FORCE & PRESSURE

CONTENTS

FORCE

The external agent which can changes :

the speed and direction of motion or

the shape of a body

is called **force**.

It is a vector quantity

◈ **Types of forces :**

(A) Contact forces :

The forces that act on bodies when they are in actual contact are known as contact forces.

Ex. Frictional force, normal reaction force, tension in string, force exerted during collision, force applied as a push or a pull etc.

(B) Non-contact forces :

The forces that act on bodies without being touched are called non-contact forces.

Ex. Gravitational force, electrostatic force, magnetic force etc.

NEWTON'S LAWS OF MOTION

(A) Newton´s Ist law :

A body can not change its state of motion by itself. If the object is at rest it will remain at rest and if it is in uniform motion, it continues to be in motion unless some external force is applied on it.

This law is also known as *law of inertia.*

(B) Newton´s second law :

Newton's second law can be written as

$$\vec{F} = m\vec{a} = m\left[\frac{v-u}{t}\right]$$

Ex.1 Calculate the force required to produce an acceleration of 5 m/s^2 in a body of mass 2.4 kg.

Sol. We know that force = mass × acceleration

$= 2.4 \text{ kg} \times 5 \text{ m/s}^2 = 12.0\text{N}$

Ex.2 A force acts for 0.2 s on a body of mass 2.5 kg initially at rest. The force then ceases to act and the body moves through 4m in the next one second. Calculate the magnitude of force.

Sol. When the force ceases to act, the body will move with a constant velocity. Since it moves a distance of 4 m in 1 s, therefore, its uniform velocity = 4m/s.

Now, initial velocity, $u = 0$

Final velocity, $v = 4$ m/s

Time interval $\Delta t = 0.2$ s

$\therefore$ Acceleration, $a = \dfrac{v-u}{\Delta t} = \dfrac{4-0}{0.2} = 20\text{m/s}^2$

From the relation,

F = ma, we get

Force, $F = 2.5 \times 20 = 50$ N

Ex.3 A ball of mass 20 gm is initially moving with a velocity of 100 m/s. On applying a constant force on the ball for 0.5s, it acquires a velocity of 150 m/s. Calculate the following :

(i) Acceleration of the ball

(ii) Magnitude of the force applied

Sol. Given , m = 20 gm = kg = 0.02 kg

Initial velocity, u = 100 m/s

Time interval, t = 0.5 s

Final velocity, v = 150 m/s

(i) Acceleration, $a = \frac{v-u}{t} = \frac{150-100}{0.5} = 100\text{ms}^{-2}$

(ii) Force, F = mass × acceleration

=0.02 × 100 = 2.0 N

Ex.4 A cricket ball of mass 200 gm moving with a speed of 40 m/s is brought to rest by a player in 0.04s. Calculate the average force applied by the player.

Sol. Mass, m = 200 gm = $\frac{200}{1000}$ kg = 0.2 kg

Initial velocity, u = 40 m/s

Final velocity, v = 0

Time, t = 0.04s

Average force =

$\frac{\text{Change in momentum}}{\text{Time}} = \frac{-8.0}{0.04} = -200$ N

(The negative sign shows that the force is applied in a direction opposite to the direction of motion of the ball).

Ex. 5 A motorcycle is moving with a velocity of 108 km/hr and it takes 5 s to stop it after the brakes are applied. Calculate the force exerted by the brakes on the motorcycle if its mass along with the rider is 250 kg.

Sol. Given that initial velocity of the motorcycle

= 108 km/hr = 30 m/s

Final velocity = 0 m/s

Time taken to stop = 5s, the mass of the motorcycle with rider = 250 kg.

The change in the velocity of the motorcycle in 5s = 0 – 30 = –30 m/s

Therefore, the acceleration of the motorcycle,

$a = \frac{-30}{5} = -6\,\text{m/s}^2$

The magnitude of the force applied by the brakes is given by the equation,

F = mass × acceleration

= 250 kg × (6)m/s^2 = 1500 N

(C) Newton's third law of motion

Newton's third law of motion states that *" if a body A exerts a force on the body B, the body B will also exert an equal and opposite force on A."*

Newton's third law is also stated as "to every action there is an equal and opposite reaction."

- The force exerted by A on B is called action while the force exerted by B on A is called the reaction.

Action and reaction always act on different bodies.

Forces always occur in pairs.

eg. by hitting a table with palm we apply a force. The table also exerts a force on palm on hitting it.

THRUST AND PRESSURE

(A) Thrust :

- The force acting normally on surface is called 'thrust'.
- This is a vector quantity.
- It is measured in newton (N).

(B) Pressures :

- The thrust on an unit area of a surface is called 'pressure'.
- Pressure = $\frac{\text{Thrust}}{\text{Area}}$ or $P = \frac{F}{A}$
- Unit : The SI unit of pressure is newton per meter square or N/m^2, other units of pressure are *pascal* and *bar.*
- *One Pascal* : One pascal is defined as the pressure exerted on a surface area of 1m^2 by a thrust of 1 newton. i.e. 1 Pascal = 1 N/m^2

❖ **Some examples based on pressure**

- Inserting a pointed nail in a wooden block is an easier task than to insert a rod inside a wooden block with the same force because the nail has a smaller area and thus it will experience more pressure even with the same force.
- A sharp knife cuts better than a blunt knife.
- While walking, a man exerts more pressure on the ground in comparison to when he is standing.

❖ **Pressure in fluids**

- A substance that can flow is called a 'fluid'.
- liquids and gases are considered as fluids.

❖ **Laws of pressure**

- Pressure exerted by the liquid is the same in all directions about a point.
- Pressure exerted is the same at all points in a horizontal plane as well as in a stationary liquid.
- Pressure at a point inside a liquid increases with depth from the free surface.
- *The pressure exerted anywhere in a confined liquid is transmitted equally and undiminished in all directions throughout the liquid which is called 'Pascal's law'.*

(A) Hydrostatic Pressure : The normal force (or thrust) exerted by a liquid at rest per unit area of the surface in contact with it is called "pressure of liquid or hydrostatic pressure."

(B) Atmospheric Pressure : The pressure exerted by atmosphere is called atmospheric pressure.

- At sea level, atmospheric pressure is the pressure exerted by 0.76 m of mercury column i.e. h = 0.76 m.

Ex.6 A force of 150 N is applied on an area of 1.5 m^2. Calculate the pressure exerted.

Sol. Force, F = 150 N; area, A = 1.5 m^2

$$\text{Now, Pressure} = \frac{\text{Force}}{\text{Area}}$$

$$\text{or} \quad P = \frac{F}{A} = \frac{150\text{N}}{1.5\text{m}^2} = 100 \text{ N/m}^2$$

Ex.7 A force of 500 dynes is applied on an area of 20 cm^2. Calculate the pressure exerted.

Sol. Force, F = 500 dynes = 500×10^{-5} Newton

Area, A = 20 cm^2 = 20×10^{-4} m^2

$$\text{Pressure, } P = \frac{F}{A} = \frac{500\times10^{-5}\text{N}}{20\times10^{-4}\text{m}^2} = 2.5 \text{ N/m}^2$$

➤ BUOYANCY

When a body is immersed in a liquid, the liquid exerts an upward force on the body called as the 'upthrust' or 'buoyant force.'

❖ **Factors affacting upthrust :**

- Larger the volume of the body submerged in the liquid, greater is the upthrust.
- Larger the density of the liquid, greater is the upthrust.

❖ **Archimedes principle :**

'Archimedes' principle states that when a body is immersed in liquid partially or completely, it experiences an upthrust equal to the weight of the liquid displaced." or the loss in weight of the block, (buoyant force) acting on the block is equal to the weight of the liquid displaced.

Ex. 8 A body weighs 300 N in air and 260 N when completely immersed in water. Calculate the following :

(i) loss in weight of the body

(ii) upthrust on the body.

Sol. Given : Weight of body in air = 300 N

Weight of the body in water = 260 N

∴ Loss in weight of the body

= 300 – 260 = 40 N

∴ Upthrust of the body = Loss in weight = 40 N

➤ DENSITY

- $\text{Density} = \frac{\text{Mass}}{\text{Volume}}$ or $d = \frac{M}{V}$

  SI unit of density is kg/m^3 and CGS unit of density is g /cm^3
- Water has anomalous expansion. When water is cooled at 4ºC, its volume decreases but on further cooling its volume starts increasing.

  ⇒ the density of water is maximum at 4ºC.