FLUID MECHANICS

Online Class - Pressure and Hydrostatic Forces

by

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- Pressure: Force per Area, Pascals
- Types of Pressures – Atmospheric, Absolute and Gauge Pressure
- Pressure Variation, Pressure at a point
- p=wh, h1S1=h2S2;
- Pascal’s Law

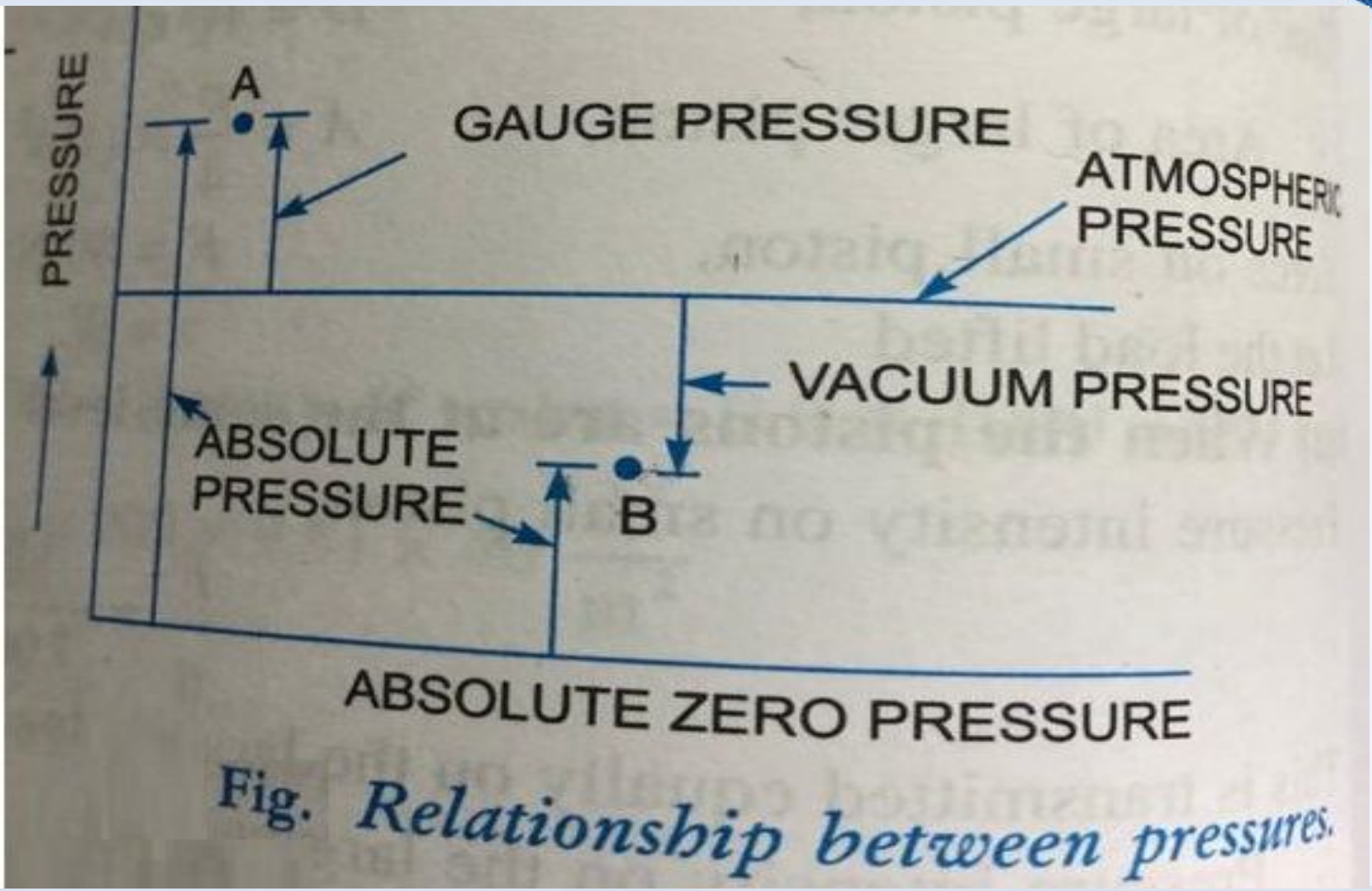


Fig. *Relationship between pressures.*

- Problem; Determine pressure due to water column of 0.4 m of water
- Problem; Oil of S=0.9, the ht of oil = 30m, Find the corresponding height of water at that point
- Problem: Determine the absolute pressure at a point 3m below the free surface of water

P atm = 1.03 Kg(f)/cm^2; Gage Pressure

= 1000 x 3=3000 Kg(f)/m^2 = 0.3 Kg(f)/cm^2

Pabs= 1.03 + 0.3 = Kg(f)/cm^2

- Measurement of Pressure
- Simple Manometers
- Piezometer
- U-tube Manometer
- Single Column Manometers
  - Inclined Single Column Manometer

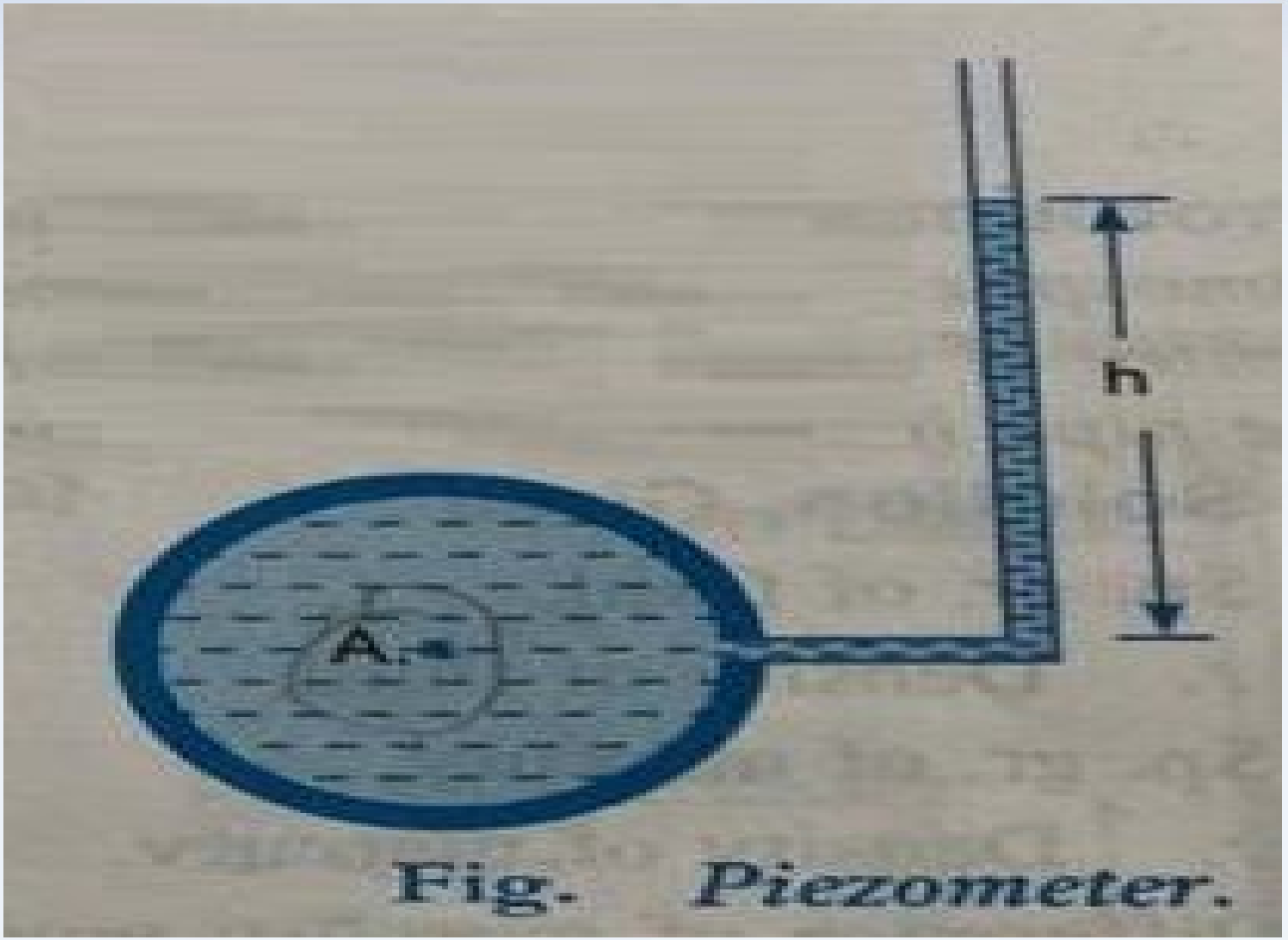


Fig. *Piezometer.*

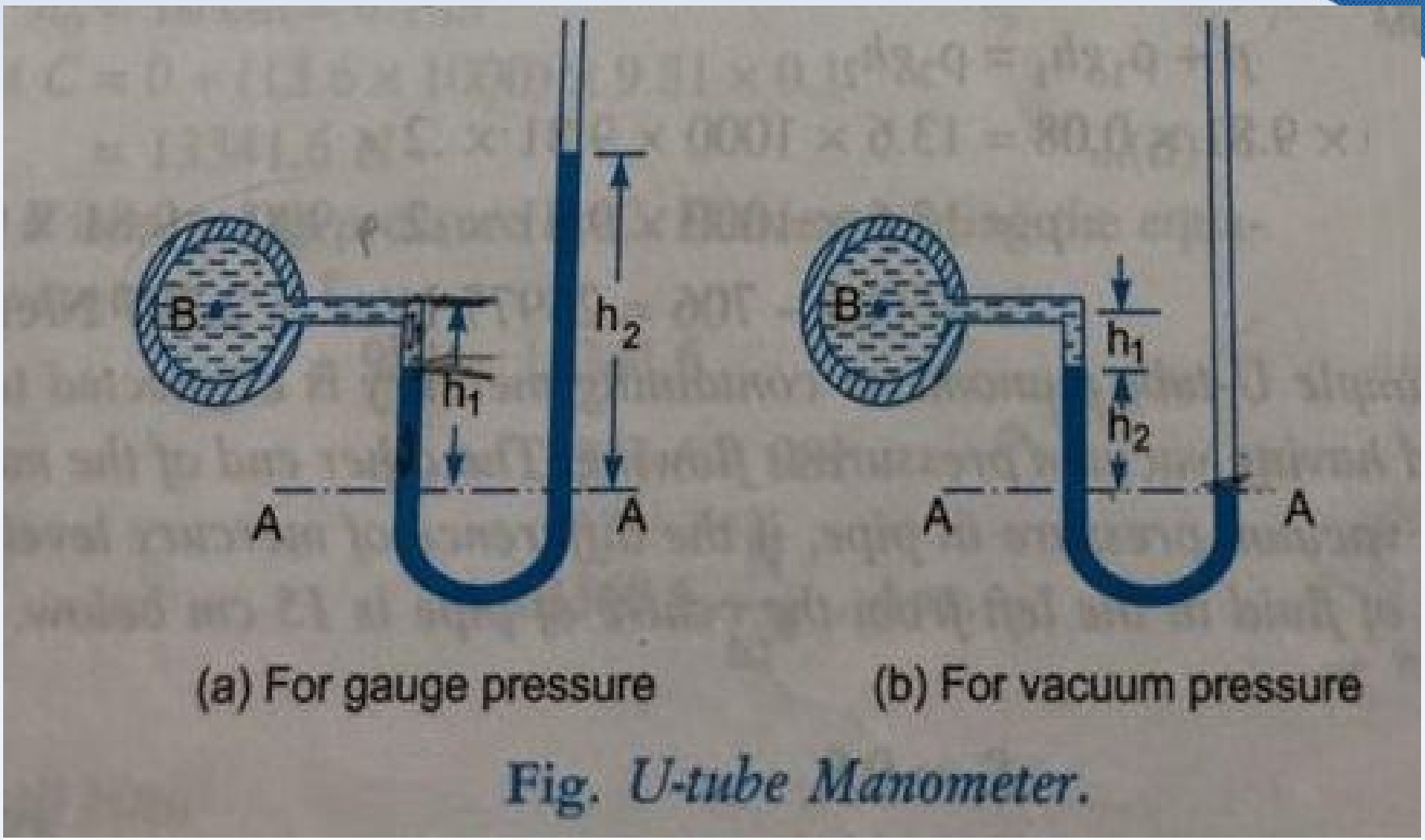


Fig. *U-tube Manometer.*

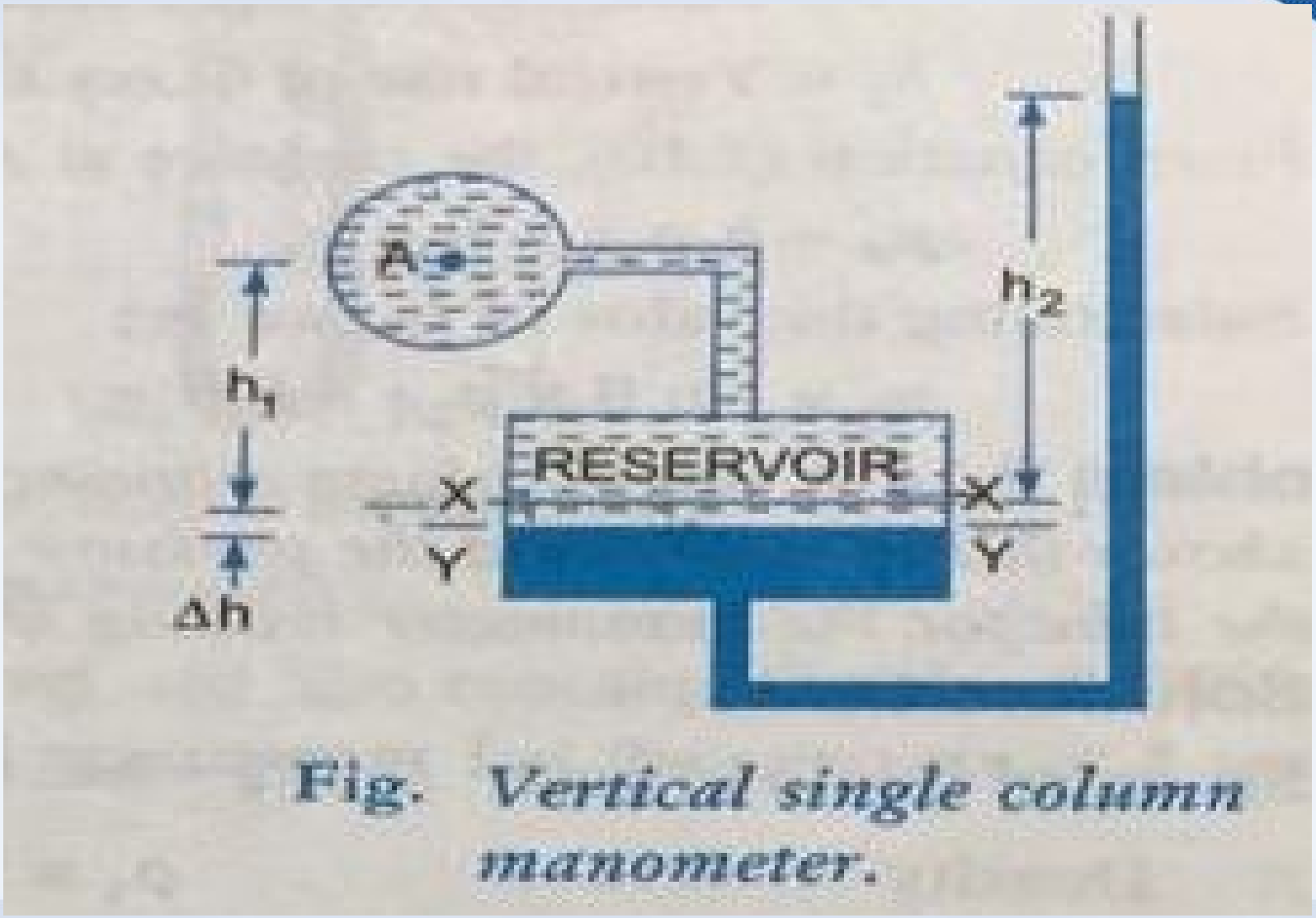


Fig. *Vertical single column manometer.*

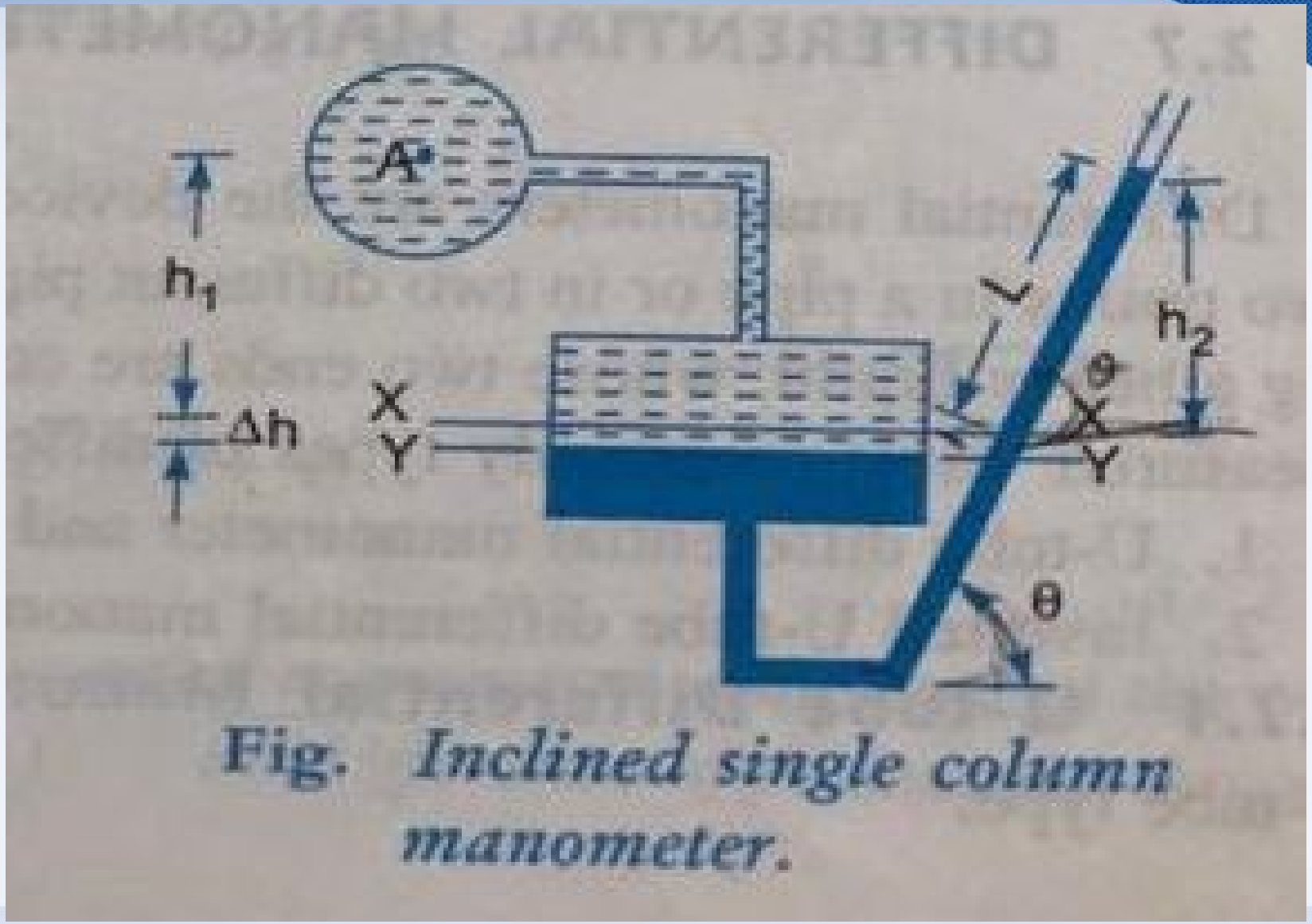


Fig. *Inclined single column manometer.*

- Measurement of Pressure
- Differential Manometers
  - Two Piezometer Manometer
  - Inverted U-tube Differential Manometer
  - U-tube Differential Manometer
  - Micromanometer

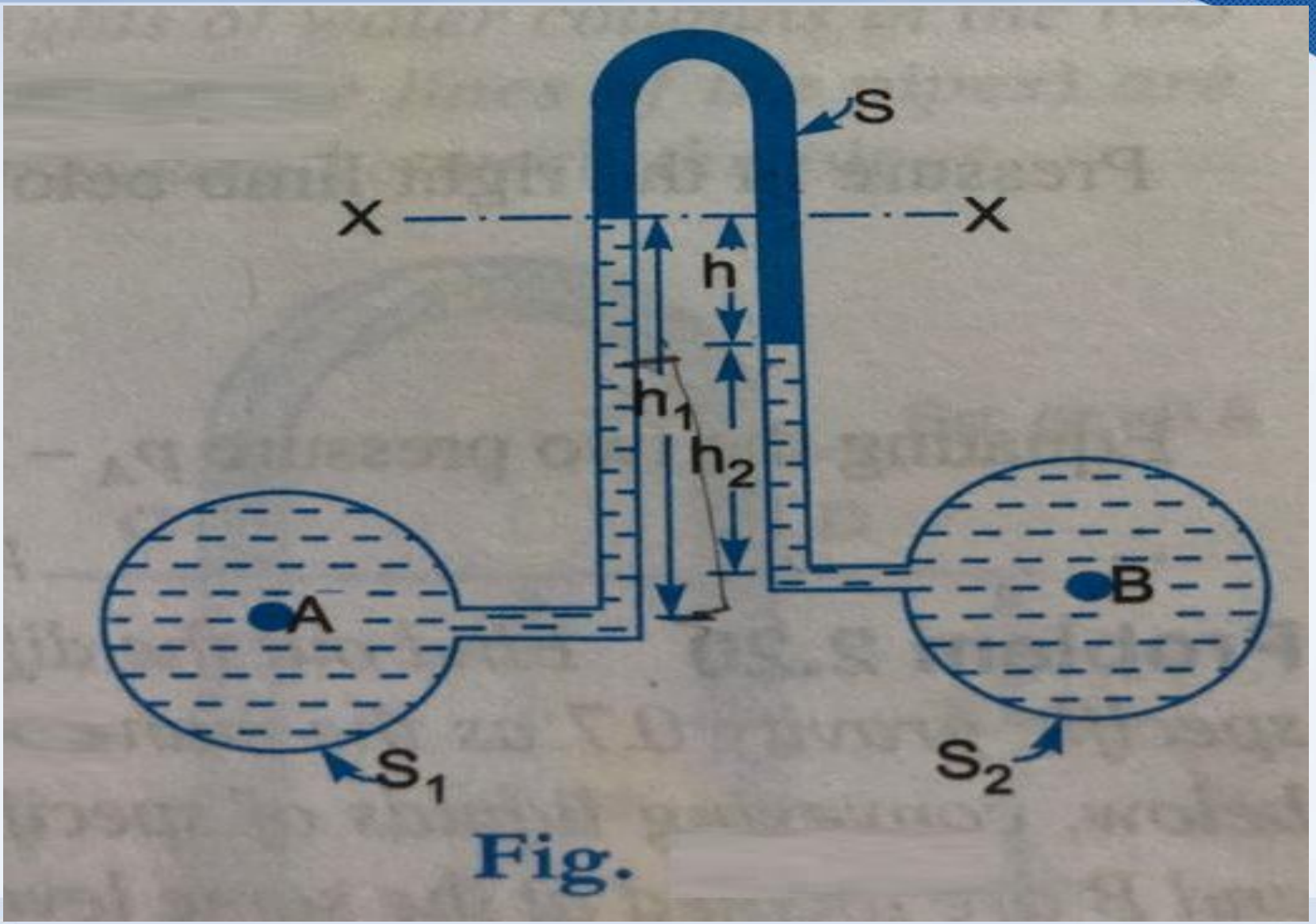
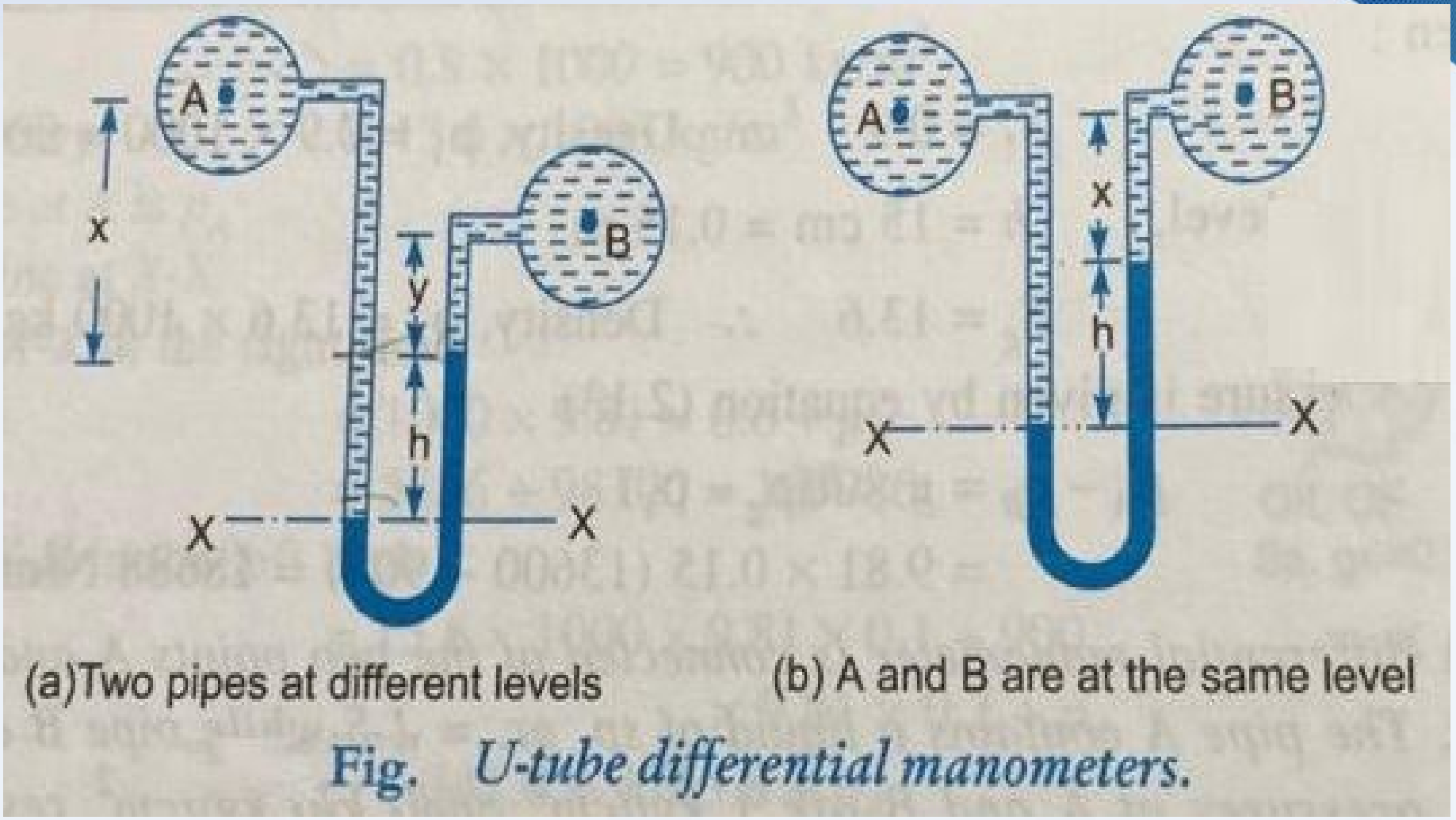


Fig.



(a)Two pipes at different levels

(b) A and B are at the same level

Fig. *U-tube differential manometers.*

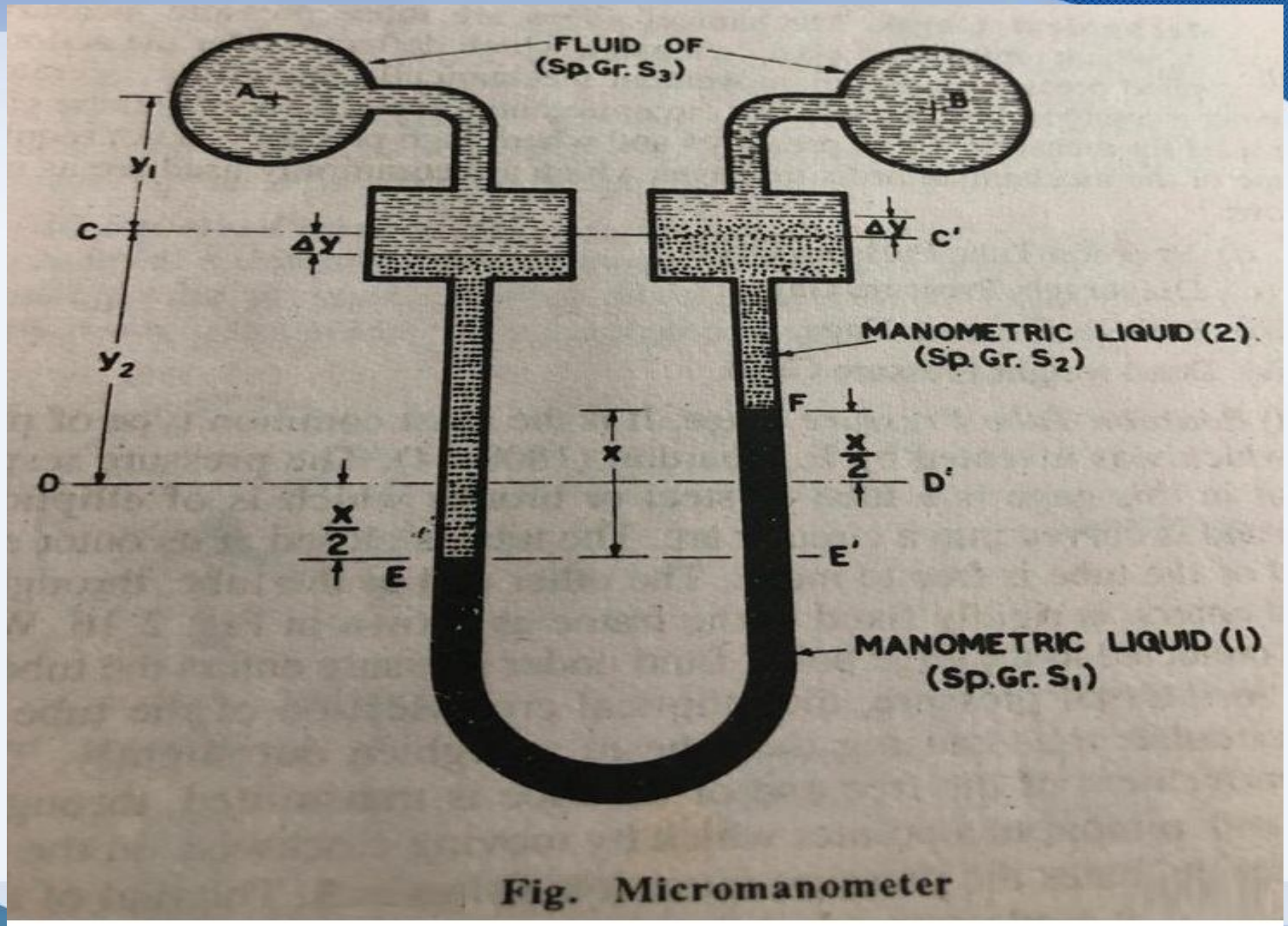


Fig. Micromanometer

MICROMANOMETER

$$A\,dY = a \times (X/2)$$

$$Pa/w + (Y1 + dY)\,S3 + (Y2 - dY + X/2)\,S2 - X\,S1 - (Y2 + dY - X/2)\,S2 - (Y1 - dY)\,S3 = Pb/w$$

- Hydrostatic Forces on Surfaces
- Total Pressure
- Center of Pressure
- Submerged Surfaces
- Horizontal plane surface Submerged in Liquid
  - Pressure Force = wAx

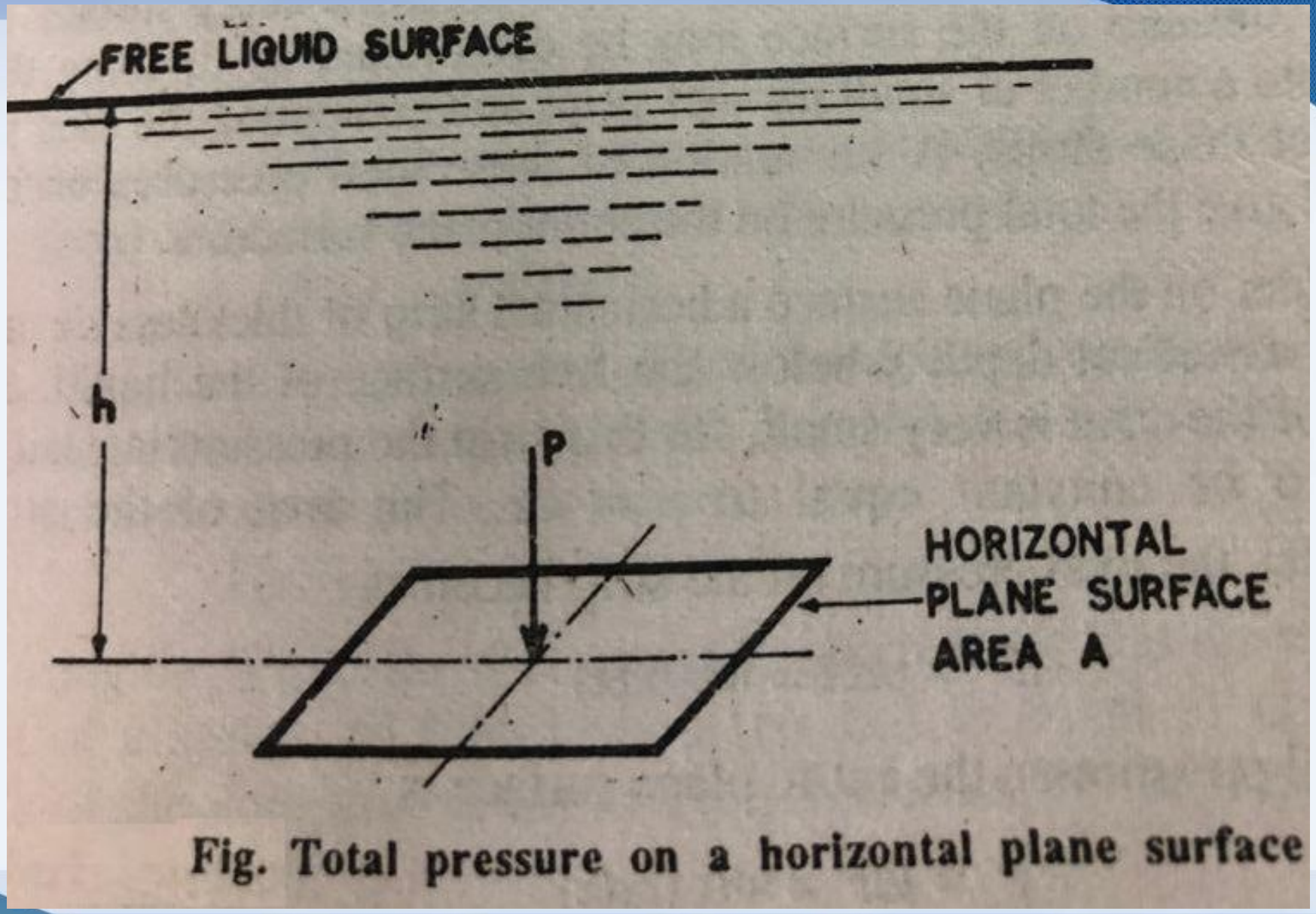


Fig. Total pressure on a horizontal plane surface

- Vertical Plane Surface Submerged in liquid
  - P=wAx
  - h= x+Icg/Ax
- Inclined Plane Surface Submerged in liquid
  - P=wAx
  - H=x+Icg Sin^2 o/Ax

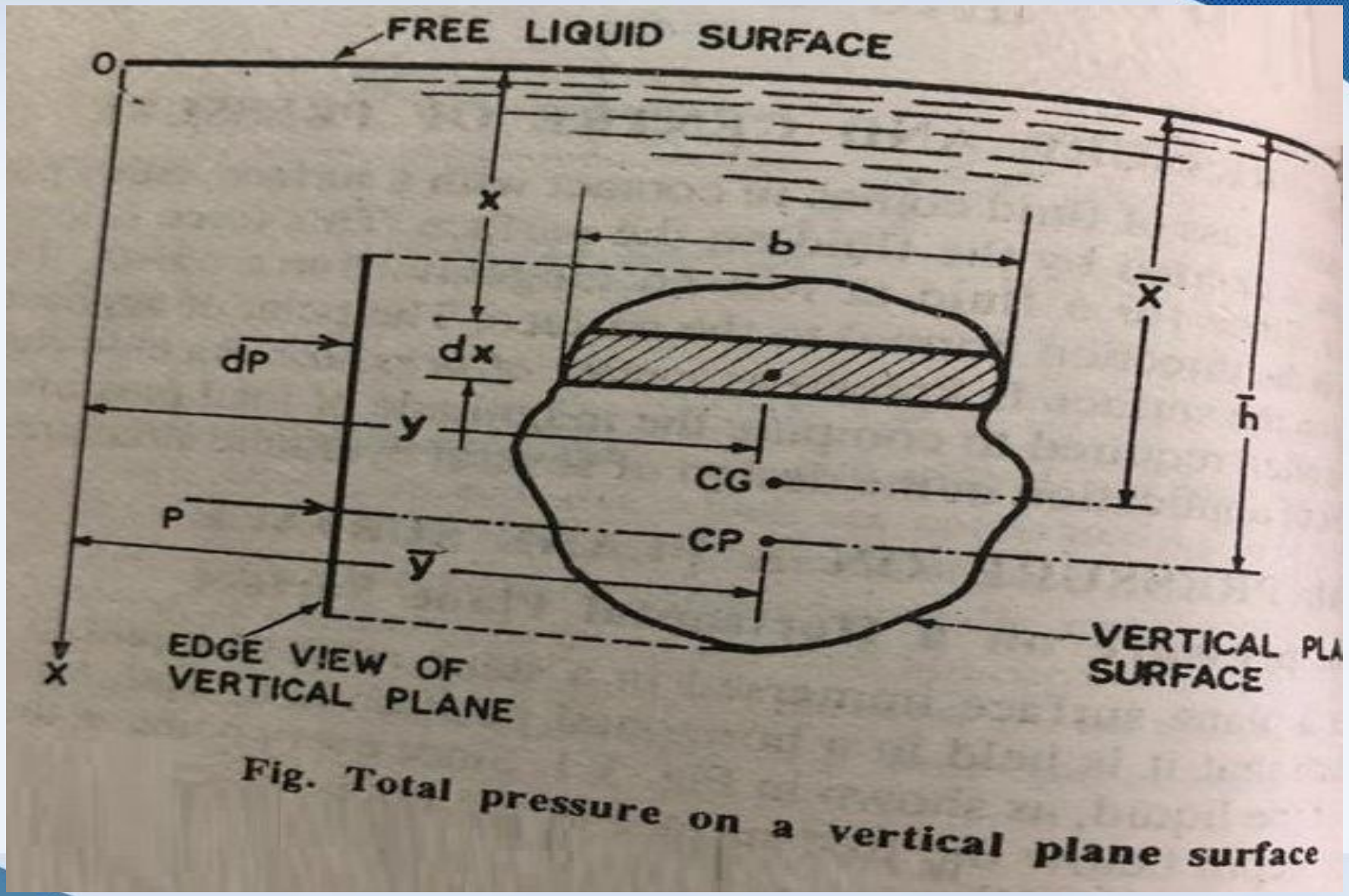


Fig. Total pressure on a vertical plane surface

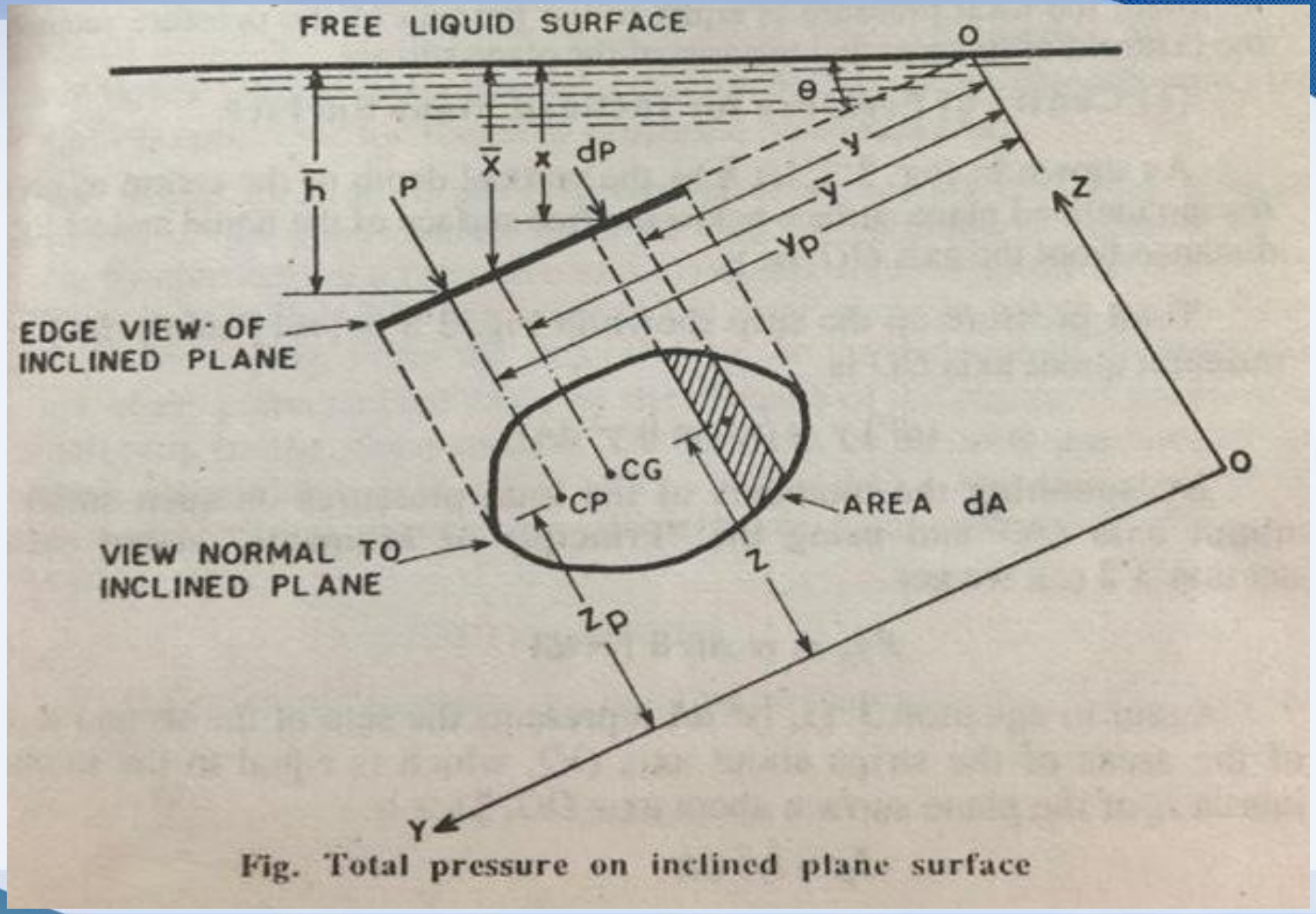


Fig. Total pressure on inclined plane surface

- Curved Surface submerged in liquid
  - Fh and Fv and Resultant Force
  - Pressure Diagram
- Practical Applications
  - Dam
  - Lock Gates

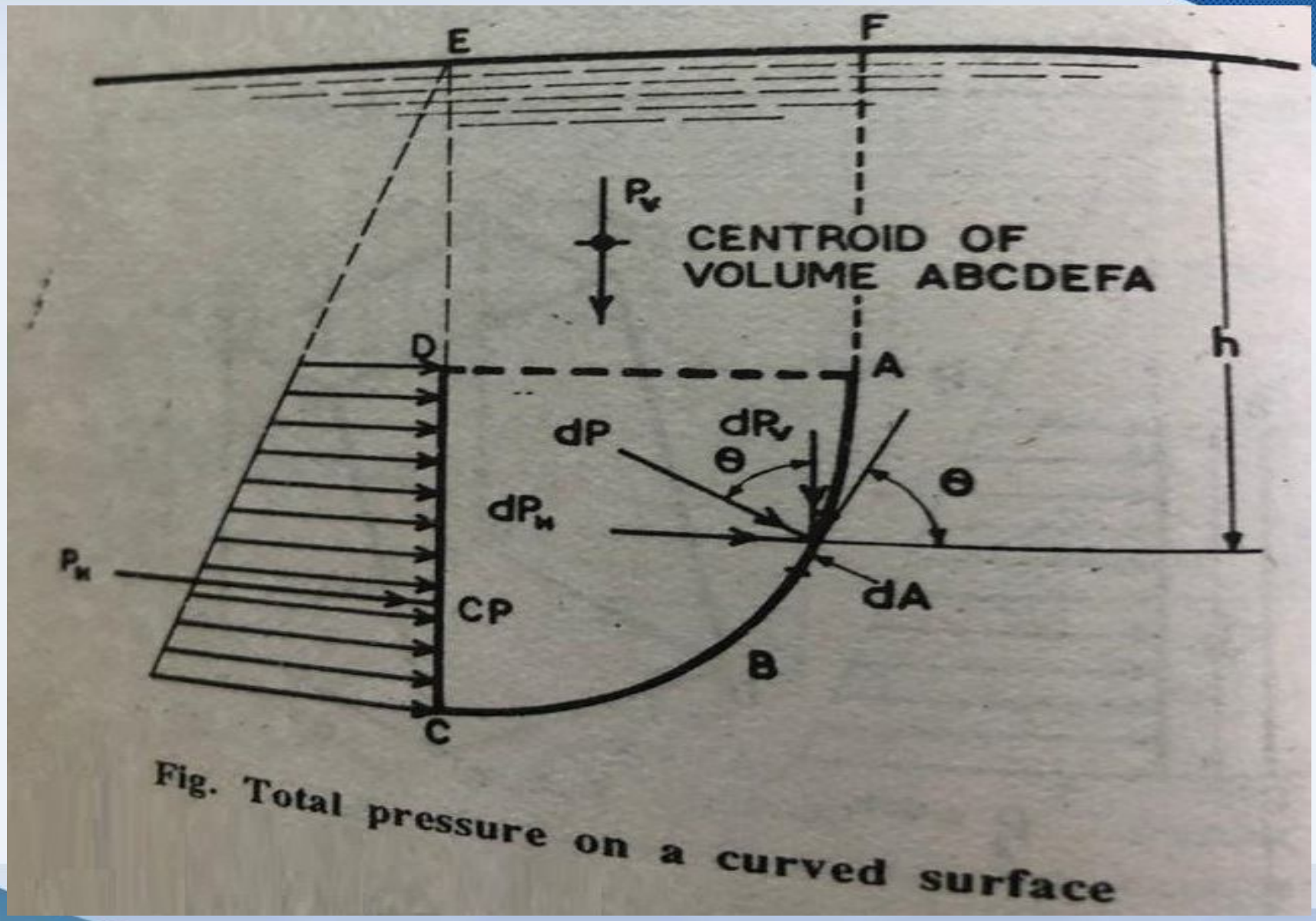
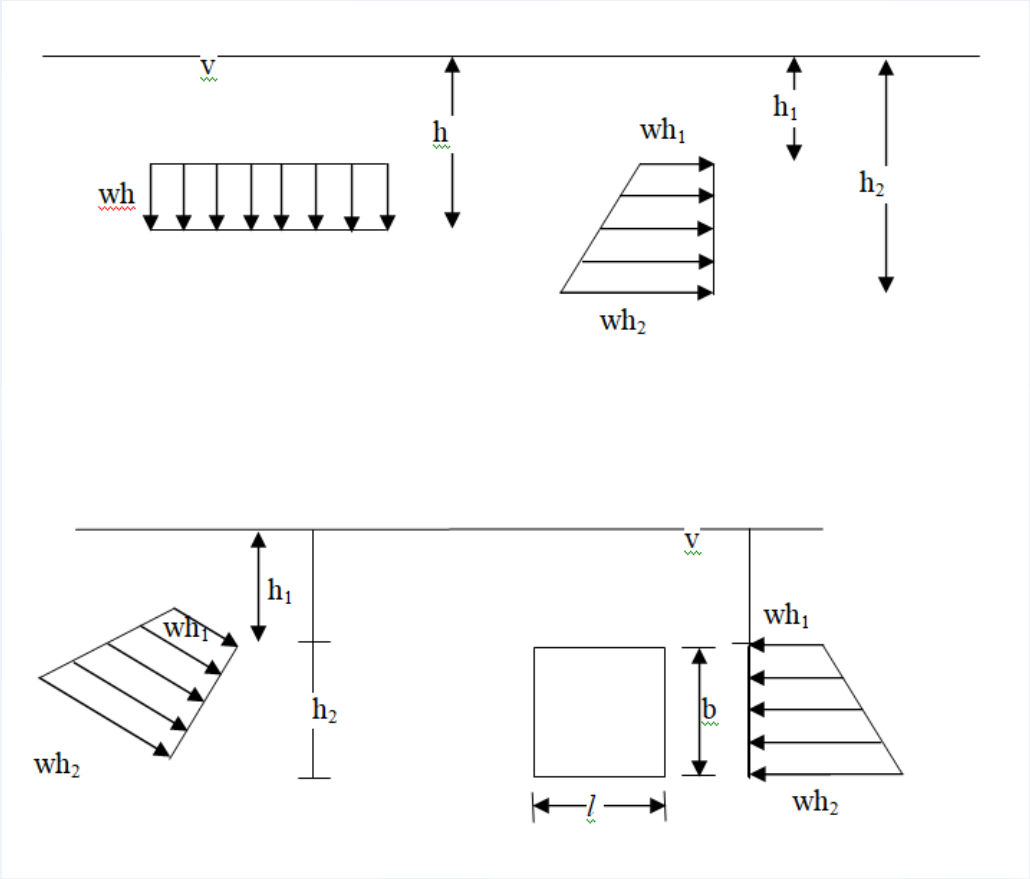


Fig. Total pressure on a curved surface

PRESSURE DIAGRAM

Graphical method for finding out total pressure and center of pressure



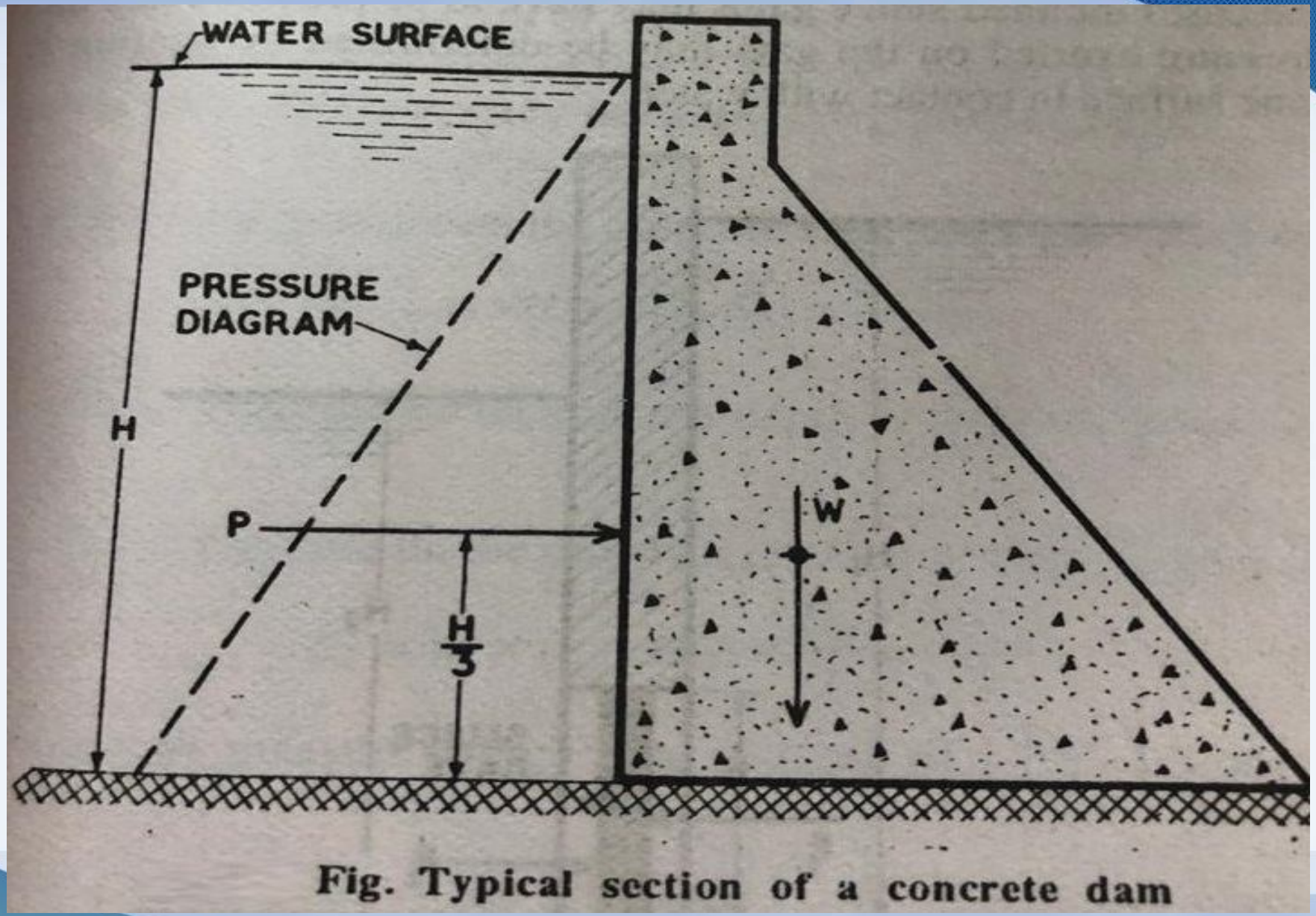


Fig. Typical section of a concrete dam

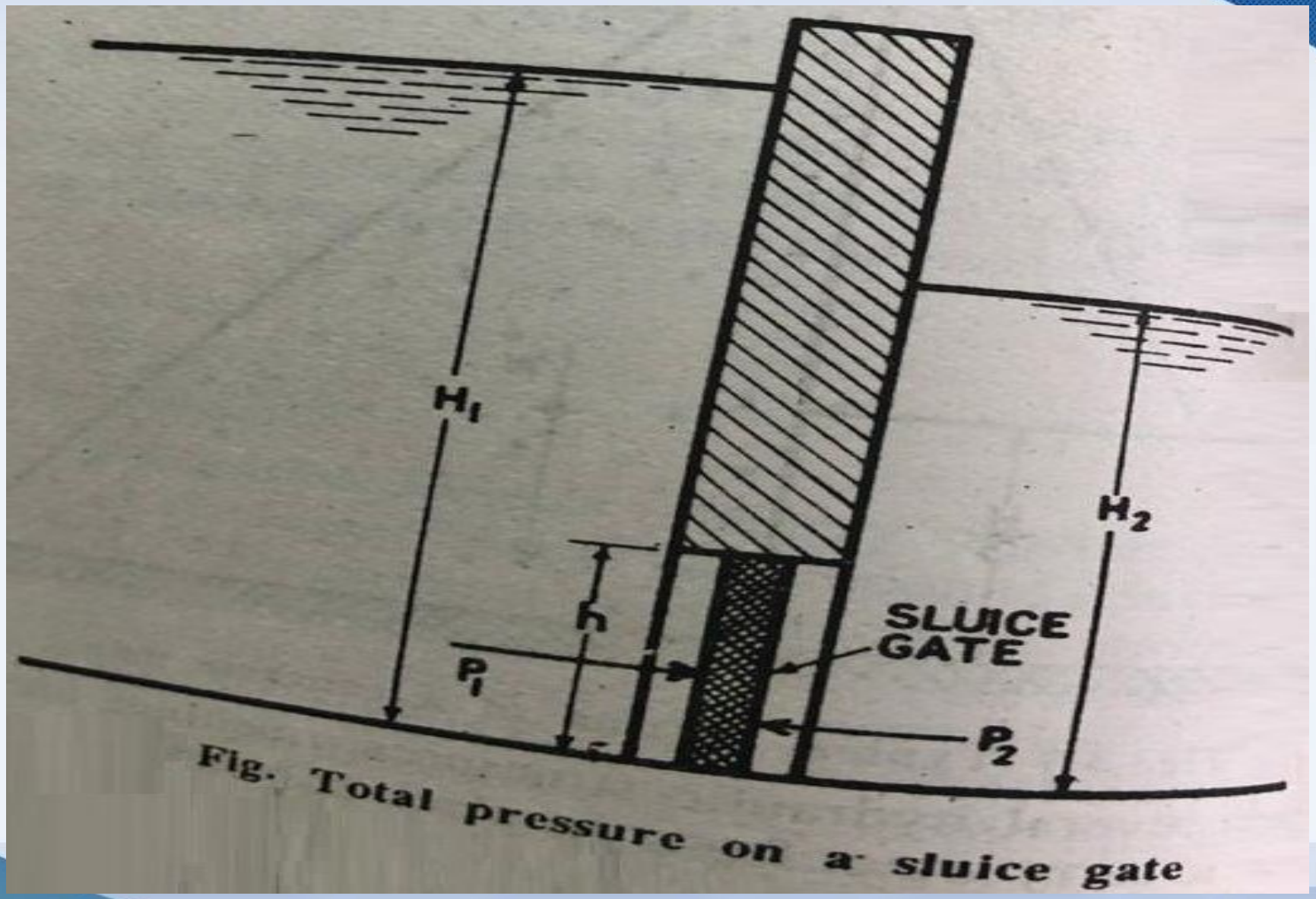
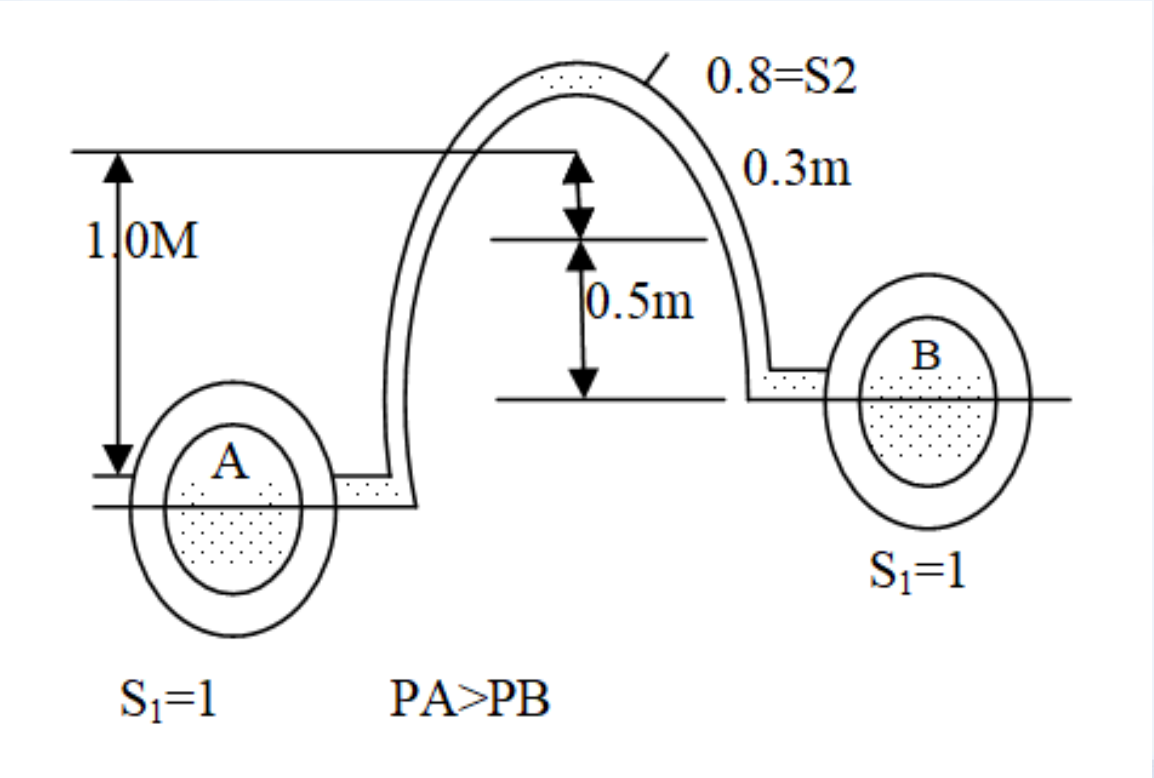


Fig. Total pressure on a sluice gate

Problem

Fig shows on inverted differential manometer connected to two pipes A and B containing water. The fluid in Manometer is oil of Sp. gravity 0.8. For the manometer shown in fig. find the difference of pressure heads between A and B.

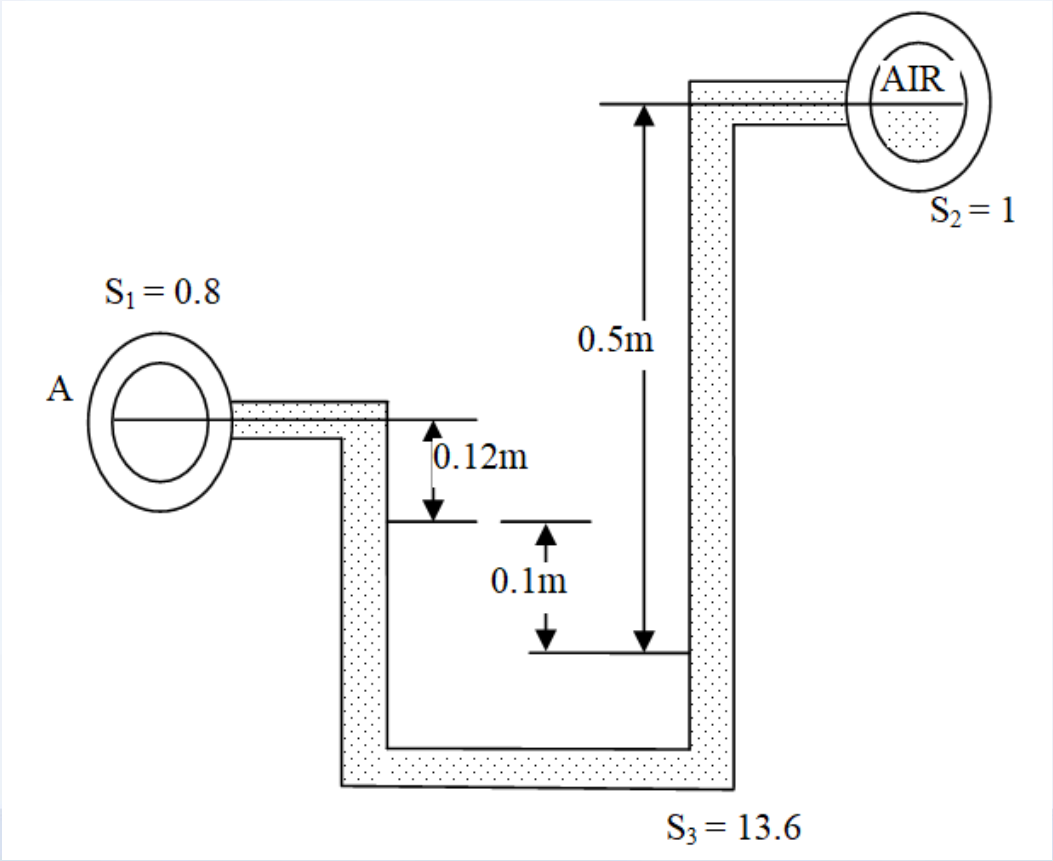
Pa/w - 1.0 x 1 + 0.3 x 0.8 + 0.5 x 1 = Pb/w ; Pa/w-Pb/w = 0.26 m



Problem

A differential manometer is connected at the two points A and B as shown. At B the pressure is 0.8 kg/cm^2, find the pressure at A.

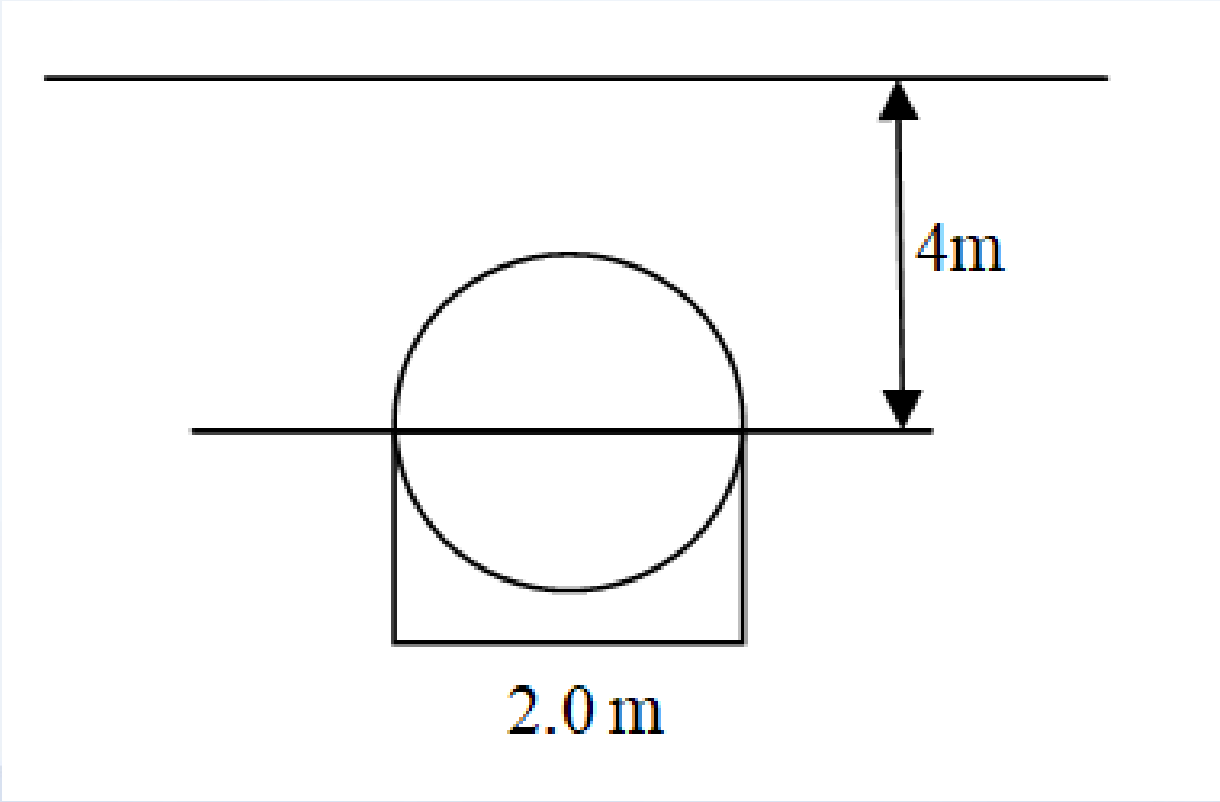
Pa/w + 0.12 x 0.8 + 0.1 x 13.6 – 0.5 x 1 = Pb/w = 8.0 m Ans: 7.044 x 10^3



Problem

Define the total pressure on a circular plate of diameter 2.0m which is placed vertically, in water in such a way that center of plate is 4m below FLS. Find the portion of center of pressure.

F = wAx= 1000 x A x 4 = 12,560 Kg(f) ; h = x + Icg/Ax = 4 + Icg/ A x 4 = 4.0625 m

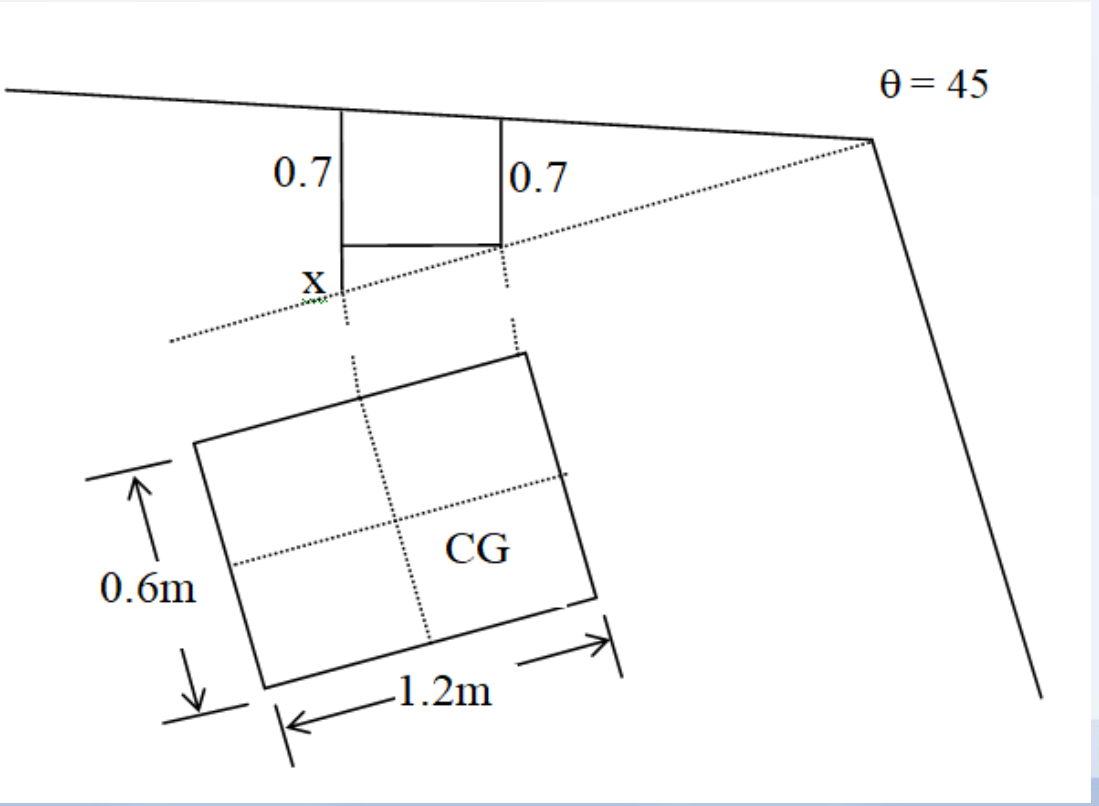


Problem

A rectangular plate 0.6m wide and 1.2m deep lies in water body such that the plane is inclined at 45^0 to the horizontal and the top edge is 0.70m below the water surface. Determine the total pressure force and the location of center of pressure

F=wAx : x = 0.7+0.6 Sin45 = 1.124 m: F= 9810x1.2x0.6x1.124=7941.15 N

h=x + Icg $Sin^2$45/Ax = 1.124+0.0864/0.6x1.2x1.124x2= 1.1776 m



Objective Questions

01. Water flowing in pumping mains may be treated as

(a) Ideal

(b) Incompressible and Non-Viscous

(c) Compressible and viscous

(d) Incompressible and viscous

02. The increase of temperature

(a) Increase the viscosity of a fluid

(b) Decreases the viscosity of a liquid

(c) Decreases the viscosity of a gas

(d) Decreases the viscosity of a fluid

03. One cubic meter of air weighs about……N.

(a) 0

(b) 12

(c) 100

(d) 0.012

04. A Hydrometer is used to measure

(a) Velocity of fluids

(b) Velocity of gases

(c) Flow (discharge) of fluids

(d) Specific weight of liquids

05. Pick up the wrong statement

(a) Piezometers cannot measure negative (vacuum) pressures

(b) Center of pressure is always below center of gravity

(c) An ideal fluid offers no resistance to shear deformation

(d) The tube in a single tube manometer is inclined to increase the accuracy

06. For measurement of very low pressures of gases, which combination of fluids is used in a Micro-manometer

(a) Mercury, Water

(b) Mercury, Kerosene

(c) Water, Kerosene

(d) Mercury, Alcohol

07. Depth of C.P. if the highest side a rectangle just touches the surface of the liquid is

(a) 2h/3

(b) 3h/2

(c) h

(d) h/2

(e) None

09. A mercury-water manometer indicates a Guage difference of 400mm. The difference of pressure in meters of water is

(a) 0.4

(b) 0.8

(c) 10.88

(d) 5.04

10. A barometer is used for measurement of

(a) Pressure in pipes

(b) Very low pressures

(c) Gauge Pressures

(d) Atmospheric pressure

11. If water (Vapour pressure = 2.6m water absolute) is used in Barometer, in place of Mercury, height of water column while measuring a pressure of 1.03 kg/sq.cm is :

(a) 10.3m

(b) 7.7m

(c) 1.03m

(d) 12.9m

(e) 3.36m

12. A vertical Gate 4m × 4m holds water with free surface at its top. The moment about bottom of gate is (y=sp.wt.)

(a) 10.67y

(b) 57y

(c) 64y

(d) 85.3y

13. 1.03 Kg(f)/ cm^2 pressure is equivalent to

(a) l bar

(b) 750 mm Hg

(c) 10.3 m of water

(d) All the above

14. The center of pressure acts at a depth of …… from the base of a dam of height ‘h’

(a) 2/3h

(b) 1/3h

(c) h/2

(d) 5/6h

17. If the gauge pressure is 0.5 kg/cm^2, the absolute pressure is approximately

(a) 0.53 kg/cm^2

(b) 10.3m of water

(c) 1.53 kg/cm^2

(d) 10.8 kg/cm^2

18. Hydrostatic force on a plane immersed surface of given area, and in a given liquid

(a) Is independent of depth of CG

(b) Decreases with increase of depth of CG

(c) Depends on area of immersion

(d) Increases with increase in depth of CG

19. Kerosene flows through a pipe under a pressure of 2.5kg/cm^2. The pressure head =

(a) 25m

(b) 20m

(c) 31.25m

(d) 2.0m

20. The forces dealt in a static fluid are …… forces.

(a) Viscous

(b) Dynamic

(c) Gravity and static pressure

(d) Frictional

21. If the submerged plane surface is vertical and touches the surface, then pressure distribution is

(a) Rectangular

(b) Triangular

(c) Trapezoidal

(d) Parabolic

22. If the depth of immersion of a vertically held circular plate is doubled then the distance between CP and CG becomes

(a) Half

(b) ¾

(c) Remains same

(d) Come closer

23 The pressure 10m below the free surface of fluid is 9600 kg/m^2. Its sp. gravity is

(a) 0.86

(b) 9.6

(c) 0.96

(d) 8.6

25. The position of Centre of pressure on a plane surface immersed vertically in a static mass of fluid is

(a) At the centroid of the submerged area

(b) Always above the centroid of the area

(c) Always below the centroid of the area

(d) Non of the above.

27. An open tank contains 1m depth water with 50cm depth of oil of specific gravity 0.8 above it. The intensity of pressure at the bottom of tank will be

(a) 400 kglm^2

(b) 1400 kg/m^2

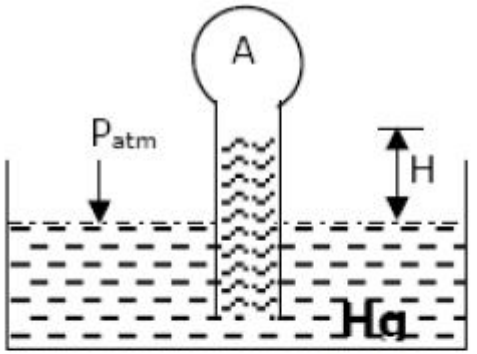
(c) 1200 kg/m^2

(d) 1000 kg/m^2

Gate Questions

GATE-1. In given figure, if the pressure of gas in bulb A is 50 cm Hg vacuum and P_{atm}=76 cm Hg, then height of column H is equal to

(a) 26 cm (b) 50 cm
(c) 76 cm (d) 126 cm



[GATE-2000]

GATE-1. Ans. (b) If the pressure of gas in bulb A is atm. H = zero.

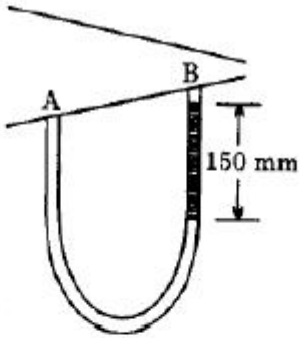
If we create a pressure of gas in bulb A is 1 cm Hg vacuum then the vacuum will lift 1 cm liquid, H = 1 cm.

If we create a pressure of gas in bulb A is 2 cm Hg vacuum then the vacuum will lift 2 cm liquid, H = 2 cm.

If we create a pressure of gas in bulb A is 50 cm Hg vacuum then the vacuum will lift 50 cm liquid, H = 50 cm.

Gate Questions

GATE-2. A U-tube manometer with a small quantity of mercury is used to measure the static pressure difference between two locations A and B in a conical section through which an incompressible fluid flows. At a particular flow rate, the mercury column appears as shown in the figure. The density of mercury is 13600 Kg/m^3 and g = 9.81m/s^2. Which of the following is correct?



(a) Flow Direction is A to B and P_A-P_B = 20 KPa
(b) Flow Direction is B to A and P_A-P_B = 1.4 KPa
(c) Flow Direction is A to B and P_B-P_A = 20 KPa
(d) Flow Direction is B to A and P_B-P_A = 1.4 KPa

[GATE-2005]

GATE-2. Ans. (a)

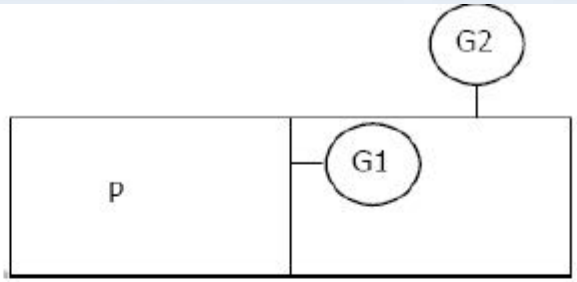
and as

$$P_B + 150\,mm - Hg = P_A \;Or\; P_A - P_B = 0.150 \times 13600 \times 9.81 \approx 20\,kPa$$

P_A is greater than P_B therefore flow direction is A to B.

Gate Questions

GATE-3. The pressure gauges G_1 and G_2 installed on the system show pressures of P_{G1} = 5.00 bar and P_{G2} = 1.00 bar. The value of unknown pressure P is? (Atmospheric pressure 1.01 bars)



(a) 1.01 bar
(b) 2.01 bar
(c) 5.00 bar
(d) 7.01 bar

[GATE-2004]

GATE-3. Ans. (d) Pressure in the right cell = P_{G_2} + Atmospheric pressure

= 1.01 + 1.0 = 2.01 bar

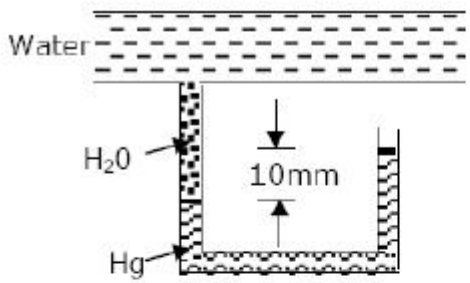
Therefore P = P_{G_1} + Pressure on right cell = 5 + 2.01 = 7.01 bar

Gate Questions

GATE-4. A mercury manometer is used to measure the static pressure at a point in a water pipe as shown in Figure. The level difference of mercury in the two limbs is 10 mm. The gauge pressure at that point is

(a) 1236 Pa (b) 1333 Pa

(c) Zero (d) 98 Pa



[GATE-1996]

GATE-4. Ans. (a)

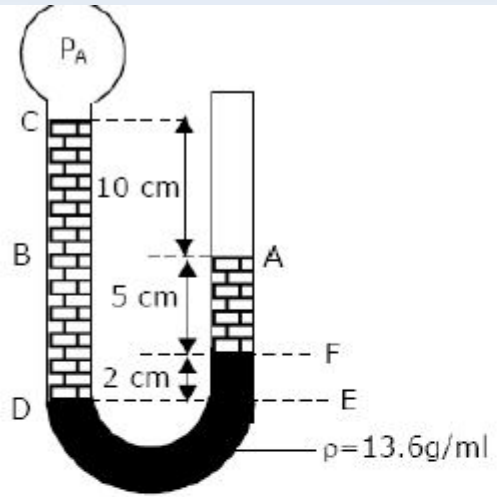
$$h = y\left(\frac{s_h}{s_l} - 1\right) \text{m of light fluid or h} = 0.010\left(\frac{13.6}{1} - 1\right) = 0.126\,\text{m of water column}$$

$$\text{or P} = \text{h}\rho\text{g} = 0.126 \times 1000 \times 9.81 = 1236\,\text{N/m}^2 = 1236\,Pa$$

Gate Questions

GATE-5. Refer to Figure, the absolute pressure of gas A in the bulb is:

(a) 771.2 mm Hg
(b) 752.65 mm Hg
(c) 767.35 mm Hg
(d) 748.8 mm Hg



[GATE-1997]

GATE-5. Ans. (a) Use 'hs' formula;

$$H_A + 170\times1 - 20\times13.6 - 50\times1 = h_{atm.}(760\times13.6) \text{ [All mm of water]}$$

$$\text{Or } H_A = 10488/13.6 \text{ mm of Hg} = 771.2 \text{ mm of Hg}(Abs.)$$

GATE-6. A siphon draws water from a reservoir and discharges it out at atmospheric pressure. Assuming ideal fluid and the reservoir is large, the velocity at point P in the siphon tube is: [GATE-2006]

(a) $\sqrt{2gh_1}$ (b) $\sqrt{2gh_2}$ (c) $\sqrt{2g(h_2-h_1)}$ (d) $\sqrt{2g(h_2+h_1}$

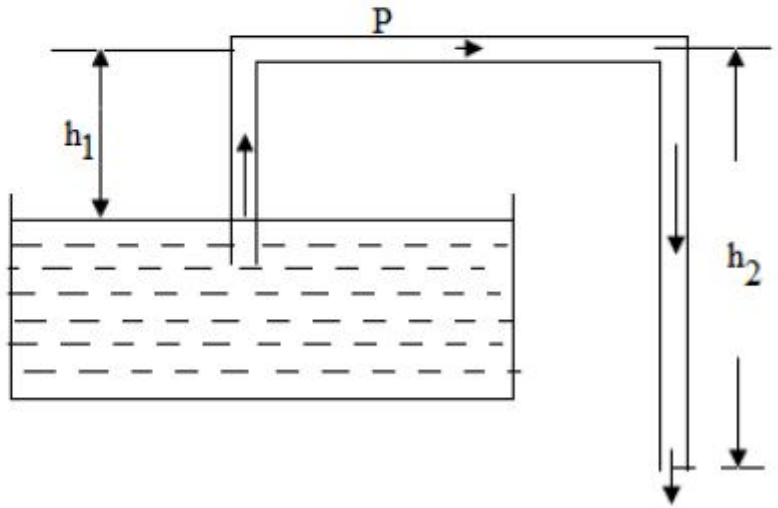
GATE-6. Ans. (c) By energy conservation, velocity at point Q =

$$\sqrt{2g(h_2-h_1)}$$

As there is a continuous and uniform flow, so velocity of liquid at point Q and P is same.

V_p =

$$\sqrt{2g(h_2-h_1)}$$



Gate Questions

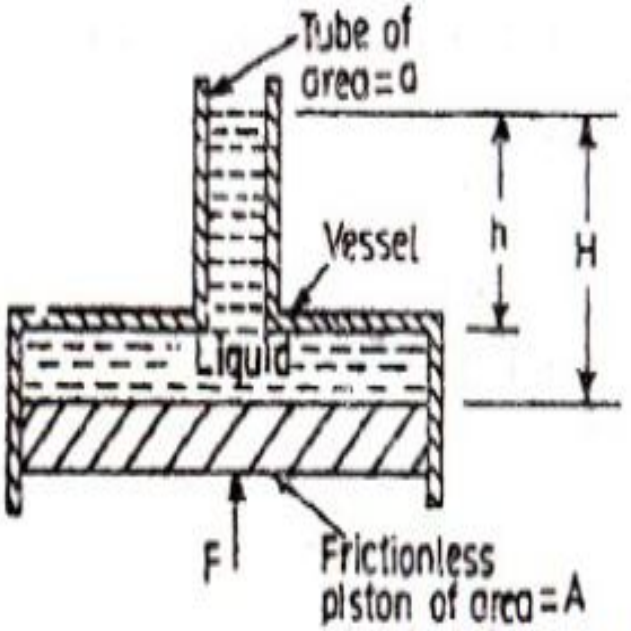
GATE-1. The force F needed to support the liquid of denity d and the vessel on top is:

(a) $gd[ha - (H - h)A]$

(b) $gdHA$

(c) $GdHa$

(d) $gd(H - h)A$



[GATE-1995]

GATE-1. Ans. (b)

One Mark Questions

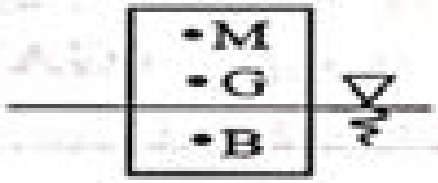
01. A floating body with its center of gravity at 'G' center of buoyancy at 'B' and meta centre at 'M' is stable when

(a) G lies above B (b) B lies above M

(c) B lies below M (d) G lies below M

01. **Ans: (d)**

Sol: Relative positions of M, G, B are shown for stable equilibrium of a floating body.



02. Shear stress develops on a fluid element, if the fluid

(a) is at rest

(b) if the container is subjected to uniform linear acceleration

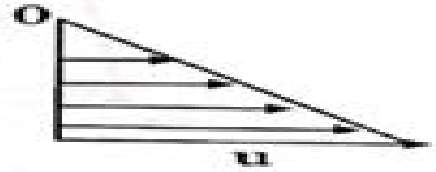
(c) is inviscid

(d) is viscous and the flow is non-uniform.

02. Ans: (d)

Sol: Real fluids are viscous in nature.

For real fluids with general or non uniform motion.



$\mu \neq 0$, $u \neq 0$ and $du \neq 0$

$\therefore \frac{du}{dy} \neq 0$ and hence $\tau \neq 0$

$\therefore$ Pascal's uniform pressure in all directions at a point is not valid for real fluids with non-uniform motion.

03. If, for a fluid in motion, pressure at a point is same in all directions, then the fluid is

(a) a real fluid
(b) a Newtonian fluid
(c) an ideal fluid
(d) a non-Newtonian fluid

03. Ans: (c)

Sol: Pressure is uniform in all directions only if shear stress is zero. Shear stress is zero always (not only in the state of rest but also in motion) for ideal fluids.

04. In a static fluid, the pressure at a point is

(a) Equal to the weight of the fluid above
(b) Equal in all directions
(c) Equal in all directions, only if, its viscosity is zero
(d) Always directed downwards

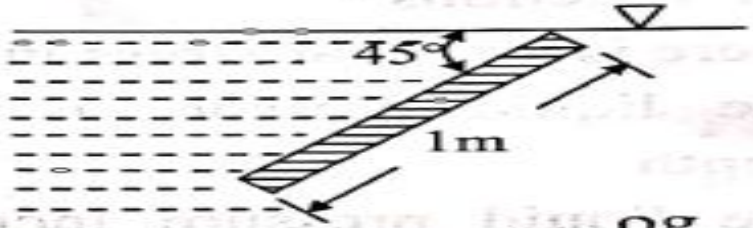
04. Ans: (b)

Sol: For static fluids $v = 0$,

$$\therefore \frac{dv}{dy} = 0 \qquad \therefore \tau = 0$$

Hence for static fluids whether ideal or real pressure is uniform in all directions at a point.

05. The force per unit width on the rectangular door submerged in a liquid of density ρ (Figure shown below) is



(a) $\sqrt{2}\ \rho g$

(b) $\frac{\rho g}{2}$

(c) $\frac{\rho g}{2\sqrt{2}}$

(d) $\frac{2}{\rho g}$

05. **Ans: (c)**

Sol: $F_N = \rho g.\bar{h}.A$

$$= \rho g.\left(\frac{1}{2}.\sin 45°\right)(1\times 1) = \rho g\ \frac{1}{2}.\frac{1}{\sqrt{2}} = \frac{\rho g}{2\sqrt{2}}$$

$\bar{h}$ = Effective vertical depth of the C.G of the plate from free surface.

06. Which one of the following statements is true with regards to bodies that float or submerged in liquids:

(a) For a body wholly submerged in a liquid the stability is ensured if the center of buoyancy is below the center of gravity of the body

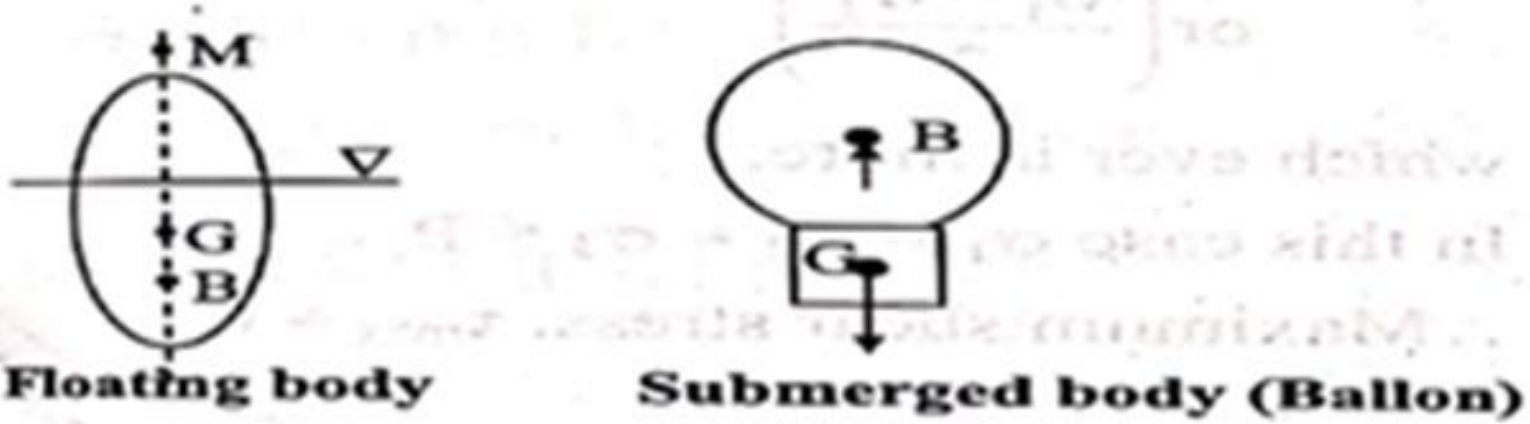
(b) For a body floating in liquid the stability is ensured if the center of buoyancy is below the centre of gravity of the body.

(c) For a body floating in a liquid the stability is ensured if the center of buoyancy and the centre of gravity coincides.

(d) For a body floating in a liquid the stability is ensured if the center of buoyancy is below the center of gravity and the metacentre is above both the centres of gravity and buoyancy.

06. **Ans: (d)**

Sol:



Floating body **Submerged body (Ballon)**

M = Meta centre

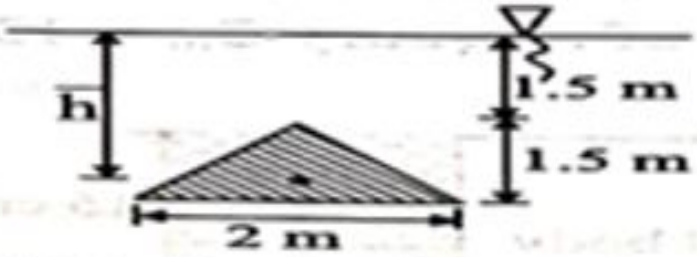
G = C.G of body

B = Centre of buoyancy

08. A triangular gate with a base width of 2 m and a height of 1.5 m lies in a vertical plane. The top vertex of the gate is 1.5 m below the surface of a tank which contains oil of specific gravity 0.8. Considering the density of water and acceleration due to gravity to be 1000 kg/m^3 and 9.81 m/s^2 respectively, the hydrostatic force (in kN) exerted by the oil on the gate is _____

08. Ans: 29.3 to 29.5

Sol:



Area of vertical triangular gate A

$$= \left(\frac{1}{2} \times 2 \times 1.5\right) = 1.5 \text{ m}^2$$

Depth of CG of plate from free surface $\bar{h}$

$$= \left(1.5 + \frac{2}{3} \times 1.5\right) = 2.5 \text{ m}$$

Density of fluid $\rho = 0.8 \times 1000 = 800 \text{ kg/m}^3$

Now, Hydrostatic force $(F) = \rho.g.\bar{h}.A$

$$= 800 \times 9.81 \times 2.5 \times 1.5$$

$$= 29430 \text{ N} = 29.43 \text{ kN}$$


THANK YOU
VERY MUCH