• What is a fluid?
• Pressure
• Pressure varies with depth
• Pascal’s principle
• Methods for measuring pressure
• Buoyant forces
• Archimedes principle
• Fluid dynamics assumptions
• An ideal fluid
• Continuity Equation
• Bernoulli’s Equation

Goals

Pascal’s principle

Archimedes Principle
Pascal’s Principle

A change in the pressure applied to an enclosed incompressible fluid is transmitted undiminished to every point of the fluid and to the walls of the container.

\[ \Delta F = \Delta P \]

Example: open container

- The pressure in a fluid depends on depth h and on the value of \( P_0 \) at the surface.
- All points at the same depth have the same pressure.

\[ P_h = P_0 + \rho gh \]

- Add piston of area A with lead balls on it & weight W. Pressure at surface increases by \( \Delta P = \frac{W}{A} \)

\[ P_{ext} = P_0 + \Delta P \]

- Pressure at every other point in the fluid (Pascal’s law), increases by the same amount, including all locations at depth h.

\[ P_h = P_0 + \rho gh + \Delta P \]

iClciker Q: Equilibrium state:

What is m?

- a) 25 kg
- b) 1 kg
- c) 25 x 250/10 = 625 kg
- d) None of above
- e) Not enough information
Pascal’s Law Device - Hydraulic press
A small input force generates a large output force
• Assume the working fluid is incompressible
• Neglect the (small here) effect of height on pressure

According to Pascal’s principle,
\[ \Delta P_1 = \Delta P_2 \]
\[ \therefore \frac{F_1}{A_1} = \frac{F_2}{A_2} \]
\[ \therefore F_2 = F_1 \frac{A_2}{A_1} \]
If \( A_2 \gg A_1 \), small \( F_1 \) can produce large \( F_2 \) mechanical advantage!

Other hydraulic lever devices using Pascal’s Law:
• Hydraulic brakes
• Hydraulic jacks
• Forklifts, backhoes

Pascal’s Law Device - Hydraulic press
A small input force generates a large output force
• Assume the working fluid is incompressible
• Neglect the (small here) effect of height on pressure

• The volume of liquid pushed down on the left equals the volume pushed up on the right, so:
\[ A_1 \Delta x_1 = A_2 \Delta x_2 \]
\[ \therefore \frac{\Delta x_2}{\Delta x_1} = \frac{A_1}{A_2} = \frac{F_1}{F_2} \]
Work\(_1\) = \( F_1 \Delta x_1 \) = Work\(_2\) = \( F_2 \Delta x_2 \)
\rightarrow \text{no loss of energy in the fluid}
Archimedes Principle  C. 287 – 212 BC

- Discovered nature of buoyant force - Eureka!

Why do ships float and sometimes sink?
Why do objects weigh less when submerged in a fluid?

B (buoyant force): net force from liquid outside the surface to liquid or ball inside the surface

identical pressures at every point -> identical buoyant forces

• Archimedes’s Principle:
An object immersed in a fluid feels an upward buoyant force that equals the weight of the fluid displaced by the object.
Buoyant forces do not depend on the composition of submerged objects.
Buoyant forces depend on the density of the liquid and g.
Archimedes’s Principle: totally submerged object

Object is totally submerged in a fluid of density $\rho_{\text{fluid}}$

The upward buoyant force is the weight of displaced fluid:

$$B = \rho_{\text{fluid}} g V_{\text{fluid}}$$

The downward gravitational force on the object is:

$$F_g = M_{\text{object}} g = \rho_{\text{object}} g V_{\text{object}}$$

The volume of fluid displaced and the object’s volume are equal for a totally submerged object. The net force is:

$$F_{\text{net}} = B - F_g = (\rho_{\text{fluid}} - \rho_{\text{object}}) g V_{\text{object}}$$

The direction of the net force on an object totally submerged in a fluid:

- If the density of the object < the density of the fluid net force is upward
- If the density of the object > the density of the fluid the net force is downward

Archimedes’s Principle: floating object

An object sinks or rises in the fluid until it reaches equilibrium.

At equilibrium buoyant force is balanced by the downward weight of the object:

$$F_{\text{net}} = B - F_g = 0 \Rightarrow B = F_g$$

$$V_{\text{fluid}} = \text{volume of fluid displaced}$$

$$= \text{portion of the object’s volume below fluid level}$$

$$B = \rho_{\text{fluid}} g V_{\text{fluid}} = F_g = \rho_{\text{object}} g V_{\text{object}}$$

Solving:

$$\rho_{\text{fluid}} V_{\text{fluid}} = \rho_{\text{object}} V_{\text{object}}$$

$$\frac{V_{\text{fluid}}}{V_{\text{object}}} = \frac{\rho_{\text{object}}}{\rho_{\text{fluid}}}$$

- The ratio of densities equals the fraction of the object’s volume that is below the surface
Example: What fraction of an iceberg is underwater?

\[ \rho_{\text{seawater}} = 1.03 \times 10^3 \text{ kg/m}^3 \]

\[ \rho_{\text{ice}} = 0.917 \times 10^3 \text{ kg/m}^3 \]

iClicker Q

An block of density $2.5 \times 10^3 \text{ kg/m}^3$ and of volume $2.0 \text{ m}^3$ is immersed in water of density $1.0 \times 10^3 \text{ kg/m}^3$. The block hangs from a scale which reads $W$ as the weight.

True or false:
The reading of the scale is the same before and after the block is immersed in water.

A) True
B) False
C) N.E.I.
Example
An block of density $2.5 \times 10^3$ kg/m$^3$ and of volume $2.0$ m$^3$ is immersed in water of density $1.0 \times 10^3$ kg/m$^3$.
The block hangs from a scale which reads $W$ as the weight.

Find the reading of the scale in N after the block is immersed in water.