Subject Title	**ELEMENTS OF MECHANICAL ENGINEERING**		
Subject Code	18EME15	**IA**	40
Number of Lecture Hrs /	05 hrs	**Exam Marks(appearing for)**	60(100)
Total Number of Lecture	40	**Exam Hours**	03

CREDITS – 03

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 numericals).
Steam: Formation of steam and thermodynamic properties of steam (simple numericals). 8 Hour

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. 8 Hours

Module- 3

Internal Combustion Engines
Classification, I.C. 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, and 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.
8 Hours

Module- 4

Properties, Composition and Industrial Applications of engineering materials Metals – Ferrous: cast iron, tool steels and stainless steels and nonferrous: aluminum, 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. 8 Hours

Module- 5

Lathe - Principle of working of a center lathe. Parts of a lathe. Operations on lathe - Turning, Facing, Knurling, Thread Cutting, Drilling, Taper turning by Tailstock offset method and Compound slide swiveling 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 centers and Turning centers.

Robots: Robot anatomy, joints and links, common robot configurations. Applications of Robots in material handling, processing and assembly and inspection. 8 Hours

Module - 1

Energy Resources

There are nine major areas of energy resources. They fall into two categories: nonrenewable and renewable. Nonrenewable energy resources, like coal, nuclear, oil, and natural gas, are available in limited supplies. This is usually due to the long time it takes for them to be replenished. Renewable resources are replenished naturally and over relatively short periods of time. The five major renewable energy resources are solar, wind, water (hydro), biomass, and geothermal.

Since the dawn of humanity people have used renewable sources of energy to survive wood for cooking and heating, wind and water for milling grain, and solar for lighting fires. A little more than 150 years ago people created the technology to extract energy from the ancient fossilized remains of plants and animals. These super-rich but limited sources of energy (coal, oil, and natural gas) quickly replaced wood, wind, solar, and water as the main sources of fuel.

Fossil fuels make up a large portion of today's energy market, although promising new renewable technologies are emerging. Careers in both the renewable and nonrenewable energy

Industries are growing; however, there are differences between the two sectors. They each have benefits and challenges, and relate to unique technologies that play a role in our current energy system. For a range of reasons, from the limited amount of fossil fuels available to their effects on the environment, there is increased interest in using renewable forms of energy and developing technologies to increase their efficiency. This growing industry calls for a new workforce.

Renewable Energy sources: Defined as the energy resources which are produced continuously in nature and are essentially inexhaustible at least in the time frame of human societies.

1. Ex: Direct solar energy
2. Wind energy
3. Tidal energy
4. Hydel energy
5. Ocean thermal energy

Non-Renewable Energy sources: defined as the energy resources which have been accumulated over the ages and not quickly replenish able when they are exhausted.

1. Ex: Fossil fuels
2. Nuclear fuels

NUCLEAR FUELS

- ❖ Alternative source of energy.
- ❖ Uranium is the main element required to run a nuclear reactor.
- ❖ Nuclear fission or fusion will produce tremendous amount of heat energy.

Nuclear fusion: Fusion energy is a form of nuclear energy released by the fusion (combustion) of two light nuclei (i.e. nuclei of low mass) to produce heavier mass.

$$4\,{}_1H^1 \rightarrow 2He^4 + 2\,{}_{+1}e^0$$

Nuclear fission:

$${}_{92}U^{235} + {}_0N^1 \rightarrow {}_{56}Ba^{137} + {}_{56}Kr^{97} + 2\,{}_0N^1 + \text{Energy}$$

- Nuclear fission is the process, where a heavy nucleus splits into two fragments of more or less of equal mass.

- Neutron + Heavy nucleus → Fission fragments + Neutrons (2 to 3) + energy
- The energy released by fission of I gram of U-235 is equal to that due to combustion of 50 million tons of coal ; it is about 8.5 x 10^{10} J.

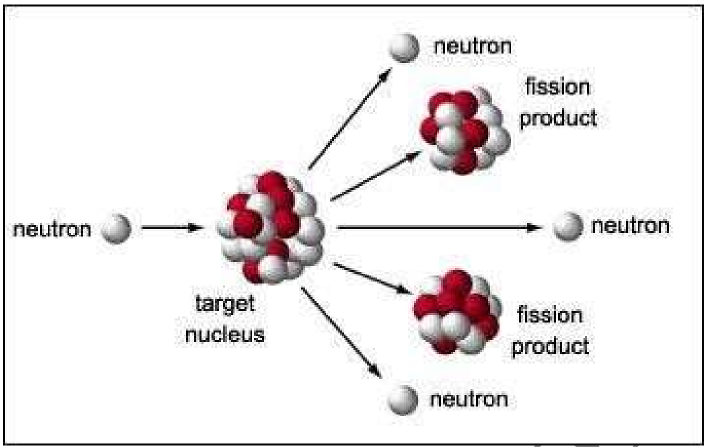


Figure 1: Nuclear fission

NUCLEAR REACTOR

- A nuclear reactor is a device which controls the nuclear fission chain reaction to hardness nuclear energy for peaceful purposes.
- A nuclear reactor which is used t generate electricity, is called a nuclear power plant.
- Fuel in the form of pellets is enclosed in several tubular claddings of steel or aluminum. This is called fuel assembly. Enriched U-235 or Pu-239 is the fuel material.
- A coolant is circulated through the reactor to remove the heat generated. Ordinary water is most commonly used coolant.
- Rods made of boron or cadmium which is neutron absorbers are used as control rods. The neutrons available for fission are controlled by moving the control rods in and out of the nuclear core. The rods can be used to shut down the reactor.

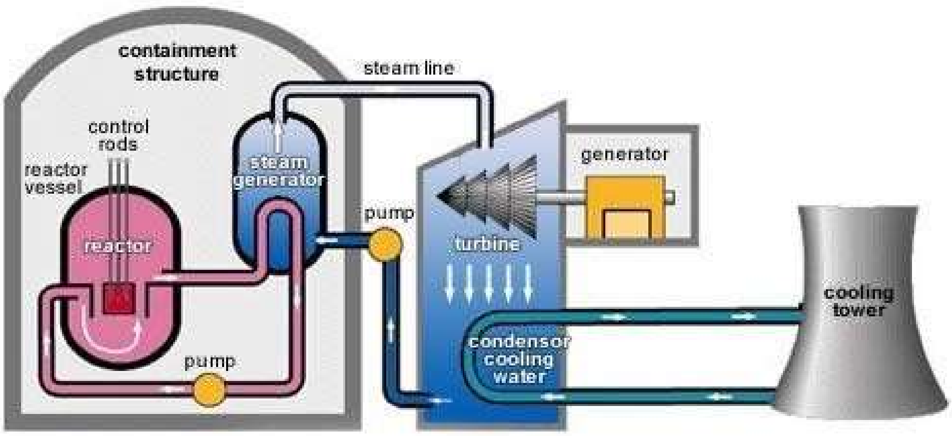


Figure 2: Nuclear reactor

- Heat produced during fission process is absorbed by the coolant and is used to convert water in to steam in the heat exchanger. The steam is used to rotate the steam turbine. The steam turbine is connected to a generator which generates electricity.
- The entire reactor is enclosed in a concrete building with lead sheets covered inside to prevent radioactive radiations being released in to the environment.

Thermodynamics

Thermodynamics involves the storage, transformation, and transfer of energy. Energy is stored as internal energy (due to temperature), kinetic energy (due to motion), potential energy (due to elevation), and chemical energy (due to chemical composition); it is transformed from one of these forms to another; and it is transferred across a boundary as either heat or work. We will present equations that relate the transformations and transfers of energy to properties such as temperature, pressure, and density. The properties of materials thus become very important. Many equations will be based on experimental observations that have been presented as mathematical statements, or laws: primarily the first and second laws of thermodynamics.

The mechanical engineers objective in studying thermodynamics is most often the analysis of a rather complicated device, such as an air conditioner, an engine, or a power plant. As the fluid flows through such a device, it is assumed to be a continuum in which there are measurable quantities such as pressure, temperature, and velocity. This book, then, will be restricted to macroscopic or engineering thermodynamics. If the behavior of individual molecules is important, statistical thermodynamics must be consulted.

Macroscopic Vs Microscopic Viewpoint

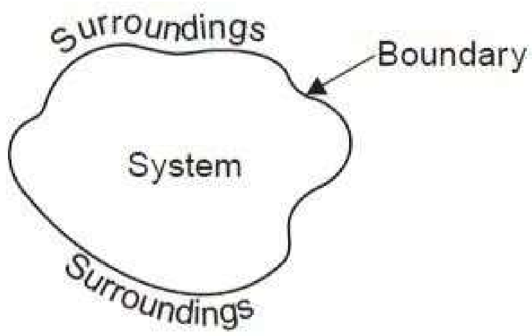
There are two points of view from which the behavior of matter can be studied: the macroscopic and the microscopic. In the macroscopic approach, a certain quantity of matter is considered, without the events occurring at the molecular level being taken into account. From the microscopic point of view, matter is composed of myriads of molecules. If it is a gas, each molecule at a given instant has a certain position, Velocity and energy, and for each molecule these change very frequently as a result of collisions. The behavior of the gas is described by summing up the behavior of each molecule. Such a study is made in microscopic or statistical thermodynamics. Macroscopic thermodynamics is only concerned with the effects of the action of many molecules, and these effects can be perceived by human senses. For example, the macroscopic quantity, Pressure, is the average rate of change of momentum due to all the molecular collisions made on a unit area. The effects of pressure can be felt. The macroscopic point of view is not concerned with the action of individual molecules, and the force on a given unit area can be measured by using, e.g., Pressure gauge.

System:

We need to fix our focus of attention in order to understand heat and work interaction. The body or assemblage or the space on which our attention is focused is called system. The system may be having real or imaginary boundaries across which the interaction occurs. The boundary may be rigid and sometimes take different shapes at different times. If the system has imaginary boundary then we must properly formulate the idea of system in our mind.

Surroundings:

Everything else apart from system constitutes surroundings. The idea of surroundings gets formulated the moment we define system. System and surroundings together form what is known as universe.



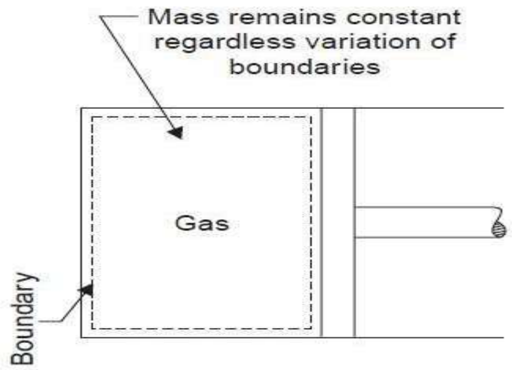
The system.

Closed system:

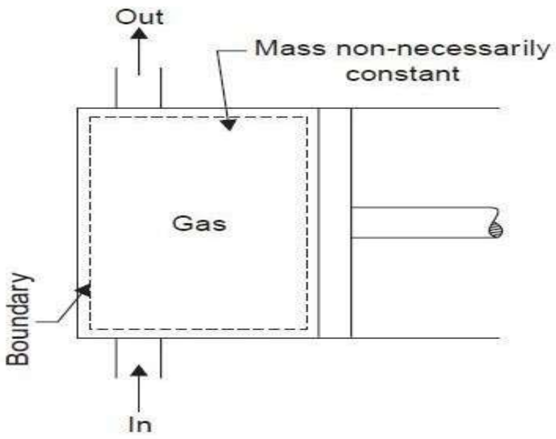
If the system has a boundary through which mass or material cannot be transferred, but only energy can be transferred is called closed system. In an actual system, there may not be energy transfer. What is essential for the system to be closed is the inability of the boundary to transfer mass only.

Open system:

If the system has a boundary through which both energy and mass can transfer, then it is called open system.



Closed system.



Open system.

Isolated System

An isolated system is that system which exchanges neither energy nor matter with any other system or with environment.

Properties:

Variables such as pressure, temperature, volume and mass are properties. A system will have a single set of all these values.

Intensive properties:

The properties that are independent of amount contained in the system are called extensive properties. For example, take temperature. We can have a substance with varying amount but still same temperature. Density is another example of intensive property because density of water is same no matter how much is the water. Other intensive properties are pressure, viscosity, surface tension.

Extensive properties:

The properties that depend upon amount contained in the system are called extensive properties. Mass depends upon how much substance a system has in it therefore mass is an extensive property.

State:

It is defined as condition of a system in which there are one set of values for all its properties. The properties that define the state of a system are called state variables.

There is certain minimum number of intensive properties that requires to be specified in order to define the state of a system and this number is uniquely related to the kind of system. This relation is phase rule which we shall discuss little later.

Process:

The changes that occur in the system in moving the system from one state to the other is called a process. During a process the values of some or all state variables change. The process may be accompanied by heat or work interaction with the system.

Equilibrium state:

A system is said to be in thermodynamic equilibrium if it satisfies the condition for thermal equilibrium, mechanical equilibrium and also chemical equilibrium. If it is in equilibrium, there are no changes occurring or there is no process taking place.

Thermal equilibrium:

There should not be any temperature difference between different regions or locations within the system. If there are, then there is no way a process of heat transfer does not take place. Uniformity of temperature throughout the system is the requirement for a system to be in thermal equilibrium. Surroundings and the system may be at different temperatures and still system may be in thermal equilibrium.

Mechanical equilibrium:

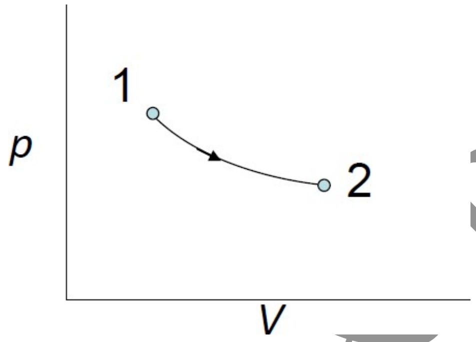
There should not be any pressure difference between different regions or locations within the system. If there are, then there is no way a process of work transfer does not take place. Uniformity of pressure throughout the system is the requirement for a system to be in mechanical equilibrium. Surroundings and the system may be at pressures and still system may be in mechanical equilibrium.

Chemical equilibrium:

There should not be any chemical reaction taking place anywhere in the system, then it is said to be in chemical equilibrium. Uniformity of chemical potential throughout the system is the requirement for a system to be in chemical equilibrium. Surroundings and the system may have different chemical potential and still system may be in chemical equilibrium.

Thermodynamic process:

A system in thermodynamic equilibrium is disturbed by imposing some driving force; it undergoes changes to attain a state of new equilibrium. Whatever is happening to the system between these two equilibrium states is called a process. It may be represented by a path which is the locus all the states in between on a p-V diagram as shown in the figure below.



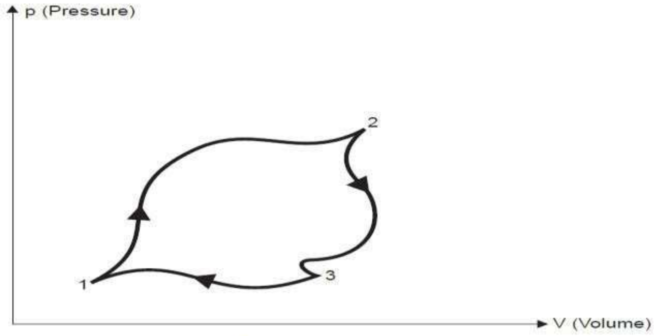
For a system of gas in piston and cylinder arrangement which is in equilibrium, altering pressure on the piston may be driving force which triggers a process shown above in which the volume decreases and pressure increases. This happens until the increasing pressure of the gas equalizes that of the surroundings. If we locate the values of all intermediate states, we get the path on a p-V diagram.

Quasi-static process:

Quasi means „almost". A quasi-static process is also called a reversible process. This process is a succession of equilibrium states and infinite slowness is its characteristic feature.

CYCLE

Any process or series of processes whose end states are identical is termed a cycle.



Cycle of operations.

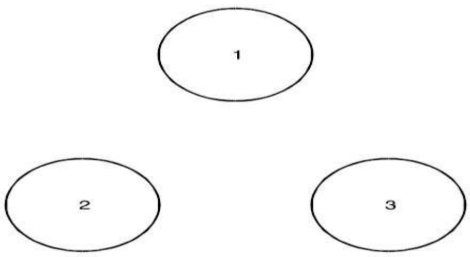
TEMPERATURE

The temperature is a thermal state of a body which distinguishes a hot body from a cold body. The temperature of a body is proportional to the stored molecular energy i.e., the average molecular kinetic energy of the molecules in a system. (A particular molecule does not have a temperature, it has energy. The gas as a system has temperature). Instruments for measuring ordinary temperatures are known as **thermometers** and those for measuring high temperatures are known as **pyrometers.**

It has been found that a gas will not occupy any volume at a certain temperature. This temperature is known as absolute zero temperature. The temperatures measured with absolute zero as basis are called absolute temperatures. Absolute temperature is stated in degrees centigrade. The point of absolute temperature is found to occur at 273.15°C below the freezing point of water. Then: Absolute temperature = Thermometer reading in °C + 273.15. Absolute temperature is degree centigrade is known as degrees Kelvin, denoted by K (SI unit).

ZEROTH LAW OF THERMODYNAMICS

'Zeroth law of thermodynamics' states that if two systems are each equal in temperature to a third, they are equal in temperature to each other.



Zeroth law of thermodynamics

WORK AND HEAT

Mechanics definition of work: Work is done when the point of application of a force moves in the direction of the force. The amount of work is equal to the product of the force and the distance through which the point of application moves in the direction of the force. i.e., work is identified only when a force moves its point of application through an observable distance.

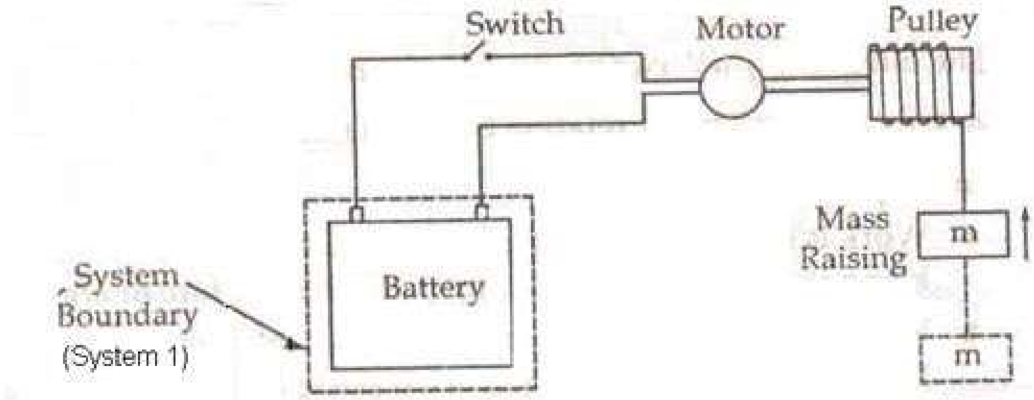
Mathematically, $W = \int_1^2 F.dx$

However, when treating thermodynamics from a macroscopic point of view, it is advantageous to tie in the definition work with the concepts of systems, properties and processes.

Thermodynamic definition of work: It is a kind of interaction that would occur at the system boundaries. It can be positive or negative. Definition of Positive work is said to be done by a system when the „sole effect" external to the system could be reduced to the raising of a weight.

Comments: The word „sole effect" indicates that the raising of weight should be the only interaction between the system and surroundings in order to say that there is work interaction between the system and the surroundings. The phrase „external to the system" indicates that the work is a boundary phenomenon. The magnitude of work interaction depends upon the system boundary. This is illustrated with an example.

Figure 1: Equivalence of Current Work Interaction between the System and the Surroundings



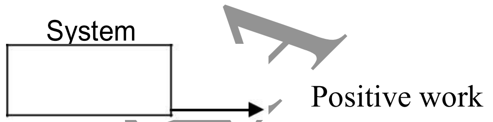
For the two systems shown in figure, system (1) comprising battery alone has work interaction with the surroundings, whereas for system (2) which includes motor, weights etc along with the battery, the work interaction is zero.

The word „could be reduced to" indicates that it is not necessary that weights should actually be raised in order to say that there is work interaction between the system and the surroundings. It is just sufficient to have an effect which is equivalent to the raising of weight.

Here an electrical storage battery constitutes system 1 whose terminals are connected to an electrical resistance coil through a switch. The circuit external to the battery constitutes the surroundings. When the switch is closed, the current flow through the coil and the resistance (surroundings) become warmer and the charge of the battery (system) decreases. Obviously there has been interaction between the system and the surroundings. According to mechanics this interaction cannot be classified as work because there has been no action of force through a distance or of torque through an angle. However, as per thermodynamics concepts, the battery (system) does work as the electrical energy crosses the system boundary. Further, the electrical resistance can be replaced by an ideal frictionless motor pulley arrangement which can wind a string and thereby raise suspended weight. The sole effect, external to the system, is raising of a weight. As such interaction of battery with resistance coil is a work.

Sign Conventions for work:

Work is said to be positive, if it is done by the system on the surroundings



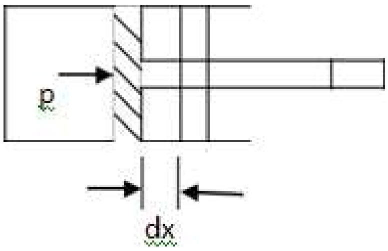
Work is said to be negative, if it is done on the system by the surroundings

Therefore, $W_{system} + W_{surroundings} = Zero$

The unit of work is N-m or Joule. The rate at which work is done by, or upon, the system is known as power. The unit of power is J/s or watt.

Work is one of the forms in which a system and its surroundings can interact with each other. There are various types of work transfer which can get involved between them.

Work done at the moving boundary of a system (Expression for displacement work)



Consider a piston-cylinder arrangement which contains certain working fluid undergoing quasi-static process.

Let p = Pressure exerted by the fluid on the piston

A = Area of c/s of the cylinder

dx = displacement of the piston when the system has undergone an infinitesimal change of state.

$\therefore$ Displacement work: dw = Force x displacement

= p.A x dx

i.e., dw = p.dV

Where dv is the infinitesimal change in volume of the system. If the system undergoes a finite change of state from state (1) to state (2).

Then the displacement work is given by

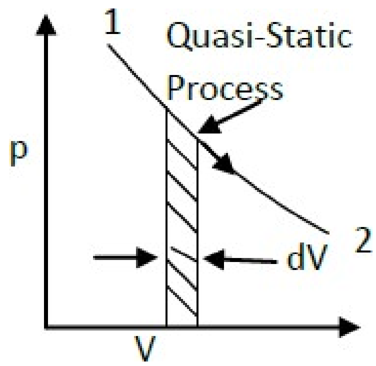
$$\int_1^2 dw = \int_1^2 p.dV$$

The integration of above equation can be done only if the relationship between P and v during the process is known i.e., if the path of the process is well defined. Hence, work is a path function. As work depends on the path of the process which it follows, there will be different values of work for different process between two given states. Hence the differentials of the path functions are in exact differentials. The symbol δ will be used to designate inexact differentials. The magnitude of the work transfer by the system during the process from state.

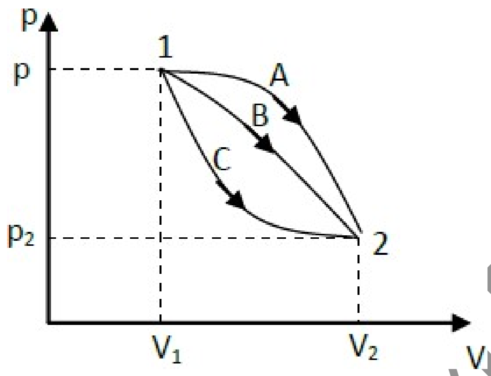
(1) to state (2) containing unit mass of the fluid will be written as, or

$$\int_1^2 \delta w = {}_1W_2 \text{ or } W_{1\text{-}2}.$$

The process can be represented by a full line on an appropriate thermodynamic coordinate system (in this case p-V diagram) and the area under the curve gives the work done by the system during the process.



Quasi-Static pdV work



Work-a path function

Inspection of the P V diagram above shows that just by specifying the end states 1 and 2 does not determine the area (or work); the nature of the curve needs to be known. The curve may be arched upwards or it may sag downwards, and the area under the curve will vary accordingly. For the same initial and final states, the work done by the system in following the paths A, B and C are different. Therefore the work is a path function and not a point function. Accordingly the work transfer across the system boundaries is not classified as a thermodynamic property.

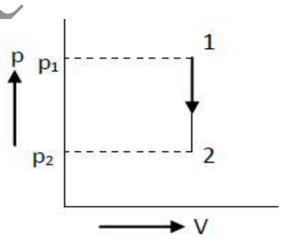
The expression w = pdV holds good under the following restrictions.

i) The system is closed
ii) There is no friction within the system
iii) The pressure and all other properties are the same on all the boundaries of the system
iv) The system is not influenced by motion, gravity, capillarity, electricity and magnetism

Expression for Displacement work for various Quasi-Static Processes (pdV work):

1) Constant volume process: **(Isochoric Process)**.

For a constant volume process i.e., V = constant (dV = 0) as represented in the p-V diagram below.

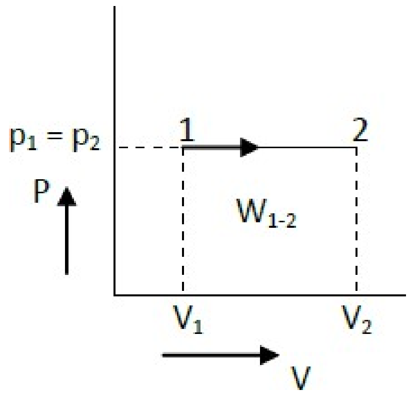


$W_{1-2} = \int_1^2 p.dV \quad$ but dV = 0

$\therefore \boxed{(W_d)_{1-2} = 0}$

2) Constant pressure process: **(Isobaric process)**.

For a closed system undergo a constant pressure process from state 1 (volume V_1 and pressure p_1) to a final state 2 (volume V_2). The process is represented in the p-V diagram as shown below.



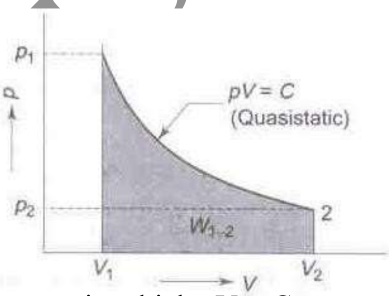
$W_{1\text{-}2} = \int_1^2 p.dV$, where p = constant

$\therefore W_{1\text{-}2} = p \int_1^2 dV$

$\therefore \boxed{(W_d)_{1\text{-}2} = p\,(V_2 - V_1)}$

3) Hyperbolic process i.e., pV = constant:

The hyperbolic expansion process from state 1 to state 2 is represented on a p-V diagram as shown below.



Process in which pV = Constant

Process in which pV = Constant

$W_{1\text{-}2} = \int_1^2 p.dV$

But pV = constant i.e., $pV = p_1V_1$, $\therefore p = \frac{p_1V_1}{V}$

$\therefore W_{1-2} = \int_1^2 p.dV$

$= \int_1^2 \frac{p_1 V_1}{V} .dV$

$= p_1 V_1 [\ln V_2 - \ln V_1]$ where p_1 = Initial pressure of the system

V_1 = Initial volume of the system

p_2 = Final pressure of the system

V_2 = Final volume of the system

i.e., $(W_d)_{1-2} = p_1 V_1 \ln \frac{V_2}{V_1}$

4) Polytropic process, i.e., pV^n = constant

A polytropic process is represented on a p-V diagram as shown below.

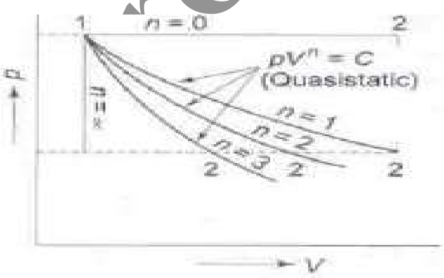


Figure: Process in which pV^n = Constant

$W_{1-2} = \int_1^2 p.dV$

But pV^n = constant i.e., $pV^n = p_1 V_1^n = p_2 V_2^n$

$\therefore W_{1-2} = \int_1^2 \frac{p_1 V_1^n}{V^n} .dV$

$= p_1 V_1^n \int_1^2 V^{-n} .dV$

$= p_1 V_1^n \left[\frac{V^{-n+1}}{-n+1} \right]_1^2$

but $p_1 V_1^n = p_2 V_2^n$

$= \frac{p_2 V_2 - p_1 V_1}{1-n}$

$$\therefore (W_d)_{1\text{-}2} = \frac{p_1V_1 - p_2V_2}{n-1}$$

Where 'n' is called the index of expansion or compression

Note: 1. Work is a transient phenomenon i.e., it is present only during a process. Mathematically

speaking, work is a path function.

$$\therefore \int_1^2 dw \quad = w_2 - w_1 \text{ is wrong}$$

$$= w_{1\text{-}2} \text{ i.e., } \delta w \text{ is inexact differentials.}$$

2. For irreversible process $\delta w \neq \int_1^2 P.dv$

Heat: Heat is a mode of energy transfer that takes place between the system and the surroundings solely due to the temperature difference. Thus, heat is a transient phenomenon. It can be recognized only during a process. It is not a thermodynamic property of the system. Like work, heat is a path function i.e., the magnitude of heat transfer between the system and surroundings depends upon the type of process the system is undergoing.

Heat transfer always takes place from a region of higher temperature to a region of low temperature. The magnitude of the heat transfer into unit mass of the fluid in the system during a process from state (1) to state (2) will be written as $\int_1^2 \delta q = {}_1q_2 \; or \; q_{1-2}$ and not as $\int_1^2 \delta q = q_1 - q_2$

$\int_1^2 \delta q$ represents the total heat transfer that takes place when the system undergoes a change of state from state 1 to state 2.

Sign Convention:

Heat transfer is considered as positive if it takes place from the surroundings to the system and it is considered as negative if it takes place from the system to the surroundings.

During an adiabatic process, Q = 0

Units: Since heat is a form of energy transfer it will have the same units as that of energy. In SI units it is expressed in Joules (J) or Kilo Joules (kJ).

Comparison between work and heat:

Similarities:

- Both are path functions and inexact differentials.
- Both are boundary phenomenon i.e., both are recognized at the boundaries of the system as they cross them.
- Both represent transient phenomenon; these energy interactions occur only when a system undergoes change of state i.e., both are associated with a process, not a state. Unlike properties, work or heat has no meaning at a state.
- A system possesses energy, but not work or heat.
- Concepts of heat and work are associated not with a store but with a process.

Dissimilarities:

- Heat is energy interaction due to temperature difference only; work is by reasons other than temperature difference.
- In a stable system, there cannot be work transfer; however there is no restriction for the transfer of heat.
- The sole effect external to the system could be reduced to rise of a weight but in the case of a heat transfer other effects are also observed.
- Heat is low grade energy whereas work is a high grade energy

FIRST LAW OF THERMODYNAMICS

First Law of Thermodynamics to open system:

In the case of closed system there is only energy transfer across the system boundary. But in many engineering applications we come across open systems where in both mass and energy transfer takes place. The energies that cross the system boundary are as follows.

1) **Internal energy**: Each kg of matter has the internal energy „u‟ and as the matter crosses the system boundary the energy of the system changes by „u‟ for every kg mass of the matter that

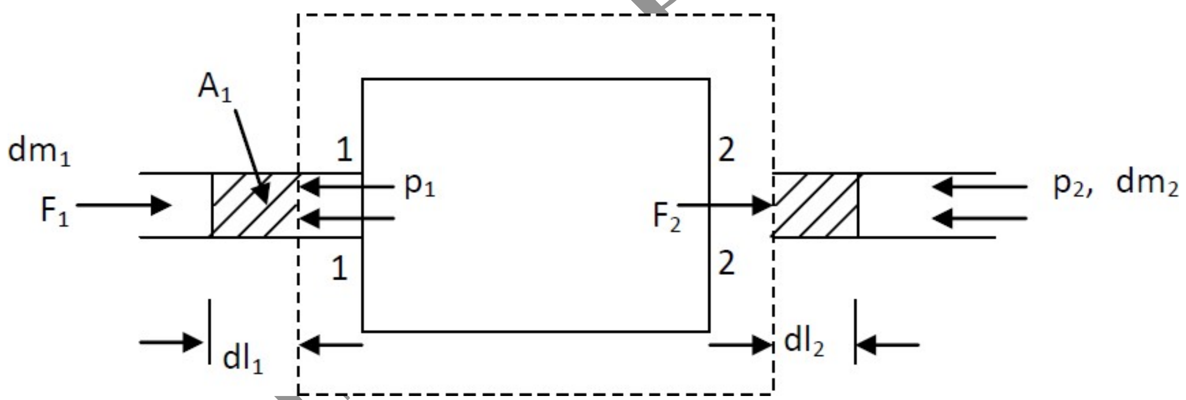
crosses the system boundary.

2) **Kinetic energy**: Since the matter that crosses the system boundary will have some velocity say V each kg of matter carries a k.E. $V^2/2$ thus causing the energy of the system to change by this amount for every kg of matter entering the system boundary.

3) **Potential energy**: P.E. is measured with reference to some base. Thus „Z" is the elevation of the matter that is crossing the system boundary, and then each kg of matter will possess a P.E. of gZ.

4) **Flow energy or Flow work**: This energy is not directly associated with the matter crossing the system boundary. But it is associated with the fact that there must be some pumping process which is responsible for the movement of the matter across the system boundary. Thus external to the system there must be some force which forces the matter across the system boundary and the energy associated with this is called flow energy.

Flow Work: Consider a flow process in which a fluid of mass dm_1 is pushed into the system at section 1 and a mass dm_2 is forced out of the system at section 2 as shown in fig.



In order to force the fluid to flow across the boundary of the system against a pressure p_1, work is done on the boundary of the system. The amount of work done is $\delta W = - F_1.dl_1$,

Where F_1 is the force and dl_1 is the infinitesimal displacement, but $F_1 = p_1A_1$

$\therefore \delta W = - p_1A_1\ dl_1 = - p_1dv_1$

i.e., the flow work at section 1 = $- p_1v_1$

Similarly, the work done by the system to force the fluid out of the system at section 2 = $+ p_2v_2$

Hence net flow work = $p_2V_2 – p_1V_1$

For unit mass, the flow work is ($p_2V_2 – p_1V_1$). Flow work is expressed entirely in terms properties of the system. The net flow work depends out on the end state of the fluid and it is a thermodynamics property. Also the fluid contains energies like internal energy, potential energy and due to the motion of the fluid, kinetic energy, in addition to the flow work. When a fluid enters an open system, these properties will be carried into the system. Similarly when the fluid leaves the system, it carries these energies out of the system. Thus in an open system, there is a change in energy of the system.

1. **Control Volume**: The first and most important step in the analysis of an open system is to imagine a certain region enclosing the system. This region having imaginary boundary is called control volume, which can be defined as follows. A C.V. is any volume of fixed shape, and of fixed position and orientation relative to the observer. Across the boundaries of the C.V. apart from mass flow, energy transfer in the form of heat and work can take place just as similar to the energy transfer across the boundaries of a system.

Thus the difference between C.V. and system are

i) The system boundary may and usually does change shape, position, orientation relative to the observer. The C.V. does not by definition.

ii) Matter may and usually does flow across the system boundary of the C.V. No such flow takes place across the system boundary by definition.

First law of thermodynamics for an open system (Flow process):

We have 1st law of thermodynamics to a closed system as,

$$\delta Q – \delta W = dU + d(KE) + d\ (PE)$$

$= d\ [E]$

$$dm_1\left[p_1v_1+u_1+\frac{V_1^2}{2}+gZ_1\right]$$

$$dm_2\left[p_2v_2+u_2+\frac{V_2^2}{2}+gZ_2\right]$$

The flow process is shown in fig. This analysis can be expressed mathematically as,

$$\delta Q-\delta W+dm_1\left[p_1v_1+u_1+\frac{V_1^2}{2}+gZ_1\right]$$

Where state (1) is the entering condition and state (2) is the leaving condition of the fluid. This is a general equation of the first law of thermodynamics applied to open system.

Note: The equation is valid to both open and closed system. For closed system, $dm_1=0$ & $dm_2=0$

Energy Equation for open system: The general form of first law of thermodynamics applied to an open system is called steady-flow energy equation (SFEE) i.e., the rate at which the fluid flows through the C.V. is constant or steady flow. SFEE is developed on the basis of the following assumptions.

i) The mass flow rate through the C.V. is constant, i.e., mass entering the C.V. / unit time = mass leaving the C.V. /unit time. This implies that mass within the C.V. does not change.

ii) The state and energy of a fluid at the entrance and exit do not vary with time, i.e., there is no change in energy within the C.V.

iii) The rates of heat and work transfer into or out of the C.V. do not vary with time.

For a steady flow process, $m=m_1=m_2$ & $d(E)_0 = 0$ as $Q \neq f(T)$ & $W \neq f(T)$

First law of thermodynamics for a closed system undergoing a cyclic process

"When a system undergoes a thermodynamic cyclic process, then the net heat supplied to the system from the surroundings is equal to the net work done by the system on its surrounding".

i.e., $\oint \delta Q = \oint \delta W$ where $\oint$ represents the sum for a complete cycle.

The first law of thermodynamics cannot be proved analytically, but experimental evidence has repeatedly confirms its validity and since no phenomenon has been shown to contradict it, therefore the first law is accepted as a law of nature

Joule’s Experiment:

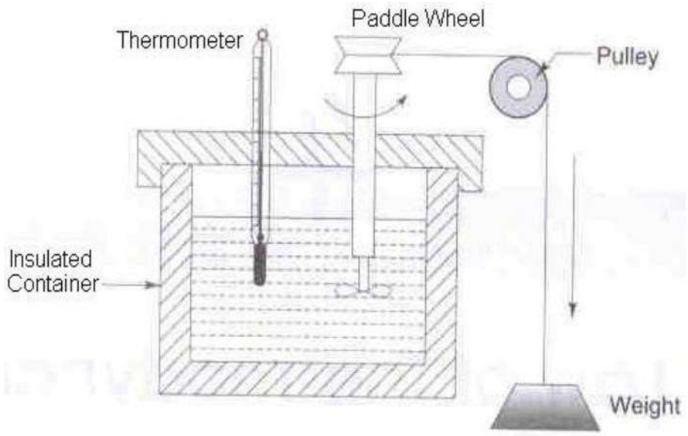


Figure: Joule‟s Experiment

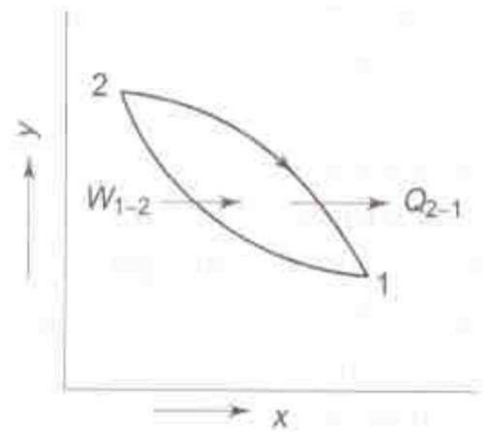


Figure: Cycle completed by a system with two energy interactions i.e., work transfer followed by heat transfer

Figure shows the experiment for checking the first law of thermodynamics. The work input to the paddle Wheel is measured by the fall of weight, while the corresponding temperature rise of liquid in the insulated container is measured by the thermometer.

The process 1-2 undergone by the system is shown in figure i.e., W_{1-2}. Let the insulation be removed. The system and the surrounding interact by heat transfer till the system returns to its original temperature, attaining the condition of thermal equilibrium with the atmosphere. The amount of heat transfer Q_{2-1} from the system during this process 2-1 is shown in figure. The system thus executes a cycle, which consists of a definite amount of work input W_{1-2} to the system followed by the transfer of an amount of heat Q_{2-1} from the system.

Joule carried out many such experiments with different type of work interactions in a variety of Systems, he found that the net work input the fluid system was always proportional to the net heat transferred from the system regardless of work interaction. Based on this experimental evidence Joule stated that,

“When a system (closed system) is undergoing a cyclic process, the net heat transfer to the system is directly proportional to the net work done by the system”. This statement is referred to as the first law for a closed system undergoing a cyclic process.

$$\text{i.e., } \oint \delta Q \;\alpha\; \oint \delta W$$

If both heat transfer and work transfer are expressed in same units as in the S.I. units then the constant of proportionality in the above equation will be unity and hence the mathematical form of first law for a system undergoing a cyclic process can be written as

$$\text{i.e., } \oint \delta Q \,\alpha \oint \delta W$$

If the cycle involves many more heat and work quantities as shown in figure, the same result will be found.

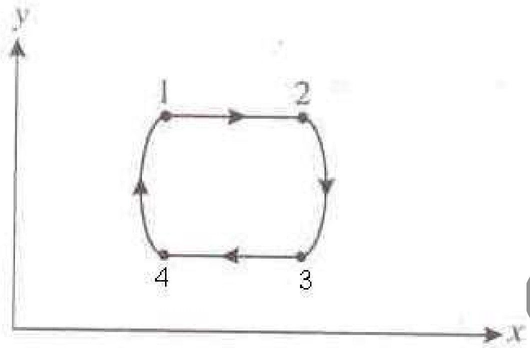


Figure: Cyclic Process on a Property Diagram

For this cyclic process the statement of first law can be written as

$$\oint_{1-2-3-4-1} \delta Q = \oint_{1-2-3-4-1} \delta W$$

The cyclic integral in the above equation can be split into a series of non cyclic integral as

$$\int_1^2 \delta Q + \int_2^3 \delta Q + \int_3^4 \delta Q + \int_4^1 \delta Q = \int_1^2 \delta W + \int_2^3 \delta W + \int_3^4 \delta W + \int_4^1 \delta W$$

or ${}_1Q_2 + {}_2Q_3 + {}_3Q_4 + {}_4Q_1 = {}_1W_2 + {}_2W_3 + {}_3W_4 + {}_4W_1$

i.e., $\oint \delta Q = \oint \delta W$

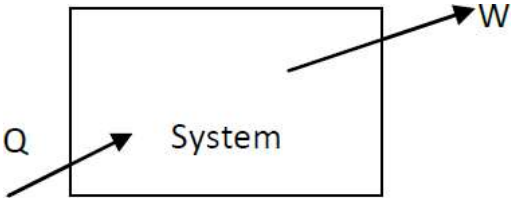
or $(\sum Q)_{cycle} = (\sum W)_{cycle}$

This is the first law for a closed system undergoing a cyclic process. i.e., it is stated as "When a closed system is undergoing a cyclic process the algebraic sum of heat transfers is equal to the algebraic sum of the work transfers".

First law for a closed system undergoing a non-cyclic process (i.e., for a change of state):

If a system undergoes a change of state during which both heat transfer and work transfer are involved, the net energy transfer will be stored or accumulated within the system.

If Q is the amount of heat transferred to the system and W is the amount of work transferred from the system during the process as shown in figure,

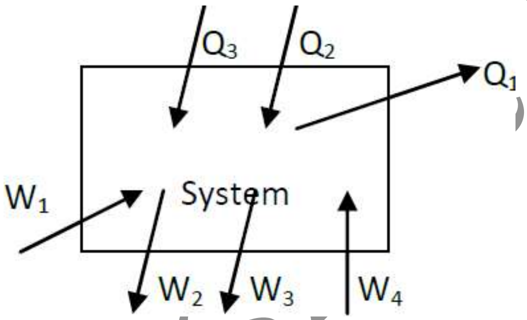


The net energy transfer (Q-W) will be stored in the system. Energy in storage is neither heat nor work and is given the name internal energy or simply, the energy of the system.

$$Q - W = \Delta E$$

$$\text{Or } Q = \Delta E + W$$

If there are more energy transfer quantities involved in the process as shown in figure.



First law gives

$(Q_2 + Q_3 - Q_1) = \Delta E + (W_2 + W_3 - W_1 - W_4)$

i.e., energy is thus conserved in the operation. Therefore the first law is a particular formulation of the principle of the conservation of energy. It can be shown that the energy has a definite value at every state of a system and is therefore, a property of a system.

Problems:

1. In a cyclic process, heat temperature are + 14.7 kJ, -25.2 kJ, -3.56 kJ and +31.5 kJ. What is the net work for this cyclic process?

Solution: 1st law of thermodynamics for a cyclic process is

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

i.e., Net work = 14.7 – 25.2 -3.56 + 31.5= 17.44 kJ

2. Consider a cyclic process in a closed system which includes three heat interactions, namely Q_1 = 20 kJ, Q_2 = -6kJ, and Q_3 = -4 kJ and two work interactions for which W_1 = 4500 N-m. Compute the magnitude of the second work interaction W_2 in Nm.

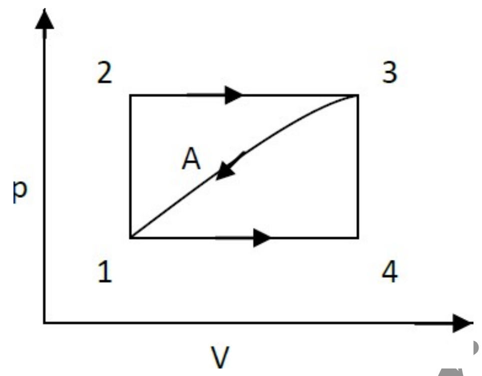
Solution: We have for a closed system undergoing cyclic process,

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

$$20000 - 6000 - 4000 = 4500 + W_2$$

$$W_2 = 5500 \text{ Nm}$$

3. When the state of a system changes from state 1 to state 3 along the path 1-2-3 as shown in figure, 80 kJ of heat flows into the system and the system does 30 kJ of work. (a) How much heat flows into the system along the path 1-4-3 if work done by the system is 10 kJ (b) when the state of the system is returned from state 3 to state 1 along the curved path, the work done on the system is 20 kJ. Does the system absorb or liberate heat? Find its magnitude. (c) If $U_1 = 0$ and $U_4 = 40$kJ, find the heat absorbed in the process 1-4 and 4-3 respectively. Solution:



a) Along the path 1-2-3,

From 1st law of thermodynamics, $Q_{1-3} = U_3 - U_1 + W_{1-3}$

from the data given, $80 = (U_3 - U_1) + 30$ $(U_3 - U_1) = 50$ kJ

along the path 1-4-3, we have

$Q_{1-3} = U_3 - U_1 + W_{1-3}$

From the data given, $Q_{1-3} = 50 + 10$

= 60 Kj

i.e., Work is done by the system

b) Along the path 3-A-1,

$(U_1 - U_3) = Q_{3-1} - W_{3-1}$

Or $Q_{3-1} = (U_1 - U_3) + W_{3-1}$

$= -50 - 20 = -70$ kJ

Negative sign indicates that heat is liberated from the system. c) Along the path 1-4

$Q_{1-4} = U_4 - U_1 + W_{1-4}$

$= 40 - 0 + 10$(since $W_{1-4-3} = W_{1-4} + W_{4-3} = 10 + 0 = 10$)

= 50 kJ

Positive sign indicates heat is absorbed by the system

Along the path 4-3

Q4-3 = U3 – U4 + W4-3

= 50 – 40 + 0 = 10 kJ

4. A domestic refrigerator is loaded with food and the door closed. During a certain period the machine consumes 1 kwhr of energy and the internal energy of the system drops by 5000 kJ. Find the net heat transfer. For the system.

Solution: W_{1-2} = 1 kwhr = -1 x3600 kJ $U_2 – U_1$ = -5000 kJ

from 1st law, $Q_{1-2} = (U_2-U_1) + W_{1-2}$

= -5000 -3600 = -8600 kJ = - 8.6 mJ

5. For the following process in a closed system find the missing data (all in kJ)

Process	Q	W	U1	U2	ΔU
a)	<u>35</u>	20	-10	<u>5</u>	15
b)	15	-6	<u>-27</u>	-6	<u>21</u>
c)	-7	10	20	<u>3</u>	<u>-17</u>
d)	<u>-27</u>	-7	<u>28</u>	8	-20

Solution: Process (a): Q = ΔU + W

$= U_2 – U_1 + W_{1-2}$ but $U_2-U_1 = 15$ $U_2 = 5$

= 15 + 20 = 35 kJ

Process (b): $Q = U_2 – U_1 + W$

$15 = -6-U_1-6$

$27 = -U_1$ $U_1 = -27$ kJ

$\Delta U = U_2 – U_1 = - 6 + 27 = 21$ kJ

Process (c) $- 7 = U_2 – 20 + 10$

$U_2 = 3$ kJ $\Delta U = 3-20 = -17$ kJ

Process (d) $\Delta U = U_2 – U_1 = - 20$

$= 8 – U_1 = - 20$ $U_1 = 28$ kJ

A = 8 – 28 – 7 = - 27 kJ

6. A fluid system, contained in a piston and cylinder machine, passes through a complete cycle of four processes. The sum of all heat transferred during a cycle is -340 kJ. The system completes 200 cycles minutes. Complete the following table showing the method for each item, and compute the net rate of work output in kW

Process	Q (kJ/min)	W (kJ/min)	ΔE (kJ/min)
1-2	0	4340	-4340
2-3	42000	0	42000
3-4	-4200	69000	-73200
4-1	-105800	-141340	35540

Solution: Given $\sum_{cycle} Q$ = -340 kJ, No. of cycle = 200 cycles / min

Process 1-2: $Q_{1-2} = (E_2 - E_1) + W_{1-2}$

$0 = \Delta E + W_{1-2}$

$\Delta E = -4340$ kJ/min

Process 2-3: $42000 = \Delta E + 0$

$\therefore Q_{1-2} = 42000$ kJ/min

Process 3-4: $-4200 = -73200 + W_{3-4}$

$W_{3-4} = 69000$ kJ/min

Process 4-1: $\sum_{cycle} Q = -340$ kJ

The system completes 200 cycle/min

$\therefore \sum_{cycle} Q = -340 \times 200 = -68000$ kJ / min

But, $Q_{1-2} + Q_{2-3} + Q_{3-4} + Q_{4-1} = -68000$

$\therefore Q_{4-1} = -68000 - 0 - 42000 + 4200$

$= -105800$ kJ/min

Also, $\oint dE = 0$, since cyclic integral of any property is zero

$(\Delta E)_{1-2} + (\Delta E)_{2-3} + (\Delta E)_{3-4} + (\Delta E)_{4-1} = 0$

$-4340 + 42000 - 73200 + (\Delta E)_{4-1} = 0$

$\therefore (\Delta E)_{4-1} = 35540$ kJ/min

Therefore $Q_{4-1} = (\Delta E)_{4-1} + W_{4-1}$

$- 105800 = 35540 + W_{4-1}$

$\therefore W_{4-1} = -141340$ kJ/min

Since $\sum_{Cycle} Q = \sum_{Cycle} W$

$= - 68000$ kJ/min

Rate of work output $= \frac{68000}{60} = 1133.33$ kW

SECOND LAW OF THERMODYNAMICS

The first law states that when a closed system undergoes a cyclic process, the cyclic integral of the heat is equal to the cyclic integral of the work. It places no restrictions on the direction of the heat and the work. As no restrictions are imposed on the direction in which the process may proceed, the cycle may be reversed and it will not violate the first law.

Example (1):

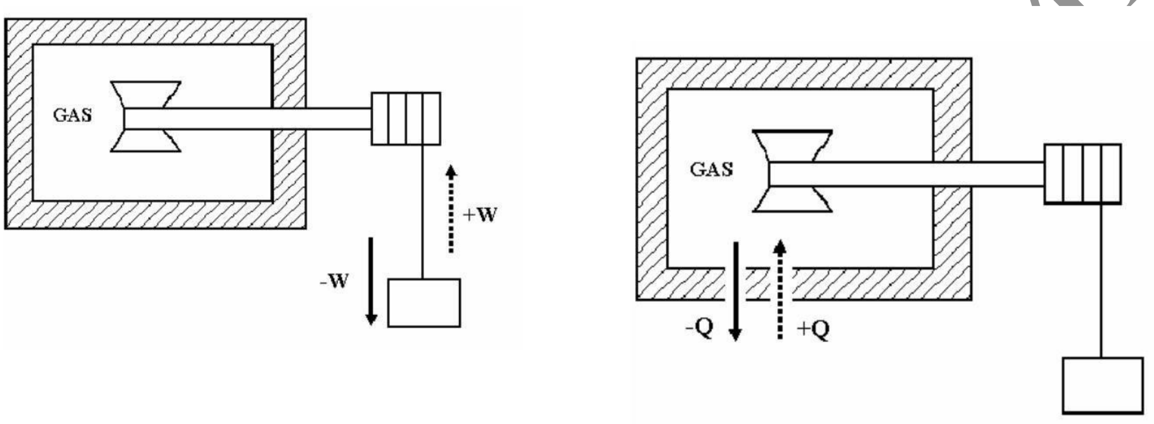
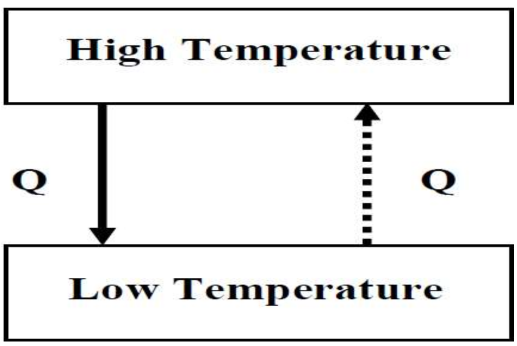


Fig: A closed system that undergoes a cycle involving work and heat.

In the example considered the system undergoes a cycle in which work is first done on the system by the paddle wheel as the weight is lowered. Then let the cycle be completed by transferring heat to the surrounding.

From experience it has been learnt that we cannot reverse this cycle. i.e., if we transfer heat to the gas, as shown by the dotted line, the temperature of the gas will increase, but the paddle wheel will not turn and lift the weigh. This system can operate in a cycle in which the heat and work transfers are both negative, but it cannot operate in a cycle when both are positive, even though this would not violate the first law

Example (2):



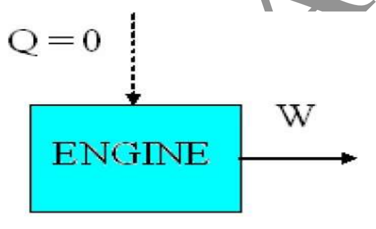
Let two systems, one at a high temperature and the other at a low temperature undergoes a process in which a quantity of heat is transferred from the high – temperature system to the low temperature system. From experience we know that this process can take place. But the reverse process in which heat is transferred from the low temperature system to the high temperature system does not occur and that it is impossible to complete the cycle by heat transfer only.

These two examples lead us to the consideration of the heat engine and heat pump (i.e., refrigerator).

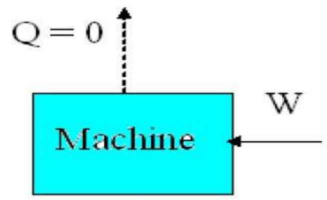
Experience tells us that the reversed processes described above do not happen. The total energy of each system would remain constant in the reversed process and thus there would be no violation of the first law. It follows that there must be some other natural principle in addition to the first law and not deducible from it, which governs the direction in which a process can take place in an isolated system. This principle is the Second law of thermodynamics.

PERPETUAL MOTION MACHINE OF FIRST KIND (PMMKI)

No machine can produce energy without corresponding expenditure of energy without corresponding expenditure of energy i.e., it is impossible to construct a PMMK of first kind. The machine violates the first law of thermodynamics. All attempts made so for to make PMMKI have failed, thus showing the validity of the first law.



A PMMK -I



The converse of A PMMK -I

Second law of Thermodynamics

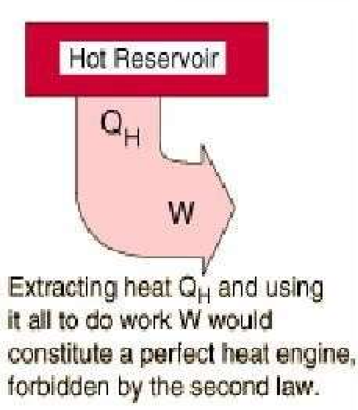
There are two classical statements of the second law of thermodynamics

1) Kelvin – Planck statement
2) Clausius statement

Kelvin – Planck statement

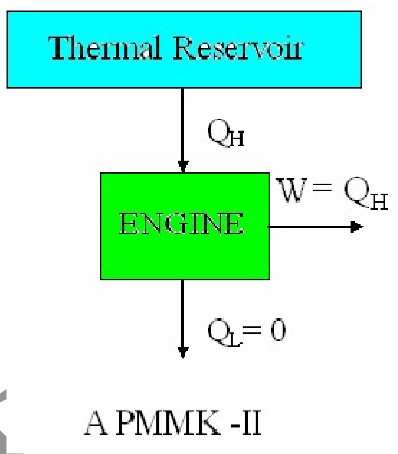
"It is impossible to construct a device which will operate in a cycle & produce no effect other than the raising of a weight and the exchange of heat with a single reservoir"

No actual or ideal engine operating in cycles can convert into work all the heat supplied to the working substance, it must discharge some heat into a naturally accessible sink because of this aspect and the second law is often referred as the law of degradation of energy.



A directional implication of the 2nd Law

PERPETUAL MOTION MACHINE OF SECOND KIND (PMMKII)



Without violating the first law a machine can be imagined which would continuously absorb heat from a single thermal reservoir and would convert this heat completely into work. The efficiency of such a machine would be 100%. This machine is called PMMK II. A machine of this kind will violate the second law of thermodynamics and hence does not exist.

Clausius Statement

It is impossible to construct a heat pump which operating in a cycle will produce no effect other than the transfer of heat from a low temperature thermal reservoir to a higher temperature thermal reservoir.

That is in order to transfer heat from a low temperature thermal reservoir to a high temperature thermal reservoir work must be done on the system by the surroundings. Although the Kelvin – Planck and Clausius statements appear to be different, they are really equivalent in the sense that a violation of one statement involves violation of the other.

Steam Formation and Properties:

<u>Steam Boilers</u>:

Steam boiler is a closed vessel, which is used to convert water into steam at required temperature and pressure by the application of heat.

<u>Classification of Boilers</u>:

1) Horizontal, vertical or inclined
2) Fire tube boiler & water tube boiler
3) Internally fired & externally fired boiler
4) Forced circulation & natural circulation
5) High pressure boiler & low pressure boiler
6) Single tube & multi tube boiler
7) Stationary & portable (locomotive) boiler

Lancashire Boiler:

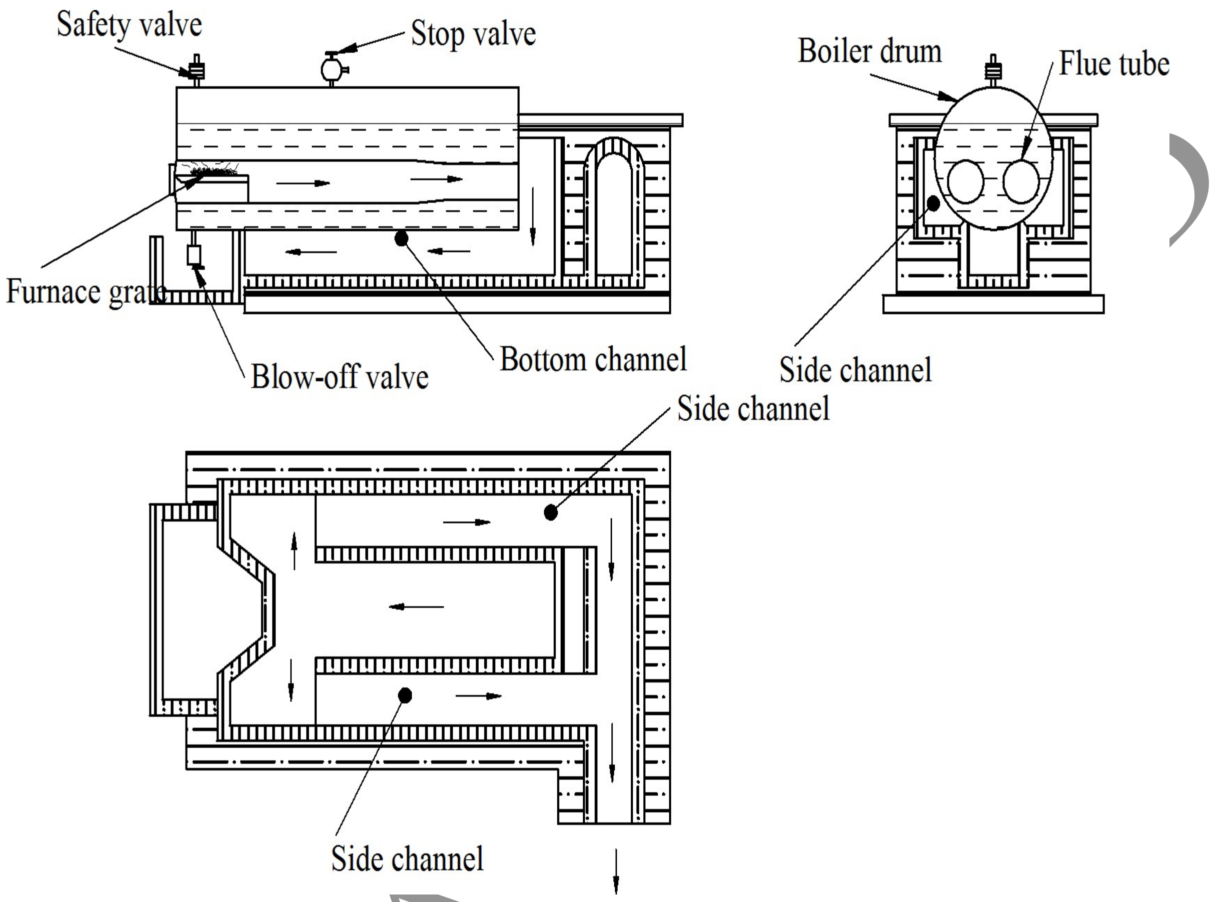


Figure :Lancashire Boiler

Babcock & Wilcox Boiler:

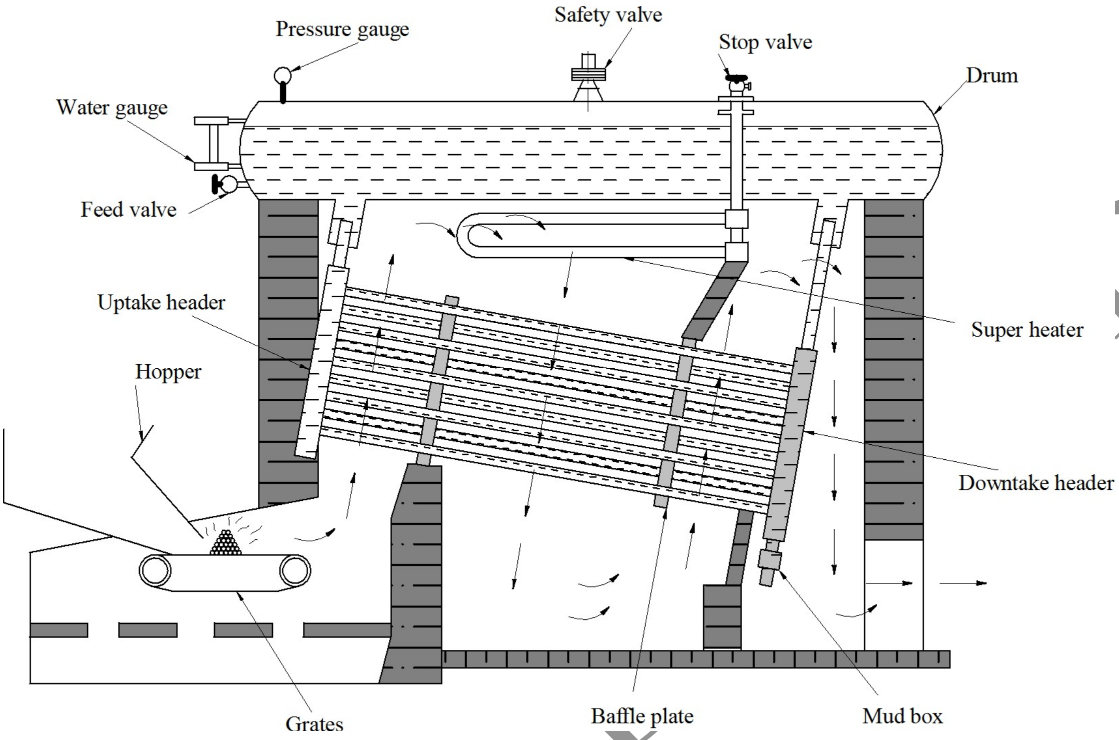


Figure: Babcock & Wilcox Boiler

Boiler mountings:

The boiler mountings are necessary for the proper function & safety of a boiler.

- Safety valve
- Water level indicator
- Pressure gauge
- Blow off valve
- Steam stop valve
- Feed check valve

Boiler accessories:

Boiler accessories are auxiliary parts used in steam boilers for their proper functioning and to improve the efficiency of the power plant.

- Super heater
- Economizer
- Air pre-heater

- Steam separator
- Steam trap

Module- 2

Turbines and IC Engines and Pumps

A turbine is a rotary engine that extracts energy from a fluid flow. The simplest turbine will have one moving part, a rotor assembly with blades attached to it, moving fluid acts on the blades or the blades react to the flow so that they rotate and impart energy to the rotor.

Steam turbines:

1. Impulse turbines
2. Impulse-reaction turbines

Impulse Steam turbine:

- The turbine consists of a series of curved blades fixed on the circumference of a single wheel called rotor which in turn is connected to a shaft
- The high pressure and low velocity steam generated in the boiler is used as a working fluid. The working fluid contains potential energy and kinetic energy
- Before reaching the turbine the fluid's potential energy gets changed to kinetic energy by accelerating the fluid through a nozzle
- The high velocity steam leaving the nozzle is directed towards the moving blades of the turbine
- The steam flowing over the blades undergoes a change in its velocity and direction thereby resulting in change of momentum
- This resulting impulse force pushes the blade in the same direction

  Example: Delaval's Turbine

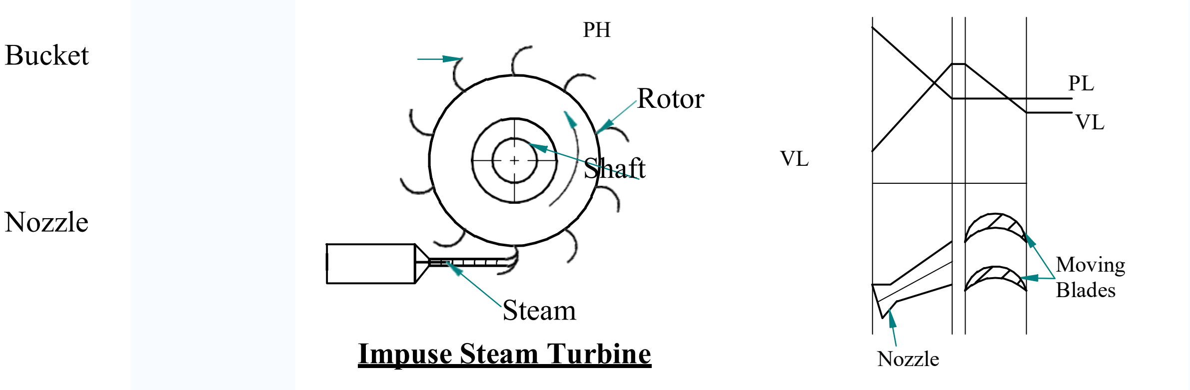


Figure 2.1 Impulse steam turbine

Reaction turbine (Impulse-Reaction Turbine):

The turbine runs by the reactive force of the jet of steam rather than the direct push or impulse as in case of impulse turbine. It consists of several alternate rows of fixed and moving blades. The fixed blades are fastened to a stationary casing, while the moving blades are mounted on the periphery of a rotating wheel called rotor which in turn is connected to a shaft. In reaction turbine the shape and the cross-section of moving and fixed blades are designed such that it acts as a nozzle.

Working

- The high pressure, low velocity steam generated in a boiler first passes over the fixed blade
- The fixed blade acts as a nozzle where the steam gets expanded to a low pressure and high velocity and it also guides the steam onto the moving blades where it undergoes a change in its velocity and direction thereby resulting in impulse force
- The kinetic energy of the steam is converted into mechanical energy by the rotation of the rotor and when the steam leaves the moving blade, a reactive force is set up

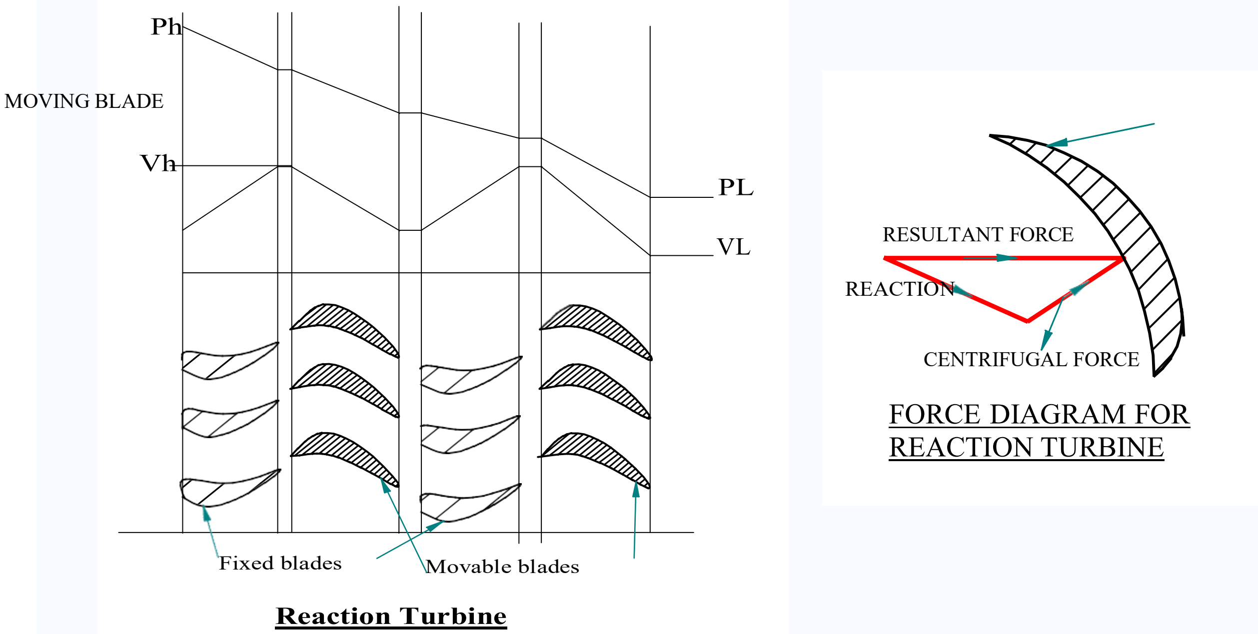


Figure 2.2 Reaction steam turbine

Gas turbines:

It is a thermal prime mover, which utilizes the heat energy of the burnt gases to obtain Power.

Classification:

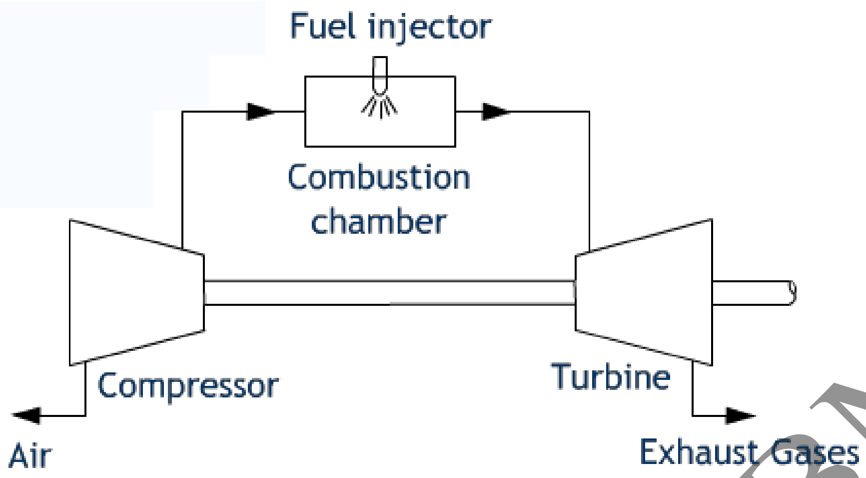
a. Open cycle gas turbine

b. Closed cycle gas turbine

Open cycle gas turbine:

It consists of a compressor, a combustion chamber and a turbine. Both turbine and the compressor are mounted on the same shaft.

- The compressor draws air from the atmosphere and compresses it o a high pressure
- The compressed air flows into the combustion chamber where the fuel is burnt at constant pressure
- The high pressure-high temperature hot gases are then made to flow through the turbine blades where heat energy gets converted into mechanical work
- The shaft of the turbine in turn will be connected to a generator for producing electricity
- The gases coming out from the turbine are discharged to the atmosphere, hence called as open cycle gas turbine

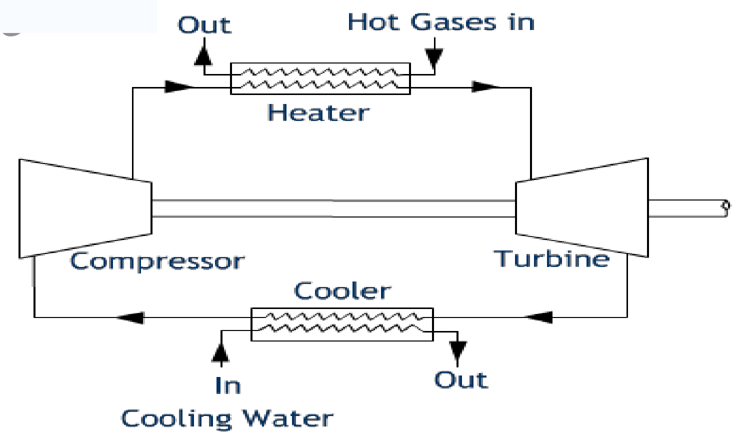


Open cycle Gas turbine

<u>Closed cycle gas turbine</u>:

It consists of a compressor, a heater, a turbine and a cooler. The compressor and turbine are mounted on the same shaft. Gases like argon, helium, nitrogen, carbon dioxide are used as working fluid for turbines.

- The working fluid is compressed in a compressor and passed on to a heater where it gets heated and the heat is transferred using an heat exchanger
- The high pressure and temperature fluid is made to flow through the turbine
- After expansion of hot gases, heat energy will get converted to mechanical work
- The fluid is then made to pass through a cooler and the low temperature and pressure fluid is made to pass to a compressor for the next cycle
- Since the working fluid is circulated again and again, hence it is called as closed cycle gas turbine



Closed cycle Gas turbine

Water Turbines:

It is a hydraulic prime mover which converts the potential and kinetic energy of water into mechanical energy in the form of rotation of shaft.

Classification of Water turbines:

1. Type of energy available at the inlet

a. **Impulse turbine**: only kinetic energy is available at the inlet of the turbine. Example- Pelton wheel

b. **Reaction turbine**: both pressure and kinetic energy are available at the inlet of the turbine. Example- Kaplan, Francis turbine.

2. Head at the inlet of the turbine

a. **High head turbine**: Head of water available at the inlet of turbine. It ranges from 100 to 1000 meters. Example- Pelton wheel

b. **Medium head turbine**: Head of water available at the inlet ranges from 50 to 400 meters Example- Francis turbine.

c. **Low head turbine**: Head of water available at the inlet will be less than 50 meters Example- Kaplan turbine.

3. Based on the direction of flow of water through the runner

a. **Tangential flow turbine**: Water flows tangential to the runner. Example- Pelton wheel

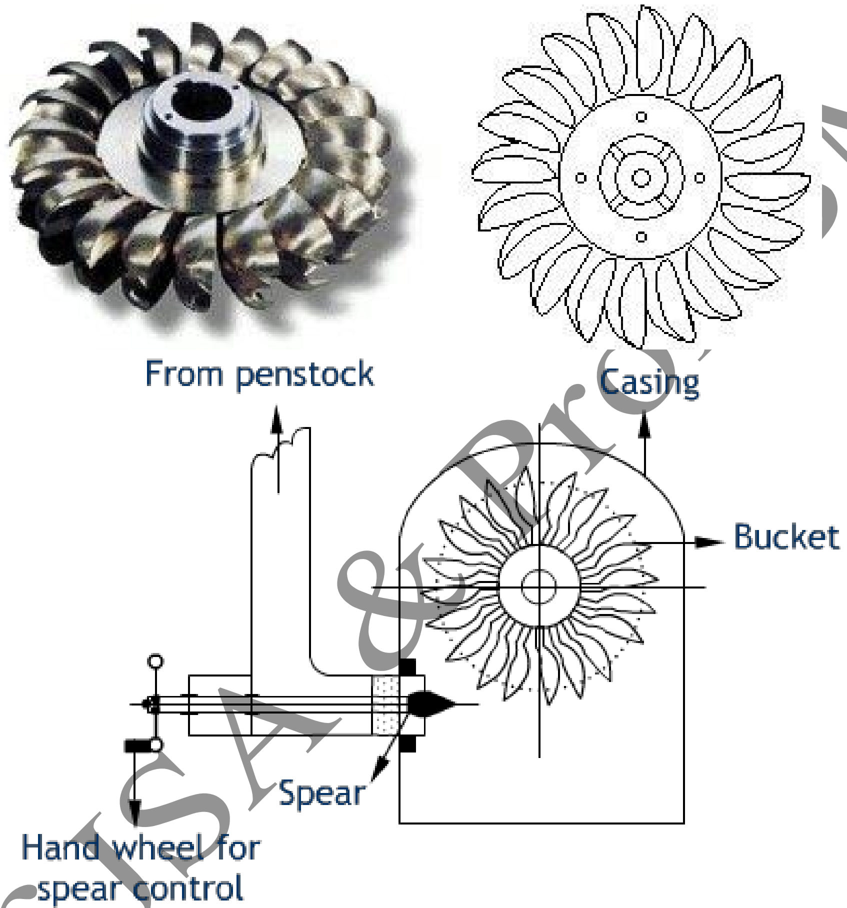
b. **Axial flow turbine**: water flows parallel to the axis of rotation of the runner. Example- Kaplan turbine.

c. **Radial flow turbine**: water flows in radial direction through the runner. Example- Thomson turbine.

Pelton wheel:

- It is a tangential flow impulse turbine used for high heads and small quantity water flow
- Water from the high head reservoirs is supplied to the nozzle provided with a needle which controls the quantity of water flowing out of the nozzle
- As the water flows through the nozzle the potential energy is converted to kinetic energy

- The high velocity jet of water from the nozzle is made to impinge on the curved blades known as Pelton cups fixed around the runner
- The impulsive force of the high velocity jet of water sets the runner into rotary Motion and the shaft coupled to the runner also rotates

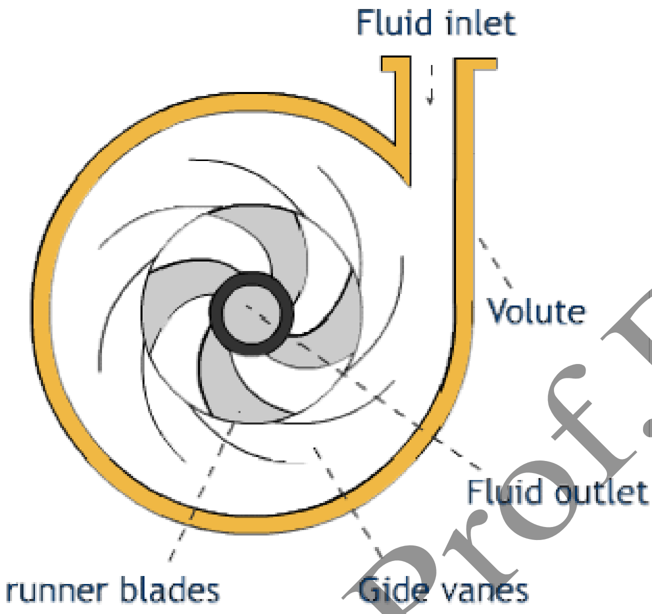


Pelton wheel turbine

Francis Turbine

- It is a medium head reaction turbine in which water flows radically inwards
- It consists of a spiral casing used to distribute water uniformly around the runner
- Water from the reservoir enters the spiral casing and flows racially inwards to the outer periphery of the runner through the guide blades and finally discharged to the tail race axially from the centre of the runner via a draft tube

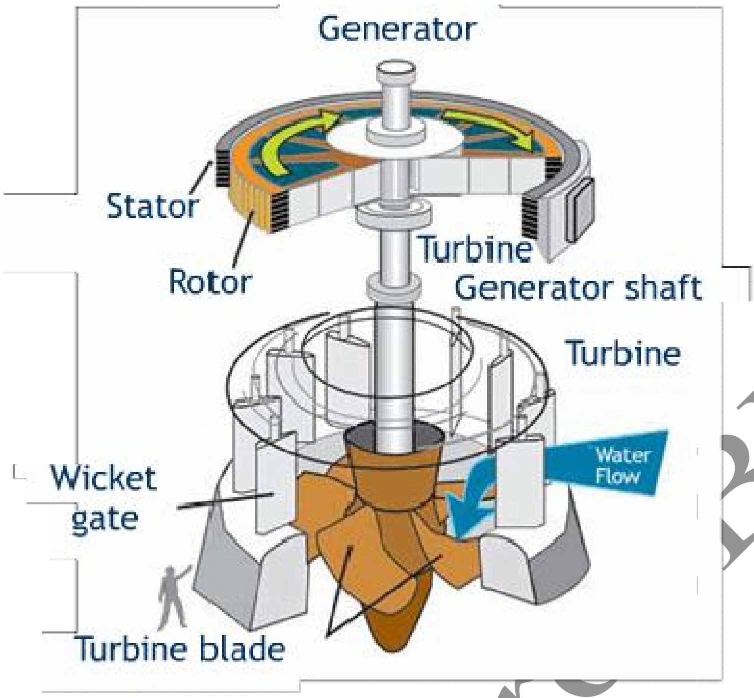
- During its flow over the moving blades it imparts kinetic energy to the energy to the runner to set it into rotational motion. Hence the shaft connected to the runner also rotates thereby doing useful work



Francis Turbine

Kaplan turbine

- It is a low head axial flow section turbine
- The runner of the Kaplan turbine resembles with the propeller of the ship hence it is also called as propeller turbine
- Water from the reservoir flows through the spiral casing where potential energy of water gets converted to kinetic energy
- The water then moves through the guide vanes (blades) and flows axially imparting the kinetic energy to set it into rotational motion
- When the water leaves the blade at high velocity a reaction force is set up and this force rotates the runner thus potential energy of water is converted into mechanical work



Kaplan turbine

Internal Combustion Engines

I C engines is called as internal combustion engine combustion (burning) takes inside the closed chamber. E C engine external combustion engine, burning take place outside the engine.
I C engine it converts heat (thermal, chemical) energy into mechanical energy.

Classification of I C engine:

a) Based on thermodynamic cycle
   (1) Otto cycle (2) Diesel cycle (3) Dual combustion cycle.
b) Based on the fuel
   (1) Petrol (2) Diesel (3) Bi-fuel (4) Gas
c) Based on strokes
   (1) Two stroke (2) Four Stroke
d) Based on the Ignition
   (1) Spark Ignition (2) Compression Ignition
e) Based on number of Cylinders
   (1) Single cylinder (2) multi cylinder

f) Based on the engine placing
   (1) V-engine (2) I or vertical engine (3) Horizontal engine
   (4) Opposed engine (5) Radial engine
g) Based on the cooling systems
   (1) Air cooled (2) Water cooled
h) Based on the application
   (1) Transport (2) Locomotive (3) Marine (4) Power generation
   (5) Agricultural (6) Earth moving

Parts of I C engine:

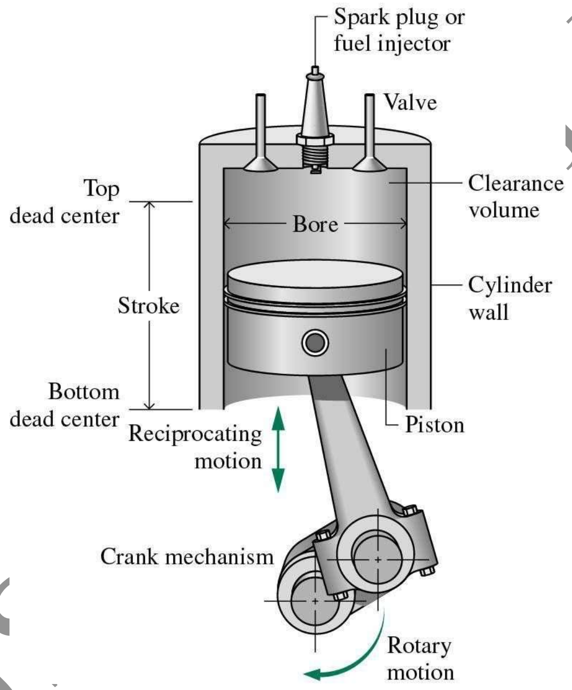


Figure :Parts of IC engine

1) Cylinder: is the heart of the engine, piston reciprocals inside the cylinder.
2) Piston : is a hallow cylinder
   It is fitted inside the cylinder
   It reciprocates inside the cylinder
   It compresses the charges and transmits the power to crank shaft.
3) Connecting Rod: it connects the piston to crank shaft. To convert reciprocating motion of the piston to rotator motioning of the crank shaft.
4) Crank shaft: it receives the rotary motion from the connection rod.
5) Valves: it controls the air/fuel to enter into the cylinder and also to discharges the exhaust gas. Inlet value air/ fuel is entering

Exhaust value Burnt gases escapes.

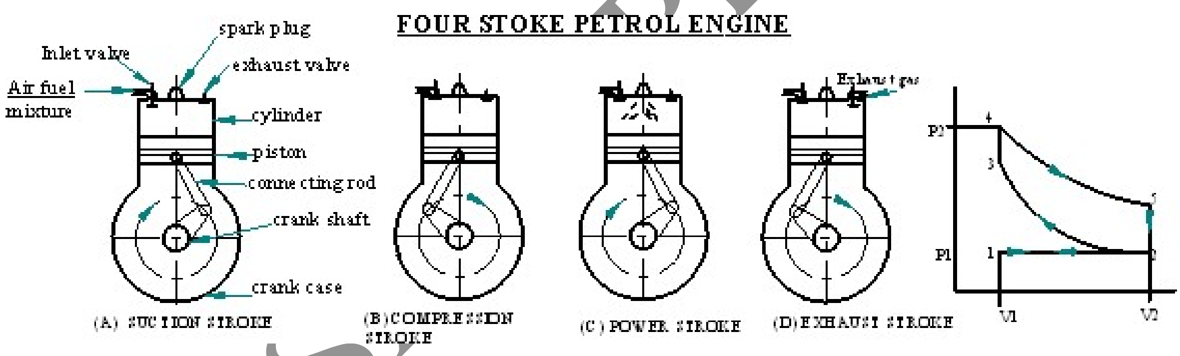
6) Fly wheel: it is fitted at end of the crank shaft.
   It stores the kinetic energy and release the energy to crank shaft.

Some of the notation:

B.D.C: Bottom dead centre
T.D.C: Top dead centre
I.V: Inlet value
O.V: Outlet value or exhaust valve.
Stroke: The piston displacement is called as stroke (T.D.C to B.D.C or B.D.C to T.D.C)
180^o revolution of the crank in 4 strokes.
Bore: Diameter of the inside cylinder.

Four Stroke Petrol Engine (Spark Ignition):

The following are the working strokes
(A) Suction (B) Compression (C) Power (D) Exhaust Stroke.



SUCTION STROKE:

1. Inlet value opens and exhaust value is closed.
2. Piston moves from top dead centre to bottom dead centre (crank rotates 0-180^o)
3. Piston sucks the air fuel mixture in to the cylinder (constant pressure and volume increase V1 to V2)

COMPRESSION STROKE:

1. Both inlet and exhaust values closed.
2. Piston moves from bottom dead centre to top dead centre. (180^o to 360^o crank rotation).
3. Pressure and temperature of the air fuel mixture increases. (volume decreases)
4. At the end of compression stroke volume remains constant for a small displacement , it is called constant volume cycle (compression ratio is 1:14)

POWER STROKE:

1. Both inlet and exhaust value closed.
2. High pressure and high temperature air fuel mixture catches the fire with spark plug.
3. High amount energy released and pushes piston down word direction.
4. Fly wheel stores the energy. (impact energy)

EXHAUST STROKE:

1. Exhaust value opens and inlet value closed
2. Piston moves from bottom dead centre to top dead centre.
3. The burnt gases escape from the cylinder.
4. Crank shaft completes the two revolutions and generates one power stroke.

FOUR STROKE DIESEL ENGINE (compression ignition)

The following are the working strokes

(A) Suction (B) Compression (3) Power stroke (4) Exhaust

SUCTION STROKE:

1. Inlet value opens and exhaust value is closed.
2. Piston moves from top dead centre to bottom dead centre (rank rotates 0-180^o)
3. Piston sucks the fresh air into the cylinder (constant pressure and volume increases) (v1 to v2)

COMPRESSION STROKE:

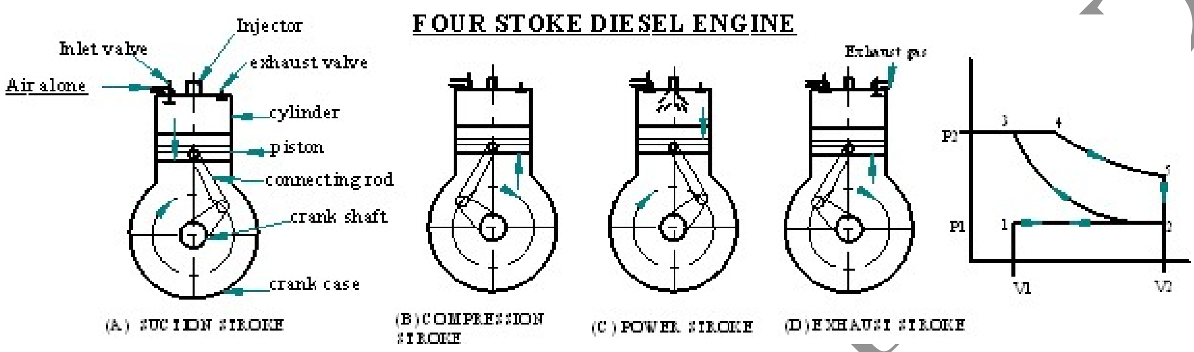
1. Both inlet and exhaust valves closed
2. Piston moves from bottom dead centre to top dead centre (180^o to 360^o rotation)
3. Pressure and temperature of the air increases to high
4. At the end of the compression stroke pressure remains constant for a small displacement of the piston. It is called constant pressure cycle compression (ratio is 1:20)

POWE STROKE:

(1) Both inlet and exhaust value closed.
(2) High pressure and high temperature air catches the fire with diesel is sprayed.
(3) High amount energy released and pushes piston down word direction.
(4) Fly wheel stores the energy. (impact energy)

EXHAUST STROKE:

(1) Exhaust value opens and inlet value closed
(2) Piston moves from bottom dead centre to top dead centre.
(3) The burnt gases escape from the cylinder.
(4) Crank shaft completes the two revolutions and generates one power stroke.



Two Stroke Petrol Engine:

1. First Stroke 2. Second Stroke

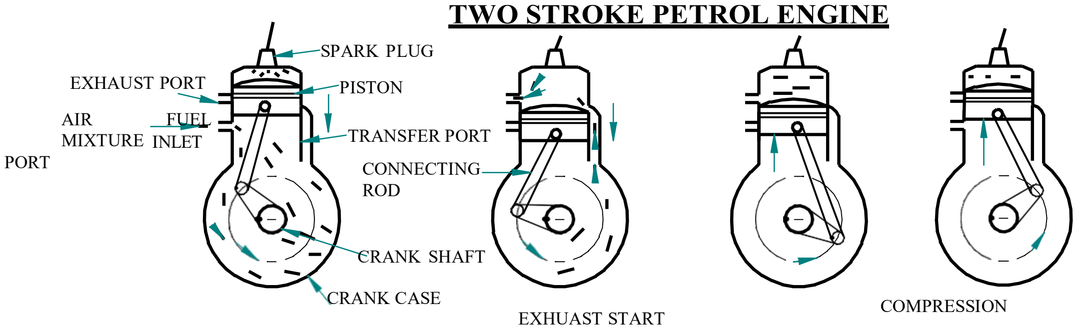
First stroke:

- The spark plug ignites the compressed petrol and air mixture
- The high pressure combustion gases force the piston downwards
- The piston performance the power stroke till it covers the exhaust port
- As soon as piston uncovers the transfer port, the fresh air fuel mixture flows from crankcase in to the cylinder
- This drives out of the exhaust gases by the incoming fresh charge is called scavenging
- Piston moves from top dead centre to bottom dead centre

Second stroke:

- In this stroke piston moves from bottom dead centre to top dead centre
- The piston covers the transfer port; air fuel mixture is cut off, suction stops
- Further movement of the piston will compress the air fuel mixture in the cylinder
- The ratio of compression is from 1:8 to 1:12
- At end of compression stroke air fuel get ignited

TWO STROKE PETROL ENGINE



(a) FIRST STROKE (b) SECOND STROKE

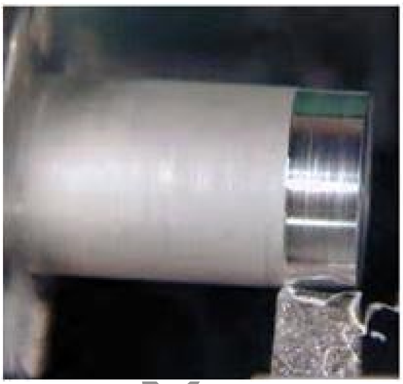
Module -3

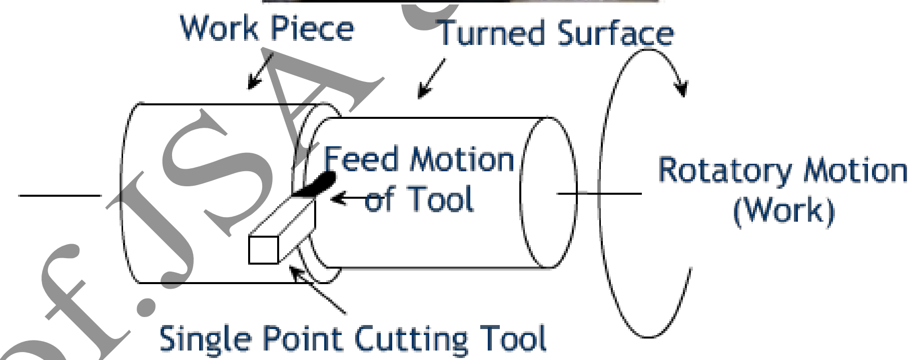
Machine Tools and Automation

Machine Tools Operations:

Turning:

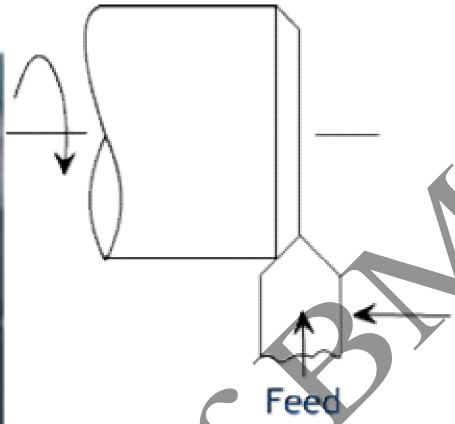
Turning is the removal of metal from the outer diameter of a rotating cylindrical work piece. Turning is used to reduce the diameter of the work piece, usually to a specified dimension, and to produce a smooth finish on the metal. Often the work piece will be turned so that adjacent sections have different diameters.



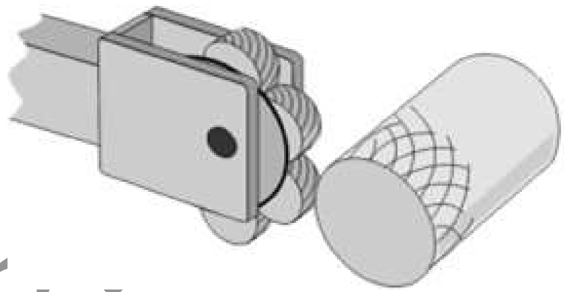


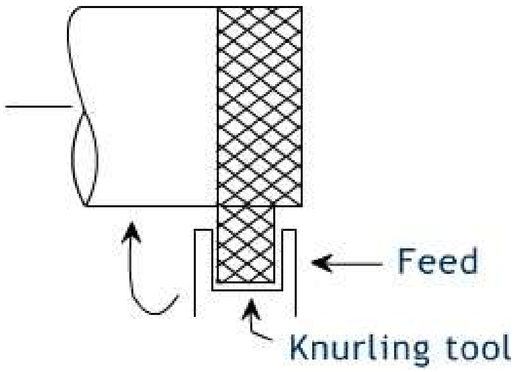
Facing: Facing is the process of removing metal from the end of a work piece to produce a flat surface. It is some time called squaring. The facing tool used is of round edge; if the tool is pointed then the work piece will not have good finishing. The work piece rotates about its axis and the facing tool is fed perpendicular to the axis of lathe. Most often, the work piece is

Cylindrical, but using a 4-jaw chuck you can face rectangular or odd-shaped work to form cubes and other non-cylindrical shapes.



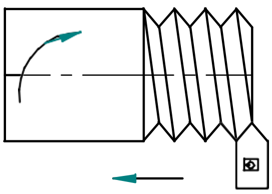
Knurling: It is the process of embossing a required shaped pattern on the surface of the work piece. This diagram shows the knurling tool pressed against a piece of circular work piece. The lathe is set so that the chuck revolves at a low speed. The knurling tool is then pressed against the rotating work piece and pressure is slowly increased until the tool produces a pattern on the work piece.



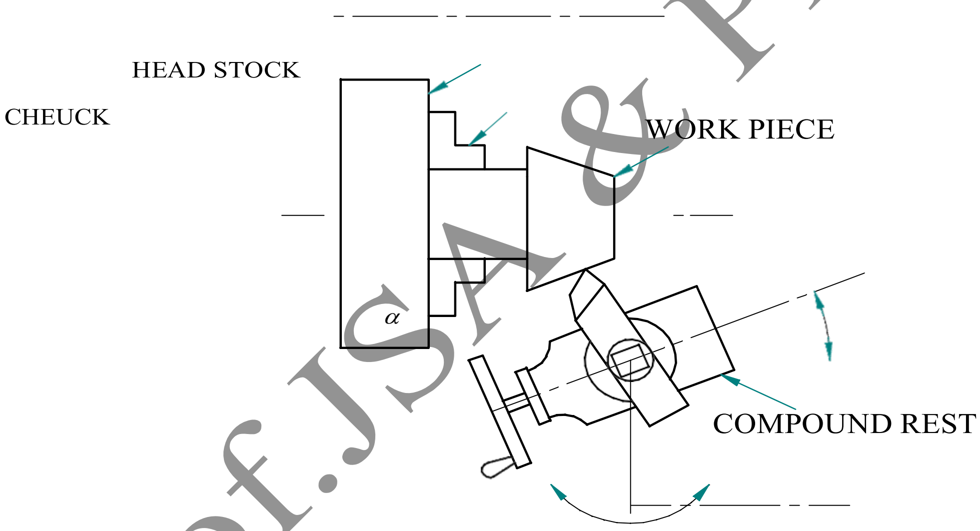


Thread cutting: A thread is a uniform helical groove cut on or in a cylinder or cone. The tool is ground to the shape of the thread and is moved longitudinally with uniform motion. The required

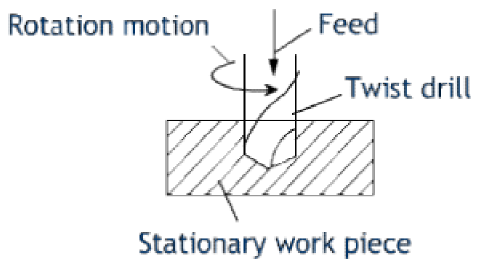
Pitch can be obtained by maintaining the appropriate gear ratio between the spindle and the lead screw which enables the tool to move longitudinally at appropriate speed.



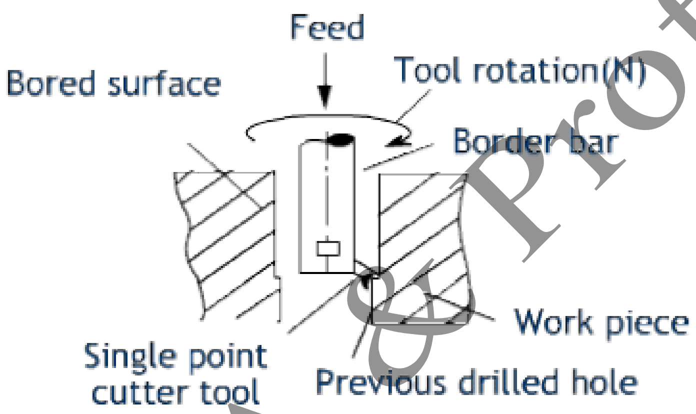
Taper Turning by swiveling the compound rest: In this method of taper the half taper angle is calculated. The compound rest has rotating base graduated in degrees, which can be rotated to any angle (according to the taper angle). In this method the tool is advanced by rotating the compound rest and hand wheel so that the tool moves according to set taper angle. This method produces taper length larger than form tool method.



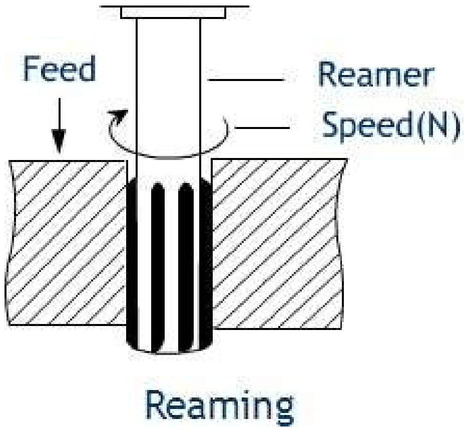
Drilling: The drilling is one of the simplest methods of producing a hole. Before drilling a hole, the center point of the hole has to be marked on the work piece. The center point of the hole is marked by just drawing two cross lines or by using instruments. The mark is indented using a center punch. The hole to be drilled may be a through hole or a blind hole. Through hole can be drilled on any machine, but to drill a blind hole we need a sophisticated machine.



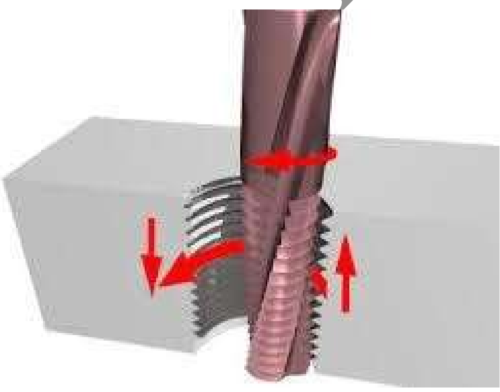
Boring: It is an operation employed to enlarge a hole by means of an adjustable cutting tool with only one cutting edge. This is necessary where suitable sized drill is not available or where the hole diameter is so large that it cannot be ordinarily drilled. It is used to finish a hole accurately and to bring it to the required size. In precision machines the accuracy is as high as 0.00125mm; the process is slower compared to reaming and requires several passes of tool.



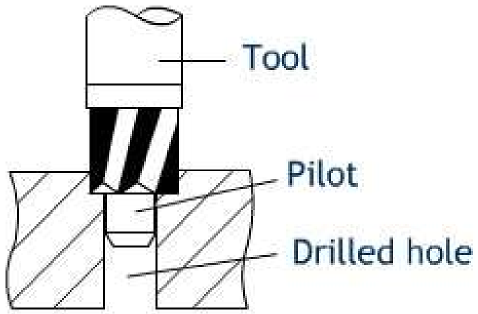
Reaming: Reaming is a sizing and finishing operation performed on a previously drilled hole. The tool used for reaming operation is known as reamer, which has multiple cutting edges. The spindle speed is half compared to drilling operation. Reamers cannot produce hole, but follow the path already defined by the drilling. The metal removed in this process is small, range is about 0.35 mm.



Tapping: Is an operation of cutting internal threads by means of a cutting tool called a ***tap***. A slightly smaller diameter hole is drilled before tapping and a tap is fitted in the tapping attachment which in turn is mounted in the drilling machine spindle.



Counter Boring: Is an operation of enlarging the end of a hole cylindrically. The enlarged hole forms a square shoulder with the original hole. The tool is guided by a pilot which extends beyond the end of the cutting edges. The pilot fits into the small diameter hole having running clearance and maintains the alignment of the tool. Counter boring is done to accommodate the heads of bolts, studs, pins etc. Counter boring can give accuracy of about 0.050mm.

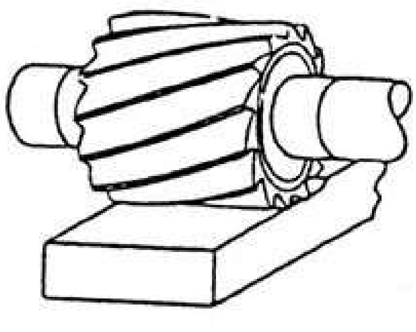


Conterboring

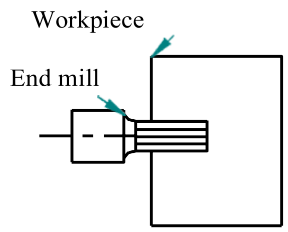
Counter Sinking: Is an operation of making a cone-shaped enlargement of the end of a hole to provide a recess for a flat head screw or countersunk rivet fitted into the hole. The tool used for countersinking is called a countersink. Standard countersinks have 60^0, 82^0 or 90^0 included angle and the cutting edges of the tool are formed at the conical surface.

Counter sinking

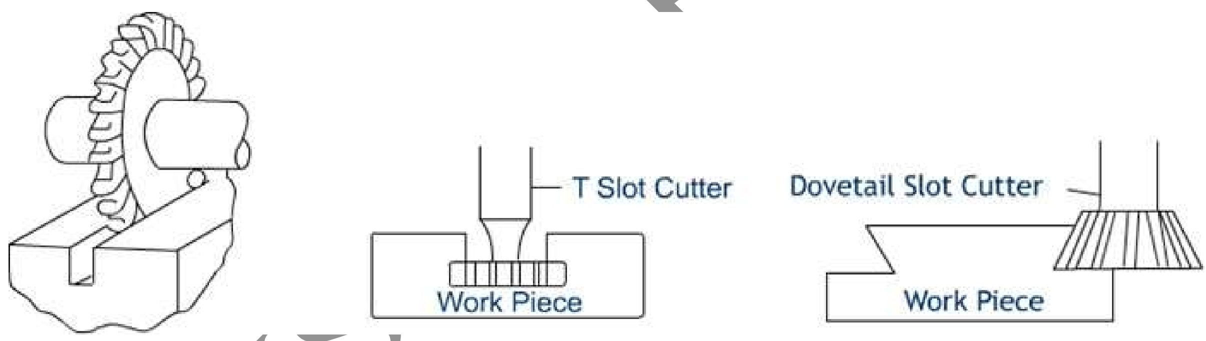
Plane milling: The plain milling is the operation of production of a plain flat horizontal surface parallel to the axis of rotation of a plain milling cutter. The operation is also called slab milling.



End milling: The end milling is the operation of production of a flat surface which may be vertical, horizontal or at an angle in reference to the table surface. Use to produce slots, grooves or key ways.



Slot milling: The process of producing keyways grooves and slots of varying shapes and sizes is known as slotting. The side milling cutter is mounted on to the arbor of a horizontal milling machine when slotting had to be done on Horizontal milling machine. T–Slots and dovetail slots are carried out on a veridical milling machine.



Robotics and Automation:

Introduction

An industrial robot is a general purpose, programmable machine possessing certain anthropomorphic characteristics. The most obvious anthropomorphic characteristic of an industrial robot is its mechanical arm, which is used to perform various industrial tasks. Other human like characteristics are the robot's capabilities to respond to sensory inputs, communicate with other machines, and make decisions. These capabilities permit robots to perform a variety of useful tasks.

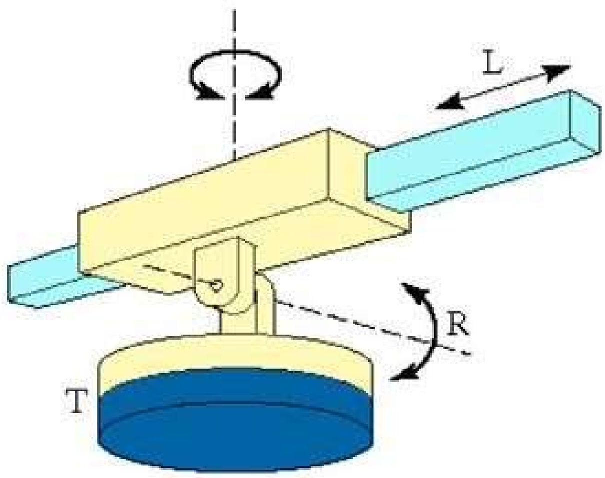
Some of the qualities that make industrial robots commercially and technologically important are listed

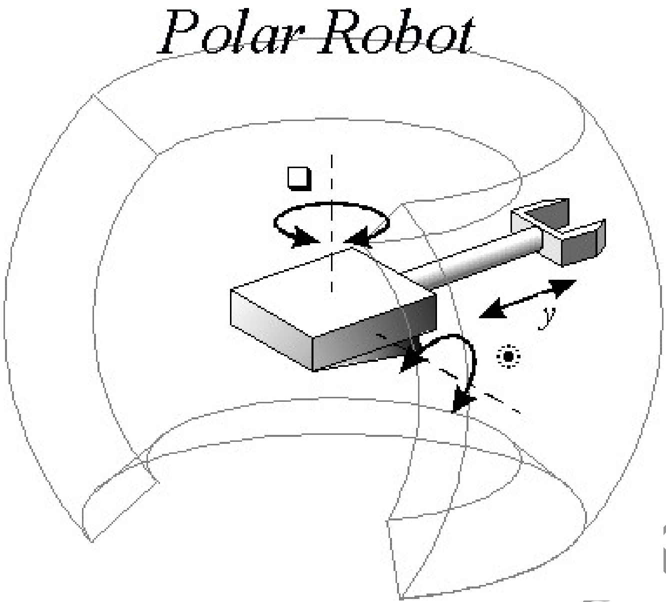
- Hazardous work environments
- Repetitive work cycle
- Consistency and accuracy
- Difficult handling task for humans
- Multi shift operations
- Reprogrammable, flexible
- Interfaced to other computer systems

Classification based on robots configuration

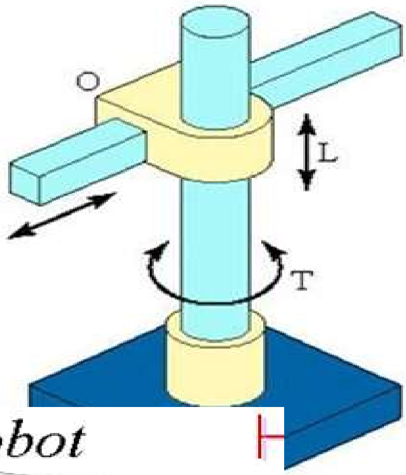
- Polar Coordinate
- cylindrical Coordinate
- Cartesian Coordinate

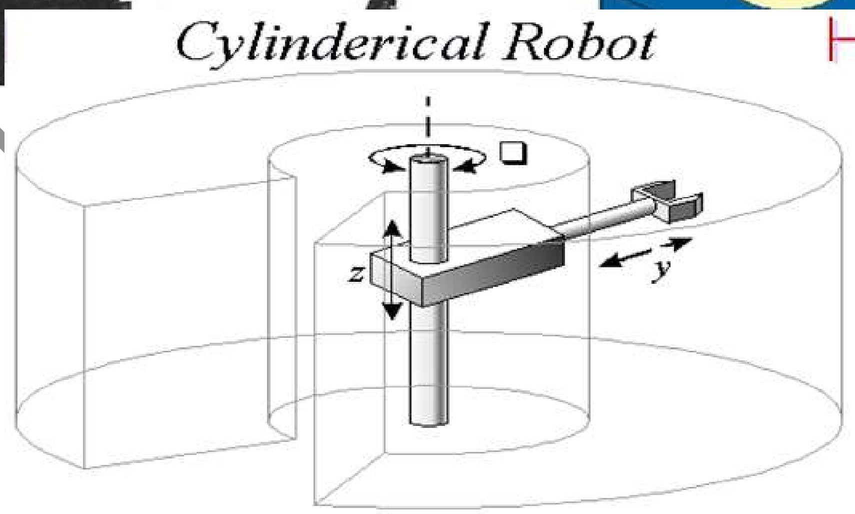
Polar Coordinate: This configuration Consists of a sliding arm (L joint) actuated relative to the body, which can rotate about both a vertical axis (T joint) and horizontal axis (R joint)

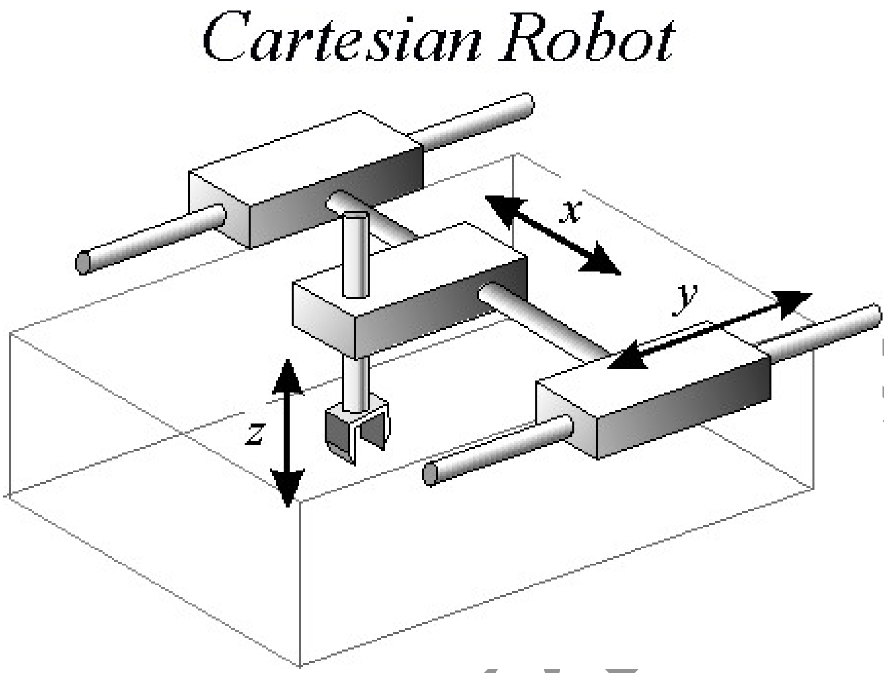




Cylindrical Coordinate: This configuration Consists of a vertical column, relative to which an arm assembly is moved up or down. The arm can be moved in or out relative to the axis of the column

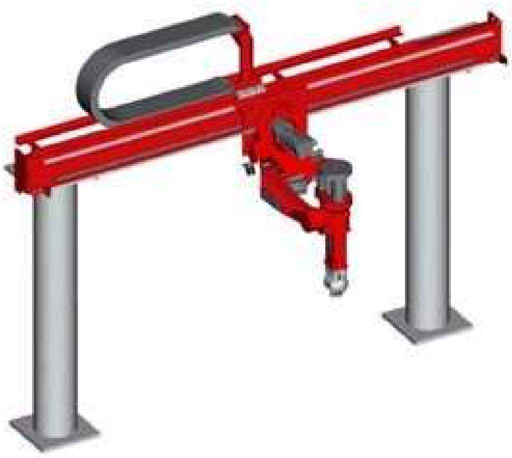


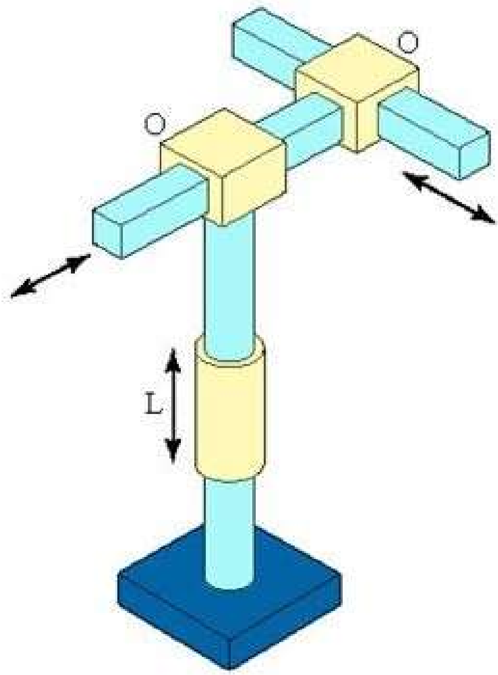




Cartesian

Coordinate: Other names for this configuration include rectilinear robot and x-y-z robot. It is composed of three sliding joints, two of which are orthogonal.





Automation:

Automated manufacturing is a manufacturing method that relies on the use of computerized control systems to run equipment in a facility where products are produced. Human operators are not needed on the assembly line or manufacturing floor because the system is able to handle both the mechanical work and the scheduling of manufacturing tasks. The development of fully automated manufacturing systems dates to the latter half of the 20th century, and this manufacturing technique is used in facilities of varying scale all over the world.

Automation of production systems can be classified into three basic types:

1. Fixed automation (Hard Automation)

2. Programmable automation (Soft Automation)

3. Flexible automation.

1. Fixed automation (Hard automation): Fixed automation refers to the use of special purpose equipment to automate a fixed sequence of processing or assembly operations. Each of the operation in the sequence is usually simple, involving perhaps a plain linear or rotational motion or an uncomplicated combination of two. It is relatively difficult to accommodate changes in the product design. This is called hard automation.

Advantages:

1. Low unit cost

2. Automated material handling

3. High production rate.

Disadvantages:

1. High initial Investment

2. Relatively inflexible in accommodating product changes.

2. Programmable automation: In programmable automation, the production equipment is designed with the capability to change the sequence of operations to accommodate different

Product configurations. The operation sequence is controlled by a program, which is a set of instructions coded. So that they can be read and interpreted by the system. New programs can be prepared and entered into the equipment to produce new products.

Advantages:

1. Flexible to deal with design variations.

2. Suitable for batch production.

Disadvantages:

1. High investment in general purpose equipment

2. Lower production rate than fixed automation.

Example: Numerical controlled machine tools, industrial robots and programmable logic controller.

3. **Fixed Automation:** (Soft automation): Flexible automation is an extension of programmable automation. A flexible automation system is capable of producing a variety of parts with virtually no time lost for changeovers from one part style to the next. There is no lost production time while reprogramming the system and altering the physical set up.

Advantages:

1. Continuous production of variable mixtures of product.

2. Flexible to deal with product design variation.

Disadvantages:

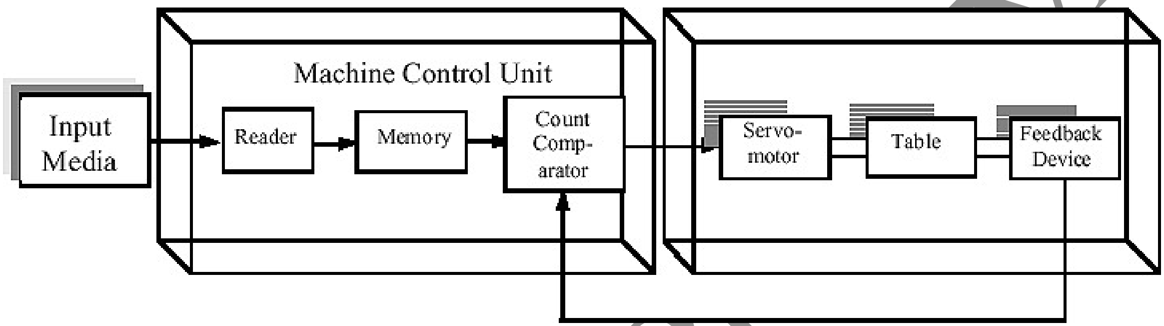
1. Medium production rate

2. High investment.

3. High 'unit cost relative to fixed automation.

Numerical control (NC):

Numerical Control refers to the method of controlling the manufacturing operation by means of directly inserted coded numerical instructions into the machine tool. It is important to realize that NC is not a machining method; rather, it is a concept of machine control. Although the most popular applications of NC are in machining, NC can be applied to many other operations, including welding, sheet metalworking, riveting, etc.



The major advantages of NC over conventional methods of machine control are as follows:

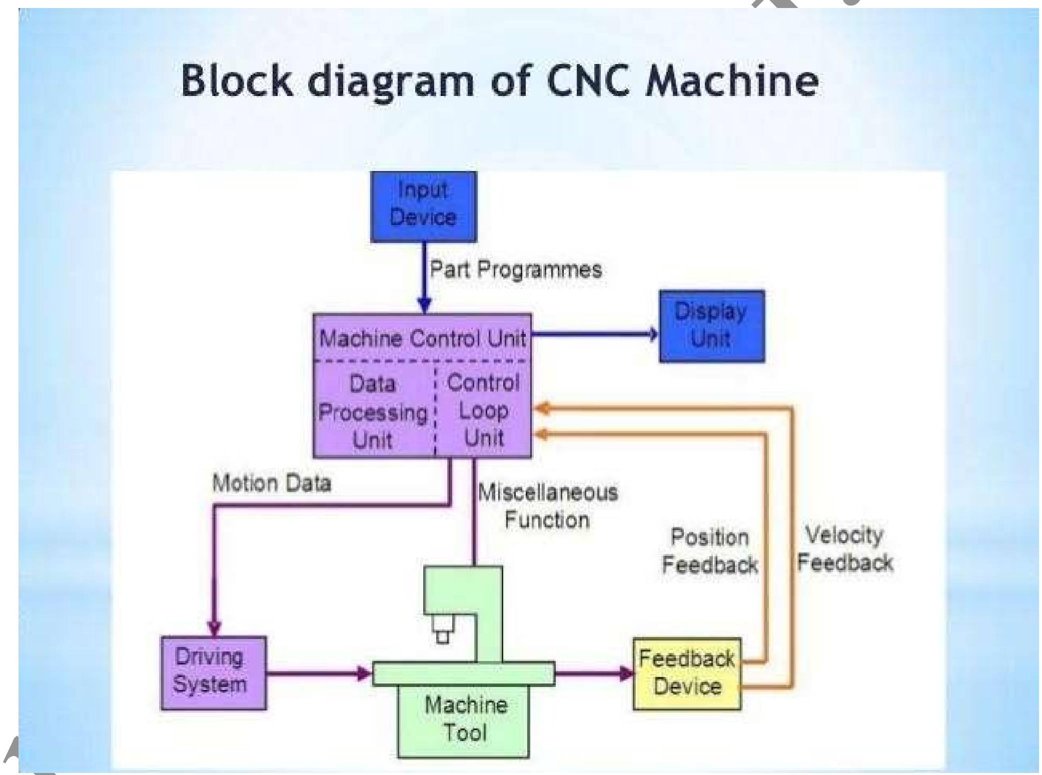
- Higher precision: NC machine tool are capable of machining at very close tolerances, in some operations as small as 0.005 mm;
- Low operator qualification: the role of the operation of a NC machine is simply to upload the work piece and to download the finished part. In some cases, industrial robots are employed for material handling, thus eliminating the human operator.
- Multi-operational machining: some NC machine tools, for example machine centers, are capable of accomplishing a very high number of machining operations thus reducing significantly the number of machine tools in the workshops. Very low operator qualification: the role of the operation of a NC
- Higher productivity: NC machine tools reduce drastically the non machining time. Adjusting the machine tool for a different product is as easy as changing the computer program and tool turret with the new set of cutting tools required for the particular part.
- Better quality: NC systems are capable of maintaining constant working conditions for all parts in a batch thus ensuring less spread of quality characteristics;

The major disadvantages of NC

- Relatively high initial cost of equipment
- Need for part programming
- Special maintenance is required
- More costly breakdown

Computer Numerical Control (CNC):

CNC is a self-contained NC system for a single machine tool that uses a dedicated computer controlled by stored instruction in the memory to implement some or all of the basic NC functions. It is flexible and relatively low-cost.



The major advantages of CNC

- Increased productivity
- High accuracy and repeatability
- Reduced production costs
- Reduced indirect operation costs

- Facilitation of complex machining operations
- Greater flexibility
- Improved production planning and control
- Lower operator skill requirement
- Facilitation of flexible automation

The major disadvantages of CNC

- High initial investment
- High maintenance
- For low production it is costlier process

ROBOTICS

Robots are devices that are programmed to move parts, or to do work with a tool. Robotics is a multidisciplinary engineering field dedicated to the development of autonomous devices, including manipulators and mobile vehicles.

The Origins of Robots

Year 1250

Bishop Albertus Magnus holds banquet at which guests were served by metal attendants. Upon seeing this, Saint Thomas Aquinas smashed the attendants to bits and called the bishop a sorcerer.

Year 1640

Descartes builds a female automaton which he calls "Ma fille Francine." She accompanied Descartes on a voyage and was thrown overboard by the captain, who thought she was the work of Satan.

Year 1738

Jacques de Vaucanson builds a mechanical duck quack, bathe, drink water, eat grain, digest it and void it. Whereabouts of the duck are unknown today.

Year 1805

Doll, made by Maillardet, that wrote in either French or English and could draw landscapes

Year 1923

Karel Capek coins the term *robot* in his play *Rossum's Universal Robots (R.U.R). Robot* Comes from the Czech word *robota,* which means "servitude, forced labor."

Year 1940

Sparko, the Westinghouse dog, was developed which used both mechanical and electrical components.

Year 1950's to 1960's

Computer technology advances and control machinery is developed. Questions Arise: Is the computer an immobile robot? Industrial Robots created. Robotic Industries Association states that an "industrial robot is a re-programmable, multifunctional manipulator designed to Move materials, parts, tools, or specialized devices through variable programmed motions to perform a variety of tasks"

Year 1956

Researchers aim to combine "perceptual and problem-solving capabilities," using computers, cameras, and touch sensors. The idea is to study the types of intelligent actions these robots are capable of. A new discipline is born: A.I.

Year 1960

Shakey is made at Stanford Research Institute International. It contained a television

Camera, range finder, on-board logic, bumps sensors, camera control unit, and an antenna for a radio link. Shakey was controlled by a computer in a different room.

The first industrial robot: UNIMATE Year 1954

The first programmable robot is designed by George Devol, who coins the term Universal Automation. He later shortens this to Unimation, which becomes the name of the first robot company (1962).

Year 1978

The Puma (Programmable Universal Machine for Assembly) robot is developed by

Unimation with a General Motors design support

Year 1980s

The robot industry enters a phase of rapid growth. Many institutions introduce programs and courses in robotics. Robotics courses are spread across mechanical engineering, electrical engineering, and computer science departments.

Year 1995-present

Emerging applications in small robotics and mobile robots drive a second growth of start-up companies and research

2003

NASA's Mars Exploration Rovers will launch toward Mars in search of answers about the history of water on Mars

Robot Physical Configuration

Industrial robots come in a variety of shapes and sizes. They are capable of various arm manipulations and they possess different motion systems.

Classification based on Physical configurations

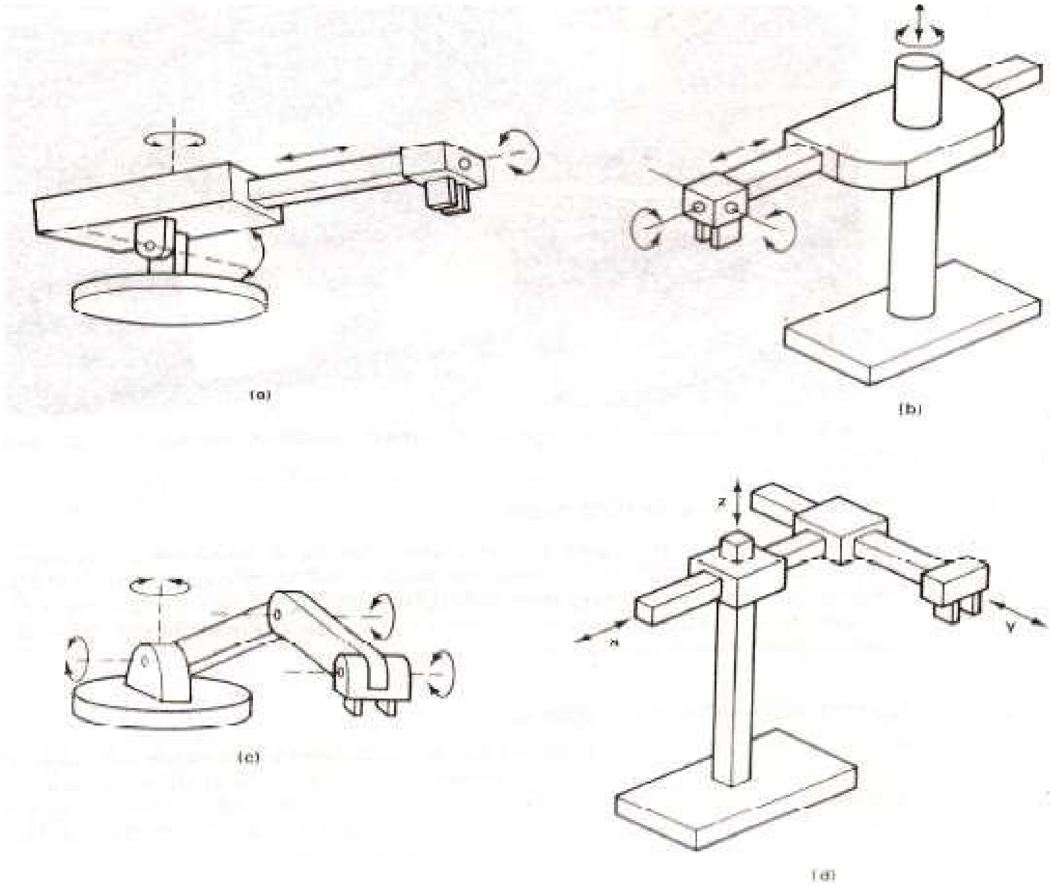
Four basic configurations are identified with most of the commercially available industrial robots

1. Cartesian configuration: A robot which is constructed around this configuration consists of three orthogonal slides, as shown in fig. the three slides are parallel to the x, y, and z axes of the Cartesian coordinate system. By appropriate movements of these slides, the robot is capable of moving its arm at any point within its three dimensional rectangular spaced work space.

2. Cylindrical configuration: in this configuration, the robot body is a vertical column that swivels about a vertical axis. The arm consists of several orthogonal slides which allow the arm to be moved up or down and in and out with respect to the body. This is illustrated schematically in figure.

3. Polar configuration: this configuration also goes by the name "spherical coordinate" because the workspace within which it can move its arm is a partial sphere as shown in figure. The robot has a rotary base and a pivot that can be used to raise and lower a telescoping arm.

4. Jointed-arm configuration: is combination of cylindrical and articulated configurations. This is similar in appearance to the human arm, as shown in fig. the arm consists of several straight members connected by joints which are analogous to the human shoulder, elbow, and wrist. The robot arm is mounted to a base which can be rotated to provide the robot with the capacity to work within a quasi-spherical space.



Basic Robot Motions

Whatever the configuration, the purpose of the robot is to perform a useful task. To accomplish the task, an end effector, or hand, is attached to the end of the robots arm. It is the end effector which adapts the general purpose robot to a particular task. To do the task, the robot arm must be capable of moving the end effectors through a sequence of motions and positions.

There are six basic motions or degrees of freedom, which provide the robot with the capability to move the end effectors through the required sequences of motions. These six degree of freedom are intended to emulate the versatility of movement possessed by the human arm. Not all robots are equipped with the ability to move in all sex degrees. The six basic motions consist of three arm and body motions and three wrist motions.

Arm and body motions

1. Vertical traverse: Up and down motion of the arm, caused by pivoting the entire arm about a horizontal axis or moving the arm along a vertical slide.

2. Radial traverse: extension and retraction of the arm (in and out movement)

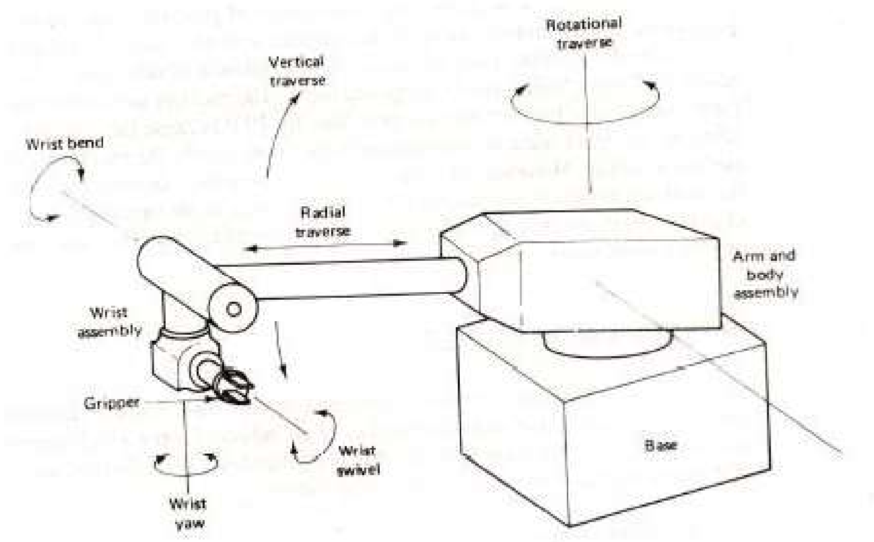
3. Rotational traverse: rotation about the vertical axis (right or left swivel of the robot arm)

Wrist Motion

• Wrist swivel: Rotation of the wrist

• Wrist bend: Up or down movement of the wrist, this also involves rotation movement.

• Wrist yaw: Right or left swivel of the wrist.



Module - 4

Engineering materials and joining processes

All metals may be classified as ferrous or nonferrous. A ferrous metal has iron as its main element. A metal is still considered ferrous even if it contains less than 50 percent iron, as long as it contains more iron than any other one metal. A metal is nonferrous if it contains less iron than any other metal.

Ferrous metals

Ferrous metals contain iron. Examples are cast iron, mild steel, medium carbon steel, high carbon steel, stainless steel, and high speed steel.

Composition, properties and uses of some common ferrous metals

Name	Composition	Properties and characteristics	Principal uses
Cast iron	*Alloy* of iron and 2-5% carbon, 1-3% silicon and traces of magnesium, sulphur and phosphorus.	*Hard* skin, softer underneath, but *brittle*. It *corrodes* by rusting.	Parts with complex shapes which can be made by casting
Mild steel	Alloy of iron and 0.15 - 0.3% carbon	*Tough*, *ductile* and *malleable*. Good *tensile strength*, poor resistance to *corrosion*	General-purpose engineering material
Medium carbon steel	Alloy of iron and 0.35 - 0.7% carbon	*Strong*, hard and tough, with a high tensile strength, but less ductile than mild steel.	Springs; any application where resistance to wear is needed
High carbon steel	Alloy of iron and carbon: 0.7 - 1.5% carbon	Even harder than medium carbon steel, and more brittle. Can be heat-treated to make it harder and tougher	Cutting tools, mechanical elements
Stainless steel	Alloy of iron and carbon with 16-26% chromium, 8-22% nickel and 8% magnesium	Hard and tough, resists wear and corrosion	Cutlery, kitchen equipment
High speed steel	Alloy of iron and 0.35 - 0.7% carbon (medium carbon steel) with tungsten, chromium, vanadium, and sometimes cobalt	Very hard, high *abrasion*- and heat-resistance	Cutting tools for machines

Non-ferrous metals

Non-ferrous metals do not contain iron. Some common non-ferrous metals are aluminum, copper, zinc, tin, brass (copper + zinc), and bronze (copper + tin).

Composition, properties and uses of some common non-ferrous metals:

Name	Composition	Properties and characteristics	Principal uses
Aluminium	Pure aluminium (an element)	Good *strength*-to-weight ratio, light, soft, *ductile*, good *conductor* of heat and electricity	Kitchen equipment, window frames, general cast components
Copper	Pure copper (an element)	*Malleable* and ductile, good conductor of heat and electricity, resistant to *corrosion*	Water pipes, electrical wire, decorative goods
Zinc	Pure zinc (an element)	Weak metal, extremely resistant to corrosion	Usually used for coating steel to make galvanised items
Brass	*Alloy* of copper and zinc	Resistant to corrosion, fairly hard, good conductor of heat and electricity	Cast items such as water taps, ornaments
Bronze	Alloy of copper and tin	Fairly strong, malleable and ductile when soft	Decorative goods, architectural fittings
Tin	Pure tin (an element)	Soft, weak, malleable, ductile and resistant to corrosion	Usually used for coating steel to form tinplate

Engineering Materials

Introduction

Materials are an important aspect of engineering design and analysis. The importance of materials science and engineering can be noted from the fact that historical ages have been named after materials. In the customer driven competitive business environment, the product quality is of paramount importance. The product quality has been found to be influenced by the engineering design, type of materials selected and the processing technology employed.

Therefore, the importance of materials and their processing techniques cannot be undervalued in today's world. Materials form the stuff of any engineering application or product. It has been found that the engineers do not give adequate attention to this important subject. Moreover, it has not been adequately represented in the course curriculum of various universities. Therefore, it becomes imperative to highlight the importance of engineering materials for all engineers related to the various aspects of engineering applications.

There is a wide variety of materials available which have shown their potential in various engineering fields ranging from aerospace to house hold applications. The materials are usually selected after considering their characteristics, specific application areas, advantages and limitations. The challenge for designers is to select an optimal material suitable for the specific design requirements. The stringent design requirements generally lead to development of new

Materials to meet the specific operating conditions and environments. The new materials are developed from the conventional materials by either by the intrinsic or the extrinsic modification. In intrinsic modification, minor alloying or heat treatment is carried out. In extrinsic modification, external reinforcements are added to the parent material to alter its properties in order to meet the specific design requirements.

The engineers are then entrusted with the task of finding suitable techniques which would lead to high quality cost-effective processing of these materials. In order to achieve this objective, it is imperative for all engineers to have a fundamental understanding of the existing materials and their processing techniques. It has been found that there are adequate of courses in the curriculum of various universities where the processing techniques for metals are dealt in detail. The processing of non-metals is usually not covered as a core subject at the under-graduate level and therefore the engineers do not have a fundamental understanding about the processing of important non-metals such as plastics and ceramics. The course has been designed to study the basic nature of different non-metals and the manufacturing processes associated thereof. The various non-metals covered in the course include glasses, ceramics, plastics and different types of composite materials.

Classification and Selection of Materials:

The first module deals with the classification of the engineering materials and their processing techniques. The engineering materials can broadly be classified as:

a) Ferrous Metals

b) Non-ferrous Metals (aluminum, magnesium, copper, nickel, titanium)

c) Plastics (thermoplastics, thermosets)

d) Ceramics and Diamond

e) Composite Materials

f) Nano-materials

Classification of Processing Techniques

The basic aim of processing is to produce the products of the required quality at a reasonable cost. The basic processes can be broadly classified as:

a) Primary Forming Processes

b) Deformative Processes

c) Material Removal Processes

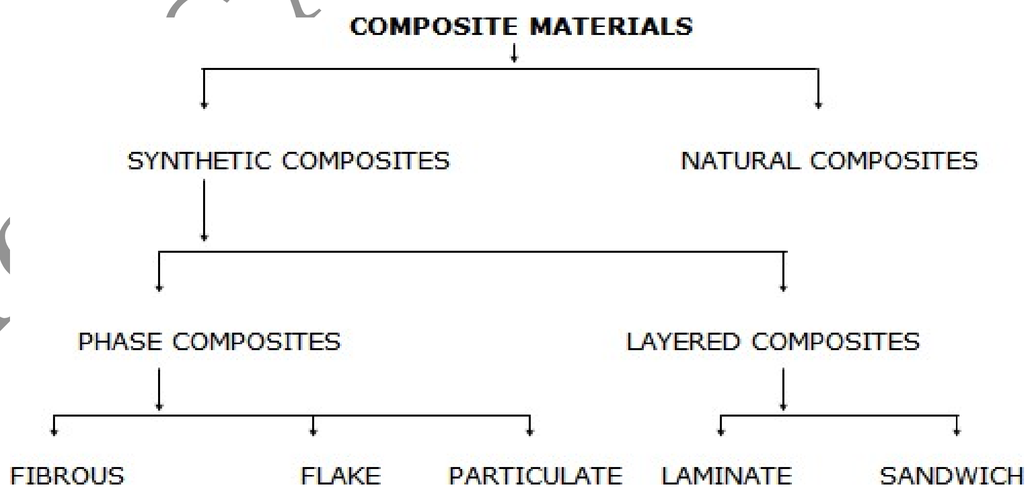
d) Joining Processes

e) Finishing Processes

Most of the engineering materials are processed either individually or in combination by the above mentioned processes. The processes can further be classified as conventional and advanced processes. The specific application area of each will depend on the design requirements and the ability with which a material renders itself to various processing techniques. The selection of a processing technique for any engineering material would broadly depend on the properties (mechanical, physical, chemical) of the material and the required number of parts to be processed.

Composites

A composite material is made by combining two or more materials – often ones that have very different properties. The two materials work together to give the composite unique properties. However, within the composite you can easily tell the different materials apart as they do not dissolve or blend into each other.



Classification of composites I (based on matrix material)

Metal Matrix Composites (MMC)

Metal Matrix Composites are composed of a metallic matrix (aluminum, magnesium, iron, cobalt, copper) and a dispersed ceramic (oxides, carbides) or metallic (lead, tungsten, molybdenum) phase.

Ceramic Matrix Composites (CMC)

Ceramic Matrix Composites are composed of a ceramic matrix and embedded fibers of other ceramic material (dispersed phase).

Polymer Matrix Composites (PMC)

Polymer Matrix Composites are composed of a matrix from thermoset (Unsaturated Polyester (UP), Epoxy (EP)) or thermoplastic (Polycarbonate (PC),Polyvinylchloride, Nylon, Polystyrene) and embedded glass, carbon, steel or Kevlar fibers (dispersed phase).

Classification of composite materials II(based on reinforcing material structure)

Particulate Composites

Particulate Composites consist of a matrix reinforced by a dispersed phase in form of particles.

1. Composites with random orientation of particles.
2. Composites with preferred orientation of particles. Dispersed phase of these materials consists of two-dimensional flat platelets (flakes), laid parallel to each other.

Fibrous Composites

1. Short-fiber reinforced composites. Short-fiber reinforced composites consist of a matrix reinforced by a dispersed phase in form of discontinuous fibers (length < 100*diameter).
   - I. Composites with random orientation of fibers.
   - II. Composites with preferred orientation of fibers.
2. Long-fiber reinforced composites. Long-fiber reinforced composites consist of a matrix reinforced by a dispersed phase in form of continuous fibers.
   - I. Unidirectional orientation of fibers.
   - II. Bidirectional orientation of fibers (woven).

Laminate Composites

When a fiber reinforced composite consists of several layers with different fiber orientations, it is called multilayer (angle-ply) composite.

Composites

Fibers or particles embedded in **matrix** of another material are the best example of modern-day composite materials, which are mostly structural.

Laminates are composite material where different layers of materials give them the specific character of a composite material having a specific function to perform. **Fabrics** have no matrix to fall back on, but in them, fibers of different compositions combine to give them a specific character. **Reinforcing materials** generally withstand maximum load and serve the desirable properties.

Further, though composite types are often distinguishable from one another, no clear determination can be really made. To facilitate definition, the accent is often shifted to the levels at which differentiation take place viz., **microscopic** or **macroscopic**.

In **matrix**-based structural composites, the matrix serves two paramount purposes viz., binding the **reinforcement phases** in place and deforming to distribute the stresses among the constituent **reinforcement materials** under an applied force.

The demands on matrices are many. They may need to temperature variations, be conductors or resistors of electricity, have **moisture sensitivity** etc. This may offer weight advantages, ease of handling and other merits which may also become applicable depending on the purpose for which matrices are chosen.

Solids that accommodate stress to incorporate other constituents provide strong bonds for the reinforcing phase are potential **matrix materials**. A few inorganic materials, polymers and metals have found applications as matrix materials in the designing of structural composites, with commendable success. These materials remain elastic till failure occurs and show decreased failure strain, when loaded in tension and compression.

Classification of Composites

Composite materials are commonly classified at following two distinct levels:

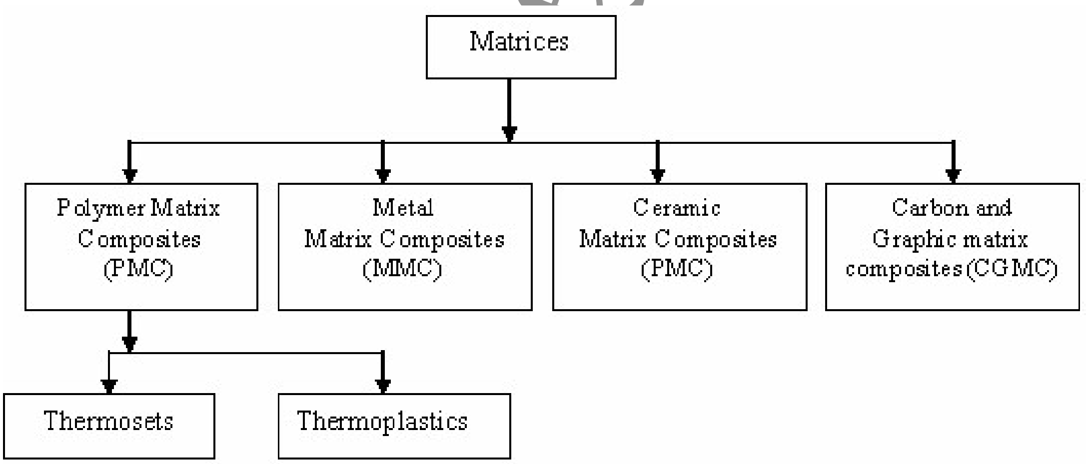
- The first level of classification is usually made with respect to the matrix constituent. The major composite classes include Organic Matrix Composites (OMCs), Metal Matrix Composites (MMCs) and Ceramic Matrix Composites (CMCs). The term organic matrix composite is generally assumed to include two classes of composites, namely Polymer Matrix Composites (PMCs) and carbon matrix composites commonly referred to as carbon-carbon composites.

• The second level of classification refers to the reinforcement form - fiber **reinforced composites**, **laminar composites** and **particulate composites**. Fiber Reinforced composites (FRP) can be further divided into those containing discontinuous or continuous fibers.

• **Fiber Reinforced Composites** are composed of fibers embedded in matrix material. Such a composite is considered to be a discontinuous fiber or short fiber composite if its properties vary with fiber length. On the other hand, when the length of the fiber is such that any further increase in length does not further increase, the elastic modulus of the composite, the composite is considered to be continuous fiber reinforced. Fibers are small in diameter and when pushed axially, they bend easily although they have very good tensile properties. These fibers must be supported to keep individual fibers from bending and buckling.

• **Laminar Composites** are composed of layers of materials held together by matrix. Sandwich structures fall under this category.

• **Particulate Composites** are composed of particles distributed or embedded in a matrix body. The particles may be flakes or in powder form. Concrete and wood particle boards are examples of this category



Organic Matrix Composites

Polymer Matrix Composites (PMC)/Carbon Matrix Composites or Carbon-Carbon Composites

Polymers make ideal materials as they can be processed easily, possess lightweight, and desirable mechanical properties. It follows, therefore, that high temperature resins are extensively used in aeronautical applications.

Two main kinds of polymers are **thermosets** and **thermoplastics**. Thermosets have qualities such as a well-bonded three-dimensional molecular structure after curing. They decompose instead of melting on hardening. Merely changing the basic composition of the resin is enough to alter the conditions suitably for curing and determine its other characteristics. They can be retained in a partially cured condition too over prolonged periods of time, rendering Thermosets very flexible. Thus, they are most suited as matrix bases for advanced conditions fiber reinforced composites. Thermosets find wide ranging applications in the **chopped fiber composites** form particularly when a premixed or molding compound with fibers of specific quality and aspect ratio happens to be starting material as in epoxy, polymer and phenolic polyamide resins.

Thermoplastics have one- or two-dimensional molecular structure and they tend to at an elevated temperature and show exaggerated melting point. Another advantage is that the process of softening at elevated temperatures can reversed to regain its properties during cooling, facilitating applications of **conventional compress techniques** to mould the compounds.

Resins reinforced with thermoplastics now comprised an emerging group of composites. The theme of most experiments in this area to improve the base properties of the resins and extract the greatest functional advantages from them in new avenues, including attempts to replace metals in die-casting processes. In crystalline thermoplastics, the reinforcement affects the **morphology** to a considerable extent, prompting the reinforcement to empower nucleation. Whenever **crystalline** or **amorphous**, these resins possess the facility to alter their **creep** over an extensive range of temperature. But this range includes the point at which the usage of resins is constrained, and the reinforcement in such systems can increase the failure load as well as creep resistance. Figure M1.2.1 shows kinds of thermoplastics

Metal Matrix Composites (MMC)

Metal matrix composites, at present though generating a wide interest in research fraternity, are not as widely in use as their plastic counterparts. High **strength**, **fracture toughness** and **stiffness** are offered by metal matrices than those offered by their polymer counterparts. They can withstand elevated temperature in corrosive environment than polymer composites. Most metals and alloys could be used as matrices and they require reinforcement materials which need to be stable over a range of temperature and non-reactive too. However the guiding aspect for the choice depends essentially on the matrix material. Light metals form the matrix for temperature application and the reinforcements in addition to the aforementioned reasons are characterized by high moduli.

Most metals and alloys make good matrices. However, practically, the choices for low temperature applications are not many. Only light metals are responsive, with their low density proving an advantage. Titanium, Aluminium and magnesium are the popular matrix metals currently in vogue, which are particularly useful for aircraft applications. If metallic matrix materials have to offer high strength, they require high modulus reinforcements. The strength-to-weight ratios of resulting composites can be higher than most alloys.

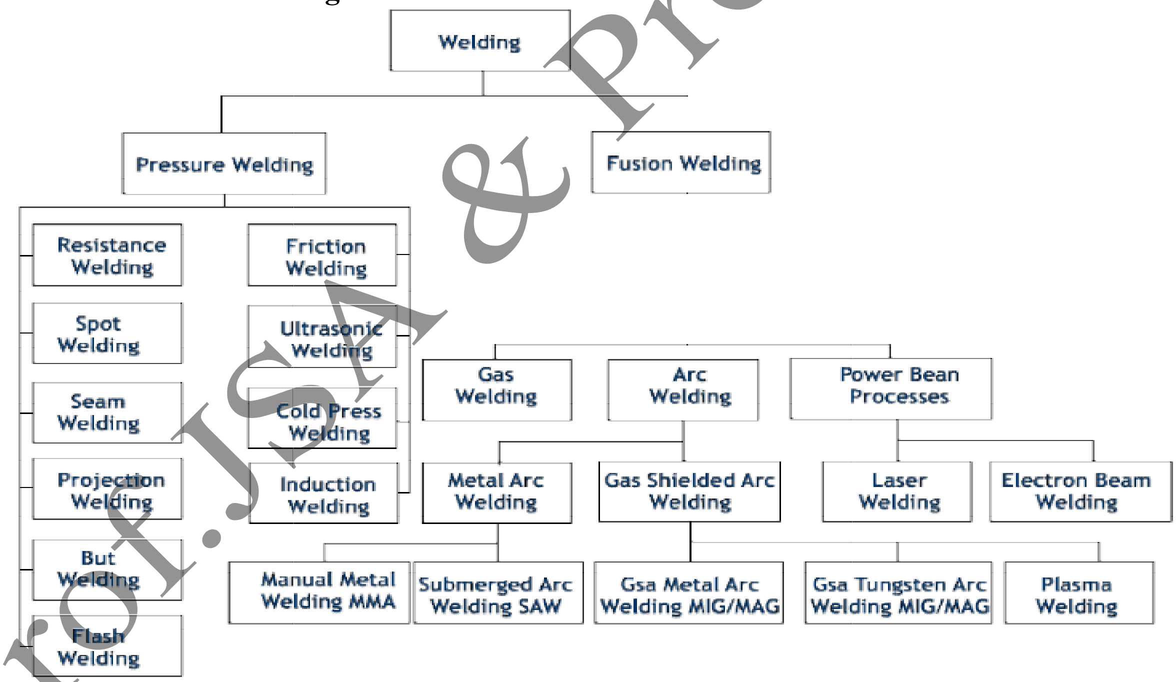
The melting point, physical and mechanical properties of the composite at various temperatures determine the service temperature of composites. Most metals, ceramics and compounds can be used with matrices of low melting point alloys. The choice of reinforcements becomes more stunted with increase in the melting temperature of matrix materials.

Soldering, Brazing and Welding:

Welding:

Welding is defined as the joining of two metal pieces, together to produce essentially a single piece of metal.

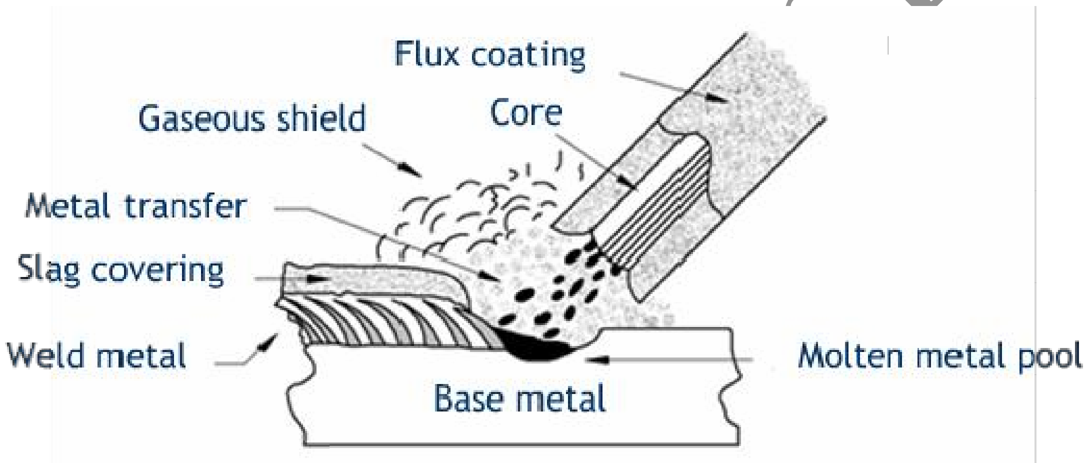
Classification of welding



Types of Welding

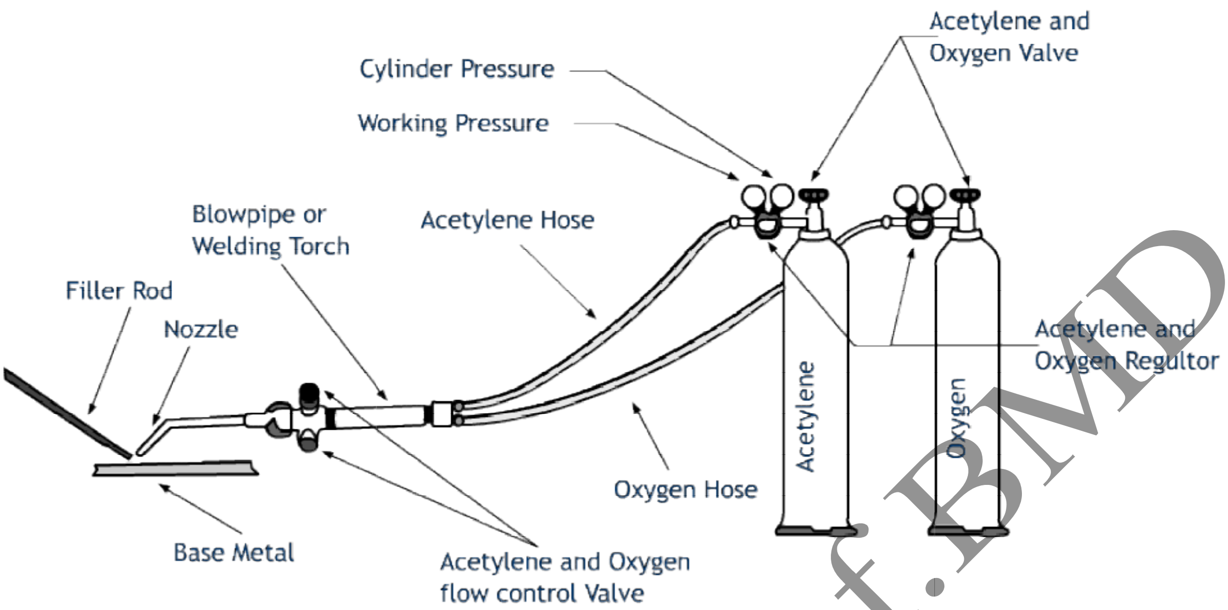
1) **Fusion Welding:** joining two metal pieces is heated up to molten state and allowed to solidify, also called as no-pressure welding.
   Ex- Arc welding and Gas welding
2) **Pressure welding:** joining parts to be heated up to plastic state and applying external pressure.
   Ex- Resistance welding and Forge welding.

Electric Arc Welding



Arc welding is one of several fusion welding processes for joining metals. By applying intense heat through a electric arc, metal at the joint is melted and caused to intermix - directly, or with an intermediate molten filler metal. Upon cooling and solidification, a metallurgical bond is created. Since the joining is an intermixture of metals, the final weldment potentially has the same strength properties as the metal of the parts.

Oxy-Acetylene Welding



This is a common gas welding process. Acetylene is the fuel gas used. Acetylene produces high heat content in the range of 3200^0 C than other fuel gases. Acetylene gas has more available carbon (92.3 %) and hydrogen (7.7 %) by weight. The heat is released when the carbon breaks away from hydrogen to combine with O_2 and burn.

$$C_2H_2+O_2 = 2CO+H_2+Heat$$

Depending up on the gas pressure required for welding or cutting oxy acetylene welding is classified into two parts:

Low pressure System and

High-pressure system

Soldering:

Soldering is a method of joining two thin metal pieces using a dissimilar metal or an alloy by the application of heat.

- Temperature is range of 150 to 350 degree.
- Application of flux is externally, usually rosin or borax.
- Soldering application will be electronics circuits.

Advantages of soldering

1) Solder joints are easy to repair
2) Solder joints are corrosion resistance.
3) Low cost and easy to use.
4) Skilled operator is required.

Brazing:

Brazing is a method of joining two similar or dissimilar metals using a special fusible alloy.

The filler metal melts and diffuses over the joint placed.

- The filler metal is called as **Spelters.**
- The flux used is borax or boric acid.
- The brazing is used in copper alloys applications.
- The temperature range is 450 to 900 degree.

Differences between soldering, brazing and Welding

Sl. No.	Welding	Soldering	Brazing
1	These are the strongest joints used to bear the load. Strength of a welded joint may be more than the strength of base metal.	These are weakest joint out of three. Not meant to bear the load. Use to make electrical contacts generally.	These are stronger than soldering but weaker than welding. These can be used to bear the load upto some extent.
2	Temperature required is up to 3800^{o}C of welding zone.	Temperature requirement is up to 450^{o}C.	It may go to 600oC in brazing.
3	Workpiece to be joined need to be heated till their melting point.	No need to heat the workpieces.	Work pieces are heated but below their melting point.
4	Mechanical properties of base metal may change at the joint due to heating and cooling.	No change in mechanical properties after joining.	May change in mechanical properties of joint but it is almost

			negligible.
5	Heat cost is involved and high skill level is required.	Cost involved and skill requirements are very low.	Cost involved and sill required are in between others two.
6	Heat treatment is generally required to eliminate undesirable effects of welding.	No heat treatment is required.	No heat treatment is required after brazing.
7	No preheating of workpiece is required before welding as it is carried out at high temperature.	Preheating of workpieces before soldering is good for making good quality joint.	Preheating is desirable to make strong joint as brazing is carried out at relatively low temperature.

Module – 5

REFRIGERATION AND CONDITIONING

Refrigeration: Refrigeration is defined as a method of reducing the temperature of a system below that of the surroundings and maintains it at the lower temperature by continuously abstracting the heat from it.

Refrigerant: in a refrigerator, a medium called refrigerant continuously extracts the heat from the space within the refrigerator which is to be kept cool at temperatures less than the atmosphere and finally rejects to it. Some of the fluids like, ammonia, Freon, Methyl chloride, carbon dioxide are the commonly used refrigerants.

Properties of good Refrigerants:

1. Thermodynamic Properties

a. A good refrigerant must have a low boiling temperature at atmospheric pressure.
b. A good refrigerant must have a very low freezing point because the refrigerant should not freeze at low temperatures.
c. In order to avoid the leakage of the atmospheric air and also to enable the detection of the leakage of the refrigerant, both the evaporator and condenser pressures should be slightly above the atmospheric pressure.
d. The latent heat of evaporation must be very high so that a minimum amount of refrigerant will accomplish the desired result in other words, it other words, it increases the refrigeration effect.
e. The specific volume of the refrigerant must be very low. The lower specific volume of the refrigerant at the suction of the compressor reduces the size of the compressor.

Physical properties

A good refrigerant must have low specific heat when it is in liquid state and high specific heat when it is vaporized.

a. The viscosity of a refrigerant at both the liquid and vapour states must be very low as it improves the heat transfer and reduces the pumping pressure.

b. A good refrigerant should be non-toxic,
c. A good refrigerant should be non-corrosive to prevent the corrosion of the metallic parts of the refrigerators.
d. Chemical stability an ideal refrigerant must not decompose under operating conditions.
e. The coefficient of performance of a refrigerant must be high so that the energy spent in refrigeration will be less.
f. A good refrigerant must be odourless, otherwise some foodstuff such as meat, butter, etc. lose their taste.
g. A good refrigerant should have any leakage can be detected by simple test.
h. A good refrigerant must not react with the lubricating oil used in lubricating the parts of the compressor.

List of refrigerants:

1. Ammonia – in vapour absorption refrigerators
2. Carbon dioxide—in marine refrigerators
3. Sulphur dioxide—in house hold refrigerators
4. Methyl chloride—in small scale refrigeration and domestic refrigerators.
5. Freon-12 in domestic vapour compression refrigerators
6. Freon-22 in Air conditioners.

Principle of refrigeration:

In refrigeration, the heat is to be removed continuously from a system at a lower temperature and transfer it to the surroundings at a higher temperature. This operation according to the second law of thermodynamics can only be performed by the aid of the external work. Therefore in a refrigerator, power is to be supplied to remove the heat continuously from the refrigerator cabinet to keep it cool at a temperature less than the atmosphere.

Refrigeration effect: in a refrigeration system, the rate at which the heat is absorbed in a cycle from the interior space to be cooled is called refrigerating effect.

Ton of refrigeration or Ice making capacity: a ton of refrigeration is defined as the quantity of heat absorbed in order to form one ton of ice in 24 hours when the initial temperature of the water is 0°C.

1 TON of refrigeration = 210 KJ/min = 3.5 KW

Coefficient of performance (COP): The COP of a refrigeration system is defined as the ratio of heat absorbed in a system to the work supplied.

If Q= Heat absorbed or removed, KW

W= work supplied, KW

COP = Q/W

Refrigeration concepts:

1. Heat flows from a system at higher temperature to another at lower temperature.
2. Fluids by absorbing the heat change from liquid phase to vapour phase and subsequently condense by giving off the heat.
3. Heat can flow from a system at low temperature to a system at higher temperature by the aid of external work as per the second law of thermodynamics.

Components of Refrigerator:

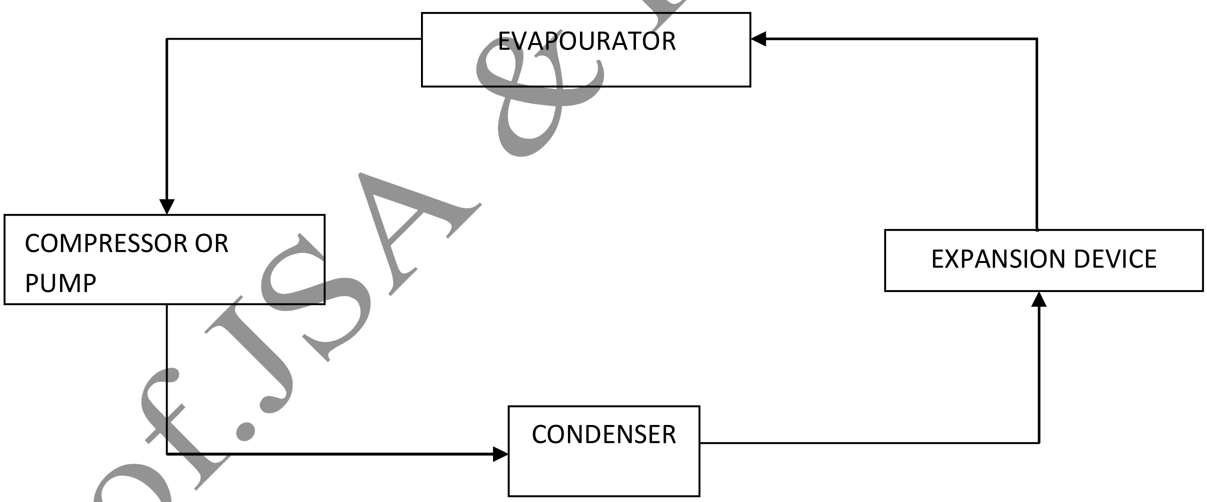


Figure 4.1 Components of Refrigerator

1) **Evaporator:** The evaporator is the heart of the refrigerator where the liquid refrigerant is evaporated by the absorption of heat from the refrigerator cabinet in which the substances which have to be cooled are kept.
2) **Circulating system:** Circulating devices such as compressor or pumps necessary to circulate the refrigerant to undergo the refrigeration cycle.

3) **Condenser:** In a condenser the refrigerant vapour gives off its latent heat to the air and consequently condenses into liquid so that it can be recirculated in the refrigeration cycle.

4) **Expansion device** device to reduce the pressure of liquid refrigerant before passes to the evaporator

Vapour Compression Refrigerator:

The refrigerant at low pressure and low temperature, passing in the evaporator coils, absorbs the heat from the contents in the freezing compartment and evaporates.

The evaporated refrigerant at low pressure from the evaporator is drawn by a compressor. Which compresses it to, high pressure so that the saturation temperature of the refrigerant, corresponding to the increased pressure is higher than the temperature of the cooling medium in the condenser.

The high pressure-high-temperature refrigerant vapour from the compressor flows to the condenser where it gives off its latent heat to the atmospheric air.

As a result of the loss of latent heat in the condenser, the refrigerant condenses.

The high pressure condensed liquid refrigerant approximately at room temperature now flows to the throttle valve in which it expands to low pressure and then passes to the evaporator coils for recirculation once again.

Hence the refrigerant coming out of the expansion valve will be a very wet vapour and at a very low temperature which will be around -10degree. He required low temperature is maintained in the refrigerator by a thermostat switch which switches on and off the compressor motor by a relay as and when the temperature either falls below or rises above the required temperature. The refrigerant is Freon-12

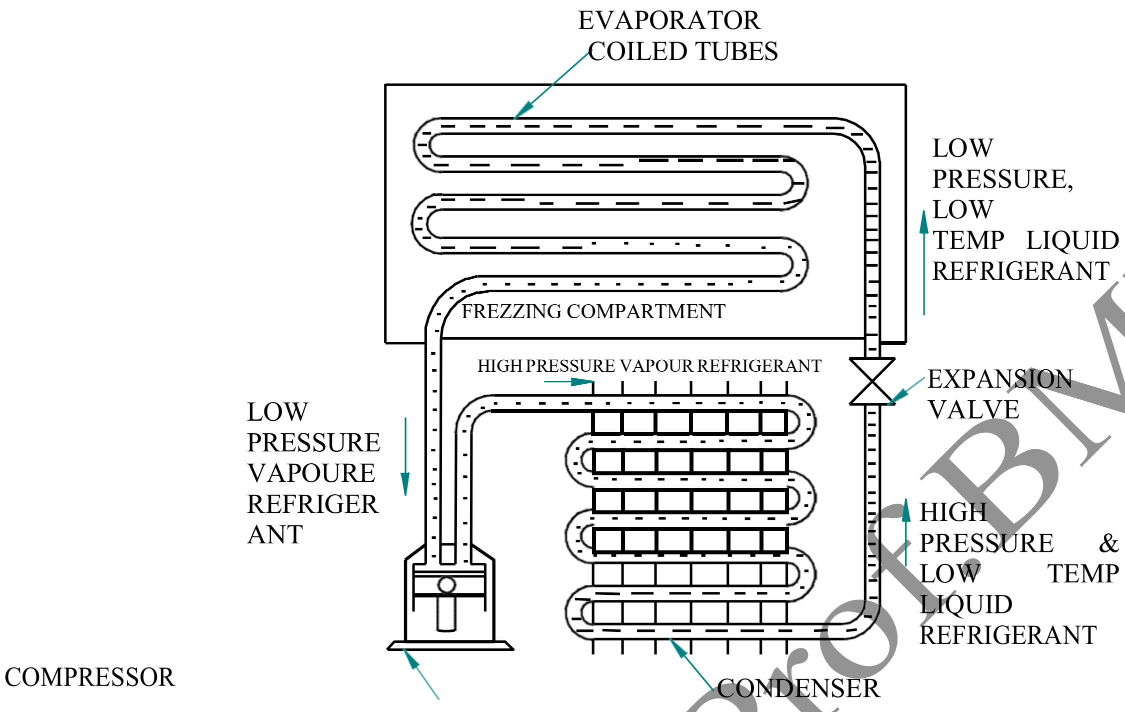


Figure 4.2 Vapour compression Refrigeration

Vapour Absorption Refrigerator:

- The liquid ammonia vapouries in the evaporator coils,
- Absorbing the latent heat from the freezing compartment thus keeping it cool and subsequently gives off heat when it condenses in a condenser.
- Dry ammonia vapour is dissolved in the cold water contained in the absorber, which will produce a strong ammonia solution which is flowing back from the heater-separator from the heat exchanger.
- The worm high pressure strong ammonia solution is passed to the heater-cum-separator provided with the heating coils.

Heating of the high pressure strong ammonia solution will drive out the ammonia vapour from it and consequently the solution in the heater-separator becomes weak which in turn flows back to the heat exchanger. Where it worms up the strong ammonia solution passing through it.

The high pressure ammonia vapour from the heater-separator now passes to a condensed.

The high pressure ammonia liquid is now expanded to a low pressure and low temperature in the throttle valve.

The low pressure condensed ammonia liquid at low temperature is passed onto the evaporator coils provided in the freezing compartment, where it absorbs the heat and evaporates.

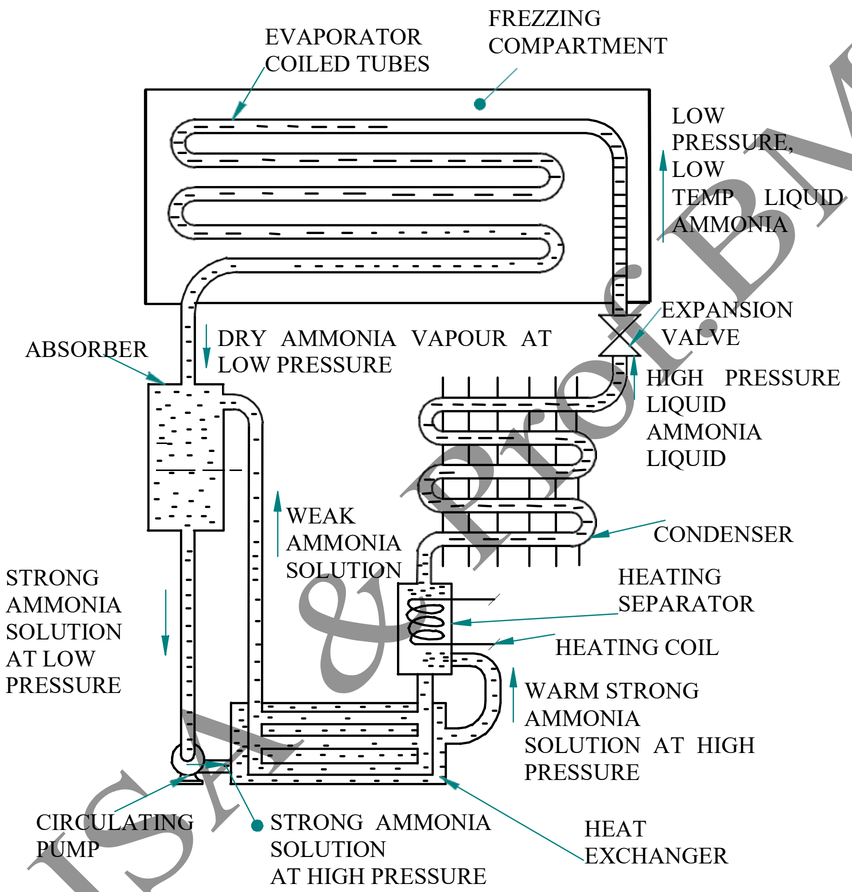


Figure 4.3 Vapour Absorption Refrigeration

Comparison between Vapour Compression and Absorption system:

Absorption system	Compression System
a) Uses low grade energy like heat. Therefore, may be worked on exhaust systems from I.C engines, etc.	a) Using high-grade energy like mechanical work.
b) Moving parts are only in the pump, which is a small element of the system. Hence operation is smooth.	b) Moving parts are in the compressor. Therefore, more wear, tear and noise.
c) The system can work on lower evaporator	c) The COP decreases considerably with

pressures also without affecting the COP.	decrease in evaporator pressure.
d) No effect of reducing the load on performance.	d) Performance is adversely affected at partial loads.
e) Liquid traces of refrigerant present in piping at the exit of evaporator constitute no danger.	e) Liquid traces in suction line may damage the Compressor.
f) Automatic operation for controlling the capacity is easy.	f) It is difficult.

Air-conditioning

Providing a cool constant indoor atmosphere at all times regardless of weather conditions needed either for human comfort or industrial purposes by artificially cooling, humidifying or dehumidifying, cleaning and recirculating the surrounding air is called air conditioning.

Room Conditioner:

The high pressure, low-temperature liquid refrigerant from the condenser is passed to the evaporator coils through the capillary tube where it undergoes expansion.

The evaporator fan continuously draws the air from the interior space within the room through air filler by forcing it to pass over the evaporator coils.

The air from the interior passing over the evaporator coils is cooled by the refrigerant which consequently evaporates by absorbing the heat from the air.

The higher temperature evaporated refrigerant from the evaporator is drawn by the suction of the compressor which compresses it and delivers it to the condenser.

The high pressure, high temperature refrigerant vapour now flows through the condenser coils.

The condenser fan draws the atmospheric air from the exposed side portions of the air conditioner which is projecting outside the building into the space behind it and discharges to pass through the centre suction of the condenser unit over the condenser coils.

The high pressure, high temperature refrigerant passing inside the condenser coils condensers by giving off the heat to the atmospheric air.

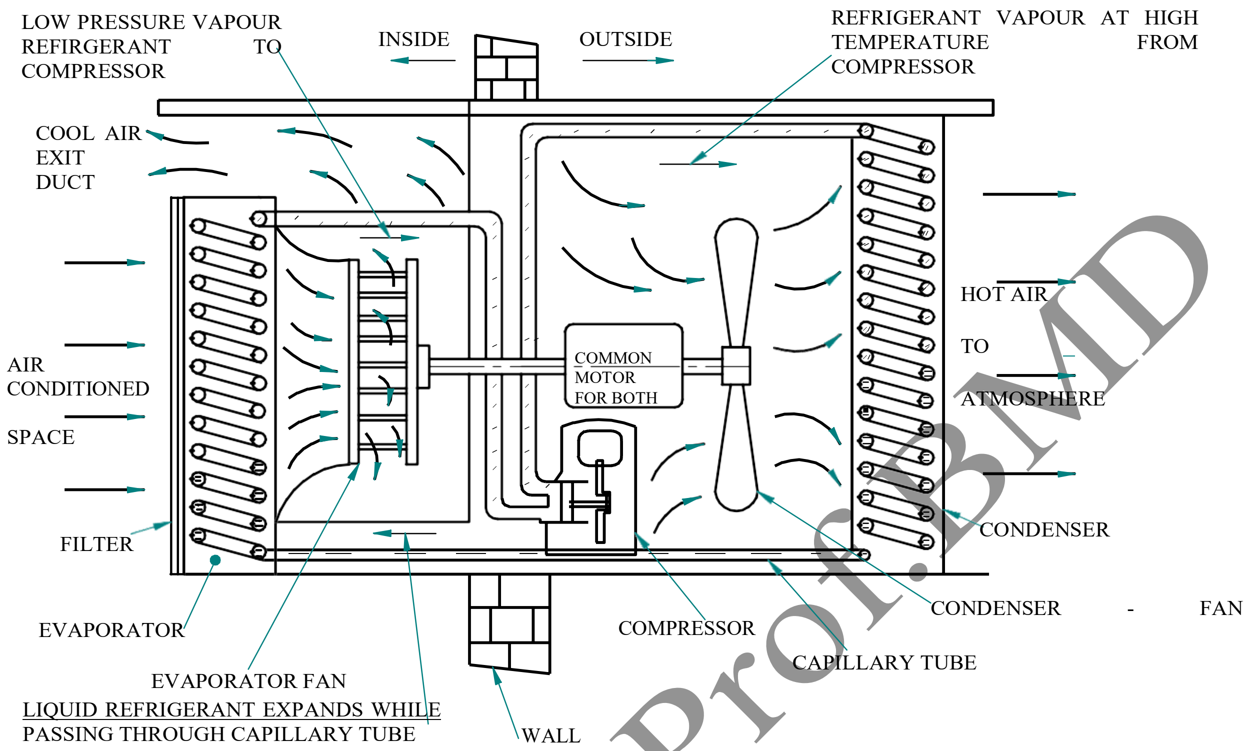


Figure 4.4 Room Air conditioner

Applications of Air-conditioning:

- Aviation industry
- Transportation
- Office applications
- Medical applications
- Agriculture industry