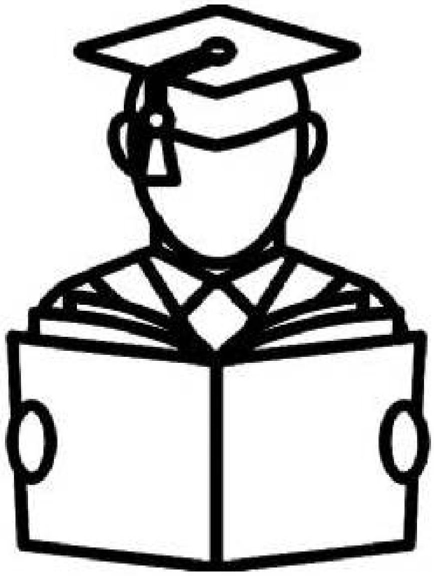
चौधरी PHOTOSTAT

"I don't love studying. I hate studying. I like learning. Learning is beautiful."



"An investment in knowledge pays the best interest."

Hi, My Name is

Mechinical Engineering for GATE/IES

(*MADE EASY*)

22nd Oct

Theory of Machines

classmate
Date
Page

Mechanics
↓
Study of motion.
According to the way of study

Kinematics
Study of motion without considering the forces
→ 1-D projectile motion

Dynamics
Study of motion considering i.e force
↓
laws of motion

Inertia → It maintain its shape
↓
Physical property

Kinematic	**Dynamic**
No mass term will be there ↓ m, m/s, m/s², m/s³	Mass term appears in the unit. ↓ Newton's 2nd lay

1st law $F_{ext} = 0$

$F = ma$

$\vec{F} = \frac{d}{dt}(m\vec{v})$

2nd law

$\vec{F}_{ext} \neq 0$

$\Rightarrow F_{ext} = \frac{d}{dt}(m\vec{v})$

$\vec{F} = m\frac{dv}{dt} + v\frac{dm}{dt}$

time is plot on x axis

Theory of machine

↓ Kinematics of machine

↓ Dynamics of machine

<u>Syllabus</u> :– • Simple mechanism
↳ understanding

• Velocity analysis (graphical)
• Instantaneous centre approach.
| Relative Velocity approach

• Acceleration (graphical)
• Gears & gears train (Analytical)
• Governors (Analytical)
• Flywheel (Analytical)
• Balancing (graph + analytical)
• Parts of Cams & Followers (Analytical + Graphical)
• Vibrations
• Automatic Control

<u>Simple mechanisms</u> :–

<u>Link or element</u> :– Every part of machine which moves relative to some other parts is known as link or element.

<u>Note</u> :– It is not necessary for the link to be perfectly rigid but its necessary for link to be resisting so that it can transfer motion

6 Aug, 2011

Basic Concepts

Thermodynamics – It is the science of energy transfer and its effects on properties of system.

The main aim of thermodynamic study is to convert disorganist form of energy (heat) into organist form of energy (work) in an efficiency manner.

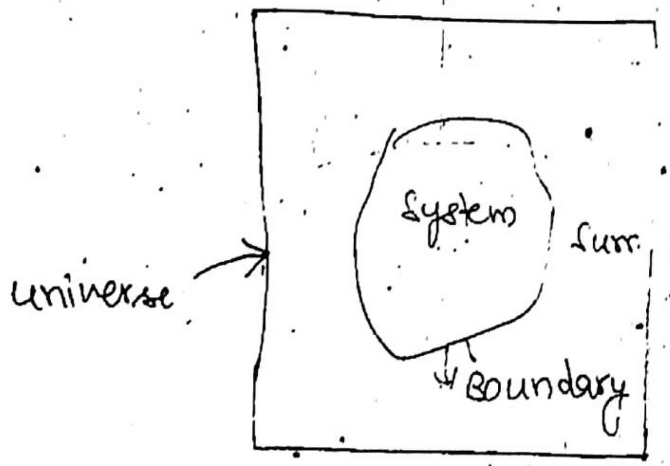
System – It is a region in space upon which study is focused.

Surroundings – Anything external to the system is known as surroundings.

Boundary – The separation b/w system & surr is known as boundary.

Note: Boundary can be rigid or flexible and it can be real or imagenary.

universe = system + surroundings



Types of system –

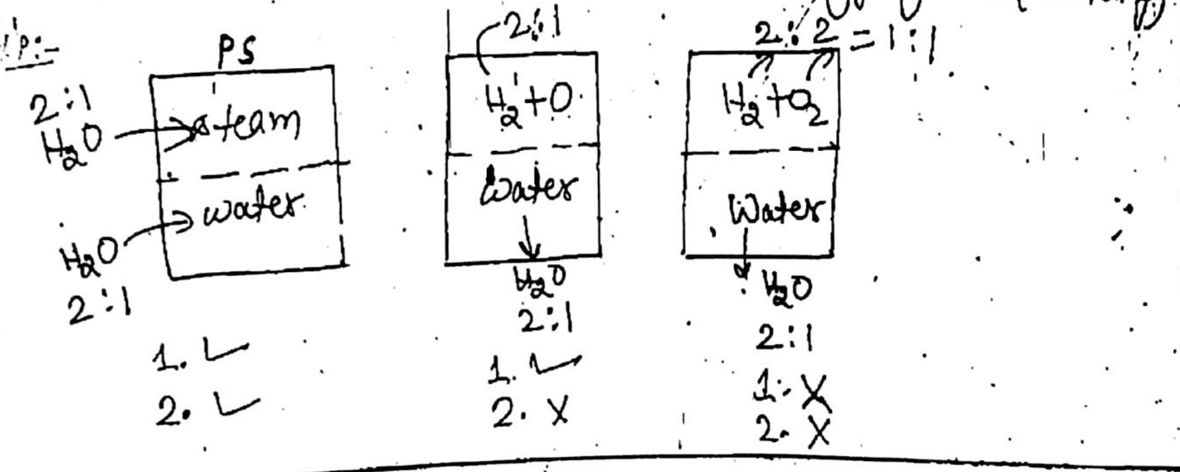
Types of system	Energy Transfer	Mass transfer	Example
closed	✓	✗	piston-cyli arrangement w/o valves
open	✓	✓	pump, Compresser Turbine
Isolated	✗	✗	Universe, Hot coffee in a well insulated flask.

Microscopic & macroscopic approach of thermodynamics -

- In microscopic approach the behaviour of individual molecules is taken into consideration and this approach is also known as statistical thermodynamics. and this approach is used at low densities (at higher altitudes).
- In macroscopic approach the behaviour of individual molecule is not taken into consideration but avg. behaviour of molec. is taken into consideration. and it is also known as classical thermodynamics.

Pure substances - A substance is said to be pure substance if it is homogeneous in chemical composition & homogeneous in chemical aggregation (bonding)

Exp:-



T.O.E.F OR (TOF)

M.P.S.T → Suitable for Brittle materials.
Suitable for ductile materials under uniaxial state of stress & bi-axial s. of stress when $\sigma_{1,2}$ are in same nature

M.S.S.T → Suitable for ductile material. it gives oversafe design (i.e. safe & uneconomic)

M.D.E.T → Suitable for ductile material.
→ Best T.O.F for ductile materials because it gives safe & economic design.

$(dim^{ns})_{MDET} < (dim^{ns})_{MSST}$ $\left[\because (S_{YS})_{MDET} > (S_{YS})_{MSST}\right]$

$S_{YS} = \frac{S_{Yt}}{\sqrt{3}}$ | $S_{YS} = \frac{S_{Yt}}{2} = 0.5\, S_{Yt}$

$S_{YS} = 0.577\, S_{Yt}$

for safe design,

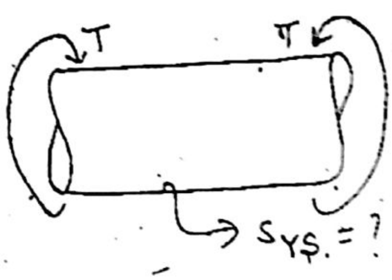
Max Stress ind. ≤ per. stress

$$\frac{\text{Load}}{\text{Dim}^{ns}} \leq \frac{\text{failure stress}}{N}$$

$$\text{failure stress} \propto \frac{1}{\text{dim}^{ns}}$$

failure stress ↑ ⇒ dimns ↓ ⇒ safety ↓ ⇒ cost ↓

failure stress ↓ ⇒ dimns ↑ ⇒ safety ↑ ⇒ cost ↑



$$\sigma_1 = \sigma_2 = \tau_{max} = \tau = \frac{16T}{\pi d^3}$$

Cond^n for failure in shear,

$$\tau_{max} \geq S_{YS}$$

$$\tau > S_{YS}$$

$$\boxed{\tau = S_{YS}} \text{ at yielding}$$

$$S_{YS} = \tau = \sigma_1 = \sigma_2$$

MDET → Ellipse eqn

$$\sigma_1^2 + \sigma_2^2 - \sigma_1 \sigma_2 = (S_{Yt})^2$$

$$\tau^2 + (-\tau)^2 - (\tau \times -\tau) = (S_{Yt})^2$$

$$3\tau^2 = (S_{Yt})^2$$

$$\tau = \frac{S_{Yt}}{\sqrt{3}}$$

$$\boxed{S_{YS} = \frac{S_{Yt}}{\sqrt{3}}}$$

M.S.S.T ⇒ Hexagon eqn

$$(\sigma_1 - \sigma_2) = \frac{S_{Yt}}{N}$$

$$\tau - (-\tau) = \frac{S_{Yt}}{N} \qquad (N = 1 \text{ for failure})$$

$$2\tau = S_{Yt}$$

$$\tau = \frac{S_{Yt}}{2}$$

$$\boxed{S_{YS} = \frac{S_{Yt}}{2}}$$

MPST ⇒ ~~Circle~~ Square eqn

$$\sigma_1 = S_{Yt}$$

$$\tau = S_{Yt}$$

$$\boxed{S_{YS} = S_{Yt}}$$

MP.St.T. ⇒ Rhombus eqn

$$\sigma_1 - \mu\sigma_2 = S_{Yt}$$

$$\tau - \mu(-\tau) = S_{Yt}$$

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Date- 10/10/11

Power Plant

- Ideal cycles have only internal reversibility.
- Reversible cycles have both internal & external reversibility.
- Higher molecular weights decreases γ value, so efficiency decreases. e.g: $\gamma_{air} = 1.4$; $\gamma_{CO_2} = 1.3$ & $\gamma_{ethane} = 1.2$
- Ideal gas can behave as real gas at very low pressure or very high temperature.
- $T\uparrow \rightarrow C_p\uparrow$, but $\gamma\downarrow$, but we assume this is const.

Cycles

- Power Cycles (+ work) (clockwise)
- Refrigeration cycles (− work) (Anti- clockwise)

Phase

Gas

e.g: Gas turbine, IC engines, hydroelectric P.P.

- Working fluid remains in the gaseous phase throughout.
- Net work output is high in comparison to vapour phase
- They work at peak load & part load plants.
- Less time reqd. to produce electricity

Vapour

e.g. Nuclear power plant etc

- Working fluid exist in the vapour phase during one part of the cycle and liquid phase during other part of cycle.
- They work at base load plants
- More time reqd to produce electricity.

Closed cycles

- Same working fluid
- Working fluid is returned to the initial state at the end of cycle and is recirculated.

Open cycle

- Working fluid is renewed at the end of each cycle, instead of being recirculated.

• No contact between working fuel & fluid so any fuel can be used. (No mixing b/w fuel & fluid)	• working fuel & fluid are in direct contact. so pure fuel is used. (mixing b/w fuel & fluid)
• work at below atm. pressure.	work at only at higher (above) atm. pressure.
• η High	• η Low.
He, Ar can be used. (γ value high)	• Air is normally used.

Internal combustion	External combustion
• Heat is supplied internally by burning the fuel within the system boundary. e.g. IC engines.	• Heat is supplied from external source i.e. fuel is burnt outside the system. e.g. steam & gas turbines.
• Limited power generating equipment.	• More power generating.
• η Low & combustion is incomplete.	• η High & combustion will be complete.
• Less preferred.	• These are generally preferred.

Difference b/w

Steam P.P.	Gas P.P.	IC engine P.P.
(62-65%) power generated in india.	(12-15%)	(1-3%)
• Rankine cycle	• Brayton/Joule cycle	• Otto or Diesel
• Vapour	• Gas	• Gas
• weight to power ratio : 55 kg/kW	• 20 kg/kW.	• 115 kg/kW
	• Preferred for aircraft due to least wt to power ratio.	
• Install period: Highest	• Medium	• Lowest
• Base Load plant	• Part & Peak load plant.	• Domestic/Instrial.
• Tmax : 620°c	• 1200°c	• 2500°c.

19/08/2011

Engg. Materials

- Material science
- Engg. Metallurgy

Material science → Study of structure & properties of Engg. materials.

- The term property denotes Quantitative index of response ~~of~~ a material to external stimulus.

Developed by 'BRAVAIS'

- Materials are classified based on structure
  - Crystalline
  - Amorphous or Non crystalline

Crystalline — 3 Dimn. long range & periodicity } ← Atoms, Molecules, ions.

All crystalline materials are classified into three varieties—

1) Atomic solids (Atoms are placed inside internal structure so called atomic)
2) Molecular solids (If molecules exist)
3) Ionic solids (If ions exist)

* Uniformity, homogeneity if exist in material so called molecular solids.

- All crystalline materials are molecular solids. (or crystalline polymers)
- All metals & alloys are atomic solids.

Crystalline materials may be further classified → 7 crystal systems

1) Cubic
2) Tetragonal system
3) Hexagonal
4) Rhombohedral

(5) Orthorhombic

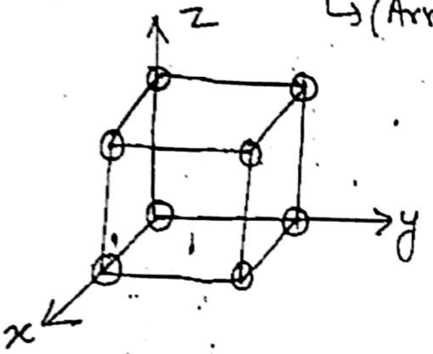
(6) Monoclinic

(7) Triclinic

- Unknown crystal structure materials can be determined by <u>X-ray diffraction</u> & <u>Electron Microscopy</u> techniques.
- All metals & alloys will crystallise in cubic & Hexagonal crystal systems.
- Remaining five will crystallise in Minerals.

Some Important Definitions —

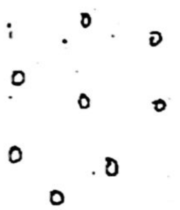
1) Unit cell → A unit cell is defined as smallest representative group of atoms which when repeated in all the crystallographic directions for infinity no. of times results in the development of <u>space lattice</u> ↳ (Arrangement)



- x, y, z are called as crystallographic directions

- Space lattice is also called as <u>Point lattice</u>.

2) Space lattice — It is a 3-D network of pt. in space. This is also called as a point lattice.



3-D Network of point

① (01.11.11)

→ LINEAR ALGEBRA ←
(MATRICES)

→ PROPERTIES OF DETERMINANTS :

- If 2 rows or column of a matrix are identical, then the determinant is zero

$$\begin{vmatrix} 0 & 2 & 0 \\ 1 & 1 & 1 \\ 2 & 3 & 2 \end{vmatrix} = 0$$

- If 2 rows or column of a matrix are interchanged, then the sign of determinant changes

$$\Delta = \begin{vmatrix} 0 & 1 & 2 \\ 1 & 2 & 3 \\ 3 & 1 & 1 \end{vmatrix} \quad \text{then} \quad -\Delta = \begin{vmatrix} 1 & 0 & 2 \\ 2 & 1 & 3 \\ 1 & 3 & 1 \end{vmatrix}$$

- If 3 rows or column of a matrix are interchanged, then the sign of determinant is unaltered.

$$\Delta = \begin{vmatrix} 0 & 1 & 2 \\ 1 & 2 & 3 \\ 3 & 1 & 1 \end{vmatrix} = \begin{vmatrix} 1 & 2 & 3 \\ 3 & 1 & 1 \\ 0 & 1 & 2 \end{vmatrix}$$

- In the determinant of a matrix if any column containing the sum or difference of 2 elements, then it can be split into the sum or difference of two determinants

$$\begin{vmatrix} a & a^2 & a^3+1 \\ b & b^2 & b^3+1 \\ c & c^2 & c^3+1 \end{vmatrix} = \begin{vmatrix} a & a^2 & a^3 \\ b & b^2 & b^3 \\ c & c^2 & c^3 \end{vmatrix} + \begin{vmatrix} a & a^2 & 1 \\ b & b^2 & 1 \\ c & c^2 & 1 \end{vmatrix}$$

***

A matrix of n^{th} order allow only $(n-1)$

- If all elements above the principal diagonal are zero, it is called a lower traingular matrix. (LOT)

- If all elements below the principal diagonal are zero, it is upper traingular matrix (UPT)

** If a matrix is either UPT or LOT then the determinant is the product of principal diagonal elements

$$A = \begin{bmatrix} 1 & 0 & 0 \\ 2 & 3 & 0 \\ 4 & 5 & 6 \end{bmatrix} \Rightarrow |A| = 6 \times 3 \times 1 = 18$$

(LOT)

1.)

$$A = \begin{bmatrix} 1 & a & a^2 \\ 1 & b & b^2 \\ 1 & c & c^2 \end{bmatrix} \quad \text{or} \quad \begin{bmatrix} 1 & 1 & 1 \\ a & b & c \\ a^2 & b^2 & c^2 \end{bmatrix}$$

$R_1 \to R_1 - R_2$, $R_2 \to R_2 - R_3$

$$|A| = \begin{vmatrix} 0 & a-b & a^2-b^2 \\ 0 & b-c & b^2-c^2 \\ 1 & c & c^2 \end{vmatrix}$$

$$|A| = (a-b)(b-c) \begin{vmatrix} 0 & 1 & a+b \\ 0 & 1 & b+c \\ 1 & c & c^2 \end{vmatrix}$$

$$|A| = (a-b)(b-c)\{1(b+c) - 1(a+b)\}$$

$$|A| = (a-b)(b-c)(c-a)$$

So $|A| = |A^T|$

2.)

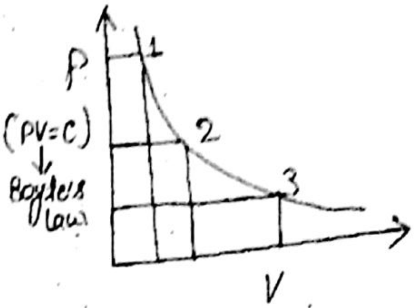
$$\Delta = \begin{vmatrix} \frac{1}{a} & a & bc \\ \frac{1}{b} & b & ca \\ \frac{1}{c} & c & ab \end{vmatrix}$$

$$\Delta = \frac{1}{abc} \begin{vmatrix} bc & a & bc \\ ca & b & ca \\ ab & c & ab \end{vmatrix} = 0$$

Some Thermodynamic Basic Concepts.

Process:— when a system undergoes a change from one condition to another condition, it is then said to have completed a process.

(1.) $P =$ Const – isobaric process
(2) $V=$ Const. – isometric or isochoric.
(3) $T =$ Const. isothermal or Hyperbolic ($PV=C$) ↓ Boyle's law
(4) $PV^{r} =$ Const – Adiabatic process.
(5) $PV^{n} =$ Const – Polytropic process



A gas can undergo different type of changes. For each change some condition will be specified. The different processes involving ~~different~~ conditions are :-

(1) Const Pressure process or isobaric.
(2) Const. volume process or isochoric or isometric.
(3) Const. Temp. process or isothermal or Hyperbolic process (for gases only)
(4) Adiabatic ~~press~~ process (No Heat supplied).
(5) Polytropic Process.

<u>Other eq. for diff. process</u> –

① when $P =$ const.

$V \propto T$ or $V = C \times T$.

$\therefore \frac{V}{T} = C \quad \therefore \boxed{\frac{V_1}{T_1} = \frac{V_2}{T_2}}$ [charles law]

② when $V =$ const.

$P \propto T$

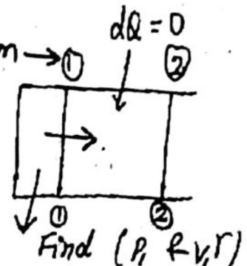
$\therefore \boxed{\frac{P_1}{T_1} = \frac{P_2}{T_2}}$ [charles law]

* Adiabatic Process –

$PV^{r} = C$

$P_1 V_1^{r} = P_2 V_2^{r}$ — ①

& $\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$ — ②



$$\left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}} = \left(\frac{T_2}{T_1}\right) \rightarrow (3)$$

$$\left(\frac{V_2}{V_1}\right)^{\gamma-1} = \frac{T_1}{T_2} \rightarrow (4)$$

* Polytropic Process –

$$PV^n = C$$

→ The value of n can be any between 0 to ∞ or 0 to −∞ (if PV, ..., TV)
it means (−∞ to +∞)

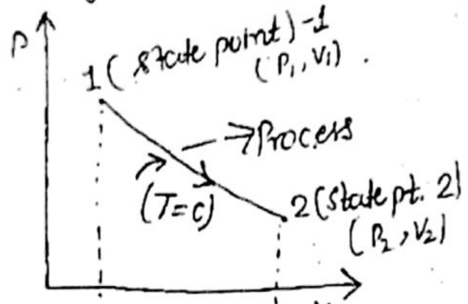
$$PV^{\frac{x}{0}} = C$$

$$P^{\frac{0}{x}} V = C^{\frac{0}{x}} = C_1$$

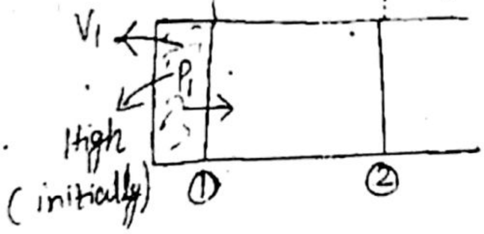
$$\boxed{V = \text{Const.}}$$

For a polytropic process the index n is a variable and can have any value b/w $\boxed{-\infty \text{ to } +\infty}$

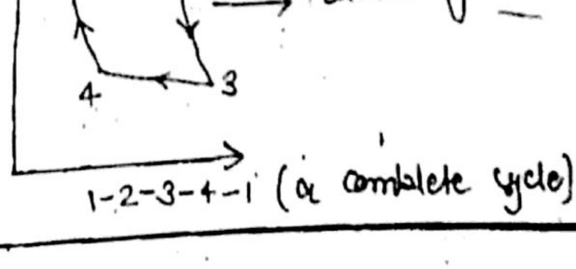
Imp * P-V Diagram:



(Indicator Diagram) OR (P-V diagram)



* Cycle : When a system, after undergoing a no. of processes (changes) such that it is able to attain its original conditions, it is then said to have completed a cycle.



1-2-3-4-1 (a complete cycle)

Heat Transfer   Date - 20/11/11

Difference b/w Thermodynamics & Heat Transfer

In thermodynamics, we deal ~~with~~ systems in equb i.e. how much heat energy is reqd. to bring a system from one equb. state to another.

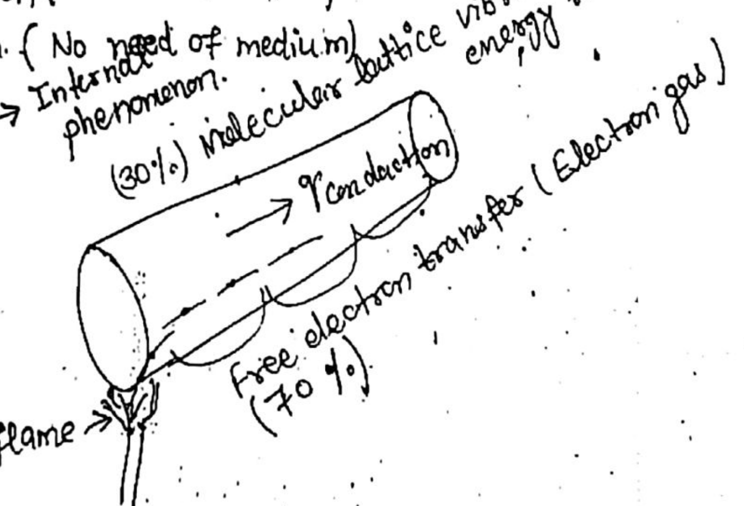
But in ~~Heat~~ transfer analysis of a problem we deal with at what rate (i.e. /sec) heat is being transfered b/w the bodies due to temp. difference satisfying clausius II law of Thermodynamics.

Modes of Heat Transfer :

1) Conduction (Requires a medium)
2) Convection (" " ")
3) Radiation. (No need of medium)

Conduction :→ Internal phenomenon.

⇓ Microscopic analysis.



Conductive materials :-

Diamond → k = 2300 w/m·k & ~~..~~ Quartz → perfectly crystalline materials so Diamond has higher k.

- Silver → k = 405 W/mK
- Copper → k = 385 W/mK
- Al → k = 200 W/m-K
- K_{glass} → 1.2 W/mK → It is a Amorphous material so has less thermal conductivity.

K_{steel} = 17 to 35 W/mK

K_{air} = 0.024 W/m-K

Conduction is a mode of heat transfer which generally occurs in solids due to temp. difference by molecular lattice vibrational energy transfer (30%) and also by free electron transfer (70%).

All electrically good conductors are also good heat conductors becoz of the presence of abundant free electrons.

e.g: All metals.

→ Insulators have very low thermal conductivity.

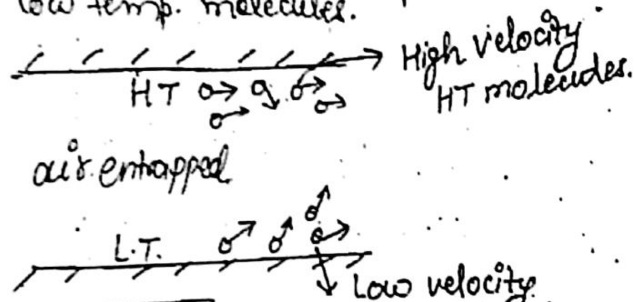
e.g: Glass wool, asbestos, refractory bricks, Rock wool, saw dust → Bad Conductors of heat.

$K_{glass\ wool} = 0.075$ W/mK

$K_{asbestos} = 0.2$ W/mK

Note: Gasses also conduct heat by molecular momentum transfer when high velocity, high temp molecules colloide with the low velocity, low temp. molecules.

$\boxed{\bar{C} \propto \sqrt{T}}$



$\boxed{K_{air} = 0.024 \text{ W/mK}}$

→ Gasses are bad Conductors of heat.

Conduction in liquid :-

$K_{water} = 0.6$ W/mK

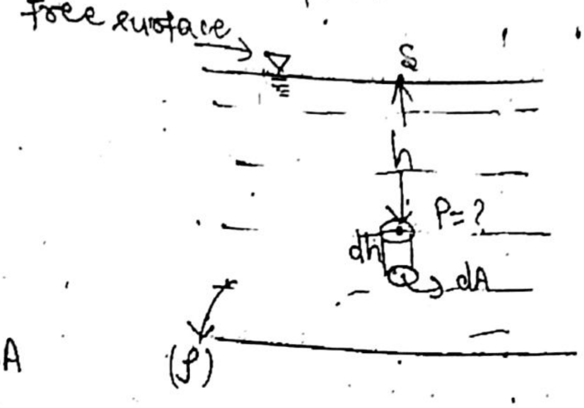
$K_{Hg} = 0.2$ W/mK (liquid metals)

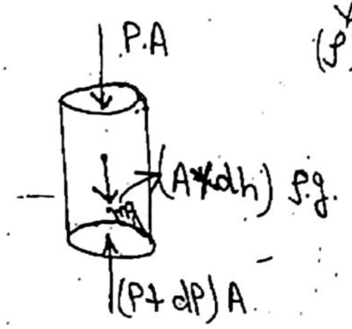
⟹ All heat transfer processes are isobaric.

[FLUID MACHINES]

BASICS OF FLUID MECHANICS

Hydrostatic Pressure — Hydrostatic pressure at a pt. becoz of some fluid"





$\rho = \frac{m}{V}$

$m = \rho \cdot Volume$

$m = \rho \cdot (A \cdot dh)$

$P.A + A dh \cdot \rho \cdot g - (P + dP)A = 0$

$A \cdot dh \cdot \rho \cdot g = dP \cdot A$

$$\boxed{\frac{dP}{dh} = \rho g} > 0$$

$$\int_0^P dP = \rho g \int_{h=0}^{h} dh$$

$$* \boxed{P = \rho g h} *$$

units: 1. $1 \frac{N}{m^2} = 1 Pa$

2. $1 \frac{kgf}{cm^2} = \frac{9.81}{10^{-4}} \frac{N}{m^2} = 9.81 \times 10^4 Pa$

3. $1 bar = 10^5 Pa$

4. 1 atm = 101325 Pa

1 atm = 101325 Pa

Water column:

$$101325 = 1000 \times 9.81 \times h \quad (\rightarrow \rho_w g h)$$

$$h = 10.3 \, m$$

$$1 \, atm = 101325 \, Pa = 10.3 \, m \, (water)$$

Hg :-

$$101325 = 13600 \times 9.81 \times h \quad (\rightarrow \rho_{Hg} \times g \times h)$$

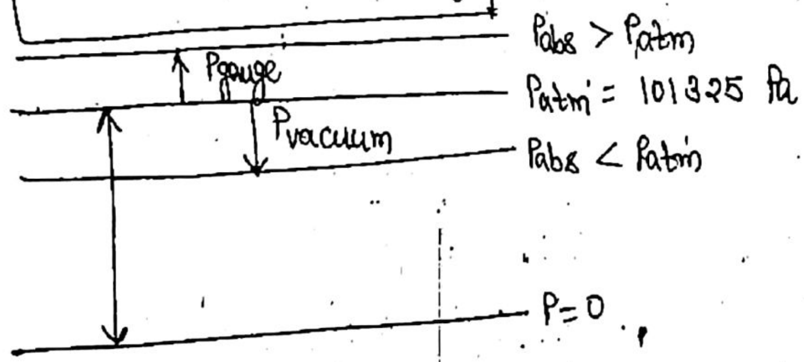
$$h = 0.760 \, m$$

$$h = 760 \, mm$$

$$1 \, atm = 101325 \, Pa = 760 \, mm(Hg)$$

mm(Hg) ⇓ Torr.

$$10.3 \, m \, (water) = 760 \, mm \, (Hg)$$



Incompressible:

ρ = const. w.r.t (Pressure)

$$\frac{\partial \rho}{\partial p} = 0$$

liq.

Water:

$$1 \, atm \Rightarrow \rho_{water} = 990 \, kg/m^3$$

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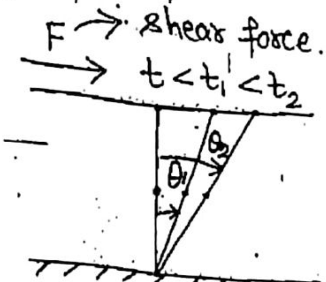
Fluid Mechanics:

A fluid is a substance which is capable of flowing or moving or deforming continuously under the action of shear force however small the force may be. After the removal of force, fluids never gain their original position.

But whereas in the case of solids ~~it is a f~~ if the force is within elastic limit, on removal of force it regains in its original position. In solids deformation doesn't vary with time. But in fluids deformation varies with time and hence in fluids rate of deformation is important than deformation.

e.g.: Liquids, gases, vapours.



Note:- For a static fluid shear force is equal = 0.

FLUID PROPERTIES

1) **Density or mass density (ρ)** :- It is the ratio of mass of fluid to its volume. Its unit is kg/m^3 and its dimensional formula is $[ML^{-3}]$

Density of water is $1000\ kg/m^3$. Density depends upon temp & pressure.

ρ → $T\uparrow \Rightarrow \rho\downarrow$
ρ → $P\uparrow \Rightarrow \rho\uparrow$

2) **Specific weight or weight density (ω)** :- It is defined as the ratio of wt. of the fluid to its volume. Its unit is N/m^3 and its dimensional formula is $[ML^{-2}T^{-2}]$.

$$\omega = \frac{\text{wt. of fluid}}{\text{vol.}} \longrightarrow \frac{N}{m^3} = \frac{MLT^{-2}}{L^3} = [ML^{-2}T^{-2}]$$

$$\omega = \frac{mg}{vol.}$$

$$\boxed{\omega = \rho g}$$

$\omega_{H_2O} = 10^3 \times 9.81$
$\omega_{H_2O} = 9810\ N/m^3$

ω → ρ → T, P
ω → g (location)

Note: Density is an absolute quantity whereas specific wt. is not an absolute quantity, becoz it varies from location to location.

3) **Specific Gravity (s)**: It is the ratio of density of fluid to the density of std. fluid. In case of liquids the std. fluid is water and incase of gases, the std fluid is either H_2 or air at a given temp. & pressure. It is dimensionless ($M^0L^0T^0$). specific gravity of water 1 and that of mercury

EM

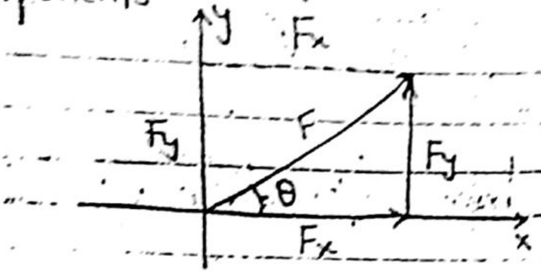
23/10/09

COMPONENTS OF A FORCE:—
- Rectangular components
- oblique components

RECTANGULAR COMPONENTS ⟶

If the angle between the components is 90°, then those components are called rectangular components.

CASE I:



If F makes angle θ with x-axis,
Then,

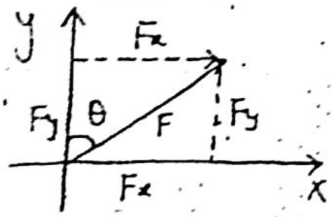
$$\cos\theta = \frac{F_x}{F} \Rightarrow \boxed{F_x = F\cos\theta}$$

$$\sin\theta = \frac{F_y}{F} \Rightarrow \boxed{F_y = F\sin\theta}$$

$$\boxed{F = \sqrt{F_x^2 + F_y^2}}$$

$$\boxed{\tan\theta = \frac{F_x}{F_y}}$$

CASE II:

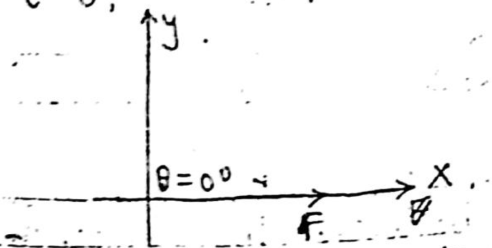


If F makes angle θ with y-axis,

$$\cos\theta = \frac{F_y}{F} \Rightarrow \boxed{F_y = F\cos\theta}$$

$$\sin\theta = \frac{F_x}{F} \Rightarrow \boxed{F_x = F\sin\theta}$$

E:- (i) If $\theta = 0°$,



$F_x = F\cos\theta = F\cos 0 = F$

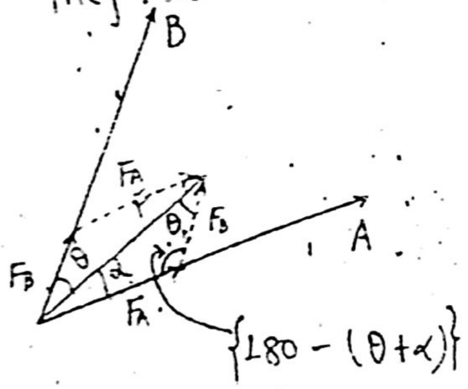
$F_y = F\sin\theta = F\sin 0 = 0$

The component of a force in its own direction is the force itself.

(ii) Any force can't have a component in it's ⊥ direction.

OBLIQUE COMPONENTS →

If the angle b/w the components is not 90°, then they are called oblique components.



By, Use Sine rule | Lame's theorem

$$\frac{F_A}{\sin\theta} = \frac{F_B}{\sin\alpha} = \frac{F}{\sin(180-[\theta+\alpha])}$$

Knowing θ, α, F we can find F_A and F_B from the above sine rule.