Theme Music: Queen

Under Pressure

Cartoon: Bill Watterson

Calvin & Hobbes

I got a helium balloon. Very nice.

I'm going to stand on this ladder and let the balloon carry me up and away.

Nothing's happening.

Try jumping.

See? There goes the balloon. You didn't hang on.
Outline

■ Quiz 9: Torque and rotational energy
■ Fluids
  – Pressure
  – Fluids under gravity
■ Archimedes’ Principle
Pressure

What forces are exerted on the box imbedded in the fluid?

\[ F = pA \]

The force takes its direction from A.

Pressure has no direction! It acts in all directions at once!
Drawing on experience

- What happens when an object is immersed in a fluid?
- Examples?
Fluids in Gravity

\[ F = p_0 A \] (could be outside air pressure or due to external weights)

A fluid of uniform density

\[ W = mg \]

\[ p_0 A \]

\[ pA \]
Variation of Pressure with Depth*

\[ F^{\downarrow} = F^{\uparrow} \]

\[ mg + p_0 A = p A \]
\[ \rho V g + p_0 A = p A \]
\[ \rho A d g + p_0 A = p A \]
\[ p = p_0 + \rho g d \]

* We assumed uniform density. Is this OK?
   For water (\( \rho \sim 1000 \text{ kg/m}^3 \)) yes.
   For air (\( \rho \sim 1 \text{ kg/m}^3 \)) OK for meters — not km.
Archimedes’ Principle: 1

- What happens when an object is immersed in a fluid?
- The pressure at the bottom is greater than the pressure at the top so overall the fluid pushes up.
Archimedes’ Principle: 2

\[ F^{\text{net}} = p_2 A - p_1 A \]
\[ p_1 = p_0 + \rho gd_1 \]
\[ p_2 = p_0 + \rho gd_2 \]
\[ F^{\text{net}} = (p_2 - p_1) A \]
\[ F^{\text{net}} = (p_0 + \rho gd_2 - p_0 - \rho gd_1) A \]
\[ F^{\text{net}} = \rho g (d_2 - d_1) A = \rho Vg = mg \]

The buoyant (upward) force = the weight of the fluid displaced.
Making sense of AP

- Consider the forces on a bag of water the same shape as an immersed object.

- The BF is equal to the weight of the water displaced – that’s what the surrounding water can hold up!
Measuring Pressure: Manometers
# Measuring Pressure: Units

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<th>millibar</th>
<th>lb/in²</th>
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