Static Fluids

Phases of Matter

- Solid
  - Maintains a fixed shape and fixed size
  - Does not readily change in shape or volume even if a large force is applied to it
- Liquid
  - Takes on the shape of its container
  - Not readily compressible
  - Volume can only be changed significantly by a very large force

- Gas
  - Neither fixed shape nor fixed volume (it expands to fill its container)
- Other
  - Not everything fits into the three ordinary phases of matter
  - Plasma
    - Ionized atoms (only occurs at very high temperatures)
    - Liquid crystals (between solid and liquid)
    - Colloids (suspension of tiny particles in liquid)

Fluid

- Substances that can flow and take the shape of the container
  - Liquids and gases
- Ideal fluid
  - Cannot be compressed
  - Non-viscous
  - Flow in a steady manner

Density

- Density is defined as mass per unit volume

$$\rho = \frac{m}{V}$$

Pressure

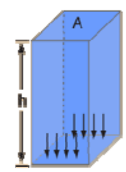
- Pressure is defined as force per unit area
  - Where force is understood to be the magnitude of the force acting perpendicular to the surface area, A

$$P = \frac{F}{A}$$

Pressure in Fluids

- A fluid can exert pressure in any direction
- The pressure increases with depth
- The pressure at any point in a fluid is equal in all directions
  - Otherwise the fluid would be in motion

- Consider a column with surface area A and depth h in a fluid of density ρ
- The upwards force due to the pressure from the liquid on the surface area A must be equal to the weight of the column of fluid



hyperphysics.phy-astr.gsu.edu

$$PA = mg = \rho Ahg$$
$$P = \rho hg$$

- If the fluid is not in a sealed container then it is also subject to atmospheric pressure, P_0

$$P = P_0 + \rho hg$$

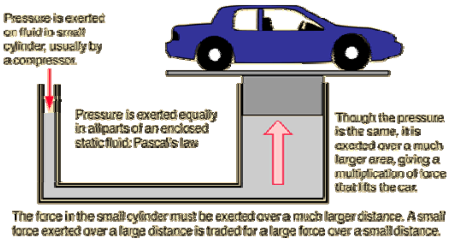
Note: in your data booklet, the equation is shown as:

$$\boxed{P = P_0 + \rho_f gd}$$

Pascal's Principle

- The pressure applied at one point in an enclosed fluid under equilibrium conditions is transmitted equally to all parts of the fluid

- A hydraulic jack uses Pascal's principle



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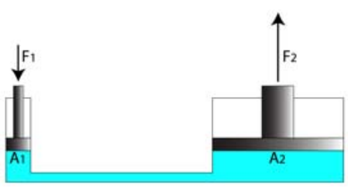

aplusphysics.com/courses/honors/fluids/Pascal.html

- The pressure applied at position 1 must be equal to the pressure at position 2

$$P_1 = P_2$$

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

Buoyancy

- Objects submerged in a fluid appear to weigh less than they do when outside the fluid
- Many objects float on water
- This buoyancy occurs because the pressure in a fluid increases with depth resulting in the upward pressure being greater than the downward pressure

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- Consider a cylinder with cross-sectional area A and height h completely submerged in a fluid of density ρ_f to a depth of d
- The fluid exerts a pressure at the top of the cylinder of $P_T = \rho_f gd$
- Resulting in a force of $F_T = P_T A = \rho_f gdA$
- Similarly the force at the bottom of the cylinder will be $F_B = P_B A = \rho_f g(d+h)A$
- The buoyant force, B, is the difference between these two forces

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$$B = F_B - F_T$$
$$B = \rho_f gA(d+h) - \rho_f gAd$$
$$B = \rho_f gAh$$
$$\boxed{B = \rho_f V_f g}$$
$$B = m_f g$$

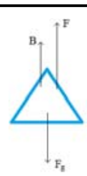
- The buoyant force is equal to the weight of the fluid displaced
- This result is valid regardless of the shape of the object
- This discovery is credited to Archimedes of Syracuse (287-212 BCE)

Archimedes' Principle

- The buoyant force on an object immersed in a fluid is equal to the weight of the fluid displaced by that object
  - "fluid displaced" is the volume of fluid equal to the part of the volume of the object that is submerged (the fluid that used to be where the object is)

Example 1

- An ancient statue lies at the bottom of the sea. The statue is estimated to have a mass of 70kg and a volume of $3.0 \times 10^{-2} m^3$. How much force is required to lift it? The density of sea water is 1.025×10^3 kgm^{-3}.



$$F + B = F_g$$
$$F = mg - \rho_f V_f g$$
$$F = (70\text{kg})(9.81\text{ms}^{-2}) - (1.025\times10^3\text{kgm}^{-3})(3.0\times10^{-2}\text{m}^3)(9.81\text{ms}^{-2})$$
$$F = 390 \text{ N}$$

- Note: Once the statue is above the water, it will take more force to continue to lift it

Example 2

www.dummies.com/how-to/content/understanding-buoyancy-using-archimedess-principle.html

- A wooden platform of thickness, h, and surface area, A, is placed in water. The distance, y, represents the amount of the platform that is submerged. Calculate the ratio y/h.

$$\rho_{\text{water}} = 1000\ \text{kgm}^{-3}$$

$$\rho_{\text{wood}} = 640\ \text{kgm}^{-3}$$

- Object is in hydrostatic equilibrium with only two forces acting on it: B and F_g

$$B = F_g$$

$$\rho_f V_f g = mg$$

$$\rho_f A y g = \rho_{\text{wood}} A h g$$

$$\frac{y}{h} = \frac{\rho_{wood}}{\rho_f}$$

$$\frac{y}{h} = \frac{640\text{kgm}^{-3}}{1000\text{kgm}^{-3}}$$

$$\frac{y}{h} = 0.64$$