The Shirpur Education Society's

R. C. Patel College of Engineering and Polytechnic, Shirpur

Department of Mechanical Engineering

NAME OF COURSE: - Fluid Mechanics and Machinery (FMM)

CODE OF COURSE: - 313309

SEMESTER: - SYME-3K

SUBJECT TEACHER: - Mr. Jayesh N. Chaudhari

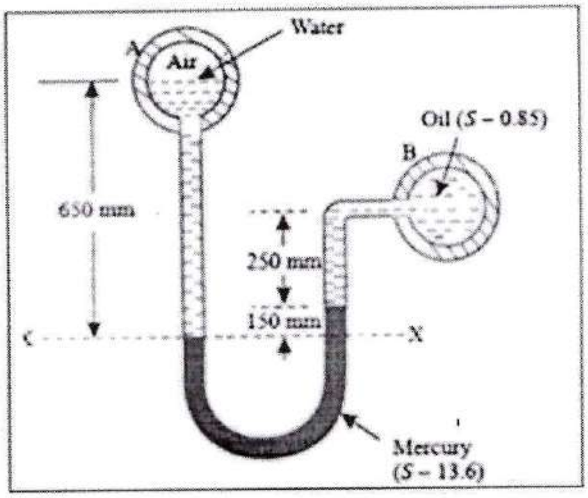
QUESTION BANK OF CHAPTER – 1 PROPERTIES OF FLUID AND FLUID PRESSURE MEASUREMENT

Program Name: Diploma in Mechanical Engineering
Name of Subject & Code : Fluid Mechanics and Machinery (313309)

Program Code: ME
Semester : THIRD

Instructions: (1) Illustrate your answers with neat sketches wherever necessary.

Q.1.	Two marks questions.	Previous Exam	CO PO Mapping
1.	The density of a liquid is 2900 kg/m3 . Calculate the specific gravity of the liquid.	W25-1.a	CO1-TLO1.1-A
2.	Define : (i) Surface tension (ii) Kinematic viscosity of fluid.	S25-1.a	CO1-TLO1.1-R
3.	Determine the diameter of droplet of water in mm, if the pressure inside is to be greater than that outside by 130 Nm2. Take 'σ' of water 7.26 × 10–2 N/m.	S25-1.d	CO1-TLO1.1-A
4.	One liter of oil weighs 7.8 N. Calculate specific gravity of oil.	W24-1.a	CO1-TLO1.1-A
5.	Define viscosity and state its type	S25-1.f	CO1-TLO1.1-R
6.	Define mass density of fluid and state its unit.	S25-1.a	CO1-TLO1.1-R
Q.2.	Four marks questions.	Previous Exam	CO PO Mapping
1.	Explain construction and working of Bourdon pressure gauge with a neat sketch.	W25-2.a S25-4.b	CO1-TLO1.3-U
2.	A vertical composite liquid column with its upper and exposed to atmosphere, comprises of 45 cm of Hg (Sp. gravity 13.6), 65 cm of water and 80 cm of oil which is having sp. gravity as 0.8. Calculate the absolute pressure in bar :– i) At the bottom of column ii) At the interface of oil and water.	W25-5.a	CO1-TLO1.3-A
3.	A simple U-tube manometer containing Hg is connected to a pipe in which a fluid of sp. gravity 0.8 and having vaccume pressure is flowing, the other end of manometer is open to atmosphere. Find the vaccume pressure in the pipe, if the difference of Hg level in the two limbs is 40 cm and the height of fluid in the left limb from the centre of pipe is 15 cm below.	W25-6.a	CO1-TLO1.3-A
4.	Calculate pressure head of kerosene of specific gravity 0.81 and carbon tetrachloride of specific gravity 1.6, if equivalent	S25- 2.a	CO1-TLO1.3-A

	pressure head of water is 100 m.		
5.	A circular plate 2 m diameter is placed vertically in water so that centre of the plate is 3 m below the free surface. Determine the depth of centre of pressure and total pressure on the plate	S25- 2.c	CO1-TLO1.4-A
6.	A circular plate of diameter 1.5 m placed vertically in water in such a way that the center of the place is 2.5 m below the free surface of water. Determine: (i) Total pressure on the plate. (ii) Position of center of pressure.	W24-2.a	CO1-TLO1.4-A
7.	As shown in Figure 1, a differential manometer connected at two points A and B. At 'A' air pressure is 100 kN/m2. Find the absolute pressure at B.  Fig. No. 1	W24-2.c	CO1-TLO1.3-A
8.	Explain the concept of atmospheric pressure, gauge pressure and vacuum pressure with a neat sketch.	W24-2.b S25-1.e	CO1-TLO1.2-U
9.	Draw neat sketch of Bourdon's tube pressure gauge and compare it with Manometers on the basis of range and working principle.	W24-2.d	CO1-TLO1.3-A
10.	A simple U-tube manometer is connected to pipe containing pressurize water. The height of water column is 0.4 m above the datum line in left limb. In right limb the rise of mercury column is 0.3 m above datum line. Find the pressure in the pipe.	S25-2.a	CO1-TLO1.3-A
11.	A circular gate having 2 m diameter is fitted in one of the vertical side of tank. The Depth of water in tank is 6 m. Gate is installed at bottom of tank. Calculate Total pressure and Centre of pressure.	S25-2.b	CO1-TLO1.4-A
	* * *Best of Luck* * *		

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★ Fluid Mechanics & Machinery ★

Chapter 1 :- Properties of Fluid & Fluid Pressure Measurement.

* Fluid :-

A fluid is a substance that flows & takes the shape of its container.

e.g. water, oil, air.

* Fluid Mechanics :-

It is the branch of engg. that studies behavior of fluid (liquid & gases) when they are in rest or motion.

Fluid Mechanics

- Hydrostatic (Study of fluid at rest)
  e.g. Fluid stored in tank.
- Hydrokinematic (Study of fluid in motion, when pressure forces not considered)
  e.g. Fluid flowing in river.
- Hydrodynamic (Study of fluid in motion, when pressure forces are considered)
  e.g. Fluid flowing in pump.

* Types of Fluid :-

1. Ideal Fluid -
   A fluid having no viscosity (no resistance to flow), cannot be compressed.
   e.g. Not found in real life. (imaginary fluid).

2. Real Fluid -
   A fluid having viscosity. (resistance is present).
   e.g. water, oil, air.

3. Newtonian Fluid -

A fluid which follows Newton's law of viscosity. (constant viscosity).

e.g. water, air.

4. Non-Newtonian Fluid -

A fluid which does not follows Newton's law of viscosity (viscosity changes).

e.g. ketchup, toothpaste.

TLO 1.1 =>

* Properties of Fluid :-

1. Density / Mass density / Specific mass (ρ) :-

It is defined as mass per unit volume.

$$\rho = \frac{mass}{volume} = \frac{m}{V} \quad \text{---- unit } \frac{kg}{m^3}$$

2. Weight density / Specific weight (w) :-

~~It is the ratio of density of fluid to density of water.~~

It is the ratio of weight per unit volume.

$$w = \frac{weight}{volume} = \frac{W}{V} \quad \text{--- unit } \frac{N}{m^3}$$

or $$w = \rho \cdot g = \frac{W}{V}$$

3. Specific Volume (V_s) :-

It is the ratio of volume per unit mass.

or It is reciprocal of mass density.

$$V_s = \frac{volume}{mass} = \frac{V}{m} \quad \text{--- unit } \frac{m^3}{kg}$$

or $$V_s = \frac{1}{\rho} = \frac{V}{M}$$

4. Specific Gravity / Relative density (S) :-

It is the ratio of density of fluid to density of water.

Or It is the ratio of sp. weight of fluid to sp. weight of water.

$$S = \frac{\rho_f}{\rho_e} = \frac{w_f}{w_w}$$ ---- unit → No unit.

5. Newton's Law of viscosity :-

It states that, "Shear stress is directly proportional to the velocity gradient (or shear strain).

Shear Stress ∝ Shear Strain

$$\tau \propto \frac{du}{dy}$$

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

6. Cohesion & Adhesion :-

Cohesion - It is the molecular attraction betn molecules of same liquid.

Adhesion - It is the attraction betn molecules of a liquid & molecules of a solid surface in contact with liquid.

7. Viscosity (μ) :-

Viscosity is the resistance offered by a fluid to flow. It tells how thick or sticky a fluid is.

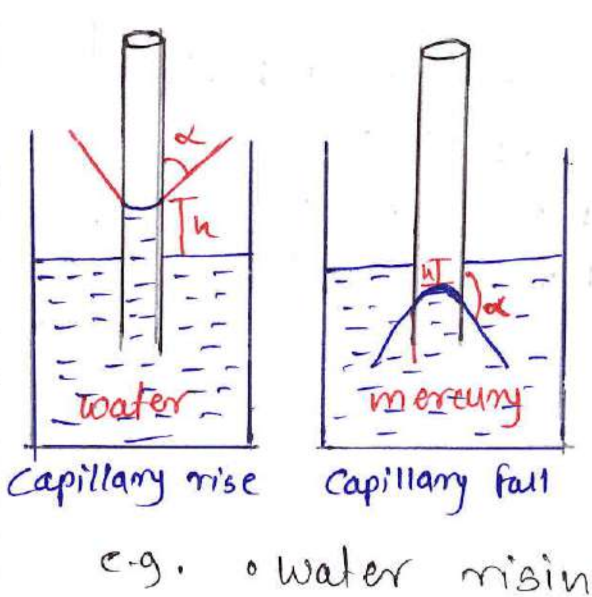
e.g. Honey → high viscosity (flows slowly)
water → Low viscosity (flows easily)

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

* Difference betn Dynamic & kinematic viscosity :-

Dynamic Viscosity (μ)	Kinematic viscosity (ν)
1. It is defined as shear stress directly proportional to shear strain.	1. It is the ratio of dynamic viscosity to mass density.
2. Internal resistance to flow.	2. Resistance considering density.
3. It depends on fluid only	3. It depends on fluid & density.
4. Notation - μ	4. Notation - ν
5. Formula - $\mu = \frac{\tau}{\frac{du}{dy}}$	5. Formula - $\nu = \frac{\mu}{\rho}$
6. SI unit - $\frac{N \cdot s}{m^2}$	6. SI unit - $\frac{m^2}{s}$
7. CGS unit - poise	7. CGS unit - Stoke

8. Capillarity -



It is the rise or fall of liquid in a thin tube due to surface tension.

It happens because of 2 forces:
- Adhesion - attraction betn { liquid, tube }
- Cohesion - attraction betn liquid molecules.

e.g.
- Water rising in thin glass tube.
- Oil rising in a wick of a lamp.
- Ink spreading in paper.

Capillary rise or fall $(h) = \frac{4 \cdot \sigma \cdot \cos\alpha}{\rho \cdot g \cdot d}$.

where h = height of rise

σ = surface tension

ρ = density

d = diam. of tube

g = gravitational acclⁿ.

Note - In case of water in a clean glass tube,

$\theta = 0^\circ$, $\cos\theta = 1$

& for mercury in clean glass tube, $\theta = 128^\circ$

9. Compressibility ($1/k$) & Bulk Modulus (k) :-

It is the ability of fluid to change its volume when pressure is applied.

- gases → highly compressible
- liquids → very less compressible.

It is also reciprocal of bulk modulus (k).

Bulk Modulus (k) -

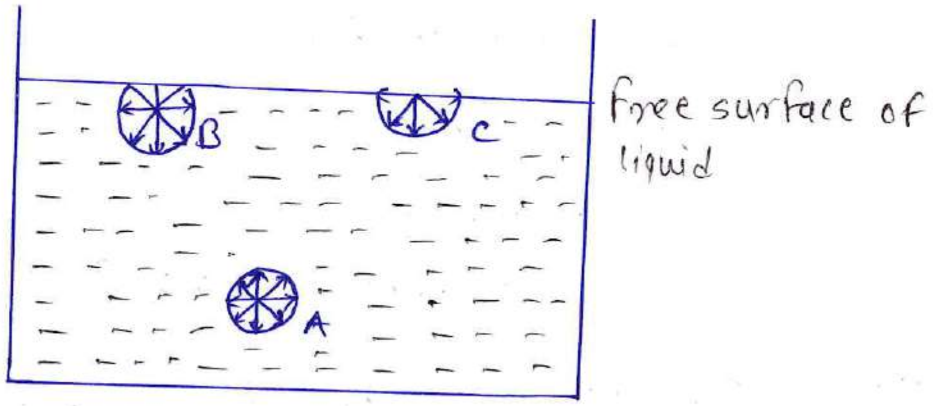
It is the ratio of increase in pressure to the volumetric strain.

$$\therefore k = \frac{\text{increase in pressure}}{\text{Volumetric strain}} = \frac{dP}{\frac{-dV}{V}} = \frac{-V \cdot dP}{dV}$$

$$\therefore \text{Compressibility} = \frac{1}{k} = \frac{1}{\frac{-V \cdot dP}{dV}} = \frac{-dV}{V \cdot dp}.$$

10. Surface Tension (σ) :-

It is the property of liquid by which its free surface behaves like a stretched elastic membrane.



It is the force that makes the surface of a liquid tight & tries to reduce its area. It happens due to molecules inside the liquid are pulled in all directions, & molecules at the surface are pulled inward only, this creates a tight surface layer.

e.g.
- water droplets are spherical.
- A needle can float on water.
- Insects walk on water.

SI unit – $\frac{N}{m}$.

$$\sigma = \frac{P \cdot d}{4}$$ — for liquid surface

$$\sigma = \frac{Pd}{8}$$ — for soap bubble

$$\sigma = \frac{Pd}{2}$$ — for liquid jet

where, P = Pressure intensity inside the droplet.
d = diam. of droplet.

11. Vapour Pressure :-

Vapour pressure is the pressure exerted by vapour of a liquid in equilibrium with the liquid.

It shows how liquid easily evaporates.

* Formulae :-

1. Density / specific mass / mass density (ρ) = $\frac{m}{V}$ — kg/m³
2. Weight density / specific mass (w) = $\frac{W}{V} = \rho \cdot g$ — N/m³
3. Specific gravity / relative density (s) = $\frac{\rho_f}{\rho_w} = \frac{w_f}{w_w}$
4. Specific volume (V_s) = $\frac{1}{\rho} = \frac{V}{m}$ — m³/kg
5. Dynamic viscosity (μ) = $\frac{\tau}{\frac{du}{dy}}$ — $\frac{N \cdot s}{m^2}$
6. Kinematic viscosity (ν) = $\frac{\mu}{\rho}$ — $\frac{m^2}{s}$
7. Capillarity (h) = $\frac{4 \cdot \sigma \cdot \cos\alpha}{\rho \cdot g \cdot d}$ — m
8. Compressibility = $\frac{-dV}{V \cdot dp}$ — $\frac{m^2}{N}$

For water
$\mu = 1.75 \times 10^{-3}$ Ns/m²
$\nu = 1.75 \times 10^{-6}$ m²/s

9. Surface tension (σ) :-

$\sigma = \frac{Pd}{2}$ — liquid jet $\sigma = \frac{Pd}{4}$ — liquid bubble

$\sigma = \frac{Pd}{8}$ — soap bubble

10. $\rho_w = 1000$ kg/m³, $\rho_{hg} = 13600$ kg/m³, 1 m³ = 1000 lit
$w_w = 9810$ N/m³, $S_w = 1$, $S_{hg} = 13.6$, 1 lit = 10^{-3} m³

11. 1 poise = $\frac{1}{10} \frac{Ns}{m^2}$, 1 centi ~~stoke~~ poise = $\frac{1}{100}$ poise = $10^{-3} \frac{Ns}{m^2}$

1 stoke = 10^{-4} m²/s

* Pressure (P) :- 1.2 Fluid Pressure :-

Pressure is the force acting per unit area on a surface.

$$\text{Pressure } (P) = \frac{\text{Force}}{\text{Area}} = \frac{F}{A} \quad --- \frac{N}{m^2}$$

* Pressure Head (h) :-

Pressure head is the height of fluid column that produces a given pressure.

$$h = \frac{P}{\rho . g} \quad --- m.$$

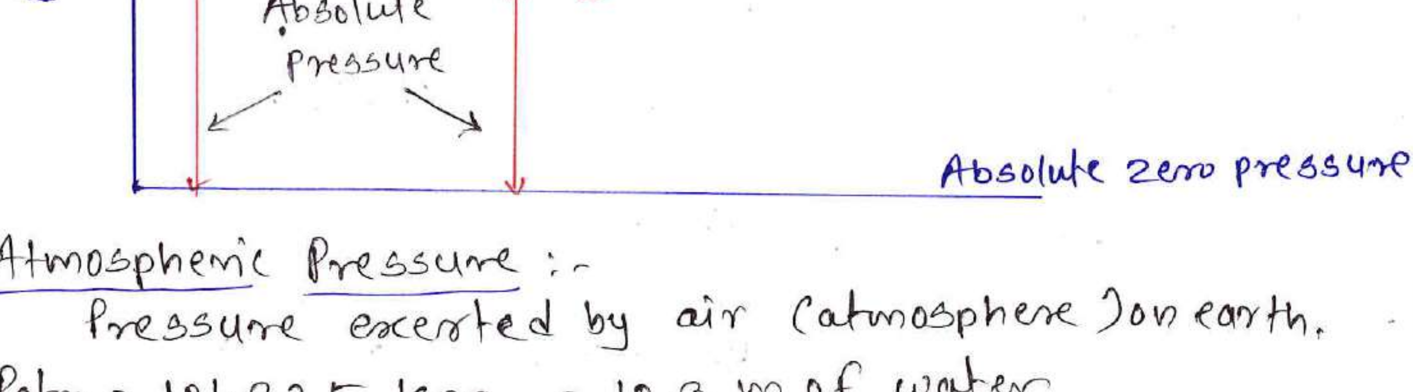
where h = pressure head

P = Pressure

ρ = density

g = gravitational accl^n.

* Types of Pressure :-



1. Atmospheric Pressure :-

Pressure excerted by air (atmosphere) on earth.

P_{atm} = 101.325 kpa = 10.3 m of water

= 760 mm of Hg.

2. Absolute Pressure :-

Pressure measured from absolute zero (perfect vacuum).

$$P_{abs} = P_{atm} \pm P_{gauge}$$

3. Gauge Pressure :-

When pressure is measured above or below atmospheric pressure then it is called as gauge pressure.

+ve gauge pressure - when pressure measured above atmospheric pressure it is called positive gauge pressure.

4. Vacuum Pressure / -ve gauge Pressure :-

When pressure measured below atmospheric pressure then it is called as -ve or vacuum pressure.

1.3 Fluid Pressure Measurement Devices :-

* Manometer :-

A manometer is a device used to measure fluid pressure by balancing it against a column of liquid.

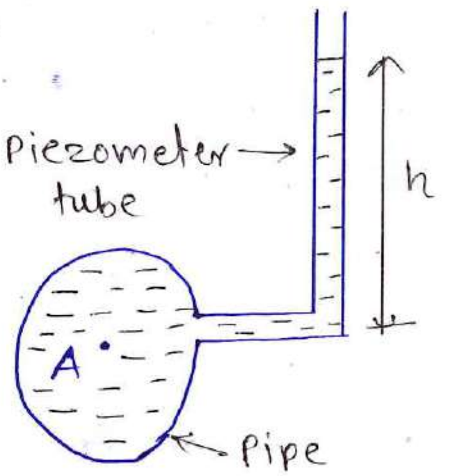
Manometer
- Simple manometer
  - Piezometer
  - U-tube manometer
  - Single column manometer
- Differential manometer
  - U-tube differential manometer
  - Inverted U-tube diff. manometer.

* Mechanical Gauge :-

It is a device used to check pressure of fluid by balancing fluid by dead weight or spring

- Bourdon's tube pressure gauge
- Dead weight Press. gauge
- Bellows press. gauge
- Diaphragm press. gauge.

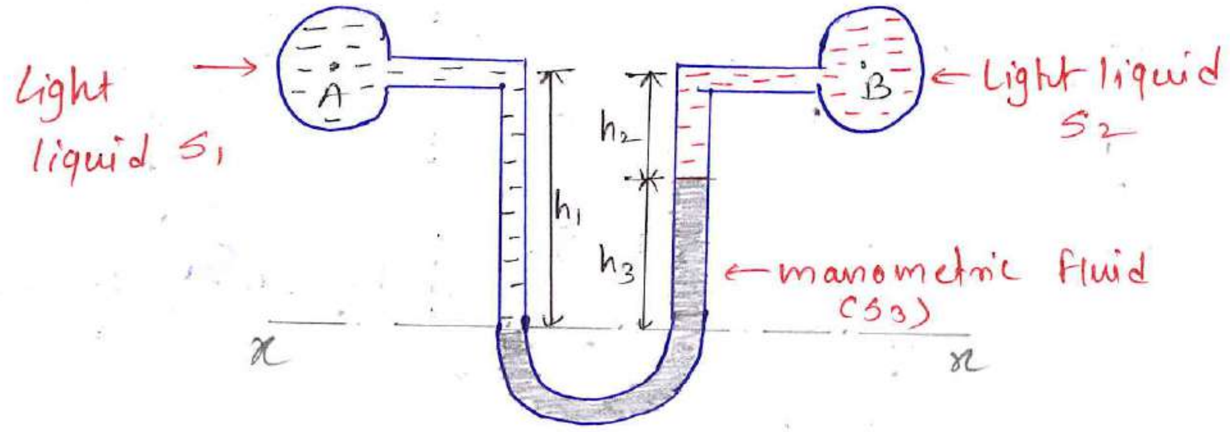
* Piezometer :-



It is a simple device used to measure pressure of a liquid at a point in a pipe or tank.
It just a vertical transparent tube connected to pipe. The height of liquid column (h) shows the pressure as it rises in tube due to pressure.

$$\text{Pressure}(P) = \rho \cdot g \cdot h$$

* U-tube Differential Manometer



It is a simple device used to measure pressure diff. betn two points. It is a 'U'-shape bent tube.

- Construction - A glass tube bent into U-shape. Filled partially with a liquid (usually mercury).
- The two ends are connected to two different press. points.
- Working - It works on the balance of liquid columns. When both sides have same press, the liquid levels are equal. When pressures are different, the liquid moves:
  - Higher pressure side → pushes liquid down
  - Lower pressure side → liquid rises up

The difference in height (h) of liquid columns shows the pressure difference.

Press difference is given by

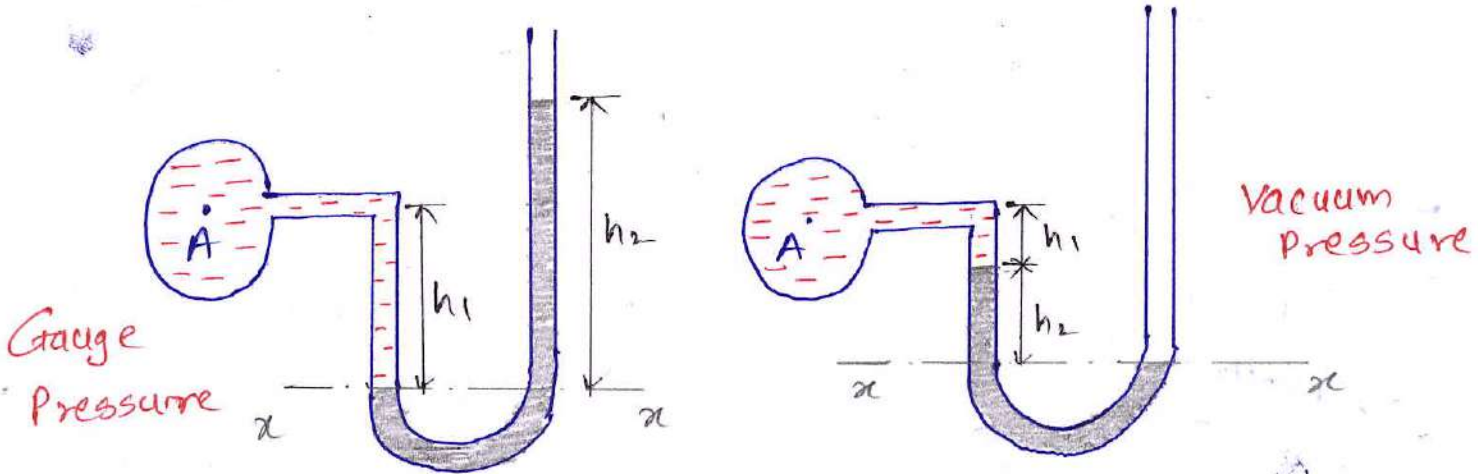
$$P_1 - P_2 = \rho g h$$

or (Press head) in left limb = Press head in right limb

$$h_A + S_1 h_1 = h_B + S_2 h_2 + S_3 h_3$$

$$h_A - h_B = S_2 h_2 + S_3 h_3 - S_1 h_1$$

* Simple U-tube Manometer :-



It is a U-tube manometer, used to measure pressure at one point (not diff. betn two points). It compares the Press. with atmospheric press (air pressure).

- Construction - A U-shaped glass tube, filled with liquid (usually mercury). One end is connected to the point where pressure is to be measured, other end is open to atmosphere.

- Working - It works on liquid level difference. When no pressure is applied → both sides have same level. When pressure is applied :
  - Fluid pushes the liquid down on one side.
  - Liquid rises on the other side.

The difference is height (h) shows pressure.

let S_1 = Specific gravity of light liquid
S_2 = Specific gravity of heavy liquid.

(Negative)
- for +ve gauge pressure.

Press. head in left limb = Pressure head in right limb.

$h_A + S_1h_1 + S_2h_2 = 0$

$$\therefore h_A = -S_1h_1 - S_2h_2$$

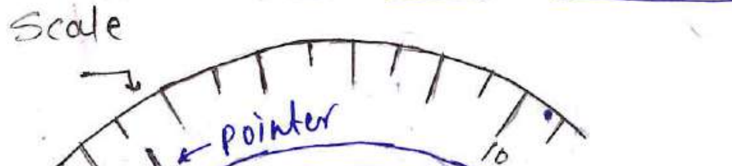
- for +ve gauge pressure :

Press. head in left limb = press. head in right limb

$S_1h_1 + h_B = S_2h_2$

$$h_B = S_2h_2 - S_1h_1$$

* Bourdon's Tube Pressure Gauge !-



It is a device used to measure Pressure of liquid & gases. It is commonly used in boilers, air compressors, hydraulic sys.

- Construction -

1. Bourdon tube - A curved (C-shaped) hollow metal tube, one end is fixed & other end is free.
2. Pressure Inlet - connected to system where press. is to be measured.
3. Link & lever mechanism - connects tube movement to pointer.
4. Gear & pinion - converts small movement into bigger.
5. Pointer & dial - shows pressure reading.

- Working -

Pressure enters the Bourdon tube, tube tries to strengthen (uncoil) due to pressure. free end of tube moves towards (outward).

This movement is transmitted through link → gears. Pointer moves on the dial → shows pressure value.

* Advantages of Mercury as a manometric Fluid :-

1. High density, so small height diff. is enough to measure large pressure.
2. Low vapour pressure so does not evaporate easily.
3. gives accurate reading even at higher temp.
4. Shiny & metallic appearance.
5. It does not stick to glass wall.
6. It does not undergo chemical reaction.
7. High surface tension, reduces chances of error due to capillary effect.
8. Stable properties - density constant so ensure reliable reading.

* Advantages of Mechanical Gauges over Manometers :-

1. Compact & portable
2. Direct reading (on dial)
3. Suitable for high pressure.
4. No liquid reqd.
5. Easy Installation
6. Quick response.
7. High accuracy & sensitivity.
8. Strong construction, durable & easy to use.
9. Low cost.

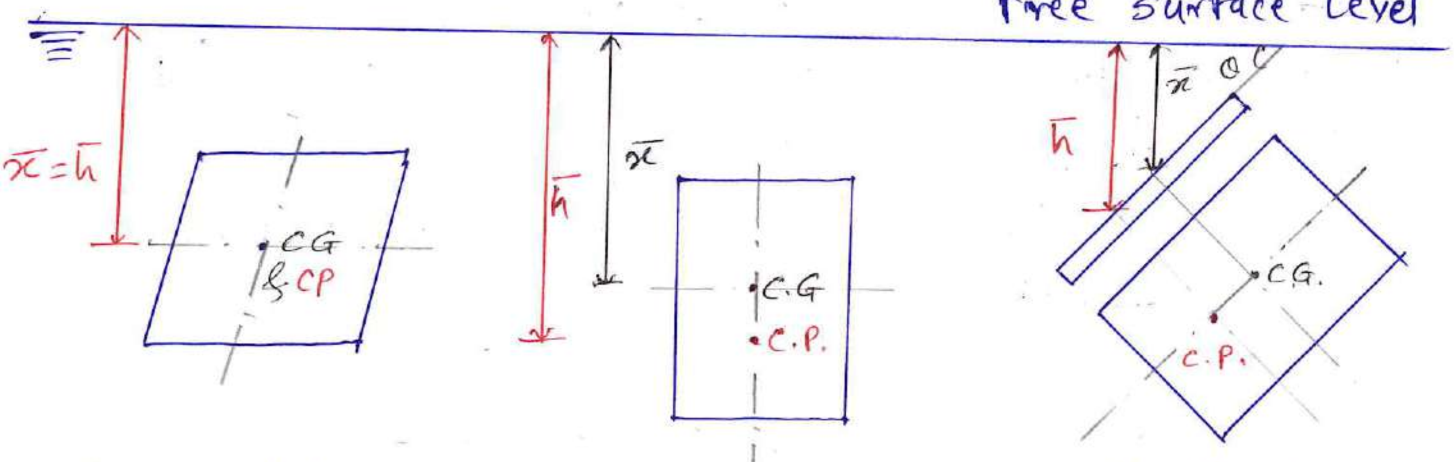
Formulae :-

- 1 pascal = 1 pa = 1 N/m^2
- 1 bar = 1×10^5 pa
- 1 kpa = 1×10^3 pa
- 1 Mpa = 1×10^6 pa
- 1 Gpa = 1×10^9 pa

1.4 Hydrostatics :-

* Total Pressure & Centre of Pressure *

* Total Pressure (F) :-



a) Horizontal immersed surface b) Vertical immersed surface c) Inclined immersed surface.

It is the total force excerted by a liquid on submerged surface.

(When a surface is inside a liquid, the liquid pushes on it due to pressure.

$$\boxed{\text{Total Pressure (F)} = w.A.\bar{x}} \quad ---N$$

where,

A = Area of plate -- m^2

$\bar{x}$ = dist. of CG. from free surface level

$\bar{h}$ = distance of Centre of pressure (C.P) from free surface level.

* Centre of Pressure ($\bar{h}$) :-

It is a point where the total pressure (F) force acts on the surface.

It is expressed in terms of depth of liquid surface.

* Pascal Law :- It states that pressure applied to a confined Fluid is transmitted equally & undiminished in all dir^n throughout Fluid. $\boxed{P = \frac{F}{A}}$ or $\boxed{\frac{F_1}{A_1} = \frac{F_2}{A_2}}$

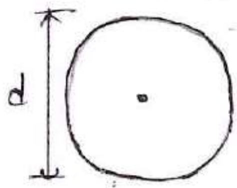
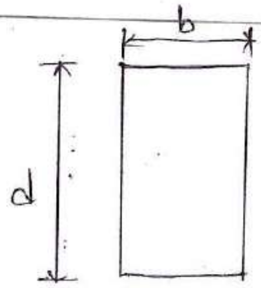
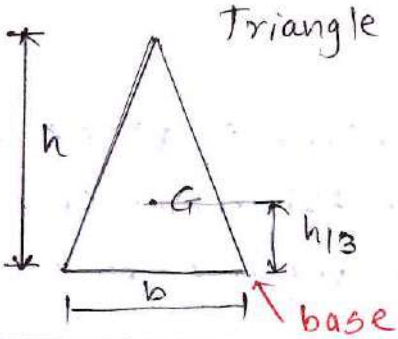
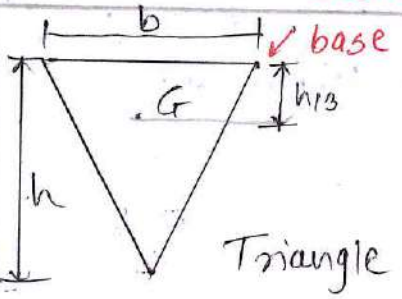
1. For horizontal surface : $\bar{h} = \bar{x}$

2. For vertical surface : $\bar{h} = \bar{x} + \frac{I_G}{A.\bar{x}}$

3. For inclined surface : $\bar{h} = \bar{x} + \frac{I_G \sin^2\theta}{A.\bar{x}}$

where, I_G = MI of surface about centroidal axis
θ = Inclination of surface with free surface level.

* Moment of ~~Inter~~ Inertia of plane surface.

Sr. No.	Surface	C.G. from base	Area	Moment of Inertia
1	 Circle	$\frac{d}{2}$	$\frac{\pi}{4}.d^2$	$\frac{\pi}{64}.d^4$
2	 Rectangle	$\frac{d}{2}$	$b.d$	$\frac{bd^3}{12}$
3.	Triangle 	$\frac{h}{3}$	$\frac{1}{2}.b.h.$	$I_G = \frac{bh^3}{36}$ $I_{base} = \frac{bh^3}{12}$
4.	 Triangle	$\frac{h}{3}$	$\frac{1}{2}.b.h$	$I_G = \frac{bh^3}{36}$ $I_{base} = \frac{bh^3}{12}$

* Numerical based on Properties of Fluid *

1. A fluid occupies $3 m^3$ & weighs 8.2kN. Calculate
   i) Mass density ii) weight density iii) sp. volume
   iv) Specific gravity.

→ Given data $V = 3 m^3$, $W = 8.2 kN = 8.2 \times 10^3 N$

i) weight density → $w = \frac{W}{V} = \frac{8.2 \times 10^3}{3}$

$$\boxed{w = 2733.33 \ N/m^3}$$

ii) Mass density →

$w = \rho \cdot g \Rightarrow \rho = \frac{w}{g} = \frac{2733.33}{9.81}$

$$\boxed{\rho = 278.62 \ kg/m^3}$$

iii) Specific volume (V_s) → $V_s = \frac{1}{\rho} = \frac{1}{278.62}$

$$\boxed{V_s = 3.59 \times 10^{-3} \ m^3/kg}$$

iv) Specific gravity (S) → $S = \frac{\rho_f}{\rho_w} = \frac{3.59 \times 10^{-3}}{1000}$

$$\boxed{S = 0.27863}$$

2. The space betn two square flat parallels is filled with oil. Each side of plate is 720 mm. The thickness of oil film is 15 mm. The upper plate, which moves at 3 m/s, requires a force of 120 N to maintain the speed. Determine: i) Dynamic viscosity of oil ii) kinematic viscosity of oil, if sp. gravity of oil is 0.95.

→ Given data: side of sq. plate = 720 mm = 0.72 m

$dy = 15 mm = 0.015 m$, $u = 3 m/s$, $F = 120 N$, $S_{oil} = 0.95$

→ Area of sq. plate = side² = 0.72^2 = 0.5184 m²

∴ Shear stress (τ) = $\frac{F}{A} = \frac{120}{0.5784}$ = 231.48 N/m²

du = 4 − 0 = 3 − 0 = 3 m/s.

i) dynamic viscosity (μ) :

$$\mu = \frac{\tau}{\frac{du}{dy}} = \frac{231.48}{\left(\frac{3}{0.015}\right)} = 1.1574 \ \frac{Ns}{m^2}$$

ii) Kinematic viscosity (ν):

$$S_{oil} = \frac{\rho_o}{\rho_w} \Rightarrow \rho_{oil} = S_o \times \rho_w$$

$$= 0.95 \times 1000$$

$$\boxed{\rho_{oil} = 950 \ kg/m^3}$$

Now $$\nu = \frac{\mu}{\rho} = \frac{1.1574}{950} = 1.218 \times 10^{-3} \ \frac{m^2}{s}$$

* Numerical on surface Tension *

3. Find the surface tension in liquid drop of 40mm diam, when the inside pressure is 3N/m² above the atmospheric pressure.

→ Given data : d = 40 mm = 40×10^{-3} m , P = 3 N/m²

For liquid droplet, surface tension (σ) = $\frac{P \cdot d}{4}$

$$= \frac{3 \times 0.040}{4}$$

$$\boxed{\sigma = 0.03 \ N/m}$$

* Numerical on Capillarity *

4. A capillary tube of 3 mm inside diam is dipped in water. If a angle of contact is 20°, determine the rise of water in capillary tube. Take surface tension of water as 0.073 N/m.

→ Given data : $d = 3\text{ mm} = 3 \times 10^{-3}$ m , $\alpha = 20°$, $\sigma = 0.073$ N/m

We know that $h = \frac{4\sigma \cdot \cos\alpha}{\rho \cdot g \cdot d}$

$$= \frac{4 \times 0.073 \times \cos(20°)}{1000 \times 9.81 \times 3 \times 10^{-3}}$$

$$h = 9.32 \times 10^{-3} \text{ m}$$

$$\boxed{h = 9.32 \text{ mm}}$$

5. Determine the surface tension of a liquid in contact with air & glass tube, if a capillary tube of diam. 2 mm is dipped in a liquid of specific gravity 0.8, the liquid rises in the tube by 15 mm making an angle of contact 25° with the tube. (W-14)

→ Given data :- $d = 2\text{ mm} = 0.002$ m , $S = 0.8$
$h = 15\text{ mm} = 0.015$ m , $\alpha = 25°$

Now find ρ ⇒ we have $S_l = \frac{\rho_l}{\rho_w}$ ⇒ $\rho_l = S_l \times \rho_w$

$$\rho_l = 0.8 \times 1000 = 800 \text{ kg/m}^3$$

Now capillarity $(h) = \frac{4\sigma \cdot \cos\alpha}{\rho \cdot g \cdot d}$ ⇒ $\sigma = \frac{h \cdot \rho \cdot g \cdot d}{4 \cdot \cos\alpha}$

$$\sigma = \frac{0.015 \times 800 \times 9.81 \times 0.002}{4 \times \cos(25°)}$$

$$\boxed{\sigma = 0.0649 \text{ N/m}}$$

* Numerical on conversion of Pressure Units *

6. How given pressure in pascal can be converted into required liquid column, (W-13)

→ 1. First convert pascal into N/m^2

So 1 pa = 1 N/m^2 i.e. pressure (P)

2. Now convert pressure (P) into liquid column (h) i.e. Pressure head

we know that $P = \rho g h$,

$$h = \frac{P}{\rho g}$$

7. Determine the height of an oil column of sp. gravity 0.8, a) in m of Hg b) in m of oil column, which will cause a pressure of 25 kpa. (S-16)

→ Given data: $S_{oil} = 0.8$, $P = 25$ kpa $= 25 \times 10^3$ pa

we know that

$$S_{oil} = \frac{\rho_{oil}}{\rho_w}$$

$$0.8 = \frac{\rho_{oil}}{1000}$$

$$\rho_{oil} = 800 \text{ kg/m}^3$$

$$S_{Hg} = \frac{\rho_{Hg}}{\rho_w}$$

$$13.6 = \frac{\rho_{Hg}}{1000}$$

$$\rho_{Hg} = 13600 \text{ kg/m}^3$$

i) in 'm' of oil column:

$$P = \rho g . h_{oil}$$

$$25 \times 10^3 = 800 \times 9.81 \times h_{oil}$$

$$h_{oil} = 3.1855 \text{ m of oil column}$$

ii) in 'm' of Hg:

$$P = \rho g h_{Hg}$$

$$25 \times 10^3 = 13600 \times 9.81 \times h_{Hg}$$

$$h_{Hg} = 0.1874 \text{ m of Hg}$$

8. Convert vacuum gauge reading of 200 mm of Hg into absolute pressure in N/m^2. (S-16)

→ Given data: $h_{vac} = 200$ mm of Hg

$h_{atm} = 760$ mm of Hg

Now

Absolute Pressure = Atmospheric Pressure − Vacuum Pressure

$h_{abs} = 760 - 200$

$= 560$ mm of Hg

$h_{abs} = 0.56$ m of Hg

Now Pressure $(P) = \rho \cdot g \cdot h$

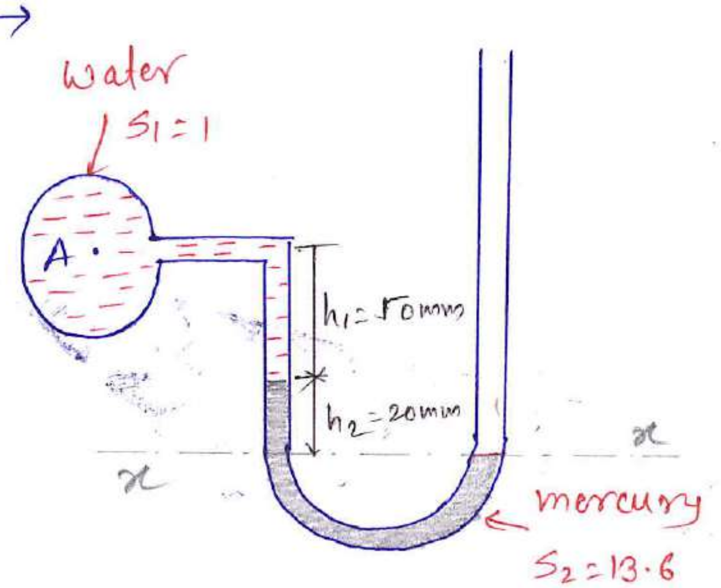
$= 13600 \times 9.81 \times 0.56$

$P_{abs} = 74712.96 \; N/m^2$

* Numerical on Simple Manometer *

9. Determine the pressure of water at point 'A' in meters of water as shown in fig. (S-13, S-16)

→



Given data:

$S_1 = 1$, $S_2 = 13.6$

$h_1 = 50$ mm $= 0.05$ m

$h_2 = 20$ mm $= 0.02$ m

Now,

height of column in left limb = height of column in right limb

$h_A + S_1 h_1 + S_2 h_2 = 0$

$h_A = -S_1 h_1 - S_2 h_2$

$= -(1 \times 0.05) - (13.6 \times 0.02)$

$h_A = -0.322$ m of water

Pressure $(P) = \rho \cdot g \cdot h$

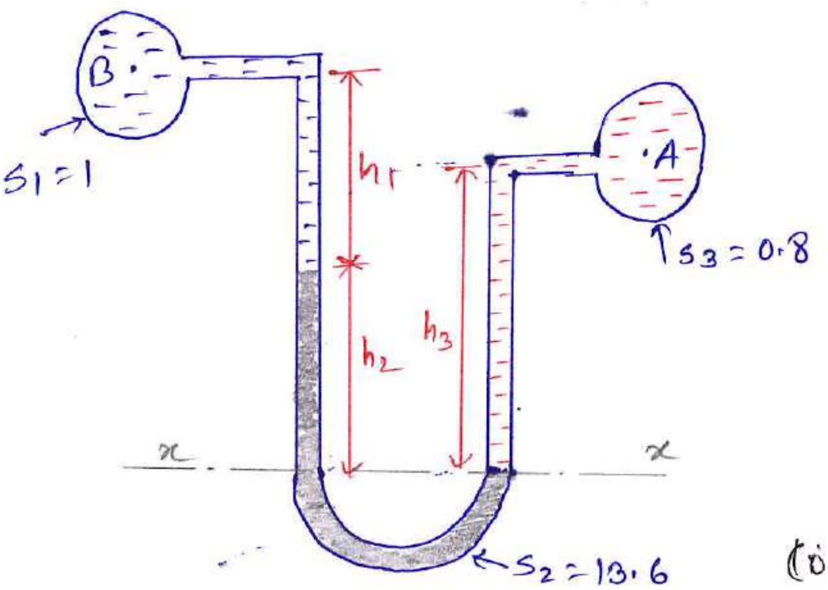
$= 1000 \times 9.81 \times h_A$

$P = -3158.82 \; N/m^2$

* Numerical on Differential 'U' Tube Manometer *

10. Calculate the pressure diff. betn liquids of pipe A & pipe B for differential "U" tube manometer. Pipe A contains liquid of specific gravity 0.8 & pipe B contains liquid of specific gravity 1.15. The difference in mercury level is 30 cm. The level of mercury is 30 cm below pipe B in left limb & 50 cm below pipe A in the right limb.

→ Given data :



$S_1 = 1.15$, $h_1 = 30\,cm = 0.3\,m$

$S_2 = 13.6$, $h_2 = 30\,cm = 0.3\,m$

$S_3 = 0.8$, $h_3 = 50\,cm = 0.5\,m$

height of column in left limb = height of column in right limb

$$h_B + S_1h_1 + S_2h_2 = h_A + S_3h_3$$

$$\therefore h_B - h_A = S_3h_3 - S_2h_2 - S_1h_1$$

$$= (0.8 \times 0.5) - (1.15 \times 0.3) - (13.6 \times 0.3)$$

$$h_B - h_A = -4.025 \text{ m of water}$$

or $$h_A - h_B = +4.025 \text{ m of water}$$

Now, $$\frac{P_A}{\rho g} - \frac{P_B}{\rho g} = 4.025$$

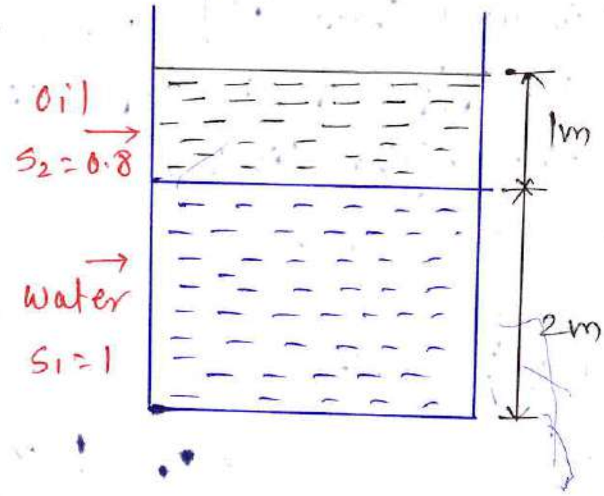
$$P_A - P_B = 4.025 \times \rho g = 4.025 \times 1000 \times 9.81$$

$$\boxed{P_A - P_B = 39485.25 \text{ N/m}^2}$$

* Numerical on Miscallaneous *

11. An open tank contains water upto depth of 2 m & above it, an oil of specific gravity 0.8 for a depth of 1m. find the pressure at the bottom of of tank. (W-14)

→ Given data:



$h_1 = 2m$ $S_{oil} = 0.8$

$h_2 = 1m$ $S_w = 1$, $\rho_w = 10^3 \, kg/m^3$

→ Now say $\rho_1 = \rho_w = 1000 \, kg/m^3$

& $\rho_2 = \rho_{oil} = \rho_w \times S_{oil}$

$= 1000 \times 0.8$

$\rho_{oil} = 800 \, kg/m^3$

∴ ~~Absolute~~ Press. at bottom of tank.

$P_{gauge} = \rho_1 g h_1 + \rho_2 g h_2$

$= (1000 \times 9.81 \times 2) + (800 \times 9.81 \times 1)$

$P_{gauge} = 27468 \, N/m^2$
$= 0.27468 \, bar$

If absolute pressure asked then,

$P_{abs} = P_{atm} + P_{gauge}$

$= 1.01325 + 0.27468$

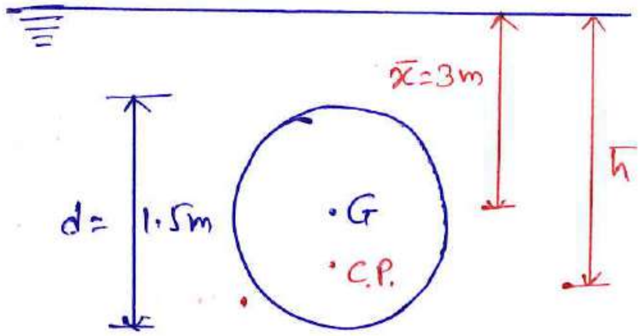
$P_{abs} = 1.28793 \, bar$

* Numerical on Total Pressure & Centre of Pressure *

12. Determine the total pressure on a circular plate of diam. 1.5 m, which is placed vertically in water in such a way that, the centre of plate is 3m below the free surface of water. find centre of pressure also. (S-13, W-13).

→ Given data:

$d = 1.5\,m, \ \bar{x} = 3\,m$



area $= A = \frac{\pi}{4} \cdot d^2$

$= \frac{\pi}{4} \cdot (1.5)^2$

$A = 1.767\ m^2$

$I_G = \frac{\pi}{64} \cdot d^4 = \frac{\pi}{64} \cdot (1.5)^4$

$I_G = 0.2485\ m^4$

1. Total Pressure (F):

$F = w \cdot A \cdot \bar{x} = 9810 \times 1.767 \times 3$

$\boxed{F = 52002.81\ N}$

2. Centre of Pressure ($\bar{h}$):

$\bar{h} = \frac{I_G}{A\bar{x}} + \bar{x} = \frac{0.2485}{1.767 \times 3} + 3$

$\boxed{\bar{h} = 3.0468\ m}$

13. An equilateral triangular plate of 3 m side is immersed vertically in such a way that apex is in downward direction & the side of base is parallel & 25 cm below free fluid surface level. The plate is immersed in a tank of oil having specific gravity 1.1. Calculate total pressure & depth of centre of pressure. (S-17)

→ Given data: $S_{oil} = 1.1$, $b = 3\,m$.

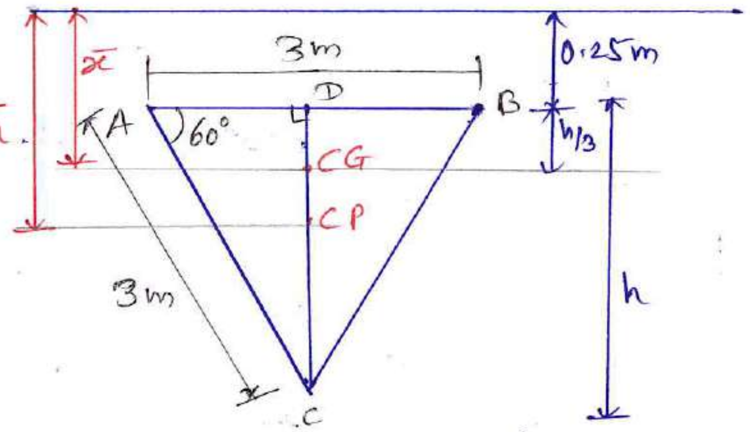
As equilateral triangle is given so, $\angle BAC = \frac{180^\circ}{3} = 60^\circ$

from ΔABC, $l(CD) = h$

& from ΔADC

$$\sin(60°) = \frac{l(CD)}{l(AC)} = \frac{h}{3}$$

$$\boxed{h = 2.598 \approx 2.6\,m}$$



$$\text{Area }(A) = \frac{1}{2}.b.h. = \frac{1}{2} \times 3 \times 2.6$$

$$\boxed{A = 3.9\ m2}$$

$$\bar{x} = 0.25 + \frac{h}{3} = 0.25 + \frac{2.6}{3}$$

$$\boxed{\bar{x} = 1.1166\ m}$$

$$\rho_o = S_o \times \rho_w = 1.1 \times 1000 = 1100\ kg/m^3$$

$$I_G = \frac{1}{36}.bh^3 = \frac{1}{36} \times 3 \times 2.6^3 = 1.464\ m^4$$

1. Total Pressure (F):

$$F = \omega.A.\bar{x} = \rho g \times A \cdot \bar{x} = (1100 \times 9.81) \times 3.9 \times 1.1166$$

$$\boxed{F = 46991.99\ N \approx 46992\ N}$$

2. Centre of Pressure $(\bar{h})$ $= \frac{I_G}{A\bar{x}} + \bar{x}$

$$= \frac{1.464}{3.9 \times 1.1166} + 1.1166$$

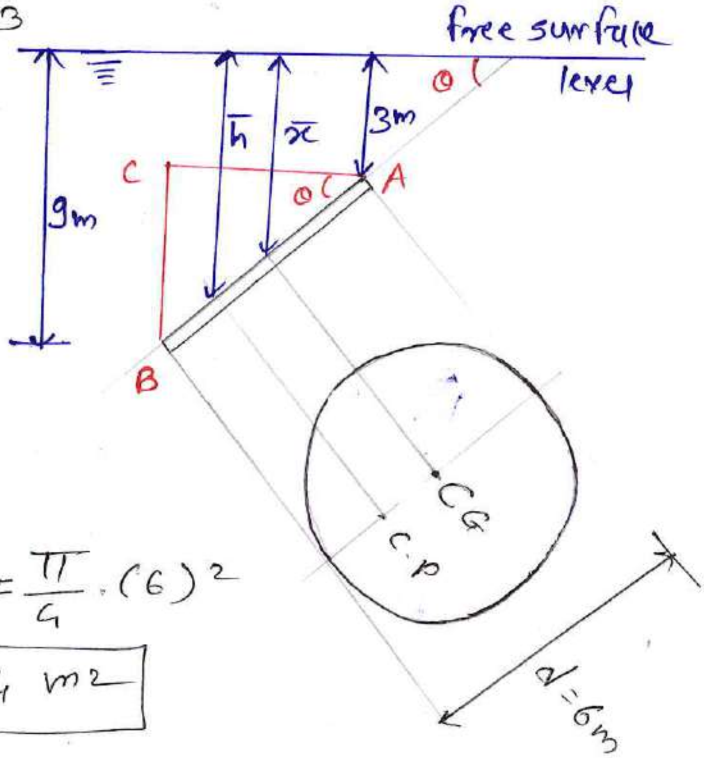
$$\boxed{\bar{h} = 1.4527\ m}$$

14. A circular plate of 6m diam. is held in water in such a way that, its max^m & min^m depth from surface of water is 3m & 9m. Determine the total pressure on plate & the position of centre of pressure. (W-14)

→ Given data:

$d = 6m$, $\rho_w = 1000\ kg/m^3$

$\bar{x} = \frac{3+9}{2} = 6m$



From right angle ΔACB,

$\sin\theta = \frac{BC}{AB} = \frac{6}{6}$

$\theta = 90°$

Area of plate (A) $= \frac{\pi}{4} \cdot d^2 = \frac{\pi}{4} \cdot (6)^2$

$A = 28.274\ m^2$

$I_G = \frac{\pi}{64} \cdot d^4 = \frac{\pi}{64} \cdot (6)^4 = 63.617\ m^4$

1. Total Pressure (F):

$F = \omega . A . \bar{x} = 9810 \times 28.274 \times 6$

$F = 1.664 \times 10^6\ N$

2. Depth of Centre of Pressure ($\bar{h}$):

$\bar{h} = \frac{I_G \sin^2\theta}{A . \bar{x}} + \bar{x} = \frac{63.617 \times \sin(90°)}{28.274 \times 6} + 6$

$\bar{h} = 6.375\ m$

15. A triangular lamina is immersed vertically in water in such a way that, its 6m wide horizontal base is 8m below the free surface of water & the apex is 4.5m above the base. Find: i) Total pressure force (W-15)
ii) Position of centre of pressure.

→

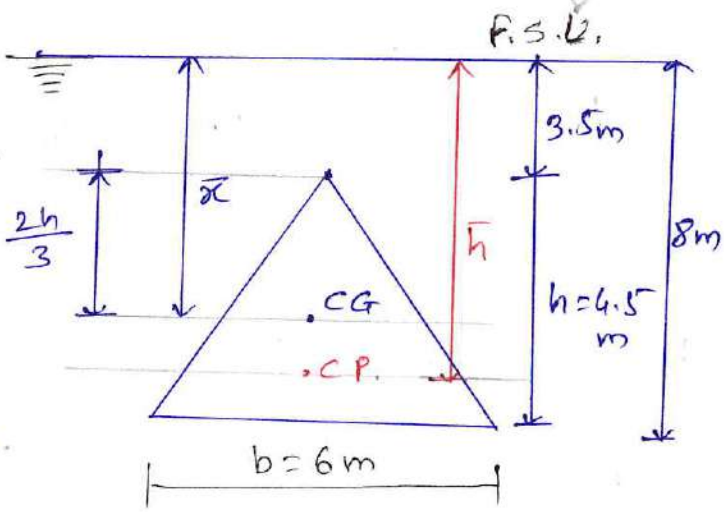
→ Given data:

$b = 6\ m$

Area $(A) = \frac{1}{2} \cdot b \cdot h =$

$= \frac{1}{2} \times 6 \times 4.5$

$A = 13.5\ m^2$



$I_G = \frac{1}{36} \cdot bh^3 = \frac{1}{36} \times 6 (4.5)^3$

$I_G = 15.1875\ m^4$

From fig. $\bar{x} = 3.5 + \frac{2h}{3}$

$= 3.5 + \frac{2 \times 4.5}{3} \Rightarrow \bar{x} = 6.5\ m$

1. Total Pressure (F):

$F = w \cdot A \cdot \bar{x} = 9810 \times 13.5 \times 6.5$

$F = 860827.5\ N$

2. Position of centre of pressure ($\bar{h}$):

$\bar{h} = \bar{x} + \frac{I_G}{A\bar{x}} = 6.5 + \frac{15.1875}{13.5 \times 6.5}$

$\bar{h} = 6.673\ m$