Candidates, Please Do Not Write Anything on the Question Paper **ROLL NO._________________**

GOVT. WOMEN ENGINEERING COLLEGE AJMER

FIRST MID TERM TEST – 2018

Class	**:**	**B.TECH. 2ND YEAR**	**Semester**	**:**	**IV**
Branch	**:**	**MECHANICAL ENGINEERING**			
Subject	**:**	**FLUID MECHANICS**			

Time : 1 HOUR **Max. Marks: 20**

Note: Attempt all the questions.

Q.1 Write a short note on following(attempt any two). [6]

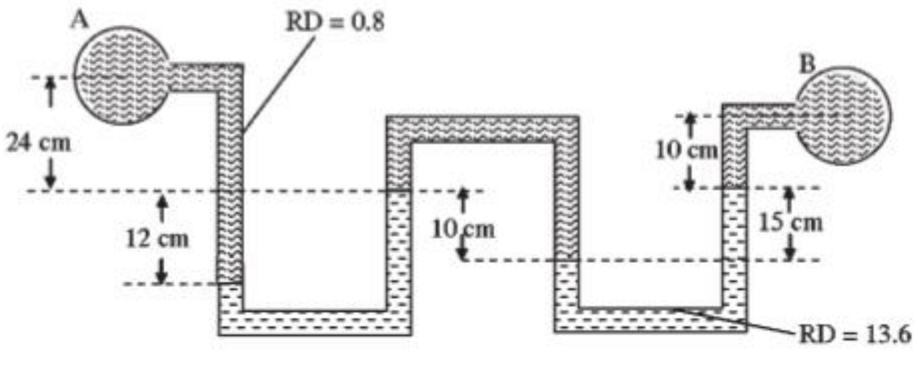
(A) Define Vapor Pressure & Cavitation.
(B) Explain Newtonian law of viscosity.
(C) Define Wetting & Non-wetting liquid.

Q.2 Discuss the conditions of stability for a floating as well as for submerged body. [6]

OR

Differentiate between Newtonian & Non-Newtonian & Explain different types of Non-Newtonian fluids with example.

Q.3 Determine the pressure difference (P_A-P_B) in Kpa, when the reading of the manometer is As Shown in the figure. [5]



OR

Derive the expression for surface tension of a soap bubble & air bubble.

Q.4 Derive the height of capillary rise if the diameter of tube is 96 cm, surface tension of capillary fluid is 7.2×10^2 N/m and capillary fluid is water.(density of fluid=1000 kg/m^3,g=10 m/s^2). [3]

OR

Derive the expression for temporal & convective acceleration for a fluid particle in (i,j,k) Coordinate system.

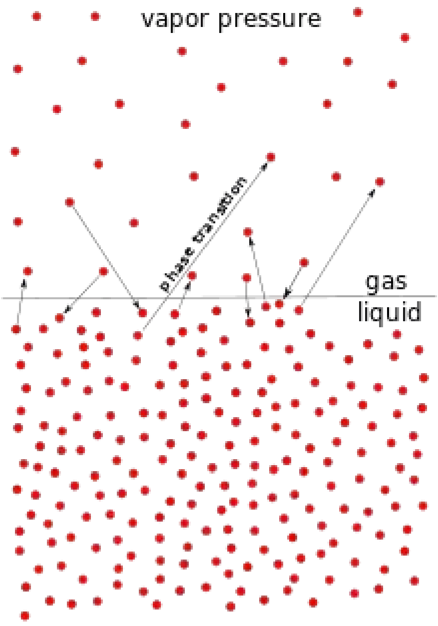
***********ALL THE BEST***********

Solution Fluid Mechanics Mid Term I

1. (a) Vapour Pressure: Vapor pressure or equilibrium vapour pressure is defined as the pressure exerted by a vapor in thermodynamic equilibrium with its condensed phases (solid or liquid) at a given temperature in a closed system. The equilibrium vapor pressure is an indication of a liquid's evaporation rate. Vapour pressure is constant at a given fluid/solid temperature.

Vapour Bubble formation & Vapour Pressure

If water & water vapour in a closed cup/beaker, etc. Observe the fluid-vapour interface. If the fluid pressure is more than vapour's, more fluid molecules would escape into vapour form. On the contrary, if the fluid pressure is less than vapour's, the vapour molecules would want to form a bubble inside the bulk fluid. This is the basic concept behind cavitation.



Cavitation: Cavitation occurs when the static pressure of the liquid falls below its vapor pressure. Boiling point of water decreases with decrease in pressure. Whenever during a flow, the pressure of water decreases and the surrounding temperature is enough to evaporate it, some of the water converts in to vapor and and a bubble is formed in the flow. This us usually happens during flows through pipes at pump impellers, suction end etc. During the flow if the pressure increases, the vapor bubble bursts and it creates small tiny cavities on the inside walls of the pipe. This is called as cavitation.

(b) Newtonian Law of Viscosity:

Newton's viscosity law's states that, the shear stress between adjacent fluid layers is proportional to the velocity gradients between the two layers.

The ratio of shear stress to shear rate is a constant, for a given temperature and pressure, and is defined as the viscosity or coefficient of viscosity.

Newton's Law of viscosity, $\tau \, \alpha \, \frac{du}{dy}$

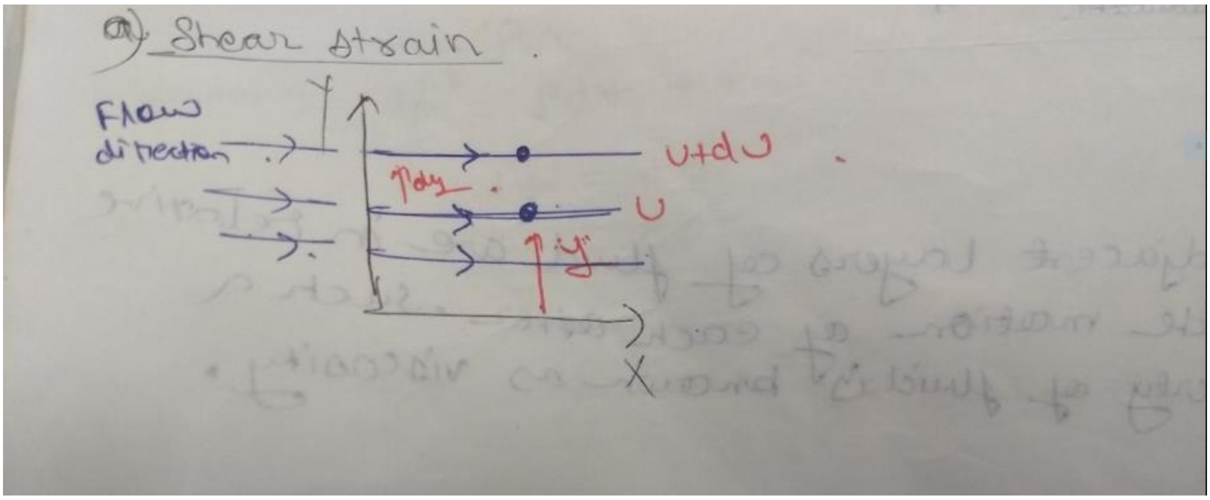
$$\tau = \mu \frac{du}{dy}$$

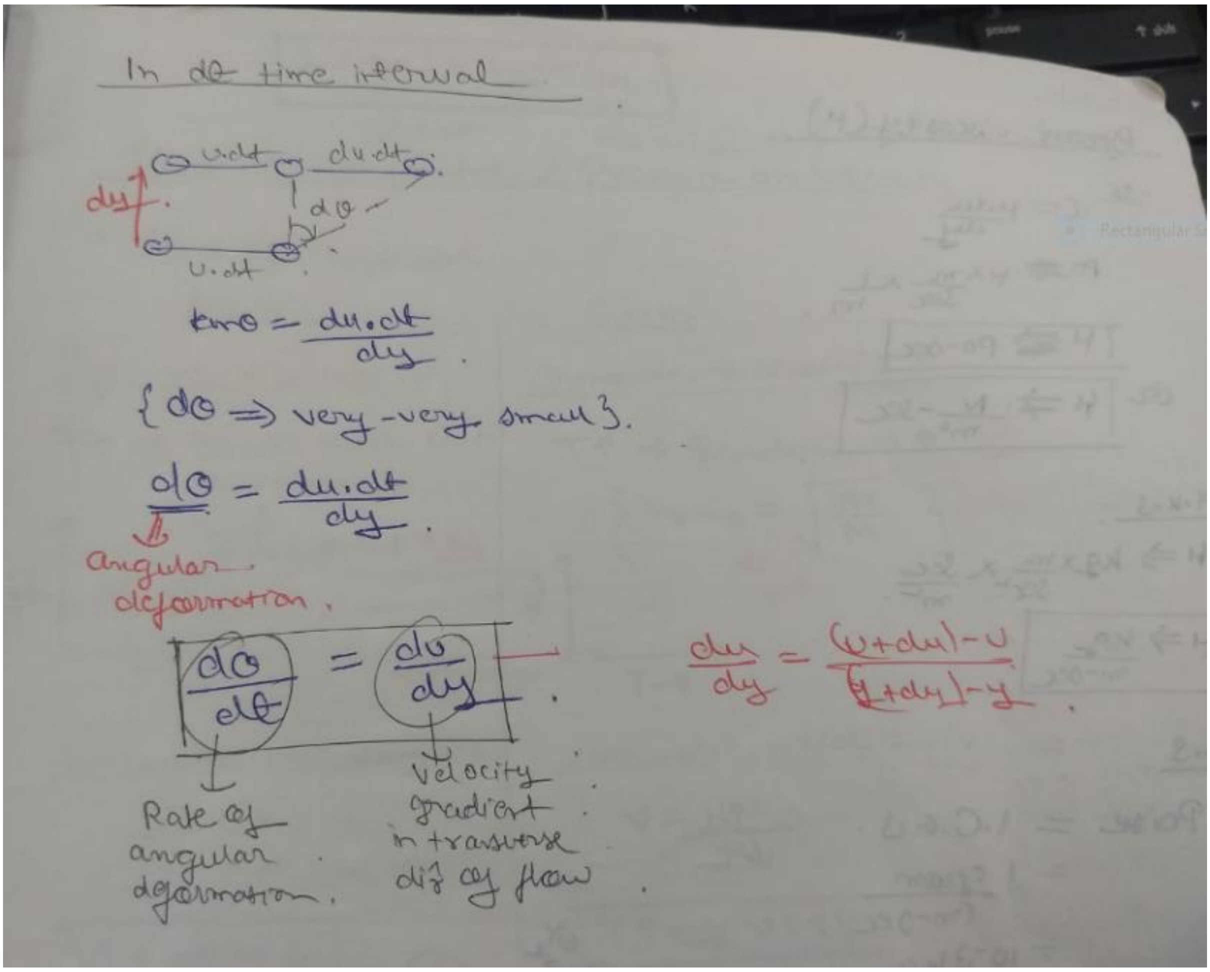
Where,.

μ = Viscosity

τ = Shear stress= F/A

$\frac{du}{dy}$ = Rate of shear deformation





In dt time interval

$$\tan\theta = \frac{du.dt}{dy}.$$

{dθ ⇒ very-very small}.

$$d\theta = \frac{du.dt}{dy}.$$

angular deformation.

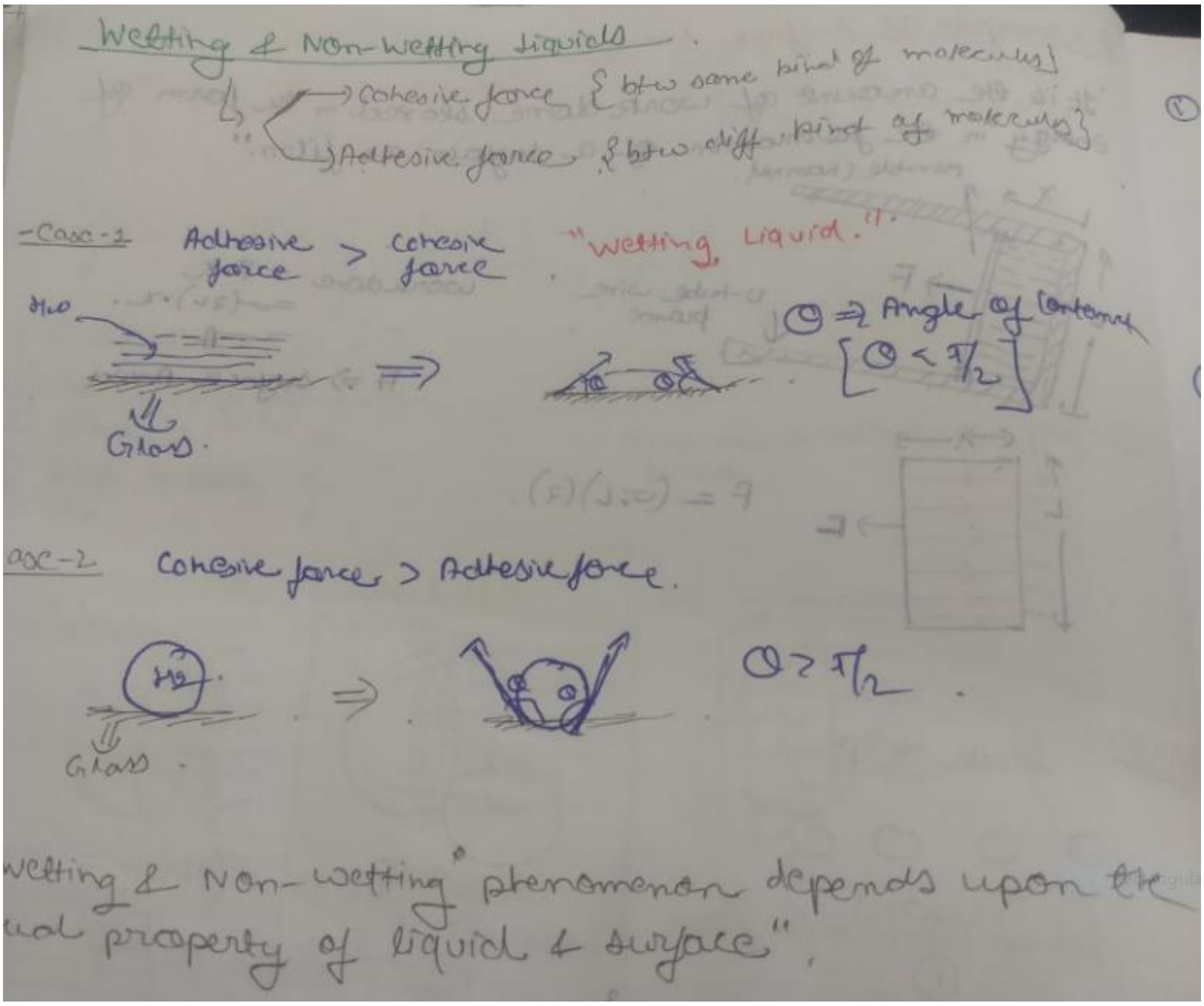
$$\boxed{\frac{d\theta}{dt} = \frac{du}{dy}}.$$

Rate of angular deformation.

Velocity gradient in transverse dir of flow.

$$\frac{du}{dy} = \frac{(u+du)-u}{(y+dy)-y}.$$

(c) Wetting & Non-Wetting Liquid :



Wetting & Non-Wetting Liquids.

↳ → Cohesive force {btw same kind of molecules}

→ Adhesive force {btw diff kind of molecules}

①

-Case-1 Adhesive force > Cohesive force. "Wetting Liquid."

H_2O ⇒

Glass.

θ ⇒ Angle of Contact

$[\theta < \pi/2]$

ase-2 Cohesive force > Adhesive force.

H_2O ⇒

Glass.

$\theta > \pi/2$.

"Wetting & Non-wetting phenomenon depends upon the

ual property of liquid & surface".

2(i). Stability of Submerged Bodies in Fluid

- The equilibrium of a body submerged in a liquid requires that the weight of the body acting through its centre of gravity should be colinear with an equal hydrostatic lift acting through the centre of buoyancy.
- In general, if the body is not homogeneous in its distribution of mass over the entire volume, the location of centre of gravity G does not coincide with the centre of volume, i.e., the centre of buoyancy B.
- Depending upon the relative locations of G and B, a floating or submerged body attains three different states of equilibrium-

Let us suppose that a body is given a small angular displacement and then released. Then it will be said to be in

- Stable Equilibrium: If the body returns to its original position by retaining the originally vertical axis as vertical.

- Unstable Equilibrium: If the body does not return to its original position but moves further from it.
- Neutral Equilibrium: If the body neither returns to its original position nor increases its displacement further, it will simply adopt its new position.

Stable Equilibrium

Consider a submerged body in equilibrium whose centre of gravity is located below the centre of buoyancy (Fig. 1a). If the body is tilted slightly in any direction, the buoyant force and the weight always produce a restoring couple trying to return the body to its original position (Fig. 1b, 1c).

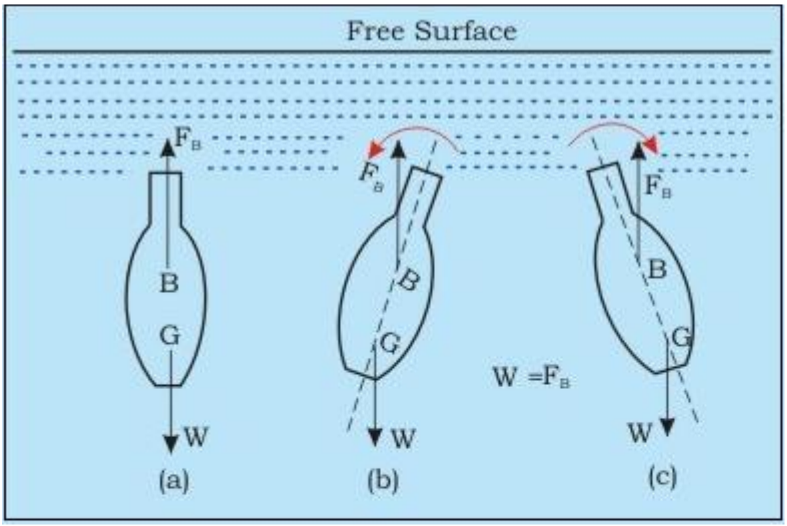


Fig 1 A Submerged body in Stable Equilibrium

Unstable Equilibrium

On the other hand, if point G is above point B (Fig. 2a), any disturbance from the equilibrium position will create a destroying couple which will turn the body away from its original position (2b, 2c).

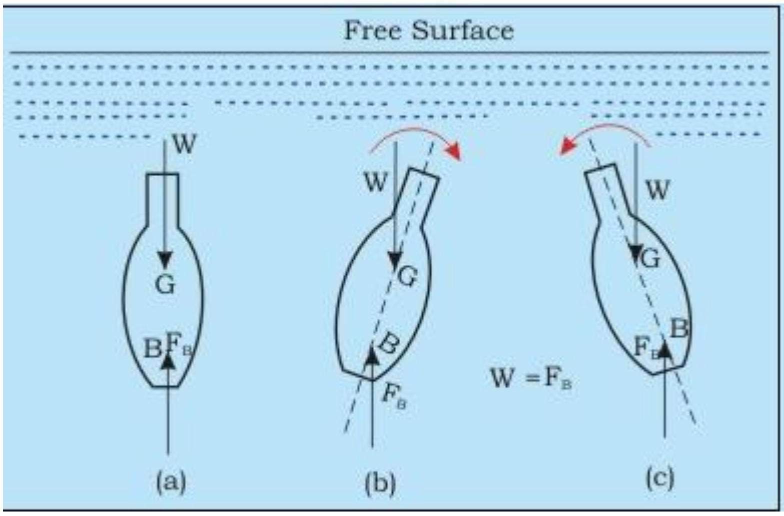


Fig 2 A Submerged body in Unstable Equilibrium

Neutral Equilibrium

When the centre of gravity G and centre of buoyancy B coincides, the body will always assume the same position in which it is placed (Fig 3) and hence it is in neutral equilibrium.

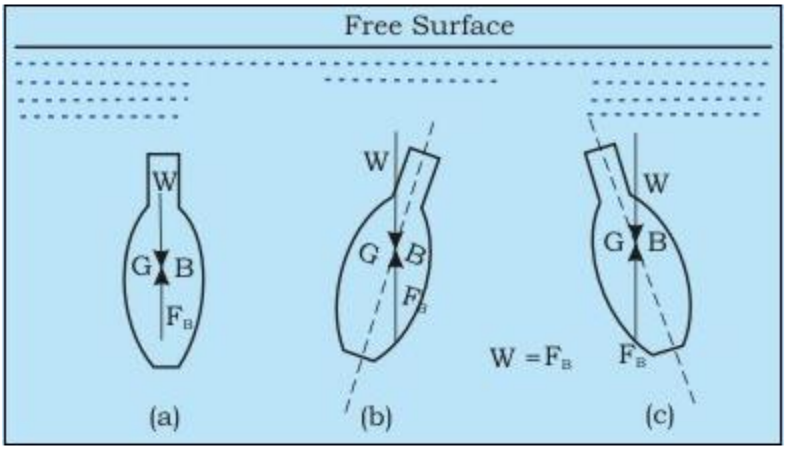


Fig 3 A Submerged body in Neutral Equilibrium

Therefore, it can be concluded that a submerged body will be in stable, unstable or neutral equilibrium if its centre of gravity is below, above or coincident with the centre of buoyancy respectively (Fig.4).

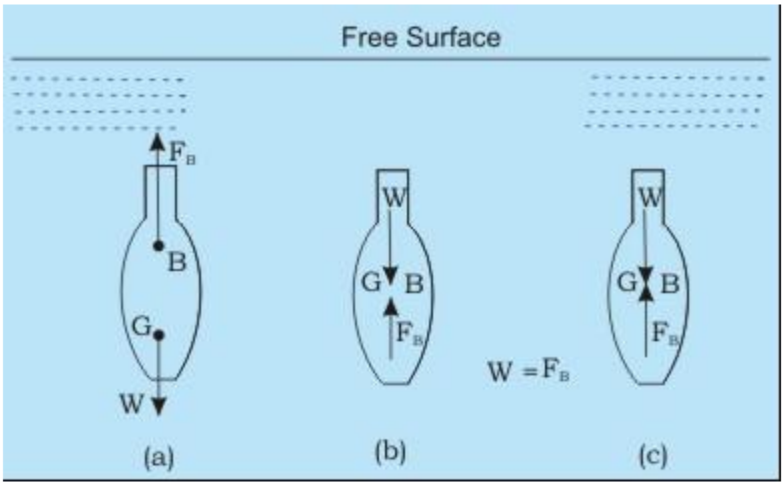


Fig 4 States of Equilibrium of a Submerged Body

(a) STABLE EQUILIBRIUM (B) UNSTABLE EQUILIBRIUM (C) NEUTRAL EQUILIBRIUM

Stability of Floating Bodies in Fluid

When the body undergoes an angular displacement about a horizontal axis, the shape of the immersed volume changes and so the centre of buoyancy moves relative to the body.

As a result of above observation stable equlibrium can be achieved, under certain condition, even when G is above B.
Figure 5 illustrates a floating body -a boat, for example, in its equilibrium position.

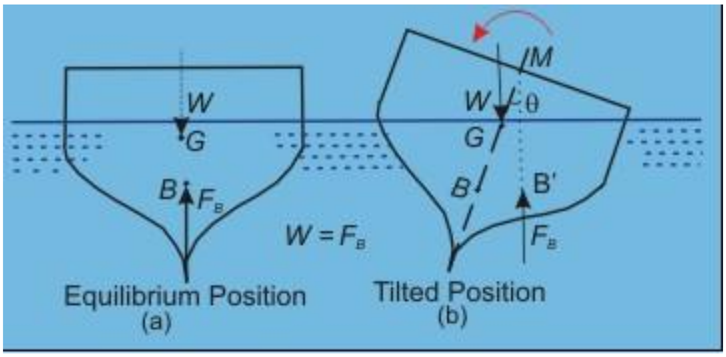


Fig 5 A Floating body in Stable equilibrium

Important points to note here are:

The force of buoyancy FB is equal to the weight of the body W

Centre of gravity G is above the centre of buoyancy in the same vertical line.

Figure 5.9b shows the situation after the body has undergone a small angular displacement q with respect to the vertical axis.

The centre of gravity G remains unchanged relative to the body (This is not always true for ships where some of the cargo may shift during an angular displacement).

During the movement, the volume immersed on the right hand side increases while that on the left hand side decreases. Therefore the centre of buoyancy moves towards the right to its new position B'.

Let the new line of action of the buoyant force (which is always vertical) through B' intersects the axis BG (the old vertical line containing the centre of gravity G and the old centre of buoyancy B) at M. For small values of q the point M is practically constant in position and is known as metacentre. For the body shown in Fig. 5.9, M is above G, and the couple acting on the body in its displaced position is a restoring couple which tends to turn the body to its original position. If M were below G, the couple would be an overturning couple and the original equilibrium would have been unstable. When M coincides with G, the body will assume its new position without any further movement and thus will be in neutral equilibrium. Therefore, for a floating body, the stability is determined not simply by the relative position of B and G, rather by the relative position of M and G. The distance of metacentre above G along the line BG is known as metacentric height GM which can be written as

$$GM=BG-GM$$

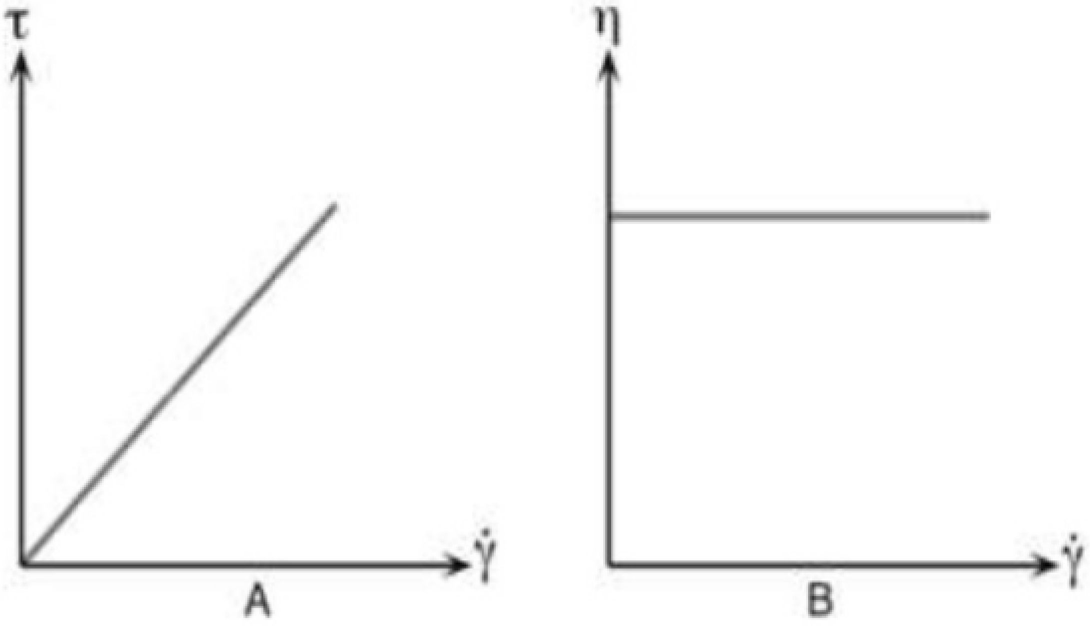
Hence the condition of stable equilibrium for a floating body can be expressed in terms of metacentric height as follows:

$GM > 0$ (M is above G)	Stable equilibrium
$GM = 0$ (M coinciding with G)	Neutral equilibrium
$GM < 0$ (M is below G)	Unstable equilibrium

The angular displacement of a boat or ship about its longitudinal axis is known as 'rolling' while that about its transverse axis is known as "pitching".

2(ii). Newtonian Fluid :

- A Newtonian fluid's viscosity remains constant, no matter the amount of shear applied for a constant temperature.These fluids have a linear relationship between viscosity and shear stress. Examples:water,Mineral oil,Gasoline,Alcohol.
- They obey the Newton's law of viscosity,which is $T=\mu\ du/dy$.
- The constant of proptionality is known as the viscosity.
- T= Shear stress exerted by the fluid("drag")
- μ=fluid viscosity-a constant of prortionality.
- Du/dy=velocity gradient perpendicular to the direction of shear.

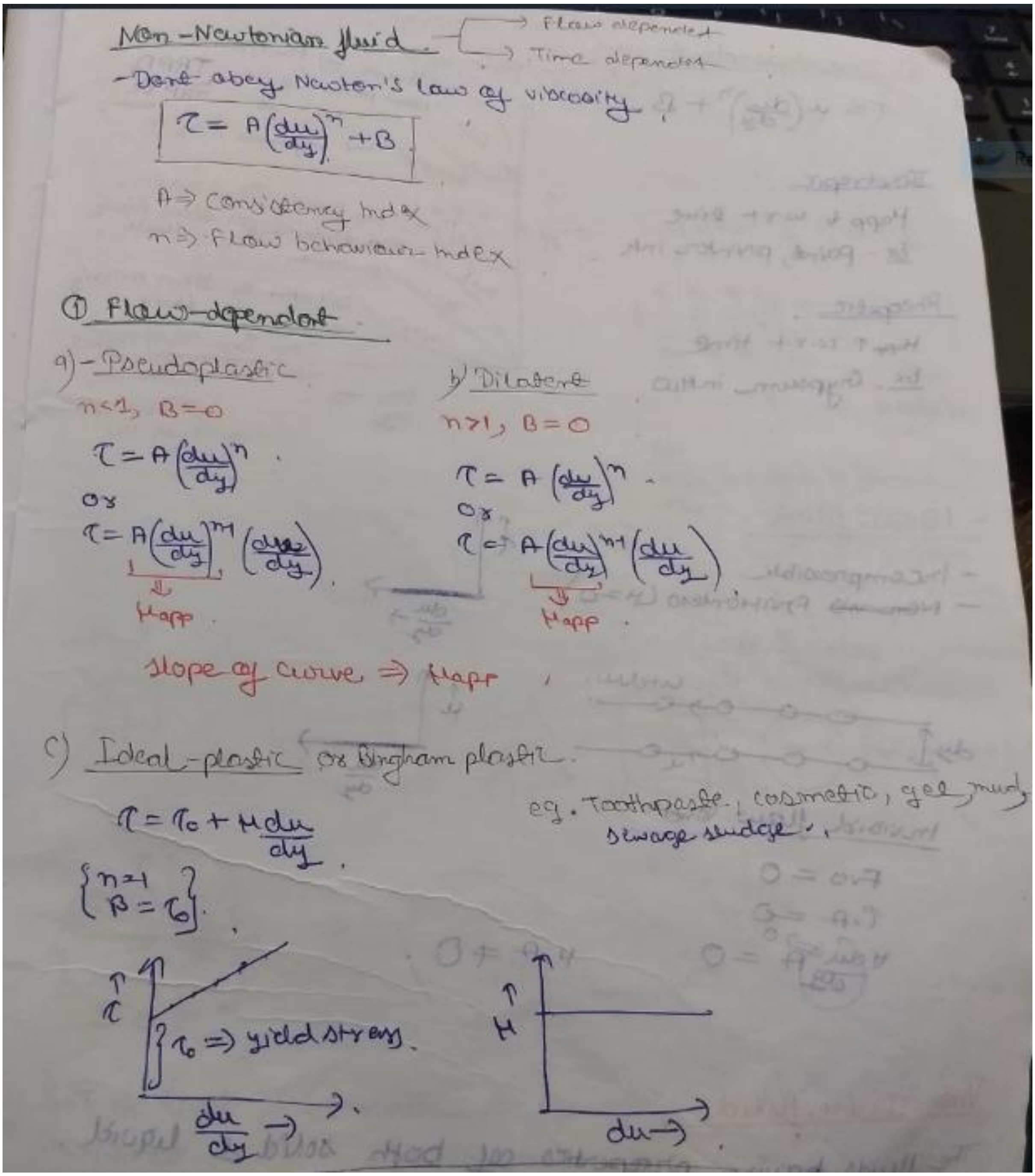


Non-Newtonian Fluid:

- Where stress is proportional to rate of strain, its higher powers and derivatives (basically everything other than Newtonian fluid).
- Non-Newtonian fluids are the opposite of Newtonian fluids.
- When shear is applied to non-Newtonian fluids, the viscosity of the fluid changes.
- A non-Newtonian fluid is broadly defined as one for which the relation T/ד is not a constant.
- It means that there is non-linear relationship between shear rate & shear stress.
- E.g. Soap solutions & cosmetics,Food such as butter,jam,cheese,soup,yogurt,natural substances such as lava,gums,etc.

The behaviour of the fluid can be described in four ways:

- Dilatant
- Pseudoplastic
- Thixotripic Fluid
- Rheopectic Fluid



Non-Newtonian fluid → Flow dependent
→ Time dependent

- Don't obey Newton's law of viscosity

$$\boxed{\tau = A\left(\frac{du}{dy}\right)^n + B}$$

A ⇒ Consistency index

n ⇒ Flow behaviour index

① Flow-dependent

a) - Pseudoplastic

$n<1,\ B=0$

$$\tau = A\left(\frac{du}{dy}\right)^n$$

or

$$\tau = \underbrace{A\left(\frac{du}{dy}\right)^{n-1}}_{\mu_{app}}\left(\frac{du}{dy}\right)$$

b) Dilatent

$n>1,\ B=0$

$$\tau = A\left(\frac{du}{dy}\right)^n$$

or

$$\tau = \underbrace{A\left(\frac{du}{dy}\right)^{n-1}}_{\mu_{app}}\left(\frac{du}{dy}\right)$$

slope of curve ⇒ μ_{app}

c) Ideal-plastic or Bingham plastic

$$\tau = \tau_0 + \mu\frac{du}{dy}$$

$\left\{\begin{matrix} n=1 \\ B=\tau_0 \end{matrix}\right\}$

eg. Toothpaste, cosmetic, gel, mud, sewage sludge

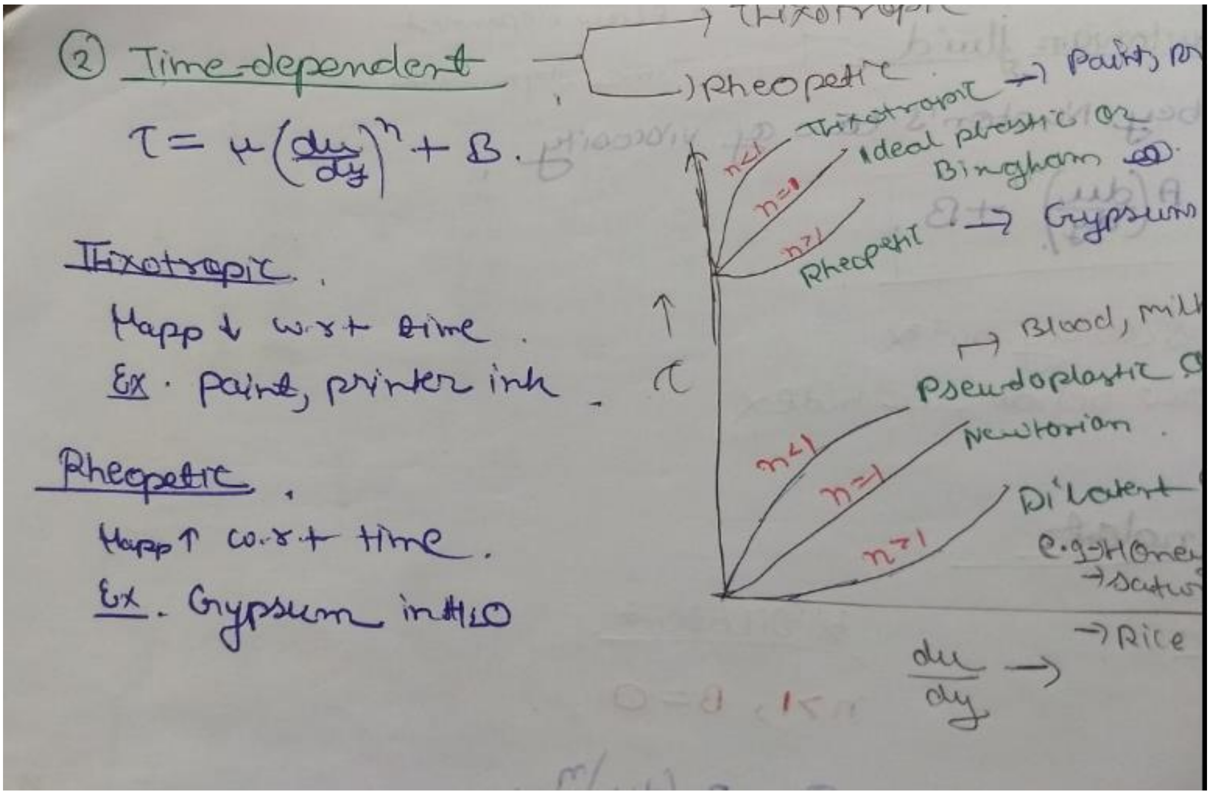
Flow Dependent

DILATANT

- Viscosity of the fluid increases when shear is applied.
- Examples : Quicksand,Corn Flour,Starch in Water,Potassium Silicate in water.
- Increasing Viscosity with an increase in shear rate characterizes the dilatant fluid.
- Although rarer than pseudo plasticity,dilatancy is frequently observed in fluids containing high levels of deflocculated solids,such as clay slurries,candy compunds and sand/water mixtures.
- Dilatancy is also referred to as shear thickening flow behaviour.

PSEUDOPLASTIC

- Pseudoplastic is opposite of dilatant i.e.the more shear applied,the less viscous it becomes.
- Examples:Ketchup,Polymer Solutions,Greases,Starch suspensions,Biological fluids,detergent slurries etc.
- This type of fluid will display a decreasing viscosity with an increasing shear rate.
- Probably the most common of the non-Newtonian fluids,pseudo-plastics include paints,emulsions,and dispersions of many types.
- This type of flow behaviour is sometimes called shear-thinning.



② Time-dependent

$\tau = \mu \left(\frac{du}{dy}\right)^n + B.$

Thixotropic.

$\mu_{app} \downarrow$ w.r.t time.

Ex. paint, printer ink.

Rheopetic.

$\mu_{app} \uparrow$ w.r.t time.

Ex. Gypsum in H_2O

Time Dependent:

Thixotropic Fluid:

- Fluids with thixotropic properties decrease in viscosity when shear is applied.
- Examples:Inks,Paints,Cosmetics,Asphalt,Glue,Drilling muds.
- These fluids exhibit a reversible decrease in shear stress with time at a constant shear rate.

Rheopectic Fluid:

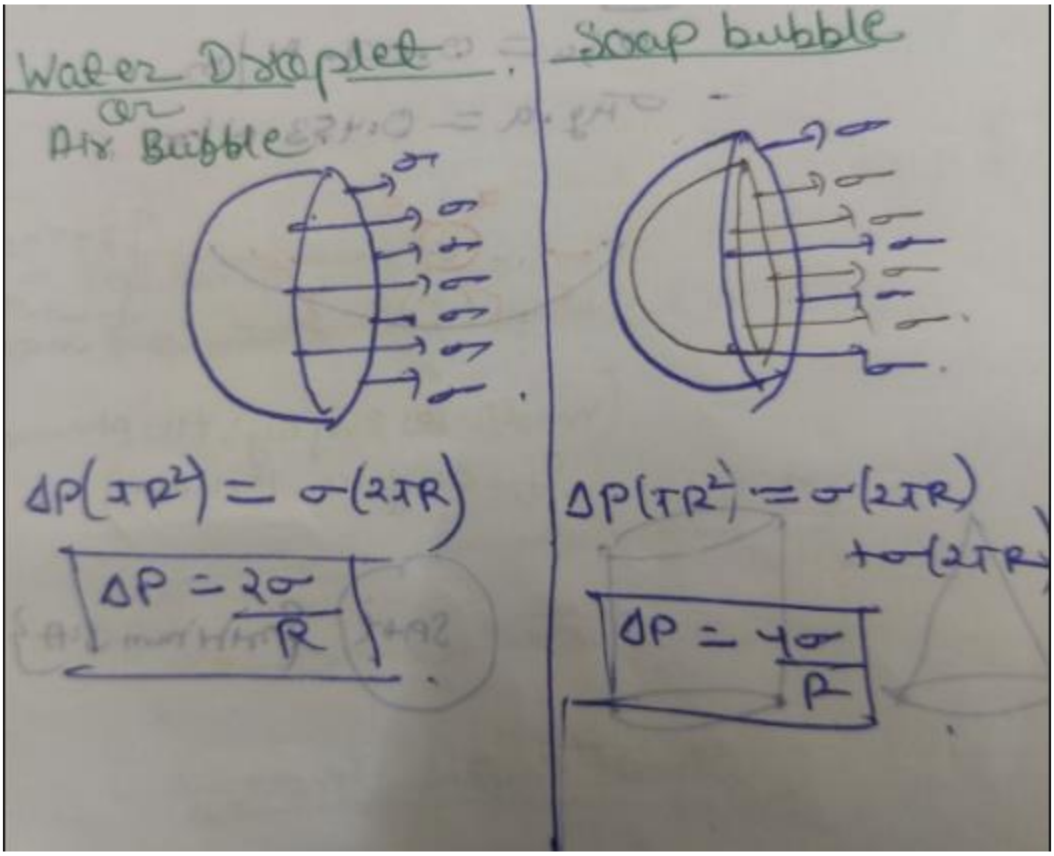
- Rheopectic is very similar to dilatant in that when shear is applied,viscosity increases.The difference here,is that viscosity increase is time-dependent.
- Examples: Gypsum paste,cream,Bentonite clay suspensions,certain sols and clay suspensions.

3(i). $PA + 0.8*β*g*0.24 + 0.8*β*g*0.12 - 13.6*β*g*0.12 + 0.8*β*g*0.10 - 13.6*β*g*0.15 - 0.8*β*g*0.10 = PB$

$PA - PB = β*g*3.384$

$= 33.84$ Kpa

(ii).



$\Delta P(\pi R^2) = \sigma(2\pi R)$

$\boxed{\Delta P = \frac{2\sigma}{R}}$

$\Delta P(\pi R^2) = \sigma(2\pi R) + \sigma(2\pi R)$

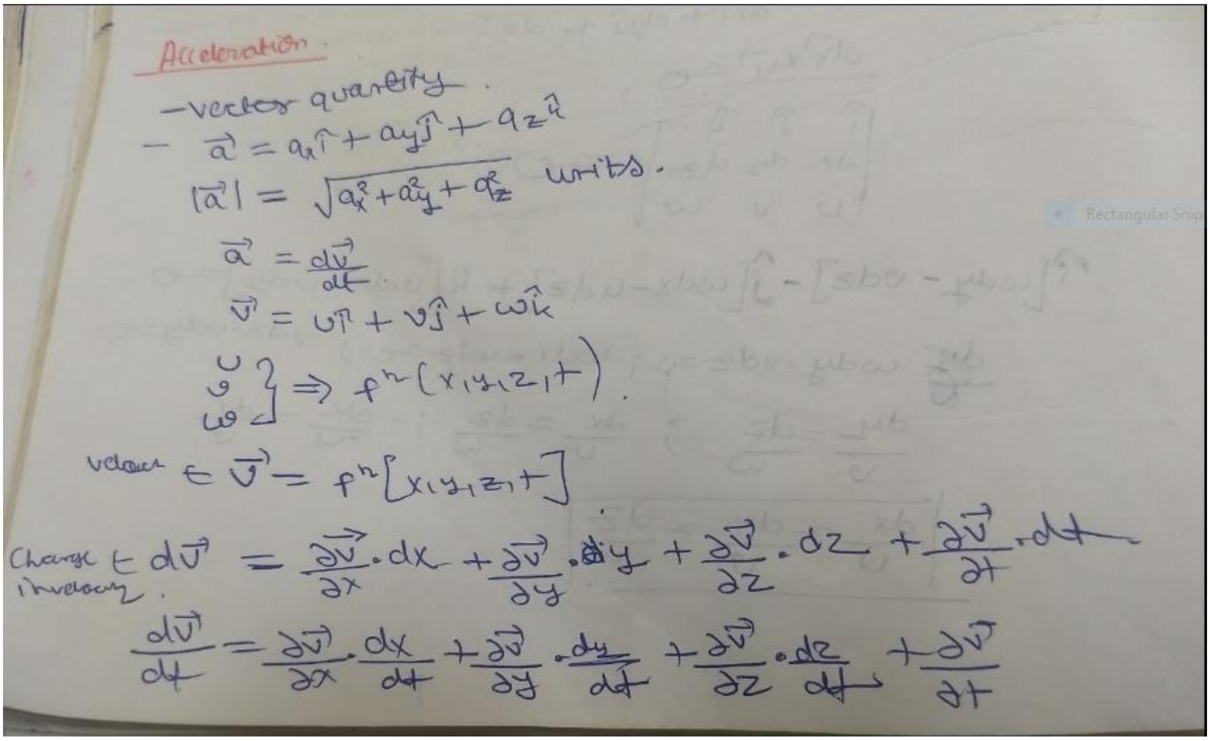
$\boxed{\Delta P = \frac{4\sigma}{R}}$

4(i). $\sigma*\pi*d*\cos\theta = β*(\pi*d^2/4*h)*g$

$h = (4*\sigma*\cos\theta)/(β*d*g)$

$= 0.3$ m

(ii).



Acceleration

- vector quantity.
- $\vec{a} = a_x\hat{i} + a_y\hat{j} + a_z\hat{k}$

$|\vec{a}| = \sqrt{a_x^2 + a_y^2 + a_z^2}$ units.

$\vec{a} = \frac{d\vec{v}}{dt}$

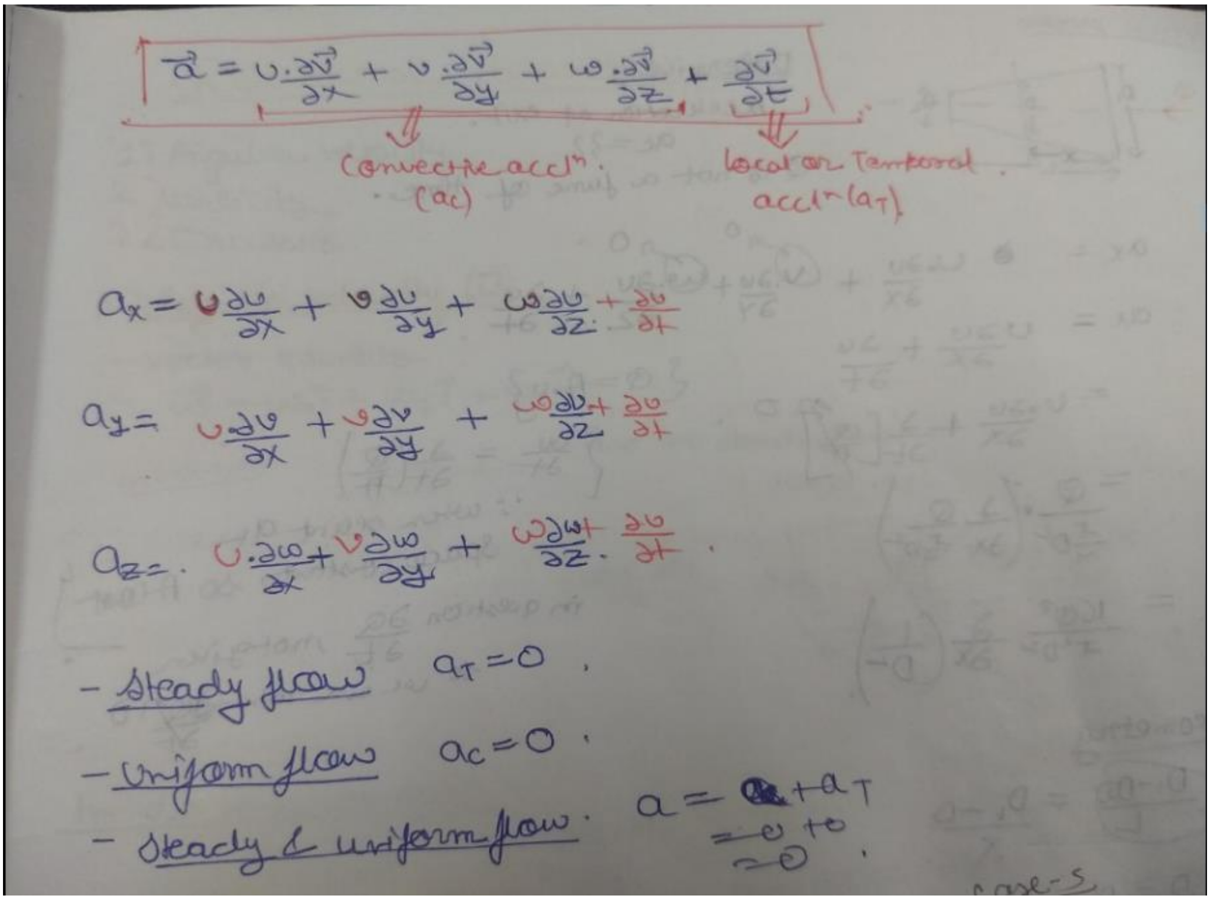
$\vec{v} = u\hat{i} + v\hat{j} + w\hat{k}$

$\left.\begin{matrix} u \\ v \\ w \end{matrix}\right\} \Rightarrow f^n(x, y, z, t)$.

velocity ∈ $\vec{v} = f^n[x, y, z, t]$

Change in velocity. $d\vec{v} = \frac{\partial \vec{v}}{\partial x} \cdot dx + \frac{\partial \vec{v}}{\partial y} \cdot dy + \frac{\partial \vec{v}}{\partial z} \cdot dz + \frac{\partial \vec{v}}{\partial t} \cdot dt$

$$\frac{d\vec{v}}{dt} = \frac{\partial \vec{v}}{\partial x} \cdot \frac{dx}{dt} + \frac{\partial \vec{v}}{\partial y} \cdot \frac{dy}{dt} + \frac{\partial \vec{v}}{\partial z} \cdot \frac{dz}{dt} + \frac{\partial \vec{v}}{\partial t}$$



$$\boxed{\vec{a} = \underbrace{u \cdot \frac{\partial \vec{v}}{\partial x} + v \cdot \frac{\partial \vec{v}}{\partial y} + w \cdot \frac{\partial \vec{v}}{\partial z}}_{\text{Convective accl}^n\text{. }(a_c)} + \underbrace{\frac{\partial \vec{v}}{\partial t}}_{\text{local or Temporal accl}^n (a_T)}}$$

$a_x = u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} + w\frac{\partial u}{\partial z} + \frac{\partial u}{\partial t}$

$a_y = u\frac{\partial v}{\partial x} + v\frac{\partial v}{\partial y} + w\frac{\partial v}{\partial z} + \frac{\partial v}{\partial t}$

$a_z = u\frac{\partial w}{\partial x} + v\frac{\partial w}{\partial y} + w\frac{\partial w}{\partial z} + \frac{\partial v}{\partial t}$.

- Steady flow $a_T = 0$.
- Uniform flow $a_c = 0$.
- Steady & uniform flow. $a = a_c + a_T = 0 + 0 = 0$.

case-5