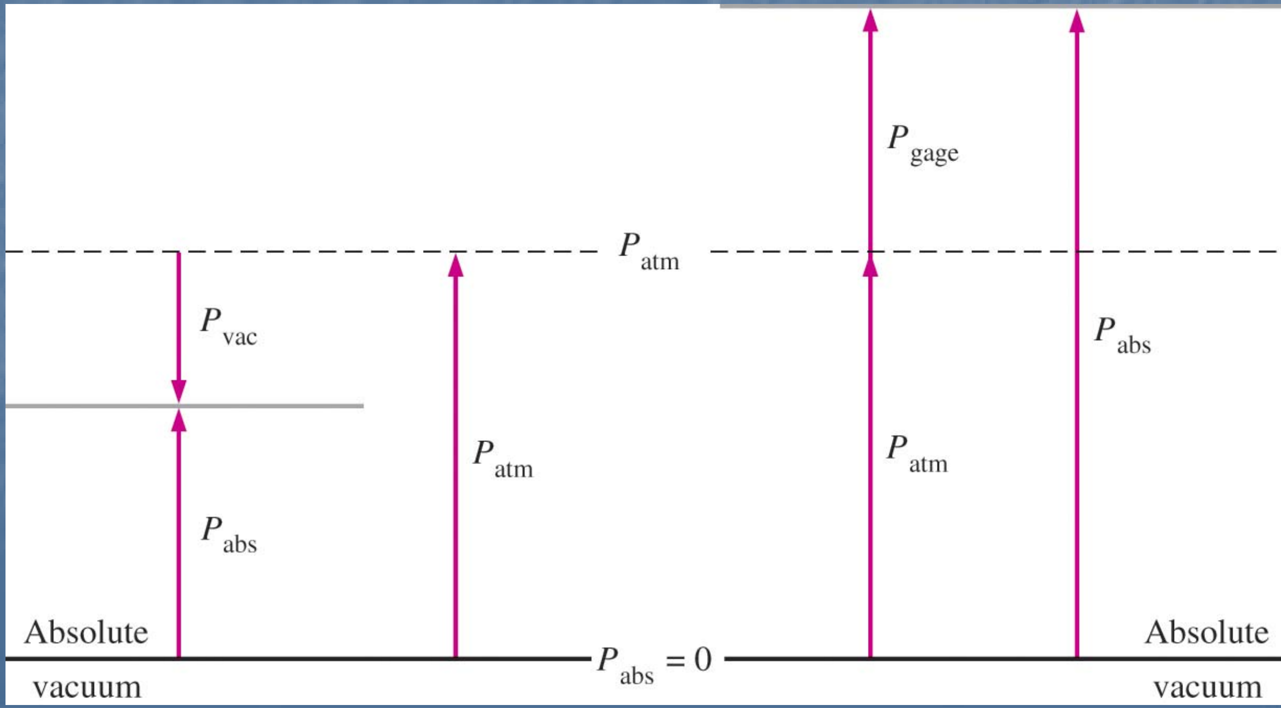
Fluid Statics

ABSOLUTE, GAUGE & VACUUM PRESSURE

- **Absolute pressure:** The actual pressure at a given position. It is measured relative to absolute vacuum (i.e., absolute zero pressure).
- **Gauge pressure:** The difference between the absolute pressure and the local atmospheric pressure. Most pressure-measuring devices are calibrated to read zero in the atmosphere, and so they indicate gage pressure.
- **Vacuum pressures:** Pressures below atmospheric pressure.

$$p_{(gauge)} + p_{(atm)} = p_{(absolute)}$$

$$P_{vac} = P_{atm} - P_{abs}$$



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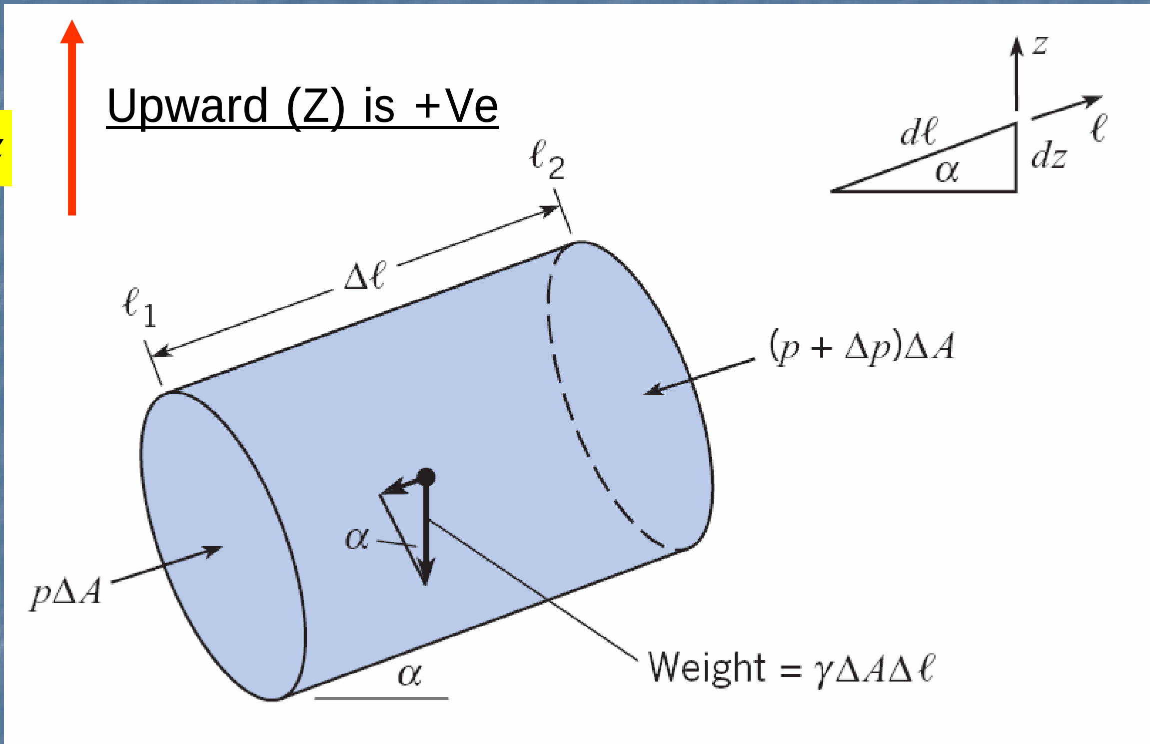
PRESSURE VARIATION WITH ELEVATION (HEIGHT)

$$\sum F_l = 0 = p\Delta A - (p + \Delta p)\Delta A - \rho g V \sin\alpha$$

$$p\Delta A - p\Delta A - \Delta p\Delta A - \rho g \Delta A \Delta l \sin\alpha = 0$$

$$V = \Delta A \Delta l$$

$$\frac{\Delta p}{\Delta l} = -\rho g \sin\alpha$$



As $\Delta l \rightarrow 0$ $\quad \sin\alpha = \frac{dz}{dl}$ $\quad (\gamma = \rho g)$

Then $\frac{dp}{dl} = -\gamma \frac{dz}{dl}$ $\quad \frac{dp}{dz} = -\gamma = -\rho g$

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$$\frac{dp}{dz} = -\gamma = -\rho g$$

The above Eqn. is the basic equation for the hydrostatic *pressure variation with elevation*. (minus sign indicates that pressure changes inversely with elevation OR height)

Example (3.2) is an application relating to the above equation

Example (3.2)

Compare the rate of change of pressure with elevation for air at sea level, 101.3 kP[a] absolute, at a temperature of 15.5°C, and for fresh water at the same pressure an[d] temperature. Assuming constant specific weights for air and water, determine also th[e] total pressure change that occurs for both with a 4-m decrease in elevation.

Solution First, determine specific weights of water and air:

$$\rho_{air} = \frac{p}{RT} = \frac{101.3 \times 10^3 \text{ N/m}^2}{287 \text{ J/kg K} \times (15.5 + 273) \text{ K}}$$

Then

$$\rho_{air} = 1.22 \text{ kg/m}^3$$

$$\gamma_{air} = \rho g = 1.22 \text{ kg/m}^3 \times 9.81 \text{ m/s}^2$$

$$= 11.97 \text{ kg/m}^2\text{s}^2 = 11.97 \text{ N/m}^3$$

and

$$\gamma_{water} = 9799 \text{ N/m}^3 \quad \text{(interpolated from Table A.5)}$$

$$\frac{dp}{dz} = -\gamma$$

Then

$$\left(\frac{dp}{dz}\right)_{air} = -11.97 \text{ N/m}^3 \qquad \left(\frac{dp}{dz}\right)_{water} = -9799 \text{ N/m}^3$$

$$\text{Total pressure change for air} = (-11.97 \text{ N/m}^3) \times (-4 \text{ m})$$

$$= 47.9 \text{ N/m}^2 = 47.9 \text{ Pa} \quad \triangleleft$$

$$\text{Total pressure change for water} = (-9799 \text{ N/m}^3) \times (-4 \text{ m})$$

$$= 39.2 \text{ kN/m}^2 = 39.2 \text{ kPa} \quad \triangleleft$$

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$$\frac{dp}{dz} = -\gamma = -\rho g$$

Equation above proves that pressure changes with height or elevation inversely.

By considering fluid density constant with the fluid under consideration, then by integrating Eqn. above, we obtain,

$$p + \rho g z = C$$

Where:

$p + \gamma z = C$ is called piezometric Pressure Eqn. (a)

$\frac{P}{\gamma} + Z = C$ is called piezometric Head Eqn. (2)

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Eqn. (a) & (b) can only applied between two points in the same fluid

Hence $$p_1 + \gamma z_1 = p_2 + \gamma z_2 = C$$

OR

$$p_2 - p_1 = -\gamma\left(z_2 - z_1\right)$$

$$\Delta p = -\gamma\,\Delta z$$

<u>END OF LECTURE</u>
<u>(2)</u>