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(2) The diameters of a small piston and a large piston of a hydraulic jack at 3 cm and 10 cm respectively. A force of 80 N is applied on the small piston. Find the load lifted by the large piston when (a) the pistons are at the same level (b) small piston is 40 cm above the large piston. The density of the liquid in the jack is given as 1000 kg/m³. (25)

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Given data:

$D = 10\text{ cm} = 10 \times 10^{-2}\text{ m}$

$d = 3\text{ cm} = 3 \times 10^{-2}\text{ m}$

$F_s = 80\text{ N}$ $\quad F_L = ?$ (a) & (b)

(20)

Solution

(a) $p_s = p_L$

$$\frac{F_s}{A_s} = \frac{F_L}{A_L} ; \quad F_L = \frac{F_s}{A_s} \times A_L = \frac{80}{\frac{\pi}{4}(3\times10^{-2})^2} \times \frac{\pi}{4}(10\times10^{-2})^2$$

$$= 888.89\text{ N}$$

(b). $\cancel{s}$ at 40 cm above the large piston. So,

$$p_s = \frac{F_s}{A_s} + (\rho \times g \times h)$$

$$= \frac{80}{\frac{\pi}{4}(3\times10^{-2})^2} + 1000 \times 9.81 \times 40 \times 10^{-2}$$

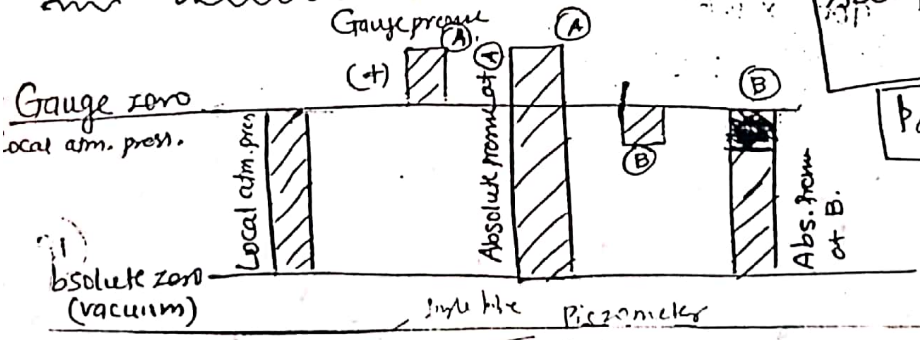
$$= 117.10 \times 10^3\text{ N/m}^2$$

$$\therefore F_L = 117.10 \times 10^3 \times A_L = 919.70\text{ N}$$

Scale of pressure measurement

Abs. pressure = atm. pressure ± gauge pressure

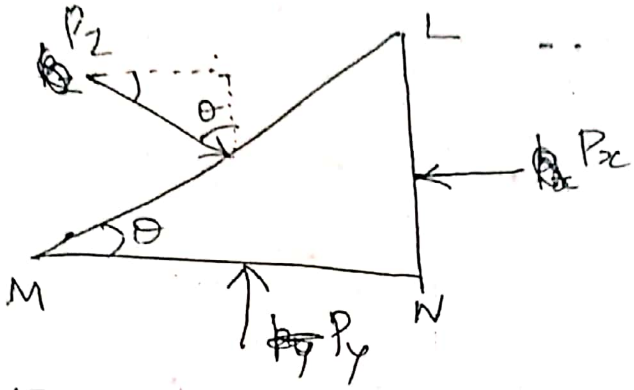
$p_{abs} = p_{atm} \pm p_{gauge}$



(19)

Manometer – Simple – Single tube: Piezometer; U-tube manometer; Single column manometer – Vertical, inclined
– Differential – two tubes: U-tube, inverted U-tube

Mech gauges – Diaphragm, Bourdon, Dead-weight, Bellows



$P_x = p_x \times LN$

$P_y = p_y \times MN$

$P_z = p_z \times LM$

~~Hydr~~ $\boxed{\text{Pascal's law}}$

For equilibrium condition,

Σ Horizontal force = Σ Vertical forces = 0.

$\cancel{P_z \sin\theta = P_x}$

$P_z \sin\theta = P_x$

$p_z \, L\cancel{M} \, \cancel{\sin\theta} = p_x \cdot L\cancel{N}$

$\boxed{p_z = p_x}$

$\sin\theta = \frac{LN}{LM}$

$\boxed{LN = LM \sin\theta}$

Vertical forces $\longrightarrow$ $P_y - P_z \cos\theta = 0$

$P_z \cos\theta = P_y$

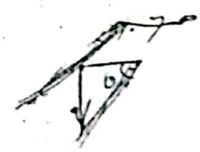
$p_z \, L\cancel{M} \, \cancel{\cos\theta} = p_y \, \cancel{MN}$

$\cos\theta = \frac{MN}{LM}$

$\boxed{MN = LM \cos\theta}$

$p_z = p_y$

$\therefore \boxed{p_x = p_y = p_z}$



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... head in terms of equivalent liquid column

(20)

$$\boxed{\begin{aligned} h_w S_w &= h_l S_l \\ h_m S_m &= h_l S_l \end{aligned}}$$

1) Convert a pressure head of 15m of water to meters of oil of relative density 0.75

(21)

Give data: Solution

$h_w = 15\ m$

$S_w = 1$

$S_l = 0.75$

$h_l = ?$

$$h_l = \frac{h_w S_w}{S_l} = \frac{15 \times 1}{0.75} = 20\,m \text{ of oil}$$

Team 2

2) Convert a pressure head of 600 mm of mercury into meters of oil of relative density 0.75

(22)

Solution

Team 2

$h_m S_m = h_l S_l$

$$h_l = \frac{600 \times 13.6}{0.75 \times 1000} = 10.88\,m \text{ of oil}$$

Scale of pressure measurement formulas (Problem)

1) What are the gauge pressure at a point 3 m below the free surface of liquid having a density of $1.53 \times 10^3\ kg/m^3$ if the atmospheric pressure is equivalent to 750 mm of mercury? The specific gravity of mercury is 13.6 and density of water = $1000\ kg/m^3$.

Given data:

$\rho = 1.53 \times 10^3 \times 9.81\ N/m^3$

$P_{atm} = 750\ mm = 750 \times 10^{-3}\ m$ of mercury

$S_m = 13.6$

$\rho_w = 1000\ kg/m^3 = 1000 \times 9.81\ N/m^3$

(23)

Solution :

P_{atm} at 3m from of free surface

$P_{atm} = \rho_{mg} h$

$= 13.6 \times 1000 \times 9.81 \times 750 \times 10^{-3}$ $\left[S_m = \frac{\rho_m}{\rho_w} \right]$

$= 100.062 \times 10^3 \ N/m^2$

$P_{gauge} = \rho_b \times g \times h$

$= 1.53 \times 10^3 \times 9.81 \times 3 = 45.03 \times 10^3 \ N/m^2$

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

$= 145.092 \times 10^3 \ N/m^2$

(2) what is the gauge pressure in mm of mercury when the abs pressure at a point is (a) 85 kN/m² and (b) 18 m of water absolute.

Given Data:

$p = 85 \ kN/m^2$

$h_{abs} = 18 m$ of water

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Atm. pressure = 101.43 kN/m²
= 760 mm of mercury
= 10.34 m of water

Solution

$p = \rho g h$

$h = \frac{85 \times 10^3}{1000 \times 9.81} = 8.67$ m of water

$h_w S_w = h_m S_m$

$h_m = \frac{8.67 \times 1}{13.6} = 0.637$ m of mercury

$h_m = 637$ mm of mercury

Gauge pressure $= P_{Abs} - P_{atm}$

$= 637 - 760 mm = -123$ mm (vacuum press)

(ii) When $h = 18$ m of water

$h_w \rho_w = h_m \rho_m$

$h_m = \frac{18}{13.6} = 1.323$ m of mercury

$= 1323.5$ mm of mercury

∴ Gauge pressure $= 1323.5$ mm $- 760$ mm

$= 563.53$ mm

(3) What is the absolute pressure in kN/m^2 when the vacuum pressure at a point is (a) 200 mm of mercury and (b) 2m of water?

<u>Given data</u>

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$P_{gauge} = 200$ mm of mercury (Vacuum)

$= 2$ m of water (Vacuum)

<u>Solution</u>

(a) $P_{abs} = P_{atm} - P_{gauge}$ (Because given as vacuum)

$= 760 - 200$

$= 560$ mm of mercury.

$P = \rho g h$; $13.6 = \frac{\rho_m}{\rho_w}$

$\cancel{= 1000 \times 9.81}$; $\rho_m = 13.6 \times 1000$

$= 13.6 \times 1000 \times 9.81 \times 560 \times 10^{-3}$

$P = 74.71\ kN/m^2$ //.

(b) $P_{abs} = 10.34 - 2$

$= 8.34$ m of water

$= 1000 \times 9.81 \times 8.34$

$= 81.82\ kN/m^2$ //

Total pressure:

Force exerted by a static fluid on a surface either plane or curved. $\boxed{P = \rho g \bar{h}}$ $\bar{h}$ = Distance of C.G. of the area from free surface of liquid.

Centre of pressure:

Point of application of the total pressure on the surface.

Fluid statics

* No Viscosity
* So forces acting are:
  - due to pressure of fluid normal to the surface
  - due to gravity (or self-weight of fluid particles)

Buoyancy:

When a body is immersed in a fluid, an upward force ~~[illegible]~~ is exerted by the fluid on the body. This upward force is equal to the weight of the fluid displaced by the body and is called the force of buoyancy or simply buoyancy.

Centre of buoyancy:

Defined as the point through which the force of buoyancy is supposed to act. It will be in the centre of gravity. (Centre of pressure).

Meta-Centre:

Defined as the point about which a body starts oscillating when the body is tilted by a small angle.

Also defined as the point at which the line of action of the force of buoyancy will meet the normal axis of the body when the body is given a small angular displacement.

Meta-Centric Height:

The distance between the meta-centre of a floating body and the centre of gravity of body.