# POSTAL Book Package 2021

## Mechanical Engineering

### Conventional Practice Sets

## Fluid Mechanics and Fluid Machinery

*Contents*




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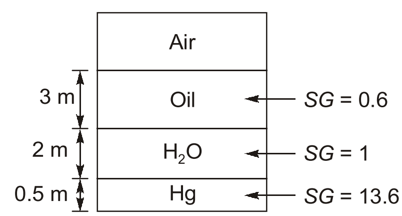
# 2 CHAPTER Fluid Pressure and its Measurement

**Q.1** A closed tank contains 0.5 m thick layer of mercury (specific gravity = 13.6) at the bottom. A 2.0 m thick layer of water lies above the mercury layer. A 3.0 m thick layer of oil (specific gravity = 0.6) lies above the water layer. The space above the oil layer contains air under pressure. The gauge pressure at the bottom of the tank is 196.2 kN/m$^2$. The density of water is 1000 kg/m$^3$ and the acceleration due to gravity is 9.81 m/s$^2$. Find the pressure of air in the air tank base.

**Solution:**




$P_{air}$ is in gauge pressure.

$P_{air} + (0.6 \times 10^3)(9.81)(3) + (10^3)(9.81)(2) + (13.6 \times 10^3)(9.81)(0.5) = 196.2 \times 10^3$

$P_{air} = 92.214$ kN/m$^2$

**Note:** It is a closed chamber, hence concept of absolute pressure cannot be applied. Calculations have to be done in the form of gauge pressure.

**Q.2** What are the gauge pressure and absolute pressure at a point 3 m below the free surface of a 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 is 1000 kg/m$^3$.

Solution:

Given:

Depth of liquid, $Z_1 = 3$ m

Density of liquid, $\rho_1 = 1.53 \times 10^3$ kg/m$^3$

Atmospheric pressure head, $Z_0 = 750$ mm of Hg = 0.75 of Hg

$\therefore$ Atmospheric pressure, $p_{atm} = \rho_0 \, g \, Z_0$

where $\rho_0$ = Density of Hg

= Specific gravity of mercury × Density of water

$= 13.6 \times 1000$ kg/m$^3$

and $Z_0$ = Pressure head in terms of mercury.

$\therefore$ $p_{atm} = (13.6 \times 1000) \times 9.81 \times 0.75$ N/m$^2$ $\quad (\because Z_0 = 0.75)$

$= 100062$ N/m$^2$

Pressure at a point, which is at a depth of 3 m from the free surface of the liquid is given by,

$$p = \rho_1 \times g \times Z_1 = (1.53 \times 1000) \times 9.81 \times 3$$

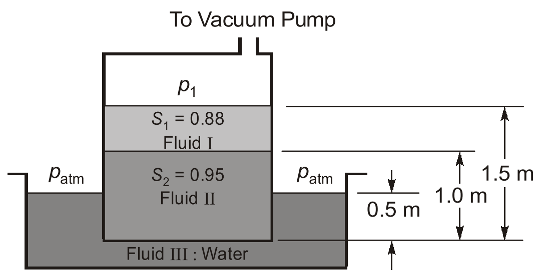
$$= 45028 \text{ N/m}^2$$

$\therefore$ Gauge pressure, $\quad p = 45028 \text{ N/m}^2$

Now, $\quad$ Absolute pressure = Gauge pressure + Atmospheric pressure

$$= 45028 + 100062 = 145090 \text{ N/m}^2$$

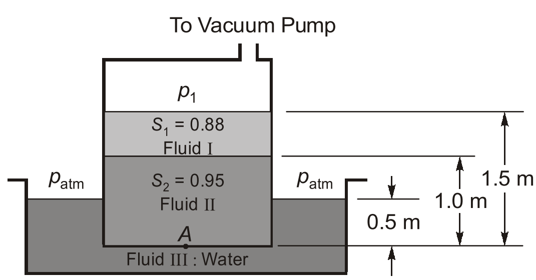
**Q3** A three-fluid system (immiscible) is connected to a vacuum pump. The specific gravity values of the fluids ($S_1$, $S_2$) are given in the figure.




Unit weight of water, $\gamma_w$ = 9.81 kN/m$^3$
Atmospheric Pressure, $p_{atm}$ = 95.43 kPa

Estimate the gauge pressure value (in kN/m$^2$, up to two decimal places) of $p_1$.

**Solution:**




Taking $p_1$ as gauge pressure.

$$p_A = p_1 + (0.88 \times 10^3)\cdot(9.81)(0.5) + (0.95 \times 10^3)(9.81)(1)$$

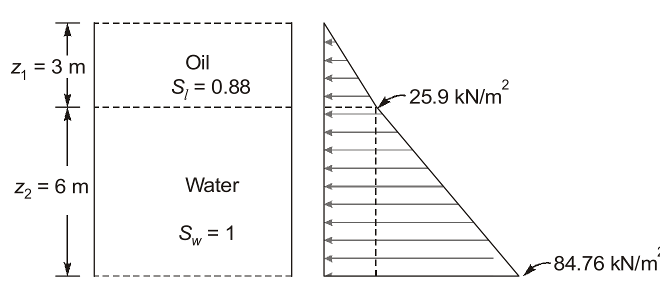
$$(10^3)(9.81)(0.5) = p_1 + (0.88 \times 10^3)\cdot(9.81)(0.5) + (0.95 \times 10^3)(9.81)(1)$$

$$p_1 = -8.73 \text{ kN/m}^2$$

**Q4** A 9 m deep tank contains 6 m of water and 3 m of oil of relative density 0.88. Determine the pressure at the bottom of the tank. What is the pressure at the bottom of the tank if the entire tank is filled with water? What is the water thrust in this case? Draw the pressure distribution diagram in both the cases.

Solution:

Case 1: Gauge pressure at top = 0




Pressure at interface $= s_l \gamma_w z_1$

$$= 0.88 \times 9.81 \times 3$$

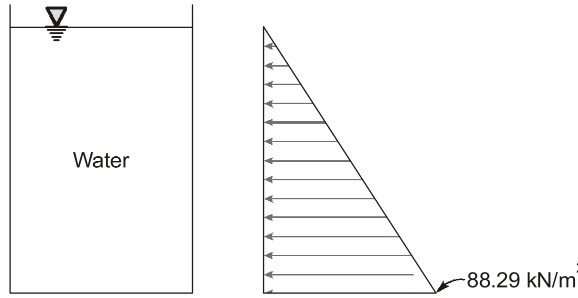
$$= 25.90 \text{ kN/m}^2$$

Pressure at bottom $= s_l \gamma_w z_1 + \gamma_w z_2$

$$= 0.88 \times 9.81 \times 3 + 9.81 \times 6$$

$$= 84.76 \text{ kN/m}^2$$

Case 2:




Pressure at top $=$ 0

Pressure at bottom $= \gamma_w H = 9 \times 9.81 = 88.29$ kN/m$^2$

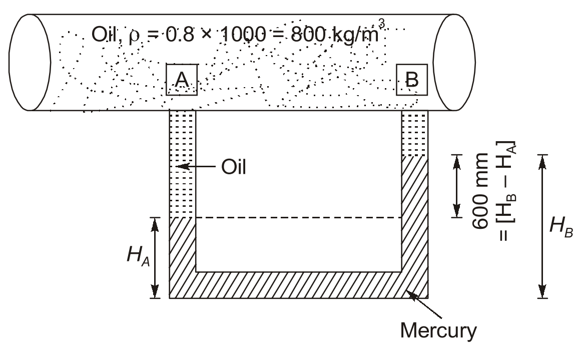
$$\boxed{\text{Water thrust} = \frac{1}{2}(\gamma_w H) \times H}$$

$$= \frac{1}{2} \times 88.29 \times 9 = 397.305 \text{ kN per meter width of wall}$$

**Q.5** U-tube differential gauge is attached to two section *A* and *B* in a horizontal pipe in which oil of specific gravity 0.8 is flowing. The deflection in mercury in the gauge is 600 mm, level of manoment fluid near A being lower one. Calculate the differential pressure in kPa. Draw a neat sketch of the arrangement.

Solution:

For arrangement




Oil density, $\rho = 0.8 \times 1000 = 800$ kg/m$^3$

Mercury density, $\rho_m = 13600$ kg/m$^3$

Let pressure at '*A*' be $P_A$, pressure at *B* be $P_B$

Equating pressure at bottom of gauge

$$P_A + \rho g(H_B - H_A) = P_B + \rho_m g(H_B - H_A)$$

i.e.,

$$P_A - P_B = (\rho_m - \rho) g (H_B - H_A)$$

$$= (13600 - 800) \times 9.81 \times \frac{600}{1000} \times \frac{1}{1000} = 75.34 \text{ kPa}$$

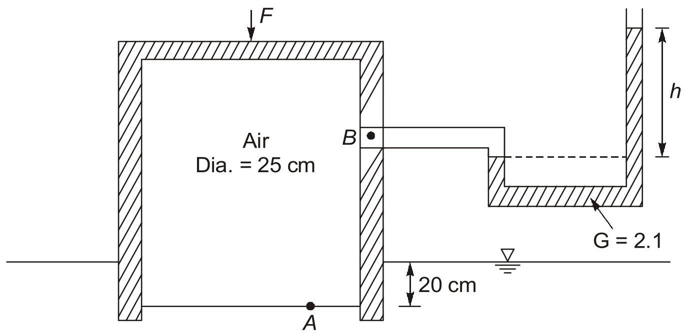
**Alternate Solution:**

From figure differential head, $h = \left(\frac{13.6}{0.8} - 1\right) \times 0.6 = 9.6$ m of oil

Differential pressure $\Delta p = (p_A - p_B) = \rho_{oil} \times g \times h = 800 \times 9.81 \times 9.6$

$= 75340.8$ Pa or 75.34 kPa

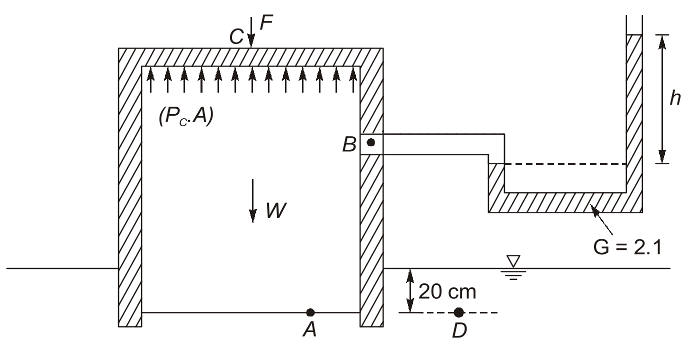
**Q.6** A cylindrical container whose weight is 65 N is inserted and pressed into water as shown in figure below:




Determine the differential height 'h' of the manometer and the force 'F' Needed to hold the container at position shown in figure.

**Solution:**

Given:




$\because$ $\Sigma F_V = 0$

$(P_C A) - F - W = 0$

$P_C A - W = F$ ...(i)

$P_A = P_B = P_C$

(With moderate change in elevation in gas, pressure does not change)

$P_D = P_A = 0.2\,\gamma_w$

$$F = 0.2\gamma_w\left(\frac{\pi}{4}\right)d^2 - W$$

$$= 0.2 \times 9810 \times \frac{\pi}{4} \times (0.25)^2 - 65$$

$= 96.31 - 65 = 31.31$ N

Also, $P_B = 2.1\,\gamma_w h$

$\Rightarrow$ $0.2\,\gamma_w = 2.1\,\gamma_w\,h$

$$h = \frac{0.2}{2.1} = \frac{2}{21}\text{m}$$

$= 9.52$ cm