NCERT Solutions Class 11 Physics chapter 5 Laws of Motion

<u>Laws of Motion</u>

ExerciseP.109

**Q.5.1:** 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 :** (a) Zero net force
The raindrop is falling with a constant speed. Hence, it acceleration is zero.
Newton's second law of motion, the net force acting on the rain drop is zero.
(b) Zero net force
As per The weight of the cork is acting downward. It is balanced by the buoyant force exerted
by the water in the upward direction. Hence, no net force is acting on the floating cork.
(c) Zero net force
The kite is stationary in the sky, i.e., it is not moving at all. Hence, as per Newton's first
law of motion, no net force is acting on the kite.
(d) Zero net force
The car is moving on a rough road with a constant velocity. Hence, its acceleration is
zero. As per Newton's second law Of motion, no net force is acting on car.
(e) Zero net force
The high speed electron is free from the influence of all fields. Hence, no net force is
acting on the electron.

**Q.5.2:** 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 :** 0.5 N, in vertically downward direction, in all cases
Acceleration due to gravity, irrespective of the direction of motion of an object, always
acts downward. The gravitational force is the only force that acts on the pebble in all
three cases. Its magnitude is given by Newton's second law of motion as:
$F = m \times a$ Where, F= Net force m= Mass of the
pebble $=0.05 kg$ $a = g = 10 m/s^2$ $\therefore F = 0.05 \times 10 = 0.5 N$ $F = m \times a$ Where, F= Net
force m= Mass of the pebble $=0.05 kg$ $a = g = 10 m/s^2$ $\therefore F = 0.05 \times 10 = 0.5 N$

The net force on the pebble in all three cases is 0.5 N and this force acts in the
downward direction.
If the pebble is thrown at an of 450 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.

**Q.5.3:** 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−2s−2 ,
(d) lying on the floor of a train which is accelerating with 1 m s−2s−2, the stone being at rest relative to the train. Neglect air resistance throughout.

**Ans :** (a) l N; vertically downward
Mass of the stone, m 0.1 kg
Acceleration Of the stone, a = g = 10 m/s2m/s2
As per Newton's second law of motion, the net force acting on the stone,
F ma = mg
=0.1 x 10=1 N
(b) l N; vertically downward
The train is moving with-I a constant velocity. Hence, its acceleration is zero in the
direction of its motion, i.e., in tie horizontal direction. Hence, no force is acting on ene
stone in the horizontal direction.
The net force acting on the stone is because of acceleration due to gravity and it always
acts vertically downward. The magnitude of this force is 1 N.
(c) l N; vertically downward
It is given that the train is accelerating at the rate Of 1 m/s2m/s2
Therefore, the net force acting on the stone, F' = ma — -0.1 x 1-0.1 N
This force is acting in the horizontal direction. Now, when the stone is dropped, the
horizontal force F,' stops acting on the stone. This is because of the fact that the force
acting on a body at an instant depends on the situation at that instant and not on earlier
Situations.
Therefore, the net force acting on the stone is given only by acceleration due to gravity.
F=mg=1NF=mg=1N

This force acts vertically downward.
(d) O.1 N, in the direction of motion of the train
The weight of the stone is balanced by the normal reaction of the floor.
The only acceleration is provided by the horizontal motion of the train.
Acceleration of the train, a = 0.1 m/s2m/s2
The net force acting on the stone will be in the direction of motion of the train. Its
magnitude is given by:
F = ma
-0.1 x 1-0.1 N

**Q.5.4:** 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) TT
(ii) T−mw2lT−mw2l
(iii) T+mw2lT+mw2l
(iv) 0

**Ans :** (i)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=mv2lF=T=mv2l
Where F is the net force acting on the particle.

**Q.5.5:** A constant retarding force of 50 N is applied to a body of mass 20 kg moving initially with a speed of 15 m s−1s-1. How long does the body take to stop ?

**Ans :** Retarding force, F = —50 N
Mass of the body, m = 20 kg
Initial velocity of the body, u = 15 m/s
Final velocity Of the body, V = O
using Newton's second law of motion, the acceleration (a) produced in the body can be
calculated as:
F=ma−50=20×a∴a=−5020=−2.5m/s2F=ma−50=20×a∴a=−5020=−2.5 m/s2
using the first equation Of motion, the time (t) taken by the body to come to rest can be
calculated as:
v=u+at∴t=−ua=−15−2.5=6sv=u+at∴t=−ua=−15−2.5=6s

**Q.5.6:** A constant force acting on a body of mass 3.0 kg changes its speed from 2.0 m s-1 to 3.5 m s−1s−1 in 25 s. The direction of the motion of the body remains unchanged. What is the magnitude and direction of the force ?

**Ans :** 0.18Ni in the direction of motion of the body  Mass of the body, m=3kg Initial speed of the body, u=2m/s Final speed of the body, v=3.5m/s0.18Ni in the direction of motion of the body  Mass of the body, m=3kg Initial speed of the body, u=2m/s Final speed of the body, v=3.5m/s
 Time, t=25s Using the first equation of motion, the acceleration (a) produced in the body can be  calculated as:  Time, t=25s Using the first

equation of motion, the acceleration (a) produced in the body can be calculated as:

$v=u+at \therefore a = v-ut = 3.5-225 = 1.525 = 0.06 m/s2$ $v=u+at \therefore a = v-ut = 3.5-225 = 1.525 = 0.06 m/s2$

As per Newton's second law of motion, force is given as: $F=ma=3\times0.06=0.18N$ As per Newton's second law of motion, force is given as: $F=ma=3\times0.06=0.18N$

Since the application of force does not change the direction of the body, the net force acting on the body is in the direction of its motion.

**Q.5.7:** 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 :** 2m/s2, at an angle of 37∘ with a force of 8N Mass of the body, m=5kg The given situation can be represented as follows: 2m/s2, at an angle of 37∘ with a force of 8N Mass of the body, m=5kg The given situation can be represented as follows:
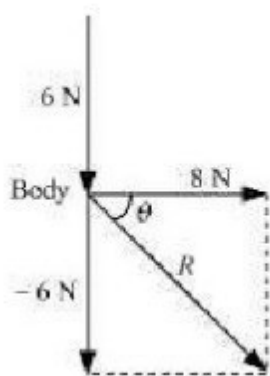


The resultant Of two forces is given as:

$R=\sqrt{(8)2+(-6)2}=\sqrt{64+36}=10N$ θ is the angle made by R with the force of 8N $\therefore \theta = \tan^{-1}(-68) = -36.87∘$ $R=(8)2+(-6)2=64+36=10N$ θ is the angle made by R with the force of 8N $\therefore \theta=\tan^{-1}(-68)=-36.87∘$

The negative sign indicates that 9 Is in the clockwise direction with respect to the force of magnitude 8 N.

As per Newton's second law of motion, the acceleration (a) of the body is given as:

$F=ma \therefore a = Fm = 105 = 2m/s2$ $F=ma \therefore a=Fm=105=2m/s2$

**Q.5.8:** 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 :** Initial speed of the three-wheeler, u=36km/h Final speed of the three-wheeler, v=10m/s Time, t=4s Mass of the three-wheeler, m=400kg Mass of the driver, m′=65kg Total mass of the system, M=400+65=465kg Initial speed of the three-wheeler, u=36km/h Final speed of the three-

wheeler, v=10m/s Time, t=4s Mass of the three- wheeler, m=400kg Mass of the driver, m'=65kg Total mass of the system, M=400+65=465kg
Using the first law of motion, the acceleration (a) of the three-wheeler can be calculated  as: $v=u+at \therefore a=v-ut=0-104=-2.5m/s2$ Using the first law of motion, the acceleration (a) of the three-wheeler can be calculated  as: $v=u+at \therefore a=v-ut=0-104=-2.5m/s2$
The negative sign indicates that the velocity of the three-wheeler is decreasing with
time.
using Newton's second law of motion, the net force acting on the three-wheeler can be
calculated as:
$F=Ma=465\times(-2.5)=-1162.5N F=Ma=465\times(-2.5)=-1162.5N$
The negative sign indicates that the force is acting against the direction of motion of the
Three-wheeler.

**Q.5.9:** A rocket with a lift-off mass 20,000 kg is blasted upwards with an initial acceleration of 5.0 m s−2s−2. Calculate the initial thrust (force) of the blast.

**Ans :**  Mass of the rocket, m=20,000kg Initial
acceleration, a=5m/s2 Acceleration due to gravity, g=10m/s2 Mass of the rocket, m=20,000kg Initial acceleration, a=5m/s2 Acceleration due to gravity, g=10m/s2
Using Newton's second law of motion, the net force (thrust) acting on the rocket is given  by the
relation: $F-mg=maF=m(g+a)=20000\times(10+5)=20000\times15=3\times105N$ Using Newton's second law of motion, the net force (thrust) acting on the rocket is given  by the
relation: $F-mg=maF=m(g+a)=20000\times(10+5)=20000\times15=3\times105N$

**Q.5.10:** A body of mass 0.40 kg moving initially with a constant speed of 10 m s−1s−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.z

**Ans :**  Mass of the body, m=0.40kg Initial speed of the
body, u=10m/s due north  Force acting on the body, F=−8.0N Mass of the body, m=0.40kg Initial speed of the body, u=10m/s due north  Force acting on the body, F=−8.0N
Acceleration produced in the body,
$a=Fm=-8.00.40=-20m/s2 a=Fm=-8.00.40=-20m/s2$
(i) at $t=-5st=-5s$
Acceleration, a′=0 and $u=10m/ss=ut+12a't2=10\times(-5)=-50m$ Acceleration, a′=0 and $u=10m/ss=ut+12a't2=10\times(-5)=-50m$
(ii) at $t=25st=25s$
Acceleration, a″=−20m/s2 and $u=10m/sS'=ut'+12a'$
$'t2=10\times25+12\times(-20)\times(25)2=250+6250=-6000m$ Acceleration, a′′=−20m/s2 and $u=10m/sS'=ut'+12a'$
$'t2=10\times25+12\times(-20)\times(25)2=250+6250=-6000m$
(iii) $\Delta tt=100s\Delta tt=100s$

For 0≤t≤30sa=−20m/s2u=10m/ss1=ut+12a″t2 For 0≤t≤30sa=−20m/s2 u=10m/ss1=ut+12a″t2
=10×30+12×(−20)×(30)2=300−9000=−8700m=10×30+12×(−20)×(30)2=300−9000=−8700m
\(\begin{array}{l}{\text { For } 30^{\prime}\)

**Q.5.11:** A truck starts from rest and accelerates uniformly at 2.0 m s−2s−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) 22.36m/s1 at an angle of 26.57∘ with the motion of the truck (b) 10m/s2 (a) Initial velocity of the truck, u=0 (a) 22.36m/s1 at an angle of 26.57∘ with the motion of the truck (b) 10m/s2 (a) Initial velocity of the truck, u=0

Acceleration, a=2m/s2 Time, t=10s As per the first equation of motion, final velocity is given
as: v=u+at=0+2×10=20m/s Acceleration, a=2m/s2 Time, t=10s As per the first equation of motion, final velocity is given
as: v=u+at=0+2×10=20m/s

The final velocity of the truck and hence, of the stone is 20m/s . At t=11s, the horizontal component (vx) of velocity, in the absence of air resistance, remains unchanged, i.e., vx=20m/s The final velocity of the truck and hence, of the stone is 20m/s . At t=11s, the horizontal component (vx) of velocity, in the absence of air resistance, remains unchanged, i.e., vx=20m/s

The vertical component (vy) of velocity of the stone is given by the first equation of motion as: vy=u+ayδt The vertical component (vy) of velocity of the stone is given by the first equation of motion as: vy=u+ayδt

Where, δt=11−10=1s and ay=g=10m/s2∴vy=0+10×1=10m/s The resultant velocity (v) of the stone is given
as: Where, δt=11−10=1s and ay=g=10m/s2∴vy=0+10×1=10m/s The resultant velocity (v) of the stone is given as:
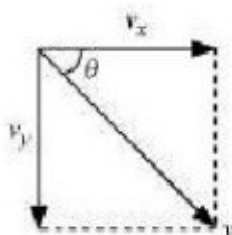


v=√v2x+v2y=√202+102=√400+100=√500=22.36m/sv=vx2+vy2=202+102=400+100=500=22.36m/s

Let θ be the angle made by the resultant velocity with the horizontal component of velocity, vx∴tanθ=(vyvx)θ=tan−1(1020) Let θ be the angle made by the resultant velocity with the horizontal component of velocity, vx∴tanθ=(vyvx)θ=tan−1(1020)
=tan−1(0,5)=26.57∘=tan−1(0,5)=26.57∘

(b)When the stone is dropped from the truck, the horizontal force acting on it becornes

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.

**Q.5.12:** 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 m s−1s−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) Vertically downward

(b) Parabolic path

(a) At the extreme position, the velocity of the bob becomes zero. If the string is cut at
this moment, then the bob will fall vertically on the ground.

(b)At the 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.

**Q.5.13:** 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 m s−1s−1 ,

(b) downwards with a uniform acceleration of 5 m s−2s−2 ,

(c) upwards with a uniform acceleration of 5 m s−2s−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 :** (a) Mass of the man, m=70kg Acceleration, a=0 Using Newton's second law of motion, we can write the equation of motion
as: R−mg=ma Where, ma is the net force acting on the man.  (a) Mass of the man, m=70kg Acceleration, a=0 Using Newton's second law of
motion, we can write the equation of motion as: R−mg=ma Where, ma is the net force acting on the man.

As the lift is moving at a uniform speed,
acceleration a=0∴R=mg=70×10=700N ¿Reading on the weighing scale = 700g=70010=70kg As the lift is moving at a uniform speed,
acceleration a=0∴R=mg=70×10=700N ¿Reading on the weighing scale = 700g=70010=70kg

(b) Mass of the man, m=70kg Acceleration, a=5m/s2 downward  Using Newton's second law of motion, we can write the equation of motion
as:  (b) Mass of the
man, m=70kg Acceleration, a=5m/s2 downward  Using Newton's second law of motion, we can write the equation of motion as:
R+mg=maR=m(g−a)=70(10−5)=70×5=350NR+mg=maR=m(g−a)=70(10−5)=70×5=350N

∴ Reading on the weighing scale =350g=35010=35kg∴ Reading on the weighing scale =350g=35010=35kg

(c) Mass of the man,m=70kg Acceleration, a=5m/s2 upward  Using Newton's second law of motion, we can write the equation of motion

as: (c) Mass of the man,m=70kg Acceleration, a=5m/s2 upward  Using Newton's second law of motion, we can write the equation of motion as: $R-mg=maR=m(g+a)=70(10+5)=70×15=1050NR-mg=maR=m(g+a)=70(10+5)=70×15=1050N$

∴ Reading on the weighing scale $=1050g=105010=105kg$∴ Reading on the weighing scale $=1050g=105010=105kg$

(d) When the lift moves freely under gravity, acceleration a=g Using Newton's second law of motion, we can write the equation of motion as: (d) When the lift moves freely under gravity, acceleration a=g Using Newton's second law of motion, we can write the equation of motion as: $R+mg=maR=m(g-a)=m(g-g)=0R+mg=maR=m(g-a)=m(g-g)=0$

∴ Reading on the weighing scale $=0g=0kg$ The man will be in a state of weightlessness. ∴ Reading on the weighing scale $=0g=0kg$ The man will be in a state of weightlessness.

**Q.5.14:** 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  4 s, 0

**Ans :** (a) For t  4 s

It can be observed from the given graph that the position of the particle is parallel to the time axis. It indicates that the particle is at rest at a distance of 3 m from the origin. Hence, no force is acting on the particle. For 0

**Q.5.15:** 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 :**  Horizontal force, F=600N Mass of body A,m1=10kg Mass of body B,m2=20kg Total mass of the system, m=m1+m2=30kg Horizontal force, F=600N Mass of body A,m1=10kg Mass of body B,m2=20kg Total mass of the system, m=m1+m2=30kg

Using Newton's second law of motion, the acceleration (a) produced in the system can  be calculated as: $F=ma∴a=Fm=60030=20m/s2$ Using Newton's second law of motion, the acceleration (a) produced in the system can  be calculated as: $F=ma∴a=Fm=60030=20m/s2$

V-Vhen force F is applied on body A:
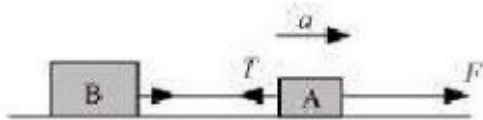


 The equation of motion can be written as: $F-T=m1a∴T=F-m1a=600-10×20=400N$... (i)  When force F is applied on body B:  The equation of motion can be written as: $F-T=m1a∴T=F-m1a=600-10×20=400N$… (i)  When force F is applied on body B:
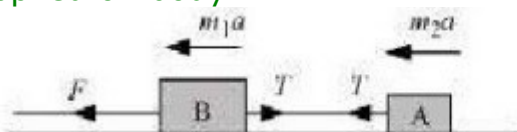


 The equation of motion can be written as: $F-T=m2aT=F-m2a∴T=600-20×20=200N$... (ii)  The equation of

motion can be written
as: $F-T=m_2a$ $T=F-m_2a$ $\therefore T=600-20\times20=200N$... (ii)

**Q.5.16:** 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 :** The given system of two masses and a pulley can be represented as shown in the
following figure:
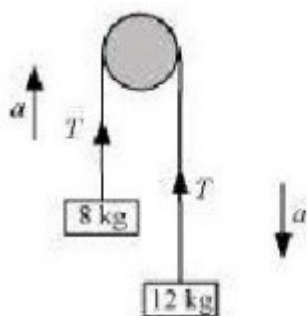


 Smaller mass, $m_1=8kg$ Larger mass, $m_2=12kg$ Tension in the string $=T$ Mass $m_2'$ owing to its weight, moves downward with acceleration a , and mass m1 moves  upward.  Smaller mass, $m_1=8kg$ Larger mass, $m_2=12kg$ Tension in the string $=T$ Mass $m_2'$ owing to its weight, moves downward with acceleration a , and mass m1 moves  upward.
 Applying Newton's second law of motion to the system of each mass:  For mass m1 .  The equation of motion can be written as: $T-m_19=ma$...
(i) Applying Newton's second law of motion to the system of each mass:  For mass m1 .  The equation of motion can be written
as: $T-m_19=ma$...(i)
 Eor mass m2 .  The equation of motion can be written as: $m_2g-T=m_2a$...
(ii) Eor mass m2 .  The equation of motion can be written
as: $m_2g-T=m_2a$...(ii)
 Adding equations (i) and (ii), we get: $(m_2-m_1)g=(m_1+m_2)a$ Adding equations (i) and (ii), we get: $(m_2-m_1)g=(m_1+m_2)a$
$\therefore a=(\frac{m_2-m_1}{m_1+m_2})g=(\frac{12-8}{12+8})\times10=\frac{4}{20}\times10=2m/s^2$ $\therefore a=(\frac{m_2-m_1}{m_1+m_2})g=(\frac{12-8}{12+8})\times10=\frac{4}{20}\times10=2m/s^2$
 Therefore, the acceleration of the masses is 2m/s2. Substituting the value of a in equation (ii), we get:  Therefore, the acceleration of the masses is 2m/s2. Substituting the value of a in equation (ii), we get:
$m_2g-T=m_2(\frac{m_2-m_1}{m_1+m_2})g$ $T=(m_2-\frac{m_2^2-m_1m_2}{m_1+m_2})g$ $m_2g-T=m_2(\frac{m_2-m_1}{m_1+m_2})g$ $T=(m_2-\frac{m_2^2-m_1m_2}{m_1+m_2})g$
$=(\frac{2m_1m_2}{m_1+m_2})g=(\frac{2\times12\times8}{12+8})\times10=\frac{2\times12\times8}{20}\times10=96N$ $=(\frac{2m_1m_2}{m_1+m_2})g=(\frac{2\times12\times8}{12+8})\times10=\frac{2\times12\times8}{20}\times10=96N$
Therefore, the tension in the string is 96 N.

**Q.5.17:** 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 $m, m_1$ and $m_2$ be the respective masses of the parent nucleus and the two daughter  nuclei. The parent nucleus is at rest.  Initial

momentum of the system (parent nucleus) =0  Let v1 and v2 be the respective velocities of the daughter nuclei having

masses m1 and m2 .  Let m,m1t and m2 be the respective masses of the parent nucleus and the two daughter  nuclei. The parent nucleus is at rest.  Initial momentum of the system (parent nucleus)

=0  Let v1 and v2 be the respective velocities of the daughter nuclei having masses m1 and m2 .

Total linear momentum of the system after

disintegration =m1v1+m2v2 According to the law of conservation of momentum:  Total initial momentum = Total final momentum  Total linear momentum of the system after disintegration =m1v1+m2v2 According to the law of conservation of momentum:  Total initial momentum = Total final momentum

0=m1v1+m2+v2v1=−m2v2m10=m1v1+m2+v2v1=−m2v2m1

Here, the negative sign indicates that the fragments of the parent nucleus move in

directions opposite to each other.

**Q.5.18:** Two billiard balls each of mass 0.05 kg moving in opposite directions with speed 6 m s−1s−1 collide and rebound with the same speed. What is the impulse imparted to each ball due to the other ?

**Ans :**  Mass of each ball =0.05kg Initial velocity of each

ball =6m/s Magnitude of the initial momentum of each

ball, pi=0.3kgm/s After collision, the balls change their directions of motion without changing the  magnitudes of their velocity.  Mass of each ball =0.05kg Initial velocity of each ball =6m/s Magnitude of the initial momentum of each ball, pi=0.3kgm/s After collision, the balls change their directions of motion without changing the  magnitudes of their velocity.

Final momentum of each ball, pf=−0.3kgm/s Impulse imparted to each ball = Change in the momentum of the

system =pf−pi=−0.3−0.3=−0.6kgm/s The negative sign indicates that the impulses imparted to the balls are opposite in  direction.  Final momentum of each ball, pf=−0.3kgm/s Impulse imparted to each ball = Change in the momentum of the

system =pf−pi=−0.3−0.3=−0.6kgm/s The negative sign indicates that the impulses imparted to the balls are opposite in  direction.

**Q.5.19:** 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 m s−1s−1, what is the recoil speed of the gun ?

**Ans :**  Mass of the gun, M=100kg Mass of the shell, m=0.020kg Muzzle speed of the shell, v=80m/s Recoil speed of the gun = V Both the gun and the shell are at rest initially.  Initial momentum of the

system =mv−MV Mass of the gun, M=100kg Mass of the shell, m=0.020kg Muzzle speed of the shell, v=80m/s Recoil speed of the gun = V Both the gun and the shell are at rest initially.  Initial momentum of the system =mv−MV
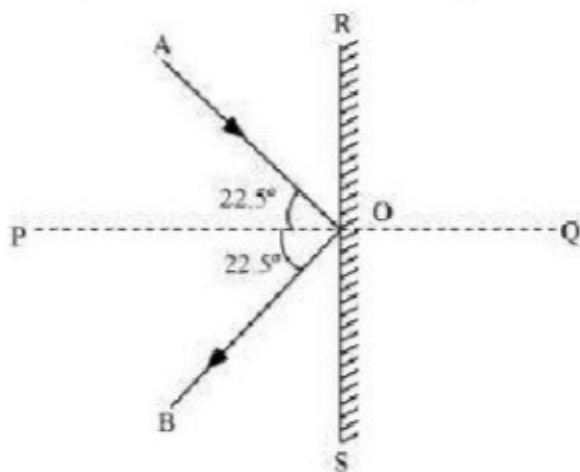
Here, the negative sign appears because the directions of the shell and the gun are  opposite to each other.  According to the law of conservation of momentum:  Final momentum = Initial momentum  Here, the negative

sign appears because the directions of the shell and the gun are opposite to each other. According to the law of conservation of momentum: Final momentum = Initial momentum

$\therefore V = \dfrac{mv}{M} = \dfrac{0.020 \times 80}{100 \times 1000} = 0.016 m/s \therefore V = \dfrac{mv}{M} = \dfrac{0.020 \times 80}{100 \times 1000} = 0.016 m/s$

**Q.5.20:** 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 :** The given situation can be represented as shown in the followIng figure.



Where, AO = Incident path of the ball OB = Path followed by the ball after deflection ∠AOB= Angle between the incident and deflected paths of the ball = 45 ∠AOP=∠BOP=22.5∘=θ Where, AO = Incident path of the ball OB = Path followed by the ball after deflection ∠AOB= Angle between the incident and deflected paths of the ball = 45 ∠AOP=∠BOP=22.5∘=θ

Initial and final velocities of the ball =v Horizontal component of the initial velocity =vcosθ along RO Vertical component of the initial velocity =vsinθ along PO Horizontal component of the final velocity =vcosθ along os vertical component of the final velocity =vsinθ along op Initial and final velocities of the ball =v Horizontal component of the initial velocity =vcosθ along RO Vertical component of the initial velocity =vsinθ along PO Horizontal component of the final velocity =vcosθ along os vertical component of the final velocity =vsinθ along op

The horizontal components of velocities suffer no change. The vertical components of velocities are in the opposite directions. ∴ Impulse imparted to the ball = Change in the linear momentum of the ball The horizontal components of velocities suffer no change. The vertical components of velocities are in the opposite directions. ∴ Impulse imparted to the ball = Change in the linear momentum of the ball =mvcosθ−(−mvcosθ)=2mvcosθ Mass of the ball, m=0.15kg Velocity of the

ball, v=54km/h=15m/s∴ Impulse =2×0.15×15cos22.5∘=4.16kgm/s=mvc osθ−(−mvcosθ)=2mvcosθ Mass of the ball, m=0.15kg Velocity of the ball, v=54km/h=15m/s∴ Impulse =2×0.15×15cos22.5∘=4.16kgm/s

**Q.5.21:** 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 :** Mass of the stone, m=0.25kg Radius of the circle, r=1.5m Number of revolution per second, n=4060=23rps Mass of the
stone, m=0.25kg Radius of the circle, r=1.5m Number of revolution per second, n=4060=23rps

Angular velocity, ω=2πn The centripetal force for the stone is provided by the tension T, in the string, i.e., Angular velocity, ω=2πn The centripetal force for the stone is provided by the tension T, in the string, i.e.,
T=F Cemiripetal =mv2r=mrω2=mr(2πn)2T=F Cemiripetal =mv2r=mrω2= mr(2πn)2
=0.25×1.5×(2×3.14×23)2=0.25×1.5×(2×3.14×23)2
=6.57N=6.57N
Maximum tension in string,Tmax=200NTmax=200N
Tmax=mv2maxr∴vmax=√Tmax×rmTmax=mvmax2r∴vmax=Tmax×rm
=√200×1.50.25=√1200=34.64m/s=200×1.50.25=1200=34.64m/s
Therefore, the maximum speed of the stone is 34.64 m/s.

**Q.5.22:** 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)When the string breaks, the stone will move in the direction of the velocity at that
instant. According to the first law of motion, the direction of velocity vector is tangential
to the path Of the stone at that instant. Hence, the stone will fly Off tangentially from the
instant the string breaks.

**Q.5.23:** 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) In order to pull a cart, a horse pu±ies the ground backward with some force. The
ground in turn exerts an equal and opposite reaction force upon the feet of the horse.
This reaction force causes the horse to move forward.
An empty *'ace is devoid Of any such reaction force. Therefore, a 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 9 is applied on it, as shown in the
following figure.
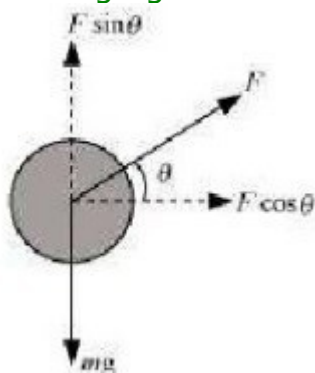


The vertical cornponent of this applied force acts upward. This reduces the effective
weight of the mower.

On the other hand, while pushing a lawn mower, a force at an angle 9 is applied on it, as
shown in the following figure.
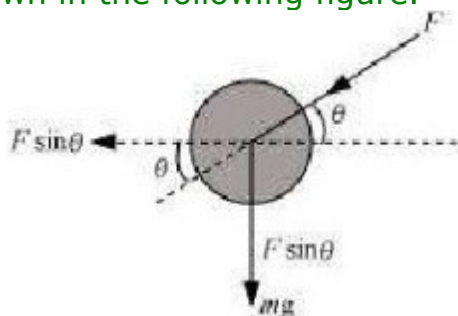


In this case, the vertical component of the applied force acts in the direction of the
weight Of the mower. This increases the effective weight of the mower.

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

(d) According to Newton's second law of motion, we have the equation of motion:

$$F = ma = m\frac{\Delta v}{\Delta t} F = ma = m\frac{\Delta v}{\Delta t}$$

Where, F= Stopping force experienced by the cricketer as he catches the ball m= Mass of the ball Δt= Time of impact of the ball with the hand  Where, F= Stopping force experienced by the cricketer as he catches the ball m= Mass of the ball Δt= Time of impact of the ball with the hand

It can be inferred from equation (i) that the impact force is inversely proportional to the  impact time, i.e.,  It can be inferred from equation (i) that the impact force is inversely proportional to the  impact time, i.e., F∝1ΔtF∝1Δt

Equation (ii) shows that the force experienced by the cricketer decreases if the time of  impact increases and vice versa.  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.  Equation (ii) shows that the force experienced by the cricketer decreases if the time of  impact increases and vice versa.  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.

Additional ExercisesP.111

**Q.5.24:** Figure 5.17 shows the position-time graph of a body of mass 0.04 kg. Suggest a suitable physical context for this motion. What is the time between two consecutive impulses received by the body ? What is the magnitude of each impulse ?
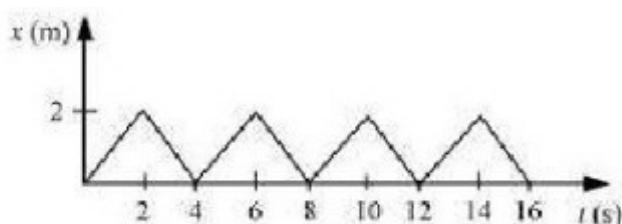


Figure 5.17

**Ans :** A ball rebounding between two walls located between at x O and x — 2 cm; after every

2 s, the ball receives an impulse of magnitude 0.08 x 10−210−2 kg m/s from the walls

The given graph shows that a body changes its direction of motion after every 2 s.

Physically, this situation can be visualized as a ball rebounding to and fro between two

stationary walls situated between positions x = O and x = 2 cm. Since the slope Of the x-

t graph reverses after every 2 s, the ball collides with a wall after every 2 s. Therefore,

ball receives an impulse after every 2 s.

Mass of the ball, m = 0.04 kg

u=(2−0)×10−2(2−0)=10−2m/su=(2−0)×10−2(2−0)=10−2m/s

Velocity of the ball before collision, u = 10−210−2 m/s

Velocity of the ball after collision, v = −10−2−10−2 m/s
(Here, the negative sign arises as the ball reverses its direction of motion.)
Magnitude Of impulse = Change in momentum
=|mv−mu|=|0.04(v−u)|=||0.04(−10−2−10−2)||=0.08×10−2kgm/s=|mv−mu|=|0.04(v−u)|=|0.04(−10−2−10−2)|=0.08×10−2kgm/s
=|mv−mu|=|0.04(v−u)|=||0.04(−10−2−10−2)||=0.08×10−2kgm/s=|mv−mu|=|0.04(v−u)|=|0.04(−10−2−10−2)|=0.08×10−2kgm/s

**Q.5.25:** Figure 5.18 shows a man standing stationary with respect to a horizontal conveyor belt that is accelerating with 1 m s−2s−2. What is the net force on the man? If the coefficient of static friction between the man's shoes and the belt is 0.2, up to what acceleration of the belt can the man continue to be stationary relative to the belt ? (Mass of the man = 65 kg.)
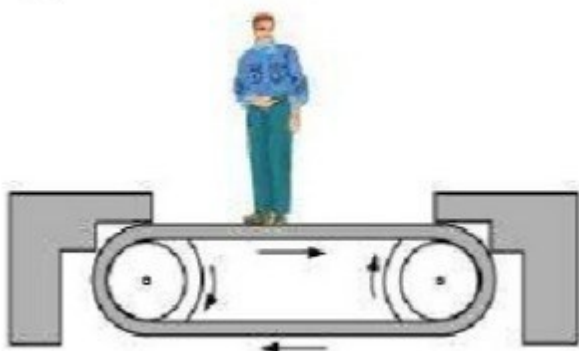


**Ans :** Mass of the man, m=65kg Acceleration of the belt, a=1m/s2 Coefficient of static friction, μ=0.2 The net force F t acting on the man is given by Newton's second law of motion as: Mass of the man, m=65kg Acceleration of the belt, a=1m/s2 Coefficient of static friction, μ=0.2 The net force F t acting on the man is given by Newton's second law of motion as:
Fret=ma=65×1=65NFret=ma=65×1=65N
The man will continue to be stationary with respect to the conveyor belt until the net force on the man is less than or equal to the frictional force fst exerted by the belt, i.e., The man will continue to be stationary with respect to the conveyor belt until the net force on the man is less than or equal to the frictional force fst exerted by the belt, i.e.,
F′net=fsma′=μmg∴a′=0.2×10=2m/s2Fnet′=fsma′=μmg∴a′=0.2×10=2m/s2
Therefore, the maximum acceleration of the belt up to which the man can stand stationary is 2m/s2 . Therefore, the maximum acceleration of the belt up to which the man can stand stationary is 2m/s2 .

**Q.5.26:** A stone of mass m tied to the end of a string revolves in a vertical circle of radius R. The net forces at the lowest and highest points of the circle directed vertically downwards are : [Choose the correct alternative]

| | Lowest Point | Highest Point |
|---|---|---|
| (a) | $mg - T_1$ | $mg + T_2$ |
| (b) | $mg + T_1$ | $mg - T_2$ |
| (c) | $mg + T_1 - \dfrac{(mv_1^2)}{R}$ | $mg - T_2 + \dfrac{(mv_1^2)}{R}$ |
| (d) | $mg - T_1 - \dfrac{(mv_1^2)}{R}$ | $mg + T_2 + \dfrac{(mv_1^2)}{R}$ |

$T_1T_1$ and $v_1v_1$ denote the tension and speed at the lowest point. $T_2T_2$ and $v_2v_2$ denote corresponding values at the highest point.

**Ans :** (a)The free body diagram of the stone at the lowest point is shown in the following figure.
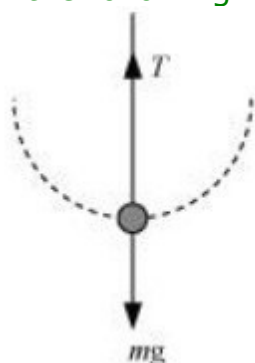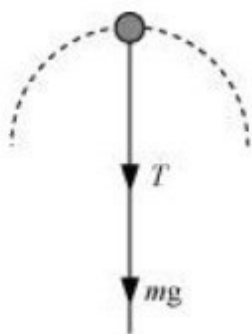


According to Newton's second law of motion, the net force acting on the stone at this point is equal to the centripetal force, i.e.,
$F_{ret} = T - mg = \dfrac{mv_1^2}{R}$ ...(i)$F_{ret} = T - mg = \dfrac{mv_1^2}{R}$ ...(i)
Where, $v_1v_1$ = Velocity at the lowest point
The free body diagram of the stone at the highest point is shown in the following figure.



Using Newton's second law of motion, we have:
$T + mg = \dfrac{mv_2^2}{R}$...(ii)$T + mg = \dfrac{mv_2^2}{R}$...(ii)
Where, $v_2v_2$ = Velocity at the highest point
It is clear from equations (i) and (ii) that the net force acting at the lowest and the highest points are respectively (T – mg) and (T + mg)

**Q.5.27:** A helicopter of mass 1000 kg rises with a vertical acceleration of 15 m s−2s−2. The crew and the passengers weigh 300 kg. Give the magnitude and direction of the
(a) force on the floor by the crew and passengers,
(b) action of the rotor of the helicopter on the surrounding air,
(c) force on the helicopter due to the surrounding air

**Ans :** (a) Mass of the helicopter, mh=1000kg Mass of the crew and passengers, mp=300kg Total mass of the system, m=1300kg Acceleration of the helicopter, a=15m/s2 Using Newton's second law of motion, the reaction force R, on the system by the floor can be calculated as: (a) Mass of the helicopter, mh=1000kg Mass of the crew and passengers, mp=300kg Total mass of the system, m=1300kg Acceleration of the helicopter, a=15m/s2 Using Newton's second law of motion, the reaction force R, on the system by the floor can be calculated as: R−mp9=ma=mp(g+a)=300(10+15)=300×25=7500N since the helicopter is accelerating vertically upward, the force on the floor by the crew and passengers is 7500N, directed downward. R−mp9=ma=mp(g+a)=300(10+15)=300×25=7500N since the helicopter is accelerating vertically upward, the force on the floor by the crew and passengers is 7500N, directed downward.
 (b) Using Newton's second law of motion, the reaction force R′ , experienced by the helicopter can be calculated as: R′−mg=mq (b) Using Newton's second law of motion, the reaction force R' , experienced by the helicopter can be calculated as: R'−mg=mq =m(g+a)=1300(10+15)=1300×25=32500N The reaction force experienced by the helicopter from the surrounding air is acting upward. Hence, as per Newton's third law of motion, the action of the rotor on the surrounding air will be 32500N, directed downward. =m(g+a)=1300(10+15)=1300×25=32500N The reaction force experienced by the helicopter from the surrounding air is acting upward. Hence, as per Newton's third law of motion, the action of the rotor on the surrounding air will be 32500N, directed downward.
(c) The force on the helicopter due to the surrounding air is 32500 N, directed upward.

**Q.5.28:** A stream of water flowing horizontally with a speed of 15 m s−1s−1 gushes out of a tube of cross-sectional area 10−210−2 m2m2, and hits a vertical wall nearby. What is the force exerted on the wall by the impact of water, assuming it does not rebound ?

**Ans :** Speed of the water stream, v=15m/s Cross-sectional area of the tube, A=10−2m2 Volume of water coming out from the pipe per second, V=AV=15×10−2m3/s Speed of the water stream, v=15m/s Cross-sectional area of the tube, A=10−2m2 Volume of water coming out from the pipe per second, V=AV=15×10−2m3/s
 Density of water, ρ=103kg/m3 Mass of water flowing out through the pipe per second =ρ×V=150kg/s The water strikes the wall and does not rebound. Therefore, the force exerted by the water on the wall is given by Newton's second law of motion as: Density of water, ρ=103kg/m3 Mass of water flowing out through the pipe per second =ρ×V=150kg/s The

water strikes the wall and does not rebound. Therefore, the force exerted by the  water on the wall is given by Newton's second law of motion as:
F= Rate of change of momentum $=\Delta P \Delta t=mvt=150\times 15=2250NF=$ Rate of change of momentum $=\Delta P \Delta t=mvt=150\times 15=2250N$

**Q.5.29:** Ten one-rupee coins are put on top of each other on a table. Each coin has a mass m. Give the magnitude and direction of
(a) the force on the 7th7th coin (counted from the bottom) due to all the coins on its top,
(b) the force on the7th7th coin by the eighth coin,
(c) the reaction of the 6th6th coin on the 7th7th coin

**Ans :**  (a) Force on the seventh coin is exerted by the weight of the three coins on its top.  Weight of one coin =mg Weight of three
coins =3mg Hence, the force exerted on the 7 th  coin by the three coins on its top is 3mg. This force  acts vertically downward.  (a) Force on the seventh coin is exerted by the weight of the three coins on its
top.  Weight of one coin =mg Weight of three coins =3mg Hence, the force exerted on the 7 th  coin by the three coins on its top is 3mg. This force  acts vertically downward.

 (b) Force on the seventh coin by the elghth coin is because of the weight of the eighth  coin and the other two coins (ninth and tenth) on its
top.  Weight of the eighth coin =mg Weight of the ninth coin =mg Weight of the tenth coin =mg (b) Force on the seventh coin by the elghth coin is because of the weight of the eighth  coin and the other two coins (ninth and tenth) on its top.  Weight of the eighth coin =mg Weight of the ninth coin =mg Weight of the tenth coin =mg
 Total weight of these three coins =3mg Hence, the force exerted on the 7 th  coin by the eighth coin is 3mg . This force acts  vertically downward.  Total weight of these three coins =3mg Hence, the force exerted on the 7 th  coin by the eighth coin is 3mg . This force acts  vertically downward.

(c) The 6th coin experiences a downward force because of the weight of the four coins
(7th, e, 90', and 100') on its top.
Therefore, the total downward force experienced by the 6th coin is 4mg. As per Newton's third law of motion, the 6+ coin will produce an equal reaction force on
the 7th coin, but in the opposite direction. Hence, the reaction force of the 6th coin on the
7th coin is of magnitude 4mg. This force acts in the upward direction.

**Q.5.30:** An aircraft executes a horizontal loop at a speed of 720 km/h with its wings banked at 15°. What is the radius of the loop ?

**Ans :**  Speed of the aircraft, v=720km/h=720×518=200m/s Acceleration due to gravity, g=10m/s2 Angle of banking, θ=15∘ For radius r, of the loop, we have the relation:  Speed of the
aircraft, v=720km/h=720×518=200m/s Acceleration due to
gravity, g=10m/s2 Angle of banking, θ=15∘ For radius r, of the loop, we have the relation:

tanθ=v2rgr=v2gtanθ=200×20010×tan15=40000.268=14925.37m=14.9
2kmtanθ=v2rgr=v2gtanθ=200×20010×tan15=40000.268=14925.37m=
14.92km

**Q.5.31:** A train runs along an unbanked circular track of radius 30 m at a speed of 54
km/h. The mass of the train is 106 kg. What provides the centripetal force required
for this purpose — The engine or the rails ? What is the angle of banking required to
prevent wearing out of the rail ?

**Ans :**  Radius of the circular track, r=30m Speed of the
train, v=54km/h=15m/s Mass of the train, m=106kg The centripetal force
is provided by the lateral thrust of the rail on the wheel. As per  Newton's
third law of motion, the wheel exerts an equal and opposite force on the
rail.  Radius of the circular track, r=30m Speed of the
train, v=54km/h=15m/s Mass of the train, m=106kg The centripetal force
is provided by the lateral thrust of the rail on the wheel. As per  Newton's
third law of motion, the wheel exerts an equal and opposite force on the
rail.
 This reaction force is responsible for the wear and rear of the rail  The
angle of banking θ, is related to the radius (r) and speed (v) by the
relation: tanθ=v2rg This reaction force is responsible for the wear and
rear of the rail  The angle of banking θ, is related to the radius (r) and
speed (v) by the relation: tanθ=v2rg
=(15)230×10=2253000=tan−1(0.75)=36.87∘ Therefore, the angle of
banking is
about 36.87∘.=(15)230×10=2253000=tan−1(0.75)=36.87∘ Therefore,
the angle of banking is about 36.87∘.

**Q.5.32:** A block of mass 25 kg is raised by a 50 kg man in two different ways as
shown in Fig. 5.19. What is the action on the floor by the man in the two cases ? If
the floor yields to a normal force of 700 N, which mode should the man adopt to lift
the block without the floor yielding ?
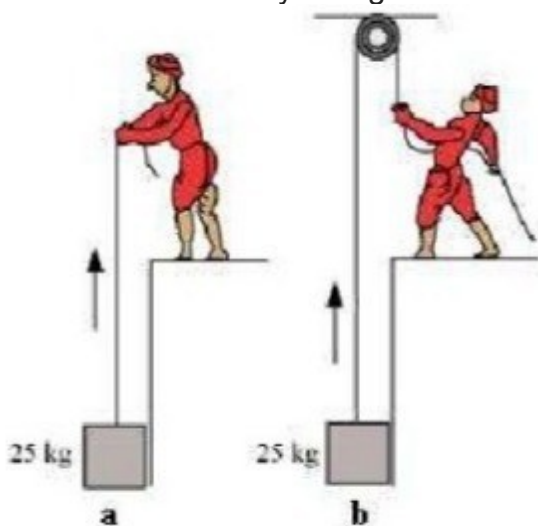


**Ans :** 750N and 250N in the respective cases; Method (b)  Mass of the
block, m=25kg Mass of the man, M=50kg Acceleration due to
gravity, g=10m/s2 Force applied on the block, F=25×10=250N Weight of
the man, W=50×10=500N750N and 250N in the respective cases;
Method (b)  Mass of the block, m=25kg Mass of the

man, M=50kg Acceleration due to gravity, g=10m/s2 Force applied on the block, F=25×10=250N Weight of the man, W=50×10=500N
Case (a): When the man lifts the block directly  In this case, the man applies a force in the upward direction. This increases his
apparent  weight.  Action on the floor by the man =250+500=750N Case (a): When the man lifts the block directly  In this case, the man applies a force in the upward direction. This increases his apparent  weight.  Action on the floor by the man =250+500=750N
Case (b): When the man lifts the block using a pulley  In this case, the man applies a force in the downward direction. This decreases
his  apparent welght. ∴ Action on the floor by the
man =500−250=250N Case (b): When the man lifts the block using a pulley  In this case, the man applies a force in the downward direction. This decreases his  apparent welght. ∴ Action on the floor by the
man =500−250=250N
If the floor can yield to a normal force of 700N, then the man should adopt the second  method to easily lift the block by applying lesser
force.  If the floor can yield to a normal force of 700N, then the man should adopt the second  method to easily lift the block by applying lesser force.

**Q.5.33:** A monkey of mass 40 kg climbs on a rope (Fig. 5.20) which can stand a maximum tension of 600 N. In which of the following cases will the rope break: the monkey
(a) climbs up with an acceleration of 6 m s−2s−2
(b) climbs down with an acceleration of 4 m s−2s−2
(c) climbs up with a uniform speed of 5 m s−1s−1
(d) falls down the rope nearly freely under gravity? (Ignore the mass of the rope).
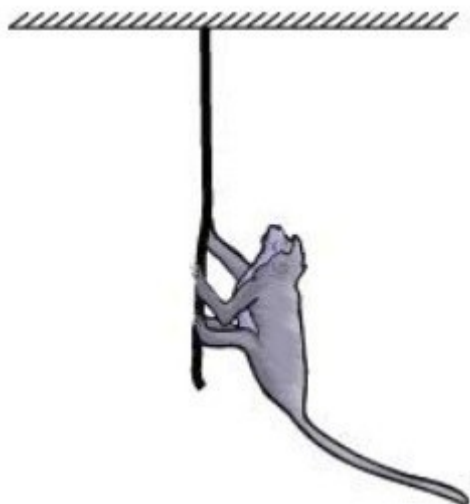


**Ans :**  Case (a)  Mass of the monkey, m=40kg Acceleration due to gravity, g=10m/s Maximum tension that the rope can
bear, Tmax=600N Acceleration of the monkey, a=6m/s2 upward  Using Newton's second law of motion, we can write the equation of motion
as:  Case (a)  Mass of the monkey, m=40kg Acceleration due to gravity, g=10m/s Maximum tension that the rope can

bear, Tmax=600N Acceleration of the monkey, a=6m/s2 upward  Using Newton's second law of motion, we can write the equation of motion as: T−mg=ma∴T=m(g+a)=40(10+6)=640N since T>T maxt  the rope will break in this
case. T−mg=ma∴T=m(g+a)=40(10+6)=640N since T>T maxt  the rope will break in this case.

Case(b)
\(\begin{array}{l}{{\text { Acceleration of the monkey, } a=4 \mathrm{m} / \mathrm{s}^{2} \text { downward }}}\\ {\text { Using Newton's second law of motion, we can write the equation of motion as: }} \\ {m g-T=m a} \\ {\therefore T=m(g-a)} \\ {=40(10-4)} \\ {=240 N} \\ {\text { since } } T

**Q.5.34:** Two bodies A and B of masses 5 kg and 10 kg in contact with each other rest on a table against a rigid wall (Fig. 5.21). The coefficient of friction between the bodies and the table is 0.15. A force of 200 N is applied horizontally to A. What are (a) the reaction of the partition (b) the action-reaction forces between A and B ? What happens when the wall is removed? Does the answer to (b) change, when the bodies are in motion? Ignore the difference between μs and μk
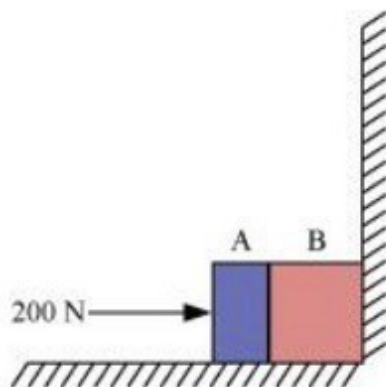


**Ans :**  (a) Mass of body A,mA=5kg Mass of body B,m8=10kg Applied force, F=200N Coefficient of friction, μs=0.15 The force of friction is given by the relation:  (a) Mass of body A,mA=5kg Mass of body B,m8=10kg Applied force, F=200N Coefficient of friction, μs=0.15 The force of friction is given by the relation:
fs=μ(mA+mB)g=0.15(5+10)×10=1.5×15=22.5N leftward  Net force acting on the partition
= 200−22.5=177.5N rightward fs=μ(mA+mB)g=0.15(5+10)×10=1.5×15 =22.5N leftward  Net force acting on the partition
= 200−22.5=177.5N rightward
 As per Newton's third law of motion, the reaction force of the partition will be in the  direction opposite to the net applied force.  Hence, the reaction of the partition will be 177.5N, in the leftward direction.  As per Newton's third law of motion, the reaction force of the partition will be in the  direction opposite to the net applied force.  Hence, the reaction of the partition will be 177.5N, in the leftward direction.
 (b) Force of friction on mass A: fA=μmAg=0.15×5×10=7.5N leftward  Net force exerted by mass A on mass B=200−7.5=192.5N rightward  As per

Newton's third law of motion, an equal amount of reaction force will be exerted by mass B on mass A, l.e., 192.5N acting leftward. (b) Force of friction on mass A: fA=μmAg=0.15×5×10=7.5N leftward Net force exerted by mass A on mass B=200−7.5=192.5N rightward As per Newton's third law of motion, an equal amount of reaction force will be exerted by mass B on mass A, l.e., 192.5N acting leftward.
 When the wall is removed, the two bodies will move in the direction of the applied force Net force acting on the moving system = 177.5N The equation of motion for the system of acceleration a , can be written as: Net force =(mA+mB)a When the wall is removed, the two bodies will move in the direction of the applied force Net force acting on the moving system = 177.5N The equation of motion for the system of acceleration a , can be written as: Net force =(mA+mB)a
∴a= Net force mA+mB=177.55+10=177.515=11.83m/s2 Net force causing mass A to move: FA=mAa=5×11.83=59.15N∴a= Net force mA+mB=177.55+10=177.515=11.83m/s2 Net force causing mass A to move: FA=mAa=5×11.83=59.15N
 This force will act in the direction of motion. As per Newton's third law of motion, an equal amount of force will be exerted by mass B on mass Ar i.e., 133.3N, acting opposite to the direction of motion. This force will act in the direction of motion. As per Newton's third law of motion, an equal amount of force will be exerted by mass B on mass Ar i.e., 133.3N, acting opposite to the direction of motion.
**Q.5.35:** A block of mass 15 kg is placed on a long trolley. The coefficient of static friction between the block and the trolley is 0.18. The trolley accelerates from rest with 0.5 m s−2s−2 for 20 s and then moves with uniform velocity. Discuss the motion of the block as viewed by (a) a stationary observer on the ground, (b) an observer moving with the trolley
**Ans :** (a) Mass of the block, m=15kg coefficient of static friction, μ=0.18 Coefficient of static friction, μ=0.18 Acceleration of the trolley, a=0.5m/s2 As per Newton's second law of motion, the force (F) on the block caused by the motion of the trolley is given by the relation: (a) Mass of the block, m=15kg coefficient of static friction, μ=0.18 Coefficient of static friction, μ=0.18 Acceleration of the trolley, a=0.5m/s2 As per Newton's second law of motion, the force (F) on the block caused by the motion of the trolley is given by the relation:
F=ma=15×0.5=7.5N This force is acted in the direction of motion of the trolley. Force of static friction between the block and the trolley: f=μmg=0.18×15×10=27NF=ma=15×0.5=7.5N This force is acted in the direction of motion of the trolley. Force of static friction between the block and the trolley: f=μmg=0.18×15×10=27N
The force of static friction between the block and the trolley is greater than the applied
external force. Hence, for an observer on the ground, the block will appear to be at rest.
When the trolley moves with uniform velocity there will be no applied external force.
Only the force of friction will act on the block in this situation.

(b) An observer, moving with the trolley, has some acceleration. This is the case of non-
inertial frame Of reference. The frictional force, acting on the trolley backward, is
opposed by a pseudo force of the sarne magnitude. However, this force acts in the
opposite direction. Thus, the trolley will appear to be at rest for the observer moving
with the trolley.

**Q.5.36:** The rear side of a truck is open and a box of 40 kg mass is placed 5 m away from the open end as shown in Fig. 5.22. The coefficient of friction between the box and the surface below it is 0.15. On a straight road, the truck starts from rest and accelerates with 2 m s−2s−2. At what distance from the starting point does the box fall off the truck? (Ignore the size of the box).
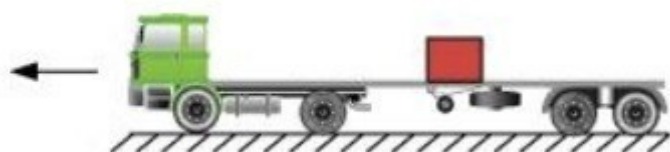


**Ans :** Mass of the box, m=40kg Coefficient of friction, μ=0.15 Initial velocity, u=0 Acceleration, a=2m/s2 Mass of the box, m=40kg Coefficient of friction, μ=0.15 Initial velocity, u=0 Acceleration, a=2m/s2
Distance of the box from the end of the truck, s′=5m As per Newton's second law of motion, the force on the box caused by the accelerated F motion of the truck is given by: F=ma=40×2=80N Distance of the box from the end of the truck, s′=5m As per Newton's second law of motion, the force on the box caused by the accelerated F motion of the truck is given by: F=ma=40×2=80N
As per Newton's third law of motion, a reaction force of 80N is acting on the box in the  backward direction. The backward motion of the box is opposed by the force of friction f acting between the box and the floor of the truck. This force is given by: f=μmg=0.15×40×10=60N As per Newton's third law of motion, a reaction force of 80N is acting on the box in the  backward direction. The backward motion of the box is opposed by the force of friction f acting between the box and the floor of the truck. This force is given by: f=μmg=0.15×40×10=60N
=0.15×40×10=60N∴ Net force acting on the
block: F net =80−60=20N backward  The backward acceleration produced in the box is given by =0.15×40×10=60N∴ Net force acting on the
block: F net =80−60=20N backward  The backward acceleration produced in the box is given by
=aback=Fmtm=2040=0.5m/s2=aback=Fmtm=2040=0.5m/s2
Using the second equation of motion, time t can be calculated as: s
′=ut+12a bad t25=0+12×0.5×t2∴t=√20s Using the second equation of motion, time t can be calculated as: s
′=ut+12a bad t25=0+12×0.5×t2∴t=20s
Hence, the box will fall from the truck after √20s from start.  The distance s, travelled by the truck in √20s is given by the

relation: s=ut+12at2=0+12×2×(√20)2=20m Hence, the box will fall from the truck after 20s from start.  The distance s, travelled by the truck in 20s is given by the relation: s=ut+12at2=0+12×2×(20)2=20m

**Q.5.37:** A disc revolves with a speed of 33133313 rev/min, and has a radius of 15 cm. Two coins are placed at 4 cm and 14 cm away from the centre of the record. If the coefficient of friction between the coins and the record is 0.15, which of the coins will revolve with the record ?

**Ans :**  Coin placed at 4cm from the centre  Mass of each coin =m Radius of the disc, r=15cm=0.15m Coin placed at 4cm from the centre  Mass of each coin =m Radius of the disc, r=15cm=0.15m

 Frequency of revolution, v=3313 rev/min =1003×60=59 rev/s  coefficient of friction, μ=0.15 Frequency of

revolution, v=3313 rev/min =1003×60=59 rev/s  coefficient of friction, μ=0.15

In the given situation, the coin having a force of friction greater than or equal to the centripetal force provided by the rotation of the disc will revolve with the disc. If this is not the case, then the coin will slip from the disc.

Coin placed at 4 cm:

Radius of revolution, r' = 4 cm = 0.04 m

Angular frequency, ω = 2πv

=2×227×59=3.49s−1=2×227×59=3.49s−1

Frictional force, f = μmg = 0.15 × m × 10 = 1.5m N

Centripetal force on the coin:

FcentFcent.

=mr′ω2=m×0.04×(3.49)2=mr'ω2=m×0.04×(3.49)2

r''= 0.49m N

Since f > Fcent, the coin will revolve along with the record.

Coin placed at 14 cm:

Radius,

= 14 cm = 0.14 m

Angular frequency, ω = 3.49 s−1

Frictional force, f' = 1.5m N

Centripetal force is given as:

FcentFcent.

=mr″ω2=m×0.14×(3.49)2=1.7mN=mr''ω2=m×0.14×(3.49)2=1.7mN

Since f

**Q.5.38:** You may have seen in a circus a motorcyclist driving in vertical loops inside a 'deathwell' (a hollow spherical chamber with holes, so the spectators can watch from outside). Explain clearly why the motorcyclist does not drop down when he is at the uppermost point, with no support from below. What is the minimum speed required at the uppermost position to perform a vertical loop if the radius of the chamber is 25 m ?

**Ans :** In a death-well, a motorcyclist does not fall at the top point Of a vertical loop because both the force of normal reaction and the weight of the motorcyclist act downward and are balanced by the centripetal force. This situation is shown in the following figure.
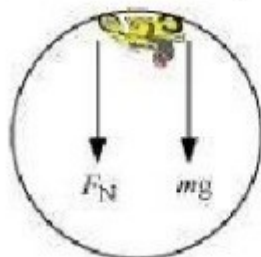
The net force acting on the motorcyclist is the sum of the normal force and the force
due to gravity (Fg mg).
The equation of motion for the centripetal acceleration a, , can be written as:
 The net force acting on the motorcyclist is the sum of the normal force (Fn) and the force  due to gravity (F9=mg) The equation of motion for the centripetal acceleration acr can be written as:  The net force acting on the motorcyclist is the sum of the normal force (Fn) and the force  due to gravity (F9=mg) The equation of motion for the centripetal acceleration acr can be written as:
F net =macFN+Fg=macFN+mg=mv2rF net =macFN+Fg=macFN+mg=mv2r
 Normal reaction is provided by the speed of the motorcyclist. At the minimum speed (vmin),Fn=0 Normal reaction is provided by the speed of the motorcyclist. At the minimum speed (vmin),Fn=0
(vmin),Fn=0mg=mv2minr∴vmin=√rg=√25×10=15.8m/s(vmin),Fn=0mg= mvmin2r∴vmin=rg=25×10=15.8m/s

**Q.5.39:** A 70 kg man stands in contact against the inner wall of a hollow cylindrical drum of radius 3 m rotating about its vertical axis with 200 rev/min. The coefficient of friction between the wall and his clothing is 0.15. What is the minimum rotational speed of the cylinder to enable the man to remain stuck to the wall (without falling) when the floor is suddenly removed ?

**Ans :** Mass of the man, m=70kg Radius of the drum, r=3m coefficient of friction, μ=0.15 Mass of the man, m=70kg Radius of the
drum, r=3m coefficient of friction, μ=0.15
 Frequency of rotation, v=20060=103 rev/s  The necessary centripetal force required for the rotation of the man is provided by the  normal force (Fn). Frequency of rotation, v=20060=103 rev/s  The necessary centripetal force required for the rotation of the man is provided by the  normal force (Fn).
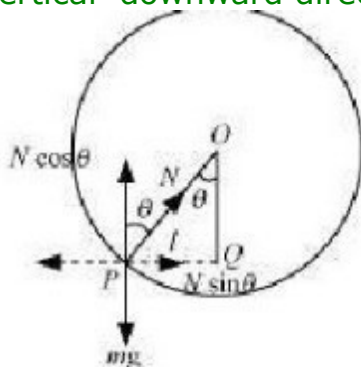 When the floor revolves, the man sticks to the wall of the drum. Hence, the weight of the  man (mg) acting downward is balanced by the frictional force (f=μFn) acting upward.  When the floor revolves, the man sticks to the wall of the drum. Hence, the weight of the  man (mg) acting downward is balanced by the frictional force (f=μFn) acting upward.
 Hence, the man will not fall until: mg√gμr Hence, the man will not fall until: mggμr

The minimum angular speed is given
as: ωmin=√gµr=√100.15×3=4.71 rad s−1 The minimum angular speed is
given as: ωmin=gµr=100.15×3=4.71 rad s−1

**Q.5.40:** A thin circular loop of radius R rotates about its vertical diameter with an
angular frequency ω. Show that a small bead on the wire loop remains at its
lowermost point for ω ≤ g / R . What is the angle made by the radius vector joining
the centre to the bead with the vertical downward direction for ω = 2g / R ? Neglect
friction.

**Ans :**  Let the radius vector joining the bead with the centre make an
angle θ, with the vertical  downward direction.  Let the radius vector
joining the bead with the centre make an angle θ, with the
vertical  downward direction.



OP=R= Radius of the circle N= Normal reaction  The respective vertical
and horizontal equations of forces can be written as: mg=Ncosθ…
(i)m||ω2=Nsinθ…(ii)OP=R= Radius of the circle N= Normal reaction  The
respective vertical and horizontal equations of forces can be written
as: mg=Ncosθ…(i)m|ω2=Nsinθ…(ii)

 In △OPQ, we have: sinθ=IR In △OPQ, we have: sinθ=IR
 Substituting equation (iii) in equation (ii), we
get: m(Rsinθ)ω2=NsinθmRω2=N…(iv) Substituting equation (iv) in
equation (i), we get:  Substituting equation (iii) in equation (ii), we
get: m(Rsinθ)ω2=NsinθmRω2=N…(iv) Substituting equation (iv) in
equation (i), we get:

 Substituting equation (iv) in equation (i), we
get: mg=mRω2cosθcosθ=gRe2…(v) Substituting equation (iv) in equation
(i), we get: mg=mRω2cosθcosθ=gRe2…(v)

 since cosθ≤1, the bead will remain at its lowermost point
for gRω2≤1ω≤√gR since cosθ≤1, the bead will remain at its lowermost
point for gRω2≤1ω≤gR

 For ω=√2gRω2=2gR On equating equations (v) and (vi), we
get:  For ω=2gRω2=2gR On equating equations (v) and (vi), we get:

 On equating equations (v) and (vi), we get 2gR=gRcosθ On equating
equations (v) and (vi), we get 2gR=gRcosθ

cosθ=12∴θ=cos−1(0.5)=60∘cosθ=12∴θ=cos−1(0.5)=60∘