Force and Laws of Motion: Exercise Questions

Q.1 An object experiences a net zero external unbalanced force. Is it possible for the object to be travelling 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.

Sol. When an object experiences a net zero external unbalanced force, it is possible for the object to be travelling with a non-zero velocity. When object in motion and there is a condition in which its motion is unopposed by any external force. The object will remain in motion. It is necessary that the object must move at a constant velocity and in a particular direction.

Q.2When a carpet is beaten with a stick, dust comes out of it. Explain.

Sol. *According to* Newton's First Law of Motion, any object remains in its state unless any external force is applied over it. When a carpet is beaten with stick, it makes the carpet come in motion suddenly, while dust particles have the tendency to remain at rest. So, these dust particles maintain the position of rest and they come out of carpet.

Q.3 Why is it advised to tie any luggage kept on the roof of a bus with a rope?

Sol. It is advised to tie any luggage kept on the roof of a bus with a rope because when bus in rest position, luggage kept on the roof of a bus has the tendency to remain at rest. As suddenly bus is in motion, luggage kept over its roof maintains the position of rest and it may fall down. Similarly, when a moving bus will come in rest by applying of brake, luggage may fall down because of its tendency to remain in motion.

Q.4 A batsman hits a cricket ball which then rolls on a 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.

Sol. (c) There is a force on the ball opposing the motion.
Explanation: When ball rolls on the ground, the friction force opposes rolling motion and after some time the ball comes to rest.

Q.5 A truck starts from rest and rolls down a hill with a constant acceleration. It travels a distance of 400 m in 20 s. Find its acceleration. Find the force acting on it if its mass is 7 tons (Hint: 1 ton = 1000 kg.)

Sol. Given: Initial velocity of truck (u) = 0
Distance travelled, s = 400 m
Time (t) = 20
Acceleration (a) =?

From second equation of motion: $s = ut + \frac{1}{2}at^2$

$400 = (0 \times 20) + \frac{1}{2} a (20)^2$
$a = (400 \times 2) / (20)^2$
$a = 2\ m/s^2$
Force acting upon truck:
Given mass of truck = 7 ton = 7 X 1000 kg = 7000
Force F = ma
= 7000 x 2 =14000 N
Therefore, Acceleration = 2 m s^{-2} and force acting upon truck = 14000 N

Q.6 A stone of 1 kg is thrown with a velocity of 20 m/s across the frozen surface of a lake and comes to rest after travelling a distance of 50 m. What is the force of friction between the stone and the ice?

Sol. Given: Mass of stone = 1 kg
Initial velocity, u = 20 m/s
Final velocity, v = 0
Distance covered, s = 50 m
Friction force =?
From the third equation of Motion: $v^2 = u^2 + 2as$

$(0)^2 = (20)^2 + 2\ a\ (50)$

$a = -400/100 = -4\ m/s^2$

Now, friction force, F = mass x acceleration
F = 1 kg X $-4ms^{-2}$
F = -4ms-2
Therefore, force of friction acting upon stone = $-4ms^{-2}$. Negative sign shows that force is acting in the opposite direction of the movement of the stone.

Q.7 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; (b) the acceleration of the train; and (c) the force of wagon 1 on wagon 2.

Sol. Given, Force of engine = 40000 N
Force of friction = 5000 N
Mass of engine = 8000 kg
Total weight of wagons = 5 x 2000 kg = 10000 kg

(a) The net accelerating force = Force exerted by engine – Force of friction
= 40000 N – 5000 N = 35000 N

(b) The acceleration of the train,
Since F = mass x acceleration
35000 N = (mass of engine + mass of 5 wagons) X a
35000 N = (8000 kg + 10000 kg) X a
35000N = 18000 kg X a
a = 35000/18000
$a = 1.944\ m/s^2$

(c) The force of wagon 1 on wagon 2 :
Since, net accelerating force = 35000 N
Mass of wagon 2 = 4 x 2000 kg = 8000 kg
We know that, F = m x a
Therefore, F = 8000 x 1.94 = 15520 N

Q.8 An automobile vehicle has a mass of 1500 kg. What must be the force between the vehicle and road if the vehicle is to be stopped with a negative acceleration of 1.7 m s-2?

Sol. Given: Mass of the vehicle, m = 1500 kg
Acceleration, a = - 1.7 m s^{-2}
The force acting between the vehicle and road, F =?
F = m x a
F = 1500 kg X -1.7 m s^{-2}
F = - 2550 N
Thus, force between vehicle and road = - 2550 N. Negative sign shows that force is acting in the opposite direction of motion.

Q.9 what is the momentum of an object of mass m, moving with a velocity v?
(a) (m v)2 (b) mv2 (c) ½ mv2 (d) mv

Sol. (d) mv

Q.10 Using a horizontal force of 200 N, 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?

Sol. As horizontal force of 200N is used to move a wooden cabinet, a friction force of 200N will be exerted on the cabinet. Because according to newton's third law of motion, an equal amount of force will be applied in the opposite direction.

Q.11 Two objects, each of mass 1.5 kg, are moving in the same straight line but in opposite directions. The velocity of each object is 2.5 m s-1 before the collision during which they stick together. What will be the velocity of the combined object after collision?

Sol. Given: Mass of first object, m_1 = 1.5 kg

Mass of second object, m_2 = 1.5 kg

Initial velocity of one object, u_1 = 2.5 m/s

Initial velocity of second object, u_2 = -2.5 m/s (due to opposite direction)

Final velocity of both the objects, which stick together:

According to law of conservation of momentum:

Momentum before collision = Momentum after collision

$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$
$(1.5 \times 2.5) + (1.5 \times -2.5) = (m_1 + m_2)\, v$
$(1.5 \times 2.5) + (1.5 \times -2.5) = 3\, v$
$0 = 3v$
$v = 0$

Therefore, final velocity of both the objects after collision will be zero.

Q.12 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.

Sol. Because of the huge mass of the truck, the inertia of truck is very high. The force applied by the student is unable to overcome from the inertia and hence that's why he was unable to move the truck. The force applied by the student and the force because of inertia are cancelling out each other.

Q. 13 A hockey ball of mass 200 g travelling at 10 m/s is struck by a hockey stick so as to return it along its original path with a velocity at 5 m/s. Calculate the change of momentum occurred in the motion of the hockey ball by the force applied by the hockey stick.

Sol. Given: Mass of hockey ball, m = 200 g = 200/1000 kg = 0.2 kg
Initial velocity of hockey ball, u = 10 m/s

Final velocity of hockey ball, v = - 5 m/s (due to opposite direction)

Change in momentum =?

Since, Momentum = mass x velocity

So, Momentum of ball before getting struck = 0.2 kg x 10 m/s = 2 kg m/s
Momentum of ball after getting struck = 0.2 kg x - 5m/s = - 1 kg m/s

Now, change in momentum = final momentum – initial momentum
Change in momentum = 2 kg m/s – (-1 kg m/s)
= 2 kg m/s + 1 kg m/s = 3 kg m/s

Thus, change of momentum of ball after getting struck = 3 kg m/s

Q.14 A bullet of mass 10 g travelling horizontally with a velocity of 150 m/s strikes a stationary wooden block and comes to rest in 0.03 s. 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.

Sol. Given: Mass of bullet, m = 10 g = 10/1000 = 0.01 kg

Initial velocity of bullet, u = 150 m/s

Final velocity, v = 0

Time, t = 0.03 s

Distance of penetration (s) =?

Magnitude of force exerted by wooden block =?
From the first equation of motion: $v = u + at$

$$a = (0-150)/0.03 = -5000 \text{ m/s}^2$$

Now, from the third equation of Motion: $v^2 = u^2 + 2as$
So, displacement $s = (v^2 - u^2)/2a = (0^2 - 150^2)/ 2 \times (-5000)$
S = 2.25 m

Now, Magnitude of force exerted by wooden block, Force = mass x acceleration
F = 0.01 kg x (– 5000) = - 50 N

Thus, Penetration of bullet in wooden block = 2.25 m

Force exerted by wooden block on bullet = - 50 N.

Q.15 An object of mass 1 kg travelling in a straight line with a velocity of 10 m/s collides with, and sticks to, a stationary wooden block of mass 5 kg. 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.

Sol. Given: mass of moving object, $m_1 = 1$ kg

Mass of the wooden block, $m_2 = 5$kg

Initial velocity of object, $u_1 = 10$ m/s

Initial velocity of wooden block, $u_2 = 0$

Final velocity or moving object and wooden block, v =?

Total momentum before collision and after collision =?

So, total momentum before the collision = m1 u1 + m2 u2 = 1 x (10) + 0 = 10 kgm/s
Total momentum after the collision = (m1 + m2) v

According to conservation of momentum: final momentum = initial momentum
(m1 + m2) x v = 10 kgm/s
6 v=10
V = 10/6 = 1.66 m/s
Therefore,

Velocity of both the object after collision = 1.66 m/sm/s Total momentum before collision = 10 kg m/s

Total momentum after collision = 10 kg m/s

Q.16 An object of mass 100 kg is accelerated uniformly from a velocity of 5 m/s to 8 m/s in 6 s. Calculate the initial and final momentum of the object. Also, find the magnitude of the force exerted on the object.

Sol. Given: Initial velocity, u = 5 m/s

Final velocity, v = 8 m/s

Mass of the given object, m = 100 kg

Time, t = 6 s

Initial momentum and Final momentum =?

Magnitude of force exerted on the object =?

Since,

Momentum = mass x velocity

Initial momentum = mass x initial velocity
= 100 kg X 5 m/s = 500 kg m/s

Final momentum = mass x final velocity

=100 kg x 8 m/s = 800 kg m/s

Acceleration a = (v-u) / t; (8-5)/6
a= 3/6 =0.5 m/s^2

Now, Force exerted on object = Mass x Acceleration

= 100 kg X 0.5 m/s^2

= 50 N

Q.17 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.

Sol. From the above scenario, Rahul gave the correct explanation. Both the motorcar and the insect experienced the same force and change in their momentum. According to law of conservation of momentum. When two objects collide, initial momentum before collision is equal to Final momentum after collision.

$$m_1 u_1 + m_2 u_2 = m_1 v_1 + m_2 v_2$$

The equal force is exerted on both but, because the mass of insect is very small it will suffer greater change in velocity.

Q.18 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 m/s^{-2}.

Sol: Given: Mass of dumbbell = 10kg

Distance, s = 80 cm = 80/100 =0.8 m

Acceleration, a = 10 m/s^2

Initial velocity u = 0

Now, from the third equation of motion: $v^2 = u^2 + 2as$

$v^2 - 0^2 = 2 \times 10 \times 0.8$

$v = 4$ m/s

So, Momentum $p = m \times v = 10 \times 4 = 40$ kg m/s