Unit- 1.

Introduction of Thermodynamics

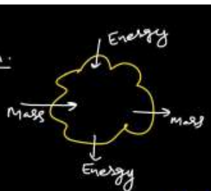
→ Thermodynamics is a two Greek Words.

Thermi → Heat, HoT.

Dynamikos → Study of Matter in Motion.

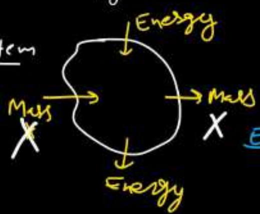
* Thermodynamics System.

(a) Open System.



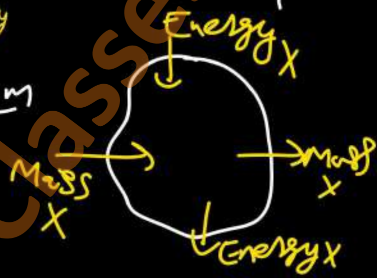
Ex- Engine

(b) Closed System



Ex- Cup of tea

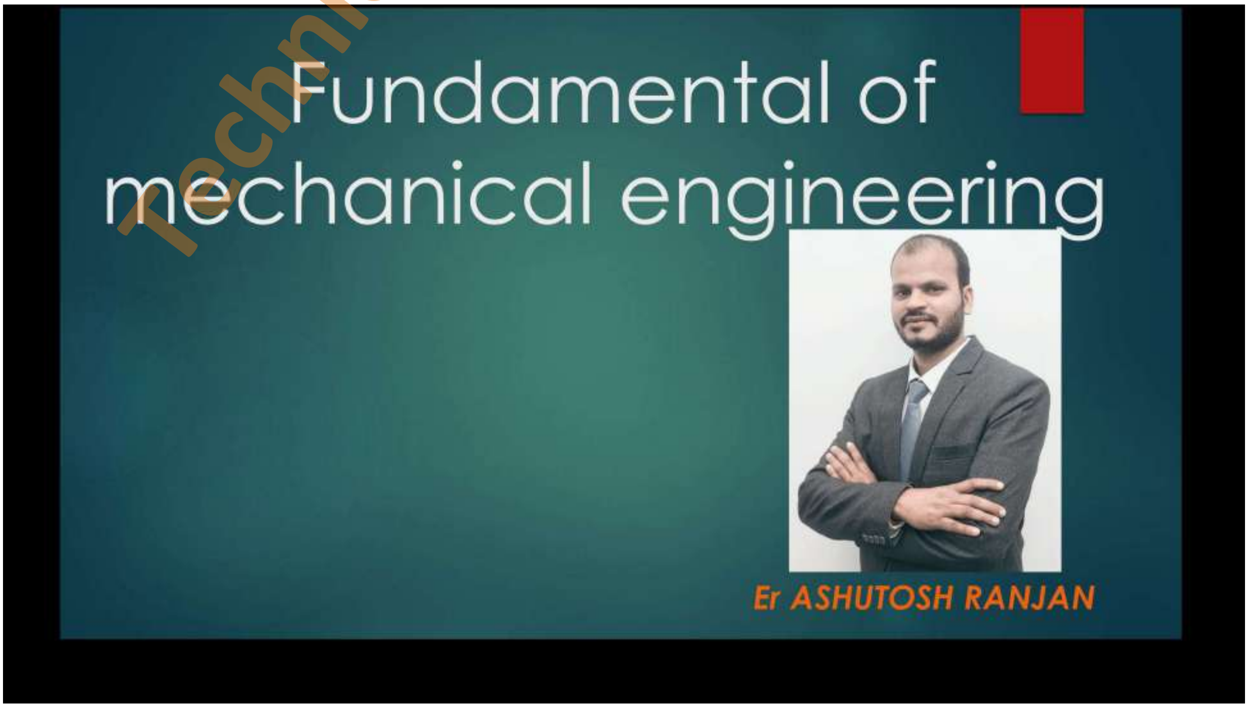
(c) Isolated System



Thermos

Note

	Mass	Energy
Open System	✓	✓
Closed "	X	✓
Isolated "	X	X



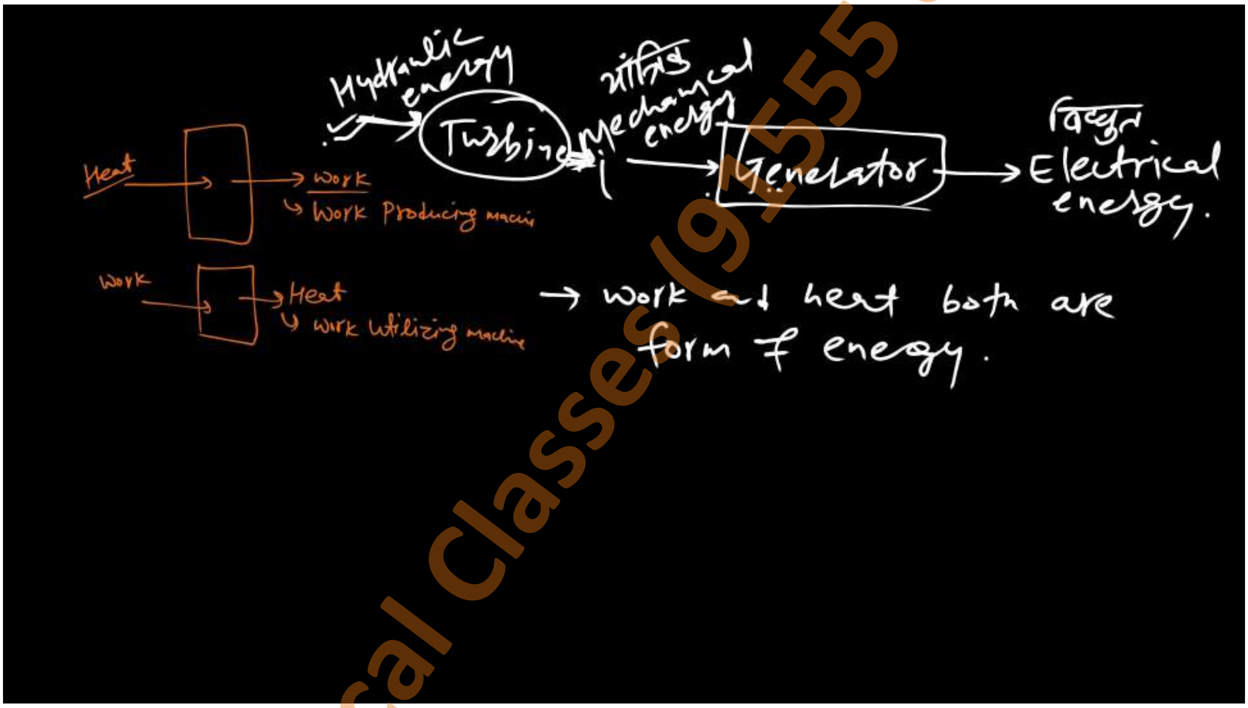
INTRODUCTION TO THERMODYNAMICS

- The word "thermodynamics" derives from two Greek words: "**therme**" meaning **hot or heat**, and "**dynamikos**" means **study of matter in motion** .

  Heat ⇌ Work

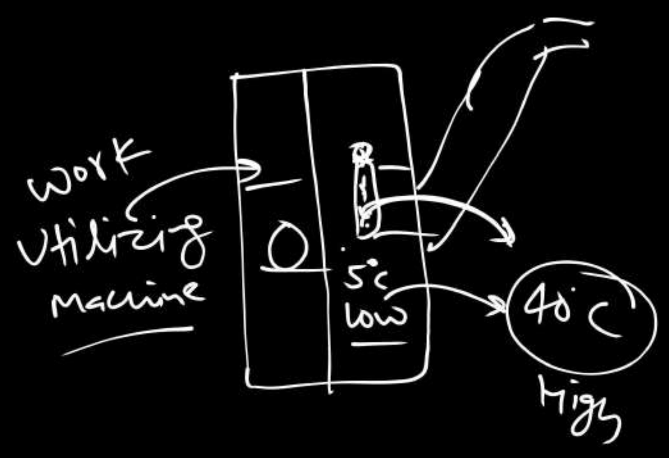
- Thus, thermodynamics is the study of heat related to matter in motion. Much of the study of engineering or applied thermodynamics is concerned with work producing or work utilizing machines such as engines, turbines and compressors together with the working substances used in such machines.

  ↳ Fuel (Diesel oil or Petrol, CNG etc)



Role of Thermodynamics in Engineering and Science

- Thermodynamics plays a crucial role in both engineering and science:
- **1. Energy Conversion:** Thermodynamics helps engineers understand and optimize processes that involve the conversion of energy, such as engines, power plants, and refrigeration systems.
- **2. Heat Transfer:** It's essential in designing systems for heat transfer, like HVAC systems, and in understanding how materials conduct heat.



Fundamental of mechanical engineering

Er ASHUTOSH RANJAN

- **Role of Thermodynamics in Engineering and Science**

  - Thermodynamics plays a crucial role in both engineering and science:
  - **1. Energy Conversion:** Thermodynamics helps engineers understand and optimize processes that involve the conversion of energy, such as engines, power plants, and refrigeration systems.
  - **2. Heat Transfer:** It's essential in designing systems for heat transfer, like HVAC systems, and in understanding how materials conduct heat.

- **3. Chemical Reactions:** Thermodynamics provides insights into chemical reactions, helping chemists and chemical engineers predict whether reactions will occur and how to control them.
- **4. Material Properties:** It's used to study and manipulate the properties of materials, such as phase changes, melting points, and superconductivity.
- **5. Environmental Engineering:** Thermodynamics principles are used to analyze and mitigate environmental issues, such as pollution control and sustainable energy production.
- **6. Aerospace Engineering:** Thermodynamics is vital in designing and optimizing propulsion systems for aircraft and spacecraft.

- In essence, thermodynamics provides a fundamental framework for understanding and solving problems in various fields of engineering and science related to energy, heat, and matter.

EC, HT, CR, EE, A.E, M.P

EC → Energy Conversion.
HT → Heat transfer.
CR → Chemical Reaction
EE → Environmental engg.

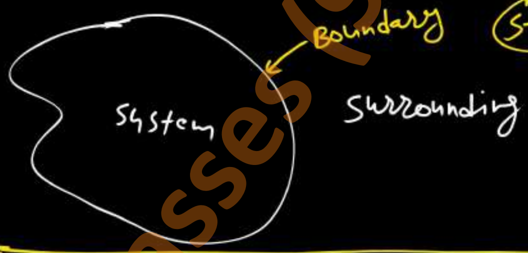
AE → Aerospace engg.
MP → Material Properties

* Thermodynamics system

Q. Explain thermodynamics. and writes Role of thermodynamics in engineering and science?

*** Thermodynamics System :—**

Thermodynamics system is a reason of area around the space where all the thermodynamics process takes place or thermodynamics analysis (study) is done.



Note :— System + Surrounding = Universe.

*** Surrounding :—** Every thing apart from the system is called surrounding.

*** Boundery :—** It is an imaginary or Real surface which seperate system and surrounding.

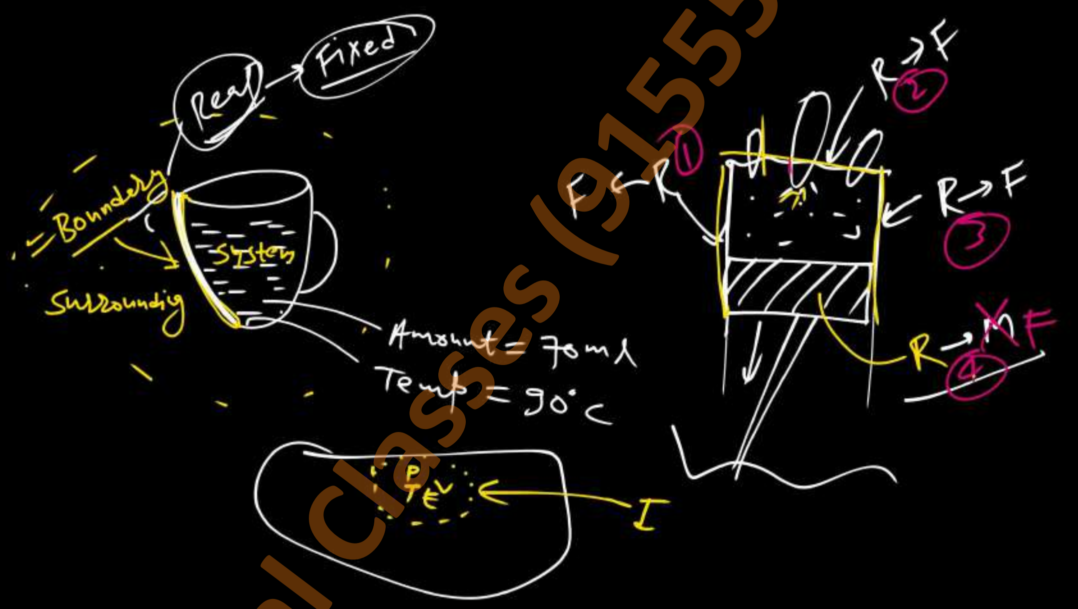
- Boundery
  - Imaginery boundary.
  - Real boundary
    - Fixed Real boundary
    - Movable Real boundary.

⇒ At least one boundary is movable for getting thermodynamics workdone.

* Types of System

There are three types of system.

- (a) Open system.
- (b) Closed system.
- (c) Isolated system.



* Thermodynamics System.

Work producing machine

→ Engine → work

(+ve)

Work utilizing machine

→ Compressor

→ Refrigerator

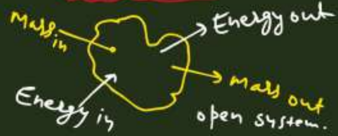
(−ve)

* Types of System

ⓐ open system.
ⓑ Closed system.
ⓒ Isolated System.

ⓐ open system

- A system in which mass as well as energy can transfer from system to surrounding or surrounding to system is known as open system.
- It is also known as Flow System.



EX → I.C engine, Turbine, Compressor, Pump. Nozzle, Diffuser etc.

Note → Most of the engineering Devices are open system.

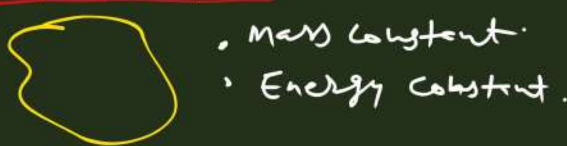
ⓑ Closed system

- A system in which mass remain constant but energy can transfer from system to surrounding or surrounding to system is known as closed system.
- It is also known as Non flow system.

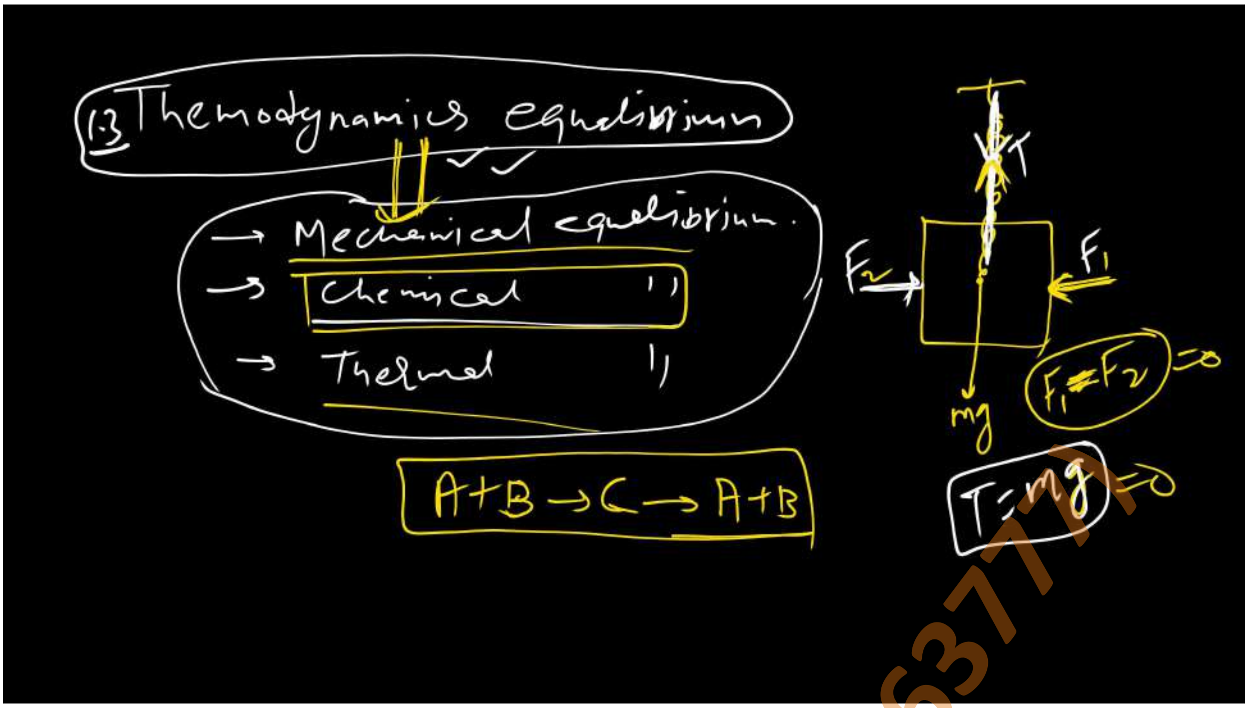
EX → Cup of hot tea, Refrigerator, Piston-cylinder without valve, etc.

ⓒ Isolated system

A system in which neither mass nor energy can transfer from system to surrounding or surrounding to system is known as Isolated system.



EX - Thermos flask, Universe etc.



THERMODYNAMICS EQUILIBRIUM

- A system is said to be in a state of thermodynamic equilibrium if the value of the property is same at all points in the system.
- A system will be in a state of thermodynamic equilibrium if the condition for the following three types of equilibrium are satisfied.

Thermodynamics equilibrium

H.W.

Q. What is thermodynamics? and write Role of Thermodynamics in engineering.

Ans →

Q. Define System and its types.?

Ans →

Q. Define Thermodynamics equilibrium.

Ans →

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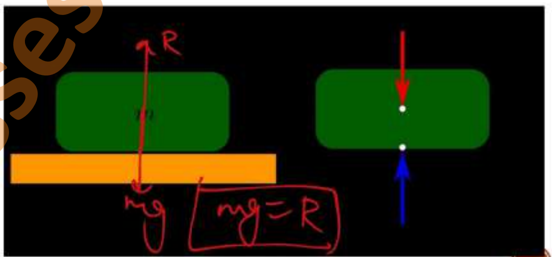
THERMODYNAMICS EQUILIBRIUM

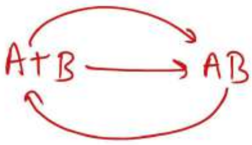
- **Mechanical equilibrium**
- A system is said to be in a state of mechanical equilibrium if there exist no unbalance force either in the interior of the system or between the system and the surrounding

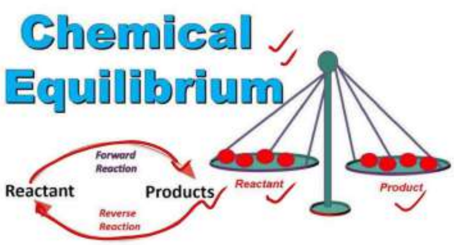


THERMODYNAMICS EQUILIBRIUM

→ Mechanical
→ Chemical

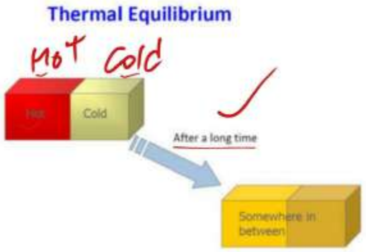
- **Chemical equilibrium**
- A system is said to be in a state of chemical equilibrium if there exist no chemical reaction for transfer of matter from one part of the system to another such as diffusion or solution

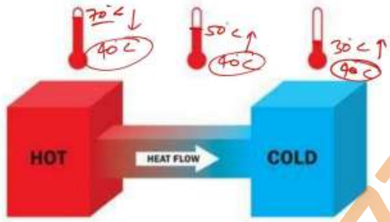




THERMODYNAMICS EQUILIBRIUM

- **Thermal equilibrium**
- A system is said to be in a thermal equilibrium if there exist and uniformity of temperature throughout the system or between system and surroundings





Thermodynamics equilibrium

- → Mechanical equi.
- → Chemical ,,
- → Thermal ,,

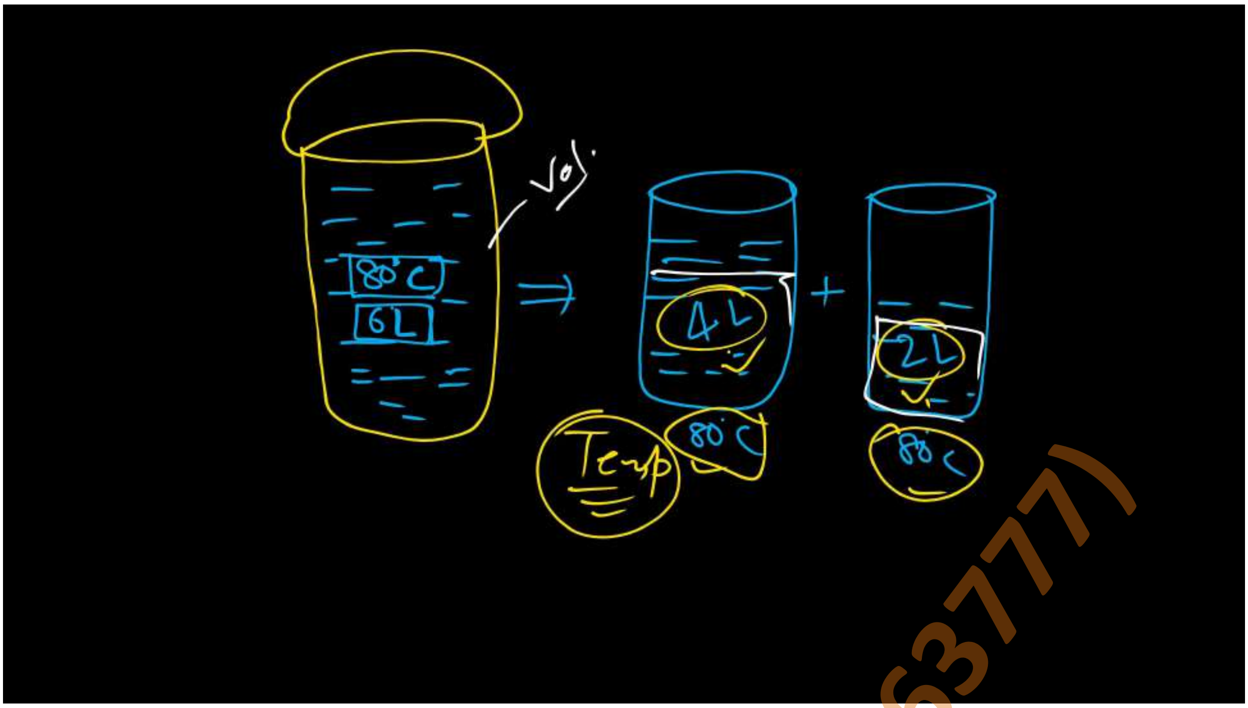
Thermodynamics Property

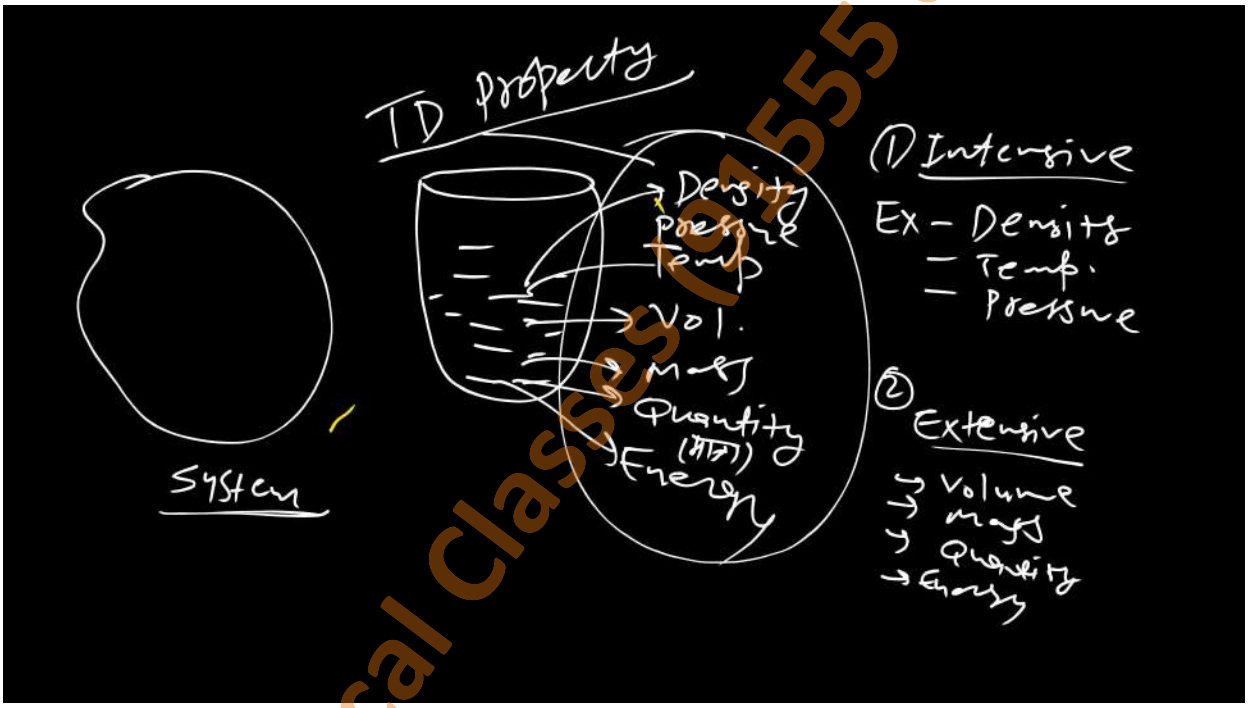
Intensive property
→ Independent of mass
or Independent size of system.

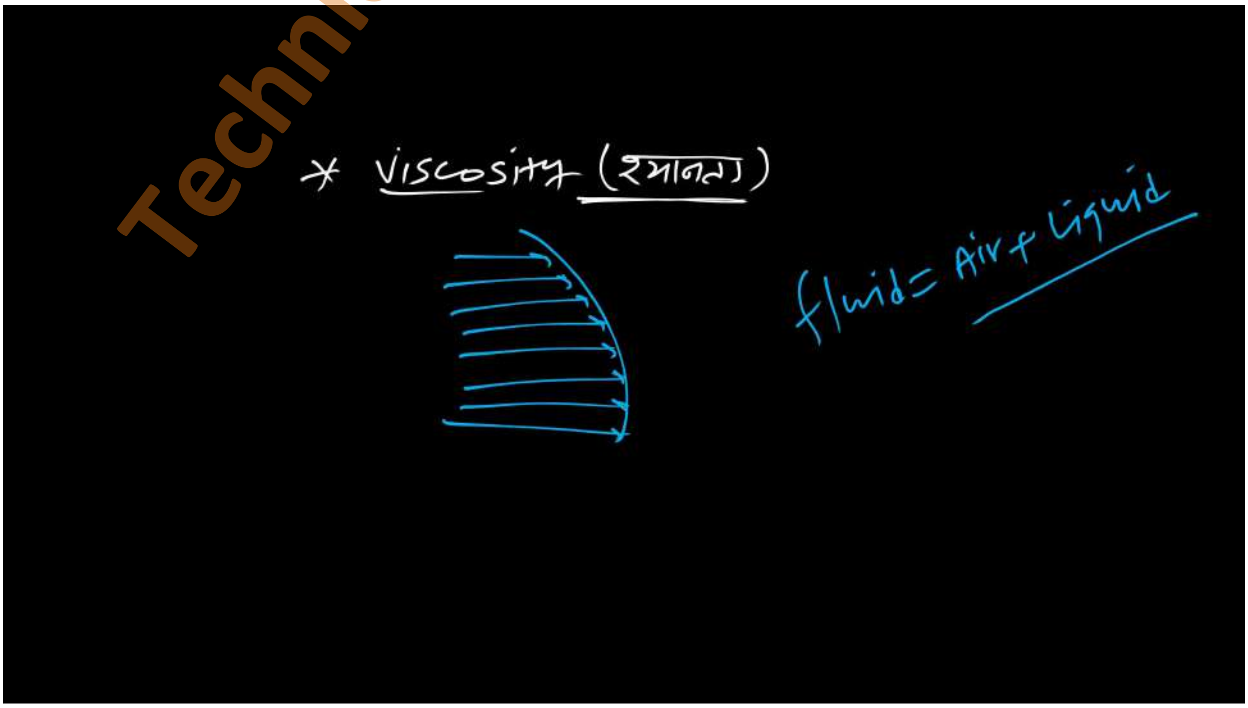
Ex– Temp,

Extensive property
→ Depends on mass
or, Depends on size of system.

Ex– Volume, mass


Vol.
80°C
6L
4L
2L
Temp
80°C
80°C


TD property
System
Density
pressure
Temp
Vol.
Mass
Quantity
(मात्रा)
Energy
① Intensive
Ex – Density
– Temp.
– Pressure
② Extensive
→ Volume
→ Mass
→ Quantity
→ Energy


* Viscosity (श्यानता)
fluid = Air + Liquid

PROPERTY OF A SYSTEM

- The physical condition of a system may be described by certain observable quantities such as volume, temperature, pressure etc.
- All the quantities which identify the condition of the system are called properties
- The thermodynamic properties of a system can be generally classified into two types
- **1. Intensive property**
- **2. Extensive property**

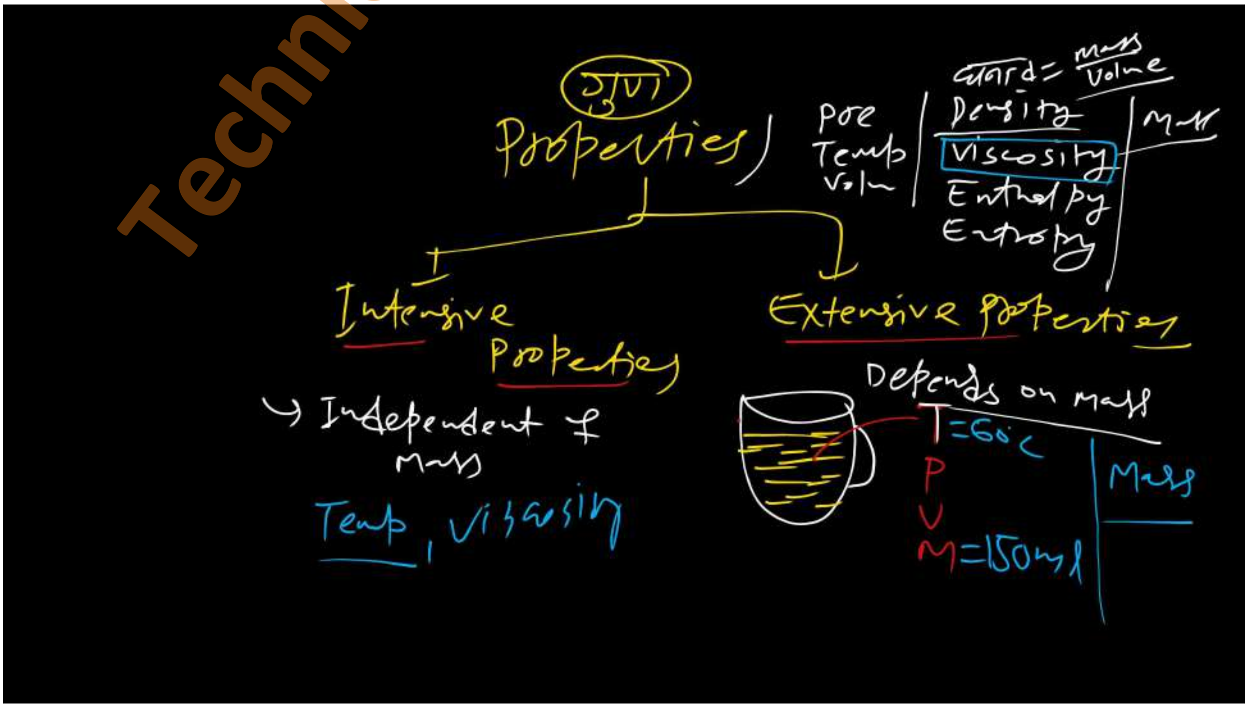
PROPERTY OF A SYSTEM

- **Intensive property**
- These properties are independent of mass or size of the system.

Ex – Pressure, temperature ,viscosity , conductivity etc (इत्यादि)

- **Extensive property**
- These properties are Depends on the mass or size of the system.

Ex – Mass ,volume , Entropy , magnetic field etc (इत्यादि)



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PROPERTY OF A SYSTEM

- **Intensive property**
- These properties are independent of mass or size of the system.

Ex- Pressure, temperature ,viscosity , conductivity etc

- **Extensive property**
- These properties are Depends on the mass or size of the system .

Mass ,volume , Entropy , magnetic field etc

• PROPERTY OF A SYSTEM

- **Note** :-
- Ratio of two extensive properties are always intensive
- Specific extensive properties are always intensive properties

Specific volume, specific energy and specific mass etc

- To decide whether the properties is intensive or extensive the system is to be divided into parts without any external interaction if property changed with respect to size then it is extensive property and if property do not change with respect size then it is intensive property.

INTENSIVE PROPERTIES

- Chemical potential
- Concentration
- Density (or specific gravity)
- Ductility
- Elasticity
- Hardness
- Melting point and boiling point
- Pressure
- Specific energy
- Specific heat capacity
- Specific volume
- Spectral absorption maxima (in solution)
- Temperature
- Viscosity

EXTENSIVE PROPERTY

- Energy
- Entropy
- Gibbs energy
- Length
- Mass
- particle number
- number of moles
- Volume
- electrical charge
- Weight

Comparison	Intensive properties	Extensive properties
Dependence	Amount independent (Mass)	Amount dependent (Mass)
Observance	Observed easily	Not observed easily
Identification	Identifiable	Non-identifiable
For samples	Helpful for the identification of samples	Helpful for describing the samples
Nature	Change physical behaviors	Change the nature of substances
Examples	Color, temperature, density, pressure, melting and boiling point, density, etc	Mass, volume, energy, enthalpy, entropy, length, etc

Q. Colour is an ______

(a) Intensive
(b) Extensive
(c) Both (a) & (b)
(d) None of these.

* Specific volume (v) (जगह घेरना)

→ The specific volume of a system is the volume occupied by the unit mass of the system.

→ SI unit of specific volume is m^3/kg.

→ Specific volume is reciprocal of density.

↓

उल्टा

$$\text{density} = \frac{\text{mass } 1}{\text{sp.volume}}.$$

$$\text{Sp. volume} = \frac{1}{\text{density}}$$ ← reciprocal of density

---

$$* \ \text{Specific volume } (v) = \frac{\text{Volume } (m^3)}{\text{Unit mass } (kg)}$$

→ S.I. $v = m^3/kg$.

→ specific volume is reciprocal of density

* Density is the ratio of mass per unit volume

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}}$$

$$\text{Density} = \frac{1}{\text{Volume}}.$$

$$\text{Specific volume} = \frac{1}{\text{Density}}$$ — Reciprocal of density. (घनत्व का उल्टा)

Q Density of any substance is $4\ kg/m^3$. then find the specific volume of substance.

$$\text{Density} = 4\ kg/m^3$$

$$\text{Specific volume} = \frac{1}{\text{Density}}$$

$$= \frac{1}{4\ kg/m^3}$$

$$\text{Specific volume} = \frac{1}{4}\ m^3/kg$$

$$= 0.25\ m^3/kg$$ Ans

Q. Define the following term.

(a) Specific volume (Sp. volume)

(b) Pressure

(c) Temperature

(d) Enthalpy.

(e) Thermodynamics Property.
- Intensive
- Extensive

* Pressure (P)

→ Pressure is defined as Normal force per unit area.

$$\text{Pressure} = \frac{\text{Force}}{\text{Area}}$$

→ SI Unit of Pressure is N/m^2 (Pascal), bar.

* Temperature (तापमान)

→ Temperature is a physical (भौतिक) quantity (राशि) which Measure (मापना) the hotness (गर्म) and coldness (ठण्डा) of a body.

→ Temperature is a quantity which decide (तय करना) the direction (दिशा) of heat flow.

→ Thermometer are used to Measure the temp. of body.

→ SI Unit of temp. is kelvin.

	F.P	B.P	Division
°C →	0°C	100°C →	100
K →	273 K	373 K →	100
°R →	0°R	80°R →	80
°F →	32°F	212°F →	180
Rankine →	492 R_n	672 R_n →	180
Ashutos →	112°A	212°A →	100

*** Unit conversion of temp.**

$$\frac{C-0}{100} = \frac{K-273}{100} = \frac{R-0}{80} = \frac{F-32}{180} = \frac{R_n-492}{180}$$

$$\frac{A-112}{100}$$

① 40°C

$$\frac{C-0}{100} = \frac{K-273}{100}$$

$C = K-273$

$K = 40+273$

$K = 313\ K$

② 40°C

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

$\frac{9}{5} \times 40 = F-32$

$72 = F-32$

$F = 72+32$

$F = 104°F$

*** Enthalpy (H)**

① T.D Property → Constant Pressure → Heat contain

Open System

② $H = U + PV$

H → Enthalpy; U → Internal energy; PV → Pressure × volume

*** Enthalpy (H)**

Enthalpy is a thermodynamic property which is equivalent to the total heat contain in a system at constant Pressure.

→ It is the sum of total internal energy (U) and product of Pressure and volume.

$$H = U + PV$$

→ Enthalpy is only define in open system.

→ Enthalpy is a Point function or State function.

→ Enthalpy is a extensive property (Depends on mass)

→ Specific enthalpy is a Intensive property. (Independent of mass)

$dH \propto m$

$dH \propto \Delta T$

For Numerical: $dH \propto m\Delta T$

$$dH = m C_p \Delta T$$

- dH → Change in enthalpy
- m → Mass
- C_p → Specific heat at constant Pressure
- ΔT → Change in temp.

5 kg, 30°C → 50°C, $C_p = 1$

---

5 kg water, 30°C + 273 = 303 K → 50°C + 273 = 323 K

$C_p = 1$

$dH = m C_p \Delta T$ (kg, kJ/kg K, K)

$= 5 \times 1 \times 20$

$$dH = 100 \text{ kJ}$$

Q. Calculate the change in enthalpy of a system if its temp. change from 300 K to 500 K and the mass is 850 gm. Take $C_p = 1.028$ kJ/kg K.

Soln Given data

$T_1 = 300$ K

$T_2 = 500$ K

$\Delta T = 200$ K

$m = 850 \text{ gm} = \frac{850}{1000} = 0.85$ kg

$C_p = 1.028$ kJ/kg K

$dH = m C_p \Delta T$

$= 0.85 \times 1.028 \times 200$

$dH = 174.76$ kJ Ans

H.W/R.W

Q. Calculate the change in enthalpy of a system if its temp. change from 50°C to 150°C and the mass is 500gm. Take $C_p = 1.02$ KJ/kg K.

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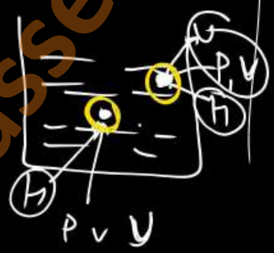
Point function or State function | Path function

Point function or State function

* Depends on point

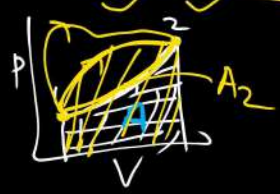
Ex → Enthalpy

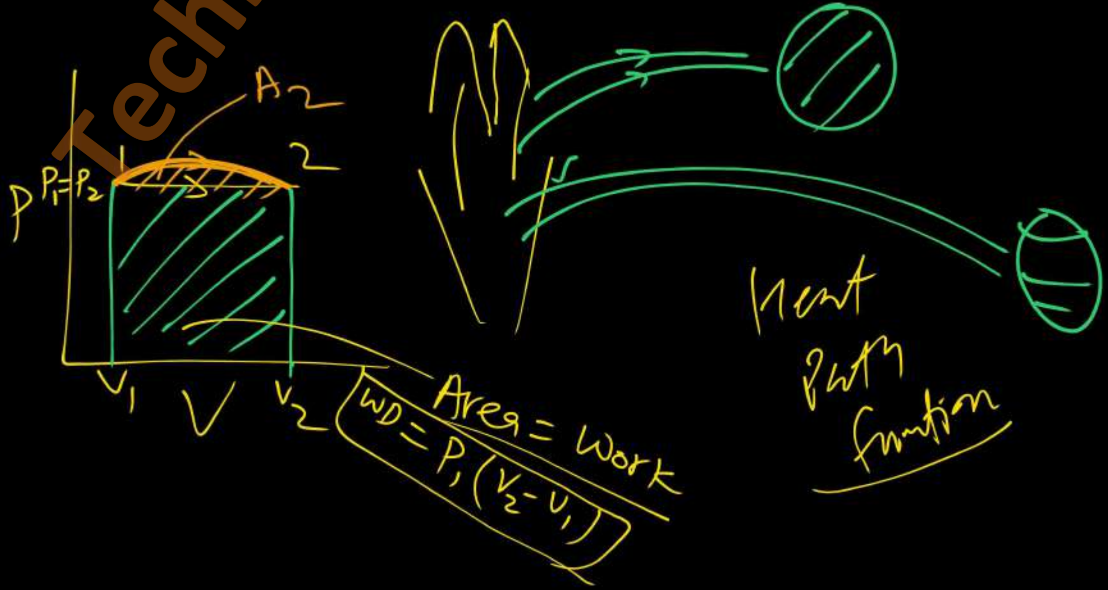


Path function

* Depends on path.

Ex → Heat and work





$T_1 = \overset{273}{50^\circ C} = 323\ K$

$T_2 = 150^\circ C = 423\ K$

$\Delta T = 100\ K$

$c_p = 1.02\ kJ/kg\ K$

$m = 500\ gm = 0.5\ kg$

$dh = m c_p \Delta T$

$0.5 \times 1.02 \times 100 = 51\ kJ$ Ans

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* Thermodynamics workdone

→ In thermodynamics work is defined as the product of pressure and change in volume.

We know that

Work done (कार्य) = Force (बल) × Displacement (विस्थापन)

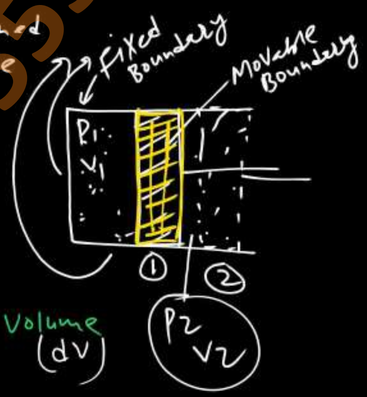
Pressure (दाब) (P) = Force(F) / Area (A) — क्षेत्रफल

F = P × A

WD = P × A × Displacement — Volume (dV)

WD = P × dV

$$WD = \int_1^2 P\,dV$$

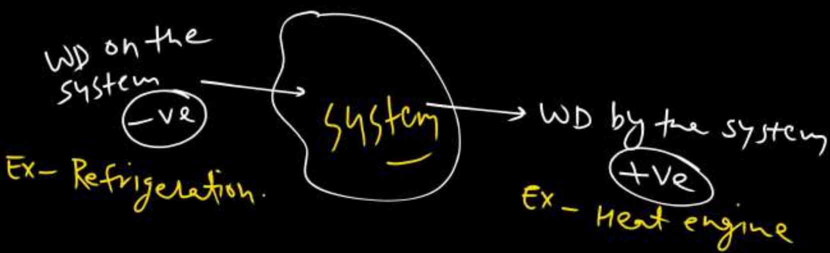


→ S.I unit of workdone is Joule.

→ Work done is a path function.

→ Work done by the system is +ve.

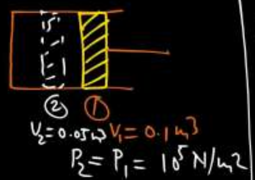
→ Work done on the system is −ve.



Q. A Gas of volume 0.1 m^3 is enclosed in a piston cylinder arrangment. How the gas is compressed to 0.05 m^3 with a constant pressure of 1 bar. Calculate the workdone on the system.

$1\ bar = 10^5\ N/m^2$

Soln :—



$$WD = \int_1^2 P\,dV$$

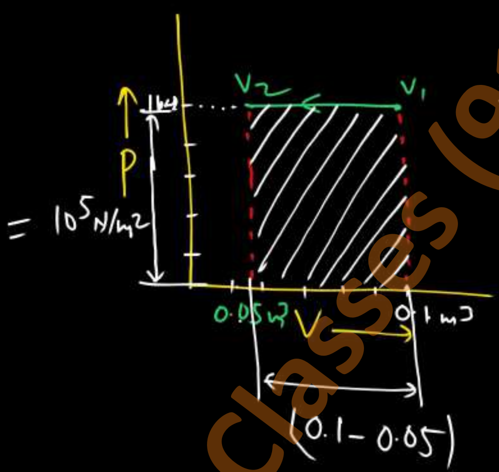
$$= P \int_1^2 dV$$

$$WD = P(V_2 - V_1)$$

$$= 10^5 (0.05 - 0.1)$$

$$= -10^5 \times 0.05$$

→ WD is -ve so it is WD on the system.



→ Work done is defined as Area under curve on volume axis.

$$Area = (0.05 \times 10^5\ J)$$

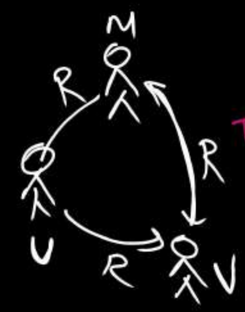
FUNDAMENTAL OF MECHANICAL ENGINEERING

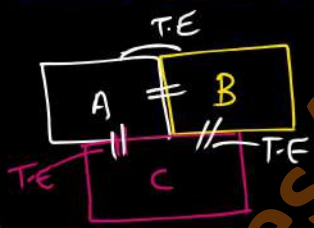
By Ashutosh Ranjan

Law of Thermodynamics
(ऊष्मागतिकी का नियम)

- Zeroth law of Thermodynamics
- 1st law of Thermodynamics
- 2nd law of "
- 3rd law of "

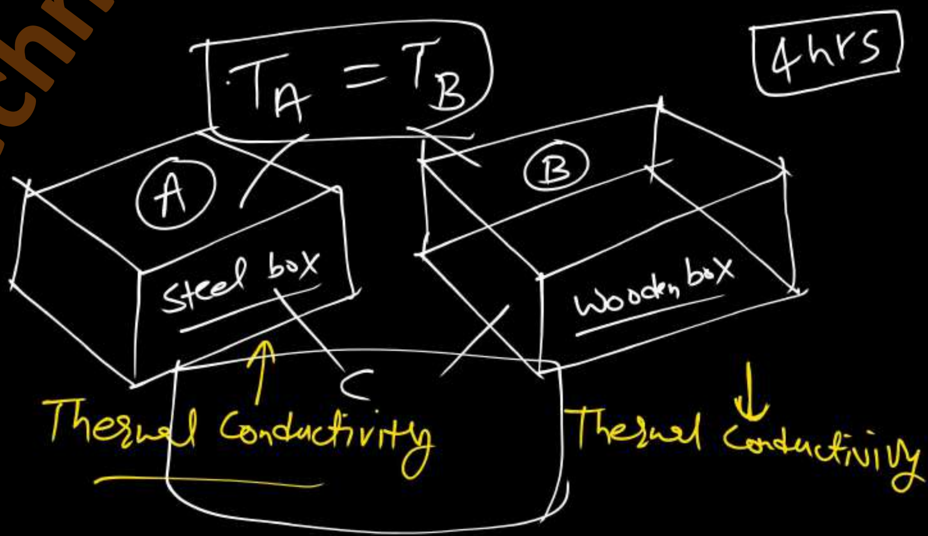
* Zeroth law of Thermodynamics

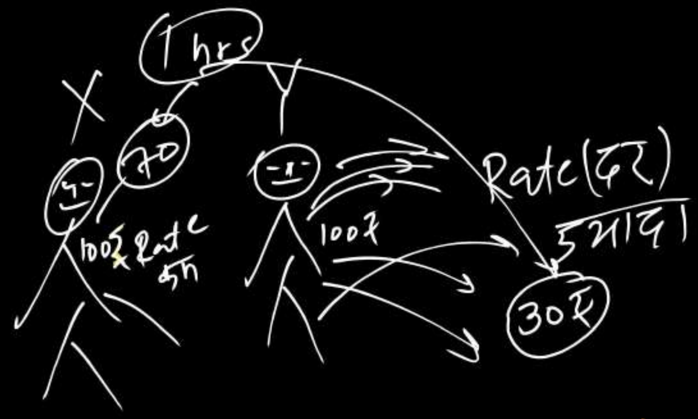




$T_A = T_B$
$T_A = T_C$
$\therefore T_A = T_B = T_C$

If body 'A' is thermal equilibrium with body 'B' and body 'A' also thermal equilibrium with body 'C' then body 'C' also thermal equilibrium with body 'B'.





ZEROTH LAW OF THERMODYNAMICS

- When a body A in thermal equilibrium with a body B and also separately with a body C then B and C will be in thermal equilibrium with each other.

OR

- If two bodies are in thermal equilibrium with third body then they are thermal equilibrium with each other.
- This is known as the zeroth law of thermodynamics. it is the basis of temperature measurement.

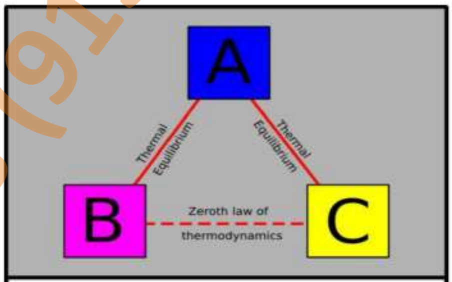
If TA=TB

Tc=TB

Then according to zeroth law,

{TA=Tc}

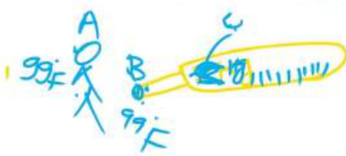
$T_A = T_B = T_C$



Zeroth law of thermodynamics

ZEROTH LAW OF THERMODYNAMICS

- NOTE:-
- Temperature is defined by zeroth law of thermodynamics
- Thermometer is based on zeroth law of thermodynamics

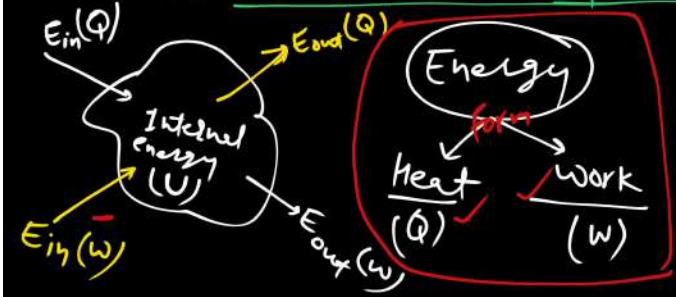


* Law of thermodynamics

* ~~Zeroth law of thermodynamics~~

* 1st law of Thermodynamics

or law of conservation of energy



$$\Delta U = Q - W$$

- ΔU — Change in Internal energy
- Q — Heat added
- W — workdone.

$$Q = \Delta U + W$$

* 1st law of Thermodynamics

→ Energy can neither be created nor be destroyed only change one form of energy to another form of energy.

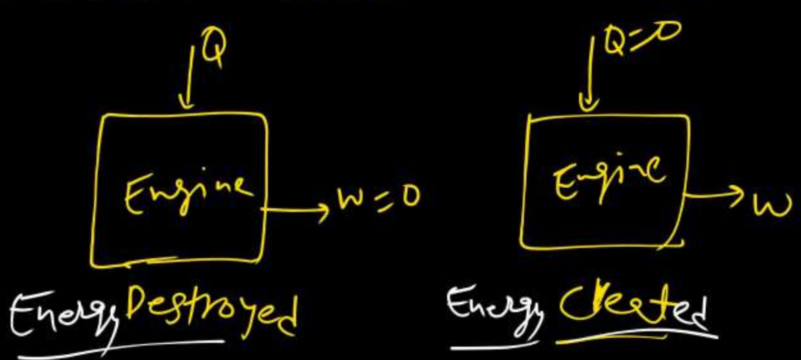
→ It is also known as "conservation of energy" or "Joule's law."

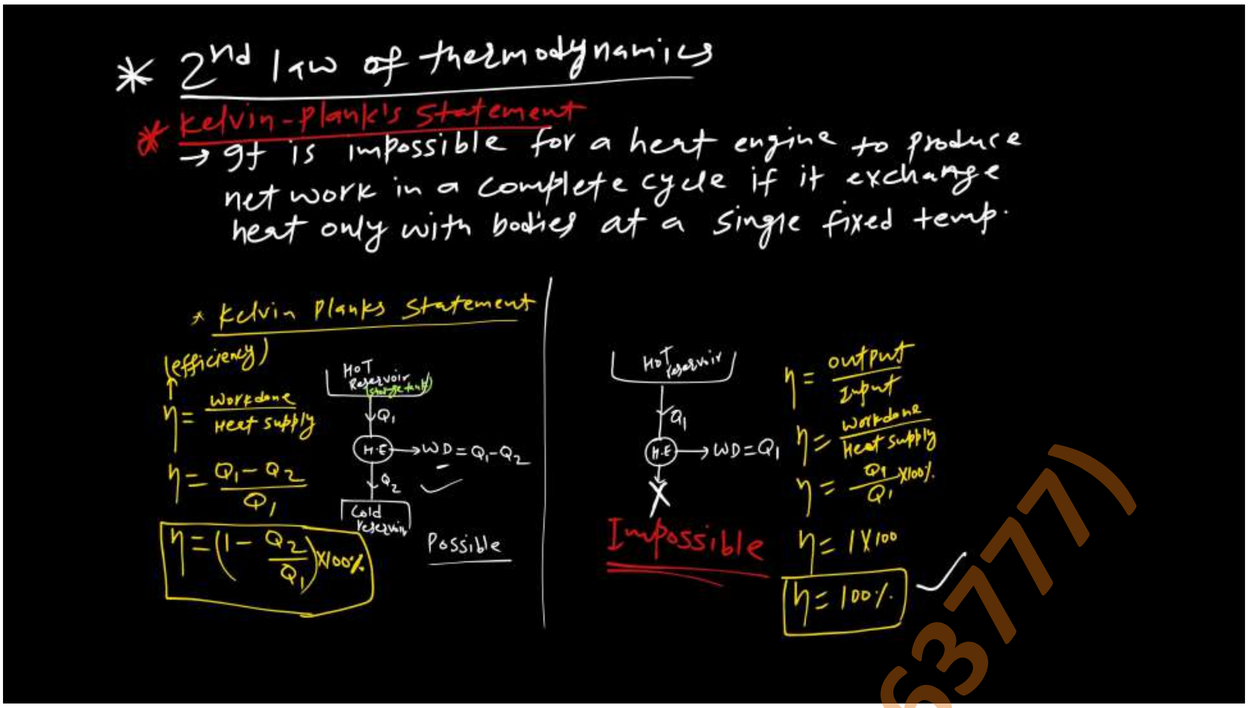
In other words

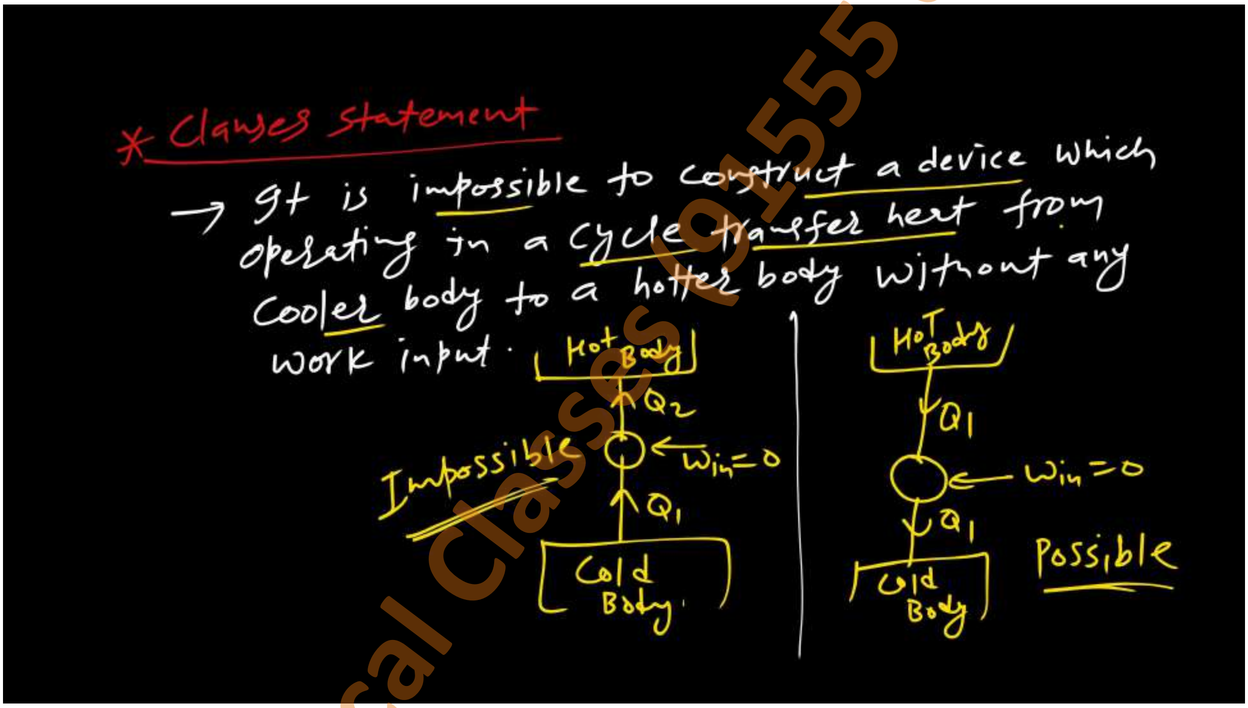
→ The change in internal energy of a system is equal to the heat added to the system minus the workdone by the system.

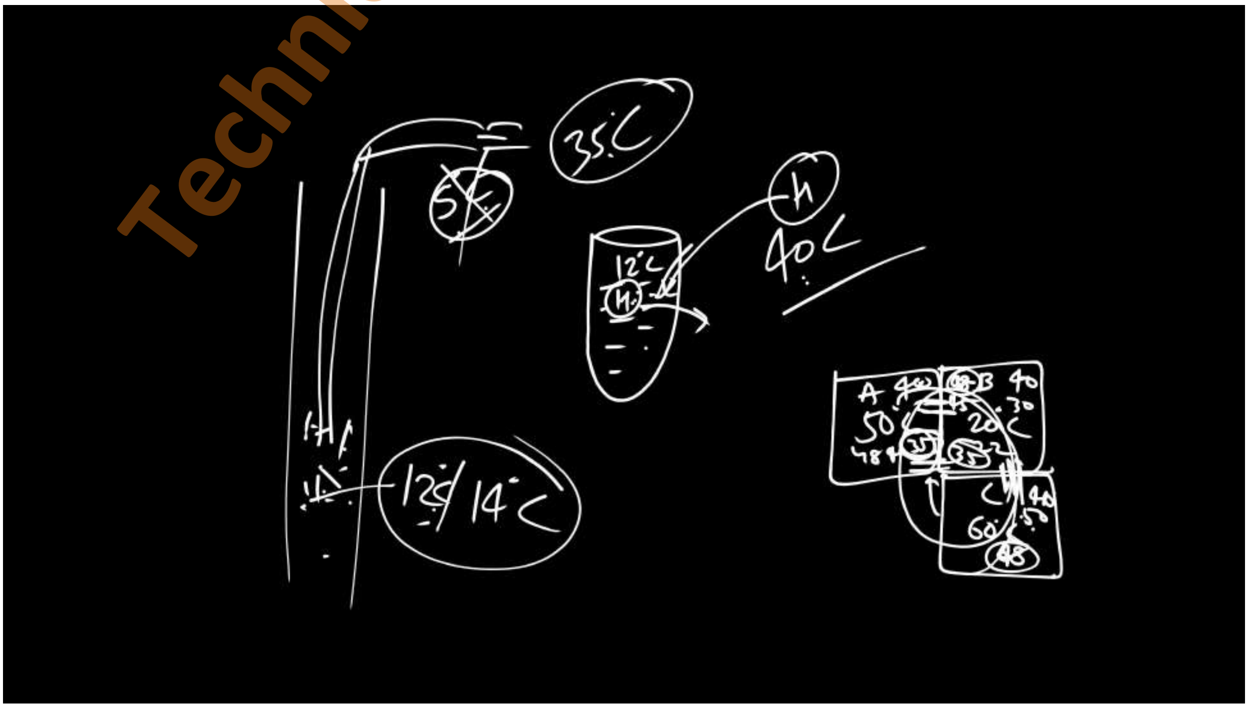
$$\Delta U = Q - W$$

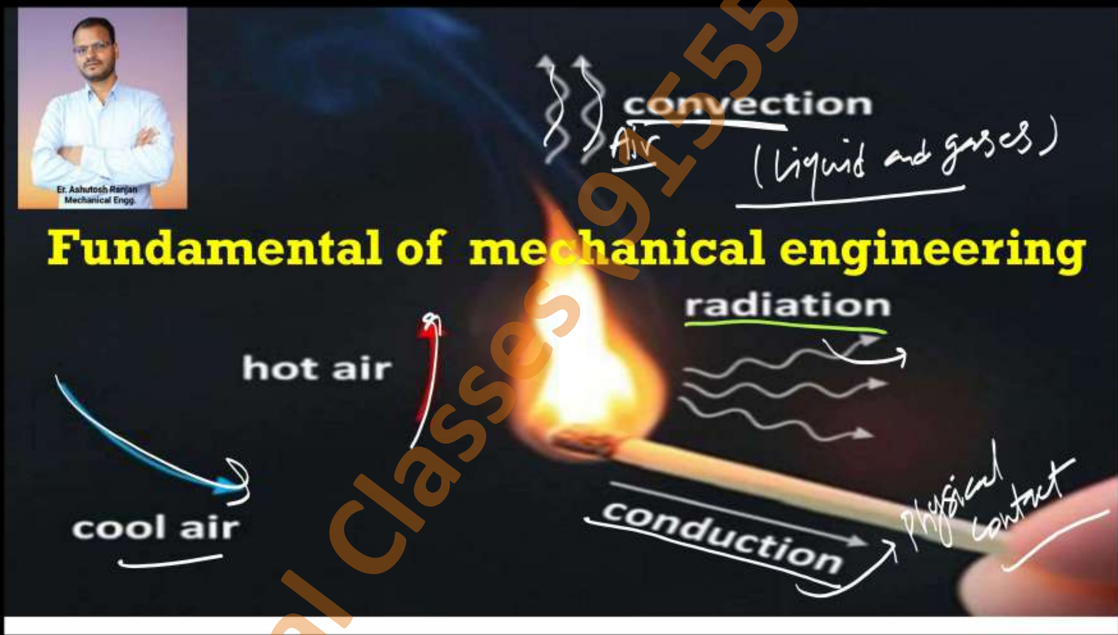
* PMM₁ (Prepetual motion machine of 1st kind)




* 2nd law of thermodynamics
* Kelvin-Plank's Statement
→ It is impossible for a heat engine to produce net work in a complete cycle if it exchange heat only with bodies at a single fixed temp.
* Kelvin Planks Statement
(efficiency)
η = Workdone / Heat supply
η = (Q1 − Q2) / Q1
η = (1 − Q2/Q1) × 100%
HOT Reservoir
Q1
H.E
WD = Q1 − Q2
Q2
Cold Reservoir
Possible
HOT reservoir
Q1
H.E
WD = Q1
Impossible
η = output / Input
η = Workdone / Heat supply
η = Q1/Q1 × 100%
η = 1 × 100
η = 100%


* Clauses statement
→ It is impossible to construct a device which operating in a cycle transfer heat from cooler body to a hotter body without any work input.
Hot Body
Q2
Win = 0
Q1
Cold Body
Impossible
HoT Body
Q1
Win = 0
Q1
Cold Body
Possible


35°C
40C
12°C

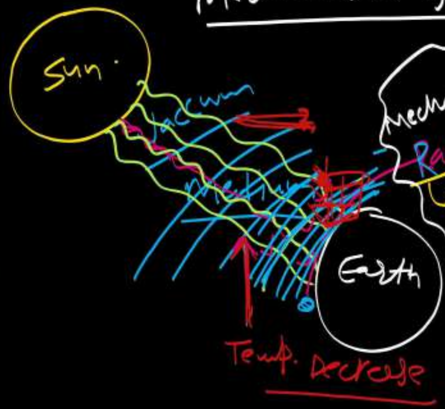


Mechanism of Conduction

(a) latics vibration of molecules and atom.

(b) Movements of electrons.

Mechanism of Radiation



Mechanism of Radiation

- Electromagnetic Radiation → Maxwell theory
- and Descrite Photon → Max. plank theory

Mechanism of convection

- → Liquid and gases
- → Density Difference
- → collision of Molecules

$d = \frac{mass}{volume}$ ↑↓

Mode of Heat transfer

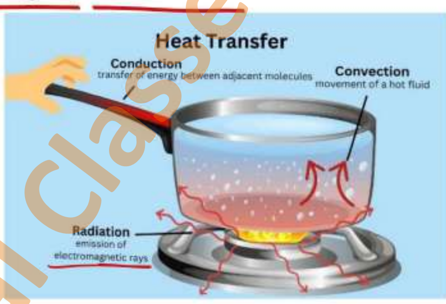
1. Conduction
2. Convection
3. Radiation

- → Heat transfer due to temp. difference.
- → Hot body heat loss is equal to cold body heat gain.
- → Heat is always flow high temp. to low temp.
- → Substance expanding on heating.

- **HEAT TRANSFER**
- Heat is a form of energy in transit due to temperature difference. Whenever there exists a temperature difference in medium or within a media, heat transfer must occur.

MODES OF HEAT TRANSFER

- **Conduction**: It is the method in which the transfer of heat takes place between atoms and molecules in direct contact.
- **Convection**: It is the method in which the transfer of heat happens by the movement of the heated substance.
- **Radiation**: It is the method in which the transfer of heat takes place by electromagnetic waves.



* Fourier's law of heat conduction

$$Q \propto A \frac{dt}{dx}$$

$$Q = -kA\frac{dt}{dx}$$

k → Thermal conductivity; A → Area; $\frac{dt}{dx}$ → Temp. gradient

°C/k

$k = -270$

$5m^2 = A$, m^2, $L \times W$, 3m, m

$\frac{dt}{dx} = \frac{(T_2 - T_1)}{dx}$

$\frac{dt}{dx} = \frac{50-150}{4}$

$\frac{dt}{dx} = -\frac{100}{4}$

$\frac{dt}{dx} = -25$

$Q = -270 \times 5 \times -25$

$Q = +ve$

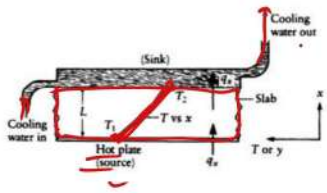
FOURIER'S LAWS OF HEAT CONDUCTION

"The rate of flow of heat through a simple homogeneous solid is directly proportional to the area of the section at right angles to the direction of heat flow, and to change of temperature with respect to the length of the path of the heat flow".

Mathematically, it can be represented by the equation :

$$Q \propto A.\, dt/dx$$

where.



Q = Heat flow through a body per unit time (in watts),
A = Surface area of heat flow (m^2)
dt = Temperature difference of the faces of block (homogeneous solid) of thickness 'dx' through which heat flows, °C or K,
dx = Thickness of body in the direction of flow, m.

Thus,

$$Q = -k.\, A\, dt/\, dx$$

$$Q = -KA \frac{dt}{dx}$$

where, k = Constant of proportionality and is known as **thermal conductivity** of the body.

NOTE:-
The -ve sign of k is to take care of the decreasing temperature along with the direction of increasing thickness or the direction of heat flow. The temperature gradient is always negative dx along positive x direction and, therefore, the value of Q becomes +ve.

$\frac{dt}{dx}$

- **Assumptions :**
- The following are the assumptions on which Fourier's law is based :
- 1. Conduction of heat takes place under steady state conditions. → Independent on time.
- 2. The heat flow is unidirectional.
- 3. The temperatures gradient is constant and the temperature profile is linear.
- 4. There is no internal heat generation.
- 5. The bounding surfaces are isothermal in character. (Constant temp.)
- 6. The material is homogeneous and isotropic (i.e., the value of thermal conductivity is constant in all directions).

Some essential features of Fourier's law :

- 1. It is applicable to all matter (solid, liquid or gas).
- 2. It is based on experimental evidence and cannot be derived from first principle.
- 3. It is a vector expression indicating that heat flow rate is in the direction of decreasing temperature and is normal to an isotherm.
- 4. It helps to define thermal conductivity 'k' (transport property) of the medium through which heat is conducted.

$$Q = -KA\frac{dt}{dx}$$

$$k = \frac{Q\,dx}{A\,dt}$$

* Thermal conductivity (K) of material

The amount of energy conducted through a body of unit area and unit thickness in unit time when the difference in temp. b/w (between) the face causing heat flow in unit temp. difference.

$$K = \frac{Q\,dx}{A\,dt} \quad \frac{W \cdot m}{m^2\,°C \text{ or } K}$$

Unit of thermal conductivity is – W/m°C or W/mK

* Thermal conductivity depends upon the following factor : –

- (a) Material structure.
- (b) Moisture content.
- (c) Density of material.
- (d) Pressure and temperature.

Thermal conductivity of metal

Daimod
silver
copper
Aluminium
Gold
Cast iron

Q. Which of the following have highest thermal conductivity ——

(a) cast iron
(b) steel
(c) Aluminium
(d) silver.

Q. Calculate the rate of heat transfer per unit area through a copper plate 45 mm thick, whose one face is maintained at 350°c and the other face at 50°c. Take thermal conductivity of copper as 370 W/m°c.

Soln: — Given data

(Thickness) $dx = 45\,mm = 0.045\,m$

Temp. $T_1 = 350°c$

Temp. $T_2 = 50°c$

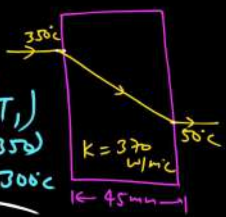
$dt = (T_2 - T_1)$

$dt = (50 - 350)$

$dt = -300°c$

Area. $A = 1\,m^2$

Thermal conductivity $K = 370\,W/m°c$



$$Q = -KA\frac{dt}{dx}$$

$$Q = \frac{(-370)\times 1\times(-300)}{0.045}$$

$$Q = 2.467\times 10^{6}\ \text{Watt}$$

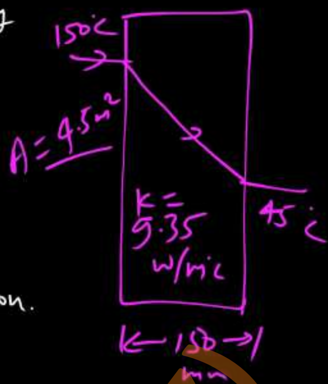
Ans

Q. A Plane wall is 150 mm thick and its wall Area is 4.5 m². If its conductivity is 9.35 W/m°C and surface temp. are steady at 150°C and 45°C determine —

$Q = -kA\frac{dt}{dx}$

(a) Heat flow across the plane wall.

(b) Temperature gradient in the flow direction. → $\frac{dt}{dx}$



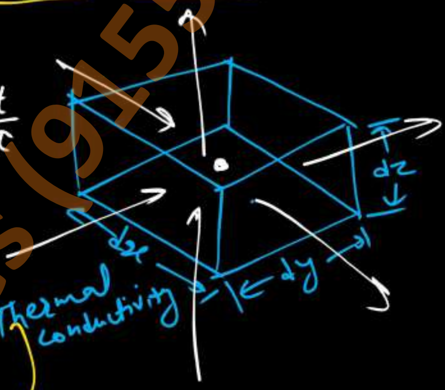
General heat conduction eqn.

$$\frac{\partial^2 t}{\partial x^2}+\frac{\partial^2 t}{\partial y^2}+\frac{\partial^2 t}{\partial z^2}+\frac{q_g}{k}=\frac{\rho c}{k}\frac{\partial t}{\partial \tau}$$

$$\frac{\partial^2 t}{\partial x^2}+\frac{\partial^2 t}{\partial y^2}+\frac{\partial^2 t}{\partial z^2}+\frac{q_g}{k}=\frac{1}{\alpha}\frac{\partial t}{\partial \tau}$$

$\left(\because \alpha = \frac{k}{\rho c}\right)$

α — Thermal diffisivity; k — Thermal conductivity; ρc — Thermal capacity



* Heat conduction through a plane wall

$$\frac{\partial^2 t}{\partial x^2}+\frac{\partial^2 t}{\partial y^2}+\frac{\partial^2 t}{\partial z^2}+\frac{q_g}{k}=\frac{1}{\alpha}\frac{\partial t}{\partial \tau}$$

* For steady state

$$\frac{\partial t}{\partial \tau}=0$$

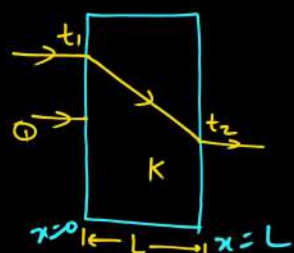
* For one Dimensional

$$\frac{\partial^2 t}{\partial y^2}+\frac{\partial^2 t}{\partial z^2}=0$$

* No. Internal heat generation

$$\frac{q_g}{k}=0$$

$$\frac{\partial^2 t}{\partial x^2}=0$$



$$\frac{d^2t}{dx^2} = 0$$

$$\frac{dt}{dx} = C_1$$

$$t = C_1x + C_2$$

C_1 and C_2 are arbitary constant

find the value of C_1 and C_2 at condition:—

At $x=0$ $\quad t=t_1$

$$\boxed{t_1 = C_2}$$

At $x=L$ $\quad t=t_2$

$$t_2 = C_1L + C_2$$

$$t_2 = C_1L + t_1$$

$$\boxed{C_1 = \left(\frac{t_2-t_1}{L}\right)}$$

$$t = \left(\frac{t_2-t_1}{L}\right)x + t_1$$

$$\boxed{Q = -KA\frac{dt}{dx}}$$

$$\frac{dt}{dx} = \frac{d}{dx}\left[\left(\frac{t_2-t_1}{L}\right)x + t_1\right]$$

$$\frac{dt}{dx} = \left(\frac{t_2-t_1}{L}\right)$$

$$Q = -KA\frac{(t_2-t_1)}{L}$$

$$\boxed{Q = KA\frac{(t_1-t_2)}{L}}$$

$$Q = \frac{t_1-t_2}{L/KA}$$

$$\boxed{Q = \frac{t_1-t_2}{(R_{th})_{cond.}}}$$

$\frac{L}{KA} = R_{th} \rightarrow$ Thermal Resistance

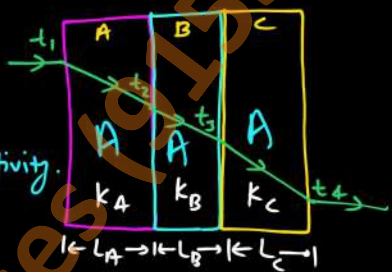
* Conduction through a Composite wall.

Thickness of slab $= L_A, L_B, L_C$

t_1 & t_4 temp. at outer face.

t_2 & t_3 temp. at interface.

K_A, K_B and K_C are thermal conductivity.



$$Q = \frac{K_A A(t_1-t_2)}{L_A} \quad \text{— (1)}$$

$$Q = \frac{K_B \cdot A(t_2-t_3)}{L_B} \quad \text{— (2)}$$

$$Q = \frac{K_C \cdot A(t_3-t_4)}{L_C} \quad \text{— (3)}$$

$$t_1 - t_2 = \frac{Q \cdot L_A}{K_A \cdot A} \quad \text{— (4)}$$

$$t_2 - t_3 = \frac{Q \cdot L_B}{K_B \cdot A} \quad \text{— (5)}$$

$$t_3 - t_4 = \frac{Q\, L_C}{K_C \cdot A} \quad \text{— (6)}$$

Adding eqn (4), (5) and (6) we get

$$\boxed{t_1 - t_4 = Q\left(\frac{L_A}{K_A A} + \frac{L_B}{K_B A} + \frac{L_C}{K_C A}\right)}$$

$$t_1 - t_4 = Q(R_{th\,A} + R_{th\,B} + R_{th\,C})$$

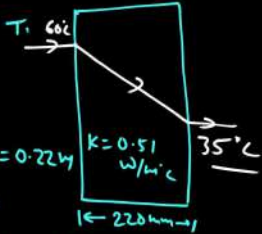
$$\boxed{Q = \left(\frac{(t_1-t_4)}{\frac{L_A}{K_A \cdot A} + \frac{L_B}{K_B \cdot A} + \frac{L_C}{K_C \cdot A}}\right)}$$

$$\boxed{Q = \frac{(t_1-t_4)}{R_{th\,A} + R_{th\,B} + R_{th\,C}}}$$

Q. The inner surface of a plane brick wall is at 60°C and the outer surface is at 35°C. Calculate the rate of heat transfer per m^2 of surface area of the wall. Which is 220 mm thick. The Thermal conductivity of the brick is 0.51 W/m°C.

Soln :– Given data

– Inner surface temp (T_1) = 60°C
– outer surface temp (T_2) = 35°C
– Thickness of wall = 220 mm = 0.22 m
– Thermal conductivity = 0.51 W/m°C

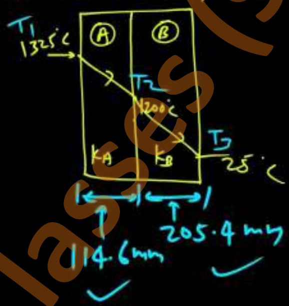


Rate of heat transfer per m^2:

$$q = \frac{Q}{A} = \frac{KA(T_1 - T_2)}{A \times L} = \frac{W}{m°C} \times \frac{°C}{m}$$

$$q = \frac{0.51 \times 25}{0.22} = 57.954\ W/m^2$$

Q. A reactor's wall made up of an inner layer of fire brick (K_A = 0.84 W/m°C) covered with a layer of insulation (K_B = 0.16 W/m°C). The reactor operates at a temp of 1325°C and the ambient temp. is 25°C. Calculate the heat loss presuming that the insulating material has a maximum temp. of 1200°C



Soln :–

$$q = \frac{(T_1 - T_2)}{\left(\frac{L_A}{K_A}\right)}$$

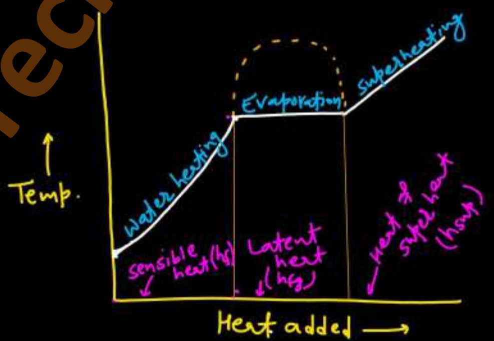
$$= \frac{(1325 - 1200)}{\left(\frac{0.1146}{0.84}\right)}$$

$$q = \frac{125}{136.43 \times 10^{-3}}$$

$$q = 916.23\ W/m^2$$

Ans

* Graphical Representation of formation of steam.



* Sensible heat of water (h_f)

– It is defined as the quantity of heat absorbed by 1 kg of water when it is heated from 0°C to boiling point (100°C).

→ sensible heat of water is 418 KJ (of 0°C to 100°C)

* Latent heat (h_{fg})

- It is the amount of heat required to convert water at a given temp and pressure into steam at the same temp and pressure.

* Dryness fraction (X)

- It is defined as the ratio of the mass of the actual dry steam to the mass of steam containing it.

$$X = \frac{M_g}{M_g + M_w}$$

$M_g \rightarrow$ Mass of Dry steam.

M_w = weight of water particle.

* Enthalpy of wet steam (h)

- It is defined as the quantity of heat required to convert 1 kg of water at 0°C wet steam at constant pressure.
- It is the sum of total heat of water and the latent heat and this sum is also called enthalpy.

$$h = h_f + X h_{fg}$$

Enthalpy of wet steam = Sensible heat + Dryness fraction × latent heat

Note

→ For Dry steam
$X = 1$

→ For wet steam
X is alway less than 1

Unit – 01

The end

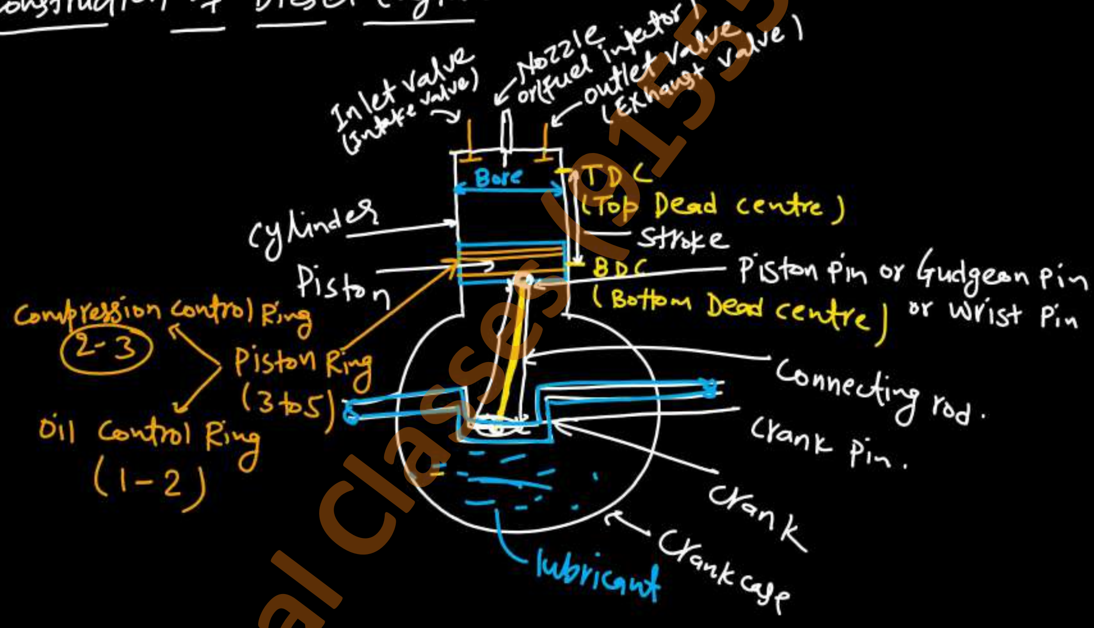
U-2. Internal combustion engine and Refrigeration

* **Engine** → Engine is a device which are used to convert chemical energy (Fuel) into Mechanical energy vai heat energy.

* **Types of engine.**

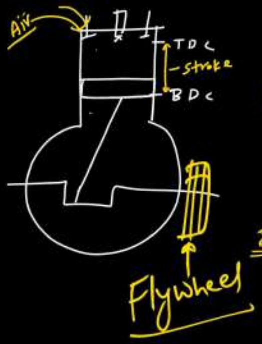
- Engine
  - External Combustion engine (EC engine)
    - Ex – Steam engine, Turbine etc
  - Internal Combustion engine (I.C engine)
    - Petrol engine (S.I engine) (Spark Ignition engine)
      - 4-Stroke engine
      - 2-Stroke engine
    - Diesel engine (CI engine) (Compression Ignition engine)
      - 4-Stroke engine
      - 2-Stroke engine.

* Construction of Diesel engine



Internal combustion engine

- P
  - 4-S
  - 2-S
- D
  - 4-S
  - 2 S



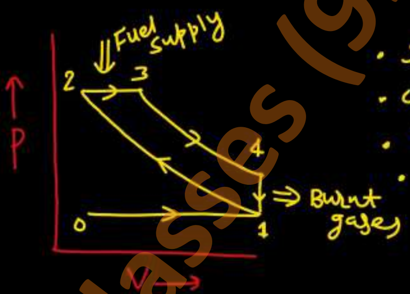
Working of 4-S Diesel engine

1. Suction stroke (Intake stroke)
   - → Piston → TDC to BDC
   - → inlet valve open and fresh air comeing inside cylinder.
2. Compression stroke
   - → Piston – BDC to TDC
   - → Inlet and outlet both valve are closed.
3. Power stroke or working stroke or Expansion stroke
   - → Piston — TDC to BDC
4. Exhaust stroke
   - → Piston – BDC to TDC
   - → open outlet valve and burnt gases out from Combustion chamber.

Working cycle of Diesel engine.

→ Diesel cycle is a working cycle of Diesel engine.

→ In Diesel engine fuel (Diesel) are injected at constant pressure.

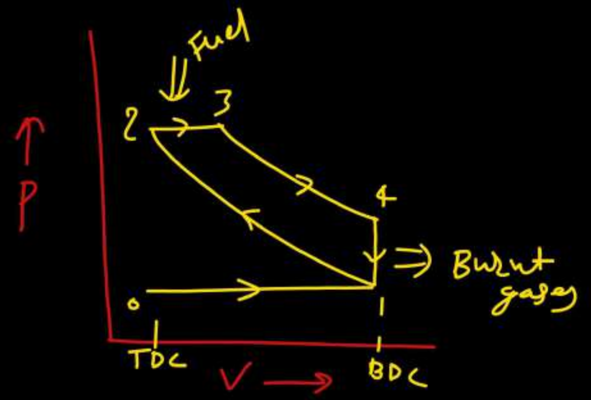


- Suction stroke → 0–1
- compression stroke → 1–2
- Power stroke ⇒ 3–4
- Exhaust stroke ⇒ 4–1

P-V Daigram of Diesel engine

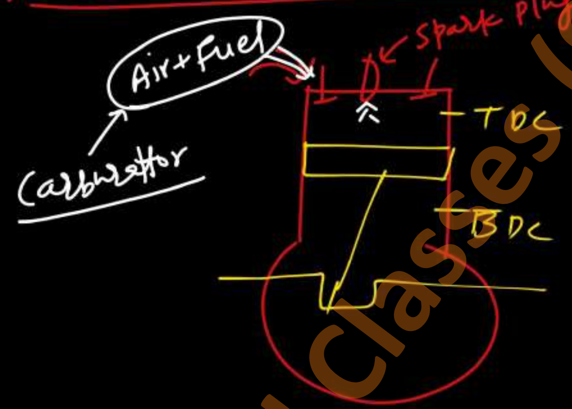
Q. In diesel engine fuel are injected at - - - -

(a) constant volume (b) constant pressure (c) constant volume & pressure (d) None of these.



P-V Daigram of Diesel engine

* 4-Stroke Petrol engine (SI engine or gasoline engine)



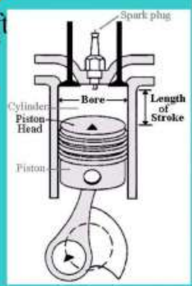
① Suction stroke (TDC to BDC)
② Compression stroke (BDC to TDC)
③ Power stroke (TDC to BDC)
④ Exhaust Stroke (BDC to TDC)

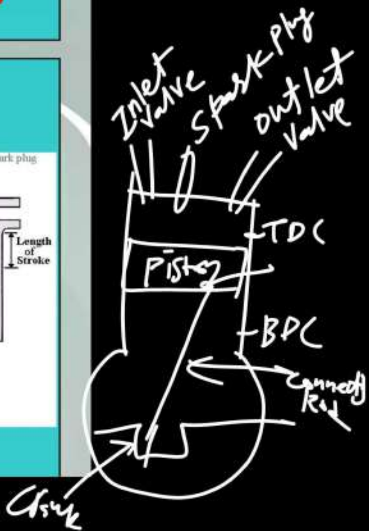
Q. Write the construction and working of 4-Stroke Petrol engine?

Four stroke cycle Petrol Engines

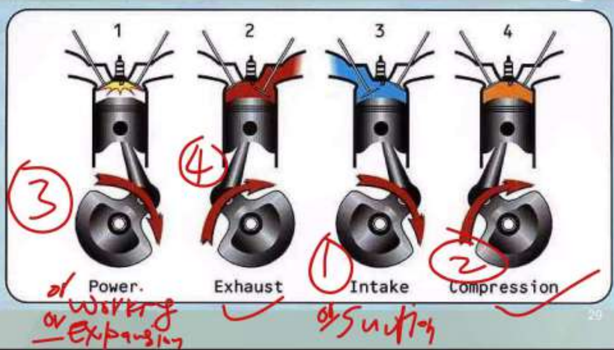
Construction :

- A piston reciprocates inside the cylinder.
- The piston is connected to the crank shaft by means of a connecting rod and crank.
- The inlet and exhaust valves are Mounted on the cylinder head.
- A spark is provided on the cylinder Head.
- The fuel used is petrol





Four Stroke Petrol Engine- Working



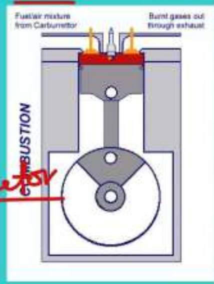
Four Stroke Petrol Engine - Working

or Intake stroke

(a) Suction Stroke (First Stroke of the Engine)

- Piston moves down from TDC to BDC
- Inlet valve is opened and the exhaust valve is closed.
- Pressure inside the cylinder is reduced below the atmospheric pressure.
- The mixture of air fuel is sucked into the cylinder through the inlet valve

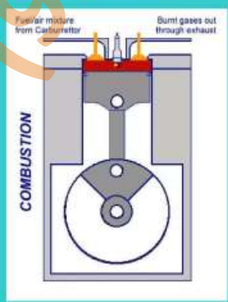
Carburettor



Four Stroke Petrol Engine - Working

(b) Compression Stroke : (Second Stroke of the piston)

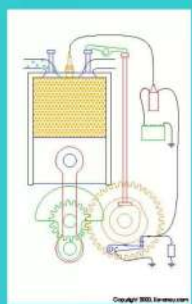
- Piston moves up from BDC to TDC
- Both inlet and exhaust valves are closed.
- The air fuel mixture in the cylinder is compressed.



Four Stroke Petrol Engine - Working

(c) Working or Power or Expansion Stroke: (Third Stroke of the Engine)

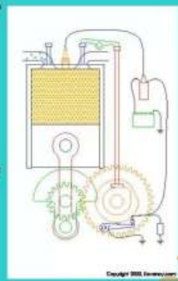
- The burning gases expand rapidly. They exert an impulse (thrust or force) on the piston. The piston is pushed from TDC to BDC
- This movement of the piston is converted into rotary motion of the crankshaft through connecting rod.
- Both inlet and exhaust valves are closed.



Four Stroke Petrol Engine - Working

(d) Exhaust Stroke (Fourth stroke of the piston)

- Piston moves upward from BDC To TDC.
- Exhaust valve is opened and the inlet valve is closed.
- The burnt gases are forced out to the atmosphere through the exhaust valve (Some of the burnt gases stay in the clearance volume of the cylinder)
- The exhaust valve closes shortly after TDC
- The inlet valve opens slightly before TDC and the cylinder is ready to receive fresh charge to start a new cycle.

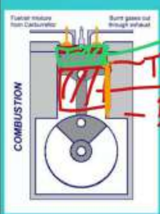


Four Stroke Petrol Engine - Working

Summary :

petrol engine

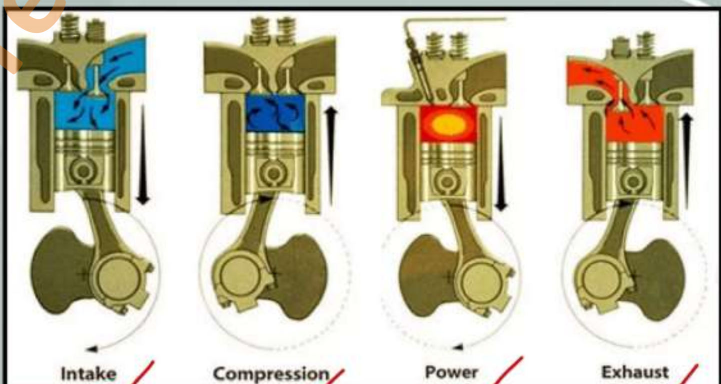
- Compression ratio varies from 5 to 8
- The pressure at the end of compression is about 6 to 12 bar.
- The temperature at the end of the compression reaches 250° C to 350° C



5 : 1 to 8 : 1

Compression ratio (R) = Total volume / Clearance volume

Four Stroke Diesel Engine



Four Stroke Diesel Engine

Construction:

- A piston reciprocates inside the cylinder
- The piston is connected to the crankshaft by means of a connecting rod and crank.
- The inlet and exhaust valves are mounted on the cylinder head.
- A fuel injector is provided on the cylinder head
- The fuel used is diesel.

Nozzle

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Four Stroke Diesel Engine - Working

(a) Suction Stroke (First Stroke of the piston)

- Piston moves from TDC to BDC
- Inlet valve is opened and the exhaust valve is closed.
- The pressure inside the cylinder is reduced below the atmospheric pressure.
- Fresh air from the atmosphere is sucked into the engine cylinder through air cleaner and inlet valve.

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Four Stroke Diesel Engine - Working

(b) Compression stroke (Second stroke of the piston)

- Piston moves from BDC to TDC
- Both inlet and exhaust valves are closed.
- The air is drawn during suction stroke is compressed to a high pressure and temperature

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Four Stroke Diesel Engine - Working

(c) Working or power or expansion stroke (Third stroke of the piston)

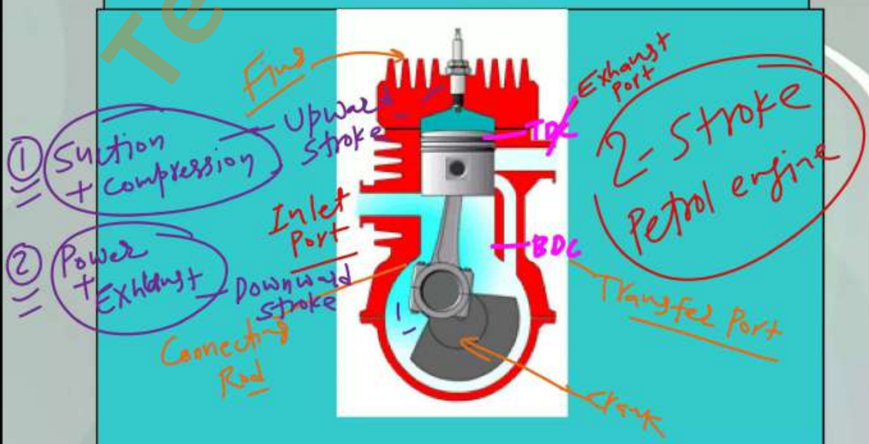
- The burning gases (products of combustion) expand rapidly.
- The burning gases push the piston move downward from TDC to BDC
- This movement of piston is converted into rotary motion of the crank shaft through connecting rod.
- Both inlet and exhaust valves are closed.

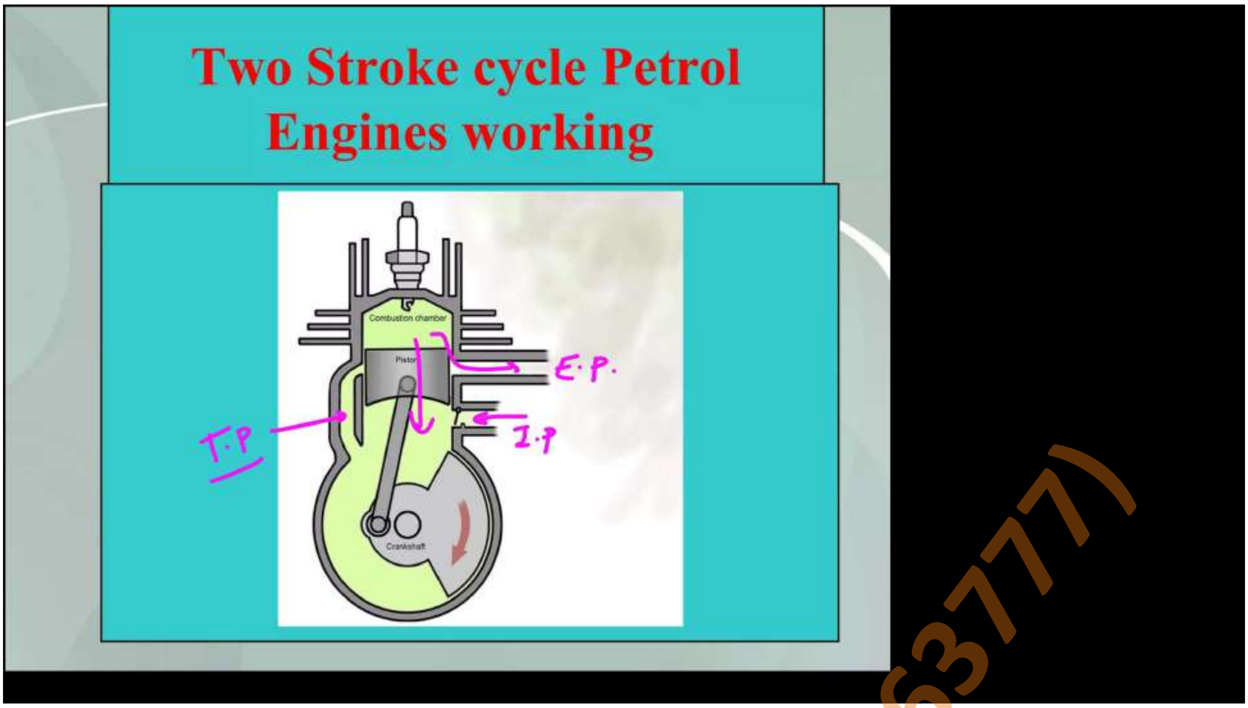
Four Stroke Diesel Engine - Working

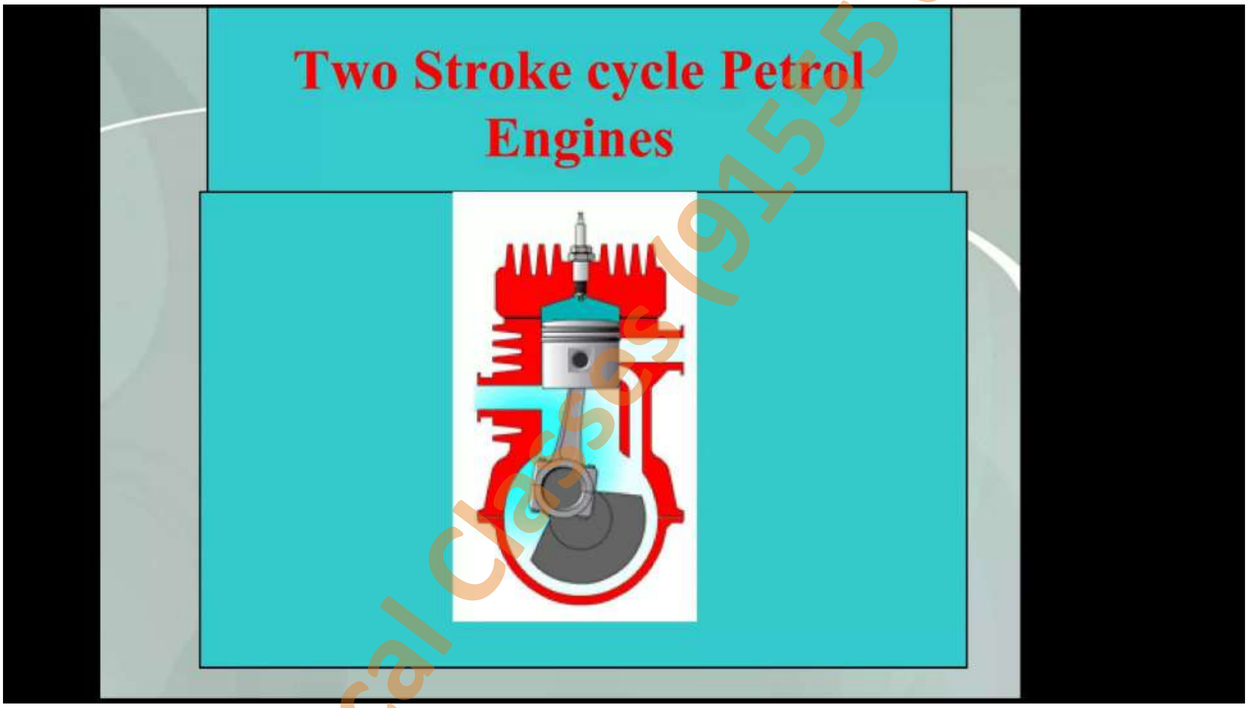
(d) Exhaust Stroke (Fourth stroke of the piston)

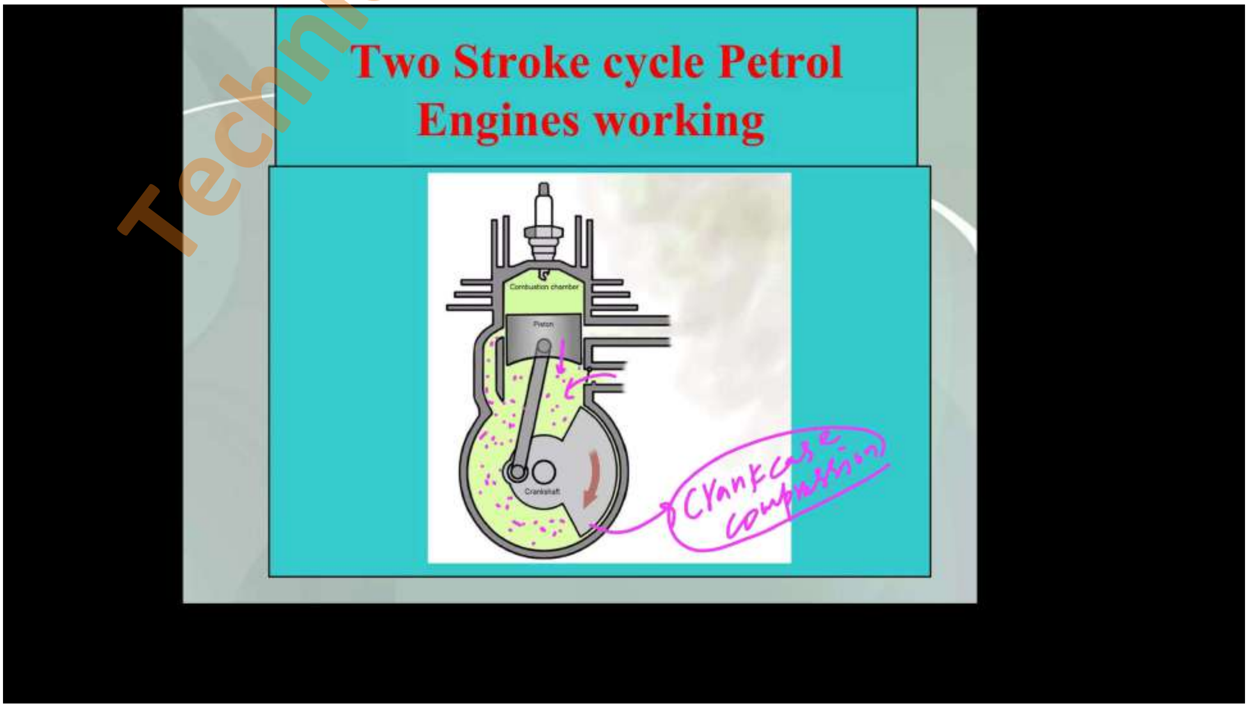
- Piston moves from BDC to TDC
- Exhaust valve is opened the inlet valve is closed.
- The burnt gases are forced out to the atmosphere through the exhaust valve. (some of the burnt gases stay in the clearance volume of the cylinder)
- The exhaust valve closes shortly after TDC
- The inlet valve opens slightly before TDC and the cylinder is ready to receive fresh air to start a new cycle.

Two Stroke cycle Petrol Engines




Two Stroke cycle Petrol
Engines working
Combustion chamber
Piston
Crankshaft
E.P.
I.P
T.P


Two Stroke cycle Petrol
Engines


Two Stroke cycle Petrol
Engines working
Combustion chamber
Piston
Crankshaft
Crankcase compression

Two Stroke Cycle Petrol Engine - Construction

Construction :

- A piston reciprocates inside the cylinder
- It is connected to the crankshaft by means of connecting rod and crank
- **There are no valves in two stroke engines, instead of valves ports are cut on the cylinder walls.**
- There are three ports, namely **inlet, exhaust** and **transfer** ports.
- The closing and opening of the ports are obtained by the movement of piston. The crown of piston is made in to a shape to perform this.
- A spark plug is also provided.

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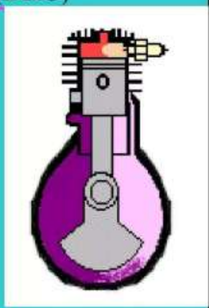
Two stroke cycle Petrol Engines - Working

First Stroke : (Compression, ignition and inductance) (Upward stroke of piston)

(a) compression:

- The piston moves up from Bottom Dead Centre (BDC) to Top Dead Centre (TDC)
- Both transfer and exhaust ports are covered by the piston.
- Air fuel mixture which is transferred already into the engine cylinder is compressed by moving piston.
- The pressure and temperature increases
- at the end of compression.

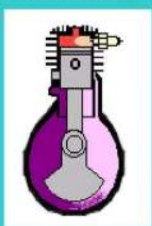


Two stroke cycle Petrol Engines - Working

First Stroke : (Compression, ignition and inductance) (Upward stroke of piston)

(b) Ignition and Inductance:

- Piston almost reaches the top dead centre
- The air fuel mixture inside the cylinder is ignited by means of an electric spark produced by a spark plug
- At the same time, the inlet port is uncovered by the plunge. Piston
- Fresh air fuel mixture enters the crankcase through the inlet port.



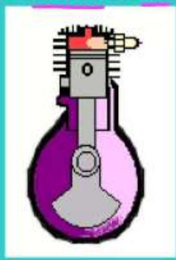
Two stroke cycle Petrol Engines - Working

Second Stroke: (Downward Stroke of the engine) :

(c)Expansion and Crankcase compression

- The burning gases expand in the cylinder
- The burning gases force the piston to move down. Thus useful work is obtained.
- When the piston moves down, the air fuel mixture in the crankcase is partially compressed.

This compression is known as *Crank case compression.*

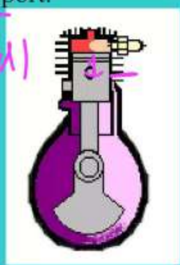


Two stroke cycle Petrol Engines - Working

Second Stroke: (Downward Stroke of the engine) :

(d) Exhaust and transfer:

- At the end of expansion, exhaust port is uncovered.
- Burnt gases escape to the atmosphere.
- Transfer port is also opened. The partially compressed air fuel mixture enters the cylinder through the transfer port.
- The crown of the piston is made of a deflected shape. So the fresh charge entering the cylinder is deflected upwards in the cylinder.
- Thus the escape of fresh charge along with the exhaust gases is reduced.



Two stroke cycle Diesel Engines-Construction

Construction :

- Two stroke cycle diesel engines require air supply
- This air is used to blow out the exhaust gases and to fill the cylinder with clean air
- This air is supplied by a blower or air compressor which is driven by engine itself.
- These engines may be valve or port type.
- A plate is provided in the crank case to admit air into the crank case.
- Transfer and exhaust ports are provided in the cylinder.
- These ports are covered and uncovered by the moving piston.

Two stroke cycle Diesel Engines- Working

First Stroke (Upward Stroke of the piston)

(a) Compression and inductance:

- The piston moves upwards from Bottom Dead Centre (BDC) to Top Dead Centre (TDC).
- Both transfer and exhaust ports are covered.
- Air which is transferred already into the engine cylinder is compressed by moving piston.
- The pressure and temperature of the air increases.
- At the same time, fresh air is admitted into the crankcase through the plate valve (reed valve)

Two stroke cycle Diesel Engines- Working

First Stroke (Upward Stroke of the piston)

(b) Ignition and inductance.

- Piston almost reaches the top dead centre.
- The fuel is injected into the hot compressed air inside the cylinder. The fuel mixed with hot air and burns.
- The admission of fresh air into the crankcase continues till the piston reaches the top centre.

Two stroke cycle Diesel Engines- Working

Second Stroke (Downward Stroke of the piston)

(c) Expansion and crank case compression:

- The burning gases expand in the cylinder.
- Burning gases force the piston to move down. Thus useful work is obtained.
- At the same time, the air in the crank case is compressed by the movement of the piston.
- All the ports and the plate valve are in closed position

Two stroke cycle Diesel Engines-Working

Second Stroke (Downward Stroke of the piston)

(d) Exhaust and Transfer:

- At the end of expansion, the exhaust port is uncovered.
- The burnt gases escape to the atmosphere through the exhaust port.
- Transfer port is also uncovered shortly after the exhaust port is opened.
- The partially compressed air from crank case enters the cylinder the transfer port.
- This air is deflected upwards by the deflected shape of the piston.
- Thus the entering air helps in forcing out the combustion products from the cylinder
- The plate valve remains during this period.

Comparison between SI and CI Engines (General Comparison)

S.No.	Spark Ignition Engines (SI) (Petrol engine)	Compression Ignition Engines (CI) (Diesel engine)
1	It draws air fuel mixture into the cylinder during suction stroke	It draws only air into the cylinder during suction stroke.
2	Petrol engines operate with low pressure and temperature (CR 5:1 to 8:1)	Diesel engines operate with high pressure and temperature (CR 14:1 to 22:1)
3.	Pressure ranges from 6 to 12 bar	Pressure ranges from 35 to 40 bar
	Temperature ranges from 250° to 300° C	Temperature ranges from 600° to 700° C

Comparison between SI and CI Engines (General Comparison)

S.No.	Spark Ignition Engines (SI)	Compression Ignition Engines (CI)
4	It is fitted with carburettor and spark plugs	It is fitted with fuel injection pump and injectors
5	The burning of fuel takes place at constant volume	The burning of fuel takes place at constant pressure
6.	Ignition of air fuel mixture takes place by an electric spark produced by spark plug	Ignition of air fuel takes placed by a injection of fuel into the hot compressed air.

Comparison between SI and CI Engines (General Comparison)

S.No.	Spark Ignition Engines (SI)	Compression Ignition Engines (CI)
7	Petrol engines are quality governed engines. The speed of petrol engines are controlled by varying the quantity of air fuel mixture.	Diesel engines are quantity governed engines. The speed of diesel engines are controlled by varying quality of air fuel mixture. (rich or weak mixture)
8	Petrol engines are widely used in automobiles and aeroplanes etc., cars	Diesel engines are widely used in heavy vehicles, such as buses, lorries, trucks etc.,

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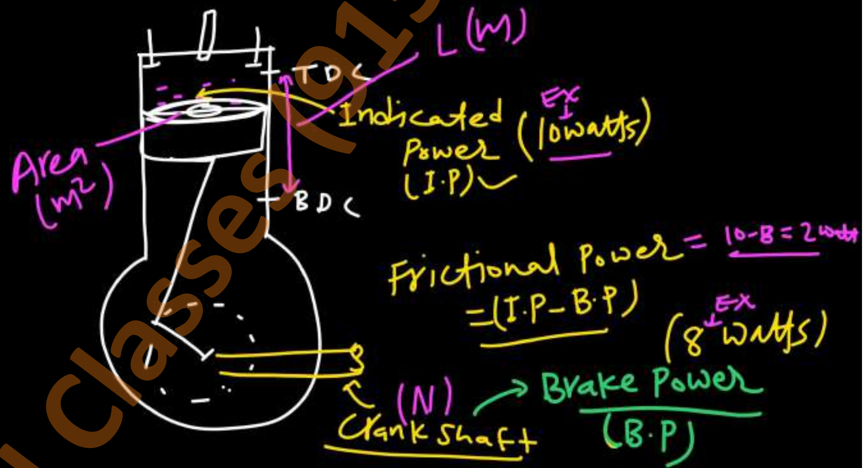


* **Indicated power** — It is the power of an engine developed in its cylinder. It is a measured by a form of pressure indicator connected to the cylinder head.

⇒ For 2-stroke cycle

$$I.P = \frac{P_m L A N}{60} \text{ watts}$$

⇒ For 4-stroke cycle

$$I.P = \frac{P_m L A N}{60 \times 2} \text{ watts}$$

Where

P_m = Indicated mean effective pressure.

L = Length of stroke (m)

A = cross sectional Area of piston. (m^2)

N = R.P.M of crank.

* **Brake Power** – The brake power of an engine is the power available at the crank shaft of the engine for doing external work.
  - It is measured by Brake dynamometer.

* **Frictional Power** – The indicated power of an engine is always greater than its brake power because there is a loss of power between the cylinder and the crank shaft due to friction between the moving parts.

$$F.P = I.P - B.P$$

* **Mechanical efficiency** – It is the ratio of power obtained at crank shaft (B.P) to the indicated power (IP).

$$\text{Mechanical efficiency} = \frac{\text{Brake Power}}{\text{Indicated Power}}$$

* **Brake thermal efficiency** or (overall efficiency) – It is the ratio of brake power obtained to the energy supplied by fuel.

$$\text{Brake thermal efficiency} = \frac{\text{Heat equivalent to BP per minute}}{\text{Heat supplied by fuel per minute}}$$

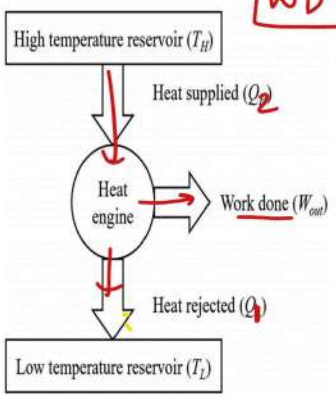
NOTE

The value of Brake thermal efficiency varies for 25% to 33% for Petrol engine and 30% to 45% for Diesel engine.

HEAT ENGINE

- In a heat engine the heat supplied to the engine is converted into useful work. if Q2 is the heat supplied to the engine and Q1 is the heat rejected from the engine.then the net work done by the engine is given by

$$WD = Q_2 - Q_1$$



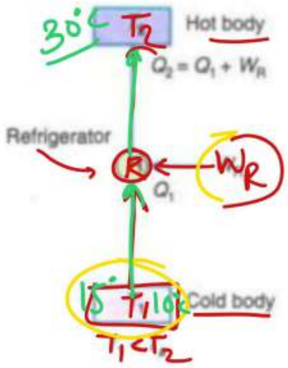
The performance of a heat engine is expressed by its efficiency we know that the efficiency of an engine.

$$\eta = \frac{\text{Work done}}{\text{Heat supplied}} = \frac{Q_2 - Q_1}{Q_2}$$

$$\eta = \left(1 - \frac{Q_1}{Q_2}\right) \times 100\,\%$$

REFRIGERATOR

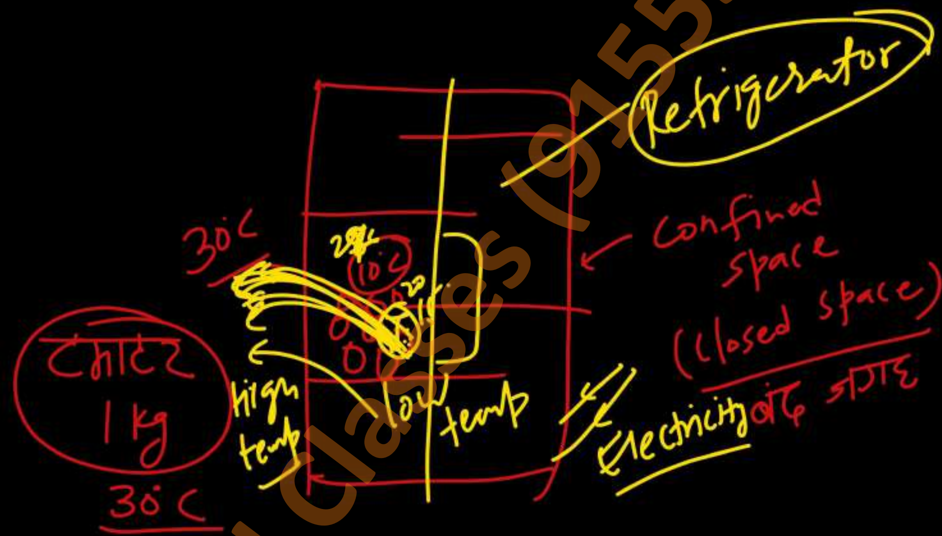
- Refrigeration is the process of removal of heat from the confined (closed) space so as to reduce its temperature below the surrounding temperature and maintain it at that temperature.



This is done by extracting the heat (Q_1) from a cold body and delivering it to a hot body (Q_2). In doing so, work W is required to be done on the system. According to First Law of Thermodynamics.

$$Q_2 = W_R + Q_1$$
$$W_R = Q_2 - Q_1$$

$$WR = Q_2 - Q_1$$



- The performance of a refrigerator is expressed by the ratio of amount of heat taken from the cold body (Q1,) to the amount of work required to be done on the system (WR). This ratio is called coefficient of performance. Mathematically, coefficient of performance of a refrigerator,

COP = Heat extracted in the refrigerator / work done

$$COP = \frac{Q_1}{Q_2 - Q_1}$$

$$COP = \frac{Q_1}{Q_2} - 1$$

→ COP is the reciprocal of the efficiency of a heat engine.

→ COP is always greater than unity.

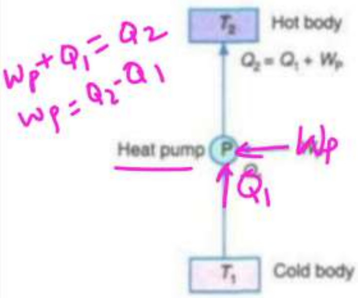
* Unit of Refrigeration

The unit of Refrigeration is expressed in term of 'tonne of Refrigeration' (TR).

- TR is defined as the amount of Refrigeration effect produce by the uniform melting of one tonne (1000 kg) of ice from and at 0°C in 24 hours.

HEAT PUMP

- It is just opposite to the refrigerator i.e.. "It is a device operating in a cycle, maintains a body say B at a temperature higher than the temperature of the surroundings".

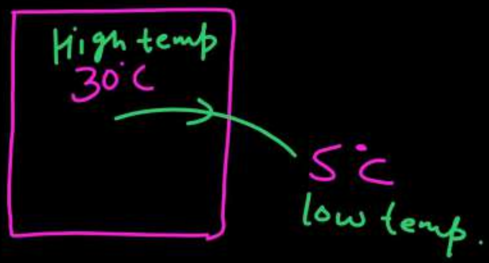


The performance of a heat pump is expressed by the ratio of the amount of heat delivered to the hot body (2) to the amount of work required to be done on the system (Wp). This ratio is called coefficient of performance or energy performance ratio (E.P.R.) of a heat pump. Mathematically, coefficient of performance or energy performance ratio of a heat pump,

$$EPR = \frac{\text{heat delivered to the hot body}}{\text{work done on the system}}$$

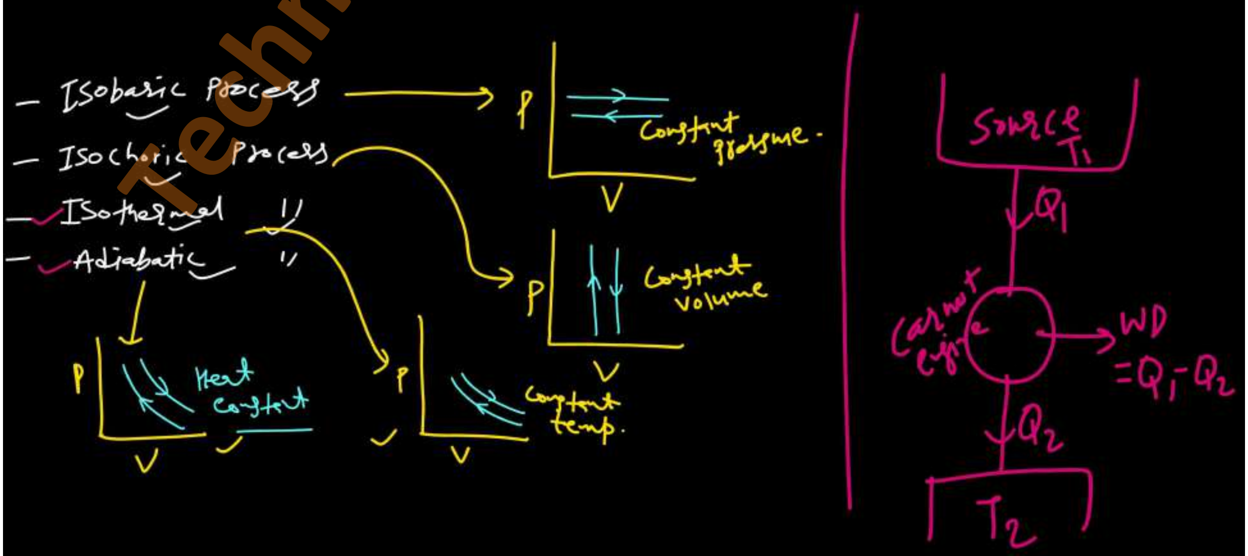
$$E.P.R = \frac{Q_1}{Q_2 - Q_1}$$

$$E.P.R. = \frac{Q_1}{Q_2} - 1$$



CARNOT CYCLE

- The Carnot cycle is a hypothetical cycle developed by Carnot for either a heat engine or a reversed heat engine.
- The Carnot cycle is a reversible cycle because it consists of two isothermal and two adiabatic processes.
- All the processes involved in the cycle are reversible, thereby providing the best possible device that one could construct.
- Results from the cycle analysis can be used to determine the maximum efficiency of performance possible for either a heat engine or reversed heat engine.



- **Process 1-2** (Isothermal Process)

  Isothermal expansion of the working fluid at the temperature of the source T_1 accompanied by heat absorption from the source.

- **Process 2-3** (Adiabatic Process)

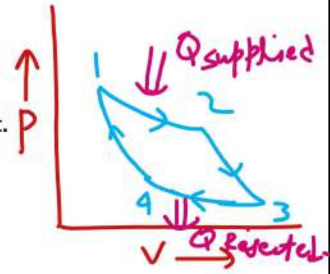
  Adiabatic expansion with temperature drop of working fluid from T_1 to T_2, the temperature of the sink.

- **Process 3-4** (Isothermal Process)

  Isothermal expansion at the temperature of the sink T_2 accompanied by the heat rejected to the sink.

- **Process 4-1** (Adiabatic Process)

  Adiabatic compression with temperature rise of working fluid from T_2 to T_1. The four processes applied for unit mass of working fluid then become.



1-2 Isothermal heat supplied.

$$Q_{12} = R\,T_1\, ln \frac{v_2}{v_1} \quad \text{— (1)}$$

2-3 Adiabatic expansion.

$$\frac{T_1}{T_2} = \left(\frac{v_3}{v_2}\right)^{\gamma-1} \quad \text{— (2)} \qquad \frac{V_3}{V_4} = \frac{V_2}{V_1}$$

3-4 Isothermal heat rejection.

$$Q_{34} = R\,T_2\, ln \frac{v_3}{v_4}. \quad \text{— (3)}$$

4-1 Adiabatic compression.

$$\frac{T_1}{T_2} = \left(\frac{v_4}{v_1}\right)^{\gamma-1} \quad \text{— (4)}$$

From eqn. (2) and (4)

$$\left(\frac{V_3}{V_2}\right)^{\gamma-1} = \left(\frac{V_4}{V_1}\right)^{\gamma-1}$$

$$\frac{V_3}{V_2} = \frac{V_4}{V_1}$$

$$\boxed{\frac{V_3}{V_4} = \frac{V_2}{V_1}} \quad \text{— (5)}$$

Putting the value of $\frac{V_3}{V_4}$ in eqn (3)

$$Q_{34} = RT_2 \ln\left(\frac{V_2}{V_1}\right)$$

Heat Rejected

Efficiency of Carnot cycle

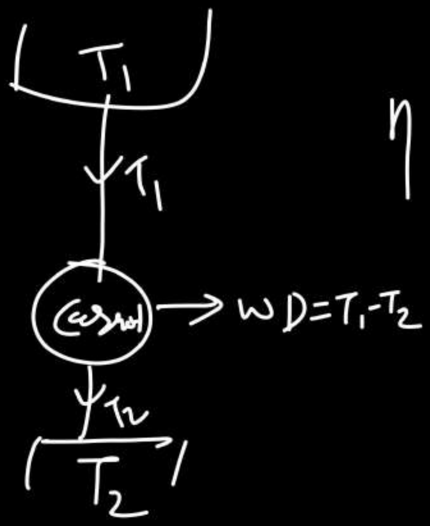
$$\eta = \frac{\text{Heat supplied} - \text{Heat Rejected}}{\text{Heat Supplied}}$$

$$= \frac{RT_1 \ln\left(\frac{V_2}{V_1}\right) - RT_2 \ln\left(\frac{V_2}{V_1}\right)}{RT_1 \ln\left(\frac{V_2}{V_1}\right)}$$

$$= \frac{R \ln\left(\frac{V_2}{V_1}\right)\left[T_1 - T_2\right]}{R \ln\left(\frac{V_2}{V_1}\right) T_1}$$

$$\eta = \frac{T_1 - T_2}{T_1}$$

$$\boxed{\eta_{Carnot} = 1 - \frac{T_2}{T_1}}$$



$$\eta = \frac{\text{Workdone}}{\text{Heat supplied}}$$

$$\eta = \frac{T_1 - T_2}{T_1}$$

$$\boxed{\eta = 1 - \frac{T_2}{T_1}}$$

Refrigerant is a substance used in refrigeration and air conditioning systems to absorb and release heat, enabling cooling or heating processes. It circulates through the system, changing states between gas and liquid, and transfers heat from one area to another.

- Refrigerants are essential for maintaining low temperatures in systems like refrigerators, air conditioners, and industrial coolers.

** Types of Refrigerants

Refrigerants are categorized based on their chemical composition and properties.

The main types include:

1. CFCs (Chlorofluorocarbons)

* Ex: R-12 (Dichlorodifluoromethane)

* Characteristics: Non-toxic and stable but have high ozone depletion potential (ODP).

* Usage: Once commonly used in refrigeration, air conditioning, and aerosol propellants, their use has been phased out due to environmental concerns (Montreal Protocol).

2. HCFCs (Hydrochlorofluorocarbons)

Ex: R-22 (Chlorodifluoromethane)

Characteristics: Contain chlorine, but less than CFCs. They still contribute to ozone depletion, though at a lower rate.

Usage: Previously used in air conditioning and refrigeration systems, but their use is being phased out due to ozone layer concerns.

3. HFCs (Hydrofluorocarbons)

Ex: R-134a (1,1,1,2-Tetrafluoroethane), R-410A

Characteristic: Do not deplete the ozone layer but have high global warming potential (GWP).

Usages: Common in modern refrigeration and air conditioning systems, particularly as replacements for CFCs and HCFCs.

4. HFOs (Hydrofluoro-Olefins)

Ex: R-1234yf, R-1234ze

Characteristics: Low GWP and zero ozone depletion potential. They are more environmentally friendly compared to HFCs.

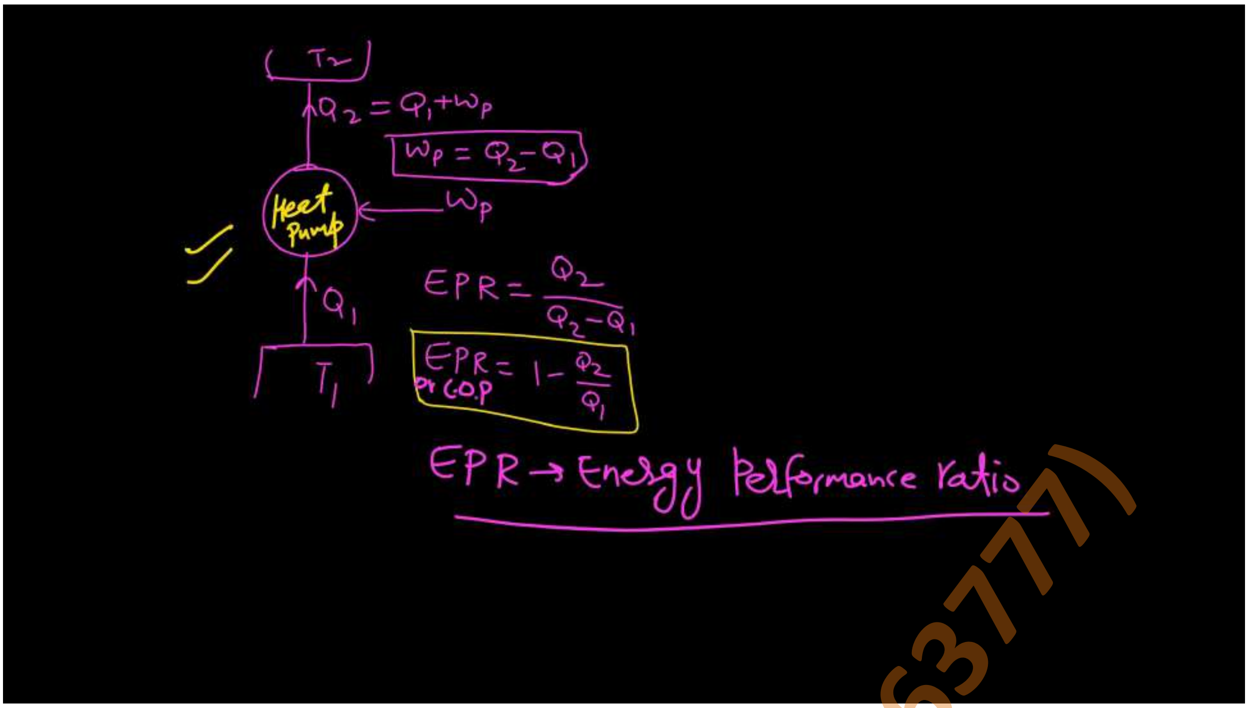
Usage: Gaining popularity as replacements for HFCs, particularly in automotive air conditioning and other cooling applications.

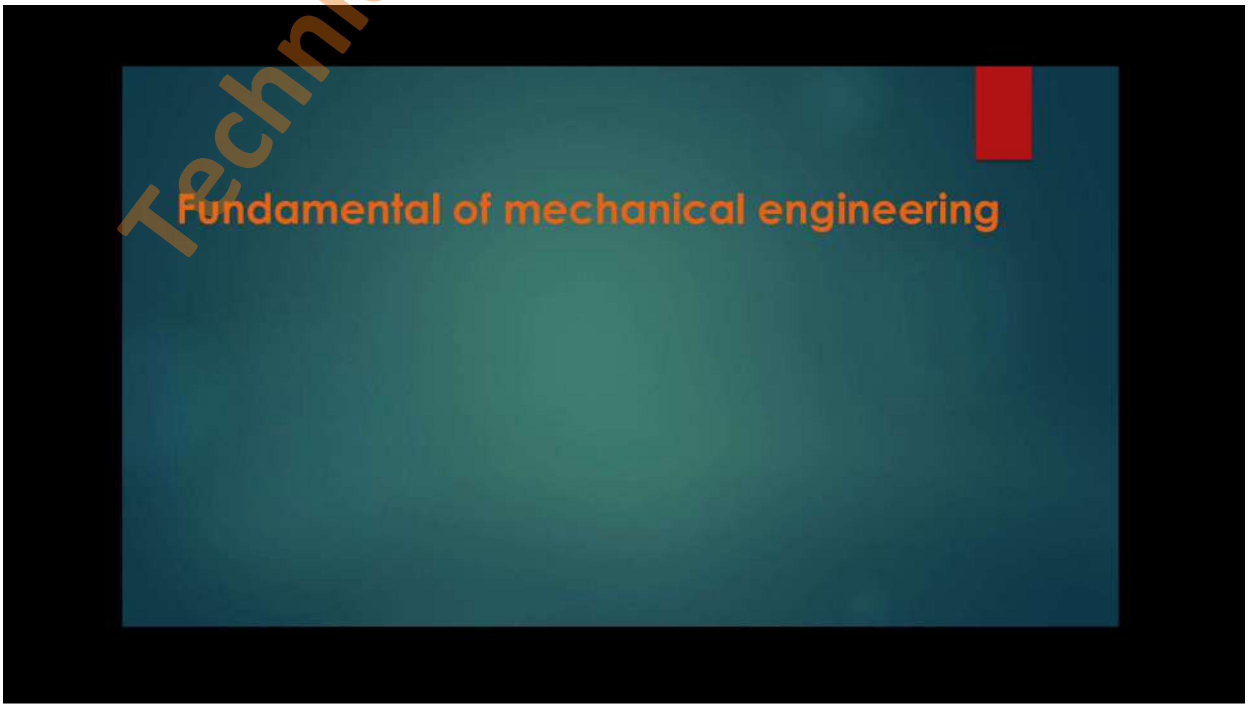
5. Natural Refrigerants

Ex: R-290 (propane), R-600a (isobutane), R-717 (ammonia), R-744 (carbon dioxide)

Characteristics: Environmentally friendly, with low GWP and zero ozone depletion potential. Some, like ammonia, are toxic or flammable, but they are used in certain industrial applications.

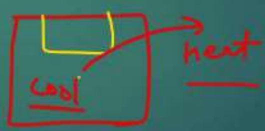
Usage: Often used in specific applications where their properties (such as flammability or toxicity) can be safely managed, or in systems designed for low environmental impact.


T2
Q2 = Q1 + Wp
Wp = Q2 − Q1
Heat Pump
Wp
Q1
T1
EPR = Q2 / (Q2 − Q1)
EPR = 1 − Q2/Q1
or C.O.P
EPR → Energy Performance ratio


Fundamental of mechanical engineering

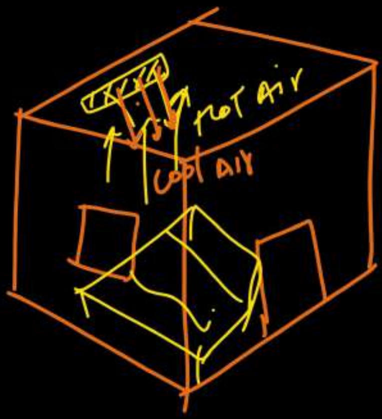
AIR CONDITIONING SYSTEM

- An air conditioning (AC) system is a device used to control the temperature, humidity, and air quality within an indoor space. It works by removing heat from the indoor air and transferring it outside, creating a cooler, more comfortable environment.



- **Types of air conditioning system**
- There are several types of air conditioning systems, each suited for different needs and building types. Here are the most common ones:
- **Central Air Conditioning**
- This system cools the air in a central location (usually a large air handler or unit) and distributes it through ductwork to multiple rooms or areas.
- Large homes, commercial buildings, or offices with multiple rooms or floors.

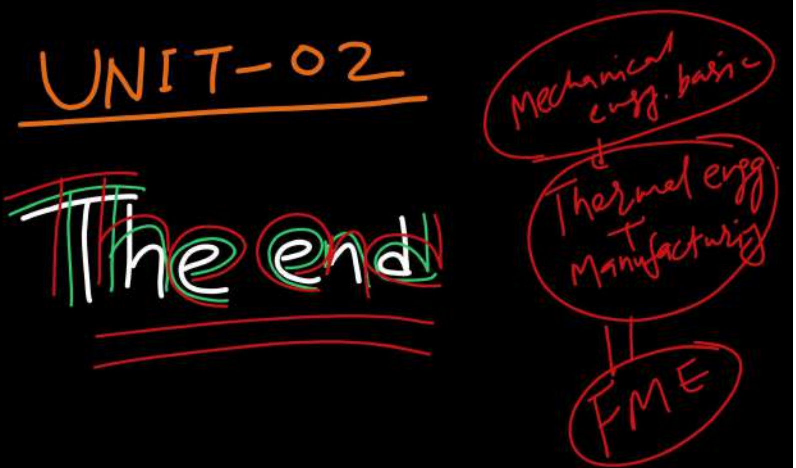
- **Window Air Conditioner**
- A compact unit that fits into a window frame and cools a single room. It expels hot air outside while cooling indoor air.
- Smaller rooms or apartments, especially in older buildings or where other systems are impractical.
- **Packaged Air Conditioner**
- All-in-one systems that contain both the evaporator and condenser coils, along with a fan and other components, in a single unit. It is often installed on the roof or outside the building.
- Commercial buildings or homes where space is limited.



Method of energy saving in refrigeration and air conditioning system

- Energy saving in refrigeration and air conditioning (A/C) systems can be achieved through a combination of technologies, operational practices, and maintenance strategies.

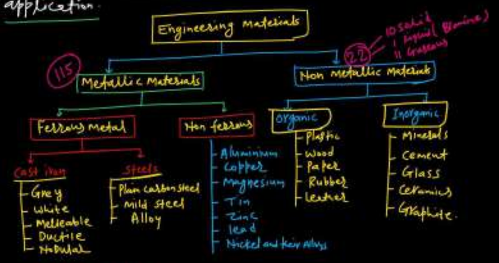
- **High-Efficiency Compressors**: Using energy-efficient compressors that consume less power and deliver better performance.
- **Heat Exchangers:** Employing high-efficiency heat exchangers to improve heat transfer and reduce energy losses.
- **Energy-Efficient Insulation:** Proper insulation around piping, evaporators, and compressors reduces energy loss.



Unit-03

* Engineering material

The engineering materials are widely use for the manufacturing of Machine and structure. The material may be metal, non metal, plastics and composites. It is desirable to understand the behaviour of these materials for a useful application.



Metallic materials

Metallic materials are inorganic substence, which are composed of one or more metal elements and some non metal elements.

→ Properties of Metallic materials

- Good Malleablity and ductility.
- Good electrical and thermal conductivity.
- Available in Solid form at the room temp.
- Form alloys
- Freshly cut surface have Shining appearance.

Metallic Materials

Metallic materials are inorganic substances, which are composed of one or more metal elements and some non-metal elements. The important properties of metallic materials are as follows:

i) Good malleability and ductility.

(ii) Good electrical and thermal conductivity.

(iii) form alloys.

(iv) available in solid form at the room temperatures

(V) freshly cut surface have a glossy (shining) appearance.

examples of the metals are iron, copper, aluminium, nickel, and titanium. The metals may compose of any one or more of these non-metal elements such as carbon, oxygen, hydrogen, nitrogen etc.

Metallic materials can be classified into two classes:

1 Ferrous materials (Fe)

2 Non-ferrous materials

Ferrous materials

* Ferrous metals

(बड़ी मात्रा में लोहा)

The materials which possess a large percentage of iron are classified as ferrous materials. Steel and cast iron are examples of the ferrous materials.

Non-ferrous metals

which have a metal other than iron as their main constituent and include aluminium, copper, lead and their alloys such as brass (copper + zinc), bronze (copper + tin) and duralumin (aluminium + copper).

Non-metallic Materials (22)

The non-metallic materials play an important role in the manufacturing field due some of their outstanding properties. Their important properties are as follows:

- Available in solid, liquid and gaseous form.
- Do not form alloys.
- Compounds are formed when combined chemically.
- Poor electrical and thermal conductivity.

Some of the most widely used non-metallic materials are wood, ceramics, composites, and electronic materials.

Cast Iron

Cast iron is an alloy of iron with more than 2% carbon as the main alloying element. Though it can have any carbon percentage between 2% and 6.67%, the practical limit is normally between 2.11% and 4.5%. In addition to carbon, cast iron also contains 0.5-3% silicon, 0.1-1.2% manganese and traces of impurities such as sulphur and phosphorus.

Gray Cast Iron

As a result of the presence of carbon in the form of graphite flakes, the fractured surface of this alloy looks grayish, and therefore it is called gray cast iron.

The grey cast iron

- Has low tensile strength but excellent compressive strengths
- Is hard and brittle without any ductlity
- is easy machineable but cannot be forged
- Has high damping capacity

White Cast Iron

When liquid cast iron is cooled rapidly, the graphitization does not take place and the carbon is present in the combined form. This type of cast iron is called white cast iron.

Properties of white cast iron

- Highly abrasive, wear resistant, hard and brittle
- high tensile strength but low compressive Strength.
- non-machinable; requires grinding to get the required shape.

Ductile Cast Iron

In ductile cast iron, graphite is present as small, rounded and well-distributed particles which results in higher ductility. Owing to the particular shape of graphite particles, it is also known as nodular or spheroidal cast iron.

* **Malleable cast iron**

It is obtained from hard and brittle white cast iron through a controlled heat treatment process that separates the combined carbon of white cast iron into nodules of free graphite.

- High yield strength and high damping capacity
- Good weldability and machinability
- can be easily hammered and rolled into different shapes

- **Carbon steel** is a type of steel where **carbon** is the primary alloying element, typically comprising **0.05% to 2.1% by weight**. It may also contain small amounts of other elements like manganese, silicon, or copper, but it lacks significant amounts of elements like chromium, nickel, or molybdenum .
- **Low-carbon steel,** also called mild steel, has less than 0.30% Carbon. It is generally used for common products such as bolts, nuts, sheet plates, tubes, and machine components that do not require high strength.

Carbon → 0.05% to 0.3%

- **Medium-carbon steel** has 0.30% to 0.60% C. It is generally used in applications requiring higher strength than those using low-carbon steels, such as gear, axle , railway track and structural components.
- **High-carbon steel** has more than 0.60% C. It is generally used for parts requireing strength, hardness, and wear resistance; examples are Cutting tools, springs, and high-strength wires.

- **Low alloy steel** is a type of steel that contains a small amount of alloying elements (generally less than **5% by weight**) in addition to **iron and carbon**. These alloying elements—such as **chromium, nickel, molybdenum, vanadium,** and **manganese**—are added to improve the steel's mechanical properties, corrosion resistance, and heat resistance compared to plain carbon steel.
- Low alloy steels are commonly used in structural, pressure vessel, automotive, and pipeline applications due to their **enhanced strength, toughness, and durability**.

- **Tool steel** is a type of **carbon and alloy steel** specifically designed for making **tools**, **dies**, **molds**, and **machine parts**. It is known for its **hardness, toughness, wear resistance, and ability to retain a sharp edge** at high temperatures. The composition of tool steel includes varying amounts of carbon, chromium, vanadium, molybdenum, tungsten, and cobalt to achieve specific properties.

- **Stainless steel** is a type of **alloy steel** known for its **corrosion resistance**, which is achieved by adding a minimum of **10.5% chromium** to the steel. Chromium forms a **passive oxide layer** on the surface that protects the material from rust and corrosion. Other elements like **nickel, molybdenum, manganese, or nitrogen** may also be added to enhance specific properties such as strength, toughness, and resistance to heat.

Iron + carbon + 10.5% Chromium
→ Stainless Steel

- **Aluminium alloys** are materials made by mixing **aluminium** with other elements such as **copper, magnesium, silicon, zinc,** and **manganese** to improve its mechanical and physical properties. Pure aluminium is lightweight and corrosion-resistant but lacks strength, which is enhanced through alloying. Aluminium alloys combine these properties, making them suitable for a wide range of applications.
- **Types of Aluminium Alloys**
- Aluminium alloys are broadly classified into two categories:
- **Cast Aluminium Alloys:**
- Formed by casting (pouring molten aluminium into molds).
- Higher silicon content for better fluidity and castability.
- Used in automotive engine blocks and aerospace components.

2. **Wrought Aluminium Alloys:**

- Mechanically worked (rolled, extruded, or forged) into shapes.
- Stronger and more ductile than cast alloys.
- Used in aircraft frames, transportation, and construction.

Nickel alloys

Nickel alloys are materials composed primarily of nickel mixed with other elements such as chromium, iron, molybdenum, cobalt, copper, and titanium. These alloys are designed to enhance specific properties, such as corrosion resistance, heat resistance, and mechanical strength, making them suitable for demanding environments like chemical processing, aerospace, and marine industries.

Copper alloys

Copper alloys are materials made by combining copper with other metals or elements to enhance its mechanical, thermal, and corrosion resistance properties. Copper is a highly versatile and conductive metal, and alloying improves its strength, wear resistance, and other specific characteristics while maintaining its excellent electrical and thermal conductivity. Common alloying elements include zinc, tin, aluminum, nickel, and silicon.

Titanium alloys

Titanium alloys are materials made by alloying titanium with other metals such as aluminum, vanadium, molybdenum, iron, or chromium to enhance its properties. Titanium is naturally lightweight, strong, and corrosion-resistant, but alloying further improves its strength, ductility, and ability to withstand high temperatures. Titanium alloys are widely used in aerospace, medical, automotive, and industrial applications due to their unique combination of properties.

Magnetic Materials

Magnetic materials are substances that exhibit a response to a magnetic field due to the alignment of their atomic magnetic moments. The degree of magnetism depends on the material's structure and atomic arrangement.

Types of Magnetic Materials:

- Diamagnetic Materials:- Weakly repel magnetic fields.Example: Copper, Gold.Applications: Magnetic levitation systems.
- Paramagnetic Materials:Weakly attracted to magnetic fields.Magnetic alignment is lost when the external field is removed.Example: Aluminum, Platinum.Applications: Magnetic resonance imaging (MRI).
- Ferromagnetic Materials:Strongly attracted to magnetic fields and retain magnetism when the field is removed.Example: Iron, Nickel, Cobalt.Applications: Transformers, motors, magnetic storage.

Q. In which of the following are paramagnetic materials ———

(a) Copper

(b) Gold

(c) Aluminium

(d) Iron.

Dielectric Materials

Dielectric Materials: Dielectric materials are electrical insulators that can be polarized when subjected to an electric field. These materials store and release electrical energy, making them essential for capacitor and insulation applications.

Nickel alloys

Nickel alloys are materials composed primarily of nickel mixed with other elements such as chromium, iron, molybdenum, cobalt, copper, and titanium. These alloys are designed to enhance specific properties, such as corrosion resistance, heat resistance, and mechanical strength, making them suitable for demanding environments like chemical processing, aerospace, and marine industries.

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Titanium alloys

Titanium alloys are materials made by alloying titanium with other metals such as aluminum, vanadium, molybdenum, iron, or chromium to enhance its properties. Titanium is naturally lightweight, strong, and corrosion-resistant, but alloying further improves its strength, ductility, and ability to withstand high temperatures. Titanium alloys are widely used in aerospace, medical, automotive, and industrial applications due to their unique combination of properties.

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Applications: Magnetic resonance imaging (MRI).

Ferromagnetic Materials: Strongly attracted to magnetic fields and retain magnetism when the field is removed. Example: Iron, Nickel, Cobalt.

Applications: Transformers, motors, magnetic storage.

Dielectric Materials

Dielectric Materials Dielectric materials are electrical insulators that can be polarized when subjected to an electric field. These materials store and release electrical energy, making them essential for capacitor and insulation applications.

Types of Dielectric Materials

Polar Dielectrics: Molecules have permanent dipole moments. Example: Water, PVDF.

Non-Polar Dielectrics Molecules lack permanent dipoles. Example: Benzene, Teflon.

Applications of Dielectric Materials:- Capacitors (to store energy).Electrical insulation (cables, transformers).RF and microwave applications.

Superconducting Material

Superconducting materials are those that exhibit zero electrical resistance and expel magnetic fields when cooled below a certain critical temperature (TcT c).

This phenomenon is known as superconductivity.

Types of Superconductors:

Type I Superconductors: Completely expel magnetic fields. Example: Pure metals like Lead, Mercury

Applications: Low-temperature magnetic shielding .

Type II Superconductors:- Allow partial penetration of magnetic fields (vortex state).Example: Niobium alloys, YBCO. Applications: High-performance magnets.

Applications of Superconducting Materials: Magnetic Resonance Imaging (MRI): Produces strong magnetic fields for imaging.

Ceramics

Ceramics are inorganic, non-metallic materials made from natural or synthetic compounds that are subjected to high heat during manufacturing. They exhibit excellent properties like high hardness, brittleness, thermal resistance, and electrical insulation. Ceramics are used across various industries due to their versatile nature.

Types of Ceramics

Ceramics are broadly classified into two main categories:

1. **Traditional Ceramics:** Derived from natural raw materials such as clay, quartz, and feldspar. Examples: Bricks, tiles, earthenware, porcelain. Applications: Construction, pottery, and household items.
2. **Advanced Ceramics:-** Engineered with high-performance synthetic materials. Examples: Zirconia, silicon carbide, aluminum oxide. Applications: Aerospace, electronics, medical devices.

Applications of Ceramics

Aerospace and Defence:- Heat shields, missile nose cones, armor plates.

Construction: Bricks, tiles, sanitary ware.

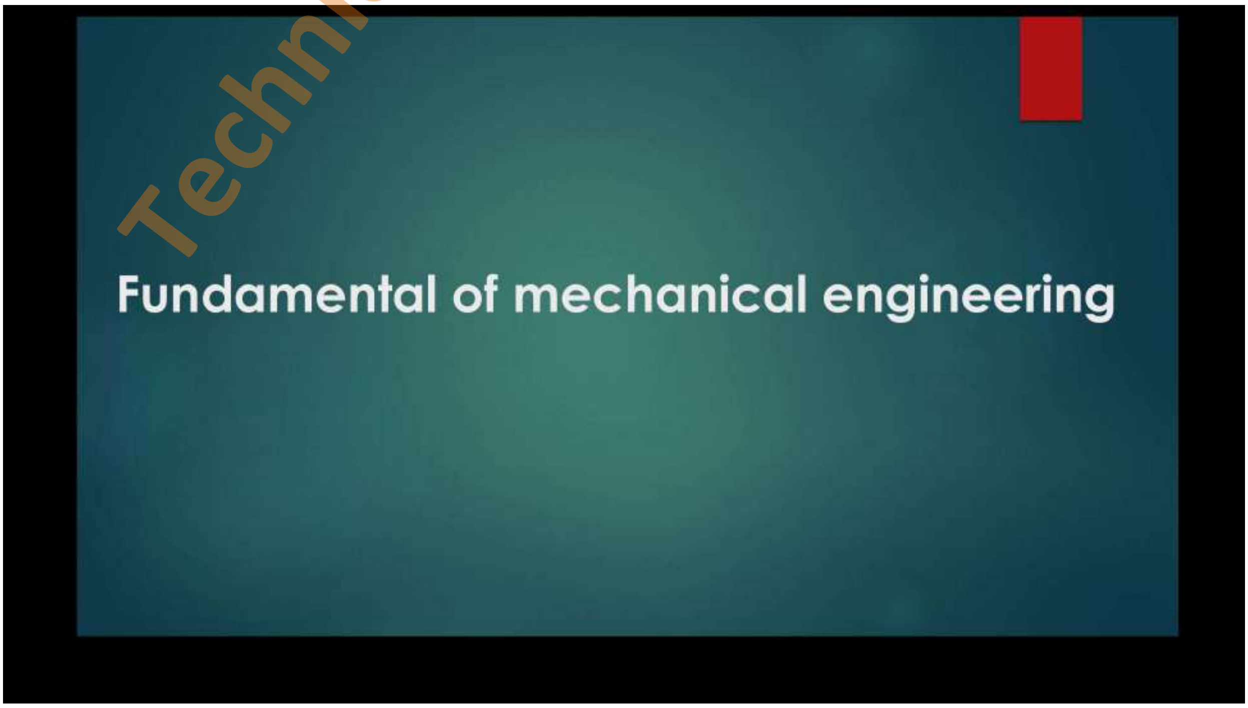
Medical: Dental crowns, joint replacements, bone implants.

Electronics:- Capacitors, insulators, semiconductors.

Automotive: Spark plugs, catalytic converters, brake pads.

Industrial:- Cutting tools, wear-resistant coatings, furnace linings.

Consumer Products:- Cookware, decorative items, watches.



Polymers

- **Polymers** are large molecules formed by the repeated linking of smaller units called **monomers**. They can be natural (e.g., rubber, cellulose) or synthetic (e.g., plastics, nylon). Polymers have diverse applications due to their flexibility, durability, and lightweight properties

Types of Polymers

Polymers are broadly classified into the following categories:

- **1. Thermoplastic Polymers**
- **Thermoplastic polymers** are materials that can be melted and reshaped multiple times upon heating without significant degradation.
- **Characteristics:**
- Soften when heated and harden upon cooling.
- Recyclable.
- Exhibit plastic deformation.
- Molecular structure: Linear or slightly branched chains.

- **2. Thermosetting Polymers**
- **Thermosetting polymers** are materials that, once cured or hardened by heat or a chemical reaction, cannot be remelted or reshaped.
- **Characteristics:**
- Irreversible hardening.
- High thermal and chemical resistance.
- Cross-linked molecular structure.

- **3. Elastomers**
- **Elastomers** are polymers that exhibit high elasticity and can stretch significantly before returning to their original shape.
- **Characteristics:**
- Highly elastic.
- Cross-linked molecular structure (light cross-linking compared to thermosetting polymers).
- Soft and flexible at room temperature.

Metallic glasses

- **Metallic glasses**, also known as **amorphous metals**, are materials that combine metallic properties with a non-crystalline, amorphous structure. Unlike conventional metals, which have an ordered crystalline structure, metallic glasses are formed by rapidly cooling molten metal alloys, preventing the atoms from arranging into a crystalline lattice.

Types of Metallic Glasses

Metallic glasses are classified based on their composition and properties:

- **1. Iron-Based Metallic Glasses:**
- Contain iron as a primary component, often combined with boron, silicon, or carbon.
- **Properties**:
  - Soft magnetic properties.
  - High corrosion resistance.

Iron → b, S or C

- **2. Cobalt-Based Metallic Glasses:**
- Alloyed with elements like boron or silicon.
- **Properties:**
  - Excellent magnetic performance.
  - High strength and thermal stability.

- **3. Nickel-Based Metallic Glasses:**
  - Nickel as the base element, often alloyed with zirconium or titanium.
  - Properties:
  - Good corrosion resistance.
  - High wear resistance.

- **4. Precious Metal-Based Metallic Glasses:**
- Made with gold, silver, or platinum as base elements.
- **Properties:**
  - High malleability. (thin sheet)
  - Attractive aesthetic properties.

Mechanical properties

- **Strength**
- The ability of a material to resist deformation or failure under an applied force.
- **Hardness**
- The ability of a material to resist surface deformation, such as scratching or indentation, or Penetration etc.
- **Elasticity**
- The ability of a material to return to its original shape after deformation when the load is removed.

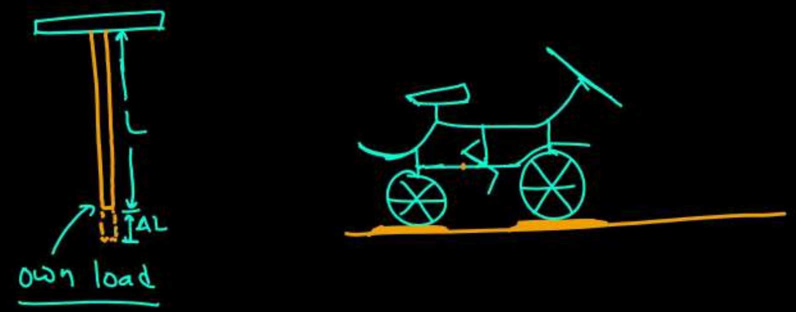
  • Most elastic material → Steel

Mechanical properties

- **Strength**
- The ability of a material to resist deformation or failure under an applied force.
- **Hardness**
- The ability of a material to resist surface deformation, such as scratching or indentation.
- **Elasticity**
- The ability of a material to return to its original shape after deformation when the load is removed.

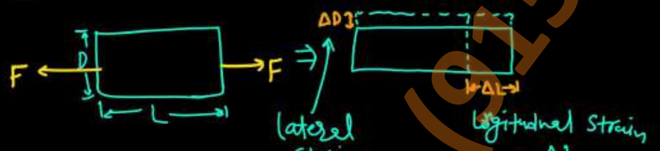
- **Plasticity**
- The ability of a material to undergo permanent deformation without breaking.
- **Ductility**
- The ability of a material to be stretched into a wire without breaking. Most Ductility material → Gold, silver, copper.
- **Malleability**
- The ability of a material to deform under compressive forces, often rolled or hammered into thin sheets. ↳ Gold, silver, Platinum, copper.
- **Toughness**
- The ability of a material to absorb energy and deform plastically without fracturing.

- **Brittleness**
- The tendency of a material to fracture or break without significant deformation.
- **Poisson's Ratio**
- The ratio of lateral strain to (or longitudinal strain) axial strain when a material is stretched or compressed. Poisson's ratio = 0.25 to 0.33
- **Fatigue Strength**
- The ability of a material to withstand (सहना) repeated or cyclic loading without failure.
- **Creep**
- The slow, permanent deformation of a material under a constant load over time, especially at high temperatures.



Strain

→ It is ratio of change in length to the original length is called strain.



lateral strain $= \frac{\Delta D}{D}$

longitudinal strain $= \frac{\Delta L}{L}$

$$P.\ ratio\ (\mu) = \frac{\text{lateral strain}}{\text{longitudinal strain}}$$

$$\mu = \frac{\Delta D}{D} \times \frac{L}{\Delta L}$$

Magnetic properties of materials

- Intensity of magnetization (M)
- The **intensity of magnetization** (M) is a measure of the magnetic moment per unit volume of a material. It quantifies how strongly a material is magnetized when exposed to an external magnetic field or due to the inherent magnetic properties of the material itself.

The intensity of magnetization is defined as:

$$M=m/V$$

where:

m is the net magnetic moment of the material,

V is the volume of the material.

- **Magnetic field strength (h)**
- The **magnetic field strength (h)** the ability of a magnetic field to induce magnetization in a material. It describes the intensity of the magnetic field generated by currents or magnetic materials, independent of the material's response.
- Magnetic intensity is measured in amperes per meter (A/m).

- **Magnetic susceptibility**
- Magnetic susceptibility is defined as the ratio of the **intensity of magnetization** (M) to the **magnetic field strength** (H):
- $\chi = M/H$

where:

- M is the intensity of magnetization (magnetic moment per unit volume),
- H is the applied magnetic field strength.

- **Retentivity**
- Retentivity is the magnitude of the residual magnetization (Mr) in a material when the external magnetizing field (H) is reduced to zero after being magnetized to saturation.
- Retentivity is measured in tesla (T) or magnetization (A/m.)

Coercivity

- Coercivity (Hc) is the value of the magnetic field strength (H) required to completely demagnetize a material.

Physical Properties of Materials

- **Density**–is the mass of a material per unit volume.
- **Specific Gravity**–is the ratio of the mass or weight of a solid or a liquid to the mass or weight of an equal volume of water.
- **Refractive index**–is the ratio of the velocity of light in vacuum to its velocity in another material.
- **Thermal Conductivity**–is the rate of heat flow in a homogeneous material under steady-state conditions, per unit area, per unit temperature gradient in a direction perpendicular to area.
- **Thermal Expansion**–is the rate at which a material elongates when heated. The rate is expressed as a unit increase in length per unit rise in temperature within a specified temperature range.
- **Poisson's Ratio**–is the absolute value of the ratio of the lateral or transverse strain to the longitudinal strain.
- **Colour**–is the property of light by which an observer may distinguish between two structure free patches of light of the same size and shape.

300 gm

150 gm

Water

Milk

$$Sp.\ gravity = \frac{300}{150} = 2$$

$$R.I\ (\mu) = \frac{\text{Velocity of light in vacuum}}{\text{Velocity of light in Medium}}$$

$$R.I\ \text{of Air}\ (\mu_{air}) = \frac{3 \times 10^8\ m/s}{3 \times 10^8\ m/s} = 1$$

Optical Properties of Material

① Dielectric properties of materials

→ It describe how materials respond to an external electric field, particularly their ability to store and dissipate electrical energy. These properties are crucial in understanding the behaviour of materials in capacitors, insulators and other electronic and electrical applications.

Unit – 03

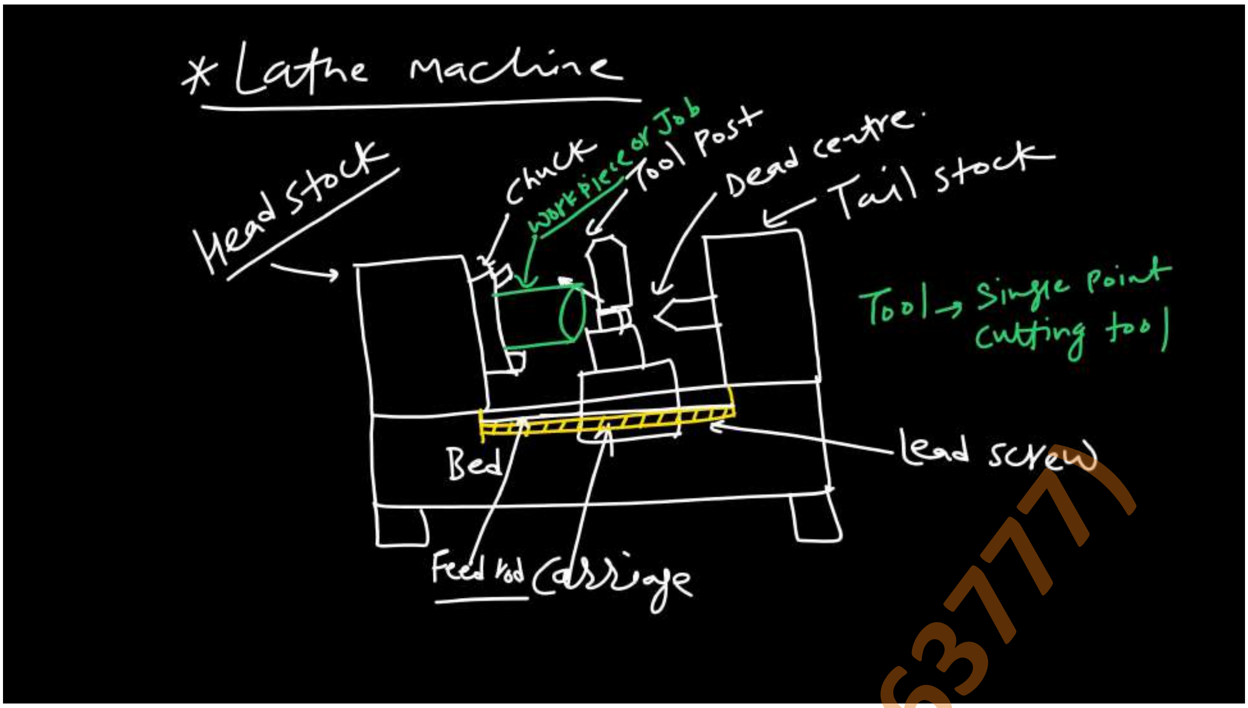
The end

Unit – 04

Introduction

1. Lathe machine
2. Drilling machine
3. Milling machine
4. Grinding machine

operation



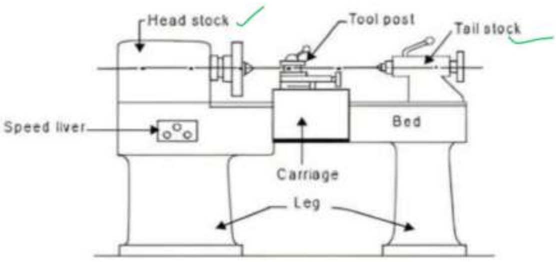
FUNDAMENTAL OF MECHANICAL ENGINEERING

Ashutosh Ranjan

4. Manufacturing process and machine tools

Introduction to Lathe Machine

- A **lathe machine** is a versatile and fundamental machine tool used to perform various operations like cutting, turning, threading, drilling, facing, and knurling on workpieces.
- It works by rotating the workpiece about its axis while a stationary cutting tool is applied to shape it into the desired form.



Components of a Lathe Machine

Bed:

- The base of the lathe, which supports all other components.
- Provides alignment and stability.

Headstock:

- Contains the spindle, gears, and motor for driving the workpiece.
- Holds the chuck or faceplate.
- **Tailstock**:
- Located opposite the headstock.
- Supports the workpiece during operations like ~~drilling~~ knurling or turning. etc

Carriage:

- Moves the cutting tool along the workpiece.
- Includes the tool post, cross slide, and saddle, compound slide

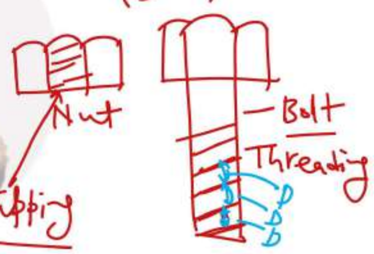
Boring/Reaming, tapping

Drilling operation perform by Lathe machine the tool is held by ——

(a) Tool Post
(b) Head Stock
(c) Tail Stock ✓
(d) None of these.

- **Chuck:** 2-Jaw chuck, 3-Jaw chuck, hydraulic chuck, magnetic chuck
- Used to hold and rotate the workpiece. Universal chuck or self centering chuck
- **Lead Screw:**
- Facilitates precise movement of the carriage for thread cutting operations. (चूड़ी)
- **Tool Post:**
- Holds the cutting tool in place.

T.P.I



Operations Performed on a Lathe

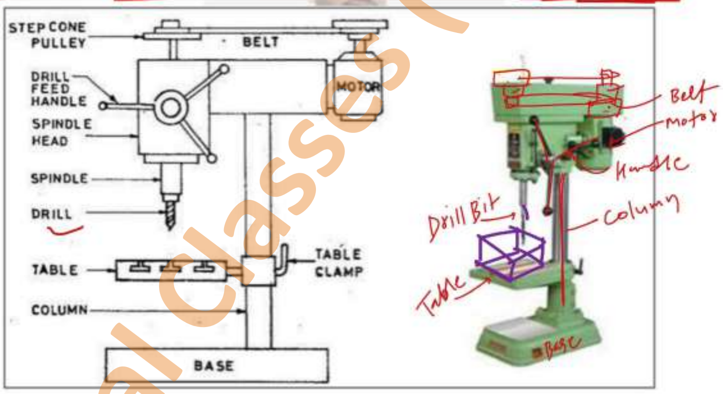
1. **Turning**: Reducing the diameter of the workpiece.
2. **Facing**: Producing a flat surface perpendicular to the axis.
3. **Thread Cutting**: Creating helical grooves (threads) on a workpiece.
4. **Drilling**: Creating holes in the workpiece.
5. **Knurling**: Producing textured patterns for better grip.

(6) Step turning
(7) Tapper turning
(8) Parting off
(9) Boring
(10) Reaming
(11) Tapping
(12) Spot facing

Surface finish of hole by reaming operation.

Introduction to Drill Machine

- A **drill machine** is a versatile tool used to create round holes in various materials such as metal, wood, plastic, and concrete.
- It works by rotating a cutting tool (drill bit) against the workpiece with a specific force, allowing material removal to form a hole.



Components of a Drill Machine

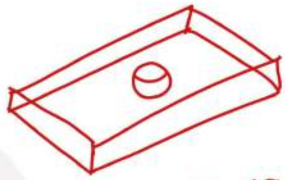
1. **Base**:
   - Provides stability and supports the entire machine.
2. **Column**:
   - A vertical structure that supports the head and arm assembly.
3. **Table**:
   - Adjustable platform where the workpiece is clamped for drilling.

4. Spindle:
Rotates the drill bit, powered by the motor or hand-operated mechanisms.

5. Chuck:
Holds the drill bit firmly in place.

6. Drill Head:
Houses the spindle, motor, and mechanism for controlling the drill's speed and feed.

Operations Performed by Drill Machines



1. **Drilling**:
   - Creating cylindrical holes in a material.
2. **Reaming**:
   - Enlarging and finishing an existing hole for precision.

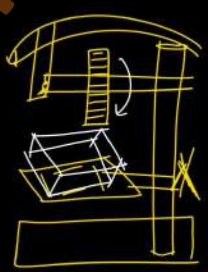
14.98 mm ±0.02 15.00 mm

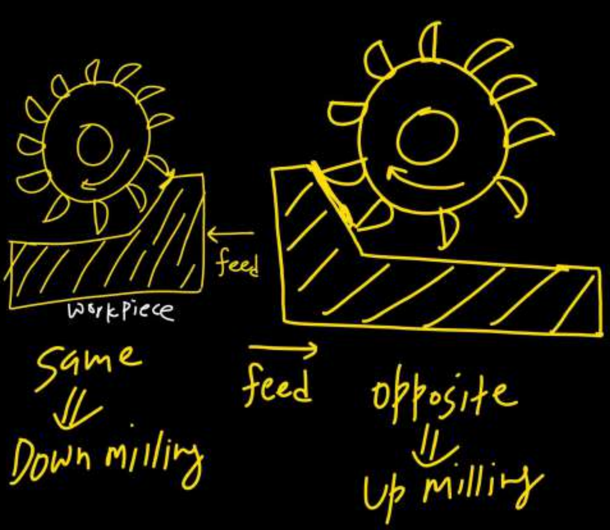
3. **Tapping**:
   - Cutting threads inside a hole for screws and bolts.
4. **Countersinking**:
   - Creating a conical surface at the top of a hole for flathead screws.
5. **Spot Facing**:
   - Machining flat surfaces around a hole.

Q. In which operation are performed in series ________

(a) Reaming, Boring, Drilling
(b) Boring, Reaming, Drilling
(c) Drilling, Reaming, Boring
(d) Drilling, Boring, Reaming.

→ Lathe M/C
→ Drilling M/C
→ Milling M/C
→ Grinding M/C





Operations Performed by Drill Machines

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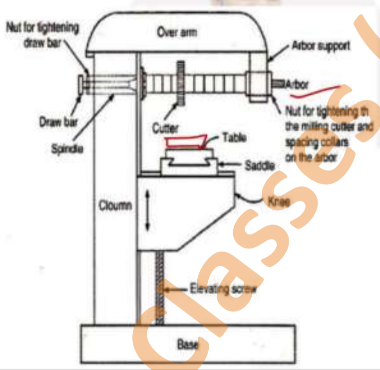
- Cutting threads inside a hole for screws and bolts.

4.Countersinking:
- Creating a conical surface at the top of a hole for flathead screws.

5.Spot Facing:
- Machining flat surfaces around a hole.

Introduction to Milling Machine

- A **milling machine** is a versatile machine tool used to shape solid materials by removing excess material through a rotating cutting tool called a **milling cutter**.
- In a milling machine, the cutting tool rotates while the workpiece is typically fixed or moves along a specific path.



Components of a Milling Machine

1.Base:
Provides support and stability to the entire machine.

2.Column:
A vertical structure that supports the machine's components.

3.Knee:
A movable part that supports the worktable and provides vertical movement.

4. Worktable:
A flat surface where the workpiece is clamped or secured.

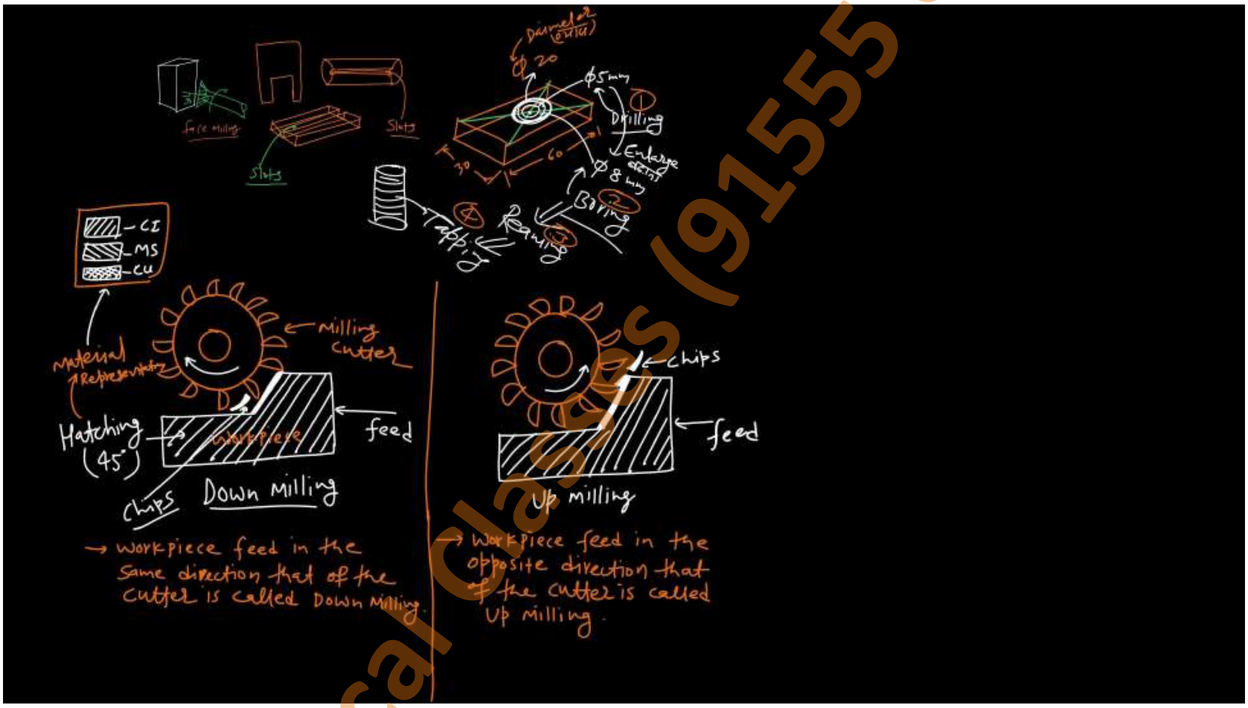
5. Spindle:
Holds and drives the milling cutter.

6. Arbor:
A shaft used to hold long milling cutters.

7. Overarm:
Supports the arbor and provides rigidity.

Types of Milling Operations

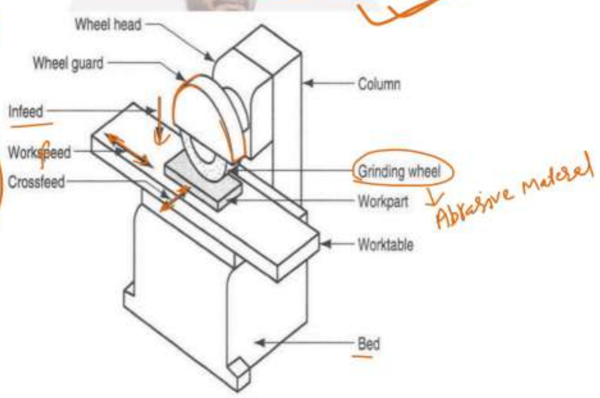
1. **Face Milling**:
   Cutting flat surfaces perpendicular to the cutter axis.
2. **End Milling**:
   Producing slots, pockets, and contours.
3. **Slot Milling**:
   Creating slots or grooves in the workpiece.
4. **Drilling and Boring**:
   Using specialized cutters for holes and enlarging existing holes.
5. Up Milling
6. Down Milling



Introduction to Grinding Machine

- A **grinding machine** is a precision tool that uses an abrasive wheel as the cutting tool to remove material from the surface of a workpiece.
- It is commonly used in manufacturing and finishing processes to achieve high accuracy, smooth finishes, and tight tolerances.

20 Target value
① 20.002
② 19.99999



Components of a Grinding Machine

1.Base:

Provides stability and support to the entire machine.

2.Worktable:

Holds and moves the workpiece during the grinding process.

3.Grinding Wheel:

The main cutting tool, made of abrasive materials like aluminium oxide or silicon carbide.

4. Spindle:

Rotates the grinding wheel at high speeds.

5.Wheel Guard:

A safety cover that protects the operator from flying particles.

Grinding Operations

1.Surface Grinding:

Achieving a smooth, flat surface.

2.Cylindrical Grinding:

Creating cylindrical shapes or finishing round parts.

3.Centerless Grinding:

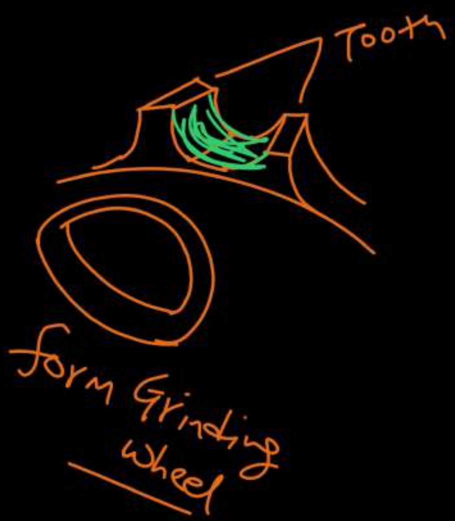
Removing material without clamping the workpiece.

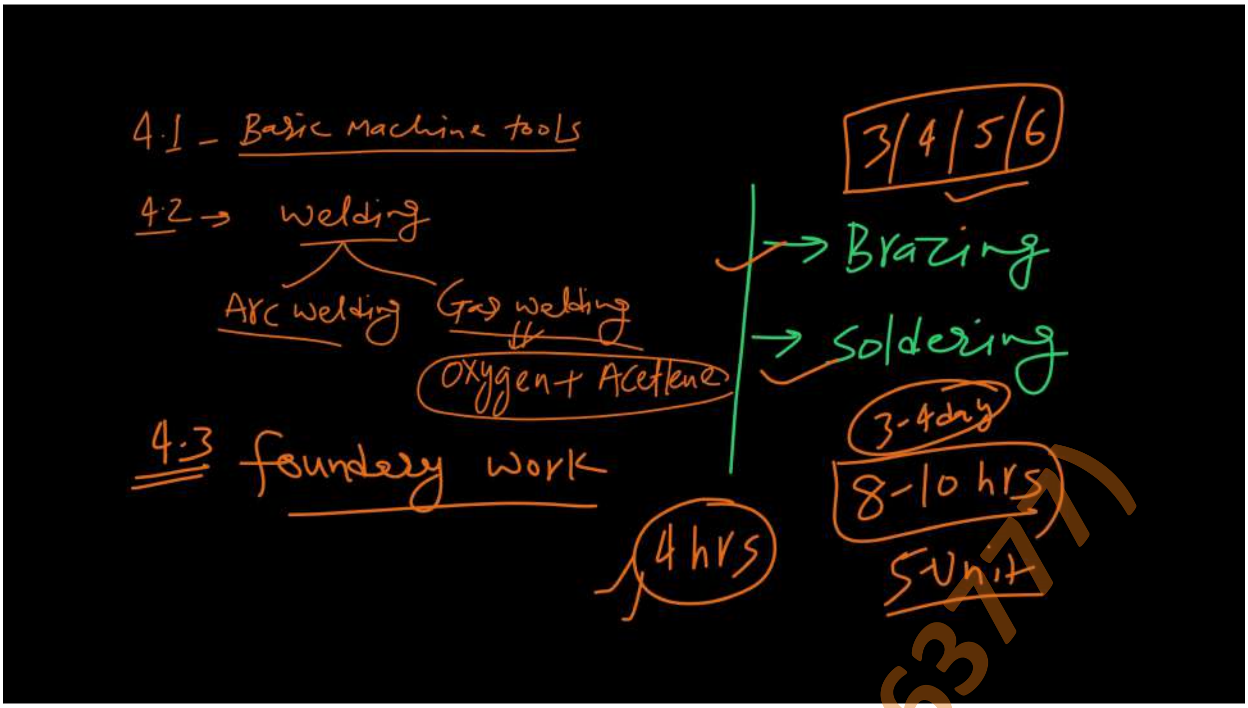
4.Form Grinding:

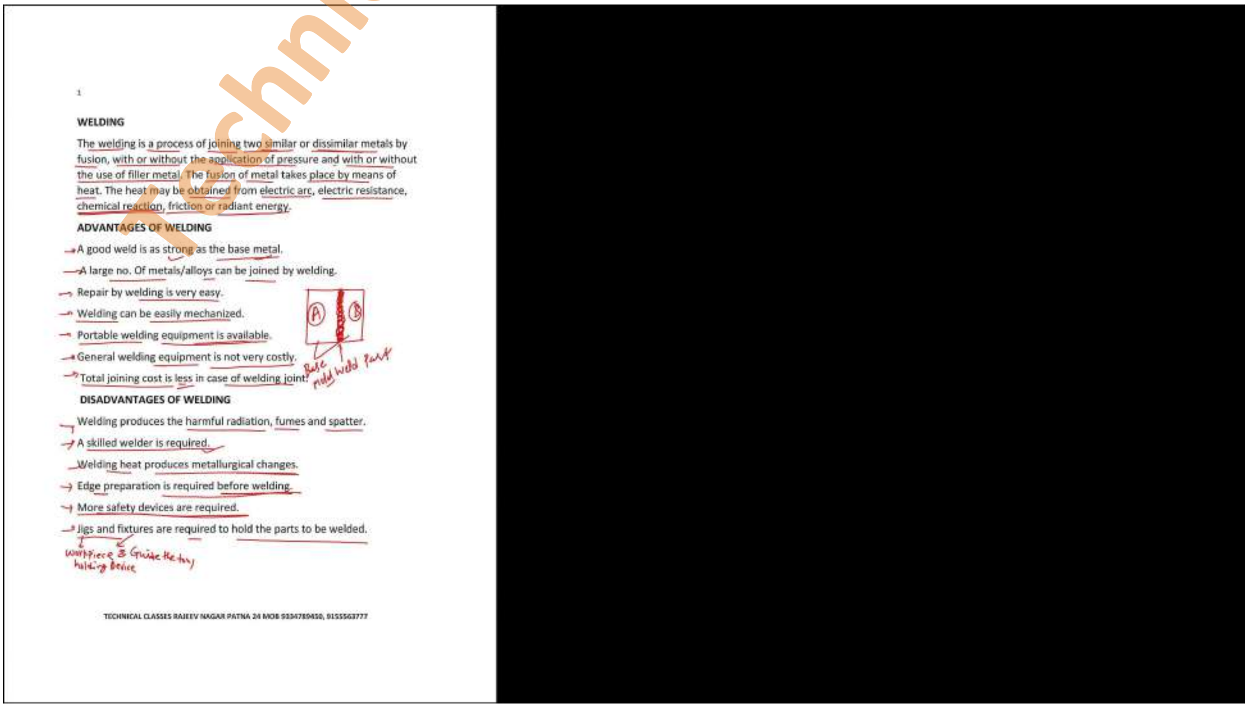
Producing specific shapes or contours.

5.Polishing and Buffing:

Achieving a fine, shiny finish.







1

WELDING

The welding is a process of joining two similar or dissimilar metals by fusion, with or without the application of pressure and with or without the use of filler metal. The fusion of metal takes place by means of heat. The heat may be obtained from electric arc, electric resistance, chemical reaction, friction or radiant energy.

ADVANTAGES OF WELDING

A good weld is as strong as the base metal.
A large no. Of metals/alloys can be joined by welding.
Repair by welding is very easy.
Welding can be easily mechanized.
Portable welding equipment is available.
General welding equipment is not very costly.
Total joining cost is less in case of welding joint.

DISADVANTAGES OF WELDING

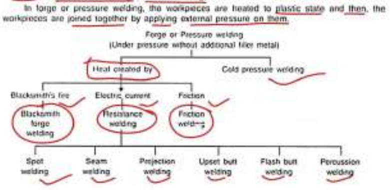
Welding produces the harmful radiation, fumes and spatter.
A skilled welder is required.
Welding heat produces metallurgical changes.
Edge preparation is required before welding.
More safety devices are required.
Jigs and fixtures are required to hold the parts to be welded.

TECHNICAL CLASSES RAJEEV NAGAR PATNA 24 MOB 9334789450, 9155563777

Types of welding

1. Forge or Pressure Welding (Plastic Welding)

In forge or pressure welding, the workpieces are heated to plastic state and then, the workpieces are joined together by applying external pressure on them.



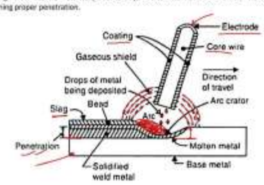
2. Fusion or Non-pressure Welding

In this welding, the material at the joint is heated to a molten state and then allowed to solidify.

Arc Welding

The arc welding is a fusion welding process in which the welding heat is obtained from an electric arc between the work (or base metal) and an electrode. The electric arc is produced when two Conductors of an electric circuit are touched together and then separated by a small distance, such that there is sufficient voltage in the circuit to maintain the flow of current through the gaseous medium (air). The temperature of heat produced by the electric arc is of the order of 6000°C to 7000°C.

The most common method of arc welding is with the use of a metal electrode which supplies filler metal. The welding is done by first making contact of the electrode with the work and then separating the electrode to a proper distance to produce an arc. When the arc is obtained, intense heat so produced quickly melts the work under the arc forming a pool of molten metal which seems to be forced out of the pool by the blast from the arc, as shown in Fig. 15.14. A small depression is formed in the work and the molten metal is deposited around the edge of this depression, which is called the arc crater. The slag is brushed off after the joint has cooled. The arc, once started, should be advanced at a uniform speed along the desired line of welding. The melting should reach to a sufficient depth below the original surfaces of the metal pieces to be joined to obtain the desired weld. This is known as obtaining proper penetration.



Both the direct current (D.C.) and alternating current (A.C.) are used for arc welding. The direct current supply for arc welding is usually obtained from a generator driven by either an electric motor or a petrol or diesel engine. The alternating current supply for arc welding is obtained from a step down transformer which receives current from the supply mains at 200 to 440 volts and transforms it to the voltage actually required (i.e., 80 to 100 volts) for striking the arc only. In order to maintain the arc, a still lower voltage say about 30 to 40 volts is required. The voltage required in case of D.C. welding is 60 to 80 volts for striking the arc and 15 to 25 volts for maintaining the arc.

TECHNICAL CLASSES RAJEEV NAGAR PATNA 24 MOB 9334789450, 9155563777

Arc Maintance

AC → 60 to 100 V 30 to 40 V

DC → 60 to 80 V 15 to 25 V

4

Gas welding

It is a method of fusion welding in which a flame produced by the combustion of gases is employed to melt the metal. The use of an oxyacetylene flame is the most widely employed method of welding iron, steel, aluminium, cast iron and copper, the equipment required, as illustrated in Fig. 4.10 being considerably cheaper and simpler than that needed for electric welding. For a certain classes of mass production work, however, electric welding will always prove superior both in quickness and cheapness.

The principle of acetylene welding is the ignition of oxygen and acetylene gases, mixed in a blow pipe fitted with a nozzle of suitable diameter; this flame is applied to the edges of the joint and to a wire filler of the appropriate metal, which is thereby melted and run into the joint. When the acetylene is burned in an atmosphere of oxygen an intensely hot flame with a temperature of about 3300°C is produced. As the melting point of steel is approximately 1300°C, the metal is fused very rapidly at the point at which the flame is applied.

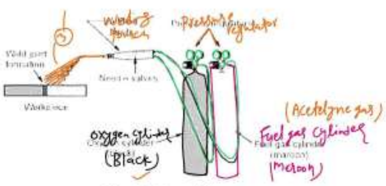


Fig. 2.1 : Gas welding

5

Types of Flames :

Following are the three types of flames of oxygen and acetylene mixture :

1. Neutral flame
2. Carburising flame
3. Oxidising flame.

Black Maroon

1.Neutral flame :- (1 : 1)

When the ratio of oxygen and acetylene is equal, a neutral flame is obtained.

This type of flame has a temperature of 3250°C, is white in colour and has a sharply defined central cone with a reddish purple envelope.

It does not react chemically with the parent metal and protects it (the metal) from oxidation.

The neutral flame is used to weld carbon steels, cast iron, copper, aluminium etc.

Neutral flame

2. Carburising flame

The ratio of oxygen to acetylene is 0.9 to 1. It consists Of the following three zones.

-Luminous zone,

- or intermediate cone of white colour, and

-Outer envelope.

It is also called as reducing flame and has a temperature of 3040°C.

The carburising flame is used for the following purposes : To join those materials which are readily oxidised. Thus it is used to weld aluminium since it prevents the formation of aluminium oxide at the time of welding.

To weld monel metal, high carbon steel and alloy steel.

To give a hard facing material in some cases.

Carburising flame
(Excess acetylene result temperature 2000 °C to 2700 °C average)

3.Oxidising flame

The ratio of oxygen to acetylene varies from about 1.2 to 1.5.

It is used in the following cases :

To weld copper, brass and bronze and zinc- bearing Alloys.

For gas cutting.

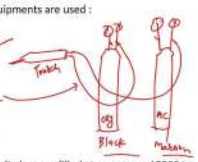
It may be noted that although, in gas welding, oxygen and acetylene mixture is popular, other fuel gases like propane, hydrogen and coal gas may also be used along oxygen to produce gas flames for welding.

Oxidising flame
(Excess oxygen results high temperature upto 3400 °C)

Equipment:

For gas welding following equipments are used :

1. Gas cylinders
2. Pressure regulators
3. Pressure gauges
4. Welding torch
5. Hoses and hose fittings
6. Safety devices etc.



1. Gas cylinders

A. Oxygen cylinder

For safety purposes oxygen cylinders are filled at a pressure 12500 to 14000 kN/m² and cylinder capacity is 6.23 m³.

The cylinder is provided with a right hand thread valve and is painted black.

The cylinders are usually provided with fragile disc and fusible plug to relieve the cylinder of its contents if subjected to overheating or excessive pressure.

B. Acetylene cylinder

The cylinder is usually filled to pressure of 1600 to 2100 kN/m².

The cylinder is provided with left hand threads for accommodating pressure regulator and is painted maroon.

Acetylene gas above one atmospheric pressure is highly explosive. Hence acetylene is stored with calcium silicate saturated with acetone. Acetone can absorb 25 times its own volume of acetylene for each atmospheric pressure.

2. **Pressure regulators.** [illegible]
3. **Pressure gauges.** [illegible]
4. **Welding torch/blow pipe** [illegible]

[illegible]

6. Safety devices :

Goggles fitted with coloured glasses should be used to protect the eyes from harmful heat ultraviolet rays.

Gloves made of leather, canvas and asbestos should be worn to protect hands from any injury. Gloves should be light so that the manipulation of the torch may be done easily.

Other requirements include spark-lighter, apron, trolley, wire brush, spindle key, spanner set, filter rods and fluxes and welding tips.

Advantages:

1. The oxy-acetylene torch is versatile. It can be used for brozing, bronze welding, soldering, heating, heat treatment, metal cutting, metal cleaning etc.
2. It is portable and can be moved almost everywhere for repair of fabrication work.
3. The oxy-acetylene flame is easily controlled and not as piercing as metallic arc welding, hence, extensively used for sheet metal fabrication work.

Disadvantages :

1. As compared to arc welding, it takes considerably longer time for the metal to heat up.
2. Owing to prolonged heating harmful thermal effects are aggravated which results in a larger heat affected area, increased grain growth, distortion and less of corrosion resistance.
3. Oxygen and acetylene gases are expensive.

महँगा

Welding

- Arc → 6000°C to 7000°C
- Gas → 3300°C

Brazing

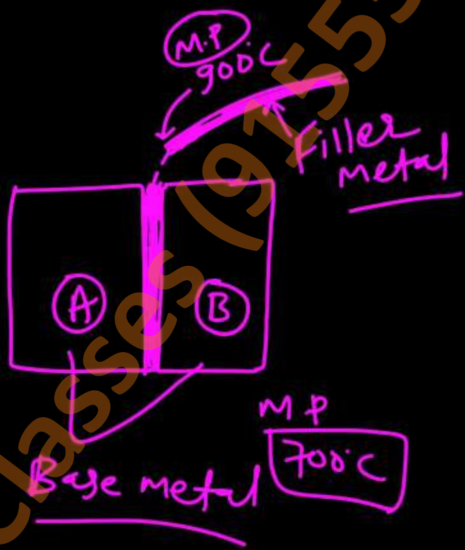
450°C ↑

Soldering

450°C ↓

BRAZING

- **Brazing** is a **metal-joining process** in which two or more metal pieces are joined by melting a **filler metal** (also called a brazing alloy) and allowing it to flow into the joint. The filler metal has a **melting point lower than that of the base metals** being joined, so only the filler melts while the base metals remain solid. The process is typically performed at temperatures above **450°C (840°F)** but below the melting point of the base metals.



- **ADVANTAGES**
- The brazing is a simple and economical process.
- Dissimilar metals can be joined by brazing process.
- Thin section plates are joined very easily but such workpieces can not be joined by welding.
- Metals with different thickness can be joined easily.
- Brazing produces leak proof and pressure tight joints.

Disadvantages:

- Heavy sections can not be joined by brazing process.
- It is suitable for small articles and thin section plates only.
- A skilled labour is required for brazing.
- Brazing results in low strength joints compared to welding.

- **Applications of Brazing**
- **Automotive industry**: Joining of heat exchangers, radiators, and fuel lines.
- **Aerospace**: For turbine blades and structural components.
- **HVAC systems**: Joining copper pipes and components.
- **Electronics**: Manufacturing electrical connectors and contacts.
- **Plumbing**: Joining of copper pipes and fittings.

SOLDERING

- **Soldering** is a **metal-joining process** that involves melting a filler metal (known as **solder**) to bond two or more metal components together. Unlike welding and brazing, **soldering occurs at a relatively low temperature**—typically below **450°C (840°F)**. The solder has a lower melting point than the base metals, meaning the base materials do not melt during the process.

- **Advantages**
  - Dissimilar metals can be joined.
  - It is simple, low cost, flexible, economical and user friendly.
  - The life of solder will be more.
  - Low amount of power is required to heat the soldering iron.
  - The soldering can be done at low temperature and controlling is very easy.

Disadvantages:

- Heavy sections can be joined by soldering process. It is suitable for small article only.
- Solders are costlier and soldering requires proper solder to get strong bonding.
- A skilled labour is required for soldering.

- **Applications of Soldering**
- **Electronics**: Circuit board assembly, connecting wires and components.
- **Plumbing**: Joining copper pipes and fittings.
- **Jewellery Making**: Repairing or assembling metal pieces.
- **Metal Artwork**: Crafting and repair of metal art objects.

Q. Difference between brazing and soldering.

Brazing	Soldering
→ operates at higher temp. (> 450°C)	→ operate at lower temp. (< 450°C)
→ Uses filler metals like brass, copper, silver alloys or Aluminium.	→ Uses filler materials like tin-lead, tin silver or tin copper alloys.
→ Stronger Joint	→ weaker Joints.
→ Requires flux to prevent oxidation at high temp.	→ Also requires flux but for lower temp. protection.
→ More expensive	→ less expensive.
→ Joining pipes, radiators heat exchangers etc.	→ Repairing circuit boards, Joining wires etc

✓ Foundery

✓ Casting

Unit - 05

✓ Power transmission

UNIT-05

Power Transmission System

→ The Components or elements which are Use to transfer mechanical power from one place to another place are called mechanical power transmission system (MPTS).

Classification of mechanical power transmission system (MPTS): →

MPTS

- Flexible power transmission syst. or Slack " " or friction drive or Negative drive
- Non flexible power transmission syst. or Positive drive.

Flexible PTS

- Belt drive
  - flat Belt drive.
  - V-Belt drive
- Rope drive
  - fiber rope
  - Wire rope

Non flexible PTS

- Gear drive
- Chain drive
- Clutches
- Coupling

** → Rope drive is use to power transmission for large distance up to 150 m.

→ flat Bet drive is use to transmit power for medium distance, while V- Belt drive is use to transmit power for smaller distance.

→ Chain drive is we to power transmit for distance between of Gear and Belt drive

** → Bush and Roller chain drive is used in automobile and bicycles etc.

** → Silent chain is used millitary tank.

→ Gear drive is use to power transmission for very small distance.

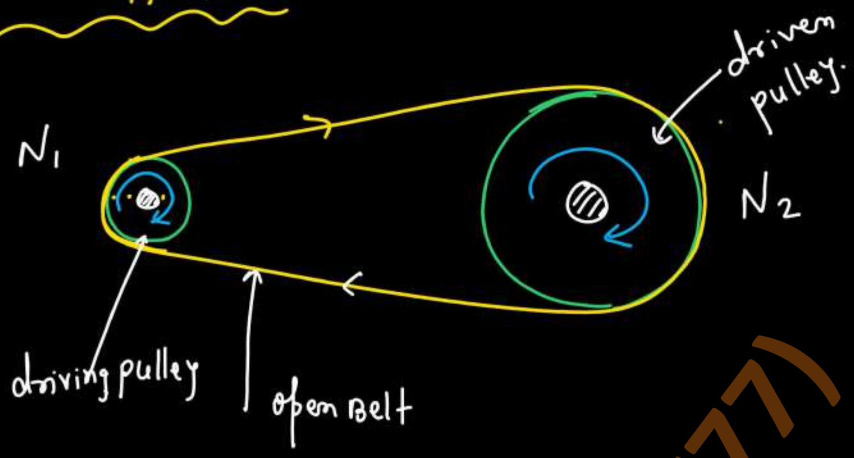
Belt drive:-

- Flat Belt drive
  - open Belt drive
  - Cross-Belt drive.
- V-Belt drive

→ Belt drive is a slack mechanical drive system because of chances of slipping between pulley and Belt

→ flat Belt drive has rectangular x-sectional area.

Open Belt drive:—



→ In case of open Belt drive, Both pulleies moves in same direction.

→ **Driving or Driver pulley:** → The pulley which rotates first by the engine is called driving pulley.

→ **Driven pulley:** → The pulley which is rotated by driver pulley with the help of Belt is called driven pulley.

→ **velocity ratio (V.R):** →

→ velocity ratio is defined as the ratio of speed of driven pulley (N_2) to the speed of driving pulley (N_1)

$$\therefore \boxed{\text{velocity ratio (V.R)} = \frac{\text{speed of driven pulley}}{\text{speed of driving pulley}} = \frac{N_2}{N_1}}$$

∵ angular speed $(\omega) = \frac{2\pi N}{60}$ rad/sec

$$V.R \therefore \frac{N_2}{N_1} = \frac{2\pi N_2}{2\pi N_1} = \frac{\omega_2}{\omega_1} = \frac{D_1}{D_2}$$

Where
$\omega_2 \rightarrow$ angular speed of driven pulley.
$\omega_1 \rightarrow$ " " " driving "
$D_1 \rightarrow$ diameter of driving pulley.
$D_2 \rightarrow$ diameter of driven pulley.

→ when slip occurs between pulley and Belt,
Then velocity ratio (V.R) →

$$V.R = \frac{N_2}{N_1} = \frac{D_1}{D_2}\left(1 - \frac{S}{100}\right)$$

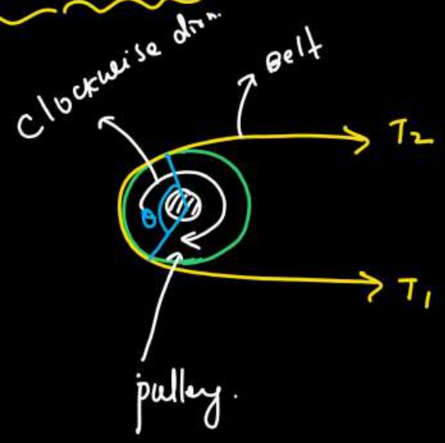
where S = Total slip = Sum of slip between Belt and driving pully and between Belt driven pulley.
$= S_1 + S_2$

Note → when slip occurs between Belt and pulley.
Then **

$$V_1 > V' > V_2$$

where V_1 = Tangential speed of driving pulley.
V' - Speed of Belt drive.
V_2 = Tangential speed of driven pulley.

Tension in the Belt :→



** $T_1 > T_2$

where

T_1 = Tension in the Tight side of Belt

T_2 = Tension in the slack side of Belt

Tight Side :→ The portion of the Belt which approaches towards the pulley is called Tight side of Belt

Slack Side :→ The portion of the Belt which moves away from the pulley is called slack side of Belt.

The relation between tension (T_1) in tight side and tension (T_2) in slack side is given by :→

$$\frac{T_1}{T_2} = e^{\mu \theta}$$

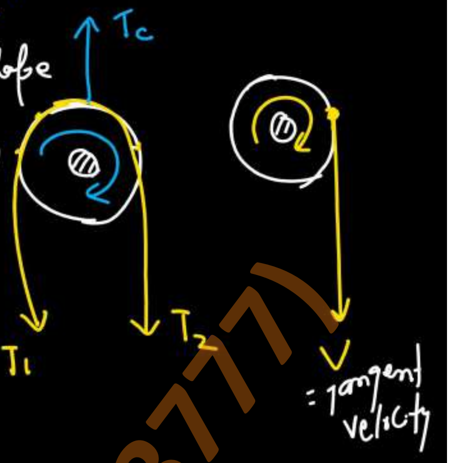
where μ = Co-efficient of friction between pulley and Belt. ($\mu < 1$)

θ = angle of wrap = angle of contact of pulley and belt (in radian)

FME

Centrifugal Tension (T_c) :→

→ The tension which develope in the belt due to rotation - al motion of pulley over which Belt is wrapped is called centrifugal tension.



→ Centrifugal tension (T_c) is given by :→

$$T_c = mv^2$$

where m = mass of belt per unit length

V = linear speed of Belt

→ Centrifugal tension is taken into consideration when $V > 8\ m/sec$

→ Centrifugal tension increases the tension on both side of belt.

∴ total tension in tight side of belt $= T_1 + T_c$

" " " slack " " " $= T_2 + T_c$.

→ For maximum power transmission :—

Maximum Tension "$(T_{max}) = 3mv^2$.

** → Centrifugal tension decreases the power transmission capacity of Belt drive.

Initial Tension (T_0) :→

→ Tension in the Belt when it is at rest over two pulleys is called initial tension.

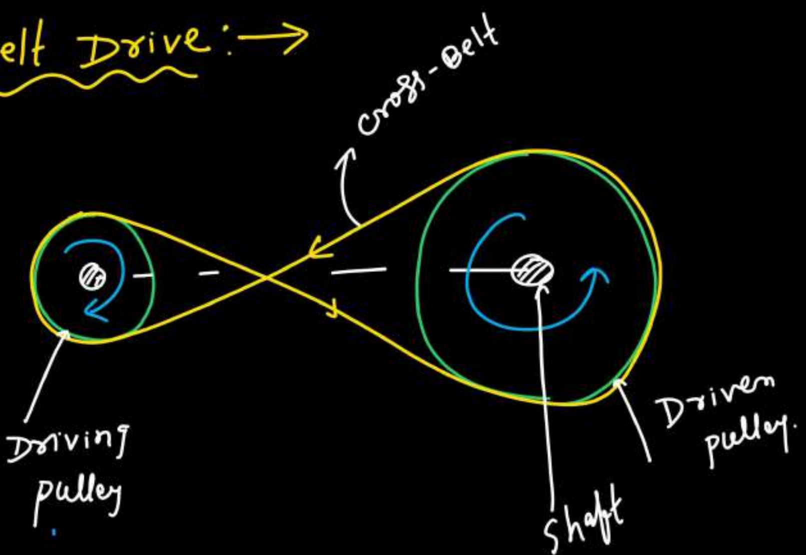
→ Initial tension over belt is provided by taking smaller length of belt than required length of Belt.

→ value of initial tension (T_0) is given by

$$T_0 = \frac{T_1 + T_2}{2} = \frac{T_1 + T_2 + 2T_c}{2}$$

** → Initial tension increases the power transmission capacity belt

II Cross-Belt Drive :→



→ In case of Cross-Belt drive both the pulleys rotates in opposite direction to each other.

→ power transmission capacity of cross-belt drive is more than that of open belt drive.

Difference between open and cross-Belt drive

open Belt drive	Cross-Belt drive
(i) It is use to transmit power between two parallel shaft which rotates in same direction	(i) It is use to transmit power between two parallel shaft. which rotates in opposite direction.
(ii) Idler pulley required to avoid slipping of Belt over pulley.	(ii) No Idler pulley required.
** (iii) power transmission capacity of open belt drive is less than power transmission capacity of cross-Belt drive	(iii) power transmission capacity of cross-Belt drive is more than the power transmission capacity of open Belt drive.

(iv) less Costlier than Cross-Belt drive.

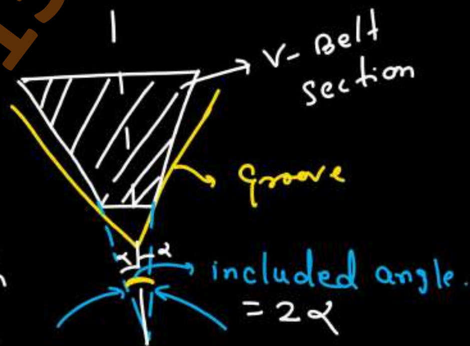
(iv) More Costlier than open Belt drive.

(v) Service life is more than Cross Belt drive

(v) Service life is less than open belt drive.

V-Belt Drive :→

→ V-Belt is use to power transmission for small distance



→ 2α is the angle which called included angle of V-Belt

$$35^\circ < 2\alpha < 45^\circ$$

** → power transmission capacity of V-Belt drive is more than flat Belt drive.

→ Relation between tension in tight side and slack side of V-Belt drive is given by:—

$$\frac{T_1}{T_2} = e^{\frac{\mu\theta}{\sin\alpha}}$$

where

T_1 = Tension in tight side of belt.

T_2 = " " slack " "

θ = angle of wrap or contact

μ = co-efficient of friction (< 1)

α = Semi included angle.

EME

Gear :→

→ Gear is a positive drive power transmission system, which is use to power transfer from one shaft to another shaft.

→ At the point of contact (P) tangential velocity of both gears will same.

i.e $\boxed{V = R_1\omega_1 = R_2\omega_2}$

where R_1 = Radius of Gear 1 = Driven Gear.

ω_1 = angular speed Gear 1.

R_2 = Radius of Gear 2 = Driver/Driving Gear / Pinion.

ω_2 = angular speed of Gear 2 =

$\because R_1\omega_1 = R_2\omega_2$

$$\Rightarrow \boxed{\frac{\omega_1}{\omega_2} = \frac{R_2}{R_1}}$$

velocity ratio:→ The ratio of speed of driven gear to the speed of driving gear is called velocity ratio.

$$\therefore \boxed{V \cdot R = \frac{\text{speed of driven gear}}{\text{speed of driving gear}} = \frac{\omega_1}{\omega_2}}$$

speed ratio:→

→ it is the ratio of speed of driving gear to the speed of driven gear.

$$\because \boxed{\text{speed ratio (S.R)} = \frac{\text{speed of driver gear / Pinion}}{\text{speed of driven gear}} = \frac{\omega_2}{\omega_1}}$$

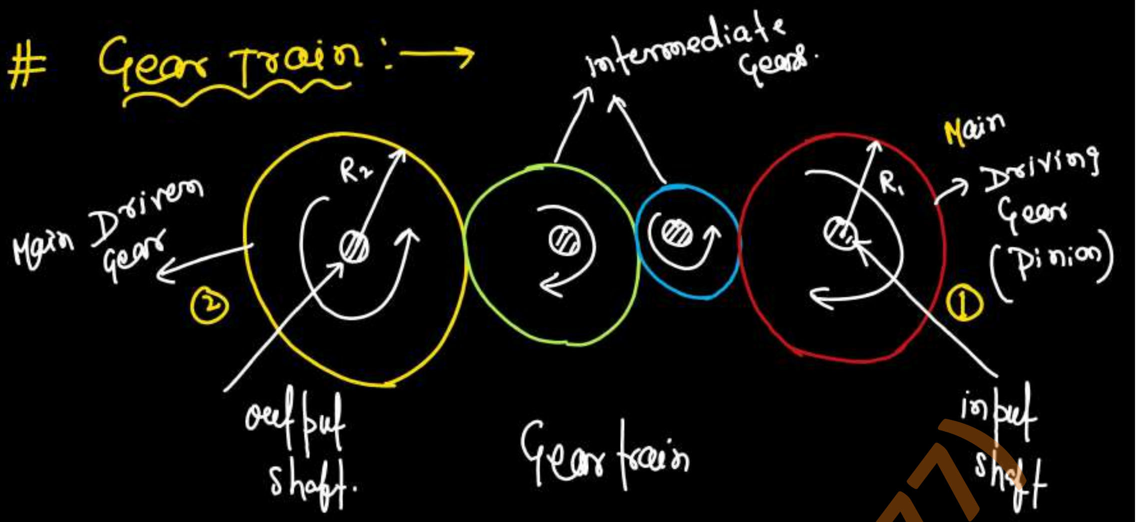
Gear ratio (G):→ it is the ratio of total number of teeth on bigger gear to the total number of teeth in smaller gear (Pinion).

$$\therefore \boxed{\text{Gear ratio (G)} = \frac{T}{t}}$$

where T = total number of teeth on bigger gear.

t = total number of teeth on smaller gear (Pinion)

Gear Train :→



→ Gear trains is the combination of multiple gears placed on different shaft which is use to power transfer between two shaft placed at larger distance with the help of intermediate Gears.

Types of Gear train :→

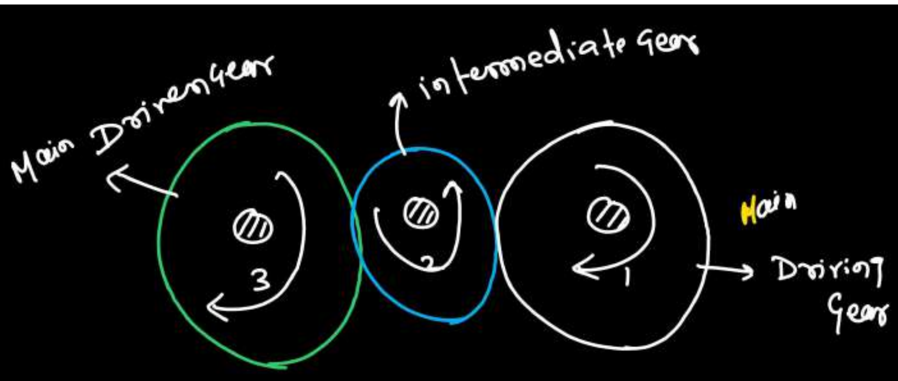
There are two types of Gear train.

(i) Simple Gear train :–

(II) Compound Gear train :

I Simple Gear train :→

→ If in a gear train system, there is only one Gear on each shaft, then, this type of Gear train is called Simple Gear train.



Simple Gear train

(ii) Compound Gear train :→

→ If in a gear train system, at least one Shaft has more than one gear, then this gear train system is called compound Gear train.

Compound Gear. train.

Note :→

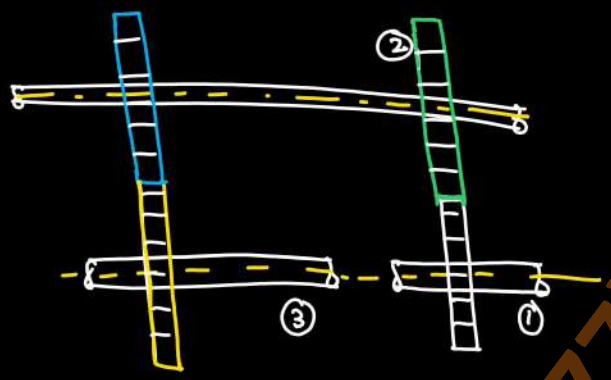
(a) Where there are odd number of intermediate Gear between main driven and main driving Gear. then both gears rotates in same direction.

(b) When there are even number of intermediate Gears between main driven and main driving gears, then both gear will rotate in opposite direction.

Reverted Gear Train System :→

Shaft ① and Shaft ③ Co-axial Shaft.

∴



Reverted gear train system.

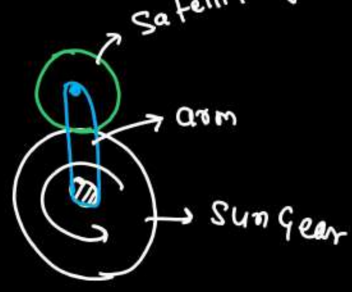
→ Reverted Gear train system is a compound Gear train System.

→ Reverted gear train system is use to power transfer between two co-axially shaft.

→ This gear system is use in clocks, mills machine etc.

epicyclic Gear Train System :→

→ Epicyclic Gear train system has at least one Gear called satellite Gear which revolve around sun gear and rotates at its own axis as well by the arm.



epicyclic gear train

→ Epicyclic Gear train is used where compact space and large power transmission is required.

Note:- Train value :→
It is the reciprocal of speed ratio of Gear train.

$$\therefore \text{Train value} = \frac{1}{S.R}$$

CLUTCH :→

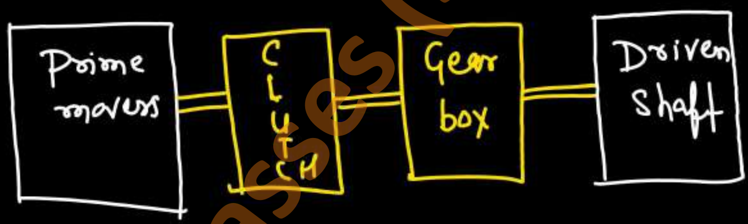
→ Clutch is a mechanical device which is use to engage and disengage, the driving shaft of engine to the driven shaft at the will of the operator.

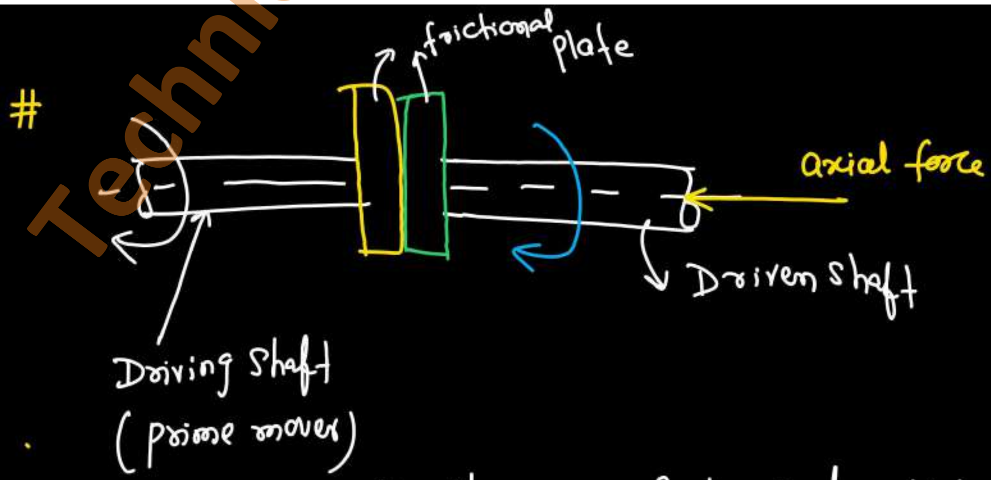
Classification of clutch :→

- Clutch
  - Jaw Clutches (Application, M/c Tools, Rolling mills)
  - Friction Clutch. (Application :– Automobile)
    - Axial friction clutch
    - Radial friction clutch.

- Axial friction Clutch
  - Plate clutch
    - Single Plate clutch (S.P.C)
    - Multi plate clutch (M.P.C)
  - Cone clutch
- Radial clutch.
  - centrifugal clutch

** → Clutch is placed in engine between prime movers and Gearbox.





→ In plate clutch, there are frictional disc plates on both driving shaft and driven shaft. when these plates comes into by an axial force on driven shaft, engagement of Clutch takes place and power is starts transfering from driving shaft to driven shaft when axial force is removed, then disengagement of plate clutch takes and only driving shaft rotates.

→ Single plate clutch is used when enough space in large size Engine is available like in BUS, Truck, Cars etc.

→ Single plate clutch (S.P.C) is also called dry Clutch. Because there is no need of lubricant between plates.

→ M.P.C is used where small space is available in small engines, like, in motorcycle, Bike etc.

Note: → if there are 'n_1' number of plates on driving shaft and 'n_2' number of plates on driven shaft, then, number of effective surfaces of plates is given by:—

$$n_1 + n_2 - 1$$

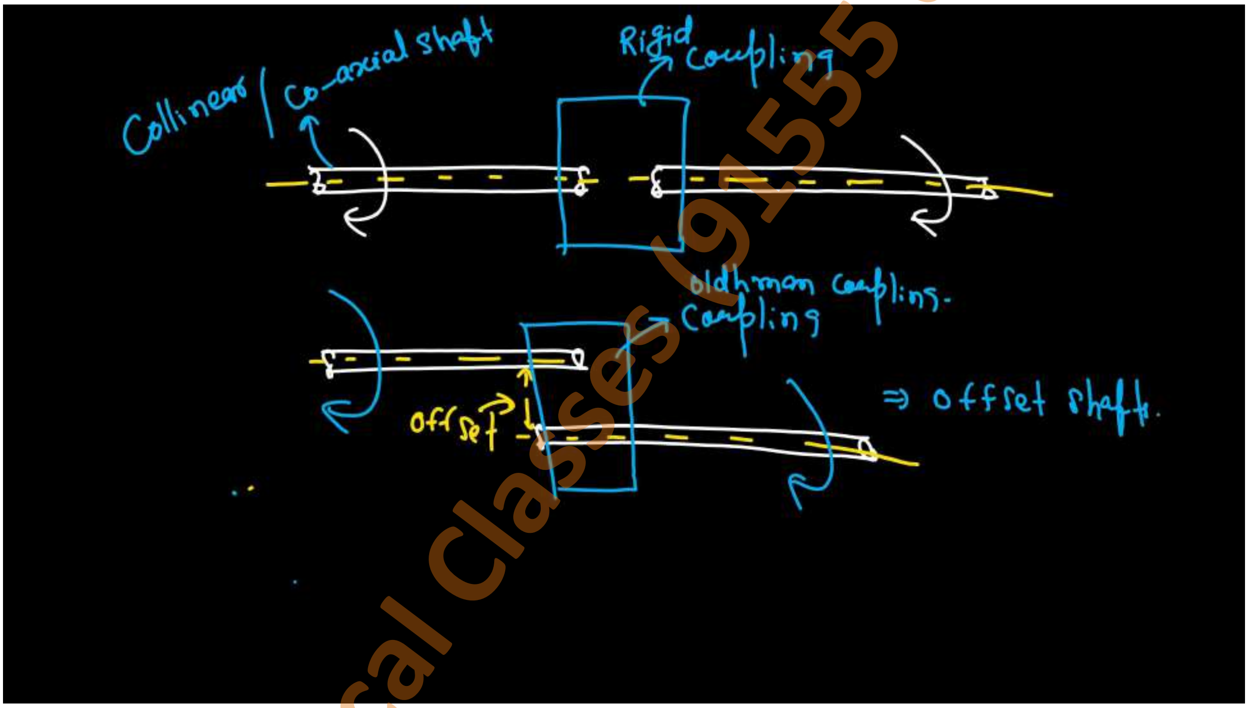
exam: 6 → Plates on driving shaft
5 — " " driven "

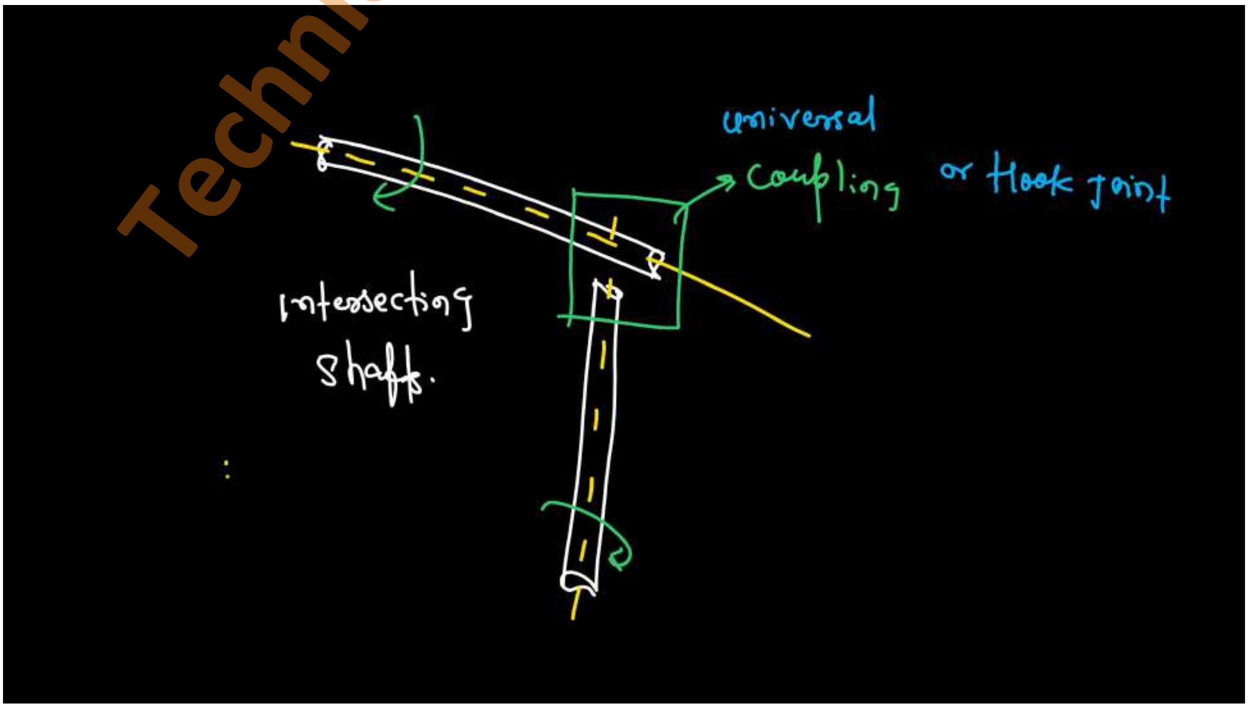
effective surface = 6+5−1 = 10 Ans.

COUPLING :→

→ Coupling is use to connect two rotating shaft to continous transfer of power between them.

→ Through coupling power transfer take place between two Collinear shaft, offset shaft, two intersecting shaft





Classification of Coupling :→

- Coupling
  - Rigid Coupling
    - Muff Coupling.
    - Flange Coupling
  - Flexible Coupling.
    - Bush Pin Coupling.
    - Oldham Coupling.
    - Universal Coupling or Hook Joint

→ Rigid Coupling is use to Connect two Collinear or Co-axial shaft.

→ flexible Coupling is use to connect two non Collinear or non Co-axial shaft.

BRAKES :→

→ Brakes are Kinetic energy / power absorbing device, which is use to stope the vehicles by absorbing their Kinetic energy.

→ Classification of Brakes :-

Brakes

- Mechanical Power
  - Radial Brakes
    - Block/Shoe brake
    - Band Brake
    - Block and band Brake
  - Axial Brakes (Disc Brake)
- (air) Pneumatic Brakes
- Hydraulic Brakes (liquid)
- Electrical Brakes

High powerful brakes. (Pneumatic, Hydraulic, Electrical)

Radial Brakes :→

→ when effort applied in radial direction of rotating shaft to stop it. is called Brakes.

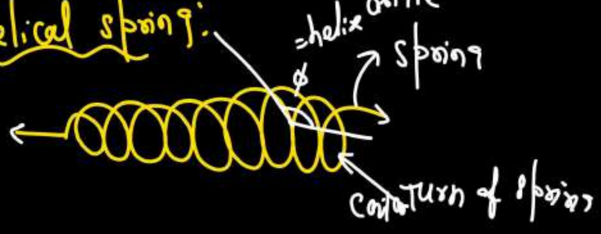
example:- Band Brake, Shoe Brakes etc.

Axial Brake :- when effort is applied along the axis of shaft then it is called axial brakes, example:- disc-Brake.

SPRING :→

→ spring is defined as the elastic element which elongates or compressed by the application external load on.

→ close coil helical spring:

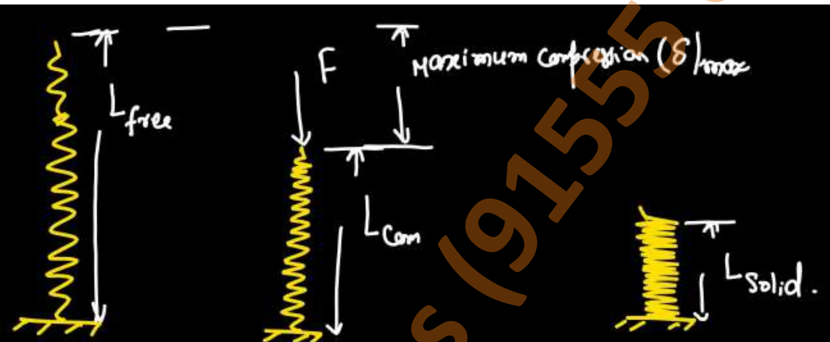


→ when all the Coils/turns of a spring lie on a same plane and helix angle is less than 7°, then type of spring is called **Closed Coil helical spring**.

→ **open coil helical spring**

→ If all Coils or turns of a spring are not on a same plane and helix angle is more than 7°, then this type of spring is called **open coil helical spring**.

#



free length (L_{free}) :– Natural length of spring is called free length

Compressed length :→ length of spring under maximum compressing load is called compressed load.

$$L_{comp} = L_{free} - (\delta)_{max}$$

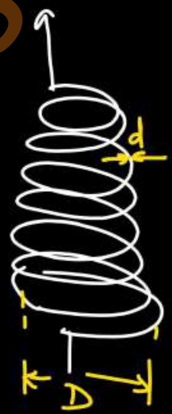
Solid length :→ Solid length of spring is the length when there is no gap between coils.

$$(\delta)_{max} = 1.5\,(L_{solid})$$

$$L_{comp} = L_{solid} + nd$$

where n = number of coil
d = diameter of wire of spring.

→ spring index $(C) = \dfrac{D}{d}$



where
D = mean diameter of coil of spring.
d = diameter of wire of spring.

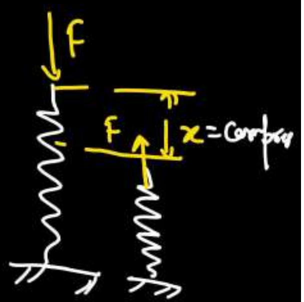
$$4 \leq C \leq 12$$

Spring constant (K) :→

$$F = -Kx$$

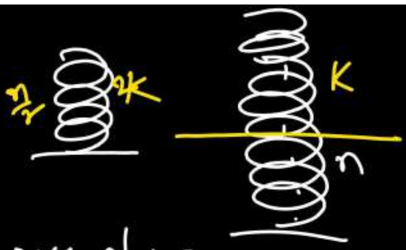
F → force in spring.

x → deflection: elongation, compression



K = spring constant
= unit → $\dfrac{\text{Newton}}{\text{meter}}\left(\dfrac{N}{m}\right)$

$$\because \quad K = \frac{G d^4}{8 D^3 n}$$



d = diameter of wire spring

D = mean diameter of coil of spring.

n = numbers of turn/coil of the spring