

Chapter 10: Fluids

Lecture 1

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10-1] Phases of Matter

There are three common phases of matter :

- i) Solid: fixed shape and fixed volume.
- ii) Liquid: variable shape and fixed volume
- iii) Gas : variable shape and variable volume

Gases and Liquids don't maintain their shape
(No fixed shape) \Rightarrow can flow and collectively
referred to as Fluids.

A fourth less common type of matter is plasma. It is a collection of positive ions and free electrons. This requires very high temperatures.

10-2] Density and Specific Gravity

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}} \Rightarrow \overset{\text{rho}}{\rho} = \frac{m}{V}$$

has units of $\frac{\text{kg}}{\text{m}^3}$ or g/cm^3
SI unit


e.g. $\rho_{\text{water}} = 1000 \text{ kg/m}^3$ or $\rho_w = 1 \text{ g/cm}^3$

Example 10-1]

What is the mass of a solid iron wrecking ball of radius 18 cm?

$$\rho_{\text{iron}} = 7800 \text{ kg/m}^3.$$

$$m = \rho V = 7800 \times \frac{4}{3} \pi (0.18)^3 = 190 \text{ kg}.$$

$$V = \frac{4}{3} \pi r^3$$
A diagram of a sphere with a horizontal line from the center to the right edge, labeled 'r'.

Specific Gravity (SG)

$$SG = \frac{\text{density of material}}{\text{density of water at } 4^\circ\text{C}}$$

$$\text{At } 4^\circ\text{C}, \rho_w = 1000 \text{ kg/m}^3.$$

$$\text{For iron: } SG = \frac{7800}{1000} = 7.8$$

10-3] Pressure in Fluids



Pressure: magnitude of the force per unit area, where the force is perpendicular to the area.



$$p = \frac{F \sin \theta}{A}$$

Pressure is a scalar quantity.

F is perpendicular to the area.

units of pressure $p = \frac{F}{A} \Rightarrow [p] = \frac{N}{m^2} \equiv \text{Pascal}.$



Example 10-2]

Calculating pressure. A 60-kg person's two feet cover an area of **500 cm²**.

(a) Determine the pressure exerted by the two feet on the ground. (b) If the person stands on one foot, what will be the pressure under that foot?

$$a) p = \frac{F}{A} = \frac{mg}{A} = \frac{60 \times 9.8}{500 \times 10^{-4}} \approx 12 \times 10^3 \frac{N}{m^2} = 12 \times 10^3 \text{ Pa}$$

$$b) p' = \frac{F}{(A/2)} = 2 \frac{mg}{A} = 24 \times 10^3 \text{ Pa}.$$

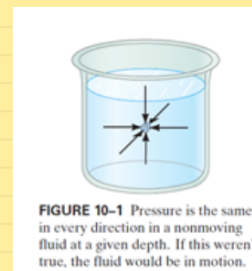


Static Fluids (Fluids at rest)

Two important properties

- 1) At a point inside the liquid, the pressure is the same in all directions.

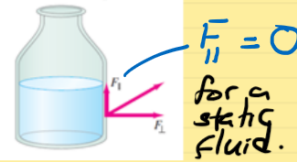
Evidence: the very small volume of the shown cube of the fluid is at rest. If the pressures were different \Rightarrow cube of liquid would move.



2) The pressure of any static fluid is always perpendicular to any surface that is in touch with the fluid.

If the force of the fluid on the container had a component $F_{||}$ parallel to the bottle's wall \Rightarrow the wall will act on the fluid with an opposite force downwards, which would move the fluid. But since the fluid is at rest $\Rightarrow F_{||} = 0$.

FIGURE 10-2 If there were a component of force parallel to the solid surface of the container, the liquid would move in response to it. For a liquid at rest, $F_{||} = 0$.



Calculating the Pressure due to the liquid at a height h below the surface of the liquid.

The pressure of the liquid on the area A is due to the weight of the liquid.

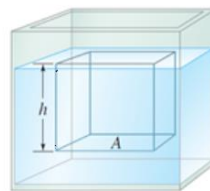


FIGURE 10-3 Calculating the pressure at a depth h in a liquid, due to the weight of the liquid above.

$$P = \frac{F}{A} = \frac{mg}{A} \quad \text{— weight of the liquid.}$$

$$P = \frac{\rho V g}{A} = \frac{\rho (Ah) g}{A} = \rho_f g h \quad \text{density of the fluid}$$

$$P = \rho_f g h$$

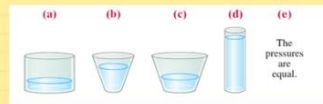
fluid pressure increases with depth below the fluid surface.

NOTE that the pressure is independent of the area A .

Example

Which container has the largest pressure at the bottom?

Container (d) since h is largest



$$P = \rho_f g h$$

$$P = \rho_f g h$$

Pressure at the top surface is

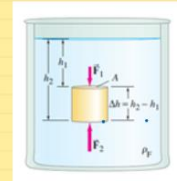
$$P_1 = \rho_f g h_1$$

Pressure at the bottom surface

$$P_2 = \rho_f g h_2 \quad \text{NOTE } P_2 > P_1$$

$$\Delta P = P_2 - P_1 = \rho_f g (h_2 - h_1)$$

$$\Delta P = \rho_f g \Delta h$$



$$\vec{F}_R = \vec{F}_2 - \vec{F}_1$$

↑
upwards
since $F_2 > F_1$

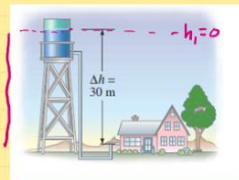
\vec{F}_R ← called buoyant force
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$F_R > mg \Rightarrow$ object floats.
 $F_R < mg \Rightarrow$ object sinks.

Example 10-3]

Pressure at a faucet

The surface of the water in a storage tank is 30 m above a water faucet in the kitchen of a house. Calculate the difference in water pressure between the faucet and the surface of the water in the tank.



$$\Delta P = \rho_f g \Delta h$$

$$\Delta P = (1000)(9.8)(30) = 2.9 \times 10^5 \frac{\text{N}}{\text{m}^2} = 2.9 \times 10^5 \text{ Pa}.$$

$$\Delta P = P_2 - P_1 = \rho_f g (h_2 - h_1)$$

$$P_2 - P_1 = \rho_f g \Delta H$$

$$P_2 = P_1 + \rho_f g \Delta H$$

$$P_2 = P_1 + \rho_f g h$$



$$\Delta H = h_2 - h_1$$

Pressure due to the liquid only $\rightarrow P_1 = \rho_f g h_1$

Pressure due liquid and air $\rightarrow P_1^{tot} = P_1 + P_{atm}$ ← atmospheric pressure

$$P_2^{tot} = P_2 + P_{atm}$$

$$P_2^{tot} - P_1^{tot} = (P_2 + P_{atm}) - (P_1 + P_{atm})$$

$$= P_2 - P_1 = \rho_f g \Delta H$$