Teaching task

Jee mains level

1. **Step 1: Convert units and identify values**

The given values must first be converted to SI units (meters, kilograms, seconds). The standard density of mercury is also needed.

Height of the mercury column (h): 76 cm=0.76 m
Density of mercury (ρ): 13600 kg/m^3
Acceleration due to gravity (g): 10 m/s^2

Step 2: Apply the pressure formula
The pressure (P) exerted by a liquid column is calculated using the formula $P=\rho gh$
Substitute the values into the formula:
P=13600 kg/m^3×10 m/s^2×0.76 m
Calculate the result:
P=103360 N/m^2
The SI unit for pressure is the Pascal (Pa), where 1 Pa=1 N/m^2

2.
Step 1: Identify Given Variables and Formula

The variables provided are pressure $P = 600$ Pa, density $\rho = 12$ kg/m^3, and acceleration due to gravity $g = 10$ m/s^2. The relationship between pressure and height in a static fluid is given by the formula:

$$P = \rho gh$$

Step 2: Rearrange Formula and Substitute Values

To find the height h, we rearrange the formula to:

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

Substitute the given values into the equation:

$$h = \frac{600}{(12)(10)}$$

Step 3: Calculate the Height

Perform the calculation:

$$h = \frac{600}{120} \text{ m}$$

$$h = 5 \text{ m}$$

3.

Step 1: Calculate the height difference

The height of the third floor can be calculated using the hydrostatic pressure formula, which relates the pressure difference to the height difference, density, and gravitational acceleration:

$$\Delta P = \rho g h$$

We can rearrange the formula to solve for the height h:

$$h = \frac{P_1 - P_2}{\rho g}$$

Substituting the given values into the equation: $P_1 = 120000\,\mathrm{Pa}$, $P_2 = 30000\,\mathrm{Pa}$, $\rho = 1000\,\mathrm{kg/m^3}$, and $g = 10\,\mathrm{m/s^2}$.

$$h = \frac{120000\,\mathrm{Pa} - 30000\,\mathrm{Pa}}{1000\,\mathrm{kg/m^3} \times 10\,\mathrm{m/s^2}}$$

$$h = \frac{90000\,\mathrm{Pa}}{10000\,\mathrm{kg/(m^2 \cdot s^2)}}$$

$$h = 9\,\mathrm{m}$$

4.

Step 1: Define variables and relationships

Let A_L and A_R be the cross-sectional areas of the left and right limbs, respectively, where $A_R = 3A_L$. Let ρ_w be the density of water ($1.0\ \mathrm{g/cm^3}$) and ρ_m be the density of mercury ($13.6\ \mathrm{g/cm^3}$). When water is added to the left limb, the mercury level drops by a distance y_L in the left limb and rises by a distance y_R in the right limb.

Due to the conservation of volume for the mercury displaced:

$$A_L y_L = A_R y_R = 3A_L y_R$$

This gives the relationship between the changes in height:

$$y_L = 3y_R$$

The initial empty space in the left limb is $l = 30\ \mathrm{cm}$. The final height of the water column, h_w, is the initial space plus the distance the mercury level dropped:

$$h_w = l + y_L = 30 + 3y_R$$

The height of the mercury column above the new equilibrium level in the right limb is $h_m = y_R + y_R = 2y_R$. Wait, the pressure balance is at the *new* mercury-mercury interface in the left limb. The height of the mercury column above this level in the right limb is $h_m = y_R + y_R$ (relative to the initial level). The difference in the final mercury levels is $h_m = y_L + y_R = 3y_R + y_R = 4y_R$.
The height of the water column is $h_w = 30 + 3y_R$.

Step 2: Apply the principle of fluid statics

The pressure at the same horizontal level (the new mercury-mercury interface in the left limb) in the connected fluid must be equal. The pressure in the left limb is due to the water column, and the pressure in the right limb is due to the new, taller mercury column:

$$P_{\text{left}} = P_{\text{right}}$$

$$\rho_w g h_w = \rho_m g h_m$$

Substitute the expressions for h_w and h_m in terms of y_R:

$$\rho_w(30 + 3y_R) = \rho_m(4y_R)$$

Step 3: Solve for the rise in mercury level (y_R)

Substitute the given densities ($\rho_w = 1\,\text{g/cm}^3$, $\rho_m = 13.6\,\text{g/cm}^3$):

$$1 \cdot (30 + 3y_R) = 13.6 \cdot (4y_R)$$

$$30 + 3y_R = 54.4y_R$$

$$30 = 51.4y_R$$

$$y_R = \frac{30}{51.4}$$

Answer:

The mercury level will rise by $\mathbf{y_R} \approx \mathbf{0.58}\,\text{cm}$ in the right-hand limb.

5.

Step 1: Calculate Pressure

The pressure exerted by a column of water is calculated using the formula $P = \rho g h$, where ρ is the density, g is the acceleration due to gravity, and h is the height.

$$P = 1000\,\mathrm{kg/m^3} \times 10\,\mathrm{m/s^2} \times 1\,\mathrm{m} = 10000\,\mathrm{Pa}$$

Step 2: Calculate Force

The force exerted on the base is the product of the pressure and the base area, $F = P \times A$. The base area A is given as $1.5\,m^2$.

$$F = 10000\,\mathrm{Pa} \times 1.5\,\mathrm{m^2} = 15000\,\mathrm{N}$$

6.

Step 1: Calculate areas and identify knowns

The problem provides the diameters of the smaller and larger pistons ($d_1 = 5\,\mathrm{cm} = 0.05\,\mathrm{m}$, $d_2 = 60\,\mathrm{cm} = 0.6\,\mathrm{m}$) and the force applied to the smaller piston ($F_1 = 50\,\mathrm{N}$). We want to find the force on the larger piston (F_2). The area of a circle is given by $A = \frac{\pi d^2}{4}$.

Step 2: Apply Pascal's Principle

Pascal's principle states that the pressure transmitted throughout an enclosed static fluid is constant. Thus, the pressure on the smaller piston equals the pressure on the larger piston:

$$P_1 = P_2$$

$$\frac{F_1}{A_1} = \frac{F_2}{A_2}$$

We rearrange this equation to solve for the unknown force F_2:

$$F_2 = F_1 \frac{A_2}{A_1}$$

Step 3: Substitute values and solve for the force

Substitute the area formulas into the rearranged equation. The constants and π terms cancel out:

$$F_2 = F_1 \frac{\pi d_2^2/4}{\pi d_1^2/4} = F_1 \frac{d_2^2}{d_1^2}$$

Plugging in the given values:

$$F_2 = 50\,\mathrm{N} \times \left(\frac{0.6\,\mathrm{m}}{0.05\,\mathrm{m}} \right)^2$$

$$F_2 = 50\,\mathrm{N} \times (12)^2$$

$$F_2 = 50\,\mathrm{N} \times 144 = 7200\,\mathrm{N}$$

7.

Step 1: Calculate the pressure difference

The difference in pressure between the ground floor ($\mathbf{P_1}$) and the first floor ($\mathbf{P_2}$) is calculated by subtracting the upper pressure from the lower pressure.

$$\Delta P = P_1 - P_2 = 40000 \text{ Pa} - 10000 \text{ Pa} = 30000 \text{ Pa}$$

Step 2: Use the hydrostatic pressure formula

The relationship between pressure difference ($\mathbf{\Delta P}$), fluid density ($\boldsymbol{\rho}$), acceleration due to gravity ($\mathbf{g}$), and height ($\mathbf{h}$) is given by the hydrostatic pressure equation: $\Delta P = \rho g h$. We rearrange this to solve for the height $\mathbf{h}$.

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

Step 3: Substitute values and solve for height

We substitute the known values into the rearranged formula, where $\Delta P = 30000 \text{ Pa}$ $\rho = 1000 \text{ kg/m}^3$, and $g = 10 \text{ m/s}^2$.

$$h = \frac{30000 \text{ Pa}}{(1000 \text{ kg/m}^3)(10 \text{ m/s}^2)} = \frac{30000}{10000} \text{ m} = 3 \text{ m}$$

8.

Step 1: Understand the Principle of Pressure Balance

In an inverted U-tube manometry system open to the atmosphere at both ends, the pressure at any horizontal level inside the tube must be constant to maintain equilibrium. Specifically, the pressure difference created by the liquid columns relative to the atmospheric pressure at the free surfaces in the beakers must balance. This is expressed by the hydrostatic pressure formula:

$$P = \rho g h$$

Where ρ is the fluid density, g is acceleration due to gravity, and h is the height of the fluid column.

Step 2: Formulate the Equation

The pressure exerted by the water column equals the pressure exerted by the kerosene column:

$$\rho_{water} g h_{water} = \rho_{kerosene} g h_{kerosene}$$

We can cancel the gravitational constant, g, from both sides:

$$\rho_{water} h_{water} = \rho_{kerosene} h_{kerosene}$$

Step 3: Substitute Values and Solve

We assume the density of water is $\rho_{water} = 1.0\,\mathrm{g/cm^3}$ [1]. Given values are $h_{water} = 10\,\mathrm{cm}$ and $\rho_{kerosene} = 0.8\,\mathrm{g/cm^3}$.

Substituting the values into the simplified equation:

$$(1.0\,\mathrm{g/cm^3})(10\,\mathrm{cm}) = (0.8\,\mathrm{g/cm^3})h_{kerosene}$$

Solving for $h_{kerosene}$:

$$h_{kerosene} = \frac{1.0 \times 10}{0.8}\ \mathrm{cm}$$

$$h_{kerosene} = \frac{10}{0.8}\ \mathrm{cm}$$

$$h_{kerosene} = 12.5\,\mathrm{cm}$$

9.

Step 1: Understand the Pressure Requirements

The total pressure (P) at a given depth in a fluid is the sum of the atmospheric pressure (P_0) and the pressure due to the fluid column (ρgh). The formula is:

$$P = P_0 + \rho gh$$

We are given that the atmospheric pressure is $P_0 = 76$ cm of mercury, which is equal to **1 atmosphere (atm)**.
The final total pressure required is $P = 4$ atm.
Therefore, the pressure that must be provided by the water column ($P_{\text{water}} = \rho gh$) is the difference between the total pressure and the atmospheric pressure:

$$P_{\text{water}} = P - P_0 = 4 \text{ atm} - 1 \text{ atm} = 3 \text{ atm}$$

Step 2: Convert Pressure to Standard Units (Pascals)

To use standard SI units for density and gravity, we convert the pressure due to the water column from atmospheres to Pascals (Pa). One atmosphere is approximately $\mathbf{1.013 \times 10^5}$ Pa.

$$P_{\text{water}} = 3 \text{ atm} \times 1.013 \times 10^5 \text{ Pa/atm} \approx 3.039 \times 10^5 \text{ Pa}$$

Step 3: Calculate the Required Depth of Water

Using the formula for hydrostatic pressure $P_{\text{water}} = \rho_{\text{water}} g h$, we can solve for the depth of the water column (h).
We use the standard density of water, $\rho_{\text{water}} = \mathbf{1000}\ \mathrm{kg/m}^{\mathbf{3}}$, and acceleration due to gravity, $g = \mathbf{9.8}\ \mathrm{m/s}^{\mathbf{2}}$.

$$h = \frac{P_{\text{water}}}{\rho_{\text{water}} g}$$

Substitute the values into the equation:

$$h = \frac{3.039 \times 10^5\ \mathrm{Pa}}{1000\ \mathrm{kg/m}^3 \times 9.8\ \mathrm{m/s}^2}$$

$$h = \frac{303900\ \mathrm{Pa}}{9800\ \mathrm{kg/(m^2 \cdot s^2)}}$$

$$h \approx 31.01\ \mathrm{m}$$

10.

Step 1: Define variables and formulas

The absolute pressure at any depth h in a fluid is given by $P = P_0 + \rho gh$, where P_0 is the atmospheric pressure, ρ is the density of the water, and g is the acceleration due to gravity. The problem provides options in cm, but the calculation with standard atmospheric pressure yields a result in meters. We assume the options should be in meters, and the correct option is the one corresponding to 20 m.

Step 2: Set up the equation

The pressure at half the depth, $P_{h/2}$, is given as two-thirds of the pressure at the bottom, P_h.

- $P_{h/2} = P_0 + \rho g \frac{h}{2}$
- $P_h = P_0 + \rho gh$
- The given condition is $P_{h/2} = \frac{2}{3} P_h$

Substituting the expressions into the condition gives the equation:

$$P_0 + \rho g \frac{h}{2} = \frac{2}{3} (P_0 + \rho gh)$$

Step 3: Solve for the height h

Rearrange the equation to solve for h:

$$3(P_0 + \rho g \frac{h}{2}) = 2(P_0 + \rho g h)$$

$$3P_0 + \frac{3}{2}\rho g h = 2P_0 + 2\rho g h$$

$$3P_0 - 2P_0 = 2\rho g h - \frac{3}{2}\rho g h$$

$$P_0 = (2 - \frac{3}{2})\rho g h$$

$$P_0 = \frac{1}{2}\rho g h$$

Solving for h:

$$h = \frac{2P_0}{\rho g}$$

Step 4: Substitute standard values

Using the standard values for atmospheric pressure $P_0 \approx 1 \times 10^5 \ \mathrm{N/m^2}$, density of water $\rho \approx 1000 \ \mathrm{kg/m^3}$, and $g \approx 10 \ \mathrm{m/s^2}$:

$$h = \frac{2 \times 1 \times 10^5}{1000 \times 10}$$

$$h = \frac{200000}{10000}$$

$$h = 20 \ \mathrm{m}$$

11.

1. Understanding the setup

We have an **open U-tube**, uniform cross-section, initially containing only mercury.

When **27.2 cm of water** is poured into **one limb**, mercury levels adjust.

Let:

- $\rho_w = 1\ \mathrm{g/cm^3}$ (water density)
- $\rho_m = 13.6\ \mathrm{g/cm^3}$ (mercury density)
- Let A = cross-sectional area (same for both limbs).

2. What happens when water is added

Let h_w = height of water column in one limb = $27.2\ \mathrm{cm}$.

Water sits above mercury in that limb.

Mercury level **falls** in that limb and **rises** in the other limb.

Let x = **fall** of mercury level in water limb from its original position (before adding water).

Then mercury rises by x in the other limb from its original position.

Thus the **difference in mercury levels** between the two limbs = $2x$.

3. Hydrostatic pressure balance

Consider the horizontal line through the lower mercury level in the two limbs (at equilibrium).

In the **water limb**, the mercury surface is **below** original level by x, so from that surface up to water top: water column of height $h_w + x$?

Wait — careful:

Actually, suppose original mercury level in both limbs was same height. After adding water:

In water limb: water height **above** mercury = h_w (given). Mercury surface in this limb is **below** original level by x.

In other limb: mercury surface is **above** original level by x.

At equilibrium:
Pressure at the bottom of the water column in water limb = pressure at same horizontal level in the other limb.

That horizontal level is **below** the mercury surface in other limb by $2x$ in mercury.
In water limb, from mercury surface upward: water column h_w down to the horizontal level? Let's clarify.

Let's choose the horizontal line through **lowest mercury** in the U-tube, but better:

Take the horizontal level of **mercury in the other limb** (right limb) as the reference for measuring **difference**?
Actually easier:

Let y = difference in mercury levels between the two limbs = $2x$.

Pressure balance at the **bottom of the water column** in left limb (interface of water-mercury):

Pressure_left = atmospheric + $\rho_w g h_w$
This equals pressure at same horizontal level in the right limb, which is atmospheric + $\rho_m g y$.

So:

$$\rho_w g h_w = \rho_m g y$$

$$y = \frac{\rho_w}{\rho_m} h_w$$

4. Calculation

$$y = \frac{1}{13.6} \times 27.2 \text{ cm}$$

$$y = 2 \text{ cm}$$

So $2x = y \implies x = 1 \text{ cm}.$

5. Interpret results

- **Difference in mercury levels** = $y = 2$ cm (between the two limbs' mercury surfaces).
- Height of mercury rise in the other limb from its initial level = $x = 1$ cm.
  That means option **A** says "height of mercury rise in the other limb from initial level is 1 cm" — this is true.
- **Difference in levels of liquids of the two sides** — they might mean difference in top surface levels of liquids? Let's compute that:

In water limb: water surface height above original mercury level = $h_w - x$? No — wait:

Water limb: original mercury level height = H (above some reference).
After: mercury surface at $H - x$. Water top at $H - x + h_w$.
Other limb: mercury surface at $H + x$, no water.
So **difference in top surfaces** between two limbs =
$[H - x + h_w] - [H + x] = h_w - 2x.$

$h_w = 27.2$, $x = 1$, so $27.2 - 2 = 25.2$ cm.

So difference in liquid **top levels** = 25.2 cm. That's option **B**.

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6. Check options

A) True (rise of mercury in other limb from its initial level = 1 cm).
B) True (difference in top levels = 25.2 cm).
C) False (that says rise = 2 cm, but that's the difference in mercury levels).
D) False (12.6 cm not matching anything here).

Correct: **A and B**.

12.

For vessels with the same base area and filled to the same height, **Statement I is TRUE**: the force on the base is the *same* because pressure ($P = \rho g h$) depends only on height, not shape, and Force = Pressure × Area. However, the *total* force exerted by water (including sides) differs, making the vessels weigh differently on a scale (hydrostatic paradox), but Statement II about base force is wrong.

Here's why:

- **Pressure at the Base (P):** In both vessels, the water depth (h) is the same, and water density (ρ) and gravity (g) are constant. Thus, pressure ($P = \rho g h$) at the base is identical.
- **Force on the Base (F):** Since the base area (A) is also the same, the force on the base ($F = P \times A$) must be the same in both cases.
- **Why they weigh differently (Hydrostatic Paradox):** The difference arises from the force exerted on the *walls*. In the vessel with wider sides (like a cone), the water exerts an upward vertical force component on the slanted walls, effectively pushing down more than the water's weight, while the narrower vessel has a downward component on its walls, meaning less total downward force than the water's weight.

Conclusion: Statement I is correct; Statement II is incorrect for the base force.

13.

- **Statement I: "Pressure is a scalar quantity as its direction is unique and not to be specified."**
  - **Incorrect reasoning:** Pressure is indeed a scalar quantity (has magnitude, not direction). However, the reason provided ("direction is unique") is wrong; pressure at a point in a fluid acts equally in **all** directions (transverse to the surface), which is why no *definite* direction is associated with it, making it scalar.

- **Statement II: "Like liquids, air also exerts pressure which is known as atmospheric pressure. If h be the height of the atmospheric air, then atmospheric pressure P is hdg, where d is the density of air."**
  - **Correct:** Air, being a fluid, exerts pressure (atmospheric pressure). The formula $P = hdg$ (or $P = \rho hg$) correctly describes the pressure exerted by a column of fluid (air, in this case) of height h, density d (or ρ), and acceleration due to gravity g.

Conclusion: Statement I's reasoning is flawed, but Statement II is correct.

.comprehension type

16. Determine Standard Atmospheric Pressure in Pascal

The standard atmospheric pressure is precisely defined as $101,325\ \mathrm{Pa}$. This value can also be calculated using the hydrostatic pressure formula $P = \rho g h$.

Step 1: Identify the given values

- Height of the mercury column, $h_{Hg} = 0.76\ \mathrm{m}$
- Standard density of mercury, $\rho_{Hg} \approx 13600\ \mathrm{kg/m^3}$
- Standard acceleration due to gravity, $g \approx 9.80665\ \mathrm{m/s^2}$

Step 2: Calculate the pressure

Using the formula $P = \rho g h$:

$$P = 13600\ \mathrm{kg/m^3} \times 9.80665\ \mathrm{m/s^2} \times 0.76\ \mathrm{m}$$

$$P \approx 101325\ \mathrm{Pa}$$

This value is commonly approximated as $1.01 \times 10^5\ \mathrm{Pa}$. Given the options, and assuming 'X' represents $10^5\ \mathrm{Pa}$:

17.

17. Determine the Height of a Water Barometer Column

To find the equivalent height of a water column, we use the same pressure and the properties of water. The pressure exerted by the water column must equal the standard atmospheric pressure.

Step 1: Identify the known values

- Standard atmospheric pressure, $P = 101325\,\text{Pa}$
- Standard density of water, $\rho_{water} \approx 1000\,\text{kg/m}^3$
- Standard acceleration due to gravity, $g \approx 9.80665\,\text{m/s}^2$

Step 2: Rearrange the hydrostatic pressure formula to solve for height

The formula is $P = \rho g h$. Rearranging for h:

$$h_{water} = \frac{P}{\rho_{water} g}$$

Step 3: Calculate the height

Substitute the values into the formula:

$$h_{water} = \frac{101325\,\text{Pa}}{1000\,\text{kg/m}^3 \times 9.80665\,\text{m/s}^2}$$

$$h_{water} \approx 10.33\,\text{m}$$

18.

Step 1: Calculate the total weight (force)

The total force exerted by the bicycle and rider on the ground is their combined weight. We use the formula $F = m \times g$, where m is the mass and g is the acceleration due to gravity (approximately 9.8m/s^2).

$$F_{\text{total}} = 90\text{kg} \times 9.8\text{m/s}^2 = 882\text{N}$$

Step 2: Determine the force supported by each tyre

Assuming the weight is distributed equally between the two tyres, the force on each tyre is half the total force.

$$F_{\text{each\_tyre}} = \frac{F_{\text{total}}}{2} = \frac{882\text{N}}{2} = 441\text{N}$$

Step 3: Calculate the area of contact for each tyre

Pressure is defined as force per unit area ($P = F/A$). We can rearrange this to find the area ($A = F/P$). We use the given gauge pressure $P = 6.9 \times 10^5\text{Pa}$ (which is 690kPa) and the force on each tyre calculated in the previous step.

$$A = \frac{F_{\text{each\_tyre}}}{P_{\text{gauge}}} = \frac{441\text{N}}{6.9 \times 10^5\text{Pa}}$$

$$A \approx 6.39 \times 10^{-4}\text{m}^2$$

19.

Step 1: Identify Given Values and Formula

The problem provides the density (ρ) of the liquid, the depth (h), and the acceleration due to gravity (g). The formula for hydrostatic pressure increase (ΔP) is $\Delta P = \rho g h$
.

Step 2: Calculate the Pressure Increase

Substitute the given values $\rho = 900\ \text{kg/m}^3$, $g = 10\ \text{m/s}^2$, and $h = 8\ \text{m}$ into the formula:

$$\Delta P = 900 \times 10 \times 8$$

The calculation yields:

$$\Delta P = 72000\ \text{Pa}$$

20.

Here's the correct matching for the devices and what they measure: **Barometer measures atmospheric pressure**, **Manometer** measures gas pressure in a container, **Thermometer** measures temperature, and **Hydrometer** measures liquid's relative density/specific gravity, so the matches are 1-a, 2-d, 3-b, and 4-c, according to standard physics definitions.

- **1) Barometer: a) atmosphere pressure**
- **2) Manometer: d) pressure of gas in a container**
- **3) Thermometer: b) temperature**
- **4) Hydrometer: c) relative density of liquid**

LEARNERS TASK

CONCEPTUAL UNDERSTANDING QUESTIONS

1.

The standard atmospheric pressure at sea level is **B) 76 cm of Hg**

This pressure is equivalent to 1 atmosphere (atm) and can also be expressed as 760 mm of Hg or approximately 101325 Pascals (Pa).

2.

Explanation

The total (or absolute) pressure in a liquid at a certain depth is calculated by considering all the forces acting on that point. The atmospheric pressure (P_0) acts on the free surface of the liquid, and the weight of the liquid column above the point adds additional pressure (gauge pressure, $P_{gauge} = \rho gh$). Therefore, the total pressure (P_{total}) is the sum of these two pressures:

$$P_{total} = P_0 + P_{gauge} = P_0 + \rho gh$$

3.

For a standard barometer, the liquid used is **mercury**.

This is because it is dense (so the barometer tube can be a manageable height), has low vapor pressure, and does not stick to glass significantly, giving a clear meniscus.

Water barometers are possible but require a very tall tube (over 10 meters), so mercury is conventional.

4.

The space above the mercury column in a barometer is called the **Torricellian vacuum** (or barometric vacuum).

It contains negligible vapor pressure of mercury (almost a vacuum) because no air is trapped there after the mercury column falls during the barometer's filling/inversion process.

5.

Atmospheric pressure decreases with increase in **altitude** (or height above sea level).

Reason: The weight of the air column above decreases as you go higher.

6.

If the barometer height suddenly falls, it indicates the arrival of a **storm** or **cyclone** (low-pressure weather system).

In meteorology, a rapid drop in atmospheric pressure often precedes stormy or rainy weather.

7.

In fluid statics, the fluid is **at rest** (not flowing).

The study involves pressure distribution, buoyancy, hydrostatic forces on surfaces, and stability of floating bodies — all under conditions of no relative motion between fluid elements.

8.

Pressure is a scalar quantity because:

1. At a point in a fluid at rest, pressure acts **equally in all directions** (Pascal's law).
2. It has **magnitude only, no direction** associated with it in the way vectors do — the force due to pressure acts perpendicular to a surface, but the pressure itself is not directional.
3. It is defined as **force per unit area** (normal force / area), and the direction of the force depends on the orientation of the surface, but the numerical value of pressure is independent of direction at a given point in a static fluid.

9.

- **A) The pressure exerted by liquids is called absolute pressure.** Incorrect. Pressure in liquids (or gases) can be absolute or gauge, depending on the reference point.
- **B) It is the maximum pressure that can be exerted at a point.** Incorrect. This isn't a definition of gauge pressure.
- **C) It is the total pressure at a point including the contribution of the atmosphere also.** Incorrect. This describes **absolute pressure**, not gauge pressure. Gauge pressure is the *difference* from atmospheric pressure.
- **D) It is the pressure measured at absolute temperature.** Incorrect. This relates to thermodynamic states, not the definition of gauge pressure.

The true definition (which isn't an option) is: **Gauge pressure is the pressure relative to the surrounding atmospheric pressure.**

- **Formula:** $P_{\text{gauge}} = P_{\text{absolute}} - P_{\text{atmospheric}}$.
- **Example:** A tire pressure gauge reads the pressure *above* the normal atmosphere.

Therefore, none of the options perfectly define gauge pressure, but option C describes **absolute pressure**, while gauge pressure is the *difference* from it.

10.

Explanation:

- **Hydrostatic Pressure Formula**: Pressure (P) at depth (h) in a fluid is given by $P = \rho g h$, where ρ is the fluid density, g is acceleration due to gravity, and h is the height/depth.
- **Same Height, Same Liquid**: Since all four vessels have the same liquid (water) and are filled to the *same level (height)*, the pressure at their bases must be identical.
- **Shape Doesn't Matter (Pascal's Principle/Hydrostatic Paradox)**: The differing shapes of the vessels (wide, narrow, conical) affect the total *force* at the bottom but not the *pressure* (force per unit area) at a specific depth.

Therefore, P1, P2, P3, and P4 are all equal.

JEE MAINS LEVEL QUESTIONS

Multiple choice question type

1.

Given:

Height $h = 10\,\mathrm{m}$

Density of water $\rho \approx 1000\,\mathrm{kg/m^3}$

Gravity $g \approx 9.8\,\mathrm{m/s^2}$

Formula for pressure due to a liquid column:

$$P = \rho g h$$

$$P = 1000 \times 9.8 \times 10$$

$$P = 98000\,\mathrm{Pa}$$

That's approximately 9.8×10^4 Pa, but the exact value is 98000 Pa

Check the options:

A) $10^6\,\mathrm{Pa}$ → No

B) $5 \times 10^6\,\mathrm{Pa}$ → No

C) $1 \times 10^5\,\mathrm{Pa}$ → $100000\,\mathrm{Pa}$, which is close to $98000\,\mathrm{Pa}$ (within rounding of g to $10\,\mathrm{m/s^2}$, then $P = 1000 \times 10 \times 10 = 10^5\,\mathrm{Pa}$ exactly).

D) $10^{-5}\,\mathrm{Pa}$ → No

If we take $g \approx 10\,\mathrm{m/s^2}$ for simplicity:

$$P = 1000 \times 10 \times 10 = 1 \times 10^5\,\mathrm{Pa}$$

2.

Step 1: Convert Units to SI

First, ensure all values are in standard SI units (meters, kilograms, seconds).

- Height, $h = 30 \text{ cm} = 0.30 \text{ m}$
- Density of mercury, $\rho = 13600 \text{ kg/m}^3$
- Acceleration due to gravity, $g = 9.8 \text{ m/s}^2$

Step 2: Apply the Pressure Formula

The pressure (P) exerted by a column of liquid is calculated using the formula $P = \rho g h$
.

Step 3: Calculate the Pressure

Substitute the values into the equation to find the pressure in Pascals (Pa).

$$P = 13600 \text{ kg/m}^3 \times 9.8 \text{ m/s}^2 \times 0.30 \text{ m}$$

$$P = 40000 \text{ kg/(m} \cdot \text{s}^2)$$

$$P \approx 40000 \text{ Pa}$$

Answer:

The pressure is approximately **40,00** Pa(Pascals), which can also be expressed as **40** kPa(kilopascals).

3.

Step 1: Calculate the height of the equivalent mercury column

The pressure exerted by the water column at the level of the mercury interface must be equal to the pressure exerted by the mercury column difference at the same horizontal level. This is given by the formula $P = \rho g h$.

We equate the pressures:

$$\rho_w g h_w = \rho_{Hg} g h_{Hg}$$

We can cancel g and rearrange the equation to find the height of the mercury column (h_{Hg}):

$$h_{Hg} = \frac{\rho_w h_w}{\rho_{Hg}}$$

Substitute the given values: $\rho_w = 1\,\mathrm{gm/cm}^3$, $h_w = 27.2\,\mathrm{cm}$, and $\rho_{Hg} = 13.6\,\mathrm{gm/cm}^3$.

$$h_{Hg} = \frac{1\,\mathrm{gm/cm}^3 \times 27.2\,\mathrm{cm}}{13.6\,\mathrm{gm/cm}^3} = 2\,\mathrm{cm}$$

Step 2: Determine the total difference in liquid levels

The total difference in the levels of the liquids in the two sides of the U-tube is the sum of the height of the water column (h_w) and the displacement of the mercury level in the other limb (h_{Hg} relative to the water-filled limb's mercury level).

Total difference $= h_w + \text{height difference between mercury surfaces}$
Total difference $= h_w + h_{Hg}$
Total difference $= 27.2\,\mathrm{cm} + 2\,\mathrm{cm}$
Total difference $= **\,29.2\ \mathrm{cm}\,**$

$$27.2\,\text{cm} - (2 \times h_{rise}) = 27.2\,\text{cm} - 2 \times 2\,\text{cm} = 23.2\,\text{cm}$$

The interpretation that uses $27.2 - 2 \times 1 = 25.2$ (where 1 cm is the rise in one limb from initial level) seems to be the intended answer for this problem.

Answer:

The difference in levels of liquids of the two sides is **25.2 cm**.

4.

Step 1: Equate Pressures

The pressure exerted by the mercury column (P_{Hg}) is equal to the pressure exerted by the water column (P_{water}). The pressure in a fluid column is given by the formula $P = \rho g h$.

$$\rho_{Hg} g h_{Hg} = \rho_{water} g h_{water}$$

Step 2: Simplify and Rearrange for Water Height

The gravitational acceleration (g) is constant and cancels out from both sides of the equation:

$$\rho_{Hg} h_{Hg} = \rho_{water} h_{water}$$

We rearrange the equation to solve for the height of the water column (h_{water}):

$$h_{water} = \frac{\rho_{Hg} h_{Hg}}{\rho_{water}}$$

Step 3: Substitute Values and Calculate

First, convert the height of the mercury column from centimeters to meters:
$h_{Hg} = 70 \text{ cm} = 0.70 \text{ m}$.
Substitute the given densities ($\rho_{Hg} = 13600 \text{ kg/m}^3$, $\rho_{water} = 1000 \text{ kg/m}^3$) and the height into the equation:

$$h_{water} = \frac{13600 \text{ kg/m}^3 \times 0.70 \text{ m}}{1000 \text{ kg/m}^3}$$

Performing the calculation:

$$h_{water} = 9.52 \text{ m}$$

5.

Step 1: Understand the principle and formula

The pressure exerted by a liquid column is determined by its density (ρ) and height (h) using the formula $P = \rho \cdot g \cdot h$, where g is the acceleration due to gravity. For the pressure in the mercury barometer to equal the pressure in the water barometer, their respective P values must be equal.

$$P_{Hg} = P_w$$

$$\rho_{Hg} \cdot g \cdot h_{Hg} = \rho_w \cdot g \cdot h_w$$

The value of g cancels out, leading to:

$$\rho_{Hg} \cdot h_{Hg} = \rho_w \cdot h_w$$

Step 2: Define known variables and convert units

Normal atmospheric pressure is defined as the pressure exerted by a **76 cm** (or 0.76 m) column of mercury.

- Height of mercury column, $h_{Hg} = 76 \text{ cm} = 0.76 \text{ m}$
- Density of mercury, $\rho_{Hg} = 13600 \text{ kg/m}^3$
- Density of water, $\rho_w = 1000 \text{ kg/m}^3$

Step 3: Calculate the height of the water column

Rearrange the equation from Step 1 to solve for the height of the water column (h_w) and substitute the known values.

$$h_w = \frac{\rho_{Hg} \cdot h_{Hg}}{\rho_w}$$

$$h_w = \frac{13600 \text{ kg/m}^3 \cdot 0.76 \text{ m}}{1000 \text{ kg/m}^3}$$

$$h_w = \frac{10336}{1000} \text{ m}$$

$$h_w = 10.336 \text{ m}$$

6.

Explanation

Standard atmospheric pressure at sea level is defined as 1 atmosphere (atm), which is approximately 101,325 Pascals (Pa). This value is commonly approximated to $1 \times 10^5\ \mathrm{Pa}$

.

This pressure can be measured using a mercury barometer. The pressure exerted by a fluid column is given by the formula $P = \rho g h$, where ρ is the density, g is the acceleration due to gravity (approx. $9.8\ \mathrm{m/s^2}$), and h is the height of the column (approx. $0.76\ \mathrm{m}$ for mercury).

Using the provided density of mercury:

$$P \approx 13600\ \mathrm{kg/m^3} \times 9.8\ \mathrm{m/s^2} \times 0.76\ \mathrm{m} \approx 101300\ \mathrm{Pa}$$

$101300\ \mathrm{Pa}$ is closest to the value presented in option A, which is $10^5\ \mathrm{Pa}$.

7.

The pressure at the bottom of the mercury column is approximately **6.67×10^5 dyne/cm^2**, which corresponds to option A). This calculation uses the hydrostatic pressure formula $P = \rho g h$.

Calculation in CGS Units

To calculate the pressure in the centimeter-gram-second (CGS) system of units (where pressure is measured in dyne/cm^2), we use the following standard values:

- **Density of mercury (ρ):** 13.6 g/cm^3
- **Acceleration due to gravity (g):** 980 cm/s^2
- **Height of the mercury column (h):** 50 cm (given)

The formula for hydrostatic pressure is:

$$P = \rho \times g \times h$$

Substituting the values into the formula:

$$P = 13.6 \text{ g/cm} \times 980 \text{ cm/s} \times 50 \text{ cm}$$

$$P = 666,400 \text{ dyne/cm}$$

This value can be expressed in scientific notation as approximately **6.66×10^5 dyne/cm^2**.
The closest option is A) 6.66×10^5 dyne/cm^2.

8.

Fluid pressure is independent of the shape of the container, the total volume or mass of the fluid, and the surface area. Instead, it depends on the vertical depth of the fluid, its density, and the acceleration due to gravity, according to the formula $P = \rho g h$.

- **Shape of the container:** A point at the same depth in different shaped containers will have the same pressure because the pressure depends on the vertical depth, not the horizontal dimensions of the container.
- **Total volume and mass:** The total amount of fluid does not change the pressure at a specific depth. For example, a narrow container and a wide container, with liquid filled to the same height, will have the same pressure at the bottom even though the wider one holds more liquid.
- **Surface area:** The pressure is the force per unit area, but the total force on the bottom of a container is related to the pressure and the area, so the pressure itself is independent of the area.

9.

Step 1: Understand the principle of hydrostatic equilibrium

In a U-tube containing two immiscible liquids at rest, the pressure at the same horizontal level in both arms must be equal. By selecting the level of the interface between the two liquids, we equate the pressures exerted by the columns above this point.

Step 2: Formulate the pressure equation

The pressure exerted by a column of liquid is given by the formula $P = \rho g h$, where ρ is the density, g is the acceleration due to gravity, and h is the height of the column. Equating the pressures for liquid A and liquid B:

$$\rho_A g h_A = \rho_B g h_B$$

The acceleration due to gravity term (g) cancels out, simplifying the equation to:

$$\rho_A h_A = \rho_B h_B$$

Step 3: Calculate the density of liquid B

We are given $\rho_A = 1.6\text{g cm}^{-3}$, $h_A = 26.6\text{cm}$, and $h_B = 50\text{cm}$. Rearrange the equation to solve for ρ_B:

$$\rho_B = \frac{\rho_A h_A}{h_B}$$

Substitute the given values into the equation:

$$\rho_B = \frac{1.6\,\text{g cm}^{-3} \times 26.6\,\text{cm}}{50\,\text{cm}}$$

$$\rho_B = \frac{42.56\,\text{g}}{50}$$

$$\rho_B = 0.8512\,\text{g cm}^{-3}$$

10.

Calculation Steps

1. **Identify Given Values:**
   - Pressure on the ground floor (P_1) = 160,000 Pa
   - Height (h) = 15 m
   - Density of water (ρ) = 1000 kg/m³ (standard value for pure water)
   - Acceleration due to gravity (g) ≈ 10 m/s² (a common approximation for physics problems, as used in the search results)

2. **Calculate the Pressure Difference:**
   The pressure difference (ΔP) due to the height of the water column is calculated using the hydrostatic pressure formula:
   $\Delta P = \rho \cdot g \cdot h$Substitute the values:
   $\Delta P = 1000\,\text{kg/m}^3 \cdot 10\,\text{m/s}^2 \cdot 15\,\text{m}$
   $\Delta P = 150,000\,\text{Pa}$

3. **Calculate the Pressure at the Fifth Floor:**

   The pressure at the fifth floor (P_2) is the ground floor pressure minus the pressure exerted by the 15m column of water above it:

   $P_2 = P_1 - \Delta P P_2 = 160,000\,\text{Pa} - 150,000\,\text{Pa}$

   $P_2 = 10,000\,\text{Pa}$

JEE ADVANCED LEVEL QUESTIONS

Multi correct answer type:

11.

The term **fluid** refers to a substance that deforms continuously under shear stress — i.e., it flows.

Both **liquids** and **gases** are fluids.Hence the correct options from the list are:

A) liquids

B) gases

(and **C) a mixture of liquid and gas** is also a fluid, since it contains fluids)

12.

Let's recall:

Gauge pressure = absolute pressure − atmospheric pressure.

A) it may be positive — True (if absolute pressure > atmospheric pressure).

B) it may be negative — True (if absolute pressure < atmospheric pressure → partial vacuum).

C) it may be zero — True (if absolute pressure = atmospheric pressure).

D) only positive — False (because gauge pressure can be negative or zero).

Correct options: **A, B, C**

13.

A) Instrument used to measure atmospheric pressure is called Barometer → **True**.

B) With change in height, season, temperature, the barometric pressure changes → **True** (height affects pressure in a fixed location's altitude sense? Actually, height above sea level for a fixed barometer's location is fixed, but seasonal/temperature changes affect pressure; also height in mountains gives lower pressure. Possibly "with change in height" here means change in altitude of the place, not height in instrument — but in general, atmospheric pressure varies with altitude, season, temperature → True).

C) If barometric height is less than 76 cm, we can say that air pressure has fallen → **True** (compared to standard 76 cm Hg, if mercury column shorter ⇒ atmospheric pressure is lower).

D) If barometric height is more than 76 cm, we can say that air pressure has increased → **True** (same logic as C; compared to standard 76 cm, higher column means higher atmospheric pressure).

All four are **correct statements** in physics.
Final answer: A,B,C,D

14.

Statement I: With depth pressure in a liquid increases → **True**

$$P = P_0 + \rho g h$$

So pressure increases with depth in a liquid.

Statement II: Force is a vector but pressure is a scalar → **True**
Force has magnitude and direction, pressure is magnitude only (force/area) and acts equally in all directions at a point in a fluid at rest.

Now, is there any causal connection between Statement I and Statement II?

Statement I describes a **property** of hydrostatic pressure variation.
Statement II describes **nature** of physical quantities (vector vs scalar).

They are **both true independently**, but Statement II is **not** the reason for Statement I.
Pressure being scalar is why we use ρgh without worrying about direction, but that alone doesn't explain *why* pressure increases with depth — the explanation comes from weight of fluid above.

Thus in an exam's "Assertion–Reason" format:

- Both statements true
- But II is **not** the correct explanation of I

They are **unrelated explanations** of different facts.

15.
Let's analyze them:

Statement I: Sudden fall of pressure at a place indicates storm → **True**
Rapid pressure drop often means a low-pressure system (cyclone/storm) approaching.

Statement II: Air flows from higher pressure to lower pressure → **True**
This is the basic principle of wind: pressure gradient force moves air from high to low pressure.
Relationship:
Statement II explains *why* a sudden pressure fall leads to storm conditions:
If pressure drops at a place, surrounding higher pressure air rushes in toward the low-pressure center, causing strong winds → part of a storm system.

So Statement II is indeed the scientific reason behind the phenomenon mentioned in Statement I.
Thus:

- Both statements are **true**
- Statement II **correctly explains** Statement I

16.

Step 1: Calculate Absolute Pressure

We assume the standard atmospheric pressure $P_{atm} = 1\text{ atm} = 1 \times 10^5\text{ Pa}$ for consistency with the multiple-choice options. The absolute pressure P_{abs} is the sum of atmospheric pressure and the hydrostatic pressure (ρgh) at depth h.

The hydrostatic pressure is calculated using the given values:

$$\rho gh = (1.03 \times 10^3\text{ kgm}^{-3}) \times (10\text{ ms}^{-2}) \times (1000\text{ m}) = 1.03 \times 10^7\text{ Pa}$$

The absolute pressure in Pascals is
$P_{abs} = P_{atm} + \rho gh = 1 \times 10^5\text{ Pa} + 1.03 \times 10^7\text{ Pa} = 1.04 \times 10^7\text{ Pa}.$
Converting to atmospheres ($1\text{ atm} = 1 \times 10^5\text{ Pa}$):

$$P_{abs} = \frac{1.04 \times 10^7\text{ Pa}}{1 \times 10^5\text{ Pa/atm}} = 104\text{ atm}$$

17.
The gauge pressure P_{gauge} is the pressure due to the fluid column alone, which is ρgh.

$$P_{gauge} = \rho gh = 1.03 \times 10^7\text{ Pa}$$

Converting to atmospheres:

$$P_{gauge} = \frac{1.03 \times 10^7\text{ Pa}}{1 \times 10^5\text{ Pa/atm}} = 103\text{ atm}$$

18.
The force F acting on the submarine window is determined by the pressure difference (ΔP) across it (which is the gauge pressure) and its area (A). The internal pressure is P_{atm}, so $\Delta P = P_{gauge}$.
The area is $A = 20\text{ cm} \times 20\text{ cm} = 0.2\text{ m} \times 0.2\text{ m} = 0.04\text{ m}^2$.

$$F = \Delta P \times A = (1.03 \times 10^7\text{ Pa}) \times (0.04\text{ m}^2) = 4.12 \times 10^5\text{ N}$$

19.

- **1) 1 atm** matches with **b) 1.013 bar** and **a) 760 torr** (since 1 atm is equal to both values).
- **2) 1 pascal** matches with **c) 1 Nm^{-2}** (by definition, a pascal is one Newton per square meter).
- **3) 760 mm of Hg** matches with **a) 760 torr** (these are equivalent units of pressure).
- **4) dyne/cm^2** matches with **d) 10^{-1} N/m^2** (this is a conversion between CGS and SI units of pressure).

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