CHAPTER 5: PRESSURE AND DEFORMATION IN SOLIDS

1. *Introduction to Matter and Forces*

Matter is composed of atoms and molecules. When external forces like weight, pressure, or heat are applied, they cause the deformation of matter, which alters its shape, dimension, and orientation.

- **Solid Matter:** Atoms and molecules are closely packed, and the intermolecular space is minimal compared to liquids and gases. As a result, solids retain their original shape and can return to equilibrium after the removal of an external force.
- **Liquid and Gaseous Matter:** Atoms and molecules in liquids and gases are loosely packed, which makes them easier to deform. They do not return to their equilibrium state unless another external force is applied.

2. *Elasticity*

Elasticity is defined as the ability of a deformed body to return to its original shape and size when the deforming forces are removed.

- **Elastic Materials:** Materials that regain their original shape, like rubber bands and springs.
- **Inelastic Materials:** Materials that do not return to their original shape after being deformed, such as plasticine, clay, and dough.

Most materials exhibit elasticity up to a certain limit known as the **elastic limit**. Beyond this limit, the material fails to return to its original shape.

2.1 Hooke's Law

- **Definition:** Hooke's Law states that within the elastic limit, the extension (or compression) of a spring is directly proportional to the applied force. Mathematically, it is expressed as:

  $F = kx$

  Where:

  - F is the restoring force,
  - k is the spring constant (force constant),
  - x is the extension or compression.

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The negative sign indicates that the force is applied in the opposite direction to the deformation (restoring force).

2.2 Applications of Hooke's Law

- **Balance Wheel in Mechanical Watches:** Hooke's law helps in the working of balance wheels in mechanical watches. The elasticity of the spring ensures the accurate and constant oscillation of the wheel.

- **Spring Scale:** It is used to measure weight or force, utilizing Hooke's law to convert the extension of the spring into a weight reading.

- **Galvanometer:** Hooke's law is used in the hair springs of galvanometers, where the deflection of the needle is proportional to the applied force.

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3. *Pressure*

Pressure is the force applied per unit area. It is represented by the formula:

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

Where:

- P is pressure,
- F is the force applied,
- A is the area over which the force is applied.

The SI unit of pressure is the **pascal (Pa)**, where:

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

3.1 Effects of Pressure

- **Increased Pressure:** When the same force is applied over a smaller area, pressure increases.

- **Examples:**
  - A needle pricking a balloon creates enough pressure to burst it.
  - High-heeled shoes exert greater pressure on the ground than flat shoes.

3.2 Calculation of Pressure

- **Example:** If a 50 kg person applies a force with one foot having an area of $0.02\ \text{m}^2$:

  Weight of person $= F = 50 \times 9.8 = 490\ \text{N}$

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Pressure exerted by one foot:

$P = \frac{490}{0.02} = 25{,}000$ Pa (or 25 kPa)

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4. ***Atmospheric Pressure***

Atmospheric pressure is the force exerted by the weight of air on the surface of Earth and all objects. At sea level, the average atmospheric pressure is **1 atm**, or approximately **101.3 kPa**. It can vary based on altitude, weather, and location.

4.1 **Measuring Atmospheric Pressure**

- **Mercury Barometer:** A mercury barometer measures atmospheric pressure by balancing the weight of mercury in a tube against the atmospheric pressure.
  - At sea level, the height of mercury in the barometer is around **760 mm** or **29.92 inches**, corresponding to **101.325 kPa**.

4.2 **Variation with Altitude**

Atmospheric pressure decreases as we go higher above sea level. At **Mount Everest**, the pressure is only **33 kPa** due to the thinner atmosphere.

4.3 **Applications of Atmospheric Pressure**

- **Suction Cups:** The atmospheric pressure holds suction cups in place when air is removed from underneath.
- **Vacuum Sealing:** When air is removed from a sealed container, atmospheric pressure pushes inward, causing the container to collapse.

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5. ***Liquid Pressure***

Liquids exert pressure due to the weight of the liquid above. The pressure in a liquid depends on its depth, density, and the acceleration due to gravity.

The pressure at a certain depth in a liquid is given by:

$$P = \rho g h$$

Where:

- ρ is the density of the liquid,
- g is the acceleration due to gravity,
- h is the height of the liquid column.

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5.1 Example Calculation

If a submarine is 8500 m below the surface of water, and the density of water is **1000 kg/m³**:

$$P = 1000 \times 9.8 \times 8500 = 8.55 \times 10^7 \text{ Pa}$$

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6. *Manometer*

A manometer is a device used to measure the pressure of a fluid. It works by balancing the pressure of the fluid with the height of a column of liquid.

The pressure difference is given by:

$$P = \rho g h$$

Where ρ is the fluid's density, g is gravitational acceleration, and h is the height of the liquid column.

6.1 Applications of Manometer

- **Measuring Fluid Pressure:** Used to measure the pressure of liquids and gases in labs and industrial settings.
- **Vacuum Measurements:** Measures the difference in pressure below atmospheric pressure.

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7. Pascal's Principle

Pascal's Principle states that any change in pressure applied to an enclosed fluid is transmitted undiminished to all parts of the fluid.

This principle is applied in systems like hydraulic lifts and brake systems, where force is transmitted through a fluid.

ALL FORMULAE (COLLECTED AT END)

1. **Pressure:**

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

2. **Hooke's Law:**

   $F = kx$

3. **Pressure in Liquid:**

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$P = \rho g h$

4. **Atmospheric Pressure:**

   $1 \text{ atm} = 101.325 \text{ kPa}$

5. **Manometer:**

   $P = \rho g h$

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