Class 11 Science NCERT Solutions for Chapter 5 Laws of Motion

Q1.Give the magnitude and direction of the net force acting on

(a) a hovercraft moving at a constant speed of 20 km/h on a rough road,

(b) a bottle cap of mass 5 gm floating on wine,

(c) an electron moving in space free of electromagnetic fields and other matter,

(d) a raindrop falling down at a constant velocity,

(e) a kite held stationary in the sky.

A.

(a) The net force acting on the hover craft is zero.

As the hovercraft is moving at a constant velocity its acceleration is zero. Thus, according to Newton's second of motion the net force acting on it is zero.

(b) The net force acting on the floating bottle cap is zero.

The weight of the cork acting downwards is balanced by the buoyant forces of the wine pushing it upwards.

(c) The net force acting on the electron is zero.

The electron moving in the remote space has no external forces working on it thus the net force acting on it is zero.

(d) The net force working on the rain drop is zero.

As the rain drop is falling at a constant velocity its acceleration is zero. Thus, according to Newton's second law of motion the net force acting on it is zero.

(e) The net force working on the kite is zero.

The kite is stationary so according to Newton's first law of motion no net force is acting on the kite.

Q2. A ball of mass 0.5 kg is tossed vertically upwards. What is the magnitude and direction of the net force acting on the ball,

(a) as it moves upwards ?

(b) as it moves downwards ?

(c) at the highest point of its vertical climb.

Do any of your answers change if the ball was kicked at a 45° angle with the horizontal plane? Ignore the air resistance.

A.

Regardless of the direction of the ball's motion, the acceleration due to gravity is the only force which acts on the ball in all the three cases and in all the cases it is acting in the vertically downwards direction. The magnitude of this force is given by, F =ma. Where m is the mass of the ball and 'a' is the acceleration due to gravity.

m = 0.5 kg

a = 10 m/s^{-2}

Therefore, F = 0.5 x 10 = 5N.

Thus, a net force of 5N acts on the ball in all the above three cases and it acts in the vertically downward direction.

If the ball was kicked at a 45° angle, it will have both the vertical and horizontal components of velocity. Nonetheless the only acceleration on the body will still be 'g' .Thus, the net force acting on the body will still be 5N.

Q3. What is the direction and magnitude of the net force acting on a 0.2 kg burger,

(a) right after someone drops it from a table,

(b) Right after someone drops it out from car moving at a constant speed of 30 km/h,

(c) Right after it is dropped out of a window of a truck accelerating at 1 m s^{-2} ,

(d) Lying on a table in a railway carriage which is accelerating at 1m/s^2.

Do not consider air resistance in any of the above cases.

A.

(a) F = ma

m = 0.2 kg

a = 10 m/s^2

F = 0.2 x 10 =2N

Acceleration due to gravity always works in the downward direction.

(b) As the speed of the car is constant there is no acceleration in the direction of motion. Thus, no horizontal force acts on the burger, as a result it is still 2N force acting on the burger in the downward direction.

(c) Even though the truck is accelerating in the horizontal direction applying a horizontal force of 0.2N (f = 0.2 x 1) on the burger. But moment the burger is dropped from the truck there is no horizontal force acting on it and the only acceleration it is experiencing is the acceleration due to gravity in the vertically downward direction. Thus here again the net force acting on the burger is 2N, in the vertically downward direction.

(d) As it lies inside an accelerating railway carriage its weight is balanced by the normal reaction force of the floor. So the only acceleration on the burger is provided by the horizontal acceleration of the train.

Thus a net force of, F = 0.2 x 1 = 0.2N acts on the burger in the horizontal direction.

Q4. A stone of mass m is tied to a string of length l. If the stone is spun at a speed of v around a fixed center, the force acting on the stone directed towards the center is:

(i) T, (ii) ???? – (mv^2) /???? (iii) ???? + (????????^{2})/ l (iv) 0

T = tension on the string.

A.

(i) T. The total force acting on the stone is the centripetal force which is provided by the tension on the string.

Q5. A 30 kg boulder was initially moving at a velocity of 10 m/s, in order to stop it 10 N of constant retarding force is applied on it. After how long will the boulder stop?

A.

Given, m = 30 kg.

Retarding force = -10N

u = 10 m/s

v = 0.

We know, F = ma

-10 = 30 x a

a = -1/3 ms^{-2}

Also, v = u + at

0 = 10 – t/3

Therefore, t = -10 x (-3) = 30 s.

Q6. A ball of mass 5 kg experiences a change in its velocity from 2 m/s to 4 m/s within 20 s, under the influence of a constant force. However, the direction the ball is moving in does not change. Find the direction and magnitude of this force.

A.

Given, m = 5 kg , t = 20s

u = 2 ms^{-1}, v = 4 m/s

We know, F =ma

Or, F = m[(v-u)/t] [Since a = (v –u)/t]

F = 5[(4 – 2)/ 20] = 0.5N along the direction of motion.

Q7. A 10 kg body is under the influence of two perpendicular forces of 6N and 8N. What is the direction and the magnitude of the acceleration in it?

Given,

m = 10 kg,

F1 = 6N, F2 = 8N

The resultant force, F = $\sqrt{F1^2 + F2^2} = \sqrt{6^2 + 8^2}$

- F = 10N

We know, acceleration, a = F/m

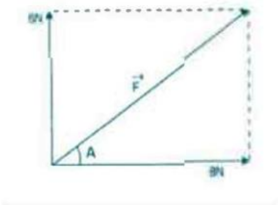
= 10/10 = 1

Thus, acceleration, a= 1 m/s^2 in the direction of the resultant force.

Or, Tan A = 6/8 = 0.75

A = $\tan^{-1}(0.75)$

= 37° with 8N Force



Q8. A man is texting on his phone as he drives his car at 40 kmph, he suddenly notices a child is crossing the road so he rams his brake bringing the car to stop in 2s. If the car's mass is 4000 kg and he weighs 60 kg, what was the retarding force on the car?

A.

Given,

m1 = 4000 kg, m2 = 60 kg

Total mass, m = 4060 kg

u = 40 kmph = 11.11 m/s

v = 0

t = 2 s

We know, acceleration = (v – u)/t

= (0 – 11.11)/2

a = -5.55 m/s^2

Thus, the retarding force, F = ma

= 4060 (-5.55)

F = -22553.3N or -2.3 x 10^4 N

Q9. A space shuttle with a lift off mass of 25000 kg is accelerating from the surface at 6 m/s^2. What is the initial thrust (Force) achieved from the blast?

A.

Given,

m = 25000 kg

a = 6 m/s^2

Acceleration due to gravity = 10 m/s^2

According to Newton's second law of motion, the net thrust acting on the rocket is:

F – mg = ma

F = m (g + a)

= 25000 (10 + 6)

=400000 N Or 4 x 10^5 N

Q10. A 0.5 kg ball is moving at a constant velocity of 5 m/s towards west. It is then subjected to a uniform 10N force towards east for 30 s. Taking the moment the force is applied on the ball to be t = 0 and the location of

the ball at that instant to be x = 0, find the location of the ball at t =- 10s, 20s and 100s.

A.

Given,

Mass of the ball = 0.5 kg

Initial speed, u = 5 m/s towards west

Force acting on the ball = -10 N

Thus, acceleration produced = F/m = -10/0.5

a = -20 ms^{-2}

(1) At t = 10s

Acceleration, a' = 0, u = 5 m/s

s = ut + ½ at^2

= 5(-10) + 0

= -50m

(2)At t = 20

Acceleration, a" = -20 m/s^2 and u = 5 m/s

S = ut + ½ $a''t^2$

S = 5×20 + ½ (-20)(20^2)

S = 100 – 4000 = -3900m

(3) At t = 100 s

For $0 \leq t \leq 30s$

a = -20 m/s^2

u = 5 m/s

s1 = ut + ½ at^2

= 5 x 30 + ½ (-20)$(30)^2$

= 150 – 9000 = -8850 m

For $30 \leq t \leq 100s$

Using the first equation of motion, for t = 30 s,

v = u + at (Where v is the final velocity)

= 5 + (−20) × 30 = −595 ms^{-1}

Velocity of the body after 30 s = −595 ms^{-1}

For motion between 30 s to 100 s (i.e. 70 s) :

s2 = vt + ½ $a''t^2$

= -595(70) + ½ (0)t^2 = -41650m

Therefore, the total distance, S = s1 + s2 = -8850 – 41650 = -50500m

Q11. A bus starting from rest starts accelerating constantly at 3 m/s^2. After 10 seconds from starting, a mobile phone slips from a man's hand who is sitting on the roof of the bus (7m above the ground). Calculate the (i) Velocity, and (ii) acceleration of the phone at 12s ?(Don't consider air resistance).

A.

Given,

u = 0, a = 3 ms^{-2}, t= 10s

We know, v = u + at

v = 0 + 10 x 3 = 30 m/s

(i) At t = 12 s,

The horizontal component (V_X) of velocity does not change, i.e., V_X = 30 m/s . (Since there is no air resistance)

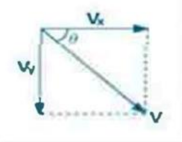
Now, according to the first equation of motion:

$V_Y = u + a_Y\delta t$ (Where V_Y is the vertical component of velocity)

Where, δt = 12 − 10 = 2 s and $a_Y = g = 10\ m/s^2$

$V_Y = 0 + 10 \times 2 = 20$ m/s

Therefore the resultant velocity (v) of the phone can be represented as :



$v = \sqrt{v_y^2 + v_x^2}$

$= \sqrt{30^2+20^2}$

= 36.05 m/s

(ii) Since at t = 12 s the only acceleration acting on the phone is the acceleration due to gravity, thus at t = 12 s the net acceleration on the cap is 10 ms^{-2}.

Q12. A 0.2 kg bob which is hung to a hook by a 1m long string is pushed into oscillation. The velocity of the bob is 1 m/s at its mean position. What is the path of motion of the bob if we cut the string when the bob is at (1) one of its extreme positions, and (2) its mean position.

A.

(1) When the bob is at either of its extreme point its velocity is zero. So if we cut the string now the bob will move vertically down under the influence of its weight.

(2) When the bob is at its mean position it has a horizontal velocity of2 m/s and upon cutting the string the bob will also experience the acceleration due to gravity. As a result the bob will behave like a projectile and trace a parabolic path to the floor.

Q13. A lady of mass 80 kg stands on a weighing machine inside an elevator. Find the readings of the weighing machine when;

(i) the lift moves up at a constant speed of 8 m/s

(ii) the lift goes down at a constant acceleration of 4 ms^{-2}

(iii) the lift moves up with a constant acceleration of 4 ms^{-2}

(iv) the wires holding the lift break causing the lift to crash down.

A.

Given,

m = 80 kg, g = 10 ms^{-2}

(i) When the elevator moves up at a uniform speed, its acceleration is 0.

According to Newton's second law of motion, the equation can be written as:

R − mg = ma

R = mg = 80 x 10 = 800N

Thus, the reading = 800/g = 80 kg

(ii) Lift goes down at, a = 4ms^{-2}

According to Newton's second law of motion, the equation can be written as: R +ma = mg

R = m (g −a) = 80 (10 − 4)

= 480 N

Thus, the reading = 480 / 10 = 48 kg

(iii) Lift goes up at, a = 4 ms $^{-2}$

According to Newton's second law of motion, the equation can be written as:

R – mg = ma

R = m (g + a) = 80 (10 + 4)

= 1120 N

Thus, the reading = 1120/10 = 112kg

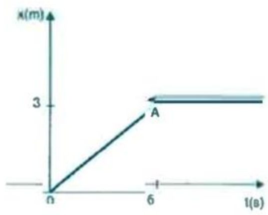
(iv) When the lift crashes down freely , a = g

According to Newton's second law of motion, the equation can be written as:

R + mg = ma

R = m (g – g) = 0. Thus, under a free fall condition the lady will be in a state of weightlessness.

Q14. The following figure is a position – time graph of a 1 kg body. Find the (i) force acting on the body at t < 0, t > 6 s , 0 < t < 6 s. (ii) impulse at t =0 and t = 6s. (Assume this to be a one dimensional motion)



A.

(a) At t < 0 , we can see from the graph that the distance covered by the body is also 0 , thus we can conclude that there is no force acting on the body or the net force on the body is zero.

At t > 6 s, we can see from the graph that at this time interval the body maintains a constant distance of 3 meters from the origin. This means that the body is at rest and no force is acting on it.

At 0 < t < 6 s, in this time interval we see that there is a constant slope in the graph. This means the acceleration in the body is 0 and no force is acting on it.

(b) Impulse = change in momentum

At t = 0

Impulse = mv – mu [Where, v = final velocity and u = initial velocity]

=m (v – u) [v =3/6 m/s , u =0]

= 1 (0.5) = 0.5 kg ms^{-1}.

At t = 6 s

Impulse = m (v – u) [v = 0, u = 3/6 ms^{-1}]

= 1 (- 0.5) = – 0.5kg ms^{-1}

Q15. Two boxes of masses 20 kg and 30 kg are tied to the ends of a light string and kept on a smooth horizontal surface. A horizontal force of 800N is applied on (1) A , (2) B along the length of the string. Find the tension being applied on the string in each case.

A.

Given,

Force applied = 800N

Mass of box A, m1 = 20 kg

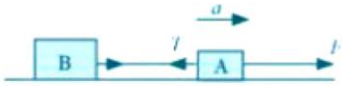
Mass of box B, m2 = 30 kg

Total mass, m = 20 + 30 = 50kg

Acceleration, a = 800 / 50 = 16 m/s^2

Let T be the tension on the string.

(1) When force is applied on A :

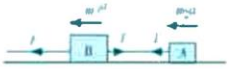


F – T = m1a

T = F – m1a

= 800 – 20 x 16 = -480 N

(2) When the force is applied on the body B



F – T = m2a

T = F – m2a

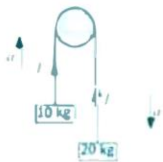
T = 800 – 30 x 16

= 320 N

Q16. Two masses of 10 kg and 20 kg are hung from the ends of an inextensible string which goes over a frictionless pulley. Find the acceleration in the masses and the tension in the string when the masses are released.

A.

The above stated system can be represented as:



Smaller mass, m1 = 10 kg

Larger mass, m2 = 20kg

As m2 is heavier it moves downward with acceleration a , and the mass m1 moves upwards.

Applying Newton's second law of motion we can write the above equation as:

For mass m1; T – m1g = m1a . . . . (1)

For mass m2; m2g – T = m2a . . . . (2)

Adding equations (1) and (2) , we get ;

(m2 – m1)g = (m1 + m2)a

a = $(\frac{m2-m1}{m2+m1})g$

Therefore , a = $(\frac{20-10}{20+10})10$

= 10 / 3 = 3.33 m/s^2

Now, putting the value of a in equation (ii) we get :

20×10 – T = 20 x 3.33

T = 200 -66.6

= 133.4 N

Q17. A nucleus is at rest, in a laboratory frame of reference. Prove that if it breaks down into two smaller nuclei the products move in opposite direction.

A.

Let v_1,v_2 be the velocities of the products and m_1 , m_2 be their respective weights.

Therefore, total linear momentum of the system after break down = $m_1 v_1 + m_2 v_2$

Before break down, the nucleus is at rest. Thus the initial momentum is 0.

Now, according to the law of conservation of momentum,

Total initial momentum = total final momentum

$0 = m_1 v_1 + m_2 v_2$

$v_2 = -(m_1 v_1)/m_2$

The negative sign indicates that the products of the original nuclei move in the opposite direction.

Q18. Two 0.02kg carroms moving towards each other at 5 m/s collide and rebound at the same speed. Calculate the impulse imparted to each carrom because of the other.

A.

Given:

Mass of each carrom, m = 0.02 kg

Initial velocity, u = 5 m/s

Initial momentum of each carrom, p_I = mu

= 0.02x 5 =0.1 kg m/s

Final momentum of each carrom, p_F = mv = 0.1 kg m/s

Thus, impulse imparted on each carrom = Change in momentum of the system

= $p_F - p_I$ = -0.1 − 0.1 = **-0.2 kg m/s**

The negative sign signifies that the impulse is imparted to the two carroms in opposite directions.

Q19. A missile of mass 2 kg is fired from a bazooka of mass 80 kg. Given that the muzzle speed of the missile is 40 m/s, calculate the recoil speed of the gun.

A.

Given,

m (mass of missile) = 2 kg

M (mass of the bazooka) = 60 kg

v (muzzle velocity) = 40 m/s

Let V be the recoil speed of the bazooka.

Initial momentum of the system = 0

Final momentum of the system = mv −MV

(There is a −ve sign because the bazooka and missile move in opposite directions)

Now, according to the law of conservation of momentum:

Final momentum = initial momentum

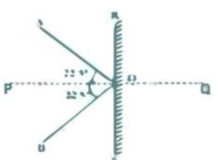
mv − MV = 0

Thus, V = mv/M

= (2 x 40) / 80 = 1 m / s.

Q20. A mid fielder deflects an incoming ball of mass 0.1 kg, at an angle of 45° without changing its initial speed which was 50 kmph. Calculate the impulse imparted on the ball.

1. The above situation can be represented as:



Where, AO = Incident path of the football

OB = path followed by the football after being deflected

∠AOB = angle between the incident and deflected paths of the ball = 45^0

AOP = ∠BOP = 22.5° = θ

Initial velocity = final velocity of the ball = v

Horizontal component of the initial velocity = vcos θ along RO

Vertical component of the initial velocity = vsin θ along PO

Horizontal component of the final velocity = vcos θ along OS

Vertical component of the final velocity = vsin θ along OP

There is no change in the horizontal components of velocities. The vertical components of velocities are in the opposite directions.

Therefore, the impulse imparted to the ball = Change in the linear momentum of the ball

= mvcos θ – (-mvcos θ)

= 2 mvcos θ

Mass of the ball, m =0.1 kg

Velocity of the ball, v = 50kmph = 13.8 m/s

Therefore, impulse = 2 x 0.1 x 13.8 cos 22.5° = 2.76 x 0.92 = 2.539 kg m/s.

Q21. A shoe of mass 0.35 kg is held by its lace and whirled round in a circle of radius 2 m at a speed of 20 rev / min in a horizontal plane. If the lace breaks at a tension of 200N calculate the maximum speed with which the shoe can be whirled? Also find the current tension on the string.

Given ,

m = 0.35 kg , r = 2 m

n = 20 rpm = 20/60 = 1/3 rps

We know, $T = mr\omega^2$ [Where ω is the angular speed = 2πn]

$T = 0.35 \times 2 \times (2\pi n)^2$

$T = 0.7\ (2 \times 3.14 \times 0.33)^2 = 3.067$ N

Now, given T_{MAX} = 200N, we have;

$T_{MAX} = (mv^2_{MAX})/r$

=> $v^2_{MAX} = (T_{MAX}\, r) / m$

=> $v^2_{MAX} = (200 \times 2)/ 0.35 = 1142.85$

Or, $v_{MAX} = \sqrt{1142.85} = 33.806$ m/s

Thus, the shoe can be whirled at a maximum speed of 33.806 m/s.

Q22. In the question above the speed of the stone is increased beyond 33.806 m/s causing the lace to break. From the following options which one best describes what happens to the shoe:

(a) the shoe flies off radially.

(b) the shoe flies off at an angle with the tangent .

(c) the shoe flies off tangentially from the time the lace breaks.

A.

(c) the shoe flies off tangentially from the moment the lace breaks.

When the lace breaks, the shoe will fly off in the direction of the velocity at that moment. In accordance to the first law of motion, the direction of velocity vector is tangential to the path of the stone at that instant. Thus, the shoe will move tangentially from the time the lace breaks.

Q23. Justify why

(i) A car cannot move forward in empty space no matter how much it accelerates its tires.

(ii) A driver is pressed back on her seat when the car she is in accelerates.

(iii) It is harder to push a lawn mower than to pull it.

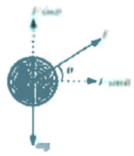
(iv) A wicket keeper draws his hands back as he makes a catch.

A.

(i) When a car moves forward its tires push the ground backwards with some force. The ground in turn pushes the car forward with equal amount of force (Newton's third law). However, in space there is no such reaction force to push the car forward as there is no ground.

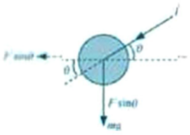
(ii) Passengers sitting in a halted car have inertia of rest, so when a car accelerates the lower part of their body gains the inertia of motion earlier than the upper , causing the lower body to move forward while the upper part of their bodies are pushed back as it is still in a state of rest.

(iii) When we pull a lawn mower, the applied force at an angle of θ, as represented in the figure below.



The vertical component of the force we apply acts upward. This causes a reduction in the effective weight of the mower.

Now, when we push a lawn mower, the applied force acts at an angle of θ , as represented in the diagram below.



The direction of the force applied causes its vertical component to work in the direction of the mower's weight. This causes an increase in the effective weight of the mower.

Thus, pushing a mower is harder than pulling it, as the effective weight of the mower is more in the former.

(iv) Using Newton's second law of motion , we get:

F =ma = m (Δ v / Δ t) . . . . (1)

Where, F = impact force the wicket keeper experiences while stopping the ball.

m = mass of the ball

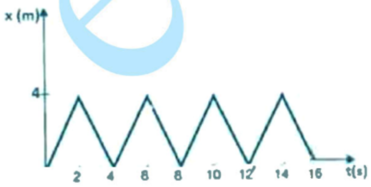
Δ t = time taken by the ball to stop

Inferring from equation (1) we can say that the stopping force is inversely proportional to the time it takes for the ball to come to stop.

F ∝ (1/ Δ t) . . . . (2)

From equation (2) we can see that the impact force experienced by the wicket keeper is less if the impact time is increased. Thus, to reduce the pain a wicket keeper draws his hands back as he makes a catch.

Q24. Given below is a position time graph of a body of mass 0.2 kg. Give a suitable physical example for this graph. Also, find the magnitude of impulse imparted on the body and the time interval between two consecutive impulses.



A.

The above graph can be a position time graph of a rubber ball bouncing off between two smooth surfaces situated 4 cm apart from each other. This rubber ball is rebounding from one wall to another every 2 seconds at a uniform velocity.

Here,

Displacement = 4 cm = 4/100 m

Time = 2s

Velocity = 4 / (2 x 100)

= 0.02 m/s

Initial momentum = mu =0.2 x 0.02 = 0.004 kg m/s

Final momentum = mv = 0.2 x (- 0.02) = 0.004 kg m/s

Therefore, Magnitude of impulse = Change in momentum

= 0.004 – (- 0.004)

= 8×10^{-3} kg m/s

And, the time between two consecutive impulses is 2 s.

Q25. A boy of mass 60 kg is standing stationary with respect to a treadmill accelerating at 2 m s^{-2}. Find the net force on the boy. Also, if the coefficient of static friction between the boy's sneakers and the treadmill is 0.3, up to what acceleration of the treadmill can the boy be stationary with respect to the treadmill?

A.

Given,

Mass of the lady, m = 60 kg

Acceleration, a = 2 m/s^2

Coefficient of friction, μ = 0.3

The total force acting on the boy, F = ma = 60 x 2 =120 N

The boy will continue to be stationary relative to the treadmill as long as the total force on the lady is equal to or less than the frictional force F_S , provided by the treadmill

$F' = F_S$

ma' = μmg

a' = 0.3 x 10 = 3 m/s^2 . Thus, the lady can stand stationary relative to the treadmill up to an acceleration of 3 m/s^2.

Q26. A body having mass m is tied to a rope that is revolving in a vertical circle of radius R. Find the net force acting on the body in the vertically downwards direction at the highest and lowest points of the circle.

When the body is at its lowest point:

The net force acting on the body, F = T – mg

Where, T = tension on the string.

mg = weight of the body

When the body is at its highest point:

The net force acting on the body , F = T + mg

Q27. A drone of mass 10 kg has a vertical acceleration of 10 m/s^2. The drone is carrying 300gm of equipments inside it. What is the direction and magnitude of the

(i) net force exerted by the equipments on the drone's floor.

(ii) action of the drone's rotors in the air surrounding it.

(iii) net force exerted on the drone by the surrounding air.

1. Given,

Mass of drone, m = 10 kg

Mass of equipments, m' = 0.300 kg

Acceleration, a = 10m/s^2

(i) force exerted on the drone by the equipments = Apparent weight of the equipments

F = m'(a + g)

= 0.3(10 + 10)

= 6 N

(ii) the action of the drone's rotor in the air surrounding it is vertically downwards .And the magnitude of this force is = (m + m')(a + g)

= (10 + 0.3) (10 + 10) = 206N

(iii) the force exerted by the surrounding air is the reaction force to the action force exerted by the rotor on the surrounding air. Thus this reaction force is 206N in the upward direction.

Q28. A jet of water gushes out of a horizontal tube of cross -section $10^{-2}m^2$ at 20 m/s. What amount of force will this jet of water exert on a body brought in front of it? Assuming that water does not rebound.

A.

Given,

Velocity of the jet, v =20 m/s

Cross sectional area, A = $10^{-2}m^2$

Volume of the water coming out of the tube every second, V = vA = 2×10^{-1} m^3/s

We know, density of water, p = 10^3 kg/m^3

Thus, mass of water coming out of the tube every second, m = V × p

= 200 kg/s

Force exerted on the body = Rate of change of momentum

= mv/t

= 200 x 20 = 4000 N

Q29. Nine cubes are stacked one on top of the other. If every cube has a mass of m kg, what is the direction and magnitude of:

(a) the force exerted on the 5th (from the bottom) cube by the cubes on top of it.

(b) the force exerted on the 5th cube by the 6th cube.

(c) the reaction of the 4th cube by the 5th cube.

A.

(a) weight of one cube = mg

Weight of three cubes = 4mg

Thus, the force exerted on the 5th cube by the cubes above it is 3mg and this force acts vertically downwards.

(b) The force exerted by the 6th cube is a resulting weight of all the cubes above it . Thus , the force exerted on the 5th cube by the 6th cube is also 4mg. And it acts in the vertically downward direction.

(c) The 4th cube will experience a force of 5mg from the 5 cubes above it , thus according to Newton's third law of motion it will also exert a reaction force of 5mg on the 5th coin in the upward direction.

Q30. A fighter jet makes vertical loop at a speed of 180 m/s with its wings banked at an angle of 20^0. Calculate the radius of the loop.

A.

Given,

$v = 180$ m/s

$g = 10$ m/s^2

Angle of banking, $\theta = 20^0$

We know,

$\tan\theta = v^2/rg$ **Where r = radius of the loop**

$r = v^2/ 10\tan\theta$

$r = 180^2/(10 \times 0.364)$

$r = 32400 / 3.64$

Therefore, $r = 8879.144$ m

Q31. A tram of mass of 10^6 kg, runs at a speed of 60 kmph along an unbanked circular track having a radius of 20m. What is responsible for providing the tram with the required centripetal force, the rails or its engine? Also, find the angle of banking to prevent the rail from wearing out.

A.

Given,

$m = 10^6$ kg

$v = 60$ kmph $= 16.66$ m/s

$r = 20$ m

The centripetal force required by the tram to make this circular motion is provided by the lateral thrust of the rails on the tram's wheel.

To find the angle of banking θ, we use:

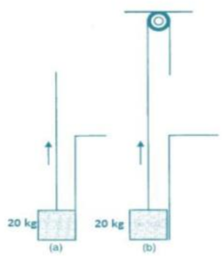
$\tan\theta = v^2 / rg = 16.66^2 / (20 \times 10)$

$\tan\theta = 1.387$

Therefore, $\theta = \tan^{-1}(1.387)$

$= 54.2^{0}$

Q32. A box of mass 20kg is raised by a 60kg man in two different ways as shown in the figure below. Find the action on the floor by the man in both the cases. If the floor breaks at a normal force of 750N, which method should the man employ in raising the box?



A.

Given,

Mass of the box, m' = 20 kg

Mass of the man, m = 60 kg

Acceleration due to gravity = 10 m/s^2

Force applied on the box, F = 20 x 10 = 200 N

Weight of the man, W = 60 x 10 = 600N

Case (a) – When the box is lifted directly the man applies an upward force. This causes his apparent weight to increase,

Therefore, Action on the floor = 600 + 200 = 800 N

Case (b) – When the box is lifted through a pulley the man is applying a downward force. This causes a decrease in his apparent weight.

Therefore, Action on the floor = 600 – 200 = 400N

So if the floor breaks at a normal force of 750N he must employ the pulley to raise the box.

Q33. A panda of mass 45 kg is climbing up a vine that can bear a maximum tension of 640 N. Identify in which of the following cases will the vine break:

(a) panda accelerates up at 5 m/s^2

(b) panda accelerates down at 5 m/s^2

(c) panda climbs up at a constant speed of 5 m/s^1.

(d) panda free falls down the vine.

A.

Given,

m = 45 kg

g = 10 m/s

(a) When he accelerates up at 5 m/s^2 :

T = m (g + a) [Using Newton's second law of motion]

= 45 (10 + 5) = 675 N

Thus the vine will break in this case.

(b) When he accelerates down at 5 m/s^2 :

T = m (g – a)

= 45 (10 -5) = 225 N

Thus the vine won't break in this case.

(c) When he climbs up with uniform speed of 5 m/s^1, a = 0

T = m (g + a)

= 45x 10 = 450 N

Thus, the vine won't break in this case.

(d) When the panda is free falling his acceleration a = g

T = m (g – g) = 0.

Thus, the rope won't break in this case.

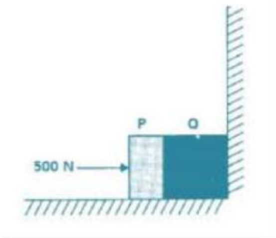
Q34. Two boxes P and Q of masses 10kg and 15 kg are resting one against the other on a platform against a rigid wall .The coefficient of friction between the boxes and the platform is 0.2 (a)When a horizontal force of 500N is applied to P. Find

(i) the reaction of the partition.

(ii) the action-reaction forces in P and Q.

(b)What would happen if the wall was removed?

If the bodies were in motion would the answer to (ii) change? Neglect the difference between μ_K and μ_S.



A.

Given,

Applied force = 500 N

Mass of P, m = 10 kg

Mass of Q, m' = 15 kg

Coefficient of friction = 0.2

(a) When the wall is there :

(i) The force of friction = μ(m + m')g

F_F = 0.2 (10 + 15)10 = 50 N Leftward

Net force on the partition = 500 − 50 = 450 N rightward

According to Newton's third law the reaction of the partition will be opposite to the direction of the action force. Thus, the reaction of the partition is 450 N towards left.

(ii) the force of friction on P = 0.20 x 10 x 10 = 20 N towards left.

Total force working on P = 500 − 20 = 480 N towards right.

Thus the box P exerts a rightward force of 480 N on Q, while Q exerts a leftward reaction force of 480 N on P.

(b) When the wall is removed the two boxes move rightwards.

When the system is moving with acceleration a, we can represent it with this equation:

Net force = (m + m')a

450 = (10 + 15) a

a = 450/25 = 18 m/s^2

And , the net force acting on P = ma

= 10 x 18 = 180 N

Thus, the force P exerts on Q = 480 − 180 = 300 N

So if the boxes start moving the answer to (ii) will change.

Q35. A 20 kg bag is kept on a trolley. The coefficient of static friction between the trolley and the bag is 0.2. The trolley then accelerates from rest at 0.5 m/s^2 for 10 s, after which it moves at a constant speed. What is the motion of the bag as viewed by (i) an observer sitting on the ground , (ii) a person moving along with the trolley

A.

(i) Given,

a = 0.5 m/s^2

m = 20kg

μ = 0.2

Force on the block = ma = 20 x 0.5

= 10 N

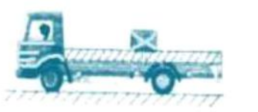
Force of Friction = μmg = 0.2 x 20 x 10

= 40 N

As the force of friction is greater than the applied force the bag will seem stationary to an observer sitting on the ground.

(ii)The trolley starts moving at uniform speed so no external forces act on it , except for the frictional force on the bag. An observer moving along with the trolley has an accelerated motion which means this person will be in a non-inertial frame of reference. This results in making the person observe the trolley to be in a resting state.

Q36. The back side of a pickup truck is open and a box of mass 30 kg is kept 4 m from the open edge, as depicted in the diagram. The coefficient of friction between the box and the floor of the trailer is 0.18. The pickup truck accelerates from zero with 3 m/s^2. Neglecting the dimensions of the box , find the distance from the starting point, at which the box will drop off.



A.

Given,

m = 30 kg

s = 4 m

μ = 0.18

a = 3 m/s^2

Force experienced by the box upon acceleration, F_A = ma

= 30 x 3 = 90N

Frictional force F_F =μmg = 0.18 x 30 x 10 = 54 N

Net force, F = $F_A - F_F$

= 90 − 54 =36 N

Now, acceleration in the backward acceleration, a'= F / m

= 36 / 30 = 1.2 m/s^2

Thus time required for the box to move 4m, i.e., drop off from the pickup truck.

S = ut + ½ at^2

4 = 0 x t + ½ x 1.2 x t^2

t = $\sqrt{6.66}$ s

Therefore, the distance travelled by the pickup in $\sqrt{6.66}$ seconds = ut + ½ at^2

S = 0 + ½ x 3 x ($\sqrt{6.66}$)^2

S = 3/2 x 6.66 = 10m

Q37. A vinyl record of a turntable spins at 35¼ revolutions per minute and has a radius of 16 cm. Two plastic chips are placed 5 cm and 14 cm away from the center of the turntable. Given that the coefficient of friction between the record and the chips is 0.14, identify the chip that will revolve with the record.

A.

If a chip is to revolve with the record then the force of friction on it should be equal to or greater than the centripetal force on it.

Given,

Frequency of revolution = 35¼ rpm = 141/4 rpm = 0.587 rps

Radius of the disc, r = 16 cm = 0.16 m

Coefficient of friction, μ = 0.14

For, chip at 5cm

Radius of revolution, r' = 5 cm = 0.05 m

Angular frequency is $\omega = 2\pi v$

= 2 x 3.14 x 0.587 =3.68 m/s

Frictional Force, $F_F = \mu mg = 0.14 \times m \times 10 = 1.4m$ N

Centripetal force on the chip

$F_C = mr' \omega^2$

$= m \times 0.05 \times 3.68^2$

F = 0.677m N

As the $F_F > F_C$, the chip will revolve with the record.

For chip at 14 cm

Radius of revolution, r" =0.14m

Angular frequency, ω = 3.49 m/s

Centripetal force, $F_C = mr'' \omega^2$

= m x 0.14 x 12.18 = 1.705m N

As $F_F < F_C$, the chip will fly off.

Q38. In a stunt called the "Deathwell" a motorcyclist rides his bike in vertical loops . Explain how the biker avoids falling down even when he is at the uppermost point of the loop without any support from below. If the radius of the loop is 20 m find the minimum speed required for a biker to be able to ride his bike at the uppermost point of the loop.

A.

A rider in the uppermost point of the vertical loop is under the influence of two downward forces: (1) weight of him and his bike (mg), and (2)the normal reaction force of the loop on him. However, these forces are balanced by the outward centrifugal force on him, thus effectively preventing him from falling down.

$R + mg = (mv^2) / r$ . . . . (i)

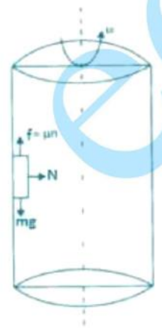
Here, m is the mass of the motorcyclist (body weight + weight of the bike), R is the normal reaction force , v is the velocity of the bike and r is the radius of the loop.

At minimum speed reaction force is

Thus, $v^2 = gr = 10 \times 20$

v = 14.14 m/s

Q39. A 40 kg boy stands pressed against the inner walls of a giant hollow cylinder that is rotating about its axis at 210 revolution per minute. If the radius of the cylinder is 5 m and the coefficient of friction between his clothes and the cylinder walls is 0.18, find the minimum speed of the cylinder required to keep the boy pressed against the wall even when the cylinder floor under his feet has been removed.



1. Given,

R = 5m

ω = 2 x 3.14 x 210/60

= 21.98 rad /s

μ = 0.18

As depicted in the diagram above the centripetal force which is required, is provided by the normal reaction N of the walls on the boy.

Thus we have:

$N = mv^2/R = m\omega^2 R$

Also, the weight of the boy acting downwards is balanced by the frictional forces acting upwards. So for the boy to remain stuck even after the floor is removed his weight, mg $\leq$ frictional forces.

$mg \leq \mu m\omega^2 R$

$g \leq \mu\omega^2 R$

Or, $g/R\mu \leq \omega^2$

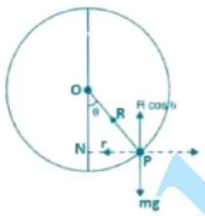
Therefore the minimum required speed to keep the boy stuck on the wall even when there is no floor is:

- $\omega^2 = g / R\mu = 10/5\times0.18$
- $\omega = 3.33$ rad / s.

Q40. A thin ring having a radius R spins about its vertical axis at an angular frequency of ω. Will a tiny pellet inside the ring stay at its lowermost point for ???? ≤ $\sqrt{\frac{g}{R}}$? Find the angle made by the radius vector connecting the pellet to the center of the ring with the vertical downward direction of ???? = $\sqrt{\frac{2g}{R}}$? Ignore friction.

A.

The above case can be depicted as:



Let the angle made by the radius vector connecting the pellet to center of the ring be θ, with the vertical downward direction.

$mg = N\cos\theta$ . . . . (1) [Where N is the normal reaction force]

$mr\omega^2 = N\sin\theta$ . . . . (2)

Or, $m(R\sin\theta)\omega^2 = N\sin\theta$

Or $mR\omega^2 = N$

Using equation (1) , $mg = mR\omega^2\cos\theta$

$\cos\theta = g/R\omega^2$ . . . .(3)

As $\cos\theta \leq 1$ the pellet will stay at its lower most point for ???? ≤ $\sqrt{\frac{g}{R}}$

When, ???? = $\sqrt{\frac{2g}{R}}$

Using equation (3)

$\cos\theta = \frac{g}{R}\left(\frac{R}{2g}\right)$

$\cos\theta = 1/2$

Therefore, $\theta = 60^0$