UNIT 03

Dynamics

Q.1. Define and explain concept of force. 09103001

Fig. 3.1

Ans: Concept of force: A force is commonly defined as a push or pull that starts, stops, or changes the magnitude and direction of an object's velocity.

Explanation:

We encounter many forces in our daily lives, some of which we apply to other objects and some that act on us.

i. For example, when we open a door, we apply force by pushing or pulling it.

ii. When sitting in a car that turns around a corner, we push against the seat due to the motion of the car.

iii. Force transfers energy to an object. For instance, when a man moves a wheelbarrow with a load, he first applies force to lift it and then applies force to push it. He adjusts the amount of force on each handle when turning to keep the wheelbarrow from tipping over.

iv. Other examples of forces acting on us include the downward force of gravity and the force of friction, which helps us walk on the ground.

Q.2. Differentiate between contact and non-contact forces with detailed examples of daily life. 09103002

Ans: i. Contact Forces

Contact forces are forces exerted by one object on another at the point of contact. Some examples of contact forces include:

(a) Friction:
Friction resists motion when the surface of one object comes into contact with another. For example, friction helps us walk by providing grip between our feet and the ground.

(b) Drag:
The drag is a resistant force caused by the motion of a body through a fluid. It acts opposite to the relative motion of the object through the surrounding fluid.

(c) Thrust:
It is an upward force exerted by a liquid on an object immersed in it. When we immerse an object in water, we feel an upward force. This force increases as we push the object deeper. For instance, a ship floats because this force balances its weight.

(d) Normal Force:

It is the force of reaction exerted by the surface on an object lying on it. This force acts outward and perpendicular to the surface. It is also called the support force of the object.

(e) Air Resistance:

It is the resistance (opposition) offered by air when an object falls through it.

(f) Tension Force:

It is the force experienced by a rope when pulled by a person or load pulls it.

(g) Elastic Force:

It is a force that brings certain materials back to their original shape after being deformed. Examples are rubber bands, springs, trampoline, etc.

ii. Non-Contact Forces

A non-contact force is defined as the force between objects that are not in physical contact. These forces work over a distance and are also known as **field forces**. Examples include:

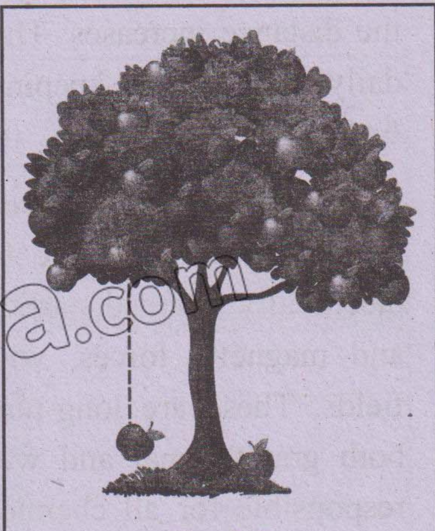

Fig. 3.2

(a) Gravitational Force:

This is an attractive force that exists among all bodies which have mass. For example, when an apple falls from a tree, it is pulled by the Earth's gravitational force. This force also keeps planets in their orbits around the Sun and holds the atmosphere and oceans on Earth. According to Newton's law of gravitation:

$$F = G\frac{m_1 m_2}{r^2}$$

Where m_1 and m_2 are two masses, r is distance between masses and G is the constant of gravitational. Its value is $6.67 \times 10^{-11}\ Nm^2kg^{-2}$

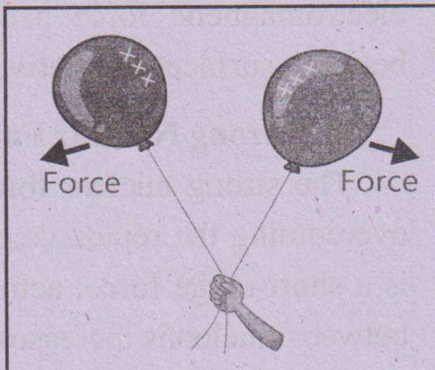

Fig. 3.3

(b) Electrostatic Force:

An electrostatic force acts between two charged objects. The Opposite charges attract each other and similar charges repel each other. Like gravitational force, electrostatic force is also a long-range force.

(c) Magnetic Force:

It is the force which a magnet exerts on other magnet and magnetic materials like iron, nickel, and cobalt. Magnetic forces can attract or repel, depending on the poles involved. For example, like poles repel, and unlike poles attract.

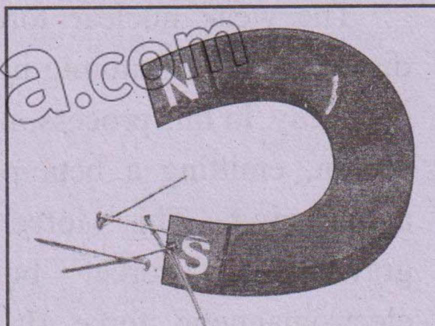

Fig. 3.4

Strong and Weak Nuclear Forces:

These are also non-contact forces acting between the subatomic particles.

Q.3. Explain four fundamental forces in nature. Explain contribution of Dr. Abdus Salam in unification of weak nuclear and electromagnetic forces. 09103003

Ans: Fundamental Forces in Nature

There are four fundamental forces in nature. These are:

i. Gravitational Force **ii.** Electromagnetic Force **iii.** Strong Nuclear Force
iv. Weak Nuclear Force

i. Gravitational Force

The gravitational force is the weakest among the four fundamental forces. It is a long-range force that extends to infinite distances, although it becomes weaker and weaker as the distance increases. This force is commonly observed in daily life, such as keeping planets in orbit and objects on Earth's surface.

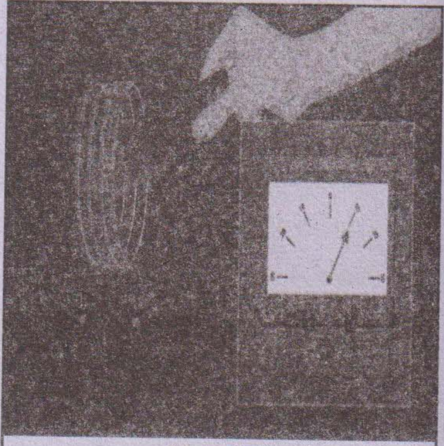

Fig. 3.5

ii. Electromagnetic Force

The electromagnetic force causes interactions between electrically charged particles. It includes both electrostatic and magnetic forces, which act through electromagnetic fields. These are long-range forces and are stronger than both gravitational and weak nuclear forces. This force is responsible for all chemical reactions, as it binds together atoms, molecules, and crystals. At the macroscopic level, electromagnetic force causes phenomena such as friction between surfaces in relative motion.

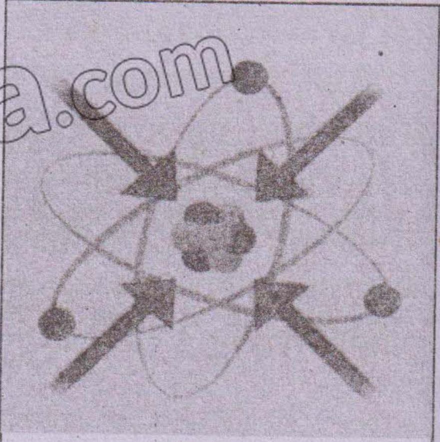

Fig. 3.6

iii. Strong Nuclear Force

The strong nuclear force binds protons and neutrons together in the atomic nucleus, overcoming the repulsive electromagnetic force between positively charged protons. This is a short-range force, acting only within a distance of about 10^{-14} meters. If the distance between nucleons increases beyond this range, the strong nuclear force ceases to act.

iv. Weak Nuclear Force

The weak nuclear force is responsible for the disintegration of atomic nuclei, such as during beta (β) decay. In this process, a neutron transforms into a proton, emitting a beta particle (electron) and an antineutrino. This force is stronger than the gravitational force but weaker than the electromagnetic force. It is a short-range force, acting over a distance of about 10^{-17} meters.

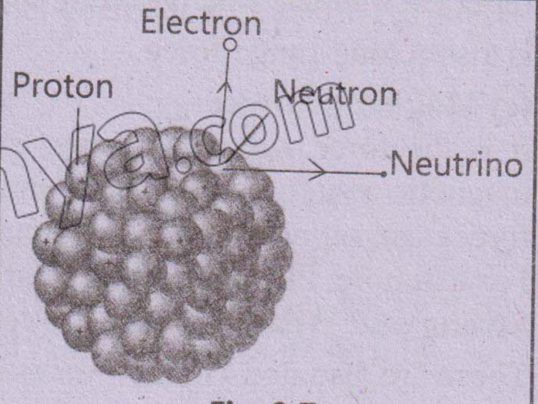

Fig. 3.7

Unification of Weak Nuclear and Electromagnetic Forces

A Pakistani scientist, Dr. Abdus Salam, along with Sheldon Glashow and Steven Weinberg, made significant contributions to the unification of the weak nuclear force and the electromagnetic force, forming what is known as the electroweak force. They were awarded the Nobel Prize in Physics in 1979 for their work.

Although these two forces appear different in everyday phenomena, the theory models them as two different aspects of the same fundamental force. This unification becomes apparent during interactions at very high energies. The effects of the electroweak force are observed in such high-energy interactions, demonstrating their common origin.

Q.4. What is meant by free-body diagram? Explain by means of a suitable example. 09103004

Ans: Free-Body Diagram

A **free-body diagram** is used to show the relative magnitudes and directions of all the forces acting on an object in a given situation. In other words, a free-body diagram is a special example of the **vector diagrams**.

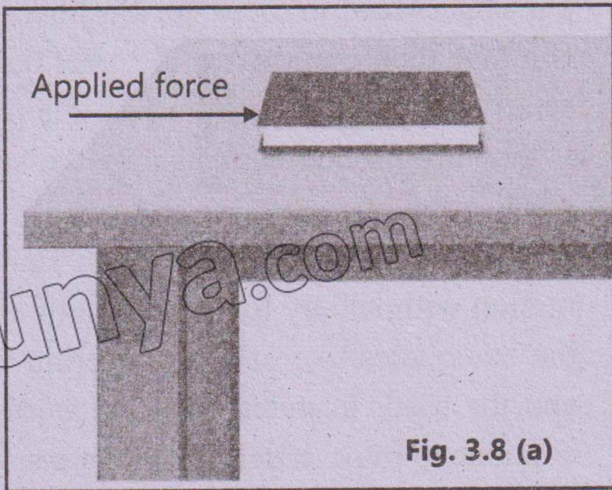

Fig. 3.8 (a)

Drawing a Free-Body Diagram

Suppose a book is pushed over the surface of a table. To represent the forces acting on the book using a free-body diagram:

- The object (the book) is represented by a **box**.
- The **force arrows** are drawn outward from the center of the box in the directions of the forces acting on the object.
- The **length of the force arrows** reflects the magnitude of the force, with longer arrows indicating greater force.
- The **arrowhead** shows the direction in which the force acts.

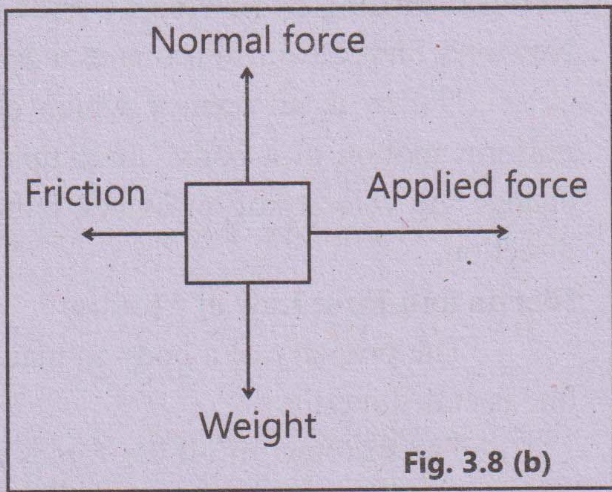

Fig. 3.8 (b)

Each force is **labeled** to indicate the exact type of force, such as **friction**, **gravity**, **normal force**, **drag**, or **tension in a string**. These labels help to identify the specific forces acting on the object.

Q.5. State and explain Newton's First Law of motion. 09103005

Ans: Newton's First Law of Motion

Newton's First Law of Motion states that:

"A body continues its state of rest or of uniform motion in a straight line unless acted upon by some external force" OR

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

Example:

For example, a **book** placed on a table will remain stationary unless a force is applied to move it. Similarly, a **ball** rolling on the floor should continue to move with the same velocity in the absence of an applied force. However, in reality, the ball eventually stops due to **friction**, which acts as an opposing force.

Fig. 3.9

Explanation:

When a **fast-moving bus** suddenly stops, the passengers tend to move forward because they want to continue their motion. On the other hand, when the bus starts moving quickly from rest, the passengers feel as if they are pushed back against the seat because their tendency is to retain their state of rest.

According to Newton's First Law, a **bus moving on the road** should continue its motion without any force exerted by the engine. However, in practice, if the engine stops, the bus comes to rest after covering some distance due to the friction between the tyres and the road. In outer space, if an object is thrown and no force acts upon it, it would continue to move indefinitely at a constant velocity.

Force according to Newton's First Law of motion

Newton's First Law also provides a definition of force:

"Force is an agency which changes or tends to change the state of rest or of uniform motion of a body." In simple words, force causes **acceleration**, meaning it can change the velocity of an object, either speeding it up, slowing it down, or changing its direction.

Inertia and First Law of Motion:

The property of a body to maintain its state of rest or uniform motion in a straight line is called inertia.

The resultant of all the forces acting on a body is called **net force**. A **net force** is required to change the velocity of an object.

Example: When a net force is applied to a **bicycle**, it can pick up speed quickly. However, if the same force is applied to a **truck**, the change in motion may be less noticeable because the truck has more **inertia**.

Dependence: Inertia is directly related to an object's **mass**. The greater the mass of an object, the greater its inertia. Therefore, the mass of an object is a measure of its inertia, that is why Newton's First Law is sometimes called the **law of inertia**.

Q.6. State and explain Newton's Second Law of Motion in detail. 09103006

Ans: Newton's second law deals with the acceleration produced in a body when a **net force** acts upon it. It states that:

"If a net external force acts upon a body, it accelerates the body in the direction of force. The magnitude of acceleration is directly proportional to the magnitude of force and is inversely proportional to the mass of the body"

Mathematical Expression

The second law can be expressed mathematically as:

$$a \propto F$$

$$a \propto \frac{1}{m}$$

$$a = \text{constant} \times \frac{F}{m}$$

According to SI units, if **m = 1 kg, a = 1 m/s²**, and **F = 1 N**, then the value of the constant is 1. Therefore, the equation simplifies to:

$$a = \frac{F}{m} \qquad \text{or } F = ma$$

Newton OR Unit of force:

One newton is the force required to produce an acceleration of **1 m/s²** in a body of mass **1 kg**.

$$1\text{N} = 1\text{kg} \cdot \text{m/s}^2$$

Effect of Force on Velocity:

Newton's second law also tells us that a force can change the **velocity** of a body by producing **acceleration** or **deceleration** in it. As velocity is a vector quantity, the change may occur in its **magnitude**, **direction**, or in both of them.

Q.7. State and explain Newton's Third Law of Motion giving examples from daily life. 09103007

Ans: Newton's third law of motion states:

"For every action, there is always an equal but opposite reaction"

This means that whenever two bodies interact, if **body A** exerts a force on **body B**, **body B** exerts a force on **body A** that is equal in magnitude but opposite in direction. The forces are simultaneous and occur between two interacting bodies.

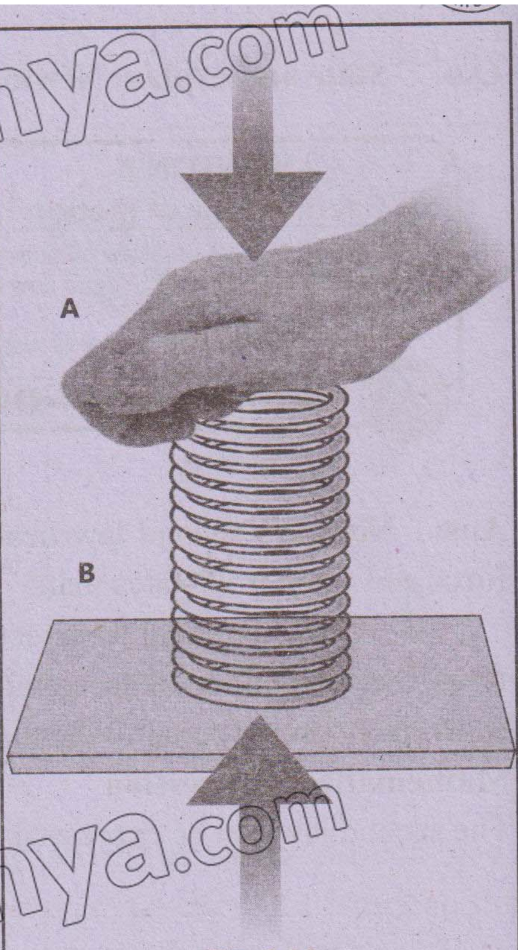

Fig. 3.10

Action and Reaction Forces

For example, when we press a spring, the **force exerted by our hand on the spring** is called the **action** force. In response to this action, **our hand experiences a force exerted by the spring**, which is the **reaction** force (as shown in Fig. 3.10).

Action and Reaction Forces Never Balance Each Other

Action and reaction forces do not balance each other because they act on two **different bodies**. Although they are equal in magnitude and opposite in direction, they **cannot cancel each other out** because they are applied to different objects. Therefore, they **never balance each other**.

Forces Act in Pairs

Forces act in pairs when two objects interact, as stated in **Newton's Third Law of Motion**. According to this law, for every action, there is always an equal but opposite reaction. When two objects interact, one object exerts a force on the other, which is the action force, and the second object exerts a force back on the first object, which is the reaction force. While we often notice the action force that makes something happen, the reaction force involved is usually less apparent.

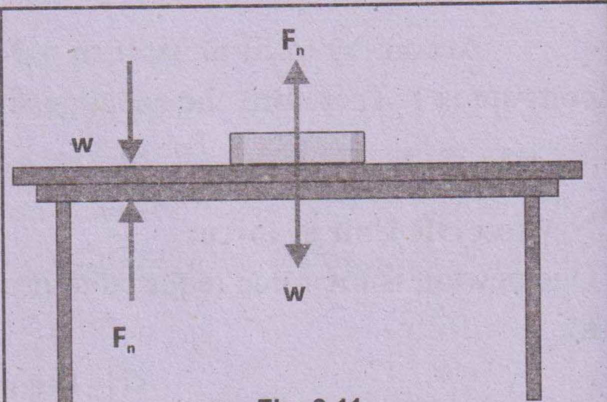

Fig. 3.11

Examples:

(i) Block on a Table:

Consider a block lying on a table as shown in Fig.3.11. The force acting downward on the block is the weight. The block exerts a downward force on the table equal to its weight **w**. The table also exerts a reaction force **F_n** on the block. The two forces on the block balance each other and the block remain at rest.

(ii) Bullet Fired from a Gun:

When a bullet is fired from a gun, the bullet moves in the forward direction with a force **F**. This is the force of action. The gun recoils in the backward direction with a reaction force **R** (Fig.3.12).

Fig. 3.12

Q.8. State the limitations of Newton's Laws of Motion. 09103008

Ans: Limitations of Newton's Laws of Motion

Newton's laws of motion can be applied with a very high degree of accuracy to the motion of objects and velocities which we come across in everyday life. However, problems arise when dealing with the motion of elementary particles having velocities close to that of light. For that purpose, **relativistic mechanics**, developed by **Albert Einstein**, is applicable. This theory helps in explaining and addressing the behavior of objects at speeds close to the speed of light.

Conclusion

After all this discussion, we can say that **Newton's laws of motion** are not exact for all types of motion, but they provide a good approximation unless an object is small enough or moving close to the speed of light.

Q.9. Differentiate between mass and weight. 09103009

Mass	Weight
The characteristic of a body which determines the magnitude of acceleration produced when a certain force acts upon it is known as mass of the body.	The weight of an object is equal to the force with which the Earth attracts the body towards its center.
It is a **scalar quantity.**	It is a **vector quantity**, directed downward towards the center of the Earth.
It remains the **same everywhere.**	It varies from place to place depending upon the value of g.
The **SI unit** of mass is **kilogram (kg)**.	The **SI unit** of weight is **newton (N)**.
Practically, mass is measured by an **ordinary balance**	Weight is measured using a **spring balance**.
Formula of mass is $m = \frac{F}{a}$	Formula of weight is w=mg

Q.10. Write a brief note on mechanical balances. 09103010

Ans: Balance Scales

Balance scales are commonly used to compare masses of objects or to weigh objects by balancing them with standard masses.

Mechanical Balances

A mechanical balance consists of a rigid horizontal beam that oscillates on a central knife-edge as a fulcrum. It has two end knife-edges equidistant from the center. Two pans are hung from bearings on the end knife-edges (Fig. 3.13). The material to be weighed is put in one pan, and standard weights are put on the other pan. The deflection of the balance may be indicated by a pointer attached to the beam. The weights on the pan are adjusted to bring the beam to equilibrium.

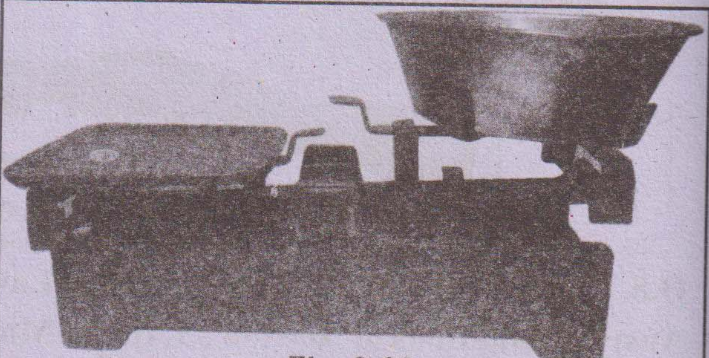

Fig. 3.13

Mechanical Platform Balances

There is another type of mechanical balance used to weigh heavy items like flour bags, cement bags, and steel bars. These are called mechanical platform balances (Fig. 3.14). Standard weights are not required to use this balance. The reason is that the fulcrum of the beam of such a balance is kept very near to one end. Therefore, much smaller weights have to be put at the other end of the beam to bring it to equilibrium. These smaller weights have already been calibrated to the standard weights.

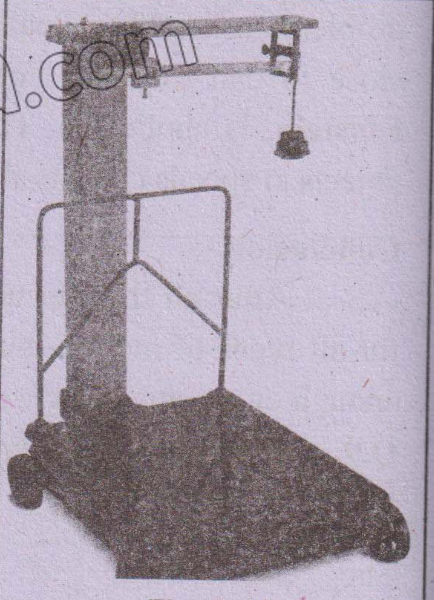

Fig. 3.14

Q.11. Explain very briefly electronic balance. 09103011

Ans: No standard weights are required to use in an electronic balance (Fig. 3.15). Only it has to be connected to a power supply. There are some models which can operate by using dry cell batteries. An electronic balance is more precise than a mechanical balance. When an object is placed on it, its mass is displayed on its screen. Nowadays, electronic balances also display the total price of the material if the rate per kg is fed to the balance.

Fig. 3.15

Q.12. Write a note on 'force meter' for measuring force. 09103012

Ans: Force Meter

A force meter is a scientific instrument that measures force. It is also called a newton meter or a spring balance (Fig. 3.16). Nowadays, digital force meters are also available. You have already learnt about mechanical and electronic balances. They measure the mass of objects in kilograms or its multiples. On the other hand, a force meter measures force directly in newtons (N).

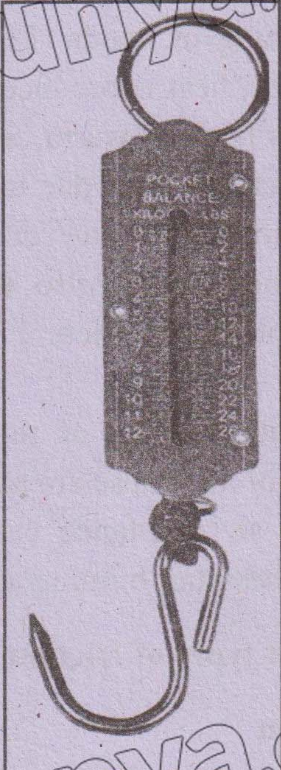

Fig. 3.16

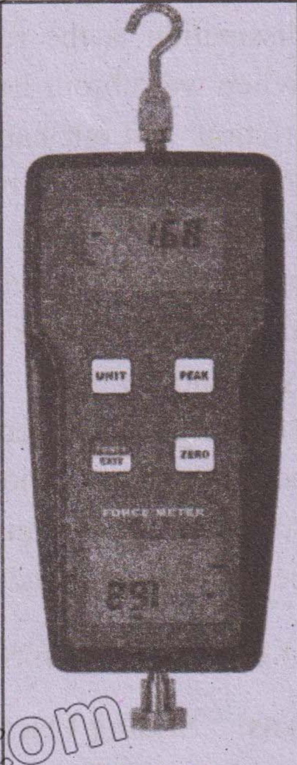

Fig. 3.17

Components and Working Principle

An ordinary force meter has a spring inside it. The upper end of the spring is attached to a handle. A hook is attached to the lower end of the spring that holds the object. A pointer is also attached to the spring at its upper end. A scale in newtons is provided along the spring such that the pointer coincides with zero on the scale when nothing is hung on the hook.

Measurement Process

The object to be weighed is hung on the hook. The mass of the object causes the spring to compress. The pointer indicates the weight of the object. However, some force meters are also based on the stretching of the spring when a load is hung. In this case, the pointer is attached at the lower end of the spring. In some spring balances, the scale measures the mass, which can be readily converted into newtons by multiplying the mass in kg with the value of $g=10ms^{-2}$.

Digital Force Meters

A digital force meter measures directly the weight of the object in Newtons (Fig. 3.17).

Q.13. Define friction. Explain dissipative effect of friction. 09103013

Ans: Friction

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

Explanation: When a cricket ball is hit by the bat, it moves on the ground with a reasonably large velocity. According to Newton's first law of motion, it should continue to move with constant velocity. But practically, we observe that it eventually stops after covering some distance. It is the force of friction between the ball and the ground that opposes the motion of the ball.

Dissipative Effect of Friction

Friction is a dissipative force due to which the energy is wasted in doing work to overcome friction. The lost energy appears in the form of heat.

Example:

A very common example of energy dissipation is the rubbing of hands (Fig. 3.18). When we rub our hands, heat is produced due to friction, and our hands become warm. Similarly, the temperature of machines rises due to friction between its moving parts, which can cause many problems. The tyres of vehicles also wear out after becoming too hot due to friction between tyres and the road.

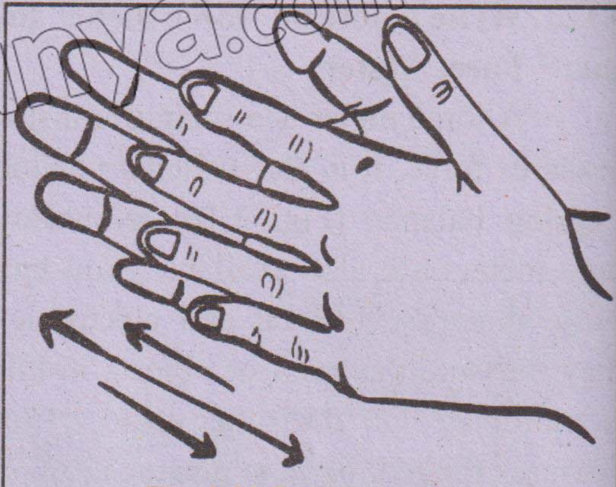

Fig. 3.18 Rubbing hands

Shooting stars seen in the sky at night also happen due to friction of air. These are actually asteroids that enter the Earth's atmosphere. As they are moving, air resistance causes the generation of heat. Their temperature becomes so high that they start burning and ultimately disintegrate.

Q.14. Write different types of friction with examples. 09103014

Ans: Sliding Friction

The friction between two solid surfaces is called sliding friction, which can be divided into two categories:

i. Static Friction
ii. Kinetic Friction

i. Static Friction

Static friction is the opposing force that prevents an object from starting to move when it is at rest on a surface.

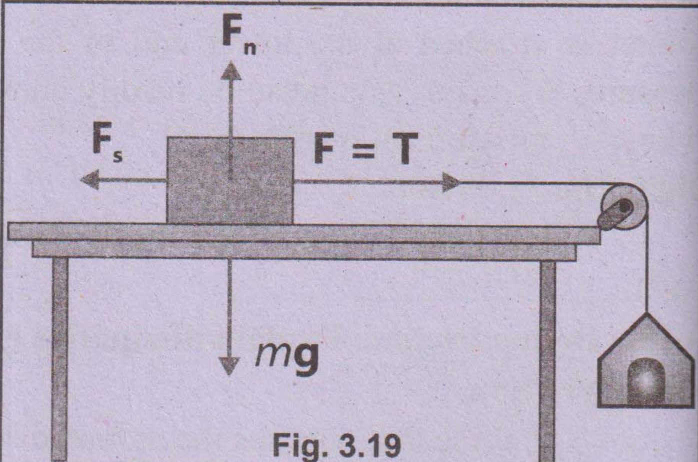

Fig. 3.19

Example

Let us consider the motion of a block on a horizontal surface. The arrangement is shown in Fig. 3.19. When a weight is put in the pan, a force **F=T** equal to the sum of this weight and the weight of the pan acts on the block. This force tends to pull the block. At the same time, an opposing force appears that does not let the block move. This opposing force is the static friction **Fs**.

ii. Kinetic Friction

If we go on adding more weights in the pan one by one in small steps, a stage will come when the block starts sliding on the horizontal surface. This is the limit of static friction that is equal to the total weights, including the pan. When the block is sliding, friction still exists. It is known as kinetic friction

Rolling Friction

"The force of friction between a rolling body and the surface over which it rolls is called **rolling friction**."

The idea of rolling friction is associated with the concept of a wheel. In our everyday life, we observe that a body with wheels faces less friction as compared to a body of the same size without wheels. Ball bearings also play the same role as is played by the wheels. Many machines use ball bearings to greatly reduce friction. The rolling friction is about one hundred times smaller than the sliding friction.

The reason for rolling friction to be less than sliding friction is that there is no relative motion between the wheel and the surface over which it rolls. The wheel touches the surface only at a point; it does not slide.

Q.15. Define and explain the concept of terminal velocity. 09103015

Ans: Terminal Velocity

Terminal velocity is the constant velocity achieved by an object when the upward force of air resistance balances the downward force of gravity, causing the object to stop accelerating and continue falling at a constant speed.

Fig. 3.20

Explanation

When an object falls freely under the influence of gravity, it is initially accelerated by $g=10\ ms^{-2}$. However, in reality, air resistance affects the motion of falling objects. If we drop two objects of the same weight, such as a cricket ball and a piece of Styrofoam, from a certain height, they would hit the ground at the same time only in the absence of air resistance. In practice, the cricket ball, with a smaller surface area, would fall faster than the Styrofoam, which faces greater air resistance due to its larger surface area. As the object falls faster, the air resistance increases. Eventually, a point is reached where the upward air resistance force equals the downward force of gravity. At this stage, the object stops accelerating and continues to fall at a constant speed—this speed is known as the terminal velocity.

Applications:

Meteorites: Even heavy objects like meteorites do not gain infinite velocity as they fall towards Earth. They reach a terminal velocity before hitting the ground due to air resistance.

Paratroopers: The principle of terminal velocity is important for paratroopers. The large surface area of a parachute increases air resistance, allowing for a controlled and safer downward movement by reducing the falling speed to a safe terminal velocity.

Q.16. Write down few methods of reducing friction. 09103016

The following methods are used to reduce friction:

i. Polishing Sliding Parts:

The parts which slide against each other are highly polished to reduce surface roughness, which in turn reduces friction.

ii. Using Oil or Grease:

Since the friction of liquids is less than that of solid surfaces, oil or grease is applied between the moving parts of machinery to reduce friction.

Fig. 3.21

iii. Using Ball Bearings:

As rolling friction is much less than sliding friction, sliding friction is converted into rolling friction by the use of ball bearings in machines and wheels under heavy objects.

iv. Streamlining Vehicles:

High-speed vehicles, airplanes, and ships also face friction while moving through air or water. If the front of a vehicle is flat, it faces more resistance from air or water. Therefore, bodies moving through air or water are streamlined to minimize air or water friction. In this case, the air passes smoothly over the slanting surface of the vehicle. This type of flow of air is known as streamline flow. Vehicles designed to be pointed from the front are said to be streamlined.

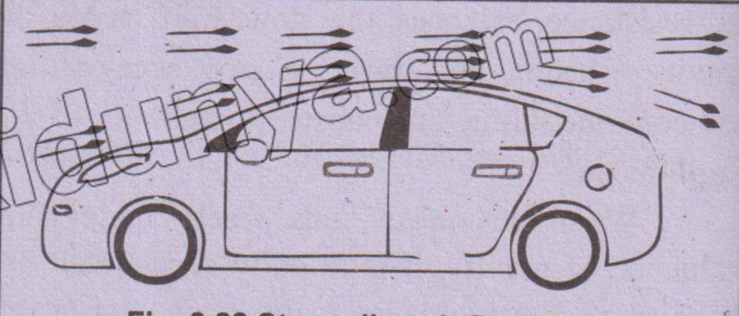

Fig. 3.22 Streamline air flow over a speedy car

Q.17. Define momentum and impulse, and demonstrate how the rate of change of momentum relates to the applied force. 09103017

Ans: Momentum:

Momentum is defined as the quantity of motion of a moving body. It depends on the mass and velocity of the object. The greater the mass, the greater the momentum; similarly, the greater the velocity, the greater the momentum. The **momentum of a moving body** is the product of its mass and velocity. Mathematically, this is represented as:

$$P = m \times v \quad \ldots\ldots\ldots\ldots (1)$$

Momentum is a vector quantity, meaning it has both magnitude and direction. The SI unit of momentum is **kg·m/s** (kilogram meter per second), which can also be written as **N·s** (Newton second).

Impulse:

Impulse refers to the total change in momentum of an object when a large force acts on it over a short interval of time. In practical situations, such as when a ball is hit by a bat, the exact value of the force and the time duration are difficult to measure. However, the change in momentum (initial and final velocities) can be easily determined. The **average acceleration** during the time interval Δt is given by:

$$a = \frac{\Delta v}{\Delta t} = \frac{v_f - v_i}{\Delta t} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

According to **Newton's second law of motion**, the **average force (F)** during this time interval is:

$$\mathbf{F = ma = m}\left(\frac{\Delta v}{\Delta t}\right)$$

Or $\quad F \times \Delta t = m\,(\Delta v) = m\,(v_f - v_i) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$

Equation (3) shows that F and Δ t cannot be exactly known but their product which is equal to the change of momentum ($mv_f - mv_i$) can be calculated. For such cases, the product $F \times \Delta t$ is called as **Impulse** of the force.

When a large force F acts on an object for a short interval of time, the impulse of the force is defined as the total change in momentum of the object.

By dividing both sides of equation (3) by Δt, we can express force in terms of momentum:

$$F = m\,\frac{(\Delta v)}{\Delta t} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

where $m(\Delta v)$ is the change in momentum Δp. Equation (4) gives the value of force in terms of momentum i.e., force acting on an object is equal to the change in momentum of the object per unit time.

$$\mathbf{F} = \frac{\Delta \mathbf{p}}{\Delta t}$$

This equation shows that **force** is equal to the rate of change of momentum. Thus, **Newton's second law of motion** can be rewritten as:

"The rate of change of momentum of a body is equal to the force acting on it."

The direction of the change in momentum is the same as the direction of the force.

Q.18. State and explain Principle of Conservation of momentum. **09103018**

Ans: A **system** is a collection of objects. If no external force acts on any object within the system, it is called an **isolated system**.

Explanation:

Consider a system of two balls with masses m_1 and m_2, moving along a straight line in the same direction with velocities v_1 and v_2 respectively. If $v_1 > v_2$, the balls will eventually collide. Let their velocities after the collision be v_1' and v_2'.

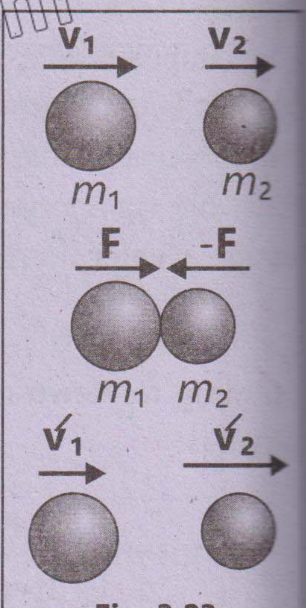

Fig. 3.23

Total Momentum Before Collision $= m_1v_1 + m_2v_2$

Total Momentum After Collision $= m_1v_1' + m_2v_2'$

The **principle of conservation of momentum** states:

"If no external force acts on an isolated system, the total momentum of the system remains constant before and after the collision."

Mathematically,

$$m_1v_1 + m_2v_2 = m_1v_1' + m_2v_2'$$

Example: Collision of Two Identical Balls:

Consider two identical balls as shown in diagram, where the first ball is moving with velocity v_1 and the second ball is initially at rest ($v_2=0$). When the moving ball collides with the stationary ball, the momentum is transferred from the first ball to the second. The first ball slows down and comes to rest. The second ball gains momentum and starts moving with the velocity that the first ball had before the collision.

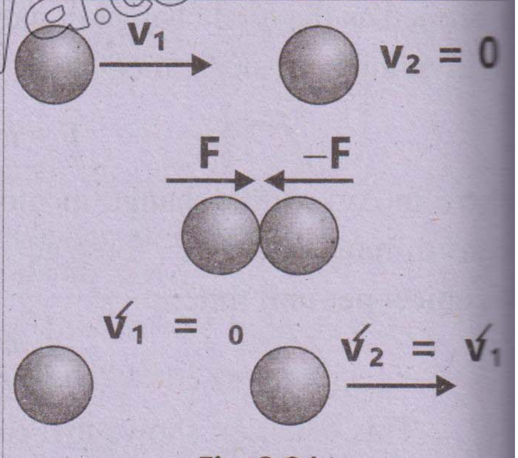

Fig. 3.24

The total momentum of the system before collision is the momentum of the first ball (m_1v_1). After the collision, the momentum of the second ball (m_2v_2') equals the momentum lost by the first ball. Therefore, the total momentum remains the same.

The **principle of conservation of momentum** is not limited to large objects but also applies to **micro-objects** such as atoms and molecules. This universal principle helps explain various physical phenomena, from everyday collisions to complex atomic interactions.

Examples

Examples 3.1 09103019

A 10 kg block moves on a frictionless horizontal surface with an acceleration of 2 m s'^2. What is the force acting on the block?

Solution:

Mass of a block $= m = 10$ kg

Acceleration $= a = 2\ m\ s^{-2}$

Force $= F = ?$

By Newton's second law of motion, $F = ma$

Putting the values, $F = 10\ kg \times 2\ m\ s^{-2} = 20 kg\ m\ s^{-2} = 20\ N$

Example 3.2 09103020

A force of 7500 N is applied to move a truck of mass 3000 kg. Find the acceleration produced in the truck. How long will it take to accelerate the truck from 36 km h^{-1} to 72 km h^{-1} speed?

Solution:

Mass of truck = m = 3000 kg

Force applied = F = 7500N

Acceleration = a = ?

Initial Speed = V_i = 36kmh^1

$$= \frac{36 \times 1000\, m}{60 \times 60\, s} = 10\, m\, s^{-1}$$

Final speed

$$= v_f = 72 \text{ km h}^{-1} = \frac{72 \times 1000\, m}{60 \times 60\, s} = 20\, m\, s^{-1}$$

Time = t = ?

By Newton's second law, F = ma

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

Putting the values, $a = \frac{7500 \text{ N}}{3000 \text{ kg}} = 2.5 m s^{-2}$

Now, using first equation of motion,

$$v_f = v_i + at$$

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

Putting the values, $t = \frac{20 \text{ m s}^{-1} - 10 \text{ m s}^{-1}}{2.5 \text{ m s}^{-2}} = 4 \text{ s}$

Example 3.3 09103021

A bullet of mass 15 g is fired by a gun. If the velocity of the bullet is 150 $m\,s^{-1}$, what is its momentum?

Solution:

Mass of bullet = m = 15 g = 0.015 kg

Velocity of bullet = v = 150 ms^{-1}

Momentum = p =?

Using the formula, p = mv

Putting the value, p = 0.015 kg × 150 m s^{-1}

Or p = 2.25 kg m s^{-1}

Example 3.4 09103022

A cricket ball of mass 160 g is hit by a bat. The ball leaves the bat with a velocity of 52 m s^{-1}. If the ball strikes the bat with a velocity of $-28\ m\,s^{-1}$ (opposite direction) before hitting, find the average force exerted on the ball by the bat. The ball remains

in contact with the bat for 4×10^{-3}s.

Solution:

Mass of ball $m = 160\text{ g} = 0.16\text{ kg}$

Initial velocity $v_i = -28\text{ m s}^{-1}$

Final velocity $v_f = 52\text{ m s}^{-1}$

Time of contact $= t = 4\times10^{-3}\text{s}$

Average force $F = ?$

From Eq. we have

$$F = \frac{m(v_f - v_i)}{t}$$

Putting the values,

$$F = \frac{0.16\text{ kg }[52\text{ m s}^{-1} - (-28\text{ms}^{-1})]}{4\times10^{-3}\text{s}}$$

or $F = 3200\text{ N}$

Example 3.5 09103023

A bullet of mass m_1 is fired by a gun of mass m_2. Find the velocity of the gun in terms of velocity of bullet v_1 just after firing.

Solution:

Before firing, the velocity of bullet as well as that of gun was zero. Therefore, total momentum of bullet and gun was also zero. After firing, the bullet moves forward with velocity v_1 whereas the gun moves with velocity v_2.

According to law of conservation of momentum,

Total momentum before firing = Total momentum after firing

Putting the values, $0 = m_1v_1 + m_2v_2$

$$m_2v_2 = -m_1v_1$$

or $$\boxed{v_2 = \frac{-m_1v_1}{m_2}}$$

The negative sign in this equation, indicates that the gun moves backward, i.e. opposite to the bullet. It is because of the backward motion of the gun that the shooter gets a jerk on his shoulder.

Examples 3.6 09103024

A ball of mass 3 kg moving with a velocity of 5 ms^{-1} collides with a stationary ball of mass 2 kg and then both of them move together. If the friction is negligible, find out the velocity with which both the balls will move after collision.

Solution:

Mass of first ball $= m_1 = 3\text{kg}$

Velocity of first ball before collision $= v_1 = 5\text{ ms}^{-1}$

Mass of second ball $= m_2 = 2\text{kg}$

Velocity of second ball before collision $= v_2 = 0$

Velocity of both the balls after collision $= v = ?$

Total mass of balls after collision $= m_1 + m_2$

By law of conversion of momentum,

Total momentum before collision = Total momentum after collision

or $m_1v_1 + m_2v_2 = (m_1 + m_2)v$

Putting the values,

$3\ kg \times 5\ m\ s^{-1} + 0 = (3\ kg + 2\ kg)\ v$

$15\ kg\ m\ s^{-1} = 5\ kg \times v$

$v = 3\ m\ s^{-1}$

Exercise

(A) Multiple Choice Questions

1. **When we kick a stone, we get hurt. This is due to:** 09103025
   (a) inertia
   (b) velocity
   (c) momentum
   (d) reaction
2. **An object will continue its motion with constant acceleration until:** 09103026
   (a) the resultant force on it begins to decrease
   (b) the resultant force on it is zero.
   (c) the resultant force on it begins to increase
   (d) the resultant force is at right angle to its tangential velocity
3. **Which of the following is a non-contact force?** 09103027
   (a) Friction
   (b) Air resistance
   (c) Electrostatic force
   (d) Tension in the string
4. **A ball with initial momentum p hits a solid wall and bounces back with the same velocity. Its momentum p' after collision will be:** 09103028
   (a) $p' = p$ (b) $p' = -p$
   (c) $p' = 2p$ (d) $p' = -2p$
5. **A particle of mass m moving with a velocity v collides with another particle of the same mass at rest. The velocity of the first particle after collision is:** 09103029
   (a) v
   (b) $-v$
   (c) 0
   (d) $-1/2$
6. **Conservation of linear momentum is equivalent to:** 09103030
   (a) Newton's first law of motion
   (b) Newton's second law of motion
   (c) Newton's third law of motion
   (d) None of these
7. **An object with a mass 5 kg moves at constant velocity of 10 ms^{-1}.A constant force then acts for 5 seconds on the object and gives it a velocity of 2 ms^{-1}. In the opposite direction. The force acting on the objects is:** 09103031
   (a) 5 N
   (b) -10N
   (c) −12 N
   (d) −15 N
8. **A large force acts on an object for a very short interval of time. In the case, it is easy to determine:** 09103032
   (a) magnitude of force
   (b) time interval
   (c) product of force and time
   (d) none of these

9. A lubricant is usually introduced between two surfaces to decrease friction. The lubricant: 09103033

(a) decreases temperature

(b) acts as ball bearings

(c) prevents direct contact of the surfaces

(d)provides rolling friction

Answer Key

1.	(d)	2.	(c)	3.	(c)	4.	(b)	5.	(c)
6.	(d)	7.	(c)	8.	(c)	9.	(c)		

SLO based Additional MCQs

Inertia

1. Inertia of a body is related to which of the following quantities: 09103034

(a) mass (b) force

(c) weight (d) friction

2. When a hanging carpet is beaten by stick. Dust flies off the carpet. It is mainly due to: 09103035

(a) Action force on carpet

(b) Reaction force by carpet

(c) Inertia of dust

(d) Rate of change of momentum of carpet

Acceleration

3. A force on 5N is applied to a body weighing 10N. Its acceleration in m/s^2 is: 09103036

(a) 0.5 (b) 2 (c) 5 (d) 50

Units

4. SI unit of linear momentum is: 09103037

(a) $kgm^{-1}s^{-1}$ (b) $kgm^{2}s^{-1}$

(c) N m (d) kg m s^{-1}

5. N kg^{-1} is equivalent to: 09103038

(a) m s^{-1} (b) m s^{-2}

(c) kg m s^{-1} (d) kg m s^{-2}

Momentum

6. The rate of change of momentum of free falling body is equal to its: 09103039

(a) momentum (b) velocity

(c) weight (d) size

7. Change in momentum of a body is equal to: 09103040

(a) (force)(velocity)

(b) (force)(time)

(c) (mass)(time)

(d) force

8. A book of mass 5 kg is placed on the table, the magnitude of net force acting on the book is: 09103041

(a) 0N (b) 5 N

(c) 25N (d) 10N

Newton's Law

9. Thrust force is a consequence of which law of motion: 09103042

(a) first (b) second

(c) third (d) fourth

Force

10. A force acts on a body for 2 seconds and it produces 50 kg m/s change in its momentum. The force acting on the body is: 09103043

(a) 100 N (b) 50 N

(c) 25 N (d) 2 N

11. The force which moves the car is: 09103044

(a) Force developed by engine

(b) Force of friction between road tyre

(c) uniform velocity

(d) Water split on the road

12. **An object of mass 1 kg placed at earth's surface experiences a force of:** 09103045
(a) 1 N
(b) 9.8 N
(c) 100 N
(d) any value

13. **Net force on the body falling in air with uniform velocity is equal to _________:** 09103046
(a) Weight of the body
(b) are resistance on the body
(c) difference of weight of body and air resistance on it
(d)zero

Centripetal Force

14. **At the fairground, the force that balances your weight is:** 09103047
(a) gravitational force
(b) centripetal force
(c) electrostatic force
(d) frictional force

Centrifugal Force

15. **A bucket having some water is revolved in vertical circle. Water does not spill out, even the bucket is upside down, due to:** 09103048
(a) Weight of water
(b) Centrifugal force on water
(c) Inertia of water
(d) Action and Reaction balance each other

Answer Key

1.	(a)	2.	(c)	3.	(a)	4.	(d)	5.	(b)
6.	(c)	7.	(b)	8.	(a)	9.	(c)	10.	(c)
11.	(a)	12.	(b)	13.	(d)	14.	(b)	15	(b)

(B) Short Questions

3.1 What kind of changes in motion may be produced by a force? 09103049

Ans: A force can produce the following changes in motion:

i. **Change in Speed:** A force can make an object move faster (acceleration) or slower (deceleration).
ii. **Change in Direction:** A force can change the direction of a moving object, such as in circular motion.
iii. **Change in Shape:** Applying a force can deform or change the shape of an object (like stretching a rubber band).
iv. **Starting or Stopping Motion:** A force can set a stationary object in motion or bring a moving object to a stop.

3.2 Give 5 examples of contact forces. 09103050

Ans: Examples of contact forces:

i. **Frictional Force:** The force that opposes the motion of an object sliding or moving across a surface (e.g., rubbing your hands together).
ii. **Tension Force:** The pulling force exerted by a string, rope, or cable when it is attached to an object (e.g., pulling a bucket up with a rope).
iii. **Normal Force:** The support force exerted by a surface perpendicular to an object resting on it (e.g., a book on a table).
iv. **Applied Force:** A force applied directly to an object by a person or another object (e.g., pushing a car).

v. **Air Resistance:** The force that opposes the motion of an object moving through the air (e.g. parachuting).

3.3 An object moves with constant velocity in free space. How long will the object continue to move with this velocity? 09103051

Ans: An object moving with **constant velocity** in free space will continue to move with that velocity forever unless an **external force** acts on it. This is because, in free space, there is no friction or air resistance to slow the object down, and according to **Newton's First Law of Motion** (law of inertia), an object in motion stays in motion at constant velocity unless acted upon by an external force.

3.4 Define impulse of force. 09103052

Impulse of force is the product of a force (**F**) and the time duration (Δt) over which it acts. It is equal to the change in momentum (**Δp**) of an object.

Formula: Impulse=**F**×Δt=**Δp**

Its unit is Newton-second (N·s) or kilogram meter per second (kg·m/s). It measures how a force changes an object's momentum over time.

3.5 Why has not Newton's first law been proved on the Earth? 09103053

Ans:Newton's First Law of Motion states that an object will remain at rest or move with constant velocity unless acted upon by an external force. This law has not been **directly proved on Earth** because of the presence of external forces like **friction** and **air resistance**, which constantly affect the motion of objects.

3.6 When sitting in a car which suddenly accelerates from rest, you are pushed back into the seat, why? 09103054

Ans: When a car suddenly accelerates from rest, you feel pushed back into the seat due to **inertia**, which is explained by **Newton's First Law of Motion. Inertia** is the tendency of objects to resist changes in their state of motion.

3.7 The force expressed in Newton's second law is a net force. Why is it so? 09103055

Ans: In **Newton's Second Law of Motion**, the force is called the **net force** because it is the **total force** acting on an object after considering **all the individual forces** acting on it. The **net force** is the sum of all these forces. It is the overall force that causes the object to accelerate.

Example:

If a car is being pushed forward while friction resists it, the net force is the total forward force after subtracting friction. This net force determines how much the car will accelerate.

3.8 How can you show that rolling friction is lesser than the sliding friction? 09103056

Ans: Rolling friction is less than sliding friction because, in rolling, only a small area of contact touches the surface at a time, reducing resistance. In contrast, sliding friction involves direct contact between two surfaces, creating more resistance due to greater surface interaction. This is why less force is needed to move an object on wheels than to slide it across a surface.

3.9 Define terminal velocity of an object. 09103057

Ans: Terminal velocity is the constant velocity achieved by an object when the upward force of air resistance balances the downward force of gravity, causing the object to stop accelerating and continue falling at a constant speed.

3.10 An astronaut walking in space wants to return to his spaceship by firing a hand rocket. In what direction does he fire the rocket? 09103058

Ans: The astronaut should fire the hand rocket in the **opposite direction** to the spaceship. This expels gases in one direction, and by **Newton's Third Law,** the equal and opposite reaction pushes the astronaut back toward the spaceship.

SLO based Additional Short Questions

Newton's laws of motion

3.1 When and where was Sir Isaac Newton born, and what is the name of his famous book? 09103059

Ans: Sir Isaac Newton was born in **Lincolnshire** on **January 4, 1643**, and the name of his famous book is "**Principia Mathematica**."

3.2 When an astronaut throws a wrench in space, he moves in the opposite direction. Why does this happen? 09103060

Ans: This happens because of Newton's third law of motion, which states that for every action, there is an equal and opposite reaction.

Mass and Weight

3.3 What is the weight of a 100 g mass? 09103061

Ans: Given data:

$m=100g=0.1kg$

$g=10ms^{-2}$

To find: $w=?$

Solution:

The weight of the body can be calculated by using formula:

$w=mg$

$w= 0.1\times10=1N$

Result: Hence the weight of the body is 1N.

Friction

3.4 Why does the water not form a wet layer between the tyre surface and the road surface on a wet road, and how does this reduce the chances of skidding? 09103062

Ans: The water does not form a wet layer between the tyre surface and the road surface due to the spaces in the tread pattern on the tyre. These spaces allow the water to be displaced, improving grip and reducing the chances of skidding on wet roads.

3.5 Why does the surface temperature of a shuttle rise to over 950°C when it re-enters the Earth's atmosphere? 09103063

Ans: The surface temperature of the shuttle rises to over 950°C when it re-enters the Earth's atmosphere due to the friction caused by the atmosphere. This friction generates intense heat, increasing the shuttle's surface temperature.

3.6 Why don't human bones normally wear out, even after many years of use? 09103064

Ans: Friction in human joints is very low because our bodies contain a natural lubricating system. As a result, even though our bones rub against each other at the joints when we move, they do not normally wear out.

3.7 How does a wheel produce a frictional force when it contacts the surface? 09103065

Ans: The contact point of the wheel is not perfectly circular; under pressure, it becomes flat. This flat portion slides against the surface, producing a frictional force.

3.8 How does a hovercraft move over both water and ground? 09103066

Ans: A hovercraft moves over both water and ground by ejecting air underneath through powerful fans, creating a cushion of air. This cushion offers very small resistance, allowing the hovercraft to move smoothly.

Momentum and Impulse

3.9 How does a cricketer reduce the impact of the ball when catching it? 09103067

Ans: A cricketer draws his hands back to reduce the impact of the ball by increasing the time over which the force is applied. This decreases the force experienced by the hands.

3.10 How does the momentum of the apple and arrow change when an arrow penetrates into an apple? 09103068

Ans: When the arrow penetrates into the apple, the momentum of the apple changes in response to the arrow's force. Conversely, the apple applies an opposing force to the arrow, causing a change in the momentum of the arrow.

3.11 How do soft packing materials protect fragile objects during transportation? 09103069

Ans: Soft packing materials, like Styrofoam, corrugated cardboard sheets, and bubble wrap, reduce the effect of quick changes in momentum. This reduces the force acting on the fragile objects, preventing them from breaking due to jerks or direct impacts with hard objects.

3.12 How do crumple zones in automobiles help protect passengers during an accident? 09103070

Ans: Crumple zones are designed to compress during an accident, absorbing deformation energy from the impact. They manage crash energy by absorbing it in the outer parts of the vehicle, rather than transmitting it to the occupants. This is done by making the outer parts weaker, like plastic bumpers, while making the passenger cabin stronger.

3.13 What is a seatbelt, and how does it help protect passengers in a car? 09103071

Ans: A seatbelt is a safety feature in a car that prevents passengers from moving forward suddenly when the car stops. It reduces the chances of passengers hitting the windshield or steering wheel.

3.14 A person falling on a cemented floor gets badly hurt. Explain why? 09103072

Ans: This is due to the second law of motion according to which the acceleration is directly proportional to the applied force. As, the person falls with large acceleration and hence with greater force. So, he is hurt due to fall on hard cemented floor $\left(a = \frac{v}{t}, a \propto F\right)$

3.15 A person falling on sand is not hurt much. Explain why? 09103073

Ans. This is also due to the second law of motion. As we fall on the sand, the sand being soft is pressed and time increases. That is why a person falling on sand is not hunt much.

$$\left(a = \frac{v}{t}, a \propto F\right)$$

3.16 A cricket player draws of pulls his hands while catching a ball. Explain why? 09103074

Ans: This is due to the Newton's second law of motion, by pulling or drawing the hands downward the time of motion increase. Therefore, the force decreases and hands are not hurt.

$$\left(a = \frac{v}{t}, a \propto F\right)$$

3.17 Why on shaking the branch of a tree fruits fall down? 09103075

Ans: This is due to the property of inertia. On shaking the branch of tree while the fruits tend to remain at rest and therefore fall down. This is due to the law of inertia.

Inertia

3.18 When a bus suddenly starts, passengers fall in the backward direction. Explain why? 09103076

Ans. The passengers sitting in stationary bus are also at rest but if the bus suddenly starts moving, the lower part of the body comes into motion while the upper part tends to remain stationary due to inertia. That is why the passengers fall in the backward direction.

3.19 Why does dust fly off, when a handing carpet is beaten with a stick? 09103077

Ans. The dust which is stuck with the carpet is initially at rest. When we beat a carpet with a stick, the carpet is set into motion suddenly while the dust particles are at rest and tends to remain at rest due to inertia. Consequently, the dust particles get removed from the carpet.

(C) Constructed Response Questions

3.1 Two ice skaters weighing 60kg and 80 kg push off against each other on a frictionless ice track. The 60 kg skater gains a velocity of 4 m s-1.Consideringall the relevant calculations involved, explain how Newton's third law applies to this situation. 09103078

Ans: When the two skaters push off each other, **Newton's Third Law** states that the force exerted by Skater 1 on Skater 2 is equal and opposite to the force exerted by Skater 2 on Skater 1. Skater 1 (60 kg) moves with a velocity of 4 m/s, so the momentum of Skater 1 is 60×4=240kg m/s. Since no external forces act, the total momentum must remain zero, so:

$$240 + 80 \times v_2 = 0$$

$$v_2 = \frac{-240}{80} = -3\text{m/s}$$

Thus, Skater 2 (80 kg) moves in the opposite direction with a velocity of -3 m/s, showing that the forces between the skaters are equal and opposite.

3.2 Inflatable air bags are installed in the vehicles as safety equipment. In terms of momentum, what is the advantage of air bags over seatbelts? 09103079

Ans: The advantage of **airbags** over **seatbelts** in terms of **momentum** is that airbags help to **increase the time** over which the **momentum of the passenger is brought to zero** during a collision. According to the **impulse-momentum theorem**, the change in momentum (Δp) is equal to the force (F) applied multiplied by the time (Δt) over which the force acts:

$$\Delta p = F \times \Delta t$$

Airbags work by **increasing the time** of the collision, which reduces the **force** experienced by the passenger.

3.3 A horse refuses to pull a cart. The horse argues, "according to Newton's third law, whatever force I exert on the cart, the cart will exert an equal and opposite force on me. Since the net force will be zero, therefore, I have no chance of accelerating (pulling) the cart." What is wrong with this reasoning? 09103080

Ans: The horse can still exert a force on the cart by pushing backward against the ground, and the ground provides a reaction force that allows the horse to move forward. Without this frictional force from the ground, the horse would not be able to pull the cart, but as long as the ground provides enough friction, the horse can accelerate and pull the cart. Therefore, the net force on the horse is not zero because the friction from the ground allows it to move.

3.4 When a cricket ball is hit high, a fielder tries to catch it. While holding the ball he/she draws hands backward. Why? 09103081

Ans: The fielder draws their hands backward to **increase the time** over which the ball's momentum is brought to zero. According to the **impulse-momentum theorem**, by increasing the time it takes to stop the ball, the **force** exerted on the fielder's hands is reduced. This reduces the risk of injury and makes it easier to catch the ball.

3.5 When someone jumps from a small boat onto the river bank, why does the jumper often fall into the water? Explain. 09103082

Ans: When someone jumps from a small boat onto the riverbank, the **action** of jumping causes an **equal and opposite reaction** on the boat (according to **Newton's Third Law**). As the person jumps forward, the boat is pushed backward. Since the boat is in water, it moves backward slightly, and the jumper might lose balance. The force that pushes the jumper forward is not balanced by the boat's backward motion, causing the jumper to fall into the water instead of successfully landing on the bank.

3.6 Imagine that if friction vanishes suddenly from everything, then what could be the scenario of daily life activities? 09103083

Ans: If friction were to suddenly vanish, daily life activities would be severely affected. Without friction:

i. **Walking**: People would be unable to walk because there would be no friction between their shoes and the ground to push against, making it impossible to move forward.

ii. **Driving**: Vehicles would slide uncontrollably since there would be no friction between the tires and the road to provide traction. Stopping the vehicle would be impossible.

iii. **Writing**: Writing with a pen or pencil would be difficult because there would be no friction between the writing instrument and paper, causing them to slide smoothly with no marks left behind.

iv. **Holding Objects**: It would be hard to hold or grip anything, such as a glass, a phone, or even a door handle, since friction between the hands and objects would disappear.

3.7 Why a balloon filled with air move forward, when its air is released? **09103084**

Ans. The balloon moves forward due to reaction of the air. This can be explained in two different ways.

(i) When air is released from balloon, the balloon pushes the air in backward direction, which is action. While in reaction, the air pushes the balloon in forward direction. As a result, the balloon moves forward. According to Newton's third law, we have, F on air = F on balloon

(ii) We can also explain the above question in terms of the law of conservation of momentum. The air and balloon forms an isolated system whose total momentum is zero. New when air is released, it rushes out with greater momentum in the backward direction. Now to conserve momentum the balloon moves forward with the same momentum.

(D) Comprehensive Questions

3.1 Explain the concept of force by practical examples. **09103085**

Ans: See QNo.1

3.2 Describe Newton's laws of motion. **09103086**

Ans: See QNo.5,6 and 7.

3.3 Define momentum and express newton's 2nd law of motion in term of change in momentum. **09103087**

Ans: See QNo.17

3.4 State and explain the principle of conservation of momentum. **09103088**

Ans: See QNo.18

3.5 Describe the motion of a block on a table taking into account the friction between the two surfaces. What is the static friction and kinetic friction? **09103089**

Ans: See QNo.14

3.6 Explain the effect of friction on the motion of vehicle in context of tyre surface and braking force. **09103090**

Ans: Friction affects vehicle motion in two key ways:

(i) Tire Surface Friction: Provides traction for acceleration, deceleration, and cornering, but also causes rolling resistance.

(ii) Braking Force and Friction: Friction between brake pads and rotor slows down the vehicle. Factors like road surface, tire condition, brake pad material, and temperature affect friction.

(E) Numerical Problems

3.1 A 10 kg block is placed on a smooth horizontal surface. A horizontal force of 5 N is applied to the block. Find: **09103091**

(a) the acceleration produced in the block.

(b) the velocity of block after 5 seconds.

Solution:

Given data:

$V_i = 0$

Mass of block = 10 kg

Applied force = F = 5 N

Time = t = 5 seconds

To find:

(a) the acceleration produced in the block = a =?

(b) the velocity of block after 5 seconds=V_f =?

(a) We can use Newton's second law of motion to find the acceleration.

$F = ma$

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

$$a = \frac{5}{10}$$

$a = 0.5\ ms^{-2}$

(b) To find the velocity we use equation of motion

$v_f = v_i + at$

$v_f = 0 + (0.5)(5)$

$v_f = 2.5 m/s$

Result:

(a) The acceleration produced in the block is 0.5 ms^{-2}.

(b) The velocity of the block after 5 sec is 2.5 ms^{-1}.

3.2 The mass of person is 80 kg. What will be his weight on the Earth? What will be its weight on the Moon? The value of acceleration due to gravity of Moon is 1.6ms^{-2}. **09103092**

Solution:

Given data:

Mass of person = m = 80 kg

Acceleration due to gravity on Earth = g_{earth} = ?

Acceleration due to gravity on moon = $g_{moon} = 1.6ms^{-2}$

To find:

Weight on earth = W_{earth}= ?

Weight on moon = W_{moon}= ?

Weight is given by formula

$W_{earth} = mg_{earth}$

$W_{earth} = (80)(10)$

$W_{earth} = 800$ N

Now, weight on mon,

$W_{moon} = mg_{moon}$

$W_{moon} = (80)(1.6)$

$W_{moon} = 128$ N

Result:

The weight on earth is 800 N and weight on moon is 128 N.

3.3 What force is required to increase the velocity of 800 kg car from 10ms^{-1} to 30ms^{-1} in 10 seconds? **09103093**

Solution:

Given date:

Mass of car = m = 800 kg

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

Final velocity = v_f = 30 ms^{-1}

Time = t = 10 seconds

To find:

Force = F = ?

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

$$a = \frac{30 - 10}{10}$$

$a = 2ms^{-2}$

By Newton's second law of motion,

$F = ma$

$F = (800)(2)$

$F = 1600\ N$

Result:

The force required to increase the velocity of car is 1600 N.

3.4 A 5 g bullet is fired by a gun. The bullet moves with a velocity of 300 ms^{-1}. If the mass of the gun is 10kg, find the recoil speed of the gun. 09103094

Solution:

Given data:

Mass of the bullet = $m_{bullet} = 5g = \frac{5}{1000} = 0.005\ kg$

Velocity of the bullet = $v_{bullet} = 300\ ms^{-1}$

Mass of the gun = $m_{gun} = 10\ kg$

Initial velocity of the gun and bullet before firing = $0\ ms^{-1}$

To find:

Recoil speed of th gun = V_{gun} = ?

Total initial momentum before fired = Total Final momentum after fired

$$0 = m_{bullet} \times V_{bullet} + m_{gun} \times V_{gun}$$

$$m_{gun} \times V_{gun} = - m_{bullet} \times V_{bullet}$$

$$V_{gun} = -\frac{m_{bullet} \times V_{bullet}}{m_{gun}}$$

$$V_{gun} = -\frac{(0.005)(300)}{10}$$

$$V_{gun} = -0.15 ms^{-1}$$

Result:

The recoil speed of the gun is $-0.15ms^{-1}$. The negative sign indicates that the gun moves in opposite direction to the bullet.

3.5 An astronaut weighs 70 kg. He throws a wrench of mass 300 g at a speed of $3.5 ms^{-1}$. Determine: 09103095

(a) the speed of astronaut as he recoils away from the wrench.

(b) the distance covered by the astronaut in 30 minutes.

Solution:

Given data:

Mass of astronaut = $m_{ast} = 70\ kg$

Mass of wrench = $m_{wer} = 300g = \frac{300}{100} = 0.3\ kg$

Velocity of wrench = $V_{wre} = 3.5ms^{-1}$

Time = t = 30 min = 30 × 60 = 1800 second

To find:

The speed of astronaut = V_{ast} = ?

Distance covered by astronaut = S_{ast} = ?

According to law of conservation of momentum, the total momentum before the wrench is thrown is zero, as both astronaut and wrench are initially at rest.

So,

$$0 = m_{ast} \times V_{ast} + m_{wre} \times V_{wre}$$

$$- m_{wre} \times V_{wre} = m_{ast} \times V_{ast}$$

$$V_{ast} = -\frac{m_{wre} \times V_{wre}}{m_{ast}}$$

$$V_{ast} = -\frac{(0.3)(3.5)}{70}$$

$$V_{ast} = -0.015ms^{-1}$$

So, the recoil speed of the astronaut is $-1.5 \times 10^{-2} ms^{-1}$, where negative sign indicates that astronaut moves in opposite direction to wrench.

Now,

Distance = speed × time

$$S_{ast} = 0.015 \times 1800$$

$$S_{ast} = 27\ m$$

Result:

The speed of the astronaut as he recoils is $-1.5 \times 10^{-2} ms^{-1}$ and the distance covered by astronaut is 27m.

3.6 A 6.5×10^3kg bogie of a goods train is moving with a velocity of 0.8 ms^{-1}. Another bogie of mass 9.2×10^3kg coming from behind with a velocity of 1.2 ms^{-1} with the first one and couples to it. Find the common velocity of two bogies after they become coupled. **09103096**

Solution:

Given data:

Mass of the first bogies, $m_1 = 6.5\times10^3$kg

Velocity of the first bogie, $v_1 = 0.8ms^{-1}$

Mass of the second bogie, $m_2 = 9.2\times10^3$kg

Velocity of the second bogie, $v_2 = 1.2ms^{-1}$

To find:

Common velocity of the two bogies v_f after coupled =?

Before the collision, the total momentum of the system is the sum of the momentum of both bogies. After collision, the total momentum is the combined mass of the two bogies moving with the common velocity v_f.

So,

$$m_1v_1 + m_2v_2 = (m_1+m_2)v_f$$

$$(6.5\times10^3)(0.8) + (9.2\times10^3)(1.2) = (6.5\times10^3 + 9.2\times10^3)v_f$$

$$5200 + 11040 = 15.7\times10^3 v_f$$

$$v_f = \frac{15840}{15.7\times10^3}$$

$$v_f = 1.03ms^{-1}$$

Result:

The common velocity of the two bogies after they coupled is $1.03ms^{-1}$.

3.7 A cyclist weighing 55 kg rides a bicycle of mass 5 kg. He starts from rest and applies a force of 90 N for 8 seconds. Then he continues at a constant speed for another 8 seconds. Calculate the total distance travelled by cyclist. **09103097**

Solution:

Given data:

Mass of cyclist = $m_{cyclist}$ = 55 kg

Mass of the bicycle = $m_{bicycle}$ = 5 kg

Total mass of system = m_{total} = 55 kg + 5 kg = 60 kg

Force applied = F = 90 N

Time for which force is applied = t_1 = 8 seconds

Time for constant speed = t_2 = 8 seconds

Initial velocity = $v_i = 0ms^{-1}$

To find:

Distance travelled by cyclist = S =?

Use Newton's second law of motion to calculate acceleration during first 8 second.

$$F = m_{total}\times a$$

$$a = \frac{F}{m_{total}} = \frac{90}{60} = 1.5ms^{-2}$$

Now we find the velocity at the end of first 8 second.

$$v_f = v_i + at_1$$

$$v_f = 0 + (1.5)(8)$$

$$v_f = 12ms^{-1}$$

Distance during First 8 seconds.

$$S_1 = v_it_1 + \frac{1}{2}at_1^2$$

$$S_1 = 0\times8 + \frac{1}{2}\times(1.5)(8)^2$$

$$S_1 = 48m$$

Distance travelled during the next 8 second when speed is constant.

$$S_2 = v_f\times t_2$$

$$S_2 = 12\times8$$

$$S_2 = 96m$$

So,

Total distance is

$$S_{total} = S_1 + S_2$$

$$S_{total} = 48 + 96$$

$$S_{total} = 144m$$

Result:

The total distance travelled by cyclist is 144m.

3.8 A ball of mass 0.4 kg is dropped on the floor from a height of 1.8 m. The ball rebounds straight upward to a height of 0.8 m. What is the magnitude and direction of the impulse applied to the ball by the floor? 09103098

Solution:

Given Data:

Mass of the ball = m = 0.4 kg

Initial height from which the ball is dropped = h_1 = 1.8 m

Rebound height = h_2 = 0.8 m

Gravitational acceleration = g = $10ms^{-2}$

To find:

Magnitude and direction of impulse =?

First of all, we calculate the velocity just hitting the floor (at height h_1)

$$2gh_1 = v_f^2 - v_i^2$$

$$2(10)(1.8) = v_f^2 - (0)^2$$

$$v_f^2 = 36$$

taking square root on both sides

$$\sqrt{v_f^2} = \sqrt{36}$$

$$v_f = 6ms^{-1}$$

Now, we calculate the velocity just after rebounding (at height h_2)

$$2gh_2 = v_f'^2 - v_i^2$$

$$2(10)(0.8) = v_f'^2 - (0)^2$$

$$v_f'^2 = 16$$

Taking square root on both sides

$$\sqrt{v_f'^2} = \sqrt{16}$$

$$v_f' = 4ms^{-1}$$

Now we calculate the impulse,

$$\Delta p = m\ v$$

$$\Delta p = m \times (v_f' - (-v_f))$$

The negative sign indicates that the ball velocity before the collision was downward, and after the collioion is upward.

$$\Delta p = (0.4)(4 - (-6))$$

$$\Delta p = (0.4)(4 + 6)$$

$$\Delta p = (0.4)(10)$$

$$\Delta p = 4 Ns$$

Direction of Impulse:

The direction of impulse is upward as the floor applies an upward force to stop the downward motion and then push the ball upward.

Result:

The magnitude of the impulse is 4Ns, and the direction is upward.

3.9 Two balls of masses 0.2 kg are moving towards each other with velocities 20 ms^{-1} and $5ms^{-1}$ respectively. After collision, the velocity of 0.2 kg ball becomes 6 ms^{-1}. What will be the velocity of 0.4 kg ball? 09103099

Solution:

Given data

Mass of the first ball = m_1 = 0.2 kg

Mass of the second ball = m_2 = 0.4 kg

Initial velocity of the first ball = u_1 =$20ms^{-1}$

Initial velocity of the second ball = u_2 = -$5ms^{-1}$

(negative sign because the balls are moving towards each other)

Final velocity of the first ball = v_1 =$6ms^{-1}$

To Find:

Final velocity of the second ball = v_2 =?

By law of conservation of momentum

$$m_1v_1 + m_2v_2 = m_1u_1 + m_2v_2$$

$$(0.2)(20) + (0.4)(-5) = (0.2)(6) + (0.4)(v_2)$$

$$4 - 2 = 1.2 + (4.2)v_2$$

$$2 = 1.2 + 0.4v_2$$

$$2 - 1.2 = 0.4v_2$$

$$\frac{0.8}{0.4} = v_2$$

$$v_2 = 2ms^{-1}$$

Result:

The velocity of 0.4 kg ball after collision is $2ms^{-1}$