NCERT Exercise Questions

Laws of motion

1. Give the magnitude and direction of the net force acting on

(a) a drop of rain falling down with a constant speed,

(b) a cork of mass 10 g floating on water,

(c) a kite skillfully held stationary in the sky,

(d) a car moving with a constant velocity of 30 km/h on a rough road,

(e) a high-speed electron in space far from all material objects, and free of electric and magnetic fields.

Ans.

Case	Magnitude and direction of net force	Reason
(a) a drop of rain falling down with a constant speed	Zero	• Constant speed • acceleration zero • force zero
(b) a cork of mass 10 g floating on water	Zero	• Weight of the cork is acting downward is balanced by the buoyant force exerted by water in upward direction. • so net force is zero.
(c) a kite skillfully held stationary in the sky	Zero	• Constant speed (held stationary) • force zero
(d) a car moving with a constant velocity of 30 km/h on a rough road	Zero	• Constant velocity • acceleration zero • force zero
(e) a high-speed electron in space far from all material objects, and free of electric and magnetic fields	Zero	• Free from all fields and forces. • Net force zero

2. A pebble of mass 0.05 kg is thrown vertically upwards. Give the direction and magnitude of the net force on the pebble,

(a) during its upward motion,

(b) during its downward motion,

(c) at the highest point where it is momentarily at rest.

Do your answers change if the pebble was thrown at an angle of 45° with the horizontal direction?

Ignore air resistance.

Ans.

Case	Force	Magnitude	Direction
(a) during its upward motion	F = mg = 0.05 x (-10) = -0.5 N	0.5	downwards
(b) during its downward motion	F = mg = 0.05 x (10) = 0.5 N	0.5	downwards
(c) at the highest point where it is momentarily at rest	F = mg = 0.05 x (10) = 0.5 N	0.5	downwards

- Pebble is thrown at an angle of 45° with the horizontal, it will have both the horizontal and vertical components of velocity. At the highest point, only the vertical component of velocity becomes zero. However, the pebble will have the horizontal component of velocity throughout its motion. This component of velocity produces no effect on the net force acting on the pebble.

3. Give the magnitude and direction of the net force acting on a stone of mass 0.1 kg,

(a) just after it is dropped from the window of a stationary train,

(b) just after it is dropped from the window of a train running at a constant velocity of 36 km/h,

(c) just after it is dropped from the window of a train accelerating with 1 m s^{-2},

(d) lying on the floor of a train which is accelerating with 1 ms^{-2}, the stone being at rest relative to the train.

Neglect air resistance throughout.

Ans.

Case	Force/Reason	Magnitude	Direction
(a) just after it is dropped from the window of a stationary train	F = mg = 0.1 x (10) = 1 N	1	downwards
(b) just after it is dropped from the window of a train running at a constant velocity of 36 km/h	• constant velocity so acceleration in horizontal direction is zero. • F = mg = 0.1 x (10) = 1 N	1	downwards
(c) just after it is dropped from the window of a train accelerating with 1 ms^{-2}	• train is accelerating(1 ms^{-2}). • So, horizontal force acting on the stone is $F' = ma = 0.1 \times 1 = 0.1$ N • when the stone is dropped, the horizontal force F,' stops acting on the stone as the force acting on a body at an instant depends	1	Downwards

	on the situation at that instant and not on earlier situations. • So, the net force acting on the stone is given only by acc. on due to gravity. i.e. F = mg = 0.1 x (10) = 1 N		
(d) lying on the floor of a train which is accelerating with 1 ms^{-2}, the stone being at rest relative to the train	• Weight of the stone is balanced by the normal reaction of the floor. • Acceleration is provided by the horizontal motion of the train. • $F = ma = 0.1 \times 1 = 0.1$ N	0.1	Along the motion of the train

4. One end of a string of length l is connected to a particle of mass m and the other to a small peg on a smooth horizontal table. If the particle moves in a circle with speed v the net force on the particle (directed towards the centre) is :

(i) T, (ii) $T - \frac{mv^2}{l}$, (iii) $T + \frac{mv^2}{l}$, (iv) 0

T is the tension in the string. [Choose the correct alternative].

Ans. (i) T

When a particle connected to a string revolves in a circular path around a centre, the centripetal force is provided by the tension produced in the string. Hence, in the given case, the net force on the particle is the tension T, i.e., $F = T = \frac{mv^2}{l}$

Where F is the net force acting on the particle.

5. A constant retarding force of 50 N is applied to a body of mass 20 kg moving initially with a speed of 15 ms^{-1}. How long does the body take to stop?

Ans. $Given: \quad F = -50N, \quad m = 20kg$

$u = 15ms^{-1}, \quad v = 0$

$To\ find: t = ?$

$Sol^n: \quad F = ma$

$-50 = 20a$

$$\boxed{a = \frac{-50}{20} = -2.5ms^{-2}}$$

$v = u + at$

$0 = 15 + (-2.5)t$

$$\boxed{t = \frac{15}{2.5} = 6s}$$

6. A constant force acting on a body of mass 3kg changes its speed from 2 ms^{-1} to 3.5 ms^{-1} in 25 s. The direction of the motion of the body remains unchanged. What is the magnitude and direction of the force?

Ans. $Given: \quad m = 3kg, \quad u = 2ms^{-1},$

$t = 25s, \quad v = 3.5ms^{-1}$

$To\ find: F = ?$

$Sol^n: \quad v = u + at$

$3.5 = 2 + 25a$

$25a = 1.5$

$$\boxed{a = \frac{1.5}{25} = 0.06ms^{-2}}$$

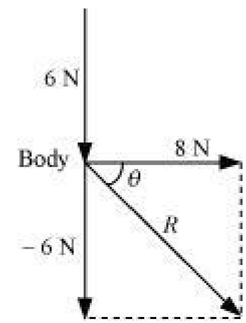
$F = ma = 3 \times 0.06 = 0.18N$

7. A body of mass 5 kg is acted upon by two perpendicular forces 8 N and 6 N. Give the magnitude and direction of the acceleration of the body.

Ans. $Given: \quad m = 5kg, \quad F_x = 8N, \quad F_y = 6N$

$To\ find: F = ?\ \theta = ?\ a = ?$

$Sol^n: \quad F = \sqrt{8^2 + 6^2} = \sqrt{100} = 10N$



$\tan\theta = \frac{6}{8}$

$$\boxed{\theta = \tan^{-1}\left(\frac{3}{4}\right)}$$

$F = ma$

$10 = 5a$

$$\boxed{a = \frac{10}{5} = 2ms^{-2}}$$

8. The driver of a three-wheeler moving with a speed of 36 km/h sees a child standing in the middle of the road and brings his vehicle to rest in 4.0 s just in time to save the child. What is the average retarding force on the vehicle? The mass of the three-wheeler is 400 kg and the mass of the driver is 65 kg.

Ans.

$$Given: \quad u = 36kmh^{-1} = 36 \times \frac{5}{18} = 10ms^{-1}$$

$$v = 0$$

$$t = 4s$$

$$m = 400kg(mass\ of\ three-wheeler)$$

$$m' = 65kg(mass\ of\ driver)$$

$$total\ mass = m + m' = 400 + 65 = 465kg$$

$$To\ find: F = ?$$

$$Sol^n: \quad v = u + at$$

$$0 = 10 + 4a$$

$$4a = -10$$

$$\boxed{a = \frac{-10}{4} = -2.5ms^{-2}}$$

$$F = ma = 465 \times (-2.5) = -1162.5N$$

9. A rocket with a lift-off mass 20,000 kg is blasted upwards with an initial acceleration of 5.0 ms^{-2}. Calculate the initial thrust (force) of the blast.

Ans.

$$Given: \quad m = 20,000kg$$

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

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

$$To\ find: F = ?$$

$$Sol^n: \quad F = m(g + a)$$

$$= 20000(10 + 5)$$

$$= 20000 \times 15$$

$$= 300000N$$

10. A body of mass 0.40 kg moving initially with a constant speed of 10 ms^{-1} to the north is subject to a constant force of 8.0 N directed towards the south for 30 s. Take the instant the force is applied to be $t = 0$, the position of the body at that time to be $x = 0$, and predict its position at t = –5 s, 25 s, 100 s.

Ans.

$$F = ma$$

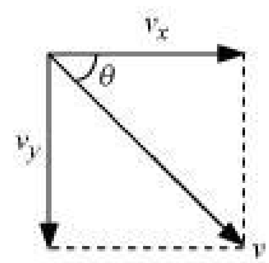
$$-8 = 0.4a$$

$$a = -20ms^{-2}$$

$t=-5s$ $a=0ms^{-2}, u=10ms^{-1}$ $s=ut+\frac{1}{2}at^2$ $=10(-5)+0$ $=-50m$	$t=25s$ $a=-20ms^{-2}, u=10ms^{-1}$ $s=ut+\frac{1}{2}at^2$ $=10(25)+\frac{1}{2}\times(-20)(25)^2$ $=250-6250$ $=-6000m$	$For\ 0\le t\le 30s$ $a=-20ms^{-2}, u=10ms^{-1}$ $s_1=ut+\frac{1}{2}at^2=10(30)+\frac{1}{2}\times(-20)(30)^2 \quad =-8700m$ $For\ t=30s$ $v=u+at=10+(-20)30=-590ms^{-1}$ $For\ t=30-100s\ \ i.e\ \ 70s$ $s_2=ut+\frac{1}{2}at^2 \quad =-590(70)+\frac{1}{2}\times 0(70)^2 \quad =-41300m$ $S=s_1+s_2=-8700-41300=-50000m$

11. A truck starts from rest and accelerates uniformly at 2.0 m s^{-2}. At t = 10 s, a stone is dropped by a person standing on the top of the truck (6 m high from the ground). What are the (a) velocity, and (b) acceleration of the stone at t = 11s? (Neglect air resistance.)

Ans. (a)



$u=0ms^{-1}$

$a=2ms^{-2}$

$t=10s$

$v=u+at \ =0+2\times 10=20ms^{-1}$

$At\ t=11s, \quad v_x=20ms^{-1}$

$v_y=u_y+a_y t'\,[u_y=0, a_y=10ms^{-2}, t'=11-10=1s]$

$=0+10(1)$

$=10ms^{-1}$

Resultant velocity $v'=\sqrt{v_x^2+v_y^2}=\sqrt{20^2+10^2}=\sqrt{500}==22.36ms^{-1}$

$\tan\theta=\frac{v_y}{v_x}$

$=\frac{10}{20}$

$\theta=\tan^{-1}\left(\frac{1}{2}\right)$

(b) When the stone is dropped from the truck, the horizontal force acting on it becomes zero. However, the stone continues to move under the influence of gravity. Hence, the acceleration of the stone is 10 m/s2 and it acts vertically downward.

12. A bob of mass 0.1 kg hung from the ceiling of a room by a string 2 m long is set into oscillation. The speed of the bob at its mean position is 1 ms^{-1}. What is the trajectory of the bob if the string is cut when the bob is (a) at

one of its extreme positions, (b) at its mean position?

Ans. (a) At extreme position, the velocity of the bob becomes zero so, the bob will fall vertically downwards.

(b) At mean position, the velocity of the bob is 1 m/s. The direction of this velocity is tangential to the arc formed by the oscillating bob. If the bob is cut at the mean position, then it will trace a projectile path having the horizontal component of velocity only. Hence, it will follow a parabolic path.

13. A man of mass 70 kg stands on a weighing scale in a lift which is moving

(a) upwards with a uniform speed of 10 ms^{-1},

(b) downwards with a uniform acceleration of 5 ms^{-2},

(c) upwards with a uniform acceleration of 5 ms^{-2}. What would be the readings on the scale in each case?

(d) What would be the reading if the lift mechanism failed and it hurtled down freely under gravity?

Ans. *Given* : $m = 70kg$

$g = 10ms^{-2}$

(i) $a = 0$

$F = m(g+a) = 70(10+0) = 700N$

(ii) $a = 5ms^{-2}$

$F = m(g-a) = 70(10-5) = 70\times 5 = 350N$

(iii) $a = 5ms^{-2}$

$F = m(g+a) = 70(10+5) = 70\times 15 = 1050N$

(iv) $a = g$

$F = m(g-a) = 70(10-10) = 70\times 0 = 0N$

14. Figure 5.16 shows the position-time graph of a particle of mass 4 kg. What is the

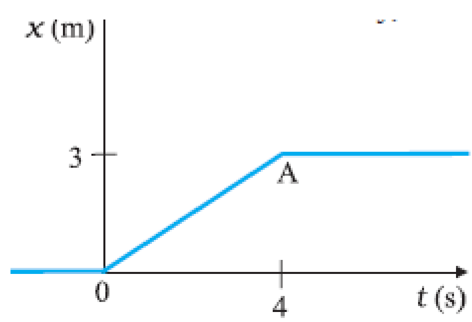
(a) force on the particle for $t < 0$, $t > 4$ s, $0 < t < 4$ s?

(b) impulse at $t = 0$ and $t = 4$ s ? (Consider one-dimensional motion only).

Ans. (a) For $t < 0$s, x = 0 so F=0N.

$t > 4$ s , v = 0 so F=0N.

$0 < t < 4$ v=constant , a = 0, so F= 0N



15. Two bodies of masses 10 kg and 20 kg respectively kept on a smooth, horizontal surface are tied to the ends of a light string. A horizontal force F = 600 N is applied to (i) A, (ii) B along the direction of string. What is the tension in the string in each case?

Ans. $Given: \quad F = 600N$

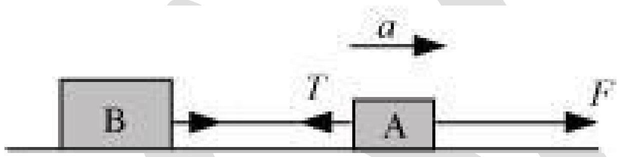
$m_1 = 10kg \qquad m_2 = 20kg$

$m = m_1 + m_2 = 10 + 20 = 30kg$

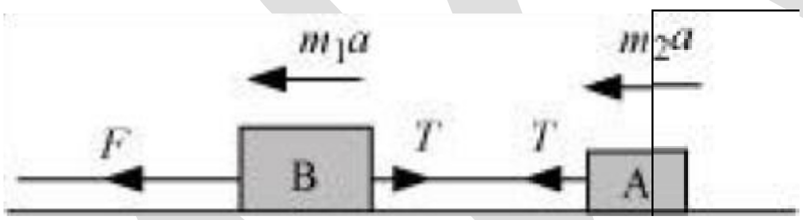
$F = ma$

$600 = 30a$

$a = 20ms^{-2}$



$T = F - m_1 a = 600 - 10 \times 20 = 600 - 200 = 400N$

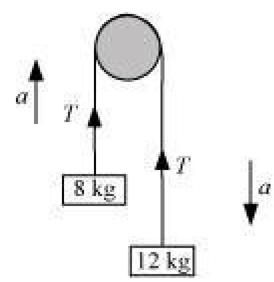


$T = F - m_2 a = 600 - 20 \times 20 = 600 - 400 = 200N$

16. Two masses 8 kg and 12 kg are connected at the two ends of a light inextensible string that goes over a frictionless pulley. Find the acceleration of the masses, and the tension in the string when the masses are released.

Ans. $For\ mass\ m_1 \quad T = F + m_1 g = m_1 a + m_1 g \quad \rightarrow (1)$

$For\ mass\ m_2 \quad T = m_2 g - F = m_2 g - m_2 a \quad \rightarrow (2)$



$From\,(1)\ and\ (2)$

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

$8a + 8 \times 10 = 12 \times 10 - 12a$

$8a + 12a = 120 - 80$

$20a = 40$

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

$From\,(1) \quad T = m_1(a+g) = 8(2+10) = 8 \times 12 = 96N$

17. A nucleus is at rest in the laboratory frame of reference. Show that if it disintegrates into two smaller nuclei the products must move in opposite directions.

Ans. Let m – mass of parent nucleus

m_1 – mass of first daughter nuclei

m_2 – mass of second daughter nuclei

As the parent nucleus is at rest so total linear momentum before disintegration = 0

Let v_1 – final velocity of first daughter nuclei after disintegration

v_2 – final velocity of second daughter nuclei after disintegration

total linear momentum after disintegration $= m_1v_1+m_2v_2$

According to law of conservation of linear momentum

total linear momentum before disintegration = total linear momentum after disintegration

$$0 = m_1v_1+m_2v_2$$

$$m_1v_1 = -m_2v_2$$

$$\boxed{v_1 = -\frac{m_2v_2}{m_1}}$$

18. Two billiard balls each of mass 0.05 kg moving in opposite directions with speed 6 ms^{-1} collide and rebound with the same speed. What is the impulse imparted to each ball due to the other?

Ans. Initial momentum of the ball $p_i = 0.05\times 6 = 0.3 kgms^{-1}$

Final momentum of the ball $p_f = -0.05\times 6 = -0.3 kgms^{-1}$

Impulse = change in momentum = $p_f - p_i = -0.3 - 0.3 = -0.6 kgms^{-1}$

19. A shell of mass 0.020 kg is fired by a gun of mass 100 kg. If the muzzle speed of the shell is 80 ms^{-1}, what is the recoil speed of the gun?

Ans. According to law of conservation of linear momentum

$MV + mv = 0$

$100V + 0.02\times 80 = 0$

$100V = -1.6$

$V = -0.016 ms^{-1}$

20. A batsman deflects a ball by an angle of 45° without changing its initial speed which is equal to 54 km/h. What is the impulse imparted to the ball? (Mass of the ball is 0.15 kg.)

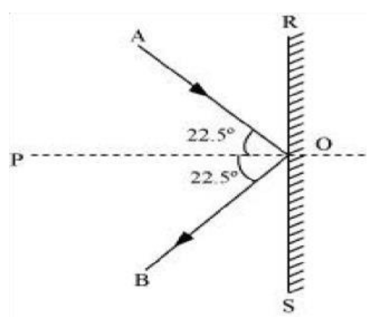
Ans. Impulse imparted to the ball = Change in the linear momentum of the ball

$I = -mv\cos\theta - mv\cos\theta$

$= -2mv\cos\theta$

$= -2\times 0.15\times 15\cos 22.5^0$

$= 4.16 kgms^{-1}$



21. A stone of mass 0.25 kg tied to the end of a string is whirled round in a circle of radius 1.5 m with a speed of 40 rev./min in a horizontal plane. What is the tension in the string? What is the maximum speed with which the stone can be whirled around if the string can withstand a maximum tension of 200 N ?

Ans. *Given*: $m = 0.25 kg$

$r = 1.5 m$

$\nu = 40\ rev./\min = 40/60\, rev./\sec$

To find : $T = ?, v = ?$

$Sol^n: \ \omega = 2\pi\nu = \frac{4\pi}{3}$

$T = m\omega^2 r \qquad \left[\because T = F_{centripetal}\right]$

$= 0.25 \times \frac{16}{9} \times 3.14 \times 3.14 \times 1.5$

$= 6.57 N$

$Now,\ T_{\max} = \frac{mv^2}{r}$

$200 = \frac{0.25 v^2}{1.5}$

$v^2 = 1200$

$v = 34.64 ms^{-1}$

22. If, in Exercise 5.21, the speed of the stone is increased beyond the maximum permissible value, and the string breaks suddenly, which of the following correctly describes the trajectory of the stone after the string breaks :

(a) the stone moves radially outwards,

(b) the stone flies off tangentially from the instant the string breaks,

(c) the stone flies off at an angle with the tangent whose magnitude depends on the speed of the particle ?

Ans. (b)Due to inertia of motion, the stone will fly off tangentially to regain its straight line path

23. Explain why

(a) a horse cannot pull a cart and run in empty space,

(b) passengers are thrown forward from their seats when a speeding bus stops suddenly,

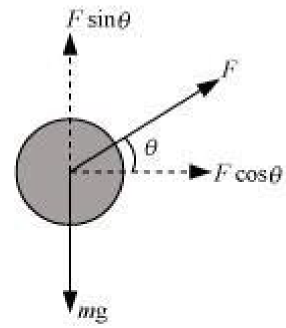
(c) it is easier to pull a lawn mower than to push it,

(d) a cricketer moves his hands backwards while holding a catch.

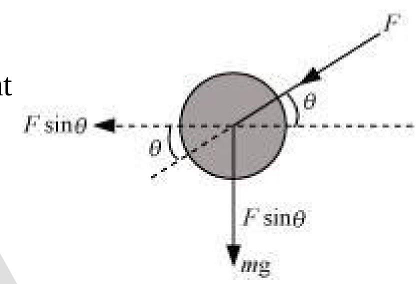
Ans. (a) The horse cart moves because of the action (applied by the horse on the ground) and reaction (applied by the ground on the feet of the horse). In empty space no reaction force is possible, so the horse cannot pull a cart and run in empty space.

(b) When a speeding bus stops suddenly, the lower portion of a passenger's body, which is in contact with the seat, suddenly comes to rest. However, the upper portion tends to remain in motion (as per the first law of motion). As a result, the passenger's upper body is thrown forward in the direction in which the bus was moving.

(c) While pulling a lawn mower, a force at an angle θ is applied on it.
The vertical component of this applied force acts upward.
This reduces the effective weight of the mower.



While pushing a lawn mower, a force at an angle θ is applied on it.
The vertical component of the applied force acts in the direction of the weight of the mower.
This increases the effective weight of the mower.



Since the effective weight of the lawn mower is lesser in the first case, pulling the lawn mower is easier than pushing it.

(d) While taking a catch, a cricketer moves his hand backward so as to increase the time of impact (Δt). This is turn results in the decrease in the stopping force, thereby preventing the hands of the cricketer from getting hurt.