CHAPTER: 3
DYNAMICS

Dynamics:-

The branch of physics in which we study about the motion of objects and the cause of motion is called dynamics.

Force:-

Force is the agent that changes or tends to change the position of a body.

Inertia:-

The property of a body due to which it resists any change in its state of rest or motion.

Momentum:-

The quantity of motion in a body due to its mass and velocity is called momentum.

Mathematically it is defined as "The product of mass and velocity is called momentum.

Formula:-

Momentum = (Mass) (velocity)

$P = mv$

Quantity:-

Momentum is a vector quantity.

NEWTON'S LAW OF MOTION

Newton's First Law Of Motion:-

Statement:-

A body continues its state of rest or of uniform motion in a straight line motion provided no net force acts on it.

Explanation:-

Newton's first law of Motion has two parts.

First Part:-

According to first part of this law if a body is at rest then it will remain at rest provided no net force acts on it.

Second Part:-

According to second part of this law if a body is moving then it does not stop by itself. Some force is required to stop this moving body.

Law of inertia:-

Newtons first law of motion is also called law of inertia.

Newton's Second Law Of Motion:-

Statement:-

When a net force acts on a body then it produces an acceleration in the body in the direction of net force. The magnitude of this acceleration is directly proportional to the net force and inversely proportional to mass of the body.

Explanation:-

If a force 'F' produce an acceleration 'a' in the body of mass 'm' then according to newtons second law.

$$a \propto F \longrightarrow (1)$$

$$a \propto \frac{1}{m} \longrightarrow (2)$$

From (1) and (2)

$$a \propto \frac{F}{m}$$

Here Constant = k And K = 1

$$a = (1)\frac{F}{m}$$

$$a = \frac{F}{m}$$

$$ma = f$$

$$F = ma$$

$$\boxed{\mathbf{F = ma}}$$

Newton's Third Law Of Motion:-

To every action there is always an equal but opposite reaction.

Example- I:-

Consider a book lying on a table. The weight of the book is acting on the table in downward direction. This is action of the book on the table. The reaction of the table acts on the book in upward direction. These actions and reactions are equal but opposite to each other. Therefore the book remains at rest on the table.

Example - II:-

In rocket motion when a rocket moves then hot gases goes out from its lower side as a reaction of these gases the rocket moves upward.

Mass:-

The quantity of matter in a body is called mass.

Weight:-

The force with which earth attracts a body towards its centre is called weight.

Difference between mass and weight:-

Mass	Weight
1. The quantity of matter in a body is called mass.	**1.** The force with which earth attracts a body towards its centre is called weight.
2. Mass is a scalar quantity.	**2.** Weigh is a vector quantity.
3. The unit of mass is kilogram (kg).	**3.** The unit of the weight is Newtron (N).
4. Mass remains same everywhere.	**4.** Weight of body changes due to change in gravity.
5. Mass is measured by ordinary balance	**5.** Weight is measured by spring balance.

MOMENTUM AND FORCE

Question

What is relation between momentum and force:-

OR

Show that rate of change of momentum of body is equal to applied force?

Ans. Momentum and force:-

There is a special relation between force and momentum. According to this relation.

"When a force acts on a body then it produces acceleration in the body and this force will be equal to rate of change of momentum"

Explanation:-

Consider a body of mass 'm' is moving with some initial velocity 'v_i'. A force F acts on the body and produce an acceleration 'a' in a body after some time 't' the velocity of the body becomes 'v_f'.

Initial momentum = $p_i = mv_i$

Final momentum = $p_f = mv_f$

Change in momentum = final momentum – initial momentum.

$= p_f - p_i$

$= mv_f - mv_i$

Taking 'm' common

$= m(v_f - v_i)$

Now

Rate of change in momentum = $\frac{\text{Change of momentum}}{\text{time}}$

Rate of change of momentum = $\frac{m(v_f - v_i)}{t}$

$$= m\left(\frac{v_f - v_i}{t}\right) \longrightarrow (1)$$

We know that

$$\frac{V_f - v_i}{t} = a \text{ put in } (1)$$

So

Rate of change of momentum = ma

We know F = ma

So

Rate of change of momentum = F

Hence

Rate of change of momentum of a body is equal to applied force.

Law of Conservation of Momentum:-

Statement:-

The momentum of an isolated system of two or more than two interacting bodies remains constant.

Explanation:-

Consider an isolated system of two bodies of masses 'm_1' and 'm_2'. These two bodies are moving in a straight line with velocities 'u_1' and 'u_2'. If the velocity of first body is greater than velocity of second body the both bodies will collide and after collision their velocities becomes v_1 and v_2.

Now

Momentum of 1st body before collision= m_1u_1.

Momentum of 2nd body before collision = $m_2 u_2$

Total momentum before collision = $m_1u_1 + m_2u_2$

Now

Momentum of 1st body after collision = m_1v_1

Momentum of 2nd body after collision = m_2v_2

Total momentum after collision = $m_1v_1 + m_2v_2$

According to law of conservation of momentum.

Total momentum before collision = Total momentum after collision

$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$

$$\boxed{m_1u_1 + m_2 u_2 = m_1v_1 + m_2v_2}$$

APPLICATION OF MOMENTUM

System of gun and Bullet:-

Consider a system of gun and a bullet in which before firing a bullet both the gun and the bullet are at rest. So total momentum of the system is zero.

Total momentum of gun and bullet before firing =0

Now if the gun is fired then the bullet shoots out of a gun and gain some momentum. To conserve this momentum of the system the gun recoils.

If 'm' is the mass of bullet and 'v' is its velocity and if 'M' is the mass of gun and 'V' is velocity of recoil.

Then

Total momentum of gun and bullet after firing = mv + MV

According to law of conservation of momentum.

(Total Momentum of gun And bullet before firing) = (Total momentum of gun and bullet after firing)

$O = mv + MV$

$MV + mv = O$

$MV = -mv$

$V = \frac{-mv}{M}$

Page No. 71 Example No. 3.7:-

Mass of bullet = m = 20g = $m = \frac{20}{1000}$ = 0.02kg

Velocity of bullet = v = 100m/sec

Mass of gun = M = 5kg

Velocity of recoil = V = ?

According to law of conservation of momentum

(Total Momentum of gun And bullet before firing) = (Total momentum of gun and bullet after firing)

$O = mv + MV$

$mv + Mv = O$

$(0.02)(100) + (5)v = 0$

$2 + 5v = 0$

$5v = -2$

$V = \frac{-2}{5}$

$V = -0.4$

$V = -0.4 m/sec$

Friction:-

The force that opposes the motion of moving objects is called friction.

Explanation:-

The force of friction depends upon normal reaction of the surface of body.

From different experiments it has been found that the force of friction is directly proportional to normal reaction of the surface of body.

$$\text{Friction} \propto R$$

$$F = (\text{constant}) R$$

$$\text{Constant} = \mu$$

So

$$F = \mu R \longrightarrow (1)$$

Here μ is a constant known as coefficient of friction.

Also

Normal reaction = weight of the body

$$R = W$$

$$R = mg$$

So from equation (1)

$$F = \mu R$$

Putting value of 'R'

$$F = \mu mg$$

$F = \mu R$

Or

$F = \mu mg$

Static Friction:-

The force of friction which act on a body when it is at rest is called static friction. It is represented by 'F_s' and its formula is

$$F_s = \mu_s R$$

Where μs = coefficient of static friction

Kinetic Friction:-

The force of friction which act on a body when it is in motion is called kinetic friction. It is represented by F_k and its and its formula is

$$F_k = \mu_k R$$

Where μ_k = coefficient of kinetic friction

Advantages of Friction:-

1. Due to friction we can walk on the ground.
2. Due to friction a moving vehicle can be stop.
3. Due to friction we can write on a paper.
4. The birds cannot fly if there is no air friction.
5. The nails that are used to join the pieces of wood stay at their position just because of friction.

Disadvantages of Friction:-

1. Due to friction the tyres of the cars and soles of the shoes wear out.
2. Due to friction energy is lost.
3. Due friction heat is created which can damage different parts of machine.
4. Due to friction the speed of the fast moving vehicles such as aeroplane decreases.

Methods of Reducing Friction:-

1. Friction can be reduced by making the sliding surface smooth.
2. Friction can be reduced by lubricating the sliding surface.
3. Rolling friction is less than sliding friction therefore sliding friction is converted into rolling friction by ball bearing.
4. The shape of fast moving vehicles such as aeroplane is made streamline (Fish Shape). Due to this streamline shape the friction is reduced.

Circular Motion:-

The motion of an object in a circular path is known as circular motion.

Centripetal Force:-

The force that keeps an object to move in a circle is called centripetal force.

Example:-

The moon revolves around the earth in a circular path. To move in this circular path moon requires a centripetal force. This centripetal force is provided by the gravitational force of earth.

Factors:-

Centripetal force depends upon three factors.

1. Mass of the body.
2. Velocity of the body.

3. Radius of the circle.

For different experiments it has been found that the centripetal force is directly proportional to mass of the body and the square of velocity but it is inversely proportional to radius of the circle.

$$F_c \propto m \longrightarrow (1)$$
$$F_c \propto v^2 \longrightarrow (2)$$
$$F_c \propto \frac{1}{r} \longrightarrow (3)$$

From (1) (2) and (3)

$$F_c = (\text{constant}) \frac{mv^2}{r}$$

Here Constant = k And k = 1

So

$$F_c = (1) \frac{mv^2}{r}$$

$$F_c = \frac{mv^2}{r}$$

Centripetal Acceleration:-

The acceleration produced by centripetal force is called centripetal acceleration. It is represented by a_c and its formula is.

$$a_c = \frac{v^2}{r}$$

Centrifugal force:-

The force that pulls an object to move out of the circular path is called centrifugal force centrifugal force is the reaction force of centripetal force. Its value is equal but opposite to the centripetal force.

$$\text{Centrifugal force} = \frac{-mv^2}{r}$$

Banking of Roads:-

When a car moves on a turning road then it needs centripetal force to move on circular track. This centripetal force is provided by the force of friction between tyres and the road. If this force of friction is not sufficient then the car will skid off the road. To solve this problem outer edge of the road is kept higher than the inner edge. This is known as banking or roads.

Washing Machine Dryer:-

In a washing machine dryer there is a cylinder which has a large number of holes in it. Wet clothes are put into this cylinder and then this cylinder is rotated at high speed. At this high speed the centripetal force could not be applied on the water present in wet clothes so as a result the water comes out through the holes of the cylinder from wet clothes.

Cream Separator:-

Cream separator is a device (machine) which separates cream and other fat materials from milk. A cream separator works on the principle of centrifuge machines. The container of milk is rotated with high speed. As a result the heavy particles will move away from centre and the light particles such as cream and butter are pushed towards the centre. From where it is collected through a pipe.

TENSION AND ACCELERATION IN A STRING

Vertical motion of bodies attached at the ends of a string. That passes over frictionless pulley

Tension:-

The force acting along a stretched string is called tension.

Consider two bodies 'A' and 'B' of masses 'm' and 'm'. These two bodies are attached at the end of the string which passes over a frictionless pulley. If the mass m_1, is greater than mass 'm_2'then the body 'A' will move downward with some acceleration 'a'. At the same time the body 'B' will move upward with same acceleration 'a'

For body 'A':-

There are two forces acting on body 'A'.

1. Its weight ($w_1 = m_1g$) acting downward.

2. Tension in the string acting upward.

Since body 'A' is moving downward

So weight > tension

$m_1 g > T$

And

Net force $= m_1 g - T$

$F_1 = m_1 g - T$

$m_1 a = m_1 g - T$ (1)

For body 'B':-

There are two forces acting on body 'B'.

1. Its weight ($w_2 = m_2 g$) acting downward
2. Tension in the string acting upward. Since body 'B' is moving upward

So

Tension > weight

$T > m_2 g$

Net force = Large value – small value

And

Net force $= T - m_2 g$

$m_2 a = T - m_2 g$ ⟶ (2)

Eq (1) + Eq (2)

$m_1 a = m_1 g - T$

$m_2 a = T = m_2 g$

$m_1 a + m_2 a = m_1 g - m_2 g$

$a (m_1 + m_2) = g (m1 - m2)$

$$a = \frac{g (m_1 - m_2)}{m_1 + m_2}$$

$$a = \frac{g (m_1 - m_2)}{m_1 + m_2}$$

Putting value of 'a' in eq (2)

$m_2 a = T - m_2 g$

$$m_2 \left(\frac{g (m_1 - m_2)}{m_1 + m_2} \right) = T - m_2 g$$

$$m_2 g \frac{(m_1 - m_2)}{m_1 + m_2} + m_2 g = T$$

$$\frac{m_2 g (m_1 - m_2) + m_2 g (m_1 + m_2)}{m_1 + m_2} = T$$

Taking m_2 g common

$$m_2 g \frac{[m_1 - m_2 + m_1 + m_2]}{m_1 + m_2} = T$$

$$m_2 g \frac{[m_1 - m_2 + m_1 + m_2]}{m_1 + m_2} = T$$

$$m_2 g \frac{(2m_1)}{m_1 + m_2} = T$$

$$\frac{2m_1 m_2)}{m_1 + m_2} = T$$

$$\boxed{\mathbf{T = \frac{2m_1 m_2 g}{m_1 + m_2}}}$$