Chapter # 3
Dynamics

Q.1: What is force? What are its unit. Distinguish between contact and non-contact forces?

Ans: Forces:

Definition:

Force is a physical quantity which moves or tends to move a body, stops or tends to stop a moving body or which tends to change the speed and directions of a moving body.

Mathematical Form:

When a force acts on a body of mass "m", it produces acceleration "a" in the body in the direction of force. Mathematically, it can be written as:

Force = mass x acceleration

Or $F = m \times a$

$F = ma$

Quantity and Unit:

Force is a vector quantity. The SI unit of force is "newton" and it is denoted by symbol "N".

So, one newton is defined as the force that produces acceleration of 1 m/s^2 in a body of mass 1 kg. i.e.

$$1\ N = 1\ kg \times 1 m/s^2$$

or

$$1\ N = kg\ m/s^2 \text{ or } kgms^{-2}$$

Types of Force:

There are two types of forces based on the interaction between objects.

1. Contact forces
2. Non – contact forces (Action at a distance forces)

Contact Forces:

Contact forces are those types of forces which result when the two bodies are physically contact with each other.

Example:

Friction forces, push or pull forces etc. are examples of contact forces. e.g. push a cart or drag a chair on floor etc.

Non-contact Forces:

Non- contact forces are those forces which result when the two bodies are not in physical contact with each other. They are also known as "action-at-a-distance forces".

Examples:

Gravitational forces, electric forces and magnetic forces are examples of non-contact forces. E.g. if we release a ball from certain height towards earth surface, then after releasing, earth's surface is not in contact with the ball, it falls down due to force of gravity, such force is called non-contact force.

Q.2: State and explain Newton's three laws of motion. Give one example of each.

Ans: **Newton's Laws of Motion:**

Isaac Newton formulated three laws based on the observation about the motion of objects. These laws express the relationship among force, mass and the motion of an object which are described below:

Newton's First Law of Motion:

Statement:

If the net (external) force acting on an object is zero, the object will maintain its state of rest or of uniform motion with constant velocity.

Or

If there is no external force acting on an object, a body at rest will remains at rest and a body in motion will continue its motion with constant velocity.

Mathematically:

Mathematically, first law can be written as:

If $\vec{F}_{net} = 0$,

Then , $\vec{a} = 0$, or $\Delta\vec{v} = 0$

Explanation:

The first law of motion consists of two parts. The first part of the law is for the "Bodies at rest" and the second part is for the "bodies in motion'.

Bodies at Rest:

The first part of the law states that a body at rest will remain at rest if no net force acts on it.

Example:

A chair lying in a room will stationary and will not start moving by itself unless someone moves it by applying a net force.

Bodies in Motion:

The second part of the law states that a body in motion will continue to move in a straight line with uniform speed if no net force acts on it.

Example:

If we roll a ball on the surface of earth, it comes to rest after sometime due to friction and air resistance. But if we remove all the forces acting on that ball, then it will move forever with uniform velocity.

Newton's First law is also known as "Law of Inertia". Inertia is the property of a body which resists any change in its state of rest or of uniform motion. In other words, we can say that all the bodies try to maintain its state of rest or continue its uniform motion due to inertia.

Example:

When a bus starts motion, suddenly the passengers experience a push in the backward direction. It is because, when the bus starts motion suddenly, then the lower parts of the passengers also comes into motion, while the upper parts are still at rest and wants to be at rest due to inertia. So, they fall in the backward direction. Conversely, if a moving bus suddenly stops, the passenger falls forward.

Newton's Second Law of Motion:

Statement:

The net force "F' on a body is equal to the product of the body's mass "m" and its acceleration "a".

Or

When a net force acts on a body, it produces an acceleration "a" in the body in its own direction. This acceleration is directly proportional to the net force and inversely proportional to the mass of the body.

Explanation:

Newton's Second law of motion establishes a relationship between net force, mass and acceleration. As we know that greater force applied to a body produces greater acceleration. Thus, the acceleration is directly proportional to the force i.e. a αF.

Now if the same amount of force is applied to different masses, it will produce different acceleration. A heavier body will acquire lesser acceleration than a lighter body. This means that the acceleration is inversely proportional to the mass of the body. i.e. $a \propto \frac{1}{m}$

Mathematical Form:

$$a \propto F \text{ ------------- (i)}$$

$$a \propto \frac{1}{m} \text{------------- (ii)}$$

combining eq (i) and (ii), we get

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

or

$$a = \text{constant. } F/m$$

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

In SI units, k =1 then,

$$a = 1 \text{ x } \frac{F}{m}$$

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

or

F = ma ....(3)

Eq(iii) represents the mathematical form of Newton's second law of motion.
Thus, Newton's second law tells us that acceleration "a" will be largest when force "F" is large and mass "m" is small.

Example:

It is easier to push an empty shopping cart than a full one, because the full shopping cart has more mass than the empty one. This means that more force is required to push the full shopping cart.

Newton's Third Law of Motion:

Statement:

"To every action there is always an equal and opposite reaction".

Explanation:

According to Newton's third law of motion, when one object exerts a force on a second object, the second object exerts a force of the same magnitude and opposite direction on the first object. So, when an object "A" exert force on object B written as F_{AB}, object "B" also exert equal force on object A written as F_{BA} but in opposite direction. i.e.

$$\vec{F}_{AB} = -\vec{F}_{BA}$$

Here, the negative sign shows that force F_{BA} is opposite to the force F_{AB}.
So, this law described these two forces as action reaction pair. Action and reaction always occur in pair because they act on different bodies i.e. action is on one body and its reaction is on another body.

Example:

1. For example, when a football is kicked, the foot exerts the force "F_{AB}" on the football and as a reaction to that, a football exerts an equal and opposite force F_{BA} on the foot. i.e. $F_{AB} = - F_{BA}$

2. When a bullet is fired from a gun, it moves on forward direction due to the action of gases which are produced due to the burning of chemicals while in reaction, the bullet pushes the gun in backward direction.

3. The jet airplanes also work on the principle of action and reaction. In action, the fuel in airplane's engines burns and hot gases rush out of the rear end (backward direction) of the airplane with very high speed. While in reaction the backward going gases exert equal and opposite force on the airplane. So, the airplane moves forward with a great speed.

Q.3: What is weight? Differentiate between mass and weight.

Ans: **Weight:**

The weight of a body is the force with which it is attracted towards the centre of the earth. It is denoted by symbol "W".

Mathematical Form:

Mathematically, weight of a body is the product of its mass and acceleration due to gravity.

Weight = mass x acceleration due to gravity

Or $W = m \times g$

$$\mathbf{W = mg}$$

Quantity and Unit:

Weight is a vector quantity and its SI unit is newton (N).

Difference Between Mass and Weight:

Mass	Weight
The quantity of matter in a body is called mass.	The force of attraction of the earth on a body is called its weight
Mass is denoted by "m".	Weight is denoted by "W".
The S.I unit of mass is kilogram (kg).	The SI unit of weight is newton (N).
Mass is a scalar quantity because it has no direction.	Weight is a vector quantity because it has a direction(downward).
Mass is a constant quantity because its value remains the same at different distances from the centre of the earth .	Weight is a variable quantity because it is different at different distances from the centre of the earth.
Mass can be measured by beam balance	Weight can be measured by spring balance .
Mass can be found by formula : **m=F/a**	Weight can found by formula: **W= mg**
Mass cannot be zero.	Weight can be zero.
Mass is the measure of inertia .	Weight is a force of gravity.

Q.4: Define momentum. Relate force to change in momentum.

Ans: Momentum:

The quantity of motion in a body is called momentum.

Or

The product of object's mass and linear velocity is called momentum. It is denoted by symbol "P".

Mathematical Form:

Mathematically, it can be written as

Momentum = Mass x velocity

$$\vec{P} = m \, x \, \vec{v}$$

Or $\vec{\boldsymbol{P}} = \boldsymbol{m} \; \vec{\boldsymbol{v}}$

Quantity and Unit:

Momentum is a vector quantity where its direction is same as that of velocity of the body and the SI unit of momentum is kilogram-meter per second ($kgms^{-1}$) or Newton-second(Ns).

Relation of force with change in momentum:

Statement:

The time rate of change of linear momentum of a body is equal to the net force acting on the body.

Mathematically, it can be written as:

$$\mathbf{F} = \frac{\Delta\vec{\mathbf{P}}}{\Delta \mathbf{t}}$$

Derivation:

According to the Newton's 2nd law of motion, when a net force "F" is applied on body having mass "m", it produces acceleration "a" in the direction of net force which is directly proportional to the force and inversely proportional to mass of the body. Mathematically, it can be written as:

$$\vec{F} = m\vec{a} \text{ .... (i)}$$

Where the acceleration "a" is defined as the time rate of change of velocity.

$$\vec{a} = \frac{\vec{v}_f - \vec{v}_i}{\Delta t}$$

Putting the value of "a" in eq (i)

$$\vec{F} = m\left(\frac{\vec{v}_f - \vec{v}_i}{\Delta t}\right)$$

$$\vec{F} = \frac{m\vec{v}_f - m\vec{v}_i}{\Delta t} \text{.............(2)}$$

As $\vec{P} = m\vec{v}$, therefore $\vec{P}_f = m\vec{v}_f$ and $\vec{P}_i = m\vec{v}_i$, So, eq (2) becomes

$$\vec{F} = \frac{\vec{P}_f - \vec{P}_i}{\Delta t} \text{ ....(3)}$$

As $\Delta\vec{P} = \vec{P}_f - \vec{P}_i$

So eq (3) becomes

$$\vec{\boldsymbol{F}} = \frac{\Delta\vec{\boldsymbol{P}}}{\Delta \boldsymbol{t}} \text{....................(4)}$$

Eq (4) shows the relation between net force and change of momentum of a body. Thus, the time rate of change of momentum of a body is equal to the net force acting on it.

Q.5: Define Isolated system. Explain the law of conservation of momentum.

Ans: Isolated System:

An isolated system is a collection of particles that can interact with each other but whose interactions with the environment outside the collection have a negligible effect on their motions.

Example:

The gas molecules enclosed in a container can be considered as an isolated system of interacting bodies in which the gas molecules collide with each other and with the walls of the container. Other forces, such as gravitational force etc. are considered to have a negligible effect on the motions of the gas molecules and container. So, in isolated system, the bodies exert forces on each other which are very large as compared with external forces.

Law of Conservation of Momentum:

Statement:

If there is no external force applied to a system of particles (Isolated system) then the total momentum of that system remains constant.

i.e. $\Delta \boldsymbol{P} = \boldsymbol{0}$

Or

In the absence of an external force (isolated system), the initial momentum (P_i) of the system must be equal to the final momentum (P_f).

i.e. $\overrightarrow{\boldsymbol{P_i}} = \overrightarrow{\boldsymbol{P_f}}$

Mathematical Derivation:

As we know that:

$$\boldsymbol{F} = \frac{\Delta \vec{\boldsymbol{P}}}{\Delta \boldsymbol{t}}$$

For an isolated system, there is no net force acting i.e. F=0. Therefore, Newton's Second law in terms of momentum can be written as:

$$0 = \frac{\Delta \vec{P}}{\Delta t} \text{ ...... (1)}$$

As $\Delta \vec{P} = \overrightarrow{P_f} - \overrightarrow{P_i}$, so eq (1) becomes

$$0 = \frac{\overrightarrow{P_f} - \overrightarrow{P_i}}{\Delta t}$$

By cross Multiplication:

$$0 \times \Delta t = \overrightarrow{P_f} - \overrightarrow{P_i}$$

$$0 = \overrightarrow{P_f} - \overrightarrow{P_i}$$

$$0 + P_i = \overrightarrow{P_f} - \overrightarrow{P_i} + P_i$$

$$\overrightarrow{\boldsymbol{P_i}} = \overrightarrow{\boldsymbol{P_f}} \text{ .... (2)}$$

Eq (2) shows that the initial momentum of system is equal to the final momentum in the absence of an external force which satisfies the law of conservation of momentum.

Examples:

1. Collision of objects
2. Firing of a gun
3. Explosion of bombs
4. Propulsion of rockets etc.

In all the above examples, the systems are initially at rest. Therefore, their initial momentum is zero i.e. $\overrightarrow{P_i} = 0$. Let all these systems consist of two parts of masses "m_1" and "m_2" with velocities "v_1" and "v_2" then their final momentum is given by

$$\overrightarrow{P_f} = m_1 v_1 + m_2 v_2$$

Now, by the law of conservation of momentum

$$\vec{P_i} = \vec{P_f}$$

$$0 = m_1 v_1 + m_2 v_2$$

$$\text{Or } -m_1 v_1 = m_2 v_2$$

So, both parts of the system will have an equal but opposite momentum. However, if we add up the momentum of both parts, the sum of total momentum will be zero.

Q.6: Define collision and explosion. Explain change in momentum in terms of collision and explosion.

Ans: Collision:

An event during which particles come close to each other and interact by means of forces is called collision.

Change in momentum in term of collision:

The forces due to the collision are assumed to be much larger than any external forces present.

Consider a system consisting of two objects A and B of masses "m_1" and "m_2" moving with velocities "u_1" and "u_2" respectively as shown in figure. The total momentum of the system before collision is given by,

$$\vec{P_i} = m_1 u_1 + m_2 u_2$$

Let "v_1" and "v_2" be the velocities of the masses after collision. Then, the total momentum of the system after collision is given by,

$$\vec{P_f} = m_1 v_1 + m_2 v_2$$

Now, by law of conservation of momentum,

$$\vec{P_i} = \vec{P_f} \quad \text{-------------- (1)}$$

Therefore, eq (1) becomes

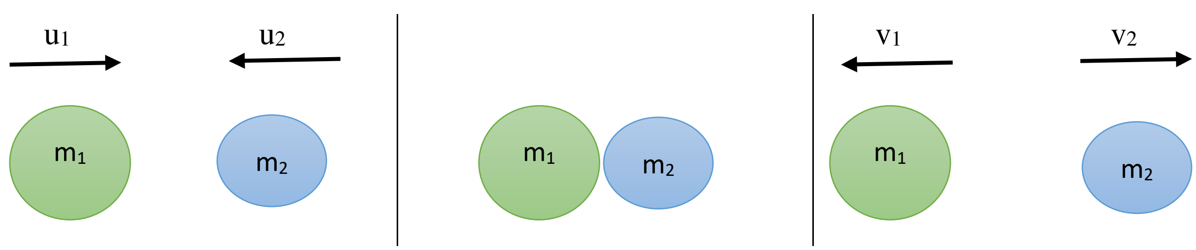
$$\mathbf{m_1 u_1 + m_2 u_2 = m_1 v_1 + m_2 v_2} \text{--------------- (2)}$$

OR

Initial momentum= final momentum

Before collision after collision

Eq(2) shows that the total initial momentum of the system before collision is equal to the total final momentum of the system after collision. Thus, the total momentum during the collision will be conserved in an isolated system, by the law of conservation of momentum.



Before Collision | During Collision | After Collision

Explosion:

The process in which the particles of the system move apart from each other after an intense interaction is known as explosion.

Change in Momentum in terms of Explosion:

If the system is isolated, its total momentum during the explosion will be conserved, by the law of conservation of momentum. Explosion is the opposite of collision.

Consider an isolated system of bullet of mass "m_1" and gun of mass "m_2". Before firing, the velocity of the bullet as well as that of gun is zero. Therefore, the total momentum of both objects before firing is zero. So, we have,

$$P_i=0$$

After firing, the bullet moves with velocity "v_1" in one direction and the gun recoils with velocity "v_2" in the other direction. Therefore, the total momentum of the system after firing is given by

$$\vec{P}_f = m_1\vec{v_1} + m_2\vec{v_2}$$

Now, by law of conservation of momentum

$$\vec{P_i} = \vec{P_f}$$

$$\mathbf{0 = m_1\vec{v_1} + m_2\vec{v_2}}$$

Hence, both gun and bullet will have an equal but opposite momentum. However, if we add up the momentum of both gun and bullet, the sum of total momentum will be zero.

Q7: **What is friction? What are microscopic basis of friction? What is normal force, how it affects friction.**

Friction:

The force which always opposes the motion of one body over another body in contact with it is called force of friction.

It is denoted by "f".

Examples:

Friction exists between,

1. The ground and the wheels of a car
2. Water and fish swimming through it.
3. A flying cricket ball and air etc.

Quantity and unit:

Friction is a vector quantity and its SI unit is newton(N).

Microscopic description of friction:

Every object has a rough surface, even surfaces that appear to be very smooth to the naked eye can actually look quite rough when examined under a microscope. Thus, if different surfaces are observed under microscope, it can be seen that there are ups and downs (irregularities) on these surfaces. Whenever the surfaces are rolled or slide over one another, their ups and downs are interlocked with each other that opposes the relative motion of each surface and gives rise to friction force. So, the main cause of friction is the roughness of the surface. The more rough and uneven surface, the more will be the cause of friction.

Normal force (F_N)

A contact force perpendicular to the contact surface that prevents two objects from passing through one another is called normal force (F_N).

Consider a book is placed on a horizontal table's surface. By Newton's third law, the book exerts the force on the table due to its weight that is acting downward and as a reaction, table also exerts a force on the book in upward direction i.e. a normal force (F_N) of table. If no other vertical forces act, then the normal force on the book by table is equal in magnitude to the book's weight i.e. $F_N=W$

But if the surface of the table is not horizontal, then the normal force is not vertical and is not equal in magnitude of the book. In this case a book slightly moves on an inclined plane of the table and become stop after covering some distance due to force of friction.

Even on a horizontal surface, if there are other vertical forces acting on the book then the normal force is not equal in magnitude to the weight of the book. In this case, normal force on the book increases that further increases the frictional force.

As we know that, $f=\mu F_N$…………(i)

According to equation(i), friction is directly proportional to the normal force. Greater is the normal force, F_N greater will be the force of friction "f". i.e.

$f \alpha F_N$ and vice versa.

Q8. Differentiate between static and kinetic friction by giving an example. Find the expression for the coefficient of kinetic and static friction.

<u>Static friction:</u>

The maximum force of friction that is opposite to the applied force and prevents the body from moving is called static friction. It is denoted by "f_s".

Mathematical form:

$$f_s=\mu_s F_N$$

Kinetic friction:

The force of friction that acts against during motion of an object in a direction opposite to the direction of motion is called kinetic friction. It is denoted by "f_k".

Mathematical form:

$$f_k=\mu_k F_N$$

Example:

When we slide a wooden block placed on a table, then the following four forces acts on the block at the same time. i.e.

1. The weight "W" of the body is acting downward.
2. The normal force "F_N" which is acting upward.
3. The applied force "F".
4. The force of static friction "f_s" which is acting in opposite direction to the applied force as shown in figure A.

The weight "W" and normal force "F_N" balance each other. Now when the applied force "F" acts on the block, still the block does not move. Such force of friction at this stage is called static friction "f_s".

If we increase the applied force further gradually, the static friction also increases and finally a stage comes when the static friction reaches to its maximum value. Such maximum value of static friction is called maximum static friction or limiting friction "$f_{s,\,max}$".

The maximum static friction does not increase further more and the block begins to move due to maximum applied force. The friction is still present while the block is moving due to applied force. Such force of friction during the motion of the body is called kinetic friction "f_k". Usually, kinetic friction is always less than static friction ($f_k < f_s$).

Coefficient of static friction (μ_s):

As we know that, the static friction "f_s" is directly proportional to the normal force "F_N" acting on the body i.e.,

$$f_s \alpha F_N$$

Or

$$\mathbf{f_s = \mu_s F_N}$$

Where "μ_s" is a constant of proportionality known as the coefficient of static friction and depends on the nature of surfaces in contact before sliding.

Thus, the coefficient of static friction "μ_s" can be written as

$$\mu_s = \frac{f_s}{F_N}$$

Coefficient of kinetic friction(μ_k):

Similarly, the kinetic friction "f_k" is directly proportional to the "F_N". i.e.,

$$f_k \propto F_N$$

or

$$\mathbf{f_k = \mu_k F_N}$$

Where "μ_k" is known as coefficient of kinetic friction and depends on the nature of surfaces in contact during sliding.

Thus, the coefficient of kinetic friction "μ_k" can be written as:

$$\mu_k = \frac{f_k}{F_N}$$

As "μ" is the ratio of forces (two similar quantities), therefore it has no unit.

Q9: What are the advantages and disadvantages of friction? Also give methods to reduce and improve friction.

Ans: **Advantages of friction:**

Some advantages of friction are given below:

1. We can walk on the ground with the help of friction between the soles of our shoes and the ground.
2. The nails remain fixed in the walls and wood due to friction.
3. The lighting of a match stick is another useful application of friction.
4. The moving vehicles can be stopped by applying brakes due to friction.
5. Friction enables us to write on paper.

Disadvantages of friction:

Some disadvantages of friction are given below:

1. The friction can produce heat in various parts of running machine.
2. Friction reduces the speed of moving vehicles to a great extent.
3. The various parts of machines become useless due to friction.
4. Cars, buses, trains, machines etc lose a part of their energy in overcoming friction due to which their efficiency decreases.

Methods of reducing friction:

Some methods of reducing friction are given below:

1. If we polish the rough surfaces, they become smooth and friction is reduced.
2. Friction can be reduced by applying lubricants (oils or grease) between the parts of machinery or any rough surface.
3. Friction can be reduced by converting sliding friction into rolling friction by using ball bearings
4. To reduce air friction, the front portions of cars and airplanes are made oblong in shape.

Q10: What is tension? If two connected bodies of masses m_1 and m_2 are hanging from the ends of a string which is passing over a pulley, find the values of tension and acceleration in it.

Ans: **Tension:**

The pulling force exerted by a stretched rope, string or cable on an object to which it is attached is called a tension force. It is denoted by "T".

Explanation:

Tension is always a pull force. Hence, the direction of a tension force is always the direction in which one would pull the object with a string or rope. Suppose a person is holding an object of mass "m" at rest with the help of a string as shown in figure. The object exerts a force on the hand through the string in downward direction due to its weight "W". By Newton's third law, the force which is exerted by the string on hand is called the tension in the string. As the object is at rest, the magnitude of tension is equal to that of weight of the object i.e., $T=W$

Acceleration and Tension in Atwood's machine:

Consider, motion of two bodies "A" and "B" having masses m_1 and m_2 (with m_1 is greater than m_2) are suspended by an extensible string which passes over a frictionless pulley. Such arrangement is known as Simplified Atwood's machine. In such an arrangement ($m_1>m_2$), m_1 will move downward and m_2 will move upward. Since, tension "T" and acceleration "a" will be same for both bodies.

Mathematical form:

In order to find acceleration and tension in the string, be proceed as follows.

Two forces acting on mass "m_1" are:

1. Weight acting downward= $W_1 = m_1g$
2. Tension in the string acting upward = T

So, the net force acting on "m_1" is given by:

$F_{net} = m_1a$

$W_1 + (-T) = m_1a$

$W_1 - T = m_1a$ $\therefore$ $W_1 = m_1g$

$m_1g - T = m_1a$ ………(i)

Similarly, two forces acting on mass "m_2" are:

1. Weight acting downward = $W_2 = m_2g$
2. Tension in the string (upward) = T

Now, the net force acting on "m_2" is given by,

$F_{net} = m_2a$

$T + (-W_2) = m_2a$

$T - W_2 = m_2a$ $\therefore$ $W_2 = m_2g$

$T - m_2g = m_2a$ (ii)

For finding acceleration:

Adding eq(i) and eq (ii)

$m_1g - T + T - m_2g = m_1a + m_2a$

$m_1g - m_2g = m_1a + m_2a$

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

Divide $(m_1 + m_2)$ on both sides

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

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

Or

$$a = \frac{(m_1-m_2)}{(m_1+m_2)}g \; \dots \dots \dots \text{iii}$$

For finding tension in string:

Dividing eq (i) and eq (ii)

$$\frac{m_1g-T}{T-m_2g} = \frac{m_1a}{m_2a}$$

$$\frac{m_1\,g-T}{T-m_2g} = \frac{m_1}{m_2}$$

By cross multiplication

$m_2(m_1 g - T) = m_1(T - m_2 g)$

$m_1 m_2 g - m_2 T = m_1 T - m_1 m_2 g$

$m_1 m_2 g + m_1 m_2 g = m_1 T + m_2 T$

$2 m_1 m_2 g = (m_1 + m_2)T$

Divide $(m_1 + m_2)$ on both sides

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

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

Or

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

Equation (iv) represents the Tension "T" in the string.

Q11: What is uniform circular motion? What are the factors on which magnitude of acceleration (centripetal acceleration) in uniform circular motion depends.

Ans: <u>Uniform circular motion:</u>

"If a body moves in a circular path with a uniform speed, its motion is called uniform circular motion."

Or

"When the speed of a moving object does not change as it travels in the circular path, it is called uniform circular motion.

Examples:

1. Motion of earth around the sun.
2. Motion of electrons around the nucleus.
3. Motion of fan etc.

<u>Centripetal acceleration</u>:

The acceleration which is produced by changing the direction of motion of a body moving in a circular path with constant (uniform) speed is called centripetal acceleration. It is denoted by "a_c".

<u>Explanation:</u>

We know that during the circular motion, the direction of velocity of the body changes at every point continuously due to which an acceleration is produced which is known as centripetal acceleration. It is perpendicular to the velocity of the body and is directed towards the center of the circle.

Mathematical form:

Mathematically it can be written as:

$$a_c = \frac{v^2}{r} \qquad \text{(i)}$$

Unit:

The SI unit of centripetal acceleration is meter per second square (m/s^2 or ms^{-2}).

Factors:

According to eq (i) the centripetal acceleration "a_c" depends on the following two factors in uniform circular motion.

1. Velocity of the body (v)
2. Radius of circle (r)

Eq (i) shows that the centripetal acceleration is directly proportional to the square of velocity of the body which means greater is the speed of the body, greater will be the centripetal acceleration. Also, centripetal acceleration is inversely proportional to the radius of the circle (r) which means smaller is the radius of circular path, greater will be the centripetal acceleration.

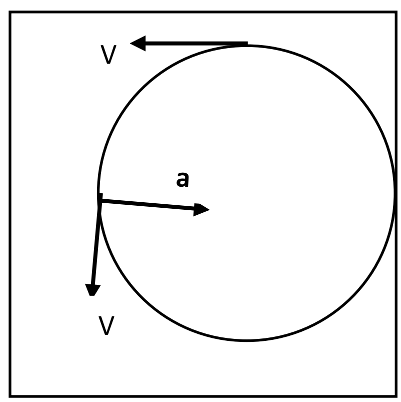
Q12: What is centripetal force? Explain how centripetal force is used in banking of roads and centrifugation.

Centripetal force:

The force which compels a body to move in a circular path is called centripetal force. It is denoted by "F_c".

Mathematical form:

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



Where "m" is the mass of the body, "v" is the velocity of the body and "r" is the radius of the circle.

Explanation

We know that in circular motion, the direction of velocity of the body changes at every point continuously. Thus, acceleration is produced during such motion and the force required for the production of centripetal acceleration is known as centripetal force which is directed forwards the centre of the circle.

<u>Applications of centripetal force:</u>

The centripetal force plays an important role in our daily life. Some of the useful applications of centripetal force are given below:

1. **<u>Banking of road:</u>**

To make the outer edge of a curved road is a little higher than the its inner edge is known as banking of road.

When a car takes a turn along a round track, sufficient centripetal force is required. In the absence of this force, the car will skid off the road to the outward direction due to inertia. The force of friction between tyres and the road provides this centripetal force and keeps the car moving on the curved path. However, if the road is slippery due to rain or snow, this reduces the friction which in turn reduces centripetal force of taking turn.

In this case, we use a technique "banking of road curves" in order to provide sufficient centripetal force to the turning vehicles by making the outer edge of a round track is slightly higher than that of the inner edge. In this case the normal force 'F_N' of the road is resolved into two components i.e. 'F_{Nx}' and 'F_{Ny}'.

The horizontal component 'F_{Nx}' balances the weight of a car whereas the vertical component 'F_{Ny}' of normal force increases the friction which provides sufficient centripetal force due to which the vehicles take a safe turn.

<u>Centrifuge:</u>

Centrifuge is a device which is used for the separation of liquids of unequal densities. Its operation depends upon centripetal force.

Construction and working:

A simplest type of centrifuge consists of a wheel which rotates horizontally and some buckets are attached to the wheel vertically. Now, if a mixture of unequal densities are introduced into the buckets and the wheel is allowed to rotate rapidly, the liquid becomes separate that is the heavy liquid remains farther from the axis of rotation while the lighter liquids remains nearer to it. This means that the heavier liquids are at the bottom of the buckets when the centrifuge is stopped.

Examples:

The same centrifuge principle can be used in some commonly used devices in our daily life i.e. cream separator and washing machine dryer are the examples of centrifuge.

TOPIC WICE QUESTION

Q1. Describe various type of friction.

Ans. Types of friction:

There are two types of frictional forces which are given below

1. Sliding friction
2. Rolling friction

1. Sliding friction:

The force which opposes the sliding of one solid body over the surface of another solid body is called sliding friction. This kind of friction is caused by the roughness of surfaces in contact.

Types of sliding friction:

Sliding friction is of two types which are given below;

a. Static friction
b. Kinetic friction

a. Static friction:

The minimum force of friction that is opposite to the applied force and prevents the body from moving is called static friction. It is denoted by f_s.

b. Kinetic friction:

The frictional force that acts against during motion of an object in a direction opposite to the direction of motion is called kinetic friction. It is denoted by f_k.

Example:

Whenever a wooden cart is dragged over a road then the friction produced is called sliding friction.

2. Rolling friction:

When a body rolls over a surface, the force of friction is called rolling friction.

Explanation:

It is commonly observed that a body with wheels move easily as compared to a body of same size without wheels. Thus, rolling friction is much less than a sliding friction because the contact surface area is much less in rolling than in sliding friction.

Example:

Whenever a ball is rolled over the ground the friction produced is called rolling friction because small surface area of both ball and ground are in contact with each other that offer less resistance.

Q2. Discuss the graphical interpretation of friction.

Ans. Graphical interpretation of friction:

The graph between applied force 'F' and frictional force 'f' shows that when the applied force increases the static frictional force 'f_c' also increases until it reaches a certain maximum value called limiting friction 'f_s max'.

At this point the object starts moving and frictional force rapidly decreases to a smaller kinetic friction 'f_k' value, which nearly remains constant.

Q3. Define and explain centripetal force.

Ans. Centripetal force:

The force which compels a body to move in a circle is called centripetal force. It is denoted by 'F_c'.

Explanation:

We know that in circular motion, the direction of velocity of body changes continuously. Thus, acceleration is produced during such motion. The force required for the production of centripetal acceleration is known as centripetal force and it is always directed towards the centre of circle. In the absence of centripetal force, the object will travel in a straight line. Hence, the effect of centripetal force is to continuously change the direction of moving object, forcing it to move in a circle.

Mathematical form:

Let 'm' be the mass of an object which is compelled to move in a circle of radius 'r' with the constant speed 'v'. Centripetal force 'F_c' produces centripetal acceleration 'a_c' in the body which can be written as:

$a_{c\,=} = \frac{v2}{m}$

Now, according to the Newton second law of motion:

$F_c = ma_c$ (i)

Putting value of a_c in eq (i):

$F_c = \frac{mv2}{r}$ (ii)

Quantity and Unit:

The centripetal force is a vector quantity and its SI unit is Newton (N).

Factors on which it depends:

According to eq (ii), the centripetal force depends upon the following three factors:

1. Mass of the body
2. Velocity of the body
3. Radius of the circle

Greater the mass and velocity of the body, greater will be the centripetal force. Also, smaller is the radius of circular path, greater will be the centripetal force.

Example:

The moon revolves around the earth because of centripetal force which is provided by the gravitational force between moon and the earth.

Q4. Write a note on cream separator.

Ans. <u>Cream separator:</u>

A cream separator is a centrifugal device which is used to separate cream from milk. It works on the principle of centrifuge.

Construction:

It consists of a set of blades connected to an axis by means of a metallic rod which is driven by an electric motor.

Working:

As milk is a mixture of light and heavy particles, the turning blades of this device spins the milk due to which the light and heavy particles of milk are separated. The light particles (cream) gather near the axis of rotation while the heavy particles of milk go away from the axis of rotation. In this way, cream is separated from milk.

Q5. Write a note on washing machine dryer.

Ans. Washing machine dryer:

A washing machine dryer is a device which is used to dry the wet clothes quickly. It works on the principle of centrifuge.

Construction:

It consists of a cylinder having small holes on its wall and a rotor which is driven by an electric motor.

Working:

When wet clothes are placed in this cylinder and it is rotated rapidly. Due to this, water moves outward to the wall of cylinder and is drained out through the holes. In this way, the clothes become dry quickly.

CONCEPTUAL QUESTIONS

Q1. Why does dust fly off, when a hanging carpet is beaten with a stick?

Ans. When we beat a carpet with a stick, the carpet is set into motion while the dust particles inside the carpet are at rest and tends to remain at rest due to inertia. As the dust particles do not move with the carpet, so they get removed from the carpet.

Q2. If your hands are wet and no towel is handy, you can remove some of the excess water by shaking them, why does this work?

Ans. We can remove some of the excess water from our wet hands by shaking them due to inertia. When we shake our hands, the hands come into state of motion while the drops of water are at rest and tend to remain at rest due to inertia. As a result, these drops are removed from our hands.

Q3. Why a balloon filled with air move forward when its air is released?

Ans. When air is released from balloon, the balloon exerts an action force on the air and pushes it out in the backward direction. While the rushing out air exerts an equal reaction force on the balloon in forward direction. As a result, the balloon moves forward.

We can also explain this in terms of the law of conservation of momentum. The air and balloon forms an isolated system whose total momentum is initially zero. Now, when air is released, it rushes out with great momentum in the backward direction. Now to conserve the momentum, the balloon moves forward with the same momentum.

Q4. Why does a hosepipe tend to move backward when the fire man directs a powerful stream of water towards fire?

Ans. It is an example of Newton's third law as well as law of conservation of momentum. By Newton's third law of motion, when the fire man directs a hose pipe towards fire, the water shoots out from the pipe in forward direction which is an action on water. While as a reaction, the water also exerts the same force on the pipe in backward direction. As a result, the house pipe moves backward.

Similarly, it can be explained by the law of conservation of momentum, the water and pipe forms an isolated system whose total momentum is zero. Now, when the water is released from the pipe it comes out with great momentum in the forward direction. Now, to conserve the momentum, the pipe moves in backward direction.

Q5. Your car is stuck in wet mud. Some students on their way to class see your predicament and help out by sitting on the trunk of your car to increase its traction. Why does it help?

Ans. When a car stuck in wet mud, the friction between tyres and mud decreases. As a result, the car cannot move. Now, when the students sit on the trunk of the car, the weight of car increases due to which the normal force 'F_N' on the car also increases.

As we know that:

$$\mathbf{f = \mu F_N}\text{..........eq (i)}$$

According to eq (i), force of friction (f) is directly proportional to the normal force (F_N) which means that greater the normal force, greater will be the force of friction. Thus, the increase in friction helps the car to come out of the mud easily.

Q6. How does friction help you walk? Is it kinetic friction or static friction?

Ans. A frictional force exists between the ground and sole of our shoes. When we walk forward, we push the ground with feet in the backward direction while in reaction, the ground also exerts a force (friction) in forward direction which moves us forward. Because of this frictional force, we are able to walk on the ground. Without friction, it is not possible for us to walk on the ground.
This is **static friction** because when we walk on the ground, our feet are at rest for a moment which provides the static friction between our feet and ground. Hence, we walk due to static friction instead of kinetic friction.

Q7. The parking brake on a car causes the air wheels to lockup. What would be the likely consequence of applying the parking brake in a car that is in rapid motion?

Ans. While driving fast on a road, if the parking brake (hand brake) is applied, the rear wheels of the car will be lock up. But the front wheels are in motion and according to inertia, the front wheels try to maintain their state of motion. As a result, the car will skid in such situation.

Q8. Why is the surface of a conveyor belt made rough?

Ans. The surface of a conveyor belt is made rough just to increase the force of friction between the belt and the objects which are placed on the surface of belt. Because on rough surface, irregularities are more due to which area of contact increases the force of friction. As a result, the things lying on the belt remain safe from falling down.

Q9. Why does a boatman tie his boat to a pillar before allowing the passengers to step on the river bank?

Ans. When the passengers jump from the boat on the river bank, they actually push the boat with their feet in the backward direction. In this way, the boat would move away from the bank and the passengers may fall in water. So, to avoid the backward push of the boat, it is first tied to the pillar before allowing the passengers to step on the river bank.

Q10. In uniform circular motion, is the velocity constant? Is the acceleration constant? Explain.

Ans. In uniform circular motion, the velocity does not remain constant because the direction of velocity of the body changes continuously from point to point and this direction of velocity is always tangent to circle at each point. Whereas, the centripetal acceleration is directed towards the centre of circular path and its direction remain unchanged. Due to uniform circular motion, the centripetal acceleration remains constant throughout the motion.

Q11. You tie a brick to the end of the rope and whirl the brick around you in a horizontal circle. Describe the path of the brick after you suddenly let go of the rope.

Ans. According to Newton's third law of motion, for every action there is an equal and opposite reaction. When we tie a brick to the end of a rope and whirl it in a circle of radius 'r', we provide centripetal force to the brick through the rope. Whereas the brick also exerts centrifugal force on our hands through the rope in a direction away from the centre of the circle. So, the reaction of the centripetal force is centrifugal force. Now, if we let go the rope suddenly then the brick will move in a straight line away from the centre of the circle due to centrifugal force.

Q12. Why the posted speed for a turn is lower than the speed limit on most highways?

Ans. When a car takes a turn, the necessary centripetal force v is provided by the force of friction between the road and tyres. We know that the centripetal force 'F_c' is given by:

$F_c = \frac{mv^2}{r}$ .... eq (i)

eq (i) shows that higher the speed of the car, greater amount of centripetal force is required to move along a circular path. At higher speed, it is not possible for the frictional force to provide necessary centripetal force for the car to take a safe turn. As a result, the car will skid away due to insufficient centripetal force. So, to avoid such risky situation, the driver should keep the speed of the car lower while taking a turn.

NUMERICAL QUESTIONS

Q1. 1580kg car is travelling with a speed of 15.0 m/s. what is the magnitude of the horizontal net force that is required to bring the car to a halt in a distance of 50.0m.

Data:

Mass = m = 1580kg

Initial velocity = vi = 15m/s

Final velocity = vf = 0m/s

Distance covered = s = 50m

Find:

Force required to stop the car = F =?

Solution:

As we know that

F = ma……………. eq (i)

First, we find 'a' by using 3rd equation of motion

$$2as = v_f^2 - v_i^2$$

Or

$$\mathbf{a} = \frac{v_f^2 - v_i^2}{2s}$$

By putting values:

$$a = \frac{(0)-(15)2}{2\times 50}$$

$$a = \frac{0-225}{100}$$

$$a = \frac{-225}{100}$$

$$\mathbf{a = -2.25 m/s^2}$$

The negative sign shows deceleration.

Now, putting value of 'a' in eq(i)

F = ma

F = 1580 × -2.25

F = -3555N

$F = -3.555 \times 10^3$ N

Or

$\mathbf{F = -3.55 \times 10^3}$ **N**

Q2. A bullet of mass 10g is fixed with a rifle. The bullet takes 0.003s to move through barrel and leaves with a velocity of 300m/s. What is the force exerted by the rifle?

Data:

Mas = m = 10g

$$m = \frac{10}{1000}$$

m = 0.01kg
Time = t = 0.003s
Initial velocity = v_i = 0m/s
Final velocity = v_f = 300m/s

Find:

Force = F =?

Solution:

We know that

$$\mathbf{F = ma} \text{ .... eq (i)}$$

1st we find 'a' by using formula

$$\mathbf{a} = \frac{v_f - v_i}{t}$$

By putting values

$$a = \frac{300-0}{0.003}$$

$$a = \frac{300}{0.003}$$

$$\mathbf{a = 100{,}000\ m/s^2}$$

Now, putting value of 'a' in eq (i)

$$F = ma$$

$$F = 0.01 \times 100{,}000$$

$$\mathbf{F = 1000N}$$

Q3. A 2200 kg vehicle travelling at 94km/h(26m/s) can be stopped in 21s by gently applying the barkers. It can be stopped in 3.8s. if the driver slams on the brakes. What average force is exerted on the vehicle in both of these stops.

Data: -

Mass = m =2200kg
Initial velocity = v_i = 94km/hr

$$v_i = \frac{94 \times 1000}{3600}$$

$$v_i = 26m/s$$

Time taken in 1st case = t_1 = 21s
Time taken in 2nd case = t_2 = 3.8s
Final velocity = v_f = 0m/s

Find:

Force required in 1st case = F_1 =?
Force required in 2nd case = F_2 =?

Solution; -

As we know that

$$\mathbf{F_1 = ma_1} \quad .... \quad (i)$$

1st we find "a_1" by using formula

$$a_1 = \frac{v_f - v_i}{t_1}$$

by putting values

$$a_1 = \frac{0-26}{21}$$

$$a_1 = \frac{-26}{21}$$

$$\mathbf{a_1 = -1.23 m/s^2}$$

Now, putting value of a_1 in eq (i)

$$F_1 = ma_1$$

$$F_1 = 2200 \times (-1.23)$$

$$F_1 = -2706N$$

$$F_1 = -2.706 \times 10^3 N$$

OR

$$\mathbf{F_1 = -2.7 \times 10^3 N}$$

For finding F_2, we know that

$$F_2 = ma_2 \quad .... \quad (ii)$$

1st we find "a_2" by using formula

$$a_2 = \frac{V_f - v_i}{t_2}$$

By putting values

$$a_2 = \frac{0-26}{3.8}$$

$$a_1 = \frac{-26}{3.8}$$

$$\mathbf{a_2 = -6.84 m/s^2}$$

Now, putting value of a_2 in eq (ii)

$$F_2 = ma_2$$

$$F_2 = 2200 \times (-6.84)$$

$$F_2 = -15048N$$

$$\mathbf{F_2 = -1.5 \times 10^4 N}$$

For finding average force "F":

$$F = \frac{F_1 + F_2}{2}$$

$$F = \frac{(-2.7 \ x \ 10^3) + (-1.5 \times 10^4)}{2}$$

$$F = \frac{-2.7 \times 10^3 \ -1.5 \times 10^4}{2}$$

$$F = \frac{-2.7 \times 10^3 \quad -0.15 \times 10^3}{2}$$

$$F = \frac{-2.85 \times 10^3}{2}$$

$$\mathbf{F = -1.42 \times 10^3\ N}$$

Q4. You want to move a 500N crate across a level floor. To start the crate moving, you have to pull with a 230N horizontal force. Once the crate "breaks loose" and starts to move, you can keep it moving at constant velocity with only 200N. What are the co-efficient of static and kinetic friction?

Data: -

Normal force = weight of crate

$F_N = W$

$F_N = 500N$

Static friction = f_s = 230N

Kinetic friction = f_k = 200N

Find

Co-efficient of static friction = μ_s =?

Co-efficient of kinetic friction = μ_k =?

Solution

For finding μ_s, using formula

$$\mu_s = \frac{f_s}{F_N}$$

$$\mu_s = \frac{230}{500}$$

$$\boldsymbol{\mu_s = 0.46}$$

For finding μ_k, using formula

$$\mu_k = \frac{f_k}{F_N}$$

$$\mu_k = \frac{200}{500}$$

$$\boldsymbol{\mu_k = 0.4}$$

Q5. Two bodies of masses 3kg and 5kg are tied to string which is passed over a pulley. If the pulley has no friction, find the acceleration of the bodies and tension in the string.

Data:

Mass of 1st body = m_1 = 5kg

Mass of 2nd body = m_2 = 3kg

Acceleration due to gravity = g = 9.8m/s^2

Find

Acceleration = a=?

Tension in the string =T=?

Solution:

1st we find "a", by using formula

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

$$a = (\frac{5-3}{5+3}) \times 9.8$$

$$a= (\frac{2}{8}) \times 9.8$$

$$a= 0.25 \times 9.8$$

$$\mathbf{a= 2.45m/s^2}$$

For finding T, using formula

$$\mathbf{T =(\frac{2m_1m_2}{m_1+m_2})g}$$

$$T = \frac{2\times5\times3}{5+3} \times 9.8$$

$$T= \frac{30}{8} \times 9.8$$

$$T= 3.75 \times 9.8$$

$$\mathbf{T= 36.75N}$$

Q6. Determine the magnitude of the centripetal force exerted by the rim of a car's wheel on a 45.0 kg tire. The tire has 0.408 meter radius and is rotating at a speed of 30.0 m/s.

Data:

Mass = m = 45 kg

Radius= r = 0.480m

Speed= v = 30 m/s

Find:

Centripetal force = F_c = ?

Solution:

We know that

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

By putting values

$$F_c = \frac{45 \times 30^2}{0.480}$$

$$F_c = \frac{45 \times 900}{0.480}$$

$$F_c = \frac{40500}{0.480}$$

$F_c = 84375$ N

$F_c = 8.4375 \times 10^4$ N

or

$\mathbf{F_c = 8.44 \times 10^4}$ **N**

Q7. A motorcyclist is moving along a circular wooden track of a circus (death well) of radius 5m at a speed of 10m/s. If the total mass of motorcycle and the rider is 150 kg, find the magnitude of centripetal force acting on him?

Data:

Mass = m = 150 kg

Radius= r = 5m

Speed= v = 10 m/s

Find:

Centripetal force = F_c = ?

Solution:

We know that

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

By putting values

$$F_c = \frac{150 \times 10^2}{5}$$

$$F_c = \frac{150 \times 100}{5}$$

$$F_c = \frac{15000}{5}$$

$\mathbf{F_c = 3000}$ **N**

Q8: A car of mass 1000kg is running on a circular motorway interchange near swabi with a velocity of 80m/s, the radius of circular motorway interchange is 800m. How much centripetal force is required?

Data:

Mass = m = 1000 kg

Radius= r = 800m

Velocity= v = 80 m/s

Find:
Centripetal force = F_c = ?
Solution:
We know that

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

By putting values

$$F_c = \frac{1000 \times 80^2}{800}$$

$$F_c = \frac{1000 \times 6400}{800}$$

$$F_c = \frac{64000}{8}$$

$$\mathbf{F_c = 8000\ N}$$

Assignment

Assignment 3.1

Find the acceleration produce in engine force of 3500N in car of mass 600 Kg and truck of mass 2400 kg.

Data:

Force = F = 3500 N

Mass of car = m_1 =600 kg

Mass of truck = m_2 = 2400 kg

Find:

Acceleration produced in car = a_1 = ?

Acceleration produced in truck = a_2 = ?

Solution:

For finding a_1, using formula

$$F = ma$$

Or

$$F = m_1a_1$$

$$\mathbf{a_1 = \frac{F}{m_1}}$$

By putting values

$$a_1 = \frac{3500}{600}$$

$$\mathbf{a_1 = 5.83\ m/s^2}$$

For finding a_2, using formula

$$F = m_2a_2$$

or $$\mathbf{a_2 = \frac{F}{m_2}}$$

By putting values

$$a_2 = \frac{3500}{2400}$$

$$a_2 = 1.458\ m/s^2$$

Or

$$\mathbf{a_2 = 1.46\ m/s^2}$$

Assignment 3.2

The weight of an astronaut and his space suit on the moon is only 250N. How much do they weigh on earth? What is the mass on the moon? On earth? (Take acceleration due to gravity for earth as g_E = 9.8m/s^2 and moon as g_M = 1.6m/s^2)

Data:

Weight of astronaut on moon = W = 250 N

Acceleration due to gravity on earth = g_E = 9.8 m/s^2

Acceleration due to gravity on moon = g_m = 1.6 m/s^2

Find:

a) Mass on moon = m_m = ?
b) b. Mass on earth = m_E = ?
c) c. Weight on earth = W_E =?

Solution

For finding m_m , using formula

$$W = mg$$

$$W = m_m g_m$$

Or $$\mathbf{m_m = \frac{W}{g_m}}$$

$$m_m = \frac{250}{1.6}$$

$$\mathbf{m_m = 156\ kg}$$

(b) As mass is constant everywhere, so mass of astronaut on earth will be also 156kg. i.e.,

$$\mathbf{m_E = 156kg}$$

(c) For finding W_E, we know that

$$W_E = m_E g_E$$

$$W_E = 156 \times 9.8$$

$$W_E = 1528.8\ N$$

$$W_E = 1.528 \times 10^3 N$$

Or

$$\mathbf{W_E = 1.5 \times 10^3 N}$$

Assignment 3.3

The fastest recorded speed for a golf ball hit by a golfer is 75.8 m/s (273km/hr). If mass of golf ball is 46g, what is the magnitude of its momentum?

Data

Velocity = V = 75.8m/s

Mass = m = 46g

$$m = \frac{46}{1000} kg$$

$$m = 0.046kg$$

Find

Momentum = P = ?

Solution

We know that

$$\mathbf{P = mv}$$

By putting values

$$P = 0.046 \times 75.8$$

$$P = 3.4868Ns$$

Or $$\mathbf{P = 3.49\ Ns}$$

Assignment 3.4

Calculate the force required to stop a car of mass 1200 kg and a loaded truck of mass 9000kg in 2 second, if they are moving with same velocity of 10ms^{-1}.

Data

Mass of car = m_1 = 1200 kg

Mass of truck = m_2= 9000kg

Time = t= 2s

Initial velocity = v_i =10 ms^{-1}

Final velocity = v_f= 0 ms^{-1}

Find

Force required to stop a car = F_1 = ?

Force required to stop a truck = F_2 = ?

Solution

As we know that

$$\mathbf{F_1 = m_1 a} \qquad \text{(i)}$$

1st we find "a", by using formula

$$\mathbf{a = \frac{v_f - v_i}{t}}$$

By putting values

$$a = \frac{0-10}{2}$$

$$a = \frac{-10}{2}$$

$$\mathbf{a = -5ms^{-1}}$$

Now putting values of "a" in eq (i)

$$F_1 = m_1 a$$

$$F_1 = 1200 \times -5$$

$$\mathbf{F_1 = -6000N}$$

For finding F_2, we know that

$$F_2 = m_2 a$$

By putting values

$$F_2 = 9000 \times -5$$

$$\mathbf{F_2 = -45000N}$$

Assignment 3.5

In carrom board game the stricker of mass having mass 0.015kg sliding to the right at velocity of 0.40m/s makes head on collision with a disk having mass 0.005kg that is initially at rest. After the collision, stricker moves to the right along the direction of disk at 0.20m/s. Find the final velocity of the disk.

Data

Mass of stricker = m_1 = 0.015kg

Mass of disk = m_2 = 0.005kg

Initial velocity of stricker = u_1 = 0.40m/s

Final velocity of stricker = v_1 = 0.20m/s

Initial velocity of disk = u_2 = 0m/s

Find

Final velocity of disk = v_2 = ?

Solution

By using law of conservation of momentum

$$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$$

$$m_1u_1 + m_2u_2 - m_1v_1 = \cancel{m_1v_1} - \cancel{m_1v_1} + m_2v_2$$

$$m_1u_1 + m_2u_2 - m_1v_1 = m_2v_2$$

Divide " m_2" on both sides

$$\frac{m_1u_1+m_2u_2-m_1v_1}{m_2} = \frac{\cancel{m_2}v_2}{\cancel{m_2}}$$

$$\frac{m_1u_1+m_2u_2-m_1v_1}{m_2} = v_2$$

Or

$$\mathbf{v_2 = \frac{m_1u_1+m_2u_2-m_1v_1}{m_2}}$$

$$v_2 = \frac{0.015\times0.40+0.005\times0-0.015\times0.20}{0.005}$$

$$v_2 = \frac{0.006+0-0.003}{0.005}$$

$$v_2 = \frac{0.003}{0.005}$$

$$\mathbf{v_2 = 0.6\ m/s}$$

Assignment 3.6

A 200kg cannon at rest contains a 10kg cannon ball. When fired, the cannon ball leaves the cannon with a speed of 90m/s. what is the recoil speed of cannon?

Data:

Mass of a cannon ball = m_1 = 10kg

Mass of a cannon = m_2 = 200kg

Velocity of cannon ball after fire = v_1 = 90m/s

Find:

Velocity of cannon after fire = v_2 = ?

Solution:

We know that

$$P_f = P_i \qquad \therefore P_i = 0$$

$$P_f = 0$$

$$m_1v_1 + m_2v_2 = 0$$

$$\cancel{m_1v_1} - \cancel{m_1v_1} + m_2v_2 = 0 - m_1v_1$$

$$m_2v_2 = - m_1v_1$$

Divide "m_2" on both sides

$$\frac{\cancel{m_2}v_2}{\cancel{m_2}} = \frac{-m_1v_1}{m_2}$$

$$\mathbf{v_2 = \frac{-m_1v_1}{m_2}}$$

$$v_2 = \frac{-(10 \times 90)}{200}$$

$$v_2 = \frac{-900}{200}$$

$$\mathbf{v_2 = -4.5m/s}$$

The negative sign shows that the cannon is pushed in opposite direction of cannon ball.

Assignment 3.7

A 5kg heavy leather bag is placed on a horizontal wooden plank. How much force is required to set it in motion if the coefficient of friction between the plank and bag is 0.1?

Data:

Mass of bag = m = 5kg

Acceleration due to gravity = g = 9.8m/s^2

Coefficient of friction = μ_k= 0.1

Find:

Normal force = F_N = ?

Force = f_k= ?

Solution:

As we know that

$$\mathbf{f_k = \mu_k F_N} \text{.........................(i)}$$

First we find F_N , we know that

$$F_N = \text{Weight of the bag}$$

$$F_N = W \qquad \therefore w = mg$$

$$F_N = mg$$

$$F_N = 5 \times 9.8$$

$$\mathbf{F_N = 49N}$$

Now, putting value of 'F_N' in eq (i)

$$\mathbf{f_k = \mu_k F_N}$$
$$f_k = 0.1 \times 49$$
$$f_k = 4.9N$$
Or
$$\mathbf{f_k = 5N}$$

Assignment 3.8

Two bodies of mass 3.5kg and 1.5kg are tied to ends of string which passes over a pulley. Find

a. **The acceleration of bodies**
b. **The tension in the string**

Data:

Mass of 1st body = m_1 = 3.5kg
Mass of 2nd body = m_2 = 1.5kg
Acceleration due to gravity = g = 9.8m/s^2

Find:

Acceleration = a = ?
Tension in string = T = ?

Solution;

For finding 'a' ,using formula

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

$$a = \left(\frac{3.5-1.5}{3.5+1.5}\right) 9.8$$

$$a = \left(\frac{2}{5}\right) 9.8$$

$$a = 0.4 \times 9.8$$
$$a = 3.92 \text{ m/s}^2$$
Or
$$\mathbf{a = 4 \text{ m/s}^2}$$

For finding 'T', using formula

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

$$T = \frac{2 \times 3.5 \times 1.5}{3.5+1.5} \times 9.8$$

$$T = \frac{10.5}{5} \times 9.8$$

$$T = 2.1 \times 9.8$$

T = 20.58N
T = 20.6N
Or
T = 21N

Assignment 3.9

A pilot is flying a small plane at 56.6m/s in a circular path with a radius of 188.5m. The centripetal force needed to maintain the plane's circular motion is 1.89×10^{4}N. What is the plane's mass?

Data:

Velocity = v = 56.6m/s

Radius = r = 188.5m

Centripetal force = F_c = 1.89×10^{4}N

Find:

Mass = m = ?

Solution:

We know that

$$F_c = \frac{mv2}{r}$$

Or

$$\mathbf{m = \frac{F_c \times r}{v^2}}$$

$$m = \frac{1.89\times10^4\times188.5}{(56.6)^2}$$

$$m = \frac{356.265\times10^4}{3203.56}$$

$$m = 0.11120 \times 10^4$$

$$m = 01112.0 \times\ 10^{-4}\ \times 10^4$$

$$m = 1112.0\ 10^{4-4}$$

Or

m = 1112kg