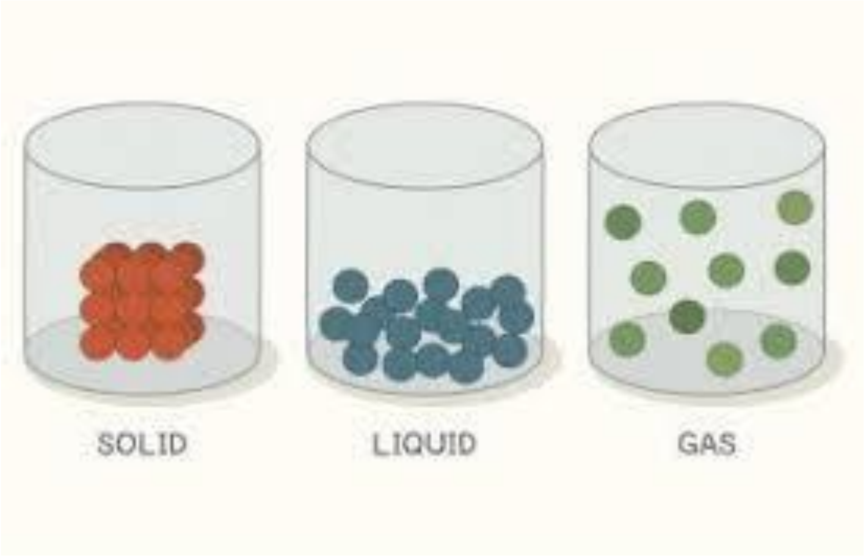
Chapter 13

Solids and Fluids



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Outline

- Chapter (13)
  - 13.2 States of Matter
  - 13.4 Pressure
    - Pressure-Depth Relation

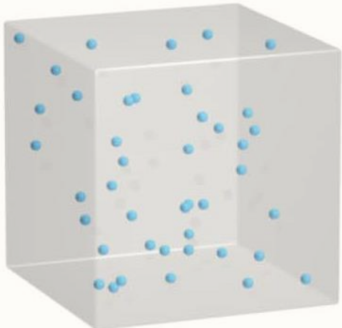
Learning Outcomes

After studying this chapter, you will be able to:

- **Differentiate between different states of matter: gas, liquid, and solid.**
- **Identify that pressure is a force per unit area.**
- **Identify density.**
- **Know the pressure- depth relation and apply it to solve problems.**

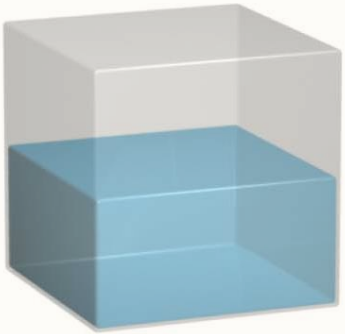
13.2 States of Matter

Gas



- Is a system in which each atom or molecule moves through space as a free particle.
- Is compressible and fills its container.

Liquid



- When a liquid is placed in a container, it fills only the volume corresponding to its initial volume.
- Is nearly incompressible.

Solid

- Does not require a container but defines its own shape.
- Is incompressible.

Fluids (Gas and Liquid)

13.2 States of Matter

Other States of Matter

- There are other states of matter that do not fit into the **solid/liquid/gas classification**.
- For example, **foams**, **gels** and matter in stars are in the form of **plasma**.

- The state of a certain matter depends on its **temperature**.

Ice - solid Water - liquid Steam - gas

13.4 Pressure

- **We will consider the pressure of the liquids and gases (fluids) at rest.**
- **Pressure** is a scalar quantity and is defined as the force per unit area:

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

- The SI unit of pressure is N/m^2, which has been given the name **pascal**, abbreviated Pa:

$$1\ \text{Pa} = \frac{1\ \text{N}}{1\ \text{m}^2}$$

- The average pressure of the Earth's atmosphere, 1 atm, is:

$$1\ \text{atm} = 1.01\ \times\ 10^5\ Pa$$

- Atmospheric pressure is often quoted in non-SI units:

$$1\ \text{atm} = 760\ \text{torr} = 760\ \text{mm Hg}$$

13.4 Density

- Every material has a certain density associated with it.
- **Density** is a measure of mass per unit of volume:

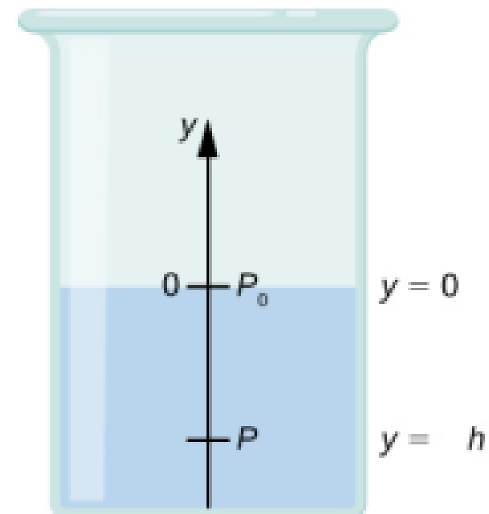
$$\boldsymbol{\rho = \frac{m}{V}}$$

- **Density** is a scalar quantity which has magnitude only.
- The SI unit of density is: kg/m^3.
- For example the density of water is 997 kg/m^3

13.4 Pressure-depth relationship

- In an open container, the pressure at any given height *h* consists of:
  1) the atmospheric pressure p_o which is the pressure at $y = 0$.
  2) the pressure due to the fluid which is equal to ρ g h.
- Therefore, the pressure *p* at depth *h*

$$p = p_0 + \rho g h$$



where ρ is the density of the fluid

g is the acceleration of gravity= 9.8 m/s^2

h is the depth.

External example

- **A stiletto heel has a surface area of approximately 2.5 cm × 2.0 cm. If a lady puts all of her 60 kg 'weight' on it, what pressure is created on the floor surface.**

SOLUTION:

Stiletto area = $(2.5 \times 10^{-2}) \times (2.0 \times 10^{-2}) = 5 \times 10^{-4}\ m^2$

Weight = magnitude of gravitational force = mg

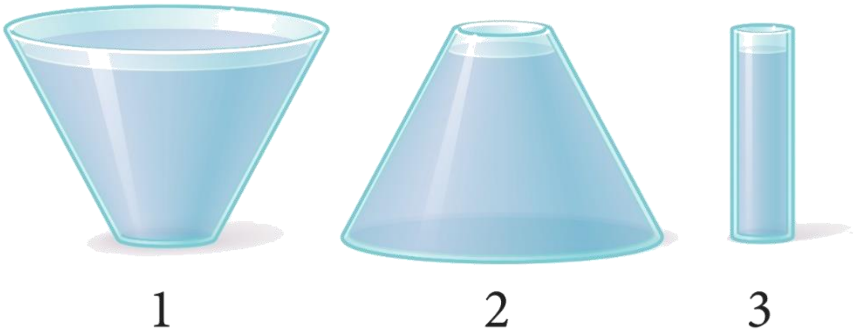
= (60 kg)×(9.8 m/s^2) = 588 N

Stiletto pressure: $P = \frac{F}{A} = \frac{588\ N}{5 \times 10^{-4} m^2} = 117.6 \times 10^4\ N/m^2 = 1.2 \times 10^6$ Pa

Concept Check

Three containers of water have different shapes. The distance between the top surface of the water and the bottom of each container is the same.

Which of the following statements correctly characterizes the pressure at the bottom of the containers?



A. The pressure at the bottom of container 1 is the highest.
B. The pressure at the bottom of container 2 is the highest.
C. The pressure at the bottom of container 3 is the highest.
D. The pressure at the bottom of all three containers is the same.

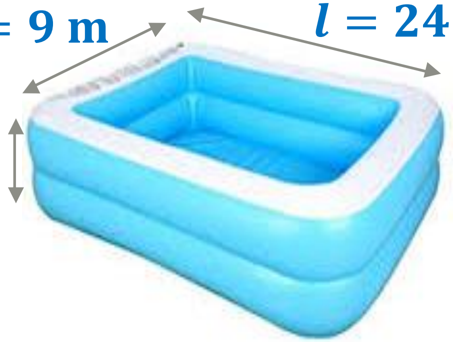
External example

A swimming pool of width 9.0 m and length 24.0 m is filled with water to a depth of 3.0 m.

a) Calculate pressure on the bottom of the pool due to the water?
b) Calculate pressure on the bottom of the pool?
c) Calculate the force on the bottom of the pool ?

Solution:

$p_o = 1.01325 \times 10^5 Pa$ $\rho = 1000$ kg/m^3 $g = 9.8 m/s^2$ $h = 3$m



a) The pressure at the bottom of the pool due to water

$\rightarrow P = \rho g h$

$\rho = 1000$ kg/m^3 , $g = 9.8$ m/s^2 $h = 3$m

$P = (1000)\times(9.8)\times(3) = 29400$ Pa

b) The force on the bottom of the pool $P = \frac{F}{A} \rightarrow F = P\,A = 1.31 \times 10^5 \times 216 = 2.82 \times 10^7 N$

c) The pressure at the bottom of the pool $\rightarrow p = p_o + \rho g h$

$p = p_o + \rho g h = 1.01325 \times 10^5 + [1000 \times 9.8 \times 3] = 1.31 \times 10^5$ Pa

Equation summary

(1) **Pressure**

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

(2) **Pressure at a given depth of a liquid:**

$$p = p_0 + \rho g h$$

(3) **Density**

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

The END OF CHAPTER (13)