Important Questions for Class 9

Science

Chapter 8 – Forces and Laws of Motion

Very Short Answer Questions **1 Mark**

1. A batsman hits a cricket ball which then rolls on level ground. After covering a short distance, the ball comes to rest. The ball slows to a stop because –
(a) The batsman did not hit the ball hard enough.
(b) Velocity is proportional to the force exerted on the ball.
(c) There is a force on the ball opposing the motion.
(d) There is no unbalanced force on the ball, so the ball would want to come to rest.
Ans: (c) There is a force on the ball opposing the motion.

2. What is the momentum of an object of mass m, moving with a velocity v?
(a) $(mv)^2$
(b) mv^2
(c) $\frac{1}{2}mv^2$
(d) mv
Ans: (d) mv

3. Using a horizontal force of $200N$, we intend to move a wooden cabinet across a floor at a constant velocity. What is the friction force that will be exerted on the cabinet?
Ans: In order to move the cabinet across the floor at a constant velocity, the net force experienced by it must be zero. Thus a frictional force of $200N$ must be exerted on the cabinet to move it across the floor at a constant velocity, against the horizontal force of $200N$.

4. What is the S.I. unit of momentum?
(a) $kgms$
(b) $\frac{ms}{kg}$

(c) $\mathbf{kgms^{-1}}$

(d) $\mathbf{\dfrac{kg}{ms}}$

Ans: (c) $kgms^{-1}$

5. What is the numerical formula for force?

(a) $\mathbf{F = ma}$

(b) $\mathbf{F = \dfrac{m}{a}}$

(c) $\mathbf{F = ma^2}$

(d) $\mathbf{F = m^2a}$

Ans: (a) $F = ma$

6. If the initial velocity is zero then the force acting is

(a) Retarding

(b) Acceleration

(c) Both

(d) None

Ans: (a) Acceleration

7. What is the S.I. unit of force?

(a) $\mathbf{\dfrac{kgm}{s^2}}$

(b) $\mathbf{\dfrac{kgm}{s}}$

(c) $\mathbf{\dfrac{kgm^2}{s^2}}$

(d) $\mathbf{kgm^2s^2}$

Ans: (a) $\dfrac{kgm}{s^2}$

8. Newton's first law of motion is also called

(a) Law of Inertia

(b) Law of Momentum

(c) Law of Action & Reaction

(d) None of these

Ans: (a) Law of Inertia

9. Which law explains swimming?
(a) Newton's first law
(b) Newton's second law
(c) Newton's third law
(d) All of these
Ans: (c) Newton's third law

10. The S.I. unit of weight is:
(a) N
(b) Nm
(c) $\frac{N}{s}$
(d) $\frac{Nm}{s}$
Ans: (a) N

11. Which equation defines Newton's Second law of motion?
(a) $F = ma = \frac{dp}{dt}$
(b) $F = m\frac{da}{dt} = P$
(c) $\frac{dF}{dt} = ma = P$
(d) $F = ma = P$
Ans: (d) $F = ma = P$

12. The people in the bus are pushed backwards when the bus starts suddenly due to
(a) Inertia due to Rest
(b) Inertia due to Motion
(c) Inertia due to Direction
(d) Inertia
Ans: (a) Inertia due to Rest

13. If the force acting on the body is zero. Its momentum is
(a) zero
(b) constant
(c) Both
(d) None

Ans: (b) constant

14. The inability of the body to change its state of rest or motion is
(a) Momentum
(b) Force
(c) Inertia
(d) Acceleration.
Ans: (c) Inertia

Short Answer Questions 2 Marks

1. An object experiences a net zero external unbalanced force. Is it possible for the object to be traveling with a non-zero velocity? If yes, state the conditions that must be placed on the magnitude and direction of the velocity. If no, provide a reason.
Ans:
- Yes, it is possible for an object to be traveling with a non-zero velocity if it experiences a net zero external unbalanced force. This is based on Newton's First law of motion, which states that an object will change its state of motion if and only if the net force acting on it is non-zero.
- Thus, in order to change its motion or to bring about motion, some external unbalanced force is required.
- In this case, the object experiences a net zero unbalanced force, which will cause it to move with some non-zero velocity provided that the object was previously moving with a constant velocity.

2. When a carpet is beaten with a stick, dust comes out of it. Explain.
Ans: When a carpet is beaten with a stick, dust comes out of it because of Newton's First Law of Motion, the law of Inertia. Initially, the dust particles and the carpet are in a state of rest. When the carpet is beaten with a stick, it causes the carpet to move, while the dust particles, due to inertia of rest, will resist the change in motion. Thus, the carpet's forward motion will exert a backward force on the dust particles, which makes them move in the opposite direction. Therefore the dust comes out of the carpet.

3. Why is it advised to tie any luggage kept on the roof of a bus with a rope?
Ans:
- It is advised to tie any luggage kept on the roof of a bus with a rope because of Newton's First Law of Motion, the law of Inertia.

- When the bus moves, the luggage will be in inertia of motion and say the bus suddenly stops, then the luggage tends to resist this change in motion, causing it to move forward and fall off, if not tied up by a rope.
- Similarly, when the bus decelerates or changes its direction while turning, the inertia of motion of the luggage will try to resist this change in motion, causing the luggage to move oppositely and fall off, if not tied up by a rope.

4. A stone of 1kg is thrown with a velocity of 20ms^{-1} across the frozen surface of a lake and comes to rest after traveling a distance of 50m. What is the force of friction between the stone and the ice?

Ans: Given:

Mass of stone: $m = 1\text{kg}$

Initial velocity of stone: $u = 20\text{ms}^{-1}$

Final velocity of stone: $v = 0\text{ms}^{-1}$ (as it comes to rest)

Distance traveled on ice: $s = 50\text{m}$

To find: Force of friction between stone and ice.

First, we need to find the deceleration:

It is known that – $v^2 = u^2 + 2as$

Thus, $0^2 = (20)^2 + 2a(50)$

$\Rightarrow 0 = 400 + 100a$

$\Rightarrow -400 = 100a$

$\Rightarrow a = -4\text{ms}^{-2}$

The negative sign implies deceleration.

Next, finding the frictional force:

$F = ma$

$\Rightarrow F = (1)(-4)$

$\Rightarrow F = -4\text{N}$

Thus, the force of friction between stone and ice is -4N.

5. An automobile vehicle has a mass of 1500kg. What must be the force between the vehicle and road if the vehicle is to be stopped with a negative acceleration of 1.7ms^{-2}?

Ans: Given:

Mass of vehicle: $m = 1500\text{kg}$

Negative acceleration: $a = -1.7\text{ms}^{-2}$

To find: Force of friction between road and vehicle.

It is known that - $F = ma$

$\Rightarrow F = (1500)(-1.7)$

$\Rightarrow F = -2550N$

Thus the force between the vehicle and road if the vehicle is to be stopped with a negative acceleration of $1.7ms^{-2}$ is $-2550N$.

6. An object of mass 100kg is accelerated uniformly from a velocity of $5ms^{-1}$ to $8ms^{-1}$ in $6s$. Calculate the initial and final momentum of the object. Also, find the magnitude of the force exerted on the object.

Ans: Given:

Mass of object: $m = 100kg$

Initial velocity of object: $u = 5ms^{-1}$

Final velocity of object: $v = 8ms^{-1}$

Time duration of acceleration: $t = 6s$

To find:

- Initial momentum
- Final momentum
- Force exerted on the object

It is known that $-$ $momentum = mass \times velocity$

$Initial\ momentum = mass \times initial\ velocity$

$\Rightarrow Initial\ momentum = 100 \times 5$

$\Rightarrow Initial\ momentum = 500kgms^{-1}$

$Final\ momentum = mass \times final\ velocity$

$\Rightarrow Final\ momentum = 100 \times 8$

$\Rightarrow Final\ momentum = 800kgms^{-1}$

Now, the force $-$ $F = ma$

$$F = m(\frac{v-u}{t})$$

$$\Rightarrow F = 100(\frac{8-5}{6})$$

$$\Rightarrow F = 100(\frac{3}{6})$$

$\Rightarrow F = 50N$

Thus,

- Initial momentum: $500kgms^{-1}$
- Final momentum: $800kgms^{-1}$
- Force exerted on object: $50N$

7. Akhtar, Kiran, and Rahul were riding in a motorcar that was moving with a high velocity on an expressway when an insect hit the windshield and got stuck on the windscreen. Akhtar and Kiran started pondering over the situation. Kiran suggested that the insect suffered a greater change in momentum as compared to the change in momentum of the motorcar (because the change in the velocity of the insect was much more than that of the motorcar). Akhtar said that since the motorcar was moving with a larger velocity, it exerted a larger force on the insect. And as a result, the insect died. Rahul while putting an entirely new explanation said that both the motorcar and the insect experienced the same force and a change in their momentum. Comment on these suggestions.

Ans:

- Kiran's statement – the insect suffered a greater change in momentum as compared to the change in momentum of the motorcar (because the change in the velocity of the insect was much more than that of the motorcar).
  Based on the law of conservation of momentum, the change of momentum experienced by both the insect and car should be equal. The change in velocity of the insect will be greater, due to its small mass, while the change in velocity of the car is insignificant, due to its larger mass. But the change in momentum before and after collision would be the same. Thus, Kiran's statement is false.
- Akhtar's statement – since the motorcar was moving with a larger velocity, it exerted a larger force on the insect. And as a result, the insect died.
  According to Newton's third law of motion, for every action, there is an equal and opposite reaction. Thus both the car and insect would experience the same force. So, we can say that Akhtar's statement is also false.
- Rahul's statement – both the motorcar and the insect experienced the same force and a change in their momentum.
  Inferring from the law of conservation of momentum and Newton's third law of motion, we can say that Rahul's statement is true.

8. State Newton's second law of motion?

Ans: Newton's Second law of motion states that when an unbalanced external force acts on an object, its velocity changes, that is, the object gets accelerated. It can also be stated as the time rate of change of the momentum of a body is equal in both magnitude and direction to the force applied on it.

Mathematically – $F = ma$, where 'F' is the force, 'm' is the mass of the object, and 'a' is the acceleration.

9. What is the momentum of a body of mass $200g$ moving with a velocity of $15ms^{-1}$?

Ans: Given:
Mass of body: $m = 200g = 0.2kg$
Velocity of body: $v = 15ms^{-1}$
To find: Momentum of the body.
It is known that – $\text{momentum} = \text{mass} \times \text{velocity}$
$\Rightarrow \text{momentum} = 0.2 \times 15$
$\Rightarrow \text{momentum} = 3kgms^{-1}$
Thus, the momentum of the body is $3kgms^{-1}$.

10. Define force and what are the various types of forces?
Ans: Force is defined as the push or pull on an object that produces a change in the state or shape of the object. It can also cause a change in the speed and/or direction of motion of the object.
The various types of force are:
(a) Mechanical force
(b) Gravitational force
(c) Frictional force
(d) Electrostatic force
(e) Electromagnetic force
(f) Nuclear force

11. A force of $25N$ acts on a mass of $500g$ resting on a frictionless surface. What is the acceleration produced?
Ans: Given:
Mass: $m = 500g = 0.5kg$
Force exerted: $F = 25N$
To find: Acceleration.
It is known that – $F = ma$

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

$$\Rightarrow a = \frac{25}{0.5}$$

$$\Rightarrow a = 50ms^{-2}$$

Thus, the acceleration produced is $50ms^{-2}$.

12. State Newton’s first law of Motion?
Ans: Newton’s first law of motion is also called the law of Inertia. It states that an object remains in a state of rest or of uniform motion in a straight line unless

compelled to change that state by an applied force. Or, an object rest will continue to be at rest and an object in motion will continue to be in motion until and unless it is acted upon by an external force.

13. A body of mass 5kg starts and rolls down 32m of an inclined plane in 4s. Find the force acting on the body?

Ans: Given:

Mass of body: $\text{m} = 5\text{kg}$

Initial velocity of body: $\text{u} = 0\text{ms}^{-1}$ (as it is starting to roll)

Distance travelled on inclined plane: $\text{s} = 32\text{m}$

Time duration of rolling: $\text{t} = 4\text{s}$

To find: Force acting on the body.

First we need to find the acceleration:

It is known that – $\text{s} = \text{ut} + \frac{1}{2}\text{at}^2$

Thus, $32 = (0 \times 4) + \frac{1}{2}(\text{a} \times 4^2)$

$\Rightarrow 32 = \frac{1}{2}(\text{a} \times 16)$

$\Rightarrow 32 = (\text{a} \times 8)$

$\Rightarrow \text{a} = 4\text{ms}^{-2}$

Next, finding the force:

$\text{F} = \text{ma}$

$\Rightarrow \text{F} = (5 \times 4)$

$\Rightarrow \text{F} = 20\text{N}$

Thus, the force acting on the body is 20N.

14. On a certain planet, a small stone tossed up at 15ms^{-1} vertically upwards takes 7.5s to return to the ground. What is the acceleration due to gravity on the planet?

Ans: Given:

Initial velocity of stone: $\text{u} = 15\text{ms}^{-1}$

Final velocity of stone: $\text{v} = 0\text{ms}^{-1}$ (as it becomes zero at the highest point)

Total time duration of flight (tossed up and falling down to the ground): $\text{t} = 7.5\text{s}$

To find: Acceleration due to gravity of the planet.

It is known that – $\text{v} = \text{u} + \text{at}$

Thus, $0 = 15 + (\text{at})$

$t = \frac{-15}{a}$ this denotes the time for one-half of the entire flight.

Thus the total duration of flight is twice this duration.

i.e. $7.5s = 2t$

$\Rightarrow 7.5 = 2(\frac{-15}{a})$

Now, the acceleration due to gravity is –

$a = \frac{2 \times (-15)}{7.5}$

$\Rightarrow a = -4ms^{-2}$

Thus, the acceleration due to gravity of the planet is $-4ms^{-2}$.

15. Why is the weight of the object more at the poles than at the equator?

Ans:

- The weight of the object is more at the poles than at the equator because the acceleration due to gravity is slightly greater at the poles than at the equator. This is because - $g = \frac{GM}{r^2}$, meaning acceleration due to gravity is inversely proportional to the square of the radius. Since the radius of the earth at the equator is greater than at the poles, the acceleration due to gravity is slightly less at the equator, than at the poles.
- Also, we know that weight is directly proportional to acceleration due to gravity $(\because w = m \times g \Rightarrow w \alpha g)$.
- Using these two implications, we can say that at the equator, where the radius is larger, the acceleration due to gravity is smaller, the weight is lower. And at the poles, where the radius is smaller, the acceleration due to gravity is greater, the weight is higher.

16. Why does the passenger sitting in a moving bus are pushed in the forward direction when the bus stops suddenly?

Ans: The passengers sitting in the moving bus are pushed in the forward direction when the bus stops suddenly due to inertia because the passengers' upper body continues to be in a state of motion, while the lower part of the body that is in contact with the seat remains at rest. As a result, the passenger’s upper body is pushed in the forward direction, in the direction in which the bus was moving before coming to a halt.

17. Why does the boat move backward when the sailor jumps in the forward

direction?

Ans: The boat moves backward when the sailor jumps in the forward direction because of Newton's third law of motion which states that for every action, there is an equal and opposite reaction. Thus, when the sailor jumps in the forward direction he is causing an action force due to which the boat moves backward. In response, the boat exerts an equal and opposite force (the reaction force) on the sailor due to which he is pushed in the forward direction.

18. Derive the law of conservation of momentum from Newton's third law?

Ans: Newton's third law of motion states that for every action, there is an equal and opposite reaction, that acts on different bodies.

Say we have two objects A and B of masses m_A and m_B are traveling in the same direction along a straight line at different velocities u_A and u_B, respectively.

Consider that there are no other external unbalanced forces acting on them.

Let $u_A > u_B$ and the two objects collide with each other.

During collision which lasts for a time t, A exerts a force F_{AB} on B and B exerts a force F_{BA} on A.

Say, v_A and v_B are the velocities of the two A and B after the collision, respectively.

It is known that – $\text{momentum} = \text{mass} \times \text{velocity}$

Momentum of A before collision: $m_A \times u_A$

Momentum of A after collision: $m_A \times v_A$

Momentum of B before collision: $m_B \times u_B$

Momentum of B after collision: $m_B \times v_B$

It is also known that force can also be defined as the rate of change of momentum,

i.e. $F = ma = m(\frac{v-u}{t}) = \frac{mv - mu}{t}$

Now, the rate of change of momentum of A during collision is $\frac{m_A v_A - m_A u_A}{t}$, which is the force F_{AB}.

And the rate of change of momentum of B during collision is $\frac{m_B v_B - m_B u_B}{t}$, which is the force F_{BA}.

Based on Newton's third law of motion, the force F_{AB} exerted by Aon B and force F_{BA} exerted by B on A are equal in magnitude but opposite in direction.

i.e. $F_{AB} = -F_{BA}$

Using the formulae –

$F_{AB} = -F_{BA}$

$\Rightarrow \frac{m_A v_A - m_A u_A}{t} = -(\frac{m_B v_B - m_B u_B}{t})$

Simplifying,

$\Rightarrow m_A v_A - m_A u_A = -(m_B v_B - m_B u_B)$

$\Rightarrow m_A v_A - m_A u_A = -m_B v_B + m_B u_B$

Rearranging,

$m_A v_A + m_B v_B = m_A u_A + m_B u_B$

Here, $m_A u_A + m_B u_B$ is the total sum of momentum of A and B before collision and $m_A v_A + m_B v_B$ is the total sum of momentum of A and B after collision.

This equation implies that the final momentum of the two objects after collision is equal to the initial momentum of the two objects before collision.

Thus the law of conservation of momentum, for an isolated system, is that the total initial momentum for an event is equal to total initial momentum.

19. An astronaut has 80kg mass on earth.

i) What is his weight on earth?

Ans: Given that

Mass of astronaut:

$m = 80\text{kg}$

To find his weight on earth

It is known that,

Acceleration due to gravity on earth:

$g_e = 10\text{ms}^{-2}$

Acceleration due to gravity on mars:

$g_m = 3.7\text{ms}^{-2}$

Weight:

$w = m \times g$

Weight on earth:

$w_e = m \times g_e$

$\Rightarrow w_e = 80 \times 10$

$w_e = 800\text{N}$

ii) What will be his mass and weight on mars with $g_m = 3.7\text{ms}^{-2}$?

Ans: Given:

Mass of astronaut: $m = 80\text{kg}$

To find his mass and weight on mars.
It is known that,
Acceleration due to gravity on earth: $g_e = 10ms^{-2}$
Acceleration due to gravity on mars: $g_m = 3.7ms^{-2}$
Weight: $w = m \times g$
Weight on mars: $w_m = m \times g_m$
$\Rightarrow w_m = 80 \times 3.7$
$w_m = 296N$
The mass of astronaut remains the same on mars because it is a constant value.
Thus, mass on mars is $m = 80kg$.

Short Answer Questions **3 Marks**

1. Which of the following has more inertia:
(a) a rubber ball and a stone of the same size?
Ans: Inertia depends on the mass of the object. The larger the mass, the greater will be its inertia and vice-versa. In the case of a rubber ball and a stone of the same size, it is clear that the stone will have greater inertia than the ball. It is because, despite being the same size, the stone weighs more than the rubber ball.

(b) a bicycle and a train?
Ans: Inertia depends on the mass of the object. The larger the mass, the greater will be its inertia and vice-versa. In the case of a bicycle and a train, it is clear that the train will have greater inertia than the bicycle because the train weighs more than the bicycle.

(c) a five rupees coin and a one-rupee coin?
Ans: Inertia depends on the mass of the object. The larger the mass, the greater will be its inertia and vice-versa. In the case of a five rupees coin and a one-rupee coin, the five rupees coin will have greater inertia than the one-rupee coin because five rupees coin weighs more than a one-rupee coin.

2. In the following example, try to identify the number of times the velocity of the ball changes:
"A football player kicks a football to another player of his team who kicks the football towards the goal. The goalkeeper of the opposite team collects the football and kicks it towards a player of his own team".
Also, identify the agent supplying the force in each case.

Ans: In the example, the number of times the velocity of football changes is four.

(i) The velocity of the football changes first when a player kicks the ball towards another player on his team. Here, the agent supplying the force is the foot of the football player who is kicking the ball.

(ii) The velocity of the football changes second when that another player kicks the ball towards the goal. Here, the agent supplying the force is the foot of the other player who is now kicking the ball towards the goal.

(iii) The velocity of the football changes for the third time when the goalkeeper of the opposite team stops the football by collecting it. Here, the agent supplying the force are the hands of the goalkeeper who collects the ball.

(iv) The velocity of the football changes for the fourth time when the goalkeeper kicks it towards a player of his team. Here, the agent supplying the force is the foot of the goalkeeper who is now kicking the ball towards his teammate.

3. Explain why some of the leaves may get detached from a tree if we vigorously shake its branch.

Ans: Some of the leaves may get detached from a tree if we vigorously shake its branch because the branches of the tree will come into motion while the leaves tend to continue in their state of rest. This is due to the inertia of rest of the leaves. The force of shaking will act on the leaves with the change in direction rapidly, which results in the leaves detaching and falling off from the tree.

4. Why do you fall in the forward direction when a moving bus brakes to a stop and fall backwards when it accelerates from rest?

Ans: The passengers sitting in the moving bus are pushed in the forward direction when the bus stops suddenly due to inertia because the passengers' upper body continues to be in a state of motion, while the lower part of the body that is in contact with the seat remains at rest. As a result, the passenger’s upper body is pushed in the forward direction, in the direction in which the bus was moving before coming to a halt.

Similarly, the passengers sitting in the bus are pushed in the backward direction when the bus accelerates from rest due to inertia, because the passengers’ upper body continues to be in a state of rest, while the lower part of the body that is in contact with the seat is set in motion. As a result, the passenger’s upper body is pushed in the backward direction, in the opposite to which the bus starts to move.

5. If action is always equal to the reaction, explain how a horse can pull a cart.

Ans:

- In this case, we are dealing with unbalanced forces. It is true that the horse exerts an action force on the cart and experiences a reaction force from the cart. But also, the horse creates an action force on the ground over which it is walking, and experiences a reaction force from the ground.
- In pulling the cart, the action force of the horse pulling the cart is greater than the reaction force of the cart, resisting the pull. Thus the cart moves in the direction of pull of the horse.
- In stepping on the ground, the horse creates an action force on the ground in the backward direction during each step, while the ground creates a reaction force pushing the horse forward.
- In this was a horse can pull a cart.

6. Explain why is it difficult for a fireman to hold a hose, which ejects large amounts of water at a high velocity.

Ans: It is difficult for a fireman to hold a hose, which ejects large amounts of water at a high velocity because of Newton's third law of motion. In this case, the water being ejected out in the forward direction with great force (action) will create a backward force that results in the backward movement (reaction) of the hose pipe. As a result of this backward force and movement, it will be difficult for the fireman to hold the hose properly with stability.

7. From a rifle of mass 4kg, a bullet of mass 50g is fired with an initial velocity of 35ms^{-1}. Calculate the initial recoil velocity of the rifle.

Ans: Given:

Mass of rifle: $m_1 = 4\text{kg}$

Mass of bullet: $m_2 = 50\text{g} = 0.05\text{kg}$

Initial velocity of rifle: $u_1 = 0\text{ms}^{-1}$ (it is stationary during firing)

Initial velocity of bullet: $u_2 = 0\text{ms}^{-1}$ (it starts from rest, inside the barrel of the rifle)

Fired velocity of bullet: $v_2 = 35\text{ms}^{-1}$

To find: Recoil velocity of rifle: v_1

By using the law of conservation of momentum, for an isolated system, is that the total initial momentum for an event is equal to total initial momentum, we get –

$m_1v_1 + m_2v_2 = m_1u_1 + m_2u_2$

Here, $m_1u_1 + m_2u_2$ is the total sum of momentum of rifle and bullet before firing and $m_1v_1 + m_2v_2$ is the total sum of momentum of rifle and bullet after firing.

Substituting the values in – $m_1v_1 + m_2v_2 = m_1u_1 + m_2u_2$

$\Rightarrow (4 \times v_1) + (0.05 \times 35) = (4 \times 0) + (0.05 \times 0)$

$\Rightarrow (4 \times v_1) + (17.5) = 0$

$\Rightarrow (4 \times v_1) = -17.5$

$\Rightarrow v_1 = -4.375 ms^{-1}$ (The negative sign indicates the backward direction in which the rifle moves when it recoils)

Thus, the recoil velocity of the rifle is $4.375 ms^{-1}$.

8. A $8000 kg$ engine pulls a train of 5 wagons, each of $2000 kg$, along a horizontal track. If the engine exerts a force of $40000 N$ and the track offers a friction force of $5000 N$, then calculate:

(a) the net accelerating force

Ans: Given:

Force exerted by engine on wagons:

$F = 40000 N$

Frictional exerted on wagons:

$f = 5000 N$

Mass of engine:

$m_e = 8000 kg$

Mass of each wagon:

$m_w = 2000 kg$

Mass of all five wagons:

$m_W = 5 \times m_w = 5 \times 2000 = 10000 kg$

Mass of entire train:

$m_T = m_e + m_W = 8000 + 10000 = 18000 kg$

To find accelerating force.

Net accelerating force can be found by subtracting the frictional force from the force exerted by the engine on the wagons.

Thus,

$NetAcceleratingForce = ForceOfEngine - FrictionalForce$

$\Rightarrow NetAcceleratingForce = F - f$

$\Rightarrow NetAcceleratingForce = 40000 - 5000$

$\Rightarrow NetAcceleratingForce = 35000 N$

(b) the acceleration of the train

Ans: Given:

Force exerted by engine on wagons:

$F = 40000 N$

Frictional exerted on wagons:

$f = 5000 N$

Mass of engine:

$m_e = 8000kg$

Mass of each wagon:

$m_w = 2000kg$

Mass of all five wagons:

$m_W = 5 \times m_w = 5 \times 2000 = 10000kg$

Mass of entire train:

$m_T = m_e + m_W = 8000 + 10000 = 18000kg$

To find acceleration of the train.

It is known that –

$F = ma$

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

$\Rightarrow a = \frac{NetAcceleratingForce}{MassOfTrain}$

$\Rightarrow a = \frac{35000}{18000}$

$\Rightarrow a = 1.944ms^{-2}$

(c) the force of wagon 1 on wagon 2.

Ans: Given:

Force exerted by engine on wagons: $F = 40000N$

Frictional exerted on wagons: $f = 5000N$

Mass of engine: $m_e = 8000kg$

Mass of each wagon: $m_w = 2000kg$

Mass of all five wagons: $m_W = 5 \times m_w = 5 \times 2000 = 10000kg$

Mass of entire train: $m_T = m_e + m_W = 8000 + 10000 = 18000kg$

To find the force exerted by wagon 1 on wagon 2

Here, wagon 1 exerts a pulling force on the remaining 4 wagons

$F = ma$

$\Rightarrow F_{21} = (4m_w) \times a$

$\Rightarrow F_{21} = (4 \times 2000) \times 1.944$

$\Rightarrow F_{21} = 15552N$

9. Two objects, each of mass $1.5kg$, are moving in the same straight line but in opposite directions. The velocity of each object is $2.5ms^{-1}$ before the

collision during which they stick together. What will be the velocity of the combined object after collision?

Ans: Given:

Mass of object 1: $m_1 = 1.5\text{kg}$

Mass of object 2: $m_2 = 1.5\text{kg}$

Initial velocity of object 1: $u_1 = 2.5\text{ms}^{-1}$

Initial velocity of object 2: $u_2 = -2.5\text{ms}^{-1}$ (negative sign because it is moving in the opposite direction)

Mass of combined object after collision: $m = m_1 + m_2 = 1.5 + 1.5 = 3\text{kg}$

To find: Final velocity of the combined object after collision: v

By using the law of conservation of momentum, for an isolated system, is that the total initial momentum for an event is equal to total initial momentum, we get –

$mv = m_1u_1 + m_2u_2$

Here, $m_1u_1 + m_2u_2$ is the total sum of momentum of objects before collision and mv is the total momentum of the combined objects after collision.

Substituting the values in – $mv = m_1u_1 + m_2u_2$

$\Rightarrow (3 \times v) = (1.5 \times 2.5) + (1.5 \times -2.5)$

$\Rightarrow (3 \times v) = (3.75) + (-3.75s)$

$\Rightarrow (3 \times v) = 0$

$\Rightarrow v = 0\text{ms}^{-1}$

Thus, the velocity of the combined object after collision is 0ms^{-1}.

10. According to the third law of motion when we push on an object, the object pushes back on us with an equal and opposite force. If the object is a massive truck parked along the roadside, it will probably not move. A student justifies this by answering that the two opposite and equal forces cancel each other. Comment on this logic and explain why the truck does not move.

Ans:

- According to the third law of motion when we push on an object, the object pushes back on us with an equal and opposite force. This pair of forces is called the action-reaction pair.
- In the case of the massive truck parked alongside the road, the action-reaction pair is the weight of the truck exerting a force on the road in the downward direction (action), and the static friction of the road in the upward direction (reaction), which keeps the truck at rest. These two equal and opposite forces cancel out each other, which is why the truck will not move.

- For it to move, we need to apply additional external force to overcome the static friction of the road.
- Thus, as the student explained, the truck does not move because the two opposite and equal forces of the truck and road cancel out each other is valid.

11. A hockey ball of mass $200g$ travelling at $10ms^{-1}$ is struck by a hockey stick so as to return it along its original path with a velocity at $5ms^{-1}$. Calculate the change of momentum occurred in the motion of the hockey ball by the force applied by the hockey stick.

Ans: Given:

Mass of hockey ball: $m = 200g = 0.2kg$

Initial velocity of hockey ball: $u = 10ms^{-1}$

Final velocity of hockey ball: $v = -5ms^{-1}$ (because it moves back in its original direction)

To find: Change in momentum of hockey ball due to the force of hockey stick

$\text{Change Of Momentum} = mv - mu$

Here, mu is the initial momentum of the hockey ball and mv is the final momentum of the hockey ball.

Substituting the values in $-\text{Change Of Momentum} = mv - mu$

$\Rightarrow \text{Change Of Momentum} = (0.2 \times -5) - (0.2 \times 10)$

$\Rightarrow \text{Change Of Momentum} = (-1) - (2)$

$\Rightarrow \text{Change Of Momentum} = -3kgms^{-1}$

Thus, the change in momentum of hockey ball due to the force of hockey stick is $-3kgms^{-1}$.

12. A bullet of mass $10g$ traveling horizontally with a velocity of $150ms^{-1}$ strikes a stationary wooden block and comes to rest in $0.03s$. Calculate the distance of penetration of the bullet into the block. Also, calculate the magnitude of the force exerted by the wooden block on the bullet.

Ans: Given:

Mass of bullet: $m = 10g = 0.01kg$

Initial velocity of bullet: $u = 150ms^{-1}$

Final velocity of bullet: $v = 0ms^{-1}$ (as it comes to rest after penetration)

Time duration of bullet travel: $t = 0.03s$

To find:

- Distance of penetration of bullet into the block
- Force exerted by the block on the bullet

(a) Distance of penetration:

It is known that – $v = u + at$

Thus, $0 = 150 + (a \times 0.03)$

$\Rightarrow (a \times 0.03) = -150$

$\Rightarrow a = -5000ms^{-2}$

Now,

$s = ut + \frac{1}{2}at^2$

$\Rightarrow s = (150 \times 0.03) + \frac{1}{2}(-5000 \times 0.03^2)$

$\Rightarrow s = (4.5) + (-2.25)$

$\Rightarrow s = 2.25m$

(b) Next, finding the force:

$F = ma$

$\Rightarrow F = (0.01 \times -5000)$

$\Rightarrow F = -50N$

Thus,

- Distance of penetration of bullet into the block is $2.25m$
- Force exerted by the block on the bullet is $-50N$

13. An object of mass $1kg$ travelling in a straight line with a velocity of $10ms^{-1}$ collides with, and sticks to, a stationary wooden block of mass $5kg$. Then they both move off together in the same straight line. Calculate the total momentum just before the impact and just after the impact. Also, calculate the velocity of the combined object.

Ans: Given:

Mass of object 1: $m_1 = 1kg$

Mass of object 2: $m_2 = 5kg$

Initial velocity of object 1: $u_1 = 10ms^{-1}$

Initial velocity of object 2: $u_2 = 0ms^{-1}$ (because it is stationary)

Mass of combined object after collision: $m = m_1 + m_2 = 1 + 5 = 6kg$

To find:

- Momentum before impact
- Momentum after impact
- Final velocity of the combined object after collision: v

(a) Momentum before impact is the Initial momentum:

$\text{Initial Momentum} = m_1u_1 + m_2u_2$
$\Rightarrow \text{Initial Momentum} = (1\times10) + (5\times0)$
$\Rightarrow \text{Initial Momentum} = 10\,kgms^{-1}$

(b) Momentum after impact is the Final momentum:
$\text{Final Momentum} = mv$
By using the law of conservation of momentum, for an isolated system, is that the total initial momentum for an event is equal to total initial momentum, we get –
$mv = m_1u_1 + m_2u_2$
Here, $m_1u_1 + m_2u_2$ is the total sum of momentum of objects before collision and mv is the total momentum of the combined objects after collision.
Thus we get – $\text{Final Momentum} = mv = m_1u_1 + m_2u_2 = 10\,kgms^{-1}$
$\Rightarrow \text{Final Momentum} = 10\,kgms^{-1}$

(c) Finding the final velocity of the combined object:
$\text{Final Momentum} = 10\,kgms^{-1}$
$\Rightarrow mv = 10$
$\Rightarrow (6\times v) = 10$
$\Rightarrow v = 1.67\,ms^{-1}$
Thus,
- Momentum before impact is $10\,kgms^{-1}$
- Momentum after impact is $10\,kgms^{-1}$
- Final velocity of the combined object after collision is $1.67\,ms^{-1}$

14. How much momentum will a dumb-bell of mass $10\,kg$ transfer to the floor if it falls from a height of $80\,cm$? Take its downward acceleration to be $10\,ms^{-1}$.
Ans: Given:
Mass of dumbbell: $m = 10\,kg$
Initial velocity of dumbbell: $u = 0\,ms^{-1}$ (as it starts from rest)
Height of fall of dumbbell: $h = 80\,cm = 0.8\,m$
Acceleration due to gravity: $g = 10\,ms^{-2}$
To find: Momentum transferred to the ground by dumbbell.
It is known that – $v^2 = u^2 + 2gh$
$\Rightarrow v^2 = (0)^2 + (2\times10\times0.8)$
$\Rightarrow v^2 = 16$

$\Rightarrow v = 4ms^{-1}$

Now, $\text{Momentum} = mv$

$\Rightarrow \text{Momentum} = (10 \times 4)$

$\Rightarrow \text{Momentum} = 40kgms^{-1}$

Thus, the momentum transferred to the ground by dumbbell is $40kgms^{-1}$.

15. A force of $15N$ acts for $5s$ on a body of mass $5kg$ which is initially at rest. Calculate.

(a) final velocity of the body

Ans: Given:

Mass of body:

$m = 5kg$

Initial velocity of body:

$u = 0ms^{-1}$

(as it starts from rest)

Force acting on the body:

$F = 15N$

Time:

$t = 5s$

To find the final velocity of the body.

First we need to find the acceleration produced.

$F = ma$

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

$\Rightarrow a = \frac{15}{5}$

$\Rightarrow a = 3ms^{-2}$

It is known that –

$v = u + at$

Thus,

$v = 0 + (3 \times 5)$

$\Rightarrow v = 15ms^{-1}$

(b) the displacement of the body

Ans: Given:

Mass of body: $m = 5kg$

Initial velocity of body: $u = 0ms^{-1}$ (as it starts from rest)

Force acting on the body: $F = 15N$

Time: $t = 5s$
To find displacement of the body.
Next, the distance of penetration:

$$s = ut + \frac{1}{2}at^2$$

$$\Rightarrow s = (0 \times 5) + \frac{1}{2}(3 \times 5^2)$$

$$\Rightarrow s = (0) + (37.5)$$

$$\Rightarrow s = 37.5m$$

16. Differentiate between mass and weight?
Ans: The difference between mass and weight is given below,

Mass	Weight
It is the measure of the inertia of a body.	It is the measurement of the gravitational force acting on an object.
It is a scalar quantity.	It is a vector quantity.
It can never be zero.	It can be zero, depending on the gravity acting on it.
Its unit is Kilograms.	Its unit is Newton.
It is a constant quantity.	It can vary depending on the gravity of the place.
It can be measured using a weighing scale.	It can be measured using a spring balance.

17. A scooter is moving with a velocity of $20ms^{-1}$ when brakes are applied. The mass of the scooter and the rider is $180kg$. The constant force applied by the brakes is $500N$.
(a) How long should the brakes be applied to make the scooter comes to a halt?
Ans: Given:
Mass of scooter and rider:
$m = 180kg$
Initial velocity of scooter:
$u = 20ms^{-1}$
Final velocity of scooter:
$v = 0ms^{-1}$
(as it halts after applying the brake)

Force of the brake:
$F = -500N$
(as it opposes the motion)
To find the time duration over which brake should be applied to stop the scooter.
Now, the force –
$F = ma$
$F = m(\frac{v-u}{t})$
$\Rightarrow -500 = 180(\frac{0-20}{t})$
Rearranging,
$\Rightarrow t = (\frac{180\times(-20)}{-500})$
$\Rightarrow t = (\frac{-3600}{-500})$
$\Rightarrow t = 7.2s$

(b) How far does the scooter travel before it comes to rest?
Ans: Given:
Mass of scooter and rider: $m = 180kg$
Initial velocity of scooter: $u = 20ms^{-1}$
Final velocity of scooter: $v = 0ms^{-1}$ (as it halts after applying the brake)
Force of the brake: $F = -500N$ (as it opposes the motion)
To find distance travelled by scooter before coming to halt.
Acceleration – $a = (\frac{v-u}{t})$
$\Rightarrow a = (\frac{0-20}{7.2})$
$\Rightarrow a = -2.78ms^{-2}$
Acceleration is negative because it is retarding the motion of the scooter.
$s = ut + \frac{1}{2}at^2$
$\Rightarrow s = (20\times7.2) + \frac{1}{2}(-2.78\times7.2^2)$
$\Rightarrow s = (144) + (-72.1)$
$\Rightarrow s = 71.9m$

18. State Newton's third law of motion and how does it explain the walking of man on the ground?

Ans: Newton's third law of motion states that for every action, there is an equal and opposite reaction acting on different bodies. This implies the existence of the action-reaction force pair. That is, for every action force created an equal and opposite reaction force will be created.

The walking of a man on the ground can be explained with Newton's third law of motion. During walking on the ground, the man creates an action force on the ground in the backward direction during each step, while the ground creates a reaction force pushing the man forward enabling him to walk.

19. With what speed must a ball be thrown vertically up in order to rise to a maximum height of 45m? And for how long will it be in air?

Ans: Given:

Final velocity of stone: $v = 0\text{ms}^{-1}$ (as it attains zero velocity at maximum height)

Height to which stone is to be thrown: $h = 45\text{m}$

Acceleration due to gravity: $g = -10\text{ms}^{-2}$ (it is negative because the stone is thrown against gravity upwards)

To find:

- Initial velocity with which the stone is to be thrown: u
- Time duration over which the stone stays in the air

(a) Initial velocity:

It is known that – $v^2 = u^2 + 2gh$

$\Rightarrow 0^2 = u^2 + (2 \times -10 \times 45)$

$\Rightarrow 0 = u^2 + (-900)$

$\Rightarrow u^2 = 900$

$\Rightarrow u = 30\text{ms}^{-1}$

(b) Time:

It is known that – $v = u + gt$

Thus, $0 = 30 + (-10 \times t)$

$-10t = -30$

$\Rightarrow t = 3\text{s}$

It takes 3s to go up and another 3s to come down. So we can say that the total time the stone is air bound is $3\text{s} + 3\text{s} = 6\text{s}$

Thus,

- Initial velocity with which the stone is to be thrown is 30ms^{-1}
- Time duration over which the stone stays in the air is 6s

20. State Newton's second law of motion and derive it mathematically?

Ans: Newton's second law of motion states that the rate of change of momentum of an object is proportional to the applied unbalanced force in the direction of the force.

Mathematical derivation:

Say we have an object of mass m that is moving along a straight line with an initial velocity, u.

It is then uniformly accelerated to velocity, v in time, t by the application of a constant force, F throughout the time, t.

Initial Momentum of object: $p_1 = m \times u$

Final Momentum of object: $p_2 = m \times v$

Now, the change of momentum is the Final momentum subtracted by the Initial momentum

Thus, $\Delta p = p_2 - p_1 = mv - mu = m(v - u)$

$\Rightarrow \Delta p = m(v - u)$

The rate of change of momentum is $\frac{\Delta p}{t}$

i.e. $\frac{\Delta p}{t} = \frac{m(v-u)}{t}$

We know that the applied force is proportional to the rate of change of momentum of the object.

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

$\Rightarrow F = \frac{m(v-u)}{t}$

But, acceleration $a = \frac{v-u}{t}$

Using these, we get

$\Rightarrow F = ma$

The SI unit of force is Newton ($Kgms^{-2}$)

The second law of motion gives a method to measure the force acting on an object as a product of its mass and acceleration.

21. A bullet travelling at $360 ms^{-1}$ strikes a block of soft wood. The mass of the bullet is $2.0 g$. The bullet comes to rest after penetrating $10 cm$ into the wood?

(a) Find the average deceleration force exerted by the wood.

Ans: Given:

Mass of bullet:

$m = 2.0g = 0.002kg$

Initial velocity of bullet:

$u = 360ms^{-1}$

Final velocity of bullet:

$v = 0ms^{-1}$

(as it comes to rest after penetration)

Distance travelled by the bullet into the block:

$s = 10cm = 0.1m$

To find the average deceleration force exerted by the wood block.

It is known that –

$v^2 = u^2 + 2as$

$\Rightarrow 0^2 = 360^2 + (2 \times a \times 0.1)$

$\Rightarrow 0 = 129600 + (0.2a)$

$\Rightarrow 0.2a = -129600$

$\Rightarrow a = -648000ms^{-2}$

The acceleration is negative because it opposes the motion of bullet.

Next, force

$F = ma$

$\Rightarrow F = (0.002 \times -648000)$

$\Rightarrow F = -1296N$

(b) Find the time taken by the bullet to come to rest.

Ans: Given:

Mass of bullet: $m = 2.0g = 0.002kg$

Initial velocity of bullet: $u = 360ms^{-1}$

Final velocity of bullet: $v = 0ms^{-1}$ (as it comes to rest after penetration)

Distance travelled by the bullet into the block: $s = 10cm = 0.1m$

To find time taken by the bullet to come to rest.

It is known that – $v = u + at$

Thus, $0 = 360 + (-648000 \times t)$

$\Rightarrow -648000t = -360$

$\Rightarrow t = 5.56 \times 10^{-4}s$

22. Two objects A and B are dropped from a height. The object B being dropped $1s$ after A was dropped. How long after A was dropped will A and B be $10m$ apart?

Ans: Given: Object B is dropped one second after object A.

To find: Time at which A and B will be $10m$ apart

We can say that the initial velocity of both A and B as $u_A = u_B = 0ms^{-1}$, since they are dropped from rest.

It is known that – $s = ut + \frac{1}{2}at^2$

For object A – $s_A = u_A t + \frac{1}{2}g{t_A}^2$

For object B – $s_B = u_B t + \frac{1}{2}g{t_B}^2$

We take acceleration to be acceleration due to gravity, because it is being dropped from a height downwards to the earth.

Acceleration due to gravity: $g = 10ms^{-2}$

Since we need to find the time at which A and B will be $10m$ apart

Let's say - $s_A - s_B = 10m$

Also, since object B is dropped one second after object A, we can say that $t_B = t_A - 1$

Substituting in – $s_A - s_B = 10m$

$\Rightarrow s_A - s_B = u_A t + \frac{1}{2}g{t_A}^2 - u_B t + \frac{1}{2}g{t_B}^2$

$\Rightarrow 10 = u_A t + \frac{1}{2}g{t_A}^2 - \left[u_B t + \frac{1}{2}g(t_A - 1)^2\right]$

$\Rightarrow 10 = (0 \times t) + \frac{1}{2}(10 \times {t_A}^2) - \left[(0 \times t) + \frac{1}{2}(10 \times (t_A - 1)^2)\right]$

$\Rightarrow 10 = (5 \times {t_A}^2) - \left[5 \times ({t_A}^2 - 2t_A + 1)\right]$

$\Rightarrow 10 = 5{t_A}^2 - 5{t_A}^2 + 10t_A - 5$

$\Rightarrow 10 = 10t_A - 5$

$\Rightarrow 10t_A = 15$

$\Rightarrow t_A = 1.5s$

Thus, the time at which A and B will be $10m$ apart is $1.5s$

23. A boy throws a stone up with a velocity of $60ms^{-1}$.

(a) How long will it take to reach the maximum height? ($g = -10ms^{-2}$)

Ans: Given:

Initial velocity of stone:

$u = 60ms^{-1}$

Final velocity of stone:

$v = 0ms^{-1}$

(as it attains zero velocity at maximum height)
Acceleration due to gravity:
$g = -10ms^{-2}$
(it is negative because the stone is thrown against gravity upwards)
To find time to reach maximum height.
It is known that –
$v = u + at$
$\Rightarrow v = u + gt$
$\Rightarrow 0 = 60 + (-10t)$
$\Rightarrow -10t = -60$
$\Rightarrow t = 6s$

(b) What will be the maximum height reached by the stone?
Ans: Given:
Initial velocity of stone:
$u = 60ms^{-1}$
Final velocity of stone:
$v = 0ms^{-1}$
(as it attains zero velocity at maximum height)
Acceleration due to gravity:
$g = -10ms^{-2}$
(it is negative because the stone is thrown against gravity upwards)
To find maximum height.
It is known that –
$s = ut + \frac{1}{2}at^2$
$\Rightarrow h = ut + \frac{1}{2}gt^2$
$\Rightarrow h = (60 \times 6) + \frac{1}{2}(-10 \times 6^2)$
$\Rightarrow h = (360) + (-180)$
$\Rightarrow h = 180m$

(c) What will be its velocity when it reaches the ground?
Ans: Given:
Initial velocity of stone: $u = 60ms^{-1}$
Final velocity of stone: $v = 0ms^{-1}$ (as it attains zero velocity at maximum height)
Acceleration due to gravity: $g = -10ms^{-2}$ (it is negative because the stone is thrown against gravity upwards)

To find velocity when it reaches the ground.
For this, we consider the initial velocity (from its maximum attained height) is zero. And the acceleration due to gravity becomes positive, because it is falling down.
i.e. Initial velocity of stone: $u = 0ms^{-1}$
Acceleration due to gravity: $g = 10ms^{-2}$
Now, $v^2 = u^2 + 2as$
$\Rightarrow v^2 = u^2 + 2gs$
$\Rightarrow v^2 = 0^2 + (2 \times 10 \times 180)$
$\Rightarrow v^2 = 3600$
$\Rightarrow v = \sqrt{3600}$
$\Rightarrow v = 60ms^{-1}$

24. A certain particle has a weight of $30N$ at a place where the acceleration due to gravity is $9.8ms^{-2}$.
(a) What are its mass and weight at a place where acceleration due to gravity is $3.5ms^{-2}$?
Ans: Given:
Weight of particle:
$w = 30N$
Acceleration due to gravity on that planet:
$g_1 = 9.8ms^{-2}$
Mass of particle:
m
To find mass and weight of particle on planet with
$g_2 = 3.5ms^{-2}$.
Weight:
$w = m \times g$
Mass of particle:
$$m = \frac{w}{g}$$
$$\Rightarrow m = \frac{30}{9.8}$$
$\Rightarrow m = 3.06kg$
Mass and Weight on planet with
$g_2 = 3.5ms^{-2}$
Mass is a constant quantity irrespective of place.

So,
$\Rightarrow m = 3.06kg$
Weight:
$w = m \times g_2$
$\Rightarrow w = 3.06 \times 3.5$
$w = 10.71N$

(b) What will be its mass and weight at a place where acceleration due to gravity is zero?
Ans: Given:
Weight of particle: $w = 30N$
Acceleration due to gravity on that planet: $g_1 = 9.8ms^{-2}$
Mass of particle: m
To find mass and weight of particle on planet with $g_3 = 0ms^{-2}$ s.
Weight: $w = m \times g$
Mass of particle: $m = \frac{w}{g}$
$\Rightarrow m = \frac{30}{9.8}$
$\Rightarrow m = 3.06kg$
Mass and Weight on planet with $g_3 = 0ms^{-2}$
Mass is a constant quantity irrespective of place.
So, $\Rightarrow m = 3.06kg$
Weight: $w = m \times g_3$
$\Rightarrow w = 3.06 \times 0$
$w = 0N$

25. Why does a person while firing a bullet holds the gun tightly to his shoulders?
Ans: A person while firing a bullet holds the gun tightly to his shoulder because of the recoil of the gun when the bullet is fired. This is in accordance with Newton's third law of motion, which states that for every action, there is an equal and opposite reaction, that acts on different bodies.
When a bullet is fired, the forward motion of the bullet (action) creates a recoil or backward motion of the gun (reaction). The action force being much greater will create an equivalent recoil force in the backward direction.

If the person who holds the gun does not hold it properly to his shoulders that can result in injury. This is because the shoulder absorbs most of the force during recoil that enables the shooter to take a steady shot.
Thus, if not held tightly to his shoulders, the shot will not be precise and this can also cause the gun to fly away from his hands.

26. A car is moving with a velocity of $16ms^{-1}$ when brakes are applied. The force applied by the brakes is $1000N$. The mass of the car its passengers is $1200kg$.

(a) How long should the brakes be applied to make the car come to a halt?

Ans: Given:
Mass of car and passengers:
$m = 1200kg$
Initial velocity of car:
$u = 16ms^{-1}$
Final velocity of car:
$v = 0ms^{-1}$
(as it halts after applying the brake)
Force of the brake:
$F = -1000N$
(as it opposes the motion)
To find time duration over which brake should be applied to stop the car.
Now, the force –
$F = ma$
$$F = m(\frac{v-u}{t})$$
$$\Rightarrow -1000 = 1200(\frac{0-16}{t})$$
Rearranging,
$$\Rightarrow t = (\frac{1200 \times (-16)}{-1000})$$
$$\Rightarrow t = (\frac{-19200}{-1000})$$
$$\Rightarrow t = 19.2s$$

(b) How for does the car travel before it comes to rest?

Ans: Given:
Mass of car and passengers: $m = 1200kg$

Initial velocity of car: $u = 16ms^{-1}$
Final velocity of car: $v = 0ms^{-1}$ (as it halts after applying the brake)
Force of the brake: $F = -1000N$ (as it opposes the motion)
To find distance travelled by car before coming to halt.

Acceleration – $a = (\frac{v-u}{t})$

$\Rightarrow a = (\frac{0-16}{19.2})$

$\Rightarrow a = -0.83ms^{-2}$

Acceleration is negative because it is retarding the motion of the scooter.

$s = ut + \frac{1}{2}at^2$

$\Rightarrow s = (16 \times 19.2) + \frac{1}{2}(-0.83 \times 19.2^2)$

$\Rightarrow s = (307.2) + (-152.98)$

$\Rightarrow s = 154.2m$

Long Answer Questions **5 Marks**

1. Two objects of masses $100g$ and $200g$ are moving along the same line and direction with velocities of $2ms^{-1}$ and $1ms^{-1}$ respectively. They collide and after the collision, the first object moves at a velocity of $1.67ms^{-1}$. Determine the velocity of the second object.

Ans: Given:

Mass of object 1: $m_1 = 100g = 0.1kg$

Mass of object 2: $m_2 = 200g = 0.2kg$

Initial velocity of object 1: $u_1 = 2ms^{-1}$

Initial velocity of object 2: $u_2 = 1ms^{-1}$

Final velocity of object 1: $v_1 = 1.67ms^{-1}$

To find: Final velocity of object 2: v_2

By using the law of conservation of momentum, for an isolated system, is that the total initial momentum for an event is equal to total initial momentum, we get –

$m_1v_1 + m_2v_2 = m_1u_1 + m_2u_2$

Here, $m_1u_1 + m_2u_2$ is the total sum of momentum of objects before collision and $m_1v_1 + m_2v_2$ is the total sum of momentum of objects after collision.

Substituting the values in – $m_1v_1 + m_2v_2 = m_1u_1 + m_2u_2$

$\Rightarrow (0.1\times1.67)+(0.2\times v_2)=(0.1\times2)+(0.2\times1)$

$\Rightarrow (0.167)+(0.2\times v_2)=(0.2)+(0.2)$

$\Rightarrow (0.167)+(0.2\times v_2)=0.4$

$\Rightarrow 0.2\times v_2=0.4-0.167$

$\Rightarrow 0.2\times v_2=0.233$

$\Rightarrow v_2=1.165ms^{-1}$

Thus, the velocity of the second object is $1.165ms^{-1}$.

2. A truck starts from rest and rolls down a hill with a constant acceleration. It travels a distance of $400m$ in $20s$. Find its acceleration. Find the force acting on it, if its mass is $7 metric Tonnes$.(Hint: $1 metric Tonne = 1000kg$)

Ans: Given:

Mass of truck: $m = 7 metric Tonne = 7000kg$

Initial velocity of truck: $u = 0ms^{-1}$ (as it is stars from rest)

Distance travelled: $s = 400m$

Time duration of travel: $t = 20s$

To find:

- Acceleration of the truck
- Force acting on the truck

(a) First we need to find the acceleration:

It is known that – $s = ut + \frac{1}{2}at^2$

Thus, $400 = (0\times20)+\frac{1}{2}(a\times20^2)$

$\Rightarrow 400 = \frac{1}{2}(a\times400)$

$\Rightarrow 800 = (a\times400)$

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

(b) Next, finding the force:

$F = ma$

$\Rightarrow F = (7000\times2)$

$\Rightarrow F = 14000N$

Thus, the acceleration of truck is $2ms^{-2}$ and the force acting on the truck is $14000N$.

3. A stone is dropped from a 100m high tower. How long does it take to fall?
(a) the first 50m
Ans: Given:
Initial velocity of stone:
$u = 0\text{ms}^{-1}$
(as it is stars from rest, before being dropped)
Height of the tower:
$s = 100\text{m}$
Distance travelled in case A:
$s_1 = 50\text{m}$
(first half distance)
Distance travelled in case B:
$s_2 = 50\text{m}$
(next half distance)
To find: Time duration of travel:
t during the first 50m.
It is known that –
$$s = ut + \frac{1}{2}at^2$$
Since the stone is dropped from a height, we can consider its acceleration to be equal to the acceleration due to gravity.
Acceleration of stone: Acceleration due to gravity
$$\Rightarrow a = g = 10\text{ms}^{-2}$$
$$s_1 = ut + \frac{1}{2}at^2$$
$$\Rightarrow 50 = (0 \times t) + \frac{1}{2}(10 \times t^2)$$
$$\Rightarrow 50 = 5 \times t^2$$
$$\Rightarrow t^2 = 10$$
$$\Rightarrow t = \sqrt{10} = 3.16\text{s}$$
$$\Rightarrow t_1 = 3.16\text{s}$$

(b) the second 50m
Ans: Given:
Initial velocity of stone: $u = 0\text{ms}^{-1}$ (as it is stars from rest, before being dropped)
Height of the tower: $s = 100\text{m}$
Distance travelled in case A: $s_1 = 50\text{m}$ (first half distance)
Distance travelled in case B: $s_2 = 50\text{m}$ (next half distance)

To find: Time duration of travel: t during the second $50m$.

It is known that – $s = ut + \frac{1}{2}at^2$

Since the stone is dropped from a height, we can consider its acceleration to be equal to the acceleration due to gravity.

Acceleration of stone: Acceleration due to gravity $\Rightarrow a = g = 10ms^{-2}$

Time duration for the next $50m$ can be found by subtracting time for the first half distance from the time for the total distance of travel.

$$s = ut + \frac{1}{2}at^2$$

$$\Rightarrow 100 = (0 \times t) + \frac{1}{2}(10 \times t^2)$$

$$\Rightarrow 100 = 5 \times t^2$$

$$\Rightarrow t^2 = 20$$

$$\Rightarrow t = \sqrt{20} = 4.47s$$

$$\Rightarrow t = 4.47s$$

Thus the time for the second half is – $t_2 = t - t_1$

$$\Rightarrow t_2 = 4.47 - 3.16$$

$$\Rightarrow t_2 = 1.31s$$

4. A body of mass $10kg$ starts from rest and rolls down an inclined plane. It rolls down $10m$ in $2s$.

(a) What is the acceleration attained by the body?

Ans: Given:

Mass of body:

$m = 10kg$

Initial velocity of body: $u = 0ms^{-1}$ (as it is starting to roll)

Distance travelled on inclined plane: $s = 10m$

Time duration of rolling: $t = 2s$

To find acceleration attained by the body.

It is known that – $s = ut + \frac{1}{2}at^2$

Thus, $10 = (0 \times 2) + \frac{1}{2}(a \times 2^2)$

$$\Rightarrow 10 = \frac{1}{2}(a \times 4)$$

$\Rightarrow 10 = (a \times 2)$

$\Rightarrow a = 5ms^{-2}$

(b) What is the velocity of the body at $2s$?

Ans: Given:

Mass of body:

$m = 10kg$

Initial velocity of body: $u = 0ms^{-1}$ (as it is starting to roll)

Distance travelled on inclined plane: $s = 10m$

Time duration of rolling: $t = 2s$

To find velocity of body at $t = 2s$.

It is known that – $v = u + at$

Thus, $v = 0 + (5 \times 2)$

$\Rightarrow v = 10ms^{-1}$

(c) What is the force acting on the body?

Ans: Given:

Mass of body: $m = 10kg$

Initial velocity of body: $u = 0ms^{-1}$ (as it is starting to roll)

Distance travelled on inclined plane: $s = 10m$

Time duration of rolling: $t = 2s$

To find force acting on the body.

$F = ma$

$\Rightarrow F = (10 \times 5)$

$\Rightarrow F = 50N$

5. A body of mass $2kg$ is at rest at the origin of a frame of reference. A force of $5N$ acts on it at $t = 0s$. The force acts for $4s$ and then stops.

(a) What is the acceleration produced by the force on the body?

Ans: Given:

Mass of body:

$m = 2kg$

Initial velocity of body: $u = 0ms^{-1}$ (as it is starting from rest)

Force acting on the body: $F = 5N$

Time duration for which force is exerted: $t = 4s$

To find acceleration produced by the force on the body.

It is known that – $F = ma$

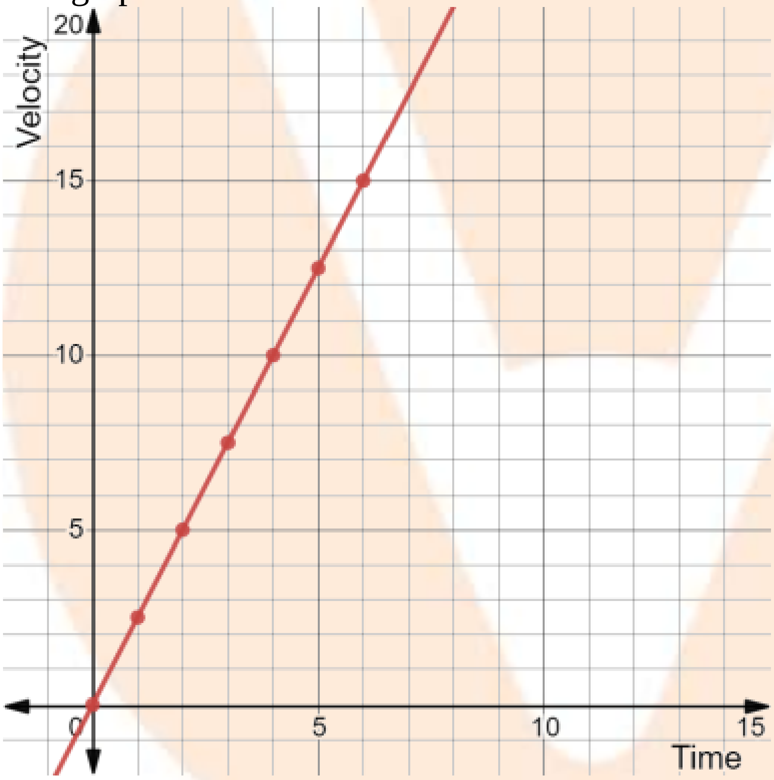
$\Rightarrow a = \frac{F}{m}$
$\Rightarrow a = \frac{5}{2}$
$\Rightarrow a = 2.5ms^{-2}$

(b) What is the velocity at $t = 4s$?
Ans: Given:
Mass of body:
$m = 2kg$
Initial velocity of body: $u = 0ms^{-1}$ (as it is starting from rest)
Force acting on the body: $F = 5N$
Time duration for which force is exerted: $t = 4s$
To find velocity of body at $t = 4s$.
It is known that – $v = u + at$
Thus, $v = 0 + (2.5 \times 4)$
$\Rightarrow v = 10ms^{-1}$

(c) Draw the v-t graph for the period $t = 0s$ to $t = 6s$.
Ans: Given:
Mass of body:
$m = 2kg$
Initial velocity of body: $u = 0ms^{-1}$ (as it is starting from rest)
Force acting on the body: $F = 5N$
Time duration for which force is exerted: $t = 4s$
To plot the v-t graph.
Plotting the v-t graph
Using the formula – $v = u + at$
At $t = 0s \Rightarrow v = 0 + (2.5 \times 0) = 0ms^{-1}$
At $t = 1s \Rightarrow v = 0 + (2.5 \times 1) = 2.5ms^{-1}$
At $t = 2s \Rightarrow v = 0 + (2.5 \times 2) = 5ms^{-1}$
At $t = 3s \Rightarrow v = 0 + (2.5 \times 3) = 7.5ms^{-1}$
At $t = 4s \Rightarrow v = 0 + (2.5 \times 4) = 10ms^{-1}$
At $t = 5s \Rightarrow v = 0 + (2.5 \times 5) = 12.5ms^{-1}$
At $t = 6s \Rightarrow v = 0 + (2.5 \times 6) = 15ms^{-1}$

Time t(s)	**Velocity** v(ms^{-1})
0	$0ms^{-1}$
1	$2.5ms^{-1}$
2	$5ms^{-1}$
3	$7.5ms^{-1}$
4	$10ms^{-1}$
5	$12.5ms^{-1}$
6	$15ms^{-1}$

The graph:



(d) Find the distance travelled in $6s$.

Ans: Given:

Mass of body: $m = 2kg$

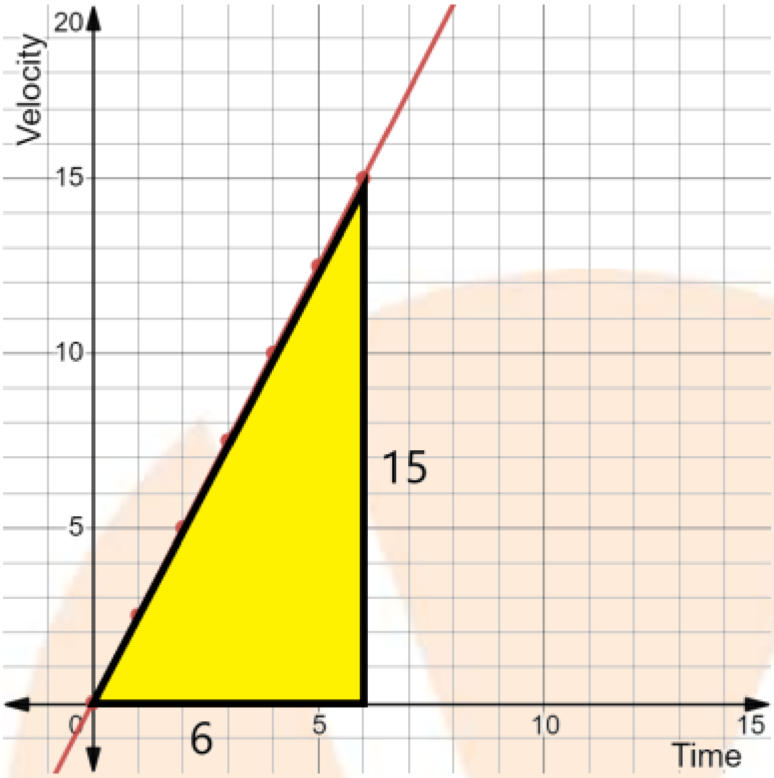
Initial velocity of body: $u = 0ms^{-1}$ (as it is starting from rest)

Force acting on the body: $F = 5N$

Time duration for which force is exerted: $t = 4s$

To find distance travelled in $t = 6s$.

This can be found by calculating the area under the v-t graph.



This is a triangle with base as 6 and height as 15

Area of triangle: $\frac{1}{2}\times b\times h=\frac{1}{2}\times 6\times 15=45$

Thus, the distance travelled in $t=6s$ is $45m$.