

CLASS 11 PHYSICS • SEC 9.2.2

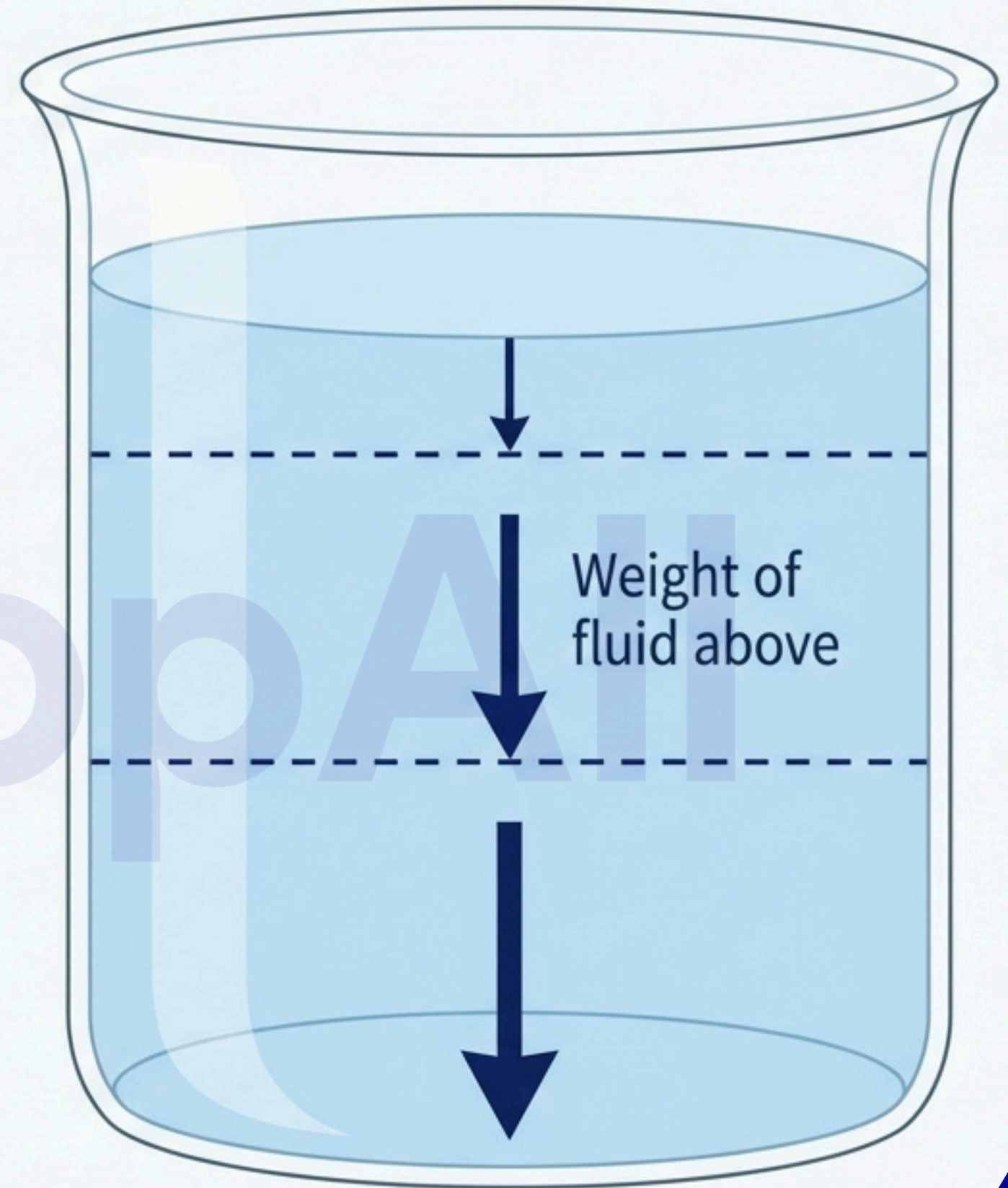
Variation of Pressure With Depth

Understanding fluid equilibrium, gauge pressure, and the hydrostatic paradox.

[NEET/JEE Concept Builder]

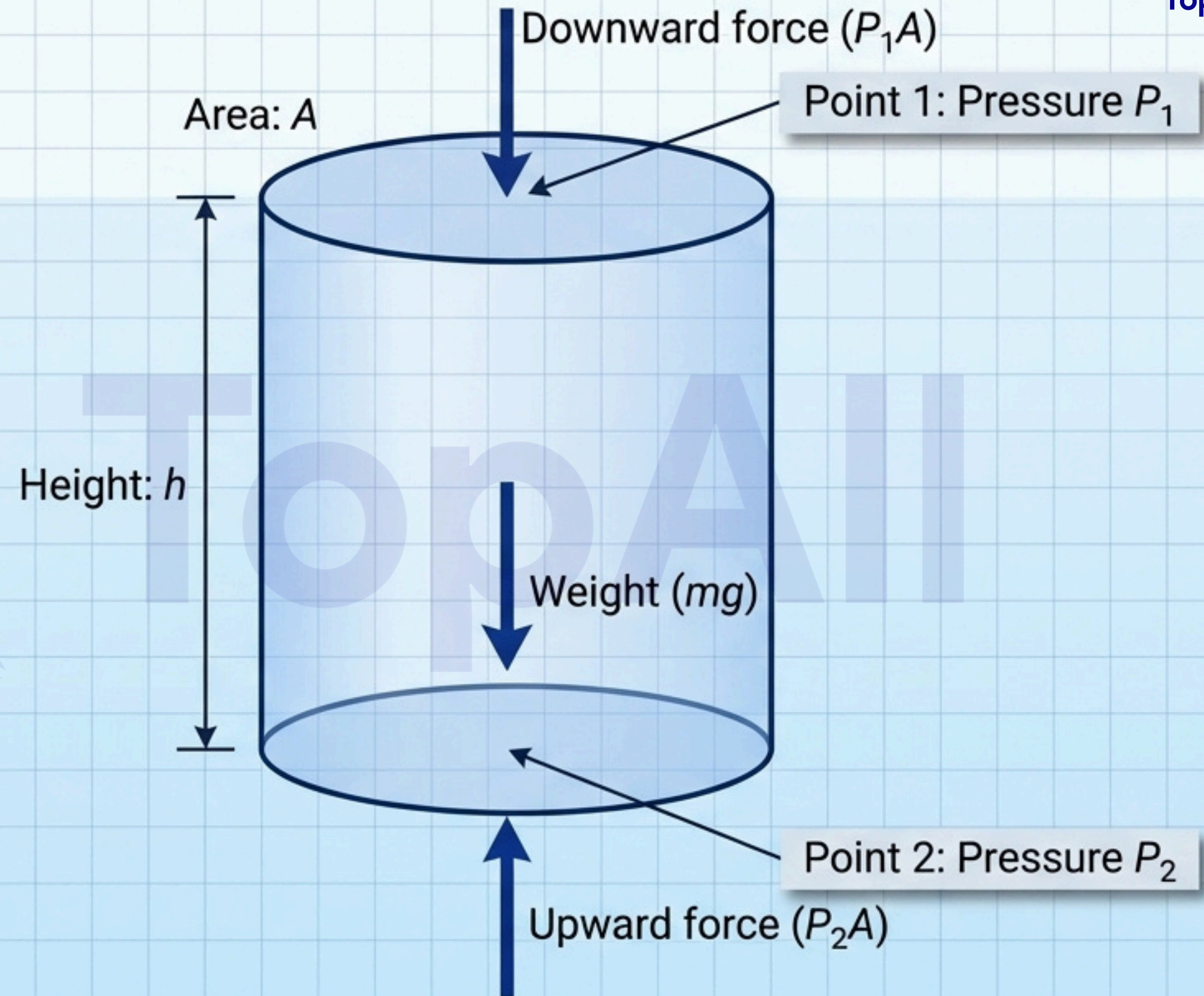
H2: The Weight of the Fluid

- Fluids at rest are continuously pulled downward by gravity.
- Upper layers of the fluid exert a downward force on the layers below them.
- As you go deeper, the total weight of the fluid above increases.
- Therefore, the pressure must increase with depth to support this weight and maintain equilibrium.



H2: Modeling a Fluid Element in Equilibrium

- Consider a cylindrical element of fluid at rest.
- Horizontal forces balance out to zero.
- Vertical forces must perfectly balance the element's weight (mg).





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$$E=mc^2$$



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H2: Deriving the Pressure-Depth Relation

Vertical Force Balance: Upward force balances downward force + weight.

$$\text{Eq. (9.5): } (P_2 - P_1) A = mg$$

Substitute Mass: Express mass (m) using fluid density (ρ) and volume ($V = hA$).

$$m = \rho V = \rho h A$$

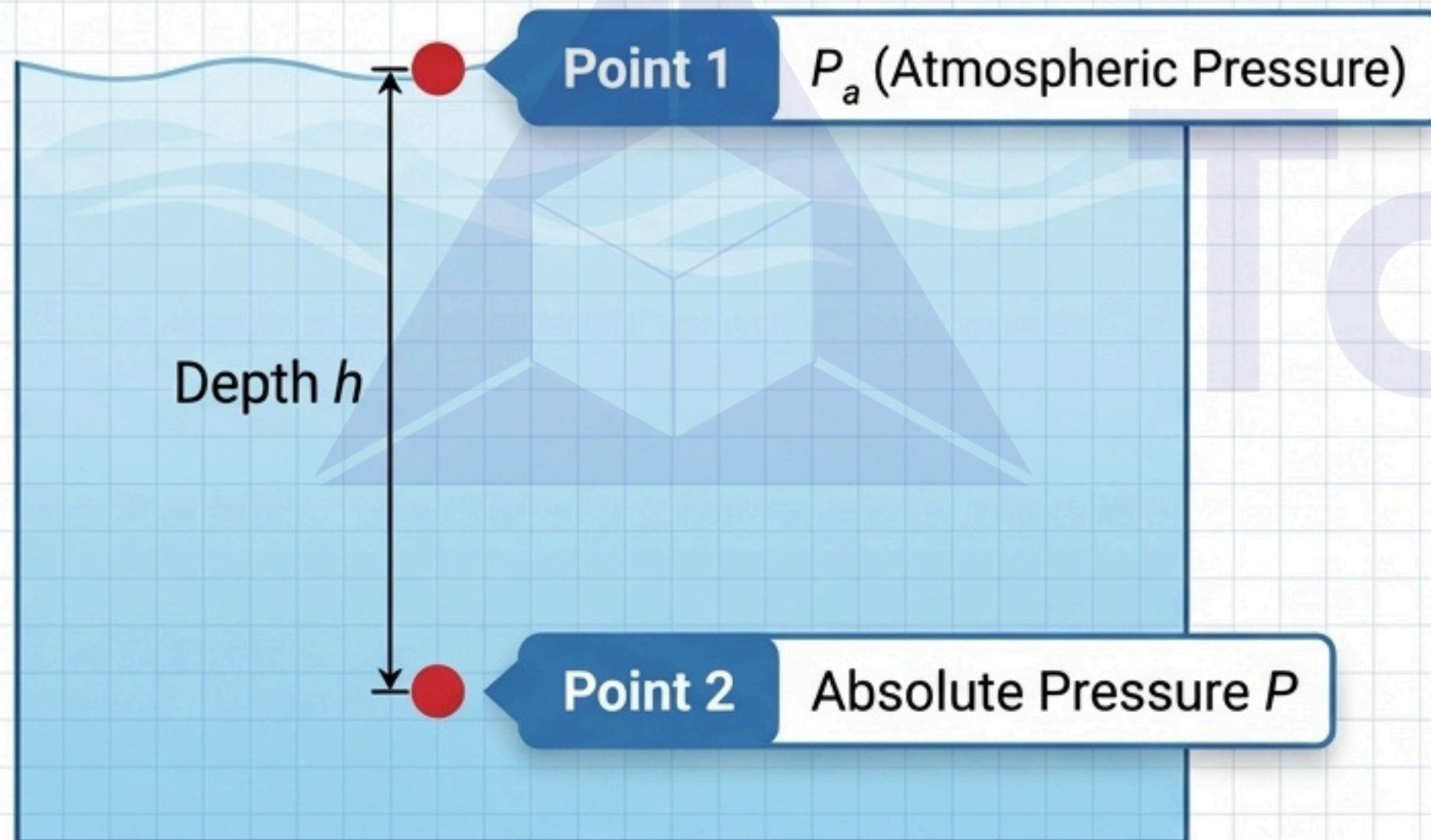
Final Equation: Substitute m and cancel Area (A).

$$\text{Eq. (9.6): } P_2 - P_1 = \rho g h$$

[EXAM TIP] Density (ρ) and gravity (g) are constant; pressure difference depends strictly on vertical height (h).

H2: Absolute vs. Gauge Pressure

If we move Point 1 to the surface open to the atmosphere, P_1 becomes atmospheric pressure (P_a).



Absolute Pressure

$$\text{Eq. (9.7): } P = P_a + \rho g h$$

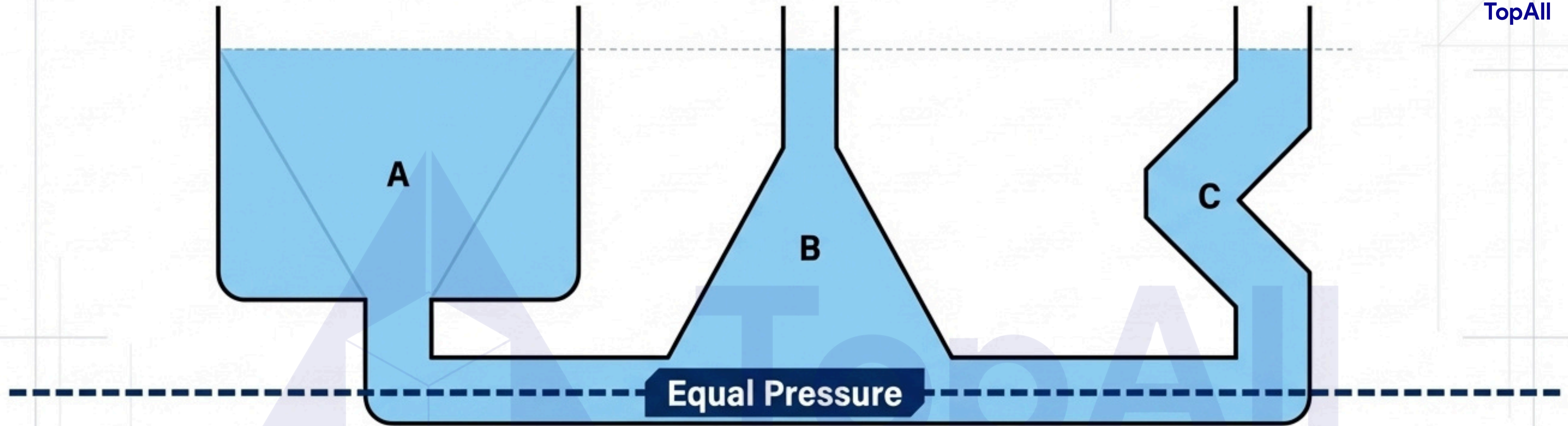
The total pressure at depth h .

Gauge Pressure

$$P - P_a = \rho g h$$

The excess pressure strictly above atmospheric level.

H2: The Hydrostatic Paradox



The Conceptual Paradox

Vessels of completely different shapes hold vastly different total volumes of water, suggesting the pressure at the bottom should vary.

The Physical Reality

Eq. (9.7) proves that liquid pressure depends only on vertical depth (h) and density (ρ). Cross-sectional area, total fluid volume, and the physical shape of the container do not affect the pressure at a given horizontal level.

H2: Key Takeaways

- **Pressure in a fluid at rest** increases **linearly** with depth to support the weight of the fluid above it.
- **Absolute Pressure** is $P = P_a + \rho g h$. **Gauge Pressure** is the difference: $\rho g h$.
- **Hydrostatic Paradox:** Pressure depends entirely on vertical depth, completely independent of container shape or total fluid volume.

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