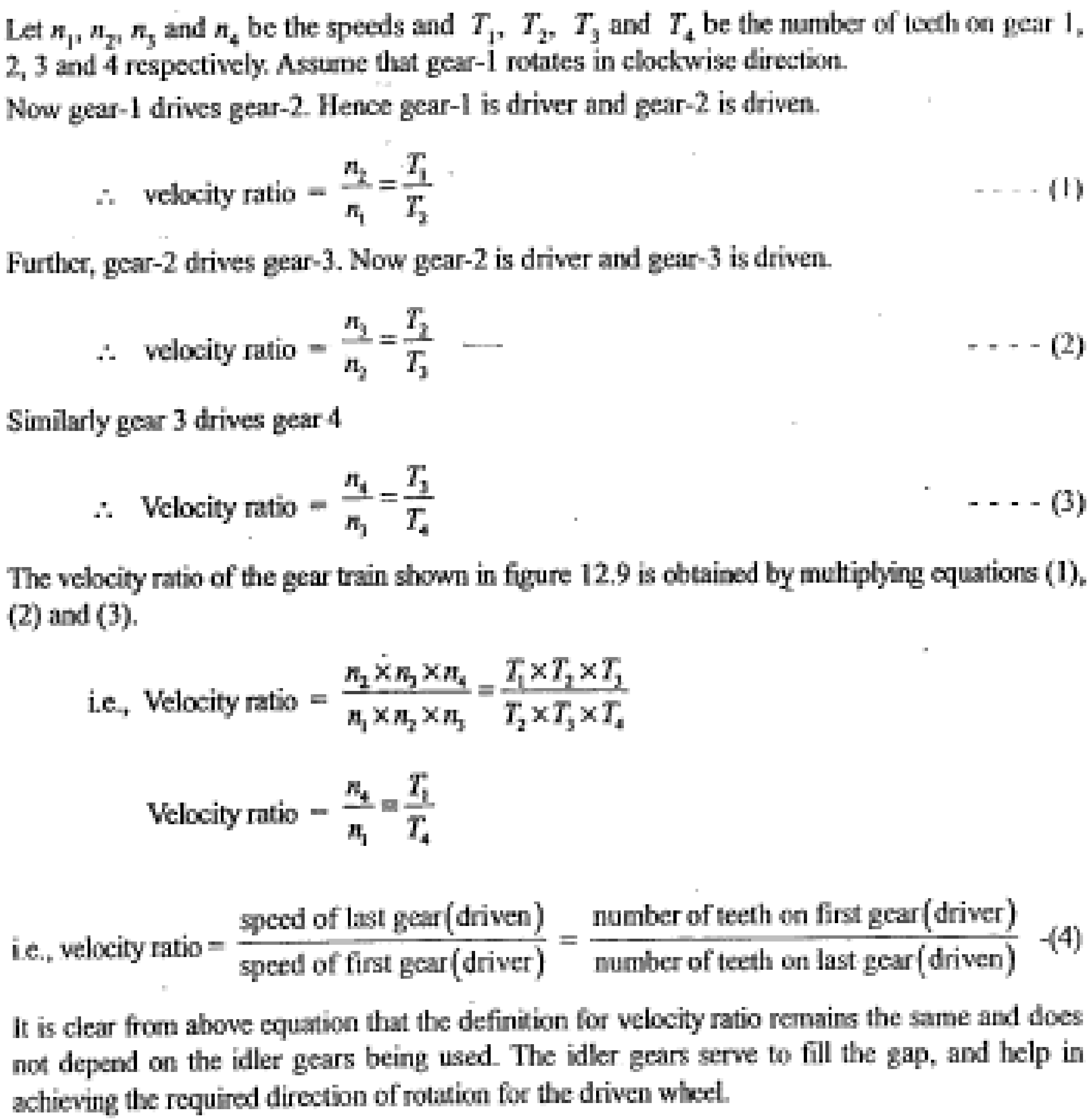




(a) Gear train with one idler



(b) Gear train with two idlers



Let n_1, n_2, n_3 and n_4 be the speeds and T_1, T_2, T_3 and T_4 be the number of teeth on gear 1, 2, 3 and 4 respectively. Assume that gear-1 rotates in clockwise direction.

Now gear-1 drives gear-2. Hence gear-1 is driver and gear-2 is driven.

$$\therefore \quad \text{velocity ratio} = \frac{n_2}{n_1} = \frac{T_1}{T_2} \qquad \text{- - - - (1)}$$

Further, gear-2 drives gear-3. Now gear-2 is driver and gear-3 is driven.

$$\therefore \quad \text{velocity ratio} = \frac{n_3}{n_2} = \frac{T_2}{T_3} \qquad \text{- - - - (2)}$$

Similarly gear 3 drives gear 4

$$\therefore \quad \text{Velocity ratio} = \frac{n_4}{n_3} = \frac{T_3}{T_4} \qquad \text{- - - - (3)}$$

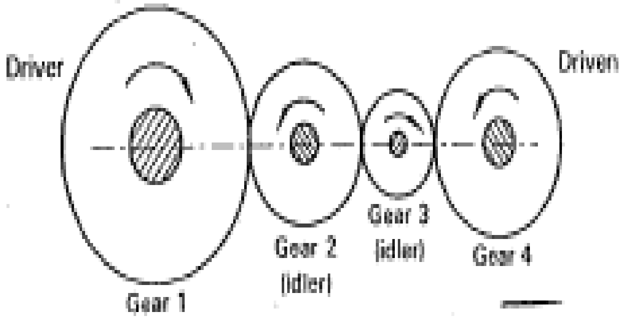
The velocity ratio of the gear train shown in figure 12.9 is obtained by multiplying equations (1), (2) and (3).

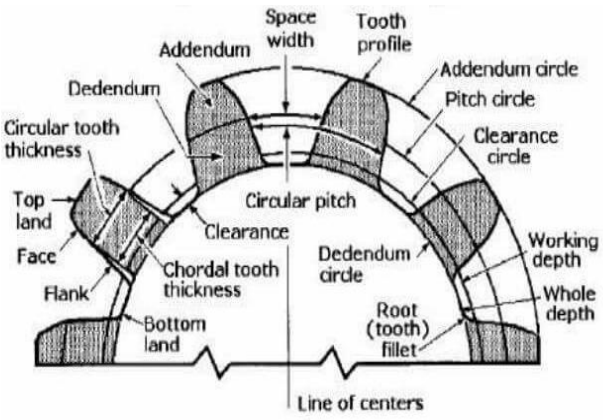
$$\text{i.e., Velocity ratio} = \frac{n_2 \times n_3 \times n_4}{n_1 \times n_2 \times n_3} = \frac{T_1 \times T_2 \times T_3}{T_2 \times T_3 \times T_4}$$

$$\text{Velocity ratio} = \frac{n_4}{n_1} = \frac{T_1}{T_4}$$

$$\text{i.e., velocity ratio} = \frac{\text{speed of last gear(driven)}}{\text{speed of first gear(driver)}} = \frac{\text{number of teeth on first gear(driver)}}{\text{number of teeth on last gear(driven)}} \quad \text{-(4)}$$

It is clear from above equation that the definition for velocity ratio remains the same and does not depend on the idler gears being used. The idler gears serve to fill the gap, and help in achieving the required direction of rotation for the driven wheel.



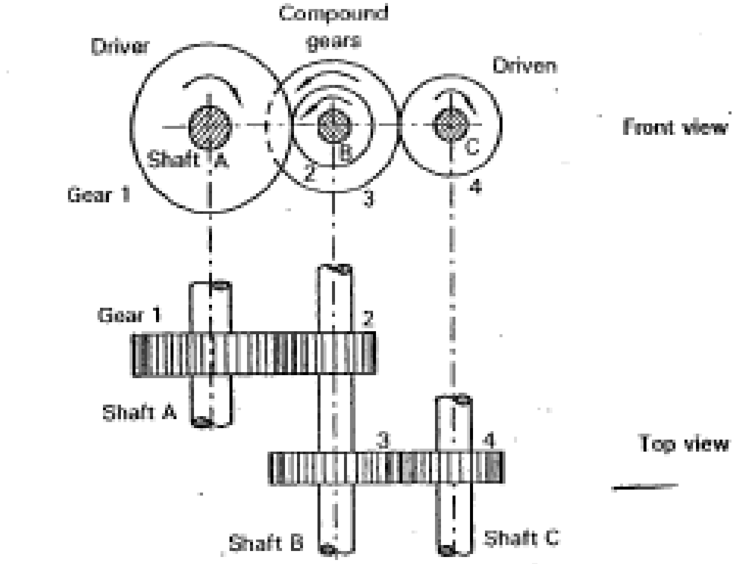


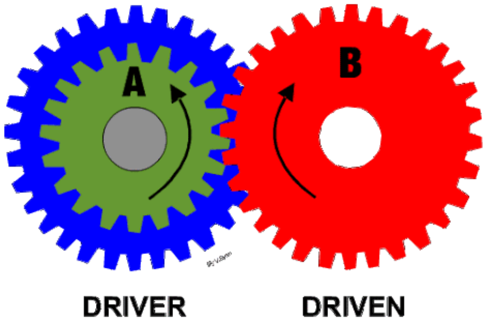
Note: If odd number of idlers are used – 1st and last gear rotates in same direction.

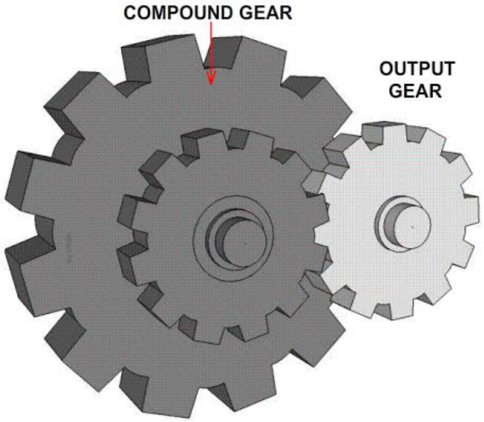
If even number of idlers are used - 1st and last gear rotates in opposite direction

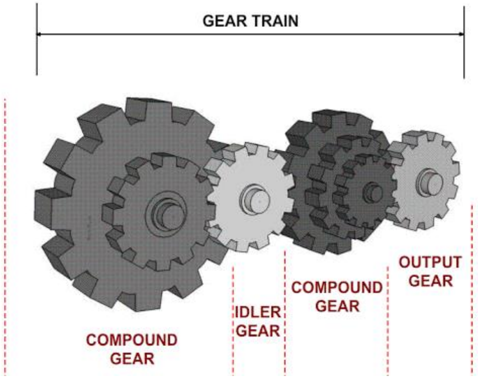
Velocity ratio for compound gear trains

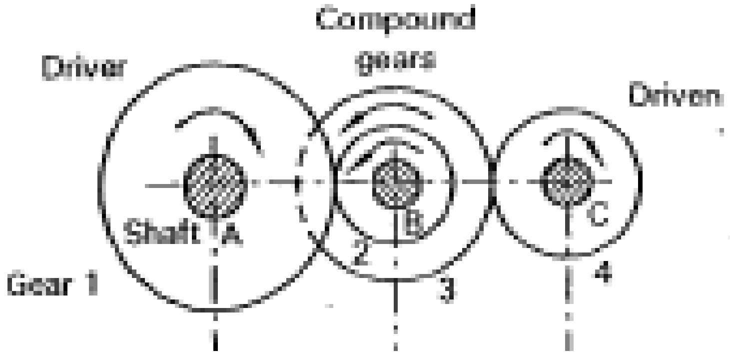
- An arrangement of gears in which two gears are mounted on a common shaft.
- Used to transmit power between the driver and driven shaft that are at large distance and higher or much lesser speed is desired.
- In the figure, gear 1 and gear 4 are mounted on separate shafts (A & C), but gear 2 and gear 3 are mounted on a single shaft B. Hence gear 2 and gear 3 are called compound gears.
- Since gear 2 and gear 3 are keyed to same spindle, they rotate at same speed.











Let n_1, n_2, n_3 and n_4 be the speeds, and T_1, T_2, T_3 and T_4 be the number of teeth on gear 1, 2, 3 and 4 respectively.

Gear-1 drives gear-2. ∴ velocity ratio $= \dfrac{n_2}{n_1} = \dfrac{T_1}{T_2}$ ---- [1]

Note that, gear-2 and gear-3 are mounted on a common shaft B. Hence when gear-2 rotates, gear-3 also rotates in the same direction and at the same speed.

Now, gear-3 drives gear-4. ∴ velocity ratio $= \dfrac{n_4}{n_3} = \dfrac{T_3}{T_4}$ ---- [2]

The velocity ratio of the gear train is obtained by multiplying equations (1) and (2).

i.e., Velocity ratio $= \dfrac{n_2 \times n_4}{n_1 \times n_3} = \dfrac{T_1 \times T_3}{T_2 \times T_4}$ ---- [3]

but $n_2 = n_3$ since gear 2 and gear 3 are keyed to the same spindle.

∴ equation (3) becomes, velocity ratio $= \dfrac{n_4}{n_1} = \dfrac{T_1 \times T_3}{T_2 \times T_4}$

i.e., velocity ratio $= \dfrac{\text{speed of last gear (driven)}}{\text{speed of first gear (driver)}} = \dfrac{\text{product of number of teeth on driver}}{\text{product of number of teeth on driven}}$

Differences between belt drives and gear drives

Sl. No.	Belt drives	Gear drives
1.	Non positive drives [reduction in power transmission due to slip]	Positive drives
2.	Efficient when the centre distance between two shaft is greater	Efficient when the centre distance between two shaft is small
3.	Used to transmit power between two parallel shafts	Parallel, non-parallel, intersecting and non intersecting shafts
4.	Due to slip, exact velocity ratio cannot be maintained	Constant velocity ratio can be maintained [absence of slip]
5.	Only moderate power can be transmitted	Low, medium and high power transmission.
6.	Low power transmission efficiency	High power transmission efficiency
7.	Lubrication is not required	Requires some kind of lubrication.

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Module – 4.4.1

Gear drives-Numericals

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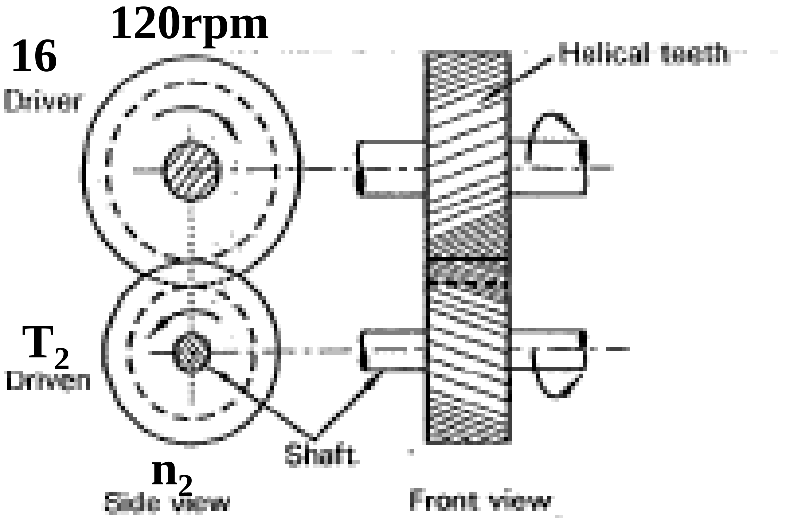
Problem 1 The velocity ratio of a gear drive is 2. Driving wheel has 16 teeth and turns at 120 r/min. Find the r/min and the number of teeth on the driven wheel. ***July 08 - 05 m***

Given:

Driver	Driven
$T_1 = 16$ $n_1 = 120$ rpm	$T_2 = ?$ $n_2 = ?$

$$\text{velocity ratio} = \frac{n_2}{n_1} = 2$$



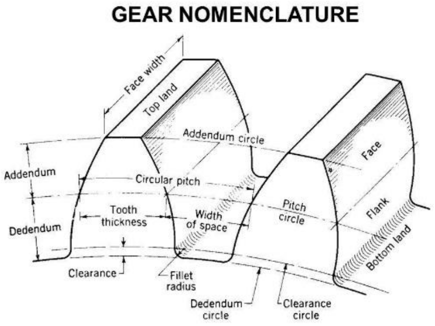
To find T_2

$$\text{velocity ratio for simple gear train} = \frac{n_2}{n_1} = \frac{T_1}{T_2}$$

$$2 = \frac{16}{T_2}, \qquad T_2 = 8 \text{ teeth}$$

To find n_2

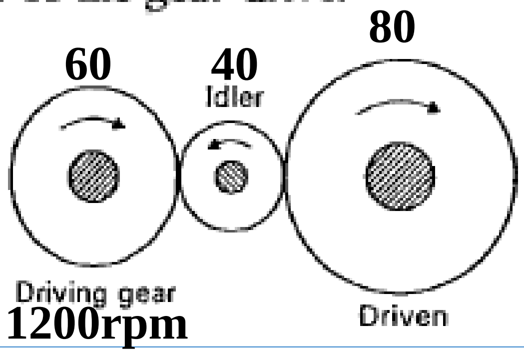
$$\text{using } \frac{n_2}{n_1} = \frac{T_1}{T_2} \text{ we have, } \frac{n_2}{120} = \frac{16}{8} \qquad \text{or} \quad n_2 = \mathbf{240\ rpm}$$



Problem 2 A simple gear train consists of 3 gears. The number of teeth on the driving gear is 60, on the idler 40, and on the driven gear 80. If the driving gear rotates at 1200 rpm, find the speed of the driven gear, and also the velocity ratio, sketch the arrangement of the gear drive.

Given:

Driving gear	Idler gear	Driven gear
$T_1 = 60$ $n_1 = 1200$ rpm	$T_2 = 40$	$T_3 = 80$ $n_3 = ?$



Note Number of teeth is proportional to diameter of gear. Hence, while sketching the drive arrangement, the diameter of the gears should be proportionate to the numerical values given.

To find n_3 & velocity ratio

Assuming driver to rotate in clockwise direction, we have, velocity ratio for simple gear train as:

$$\frac{n_3}{n_1} = \frac{T_1}{T_3}$$

$$\frac{n_3}{1200} = \frac{60}{80} \qquad n_3 = 900 \text{ rpm}$$

$$\text{velocity ratio} = \frac{n_3}{n_1} = \frac{900}{1200} = \frac{3}{4}$$

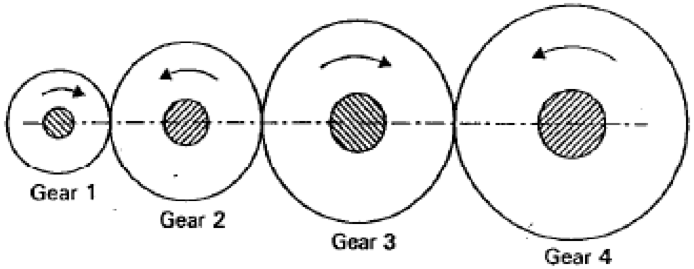
$$\textbf{velocity ratio} = \frac{n_3}{n_1} = \mathbf{3 : 4}$$

Problem 3 A simple gear train consists of four gears having 30, 40, 50 and 60 teeth respectively. Determine the speed and direction of rotation of the last gear if the first gear makes 600 rpm in clockwise direction.

MQP 2002 scheme - 06 m

Given:

Gear 1	Gear 2	Gear 3	Gear 4
$T_1 = 30$ $n_1 = 600$ rpm	$T_2 = 40$	$T_3 = 50$	$T_4 = 60$ $n_4 = ?$



$n_4 = ?$

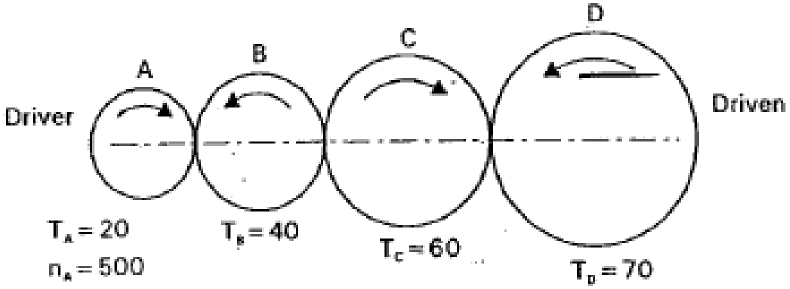
w.k.t. for a simple gear train, velocity ratio = $\frac{n_4}{n_1} = \frac{T_1}{T_4}$

$$\frac{n_4}{600} = \frac{30}{60}$$

n_4 = 300 rpm in anticlockwise direction

Problem 4 A simple gear train of wheels consists of 4 gears A, B, C and D having 20, 40, 60 and 70 teeth respectively. Gear A is mounted on the driving shaft, while gear D on the driven shaft. Gears B and C are idler gears. If gear A rotates at 500 rpm in clockwise direction, calculate: (a) Speed and direction of gear D. (b) Train value of the gear train. (c) Speed and direction of intermediate gears. Sketch the arrangement of the gear train using simple circles.

Given:



Consider gears A & B

Gear A drives gear B

w.k.t. velocity ratio: $\frac{n_B}{n_A} = \frac{T_A}{T_B}$ or $\frac{n_B}{500} = \frac{20}{40}$

$\therefore$ **speed of first idler** n_B **= 250** rpm **in anticlockwise direction**

Now Gear B drives gear C

$\therefore$ velocity ratio $= \frac{n_C}{n_B} = \frac{T_B}{T_C}$ or $\frac{n_C}{250} = \frac{40}{60}$

$\therefore$ **speed of second idler** n_C **= 166.67** rpm **in clockwise direction**

Now gear C drives gear D

$\therefore$ velocity ratio $= \frac{n_D}{n_C} = \frac{T_C}{T_D}$ or $\frac{n_D}{166.67} = \frac{60}{70}$

n_D **= 142.86** rpm **in anticlockwise direction**

Train value of gear train

w.k.t. Train value $= \frac{1}{\textit{speed (velocity) ratio}}$

speed ratio of simple gear train $= \frac{n_D}{n_A} = \frac{T_A}{T_D}$ or $\frac{n_D}{n_A} = \frac{20}{70}$

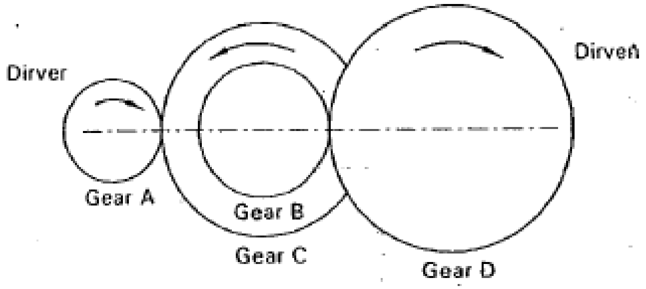
$\frac{n_D}{n_A} = \frac{1}{3.5} = 0.285 =$ Speed ratio of given drive

$\therefore$ **Train value** = Inverse of speed ratio $= \frac{1}{0.285}$ **= 3.5**

Problem 5 A gear train consists of four gears A, B, C and D of 20, 25, 50 and 75 teeth respectively. A meshes with C and B is a compound gear with C. B meshes with D. If A has a speed of 300 rpm, what is the speed of D. Sketch the gear train. ***Jan 10 - 08 m***

Given:

Gear A	Gear B	Gear C	Gear D
$T_A = 20$ $n_A = 300$ rpm	$T_B = 25$	$T_C = 50$	$T_D = 75$ $n_D = ?$



$n_D = ?$

Assume gear A to rotate in clockwise direction. Hence, Gear A drives Gear C, and Gear B drives Gear D. Gear B and Gear C are compound gears, which rotate in same direction and speed.

∴ Velocity ratio for Compound gear train =

$$= \frac{\text{Speed of last gear (driven)}}{\text{Speed of first gear (driver)}} = \frac{\text{Product of teeth on driver}}{\text{Product of teeth on driven}}$$

$$\text{i.e.,} \quad \frac{n_D}{n_A} = \frac{T_A \times T_B}{T_C \times T_D} \quad \text{or} \quad \frac{n_D}{n_A} = \frac{20 \times 25}{50 \times 75}$$

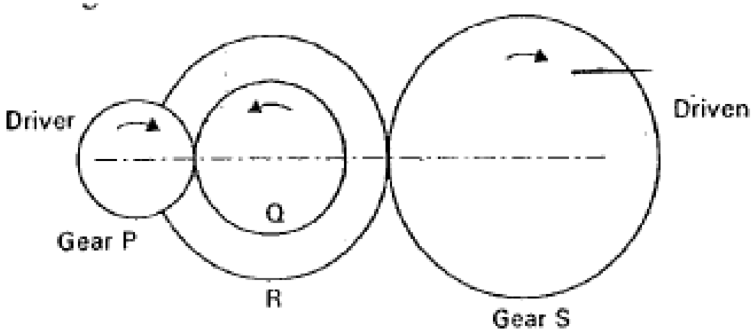
$$n_D = 40 \text{ rpm}$$

Problem 6 A compound gear train consists of 4 gears P, Q, R, S having 20, 40, 60 and 80 teeth respectively. The gear P is keyed to driving shaft; gear S to driven shaft, Q and R are compound gears, Q meshing with P and R meshes S. If P rotates at 150 rpm what is the rpm of gear S? Show gear arrangement.

Jan 04 - 06 m

Given:

Gear P (Driver)	Gear Q	Gear R	Gear S (Driven)
$T_P = 20$ $n_P = 150$ rpm	$T_Q = 40$	$T_R = 60$	$T_S = 80$ $n_S = ?$



To find $n_S = ?$

Assume Gear P to rotate in clockwise direction. Hence, Gear P drives Gear Q, and Gear R drives Gear S. Gear Q & R are compound gears.

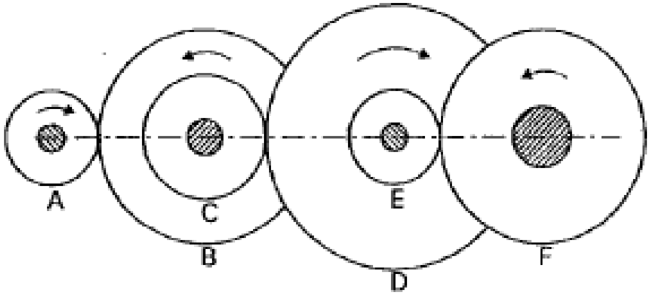
∴ Velocity ratio for Compound gear train =

$$= \frac{Speed\ of\ last\ gear\ (driven)}{Speed\ of\ first\ gear\ (driver)} = \frac{Product\ of\ teeth\ on\ driver}{Product\ of\ teeth\ on\ driven}$$

i.e., $\frac{n_S}{n_P} = \frac{T_P \times T_R}{T_Q \times T_S}$ or $\frac{n_S}{150} = \frac{20 \times 60}{40 \times 80}$ $\quad$ $n_S =$ **56.25 rpm**

Problem 7 Illustrated in figure below is the gear drive arrangement used in a machine tool. A motor drives gear A at 950 rpm. Gears B, C, D and E are fixed to parallel shafts rotating together. The number of teeth on each gear is given below. Determine the speed of gear F which is mounted on the output shaft of the machine tool.

Gear	A	B	C	D	E	F
No. of Teeth	20	50	25	75	25	65



Assume Gear A as driver & Gear F as driven. Hence, Gear A drives Gear B, Gear C drives Gear D, Gear E drives Gear F.

$$n_A = 950 \text{ rpm}$$

$$\therefore \text{ Velocity ratio } = \frac{\textit{Speed of last gear (driven)}}{\textit{Speed of first gear (driver)}} = \frac{\textit{Product of teeth on driver}}{\textit{Product of teeth on driven}}$$

$$\text{i.e., } \frac{n_F}{n_A} = \frac{T_A \times T_C \times T_E}{T_B \times T_D \times T_F} \quad \text{or} \quad \frac{n_F}{950} = \frac{20\times 25\times 25}{50\times 75\times 65}$$

$$\therefore \; n_F = \mathbf{48.7 \text{ rpm}}$$

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Module – 5.1

Lathe and Milling Machine

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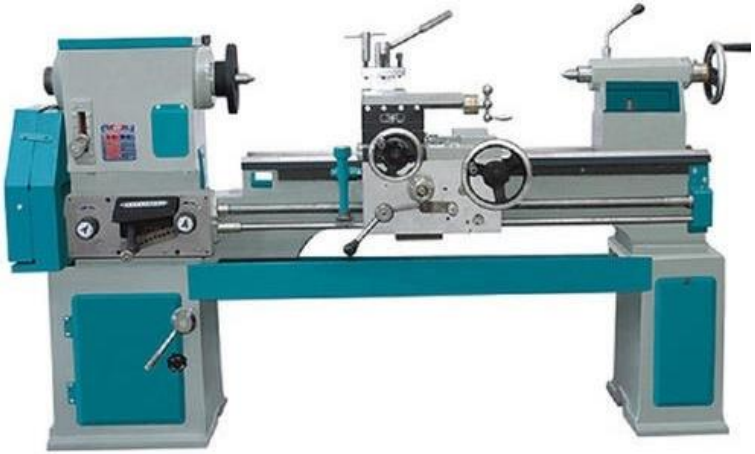
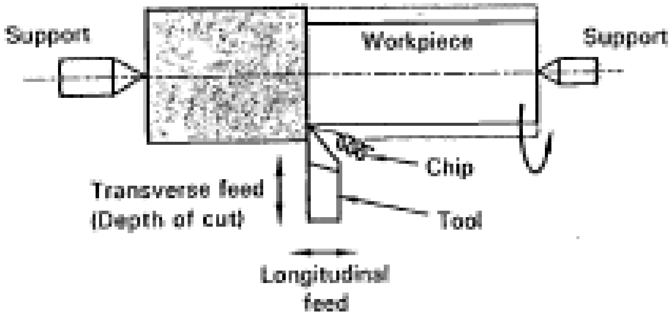
Lathe

- Oldest of all machine tools and most basic tool used in industries.
- A lathe is used to remove excess material by forcing a cutting tool against a rotating cylindrical work piece.
- Used to produce cylindrical, plain and tapered surfaces.
- It can perform several operations such as knurling, thread cutting, drilling, boring reaming etc.
- Lathes are also called as turning machines [work piece is turned or rotated between two centres].

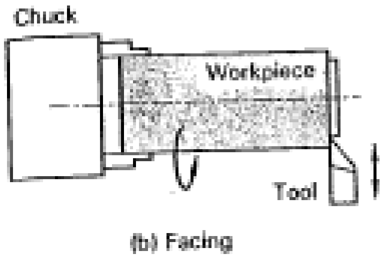


Working principle of center lathe

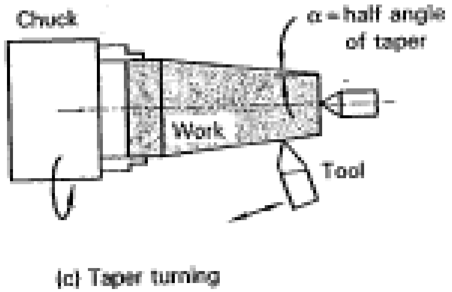
- Lathe works on the principle that when a cutting tool is moved against a rotating workpiece, tool removes material from the workpiece.
- This is accomplished by rotating the workpiece between two rigid and strong supports, while the cutting tool is fed against it.
- Basically three types of surface can be produced depending on the movement of the cutting tool with respect to the rotating workpiece.
  1. Cylindrical surface – when the tool moves parallel to the axis of rotation of the workpiece, a cylindrical surface can be produced [cylindrical/plain turning]
  2. Flat surface – When the tool moves perpendicular to the axis of rotation of the workpiece, a flat surface can be produced [Facing]
  3. Tapered surface – When the tool moves at an angle to the axis of rotation of the workpiece, a tapered surface can be produced [Taper turning]



Plain turning

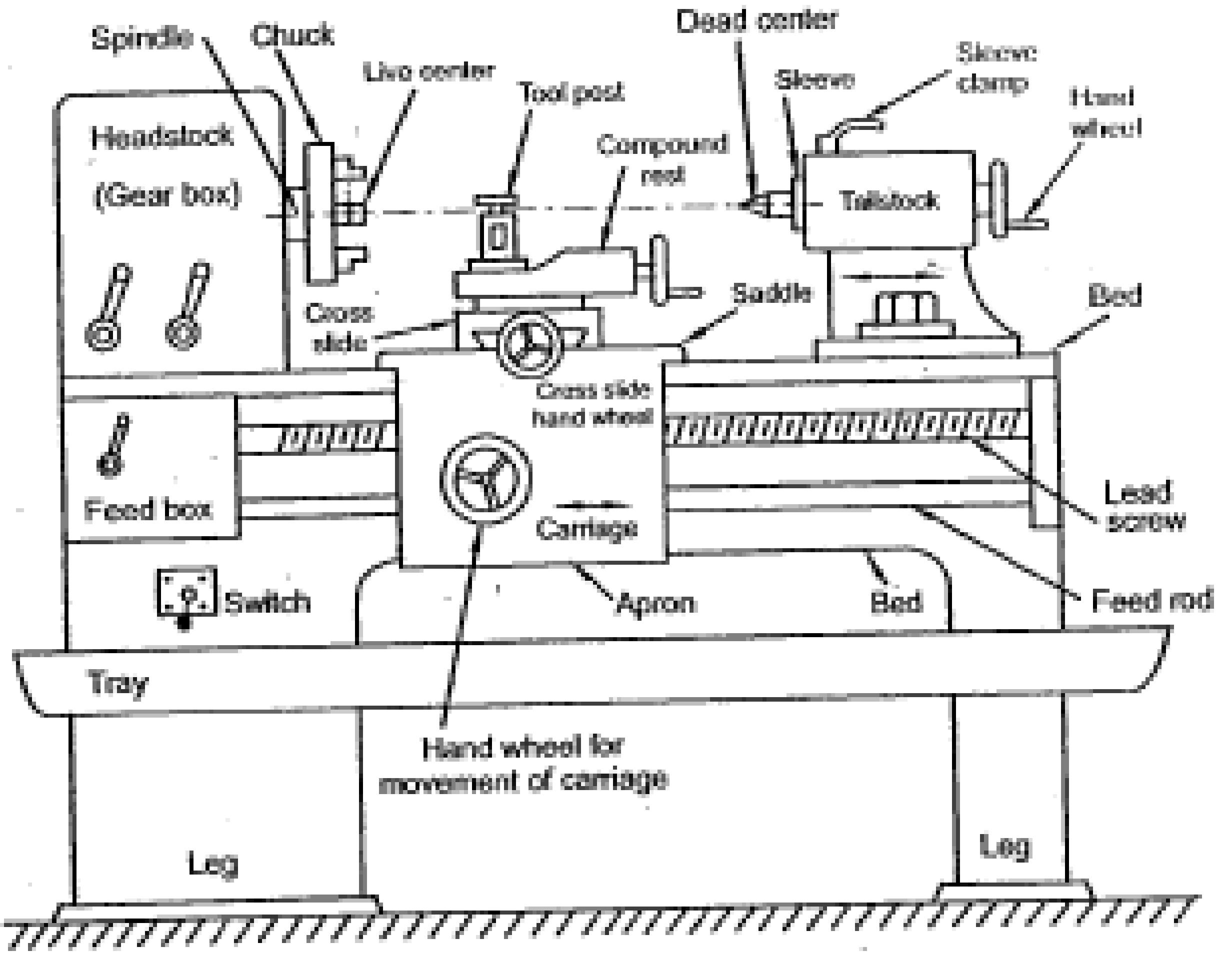


Facing



Taper turning

Parts of lathe

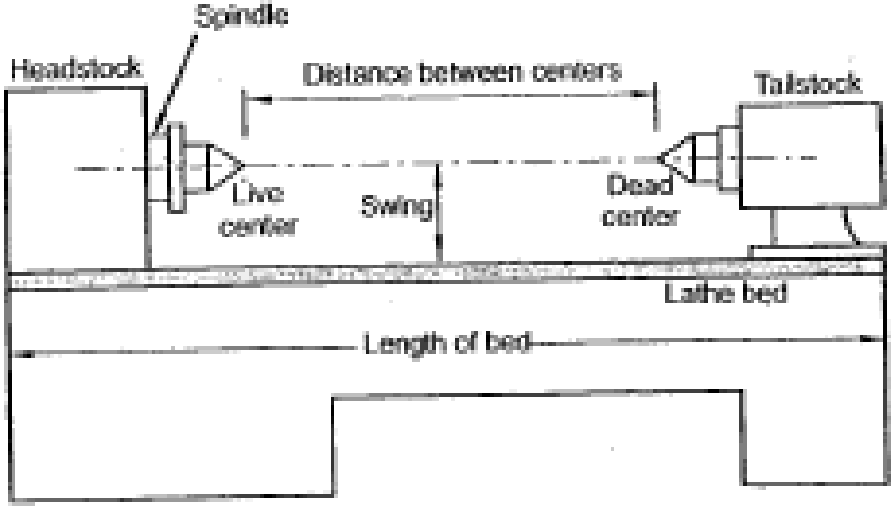


1. Bed
2. Headstock (live center)
3. Tailstock (dead center)
4. Carriage
5. Legs

Part	Features/functions
Bed	• Rigid structure which forms the base or foundation to support all the other parts. • Usually made of gray cast iron • At the top of the bed are the guideways which guides for accurate movement of carriage and tailstock
Headstock (Live center)	• Mounted at the end of the lathe bed serves as a housing for the spindle, driving gears [by means workpiece rotates]. • The headstock spindle is provided with a live center or chuck to support one end of the workpiece while it is being rotated.
Tailstock (Dead center)	• Mounted at the right end of the lathe bed • Functions: i. Provide support to the other end of the rotating workpiece. ii. Hold a tool for performing operations like facing, taper turning. • It can slide along the bed and can be clamped at any location so as to accommodate workpiece of different lengths. • It can also be shifted laterally on the bed so as to make it offset for producing taper surfaces.
Carriage	• Cutting tool is supported, moved and controlled with the help of carriage. • Parts of carriage – saddle, cross-slide, compound rest, tool post, apron, feed rod and lead screw. • *Saddle* – made to slide along the bed-ways. It supports the cross-slide, compound rest and tool post.

Part	**Features/functions**
	• *Cross slide* – Mounted on the saddle. It can move in a direction perpendicular to the saddle movement or perpendicular to the lathe axis providing the necessary depth of cut to the workpiece. • *Compound rest* – Mounted on the cross-slide and supports the tool post. It has a circular base graduated in degree which helps the cutting tool to be swivelled at any angle to obtain taper surfaces. • *Tool post* – Mounted on the compound rest, used to hold/support the cutting tool firmly in position during machining. • *Apron* – Fitted beneath the saddle facing the operator. It houses the gears, levers, hand wheels and clutches to operate the carriage by hand or by automatic power feed. • *Feed rod* – Long shaft the gives automatic feed to the carriage for various operations namely turning, facing etc. • *Lead screw* – Long shaft with square threads cut on it. The rotation of the lead screw facilitates the movement of carriage during thread cutting operations.
Legs	• Acts as supports which carry the entire load of the machine over them. • They are firmly secured to the floor by means of foundation bolts in order to prevent vibrations of machine during operation.

Specification of center lathe

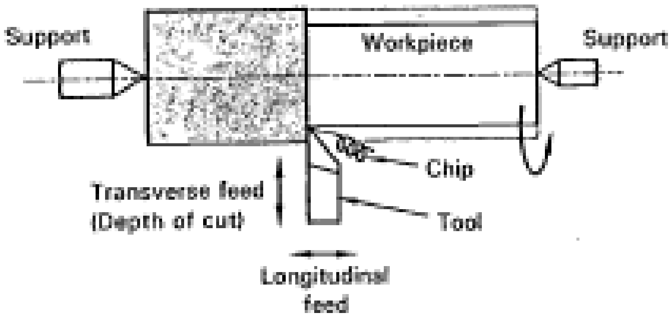


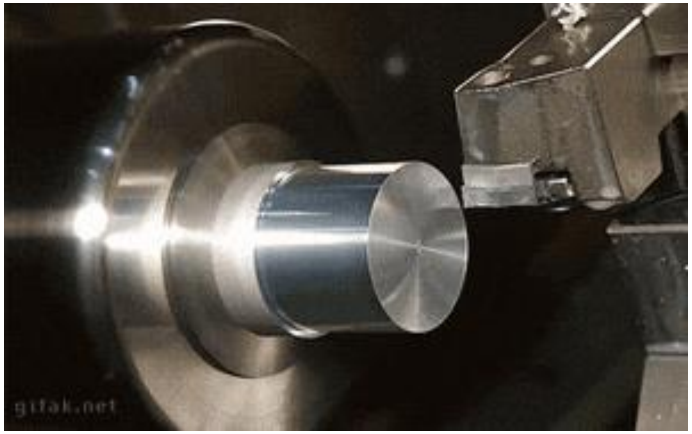
1. Distance between centers – It is the maximum length of workpiece that can be held between the live center and dead center.
2. Swing diameter – It is the maximum diameter of the workpiece that can revolve without touching the guide ways.
3. Height of centers – Height measured from the bed to the lathe center axis.
4. Length of bed – Indicates the approximate floor space occupied by the lathe.
5. Range of spindle speeds – 1000 to 4000 rpm

Lathe operations

1. Cylindrical turning

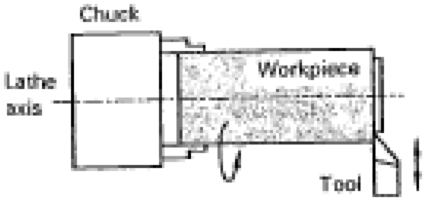
- Also called as plain turning, straight turning.
- It is the operation of removing excess material from the workpiece to produce a cylindrical surface.
- The workpiece is held rigidly and rotated between the live center and dead center.
- The cutting tool is fed against the revolving workpiece; in direction parallel to the lathe axis to produce cylindrical surface.
- Rough turning – excess material form the workpiece is removed rapidly by giving a deep depth of cut and a high feed rate.
- Finish turning – excess material is removed by giving light depth of cut and small feed.
- A smooth surface with the specified tolerance can be produced in finish turning.



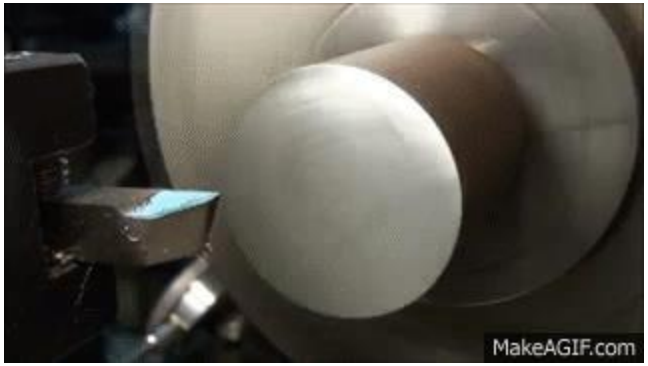


2. Facing

- Operation of generating a flat surface at the end of the workpiece.
- One end of the workpiece is held rigidly in the chuck/live center, while the other end is left un-supported.
- The tool is fed in a direction perpendicular to the lathe axis to produce a flat surface at the end of the workpiece.
- Facing is also carried out to reduce or cut the workpiece to the required length.

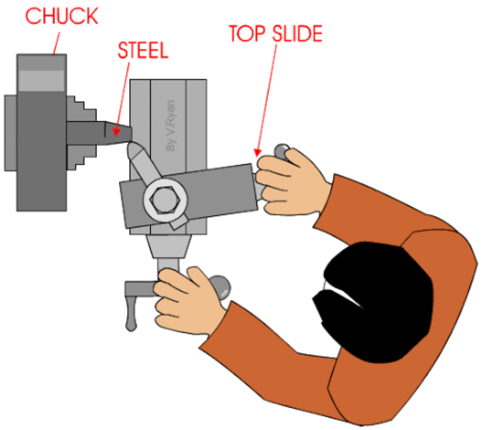


(a) Front view of facing operation

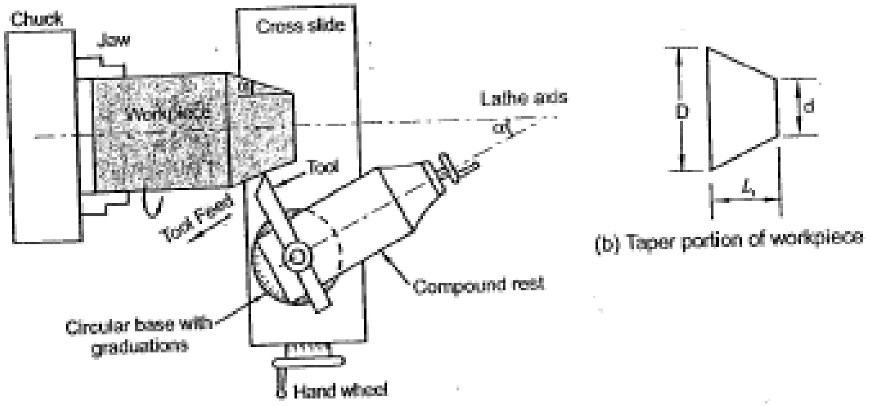


3. Taper turning

- Process of producing a conical surface from a cylindrical shaped workpiece.
- A taper is produced when the cutting tool moves at an angle to the axis of rotation of the workpiece.
- Methods of producing taper
  - i. Swivelling of compound rest
  - ii. Off-setting the tailstock
  - iii. Taper turning attachment and form tool method



Taper turning by swivelling or rotating the compound rest



(a) Top view of swivelled compound rest

(b) Taper portion of workpiece

- The compound rest supporting the cutting tool is swivelled to the desired angle at which the taper is to be produced. This angle is called half –taper angle (α) is calculated using the equation

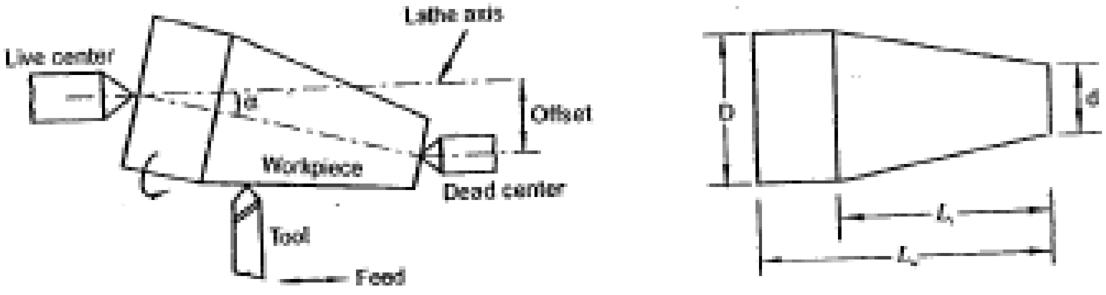
$$\text{half-taper angle } \alpha = \tan^{-1}\left(\frac{D-d}{2.L_t}\right)$$

where D = larger diameter of taper in *mm*

d = smaller diameter of taper in *mm* & L_t = Length of taper in *mm*

- The compound rest has a circular base graduated in degrees.
- The rotation of the compound rest to the calculated taper angle, will cause the tool to be fed at that angle, thereby producing the corresponding taper on the workpiece.
- This method is suitable for producing steep taper with short lengths.

Taper turning by off-setting the tailstock



(a) Tailstock offset (b) Workpiece

- The taper is produced by shifting the axis of rotation of the workpiece at an angle to the lathe axis and then the tool is moved parallel to the lathe axis.
- The angle at which the axis of rotation of the workpiece is shifted is equal to half angle of the taper.
- This is done by offsetting the body of the tailstock with respect to its base by an amount equal to

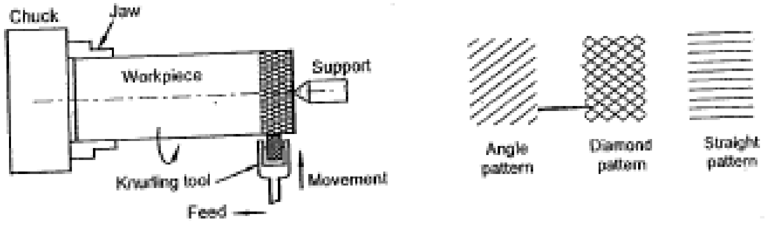
$$\text{Offset} = \frac{(D-d)L_w}{2L_t}, \quad \text{where } D = \text{Larger diameter of workpiece}$$

d = smaller diameter of workpiece, L_t = length of taper, & L_w = length of entire workpiece

- This method is used for producing small tapers on long workpieces.

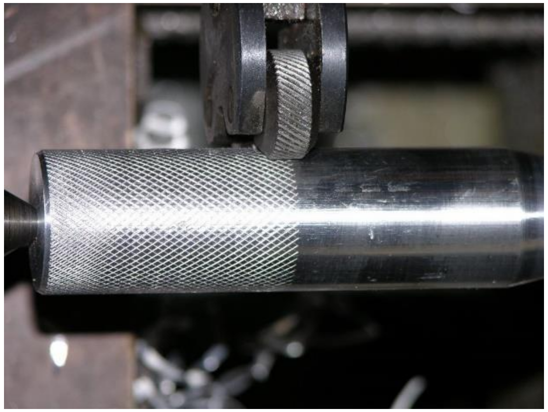
4. Knurling

- Process carried out on a lathe whereby a visually attractive criss-cross pattern is cut or rolled on the surface of workpiece.
- In operation, workpiece rotates at a slow speed.
- The knurling tool is pressed against the rotating workpiece and pressure is slowly increased until the tool produces a pattern.
- Depending on the knurling tool selected, a variety of knurled pattern can be produced.
- Produced pattern allows human hands to get a better grip on the knurled object.



(a) Knurling operation

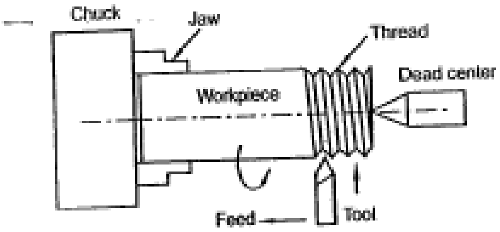
(b) Knurling patterns

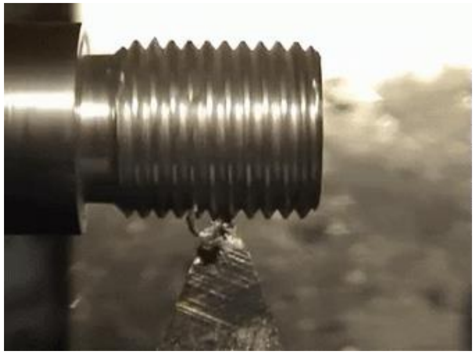


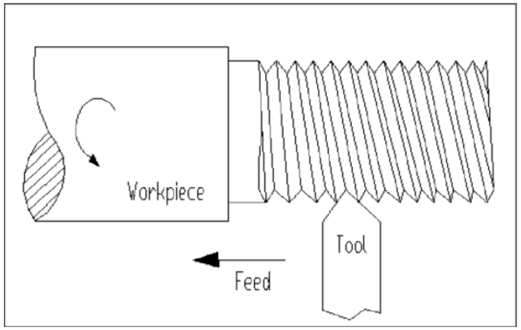
5. Thread cutting

- Thread cutting or threading is a operation for cutting screw threads on workpiece.
- In operation, a suitable tool which gives the required thread profile is mounted on the tool post.
- The carriage is connected to the lead screw with the help of a split nut.
- The rotation of the lead screw gives the required motion to the carriage relative to the rotation of the workpiece.

- The speed of the spindle in thread cutting is much lower than that used in cylindrical /flat/taper turnings. Hence the speed of the workpiece should be initially adjusted.
- The depth of cut is selected and the tool is made to move parallel to the axis of rotation of the workpiece by means of automatic arrangements.
- By dis-engaging the split nut, the carriage is brought back to its initial position to start another cut.



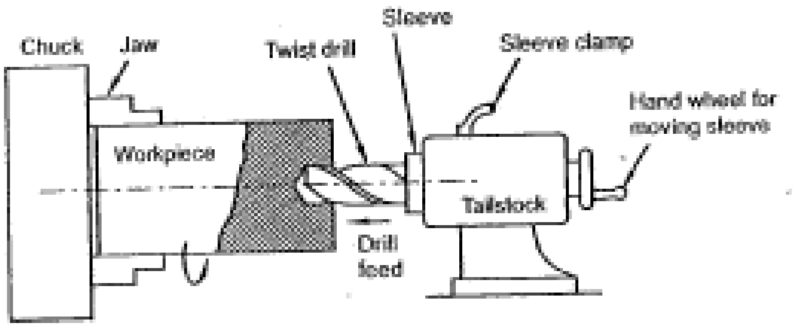


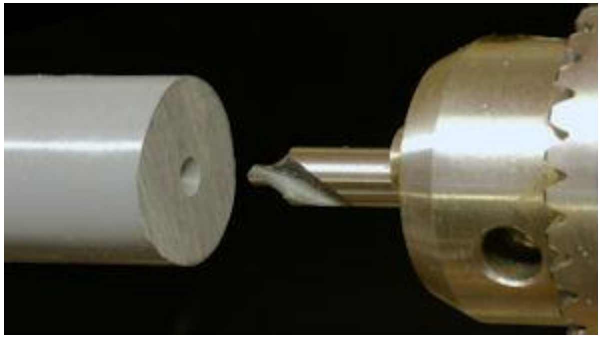


- Thread cutting is carried out in a number of passes. The final cut is a finishing cut with a very small depth of cut to obtain good surface finish.

6. Drilling on lathe

- Operation of producing a cylindrical hole by means of a revolving tool called twist drill or drill bit.
- One end of the workpiece is held in a chuck, while the other end is left free.
- The tool is held in the tapered hole of the tailstock sleeve and is fed into the rotating workpiece with the help of hand wheel of the tailstock.

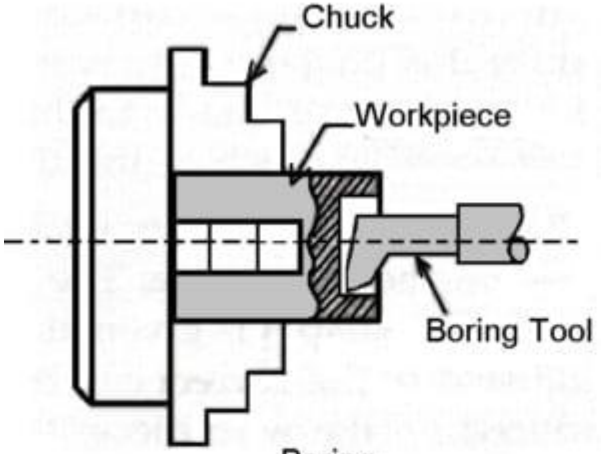




- Drilling on lathe is limited to holes through the axis of rotation of the workpiece.
- Although drilling operation can be done on lathes, it is best performed on drilling machines.

7. Boring on lathe

- Process of enlarging a hole that has already been drilled by means of a cutting tool (or of a boring head) is termed as boring.
- Boring is used to achieve greater accuracy of the diameter of a hole, and can be used to cut a tapered hole.

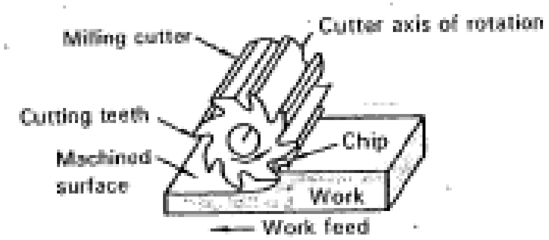


Boring

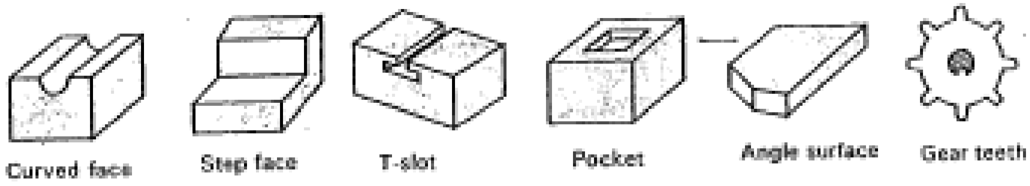
Milling Machines

Milling

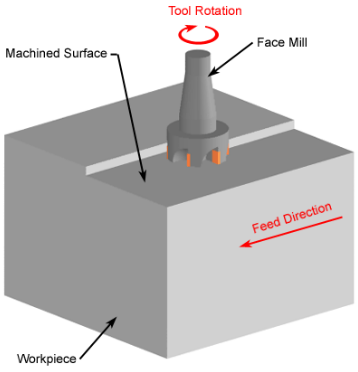
- The process of shaping work materials by feeding the work material against a multipoint rotating cutter.
- The machine used for the purpose of milling is called milling machines.
- Used for producing flat, angular or curved surfaces, for cutting threads, gears, slots etc.
- The type of cutter used in milling depends on the shape desired on the workpiece.



(a) Milling process



(b) Various shaped produced by milling



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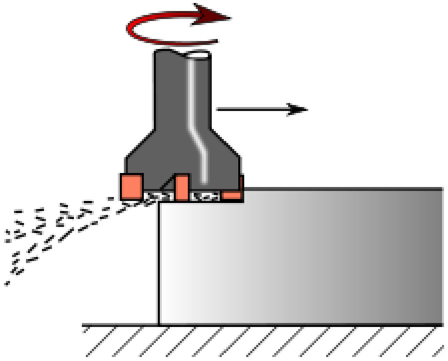
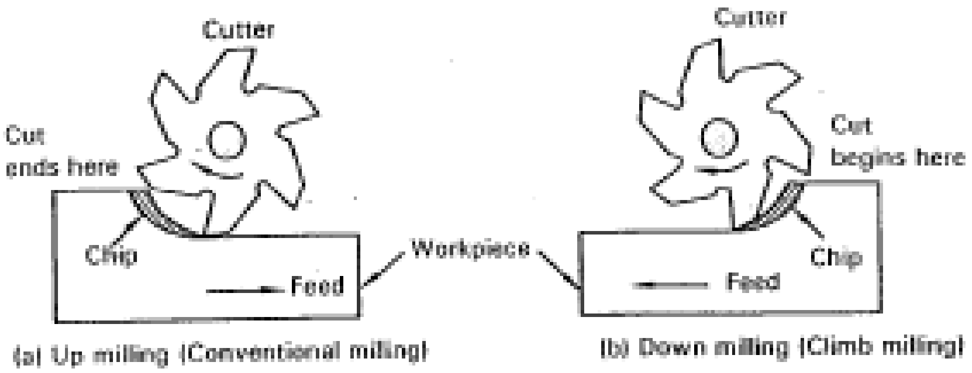


Principle of milling

- In milling, the cutter is held in the spindle of the machine and made to rotate at suitable speeds.
- The workpiece is also held rigidly by a suitable device and is fed slowly against the rotating cutter.
- The workpiece can be fed in two different directions with respect to cutter rotation.



(a) Up milling (Conventional milling)

(b) Down milling (Climb milling)

- In up milling process, the workpiece is fed in the direction opposite to that of the rotating cutter.
- In down milling process, the workpiece is fed in the same direction as that of the rotating center.

Up milling and down milling process

Sl. No.	Up milling	Down milling
1.	Workpiece is fed in the direction opposite to that of the rotating cutter.	Workpiece is fed in the same direction as that of the rotating cutter
2.	Thickness of chip – minimum at beginning of cut and reaches to a maximum when the cut ends	Thickness of chip is maximum at the beginning of cut and reaches minimum when the cut ends.
3.	Greater clamping force for the workpiece is necessary.	Lesser clamping force required
4.	Damage to the surface finish of the workpiece can be observed [accumulation of chips at T-W interface]	No damage to the surface finish of the workpiece.
5.	It is difficult for efficient circulation of coolant.	Coolant can easily reach the cutting zone. Hence efficient cooling of tool and workpiece can be achieved.
6.	Preferred for rough cuts [method enables the cutter to dig-in and start the cut below the hard upper surface]	Used for finishing operations and small work like cutting slots, grooves etc. [No dig-in of the cutter]

Classification of milling machines

I. Column and knee milling machines
  - i. Plain column and knee type
    - Horizontal spindle type
    - Vertical spindle type
  - ii. Universal column and knee type

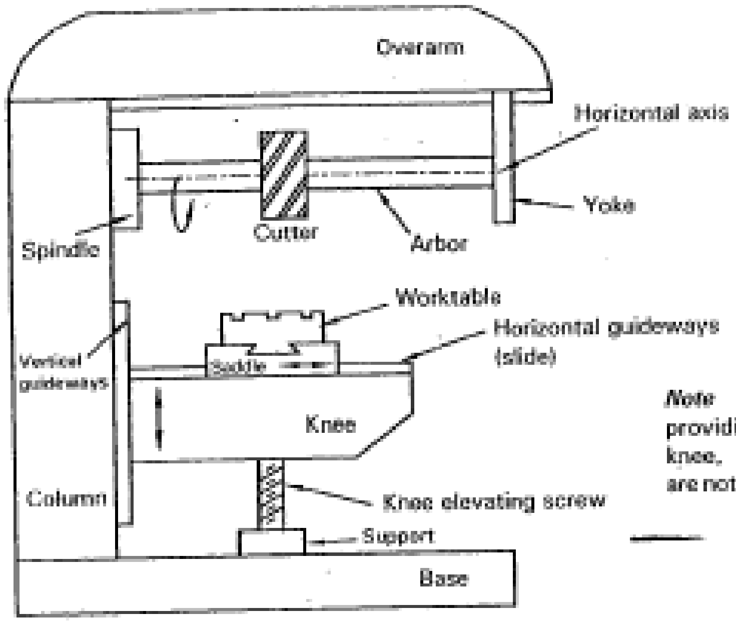
II. Bed type milling machine

III. Planer type milling

IV. Special purpose milling machine
  - i. Tracer-controlled milling machine
  - ii. Thread milling machine
  - iii. CNC milling machine

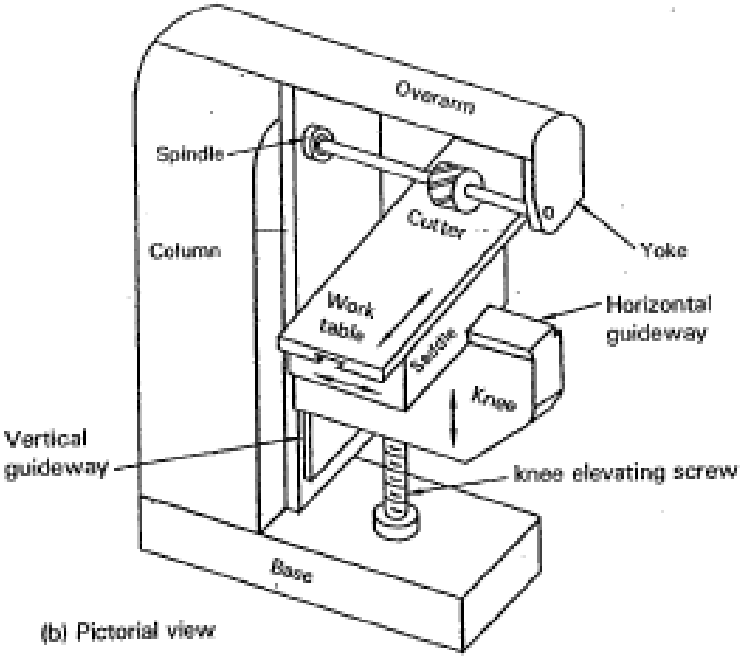
Horizontal spindle column & knee milling machine

- One of the most popular type of milling machine.
- Commonly called as horizontal milling machine, because of the horizontal position of the spindle.
- Used to cut grooves, slots, keyways, gear teeth etc.



(a) End view of a horizontal-spindle column and knee milling machine

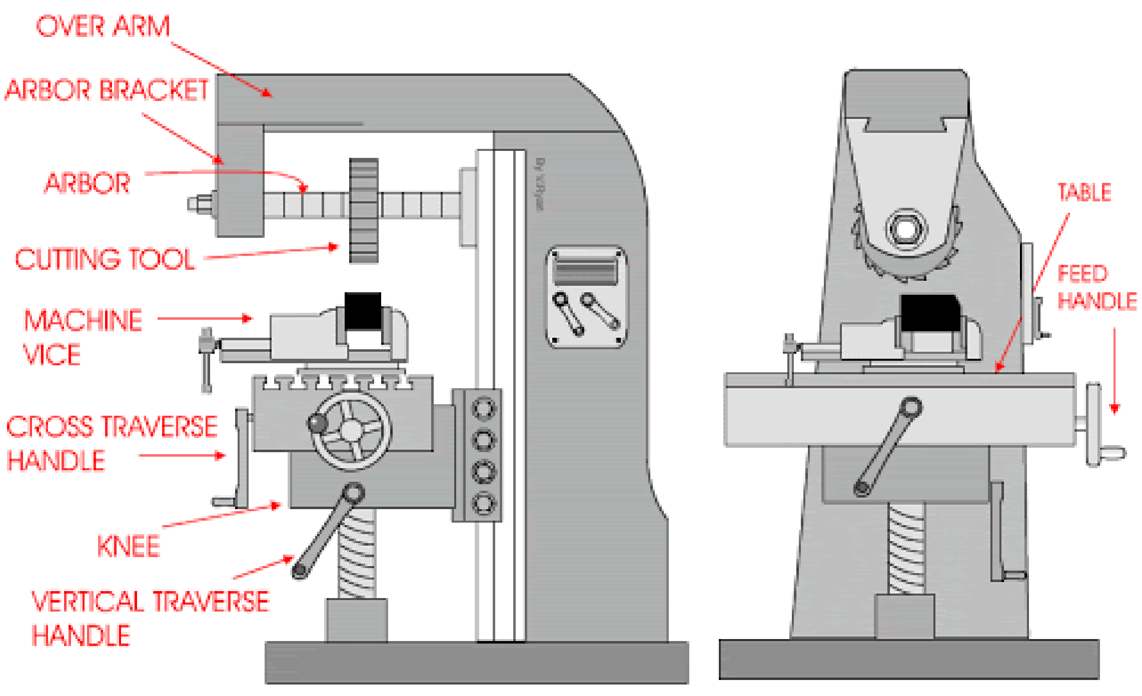
Note Hand wheel for providing motions to knee, saddle and table are not shown in figure.



(b) Pictorial view

Part	**Feature/functions**
Base	• Strong and a hollow part, which forms the foundation of the machines and upon which all other parts are mounted. • Serves as sump for cutting fluid. • A pump and filtration system can be installed in the base. • Hole provided in the center of the base, houses the support for the elevating screw that raises and lowers the knee.
Column	• A vertical hollow casting combined with base to form a single casting. • The column houses the spindle, bearings and drive units [gears, clutches, shafts and shifting mechanism] for transmitting power from the electric motor to the spindle at desired speeds. • Front face of the vertical column is provided with a square or dovetail type guideways on which the knee slides up and down.
Spindle	• Hollow shaft supported by the column with suitable bearings that absorb both radial and thrust loads. • The spindle is made hallow and tapered inside, to accept standard arbors. • Spindle obtains power from the motor and transmits it to the arbor. • The arbor carrying the cutter rotates about a horizontal axis.
Overarm	• Mounted on the vertical column, supports the yoke, which in turn supports the free end of the arbor.
Knee	• Casting that slides up and down on the vertical guideways provided on the column by means of an elevating screw. The knee supports the saddle.

Part	**Feature/functions**
Saddle	• Mounted on the knee is provided with two guideways on its top and bottom surfaces. • The slides are machined at right angles to each other. • The lower slide fits the slide provided on the top of the knee and facilitates horizontal movement of the saddle. • The upper slide provided on the saddle accepts the slide provided on the bottom surface of the worktable.
Work table	• Larger in size and rests on the saddle. • The bottom surface of the table has a dovetail slide that fits in the slide on the top surface of saddle. This facilitates the work table to move longitudinally or at right angles to the movement of the saddle. • Work table is provided with T-slots all along its length for mounting work holding devices which enables the workpiece to be clamped rigidly on the table. • Work table may be manually controlled or power fed. • A dial graduated in thousandth of an inch is provided to allow table movement and placement.



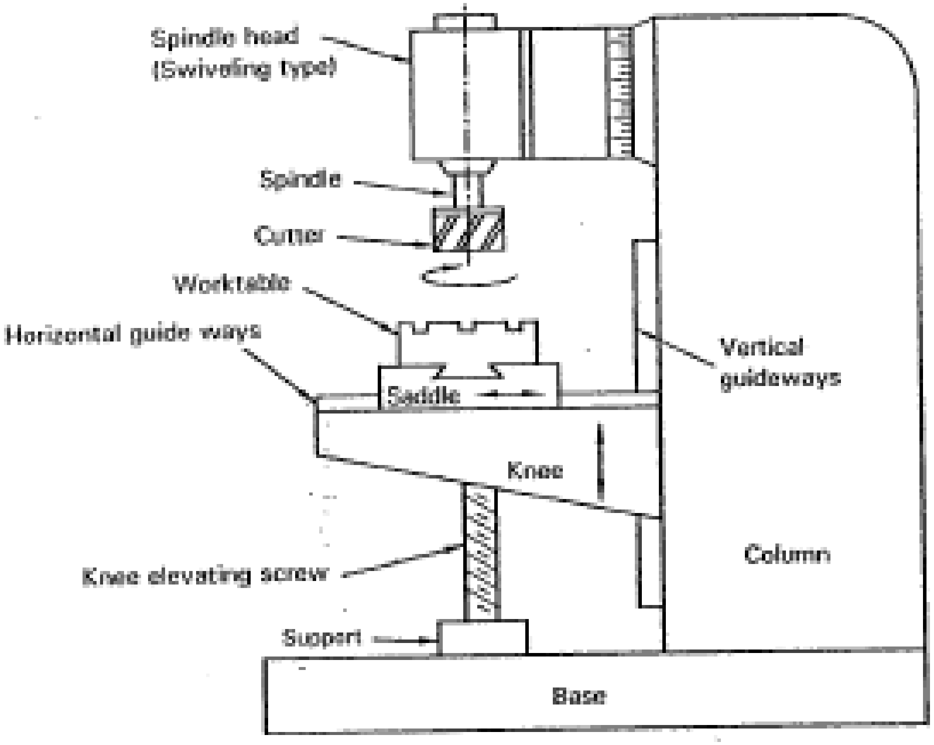
FRONT VIEW

SIDE VIEW

Horizontal milling machine

Vertical spindle column & knee milling machine

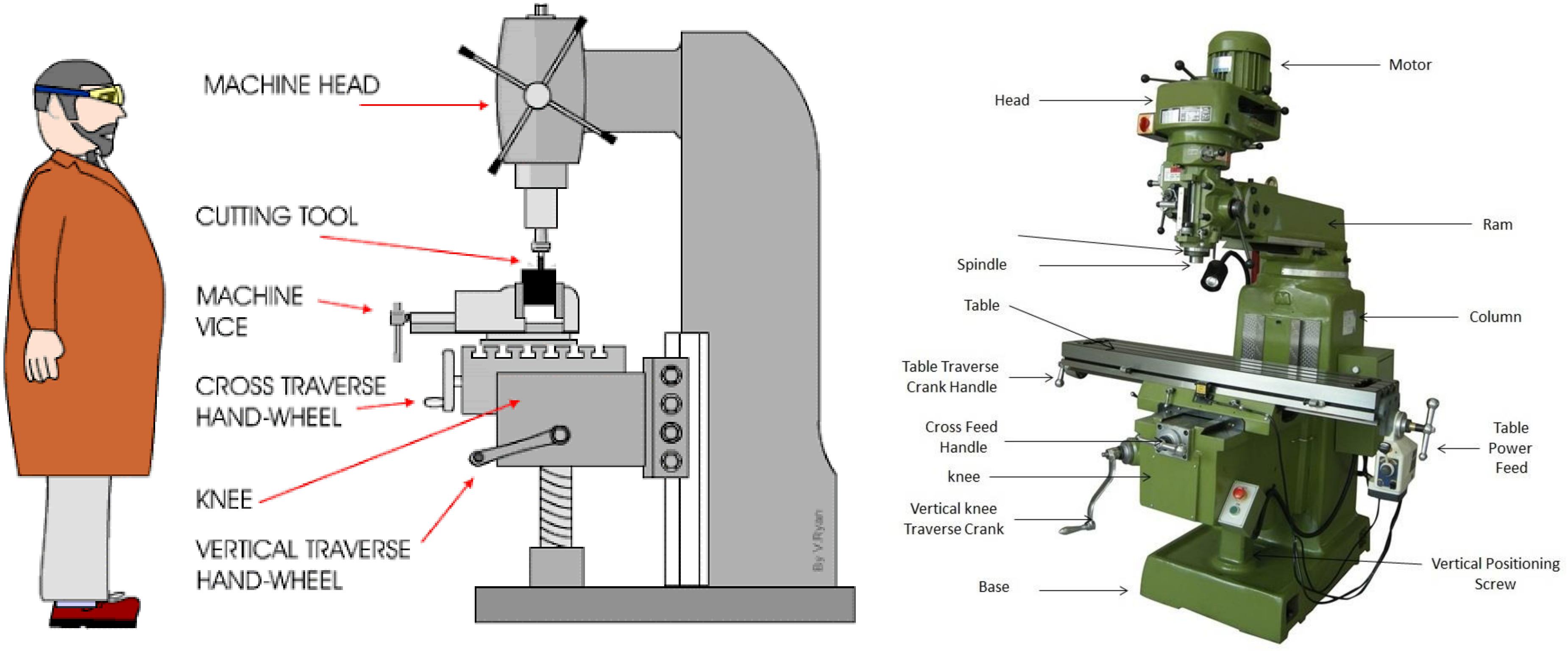
- Similar in construction to the horizontal milling machines except that the spindle is held in a vertical position.
- Used to perform end milling and face milling operations.



1. Base
2. Column
3. Spindle
4. Overarm
5. Knee
6. Saddle
7. Worktable

Part	**Feature/functions**
Base	• Strong and a hollow part, which forms the foundation of the machines and upon which all other parts are mounted. • Serves as sump for cutting fluid. • A pump and filtration system can be installed in the base. • Hole provided in the center of the base, houses the support for the elevating screw that raises and lowers the knee.
Column	• A vertical hollow casting combined with base to form a single casting. • The column houses the spindle, bearings and drive units [gears, clutches, shafts and shifting mechanism] for transmitting power from the electric motor to the spindle at desired speeds. • Front face of the vertical column is provided with a square or dovetail type guideways on which the knee slides up and down.
Spindle	• Located vertically, parallel to the face of the column and perpendicular to the top of the worktable. • Mounted in the spindle head and carries the cutter at its end. Spindle head houses the motor & feed controls [fixed type and swivelling type] • Fixed type – Spindle head is fixed and hence spindle remains vertical. • Swivelling type – spindle head can be adjusted to any angle to workpiece surface. This permits working on angular surface of workpiece
Overarm	• Mounted on the vertical column, supports the yoke, which in turn supports the free end of the arbor.

Part	**Feature/functions**
Knee	• Casting that slides up and down on the vertical guideways provided on the column by means of an elevating screw. The knee supports the saddle.
Saddle	• Mounted on the knee is provided with two guideways on its top and bottom surfaces. • The slides are machined at right angles to each other. • The lower slide fits the slide provided on the top of the knee and facilitates horizontal movement of the saddle. • The upper slide provided on the saddle accepts the slide provided on the bottom surface of the worktable.
Work table	• Larger in size and rests on the saddle. • The bottom surface of the table has a dovetail slide that fits in the slide on the top surface of saddle. This facilitates the work table to move longitudinally or at right angles to the movement of the saddle. • Work table is provided with T-slots all along its length for mounting work holding devices which enables the workpiece to be clamped rigidly on the table. • Work table may be manually controlled or power fed. • A dial graduated in thousandth of an inch is provided to allow table movement and placement.

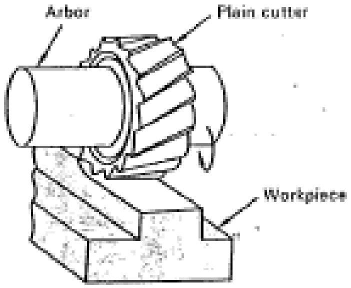


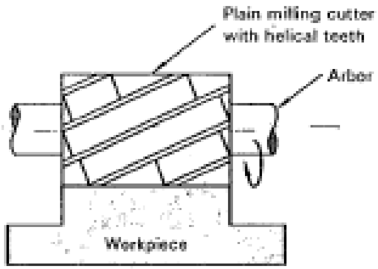
Vertical milling machine

Milling operations

1. Plain/slab/surface milling

- Operation of producing a plain horizontal surface with a milling cutter whose axis is parallel to the surface of the workpiece.
- Plain/slab milling cutter is mounted on the arbor of a horizontal milling machine to carry out the machining process.
- The cutter has straight or helical teeth formed on the periphery of a cylindrical surface.
- Helical tooth cutter removes greater amount of material and produces a smooth surface finish.

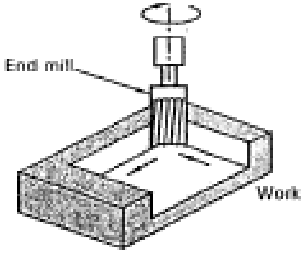




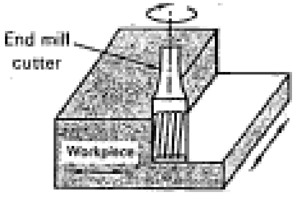
2. End milling

- Operation performed for producing flat surfaces, slots, grooves or finishing the edges of the workpiece by means of end mill or end milling tool.
- The cutter has teeth on the end as well as the periphery(sides).
- End mill are also used to produce flat surface by using end side of cutter.
- The cutter is typically mounted vertically and have straight or spiral flutes.
- Straight flute cutters – milling both soft and tough material

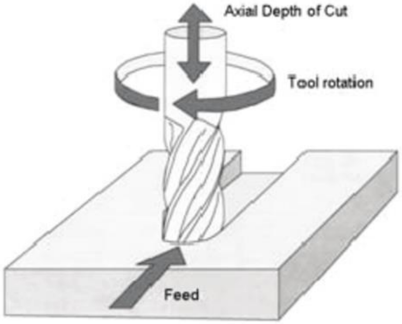
- Spiral flute – used for cutting steel.
- The surface produced by end milling may be horizontal, vertical or inclined with respect to the top of the machine table.

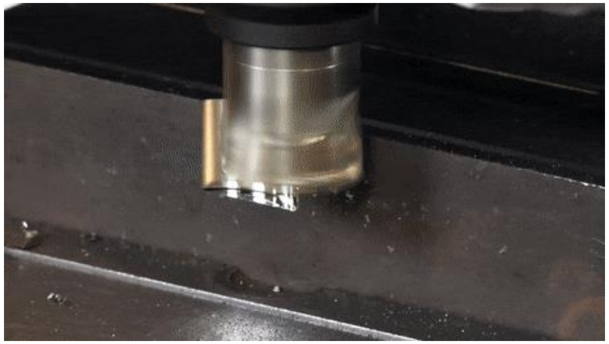


(a) Cutting with both sides of end mill cutter



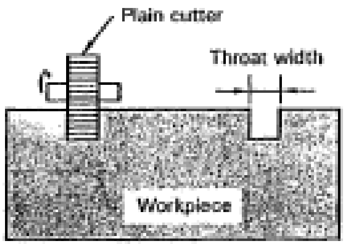
(b) Producing single flat surface



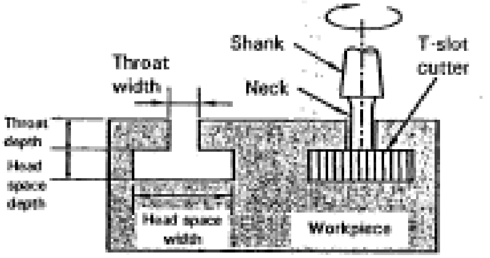


3. Slot milling

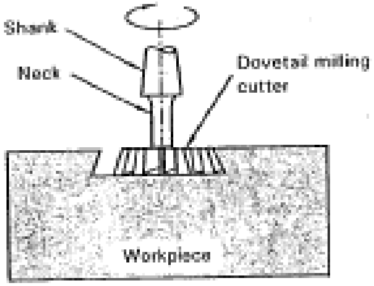
- Operation of producing various types of slots – T slot, plain slots, dovetail slot etc., in workpieces.



(a) Cutting throat with end mill cutter



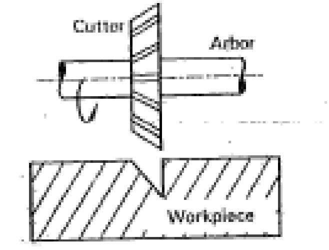
(b) Cutting slot with T-slot cutter



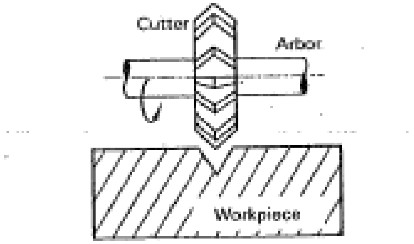
Dovetail slot

- T – slots: Two separate milling cutters are required for milling T slots. Initially a side or an end mill is used to cut the throat or open slot starting from one end of the workpiece to its other end. A T – slot milling cutter is then used to cut the head space to desired dimensions
- Dovetail slots: a dovetail slot cutter is used in place of T-slot.

4. Angular milling



(a) Angular milling with single-angle cutter

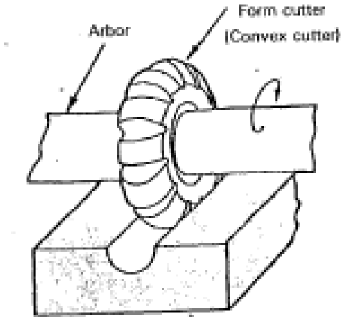


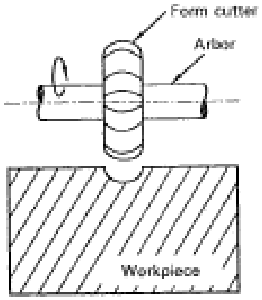
(b) Angular milling with double-angle cutter

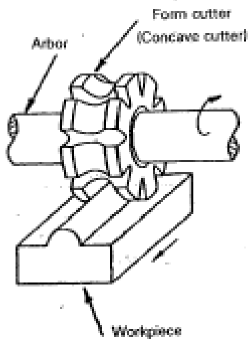
- Operation of producing all types of angular cuts like V-notches, grooves, serrations and other angular surfaces.
- Angle milling cutter or angle cutter has peripheral teeth which are neither parallel nor perpendicular to the cutter axis.
- Angle cutter may be either single angle or double angle type depending upon the type of surface to be machined.
- Single angle cutter – angled on one side to produce an angle or chamfer on workpiece edge
- Double angle cutter – angled on both sides of the cutter to produce double angle cuts
- Angle cutter may also be used to produce dovetail slots in workpieces

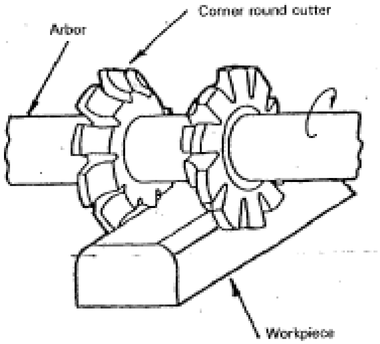
5. Form milling

- Operation of producing curved profiles with a variety of shapes like concave, convex, spline etc., using cutters whose edge is shaped to produce a special configuration on the surface of the workpiece.
- Form mill has teeth on its periphery and it is designed in various shapes to suit the type of surface being machined.
- Example of form mill – gear tooth cutter [to cut gear teeth on workpiece]



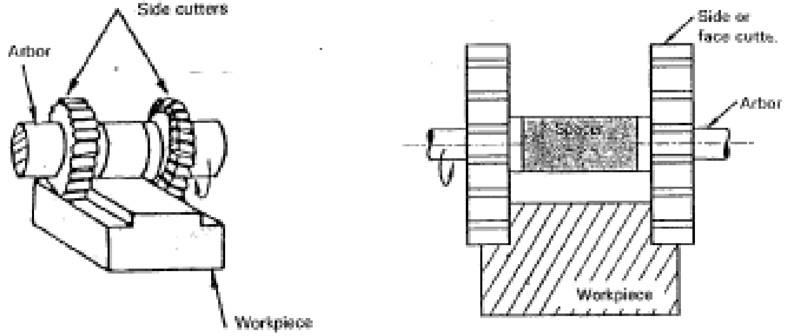






6. Straddle milling

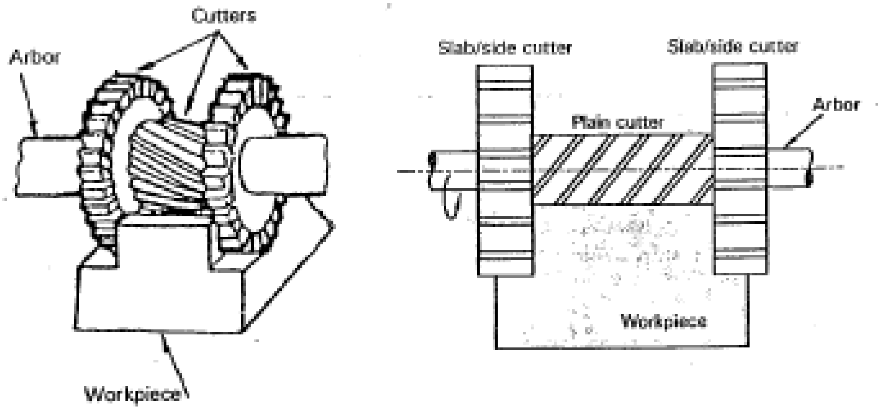
- Operation in which a pair of side milling cutters is used for milling two parallel vertical surfaces simultaneously.
- Side milling cutter has a cutting edge on one/ both sides as well as on the periphery.
- Straddle milling is accomplished by mounting two side milling cutters on the same arbor, set apart at an exact spacing with the help of spacers, washers and shims so that distance between the cutting teeth of each cutter is exactly equal to the width of the workpiece area being milled.



Straddle milling

7. Gang milling

- Operation in which two or more cutters are mounted on the same arbor, so that different profiles required on the workpiece can be milled simultaneously in a single pass.
- All the cutters used may be of the same type or of different types depending on the type of surface being milled.



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Module – 5.2

Advanced manufacturing systems

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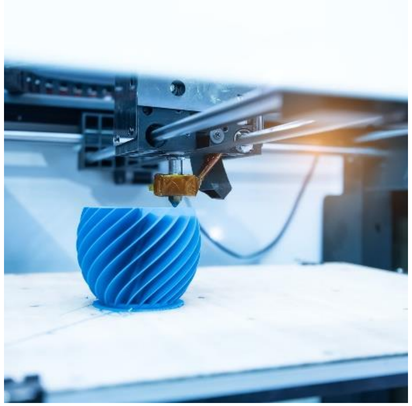
Advanced manufacturing

- Advanced manufacturing refers to the use of new innovative technologies, processes and methods for producing the desired products.
- Traditional manufacturing is based on the use of dedicated plant and production lines with little or no flexibility.
- Advanced manufacturing involves versatile production methods that fully utilize capital plant and are more effective, efficient and responsive.
- Advanced manufacturing system includes the following technologies

1. CNC machines
2. Rapid prototyping/additive manufacturing/3D printing
3. Industrial robotics

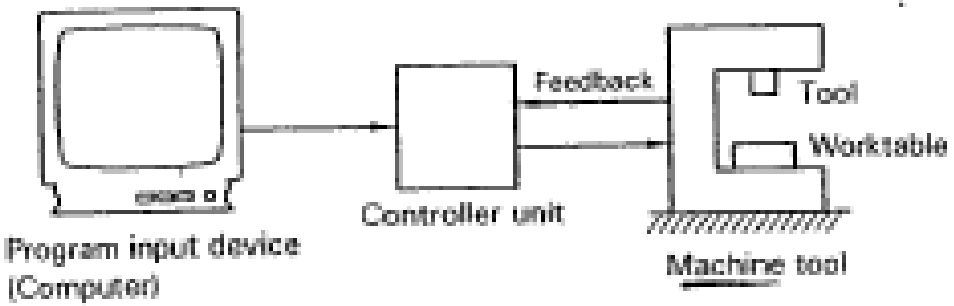


CNC Machines

- CNC – Computer Numerical Control
- A computer controller that accepts a program or a set of instructions and stores it in the memory of the computer, which in turn controls the working of the machine tool.
- The program can be modified or edited while it is in the computer memory as and whenever required [Great degree of flexibility in manufacturing].

Components of CNC Machines

- Similar to that of a NC machine.
- Basic components
  1. Part program and program input device
  2. Controller unit/Machine control unit (MCU)
  3. Machine tool



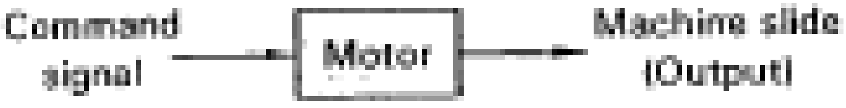
Component	Features/functions
Part program and program input device	• Part program is done either manually or with the aid of computer softwares that automatically generates the program required to produce the desired part.
Machine control unit	• It consists of a microcomputer and related control hardware that stores the program of instructions and executes it by converting each command into mechanical actions of machine tool. • MCU also includes system software, calculation algorithm and transition software to convert the part program into a usable format. • Also acts as a feedback controller for precise positioning of machine table or spindle.
Machine tool	• Performs the actual machining operations [Lathe, milling machine, drilling machine etc] • It consists of work table and tool spindles whose movement can be controlled by driving system that receives commands from the MCU. • A part with the desired features is produced by the machine tool

Types of control unit (MCU)

1. Open loop control system
2. Closed loop control system

Open loop control system

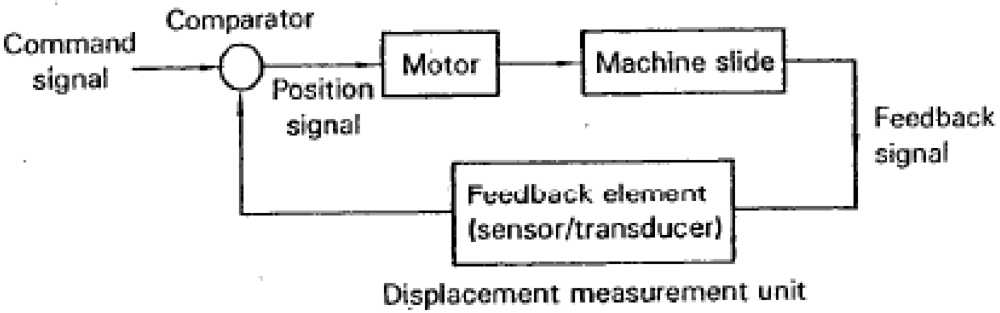
- A control system without a feedback from the output to the input.
- In a CNC machine, the programmed instructions fed into the controller unit gets converted to electrical signals by the controller which energize the motor.
- As the motor moves to the desired position, there is no feedback to the controller system to verify the action.
- The controller system will just continue performing the next step as if there is no problem until the operator resets the machine.
- Risk of overloading the machine and losing sequential steps of the program that can ruin the workpiece.
- Systems without feedback elements are not accurate and reliable [variations cannot be measured and rectified].



(a) Open loop control system

Closed loop control system

- Control system makes use of a servo-motor which has feedback sensor to monitor the output of the motor.
- Feedback element pick the signal from the output response i.e., the signal in turn is measured and compared with the input signal.
- Any variations found is rectified accordingly.
- The system is thus able to correct any errors in position, velocity, acceleration and large errors.
- Closed loop system improves the accuracy of operation [variations/errors – feedback sensors – rectification]



CNC Machining centers

- A CNC machine controlled by a computer program that can perform multiple milling operations [form milling, straddle milling etc.,] by a variety of tools with automatic tool changer (ATC) unit.
- Also called as *CNC milling machines.*

Types of CNC milling machines

Type	Description
Vertical machining centers (VMC)	• It consists of vertical spindles, used for flat type of work [plates – milling on only one face of the workpiece] • With the use of rotary tables, more than one side of a workpiece can be milled without operator intervention. • VMC which uses rotary table have four axes of motion [3 are linear motion, fourth is the table's rotary axis]
Horizontal machining centers (HMC)	• It consists of horizontal spindles, used for heavy rectangular parts [milling on more than one face of workpiece] • In HMC, cutting tools are large in size [bulk metal removal rates] • High maintenance cost • HMC have multiple axis table movements as VMC. • HMC is capable of rotating to all four sides of workpiece during tooling.

Note:

A *machine tool* is a machine for handling or machining metal or other rigid materials, usually by cutting, turning, milling etc.

Machining is process in which a workpiece is cut into a desired final shape and size by a controlled material-removal process.

CNC turning centers

- A CNC machine controlled by a computer program that can perform multiple turning operations [cylindrical turning, taper turning, thread cutting etc.] by a variety of tools mounted on a turret with automatic tool changer (ATC) unit.
- Also referred as *CNC lathe*.
- All the operations are similar in principle to that performed on a traditional lathe except the operation with relevant tools and process parameters like speed, feed, depth of cut are all controlled by the computer program.

Advantages of CNC machines

- Higher productivity, higher precision, multi operational facilities
- Does not require a skilled operator
- Improved automation
- Repeatability and reliability
- Flexibility
- Motion control – motion of cutting tool in 2 or more directions (x, y and z-axis) by means of servomotors.
- Increased machine utilization

Disadvantages of CNC machines

High initial cost of the machine, high maintenance cost, requires skilled programmer

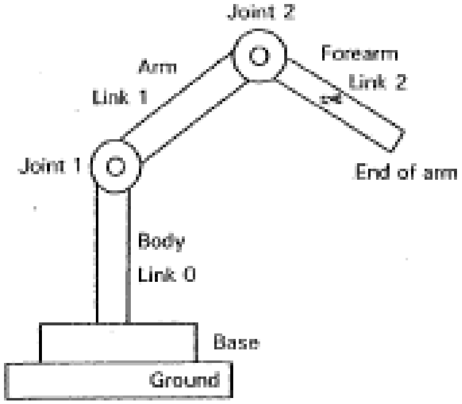
Industrial robots

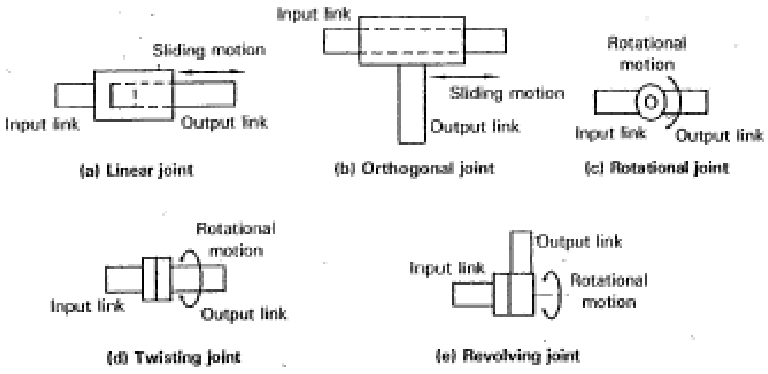
- It is a reprogrammable, multifunctional manipulator designed to move materials, parts, tools through variable programmed motions for the performance of variety of tasks.
- Acts as an artificial agent acting as a substitute for human operator.
- Basic parts of robot
  1. Manipulators – links and joints
  2. Sensors
  3. Actuators
  4. Controller unit
- Need of industrial robots
  - i. Preferred in those applications that are too dangerous or difficult for human operator to implement directly.
  - ii. To perform repetitive tasks in order to improve the accuracy and productivity of work.

Robot anatomy

- Robot anatomy deals with the study of different joints and links and other aspects of the manipulator’s physical construction.

Robot joints	Robot links
• Provides restricted relative motion between two links of the robot. • The arm and body of a robot are used to move and position parts or tools within the work space of robot. • The motion in the joint can be linear/sliding or rotary, about or along the Cartesian axis.	• Rigid member connecting the joints of the robot. • Link maintains a fixed relationship between the two joint axis through a kinematic function. • This relationship can be described by two variables – length of the link and twist of the link. • Links are numbered starting from the base of the robot.





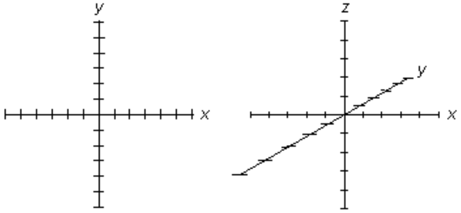
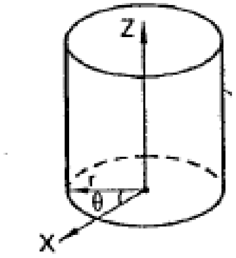
(a) Linear joint (b) Orthogonal joint (c) Rotational joint (d) Twisting joint (e) Revolving joint

Robot Configurations

- Industrial robots are designed to have various arm manipulations so as to have motion in different directions.
- The possible types of arm movements that a robot is designed with, defines the configuration of a particular robot.
- A robot can have any one of the following configurations

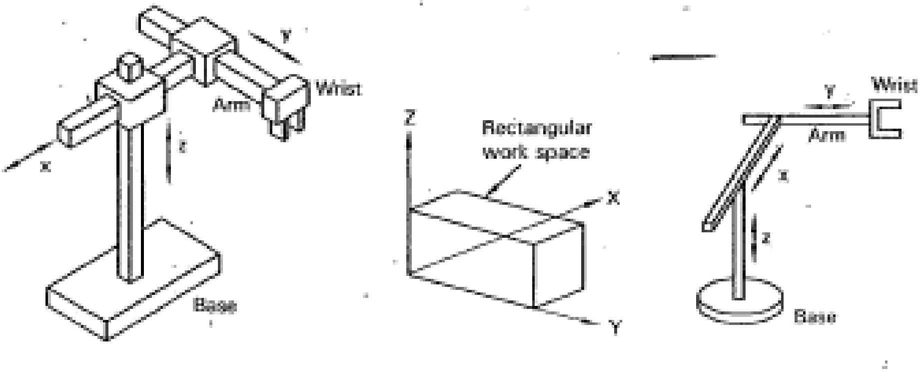
1. Cartesian configuration robot
2. Cylindrical configuration robot
3. Polar or spherical configuration robot
4. Jointed arm robot
5. Selective compliance assembly robot arm (SCARA)

Note

Cartesian coordinate system	Cylindrical coordinate system
• Provide a method of rendering graphs and indicating the positions of points on a two-dimensional (2D) surface or in three-dimensional (3D) space.  	• Three-dimensional coordinate system that specifies point positions by the distance from a chosen reference axis. 

1. Cartesian configuration robot

- The arm movement of the robot is designed to move parallel to the x, y and z-axis of a Cartesian coordinate system.
- It is capable of moving its arm to any point linearly within a rectangular work space.
- Since the arm movement is linear, the robot is also called as rectilinear or gantry robots.

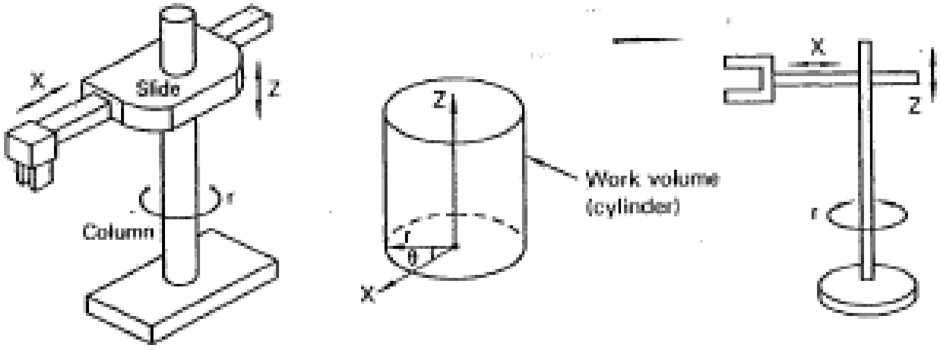


(a) Pictorial view (b) Work space (c) 2-D view

Advantages	Disadvantages	Applications
• Simple controls due to linear movements • High degree of mechanical rigidity, accuracy and repeatability • Can carry heavy loads • Motion of the wrist end is smoother	• Arm movement limited to small rectangular work space. • Occupies large area [low ratio of robot size to operating space]	• Assembly of parts, welding, machine loading and unloading, surface finishing, inspection etc.

2. Cylindrical configuration robot

- The arm movement of the robot is designed to move according to the cylindrical coordinate system.
- It consists of a vertical column and a slide that can move up and down along the column.
- The column can rotate about a vertical axis and hence is capable of achieving approximates cylinder shape work space.

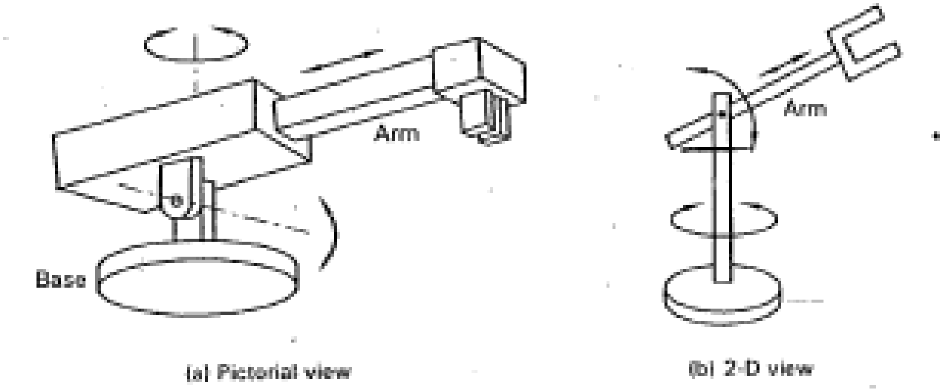


(a) Pictorial view (b) Work space (c) 2-D view

Advantages	Disadvantages	Applications
• Larger work space than Cartesian configuration robot. • Relatively easy to program	• Low mechanical rigidity • Repeatability and accuracy is less • Requires more sophisticated control system	• Pick and place operations, machine loading and unloading, forging operation, assembly, coating applications

3. Polar configuration robot

- The workspace within which a robot can move its arm is a partial sphere [spherical configuration].
- It consist of a rotary base and a pivot that can be used to raise and lower a telescoping arm similar to the formation of an arc movement.
- The sliding arm can be extended or retracted to provide required work space.

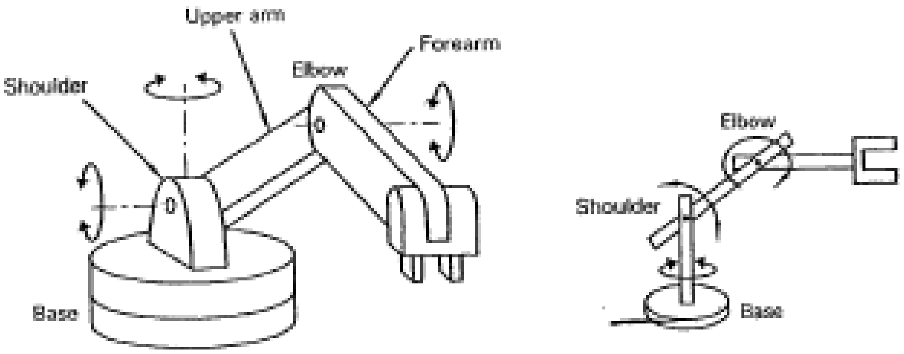


(a) Pictorial view (b) 2-D view

Advantages	Disadvantages	Applications
• Can generate large working space. • Simple in design, easy to program • Good weight lifting capabilities	• Reduced mechanical rigidity • More sophisticated control system • Limited vertical movement	• Die casting, injection moulding, forging, material transfer applications

4. Jointed arm configuration robot

- Similar to that of human arm.
- It consists of two straight components corresponding to the human arm, upper arm is mounted on a vertical pedestal that can be rotated about the base so as to provide the robot with the capacity to work within a quasi-spherical space.
- This configuration has joints that give rise to 3 rotational movements



(a) Pictorial view

(b) 2-D view

Advantages	Disadvantages	Applications
• Most flexible configuration • Large working space • Versatile configuration	• Requires complex programming • Control actions are difficult • Less stable, as the arm approaches maximum reach	• Painting, welding, automatic assembly, pick and place operations

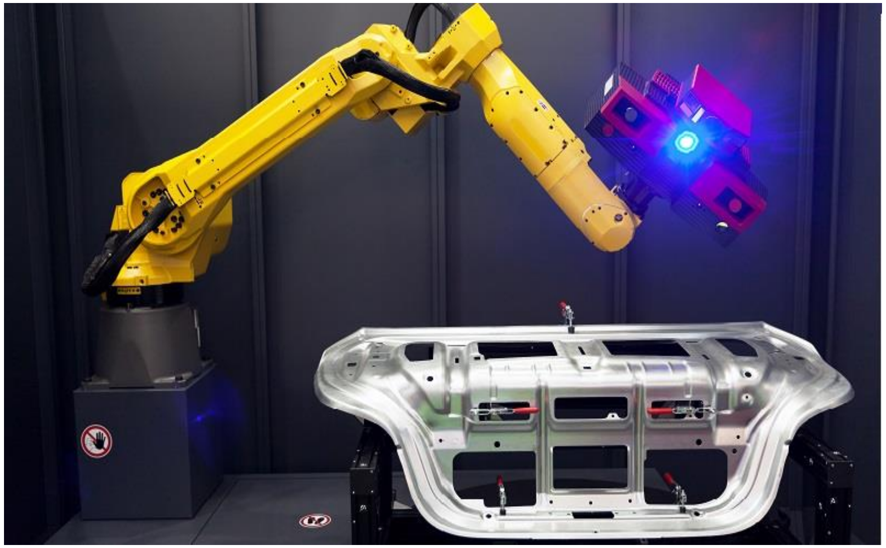
Advantages and disadvantages of industrial robots

Sl. No.	Advantages	Disadvantages
1.	Robots can perform operations with precision and repeatability every time	High initial investment and maintenance
2.	Ability to work continuously at constant speed without pausing for breaks	Incapable of performing task outside their predefined programming
3.	Increase the workplace safety	Cannot move easily [degrees of freedom to move their joints]
4.	Reduces production costs, time and material waste.	It requires considerable human intervention to perform some complex tasks
5.	Can be programmed to perform variety of tasks	Use of robots can lead to increase in unemployment

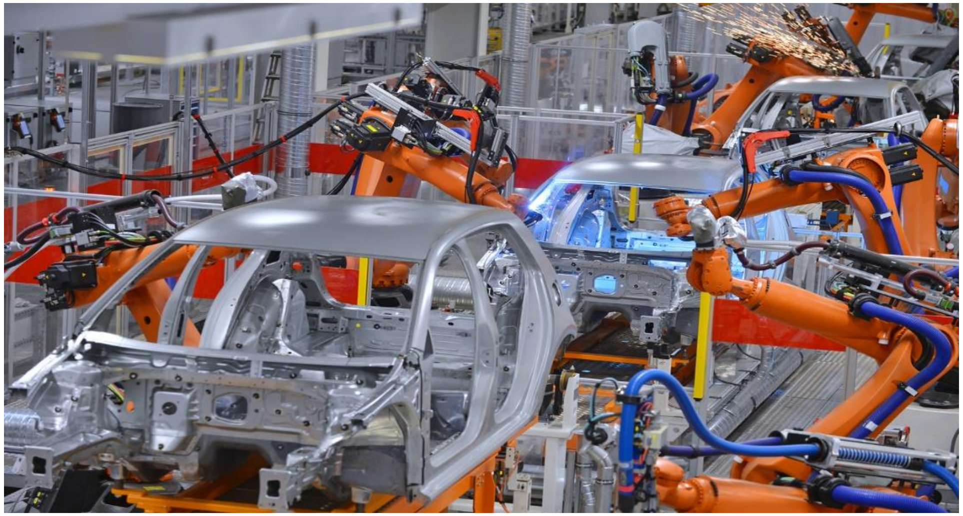
Applications of industrial robots

Categories	Applications
Material Handling(material transfer, machine loading and unloading)	• Used to move materials or work parts from one location to another [pick and place application] • Used to load and unload parts at the production industry [Kuka KR 60-3]
Processing	• Performing a process on a work part [welding, grinding, coating etc] in automotive industries. • Robot is programmed to hold and manipulate a tool to perform the desired operation [Motoman HP20-6, Kuka KR 16]
Assembly and inspection	• Used to assemble the various components of a product like picking a part and inserting into another part with precise placement and orientation [Fanuc N410] • Used in part inspection applications; robot positions a sensor with respect to the work part and determines whether the part is consistent with the quality specifications.

Material handling robots



Robot used for part inspection



Robots used in automobile sectors

Robot used for welding parts