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NCERT Solutions for 11th Class Physics:Chapter 5-Laws Of Motion

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Class 11: Physics Chapter 5 solutions. Complete Class 11 Physics Chapter 5 Notes.

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Excercises

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.

Answer

(a) As the rain drop is flling with a constant speed, its accleration, $a = 0$. Hence net force $F = ma = 0$.

(b) As the cork is floating on water, its weight is balanced by the upthrust due to water. Therefore, the net force on the cork is 0.

(c) As the kite is held stationery, in accordance with the first law of motion, the net force on the kite is 0.

(d) Force is being applied to overcome the force of friction. But as velocity of the car is constant, its accleleration, $a = 0$. Hence net force on the car $F = ma = 0$.

(e) As the high speed electron in space is far away from all gravitating objects and free of electric and magnetic fields, the net force on electron is 0.

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.

Answer

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

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 angle of 45° with the horizontal direction, 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.

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^{-2},

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

Answer

(a) Here, m = 0.1 Kg, a = + g = 10 m/s^2

Net force, $F = ma$ = 0.1 × 10 = 1.0 N

This forcer acts vertically downwards.

(b) When the train is running at a constant velocity, its acceleration = 0, No force acts on the stone due to this motion. Therefore, force on the stone F = weight of stone = mg = 0.1 × 10 = 1.0 N

This force also acts vertically downwards.

(c) When the train is accelerating with 1 m s^{-2}, an additional force $F' = ma$ = 0.1 × 1 = 0.1 N acts on the stone in the horizontal direction. But once the stone is dropped from the train, F' becomes zero and the net force on the stone is $F = mg$ = 0.1 × 10 = 1.0 N, acting vertically downwards.

(d) As the stone is lying on the floor of the trin, its acceleration is same as that of the train.

∴ force acting on stone, $F = ma$ = 0.1 × 1 = 0.1 NThis force is along the horizontal direction of motion of the train.

Note that in each case, the weight of the stone is being balanced by the normal reaction.

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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) *T*, (ii) T - mv^2 / l, (iii) T + mv^2 / l, (iv) 0

***T* is the tension in the string.**

[Choose the correct alternative].

(i)*T*

When a particle connected to a string revolves in a circular path around a centre, the centripetal force is provided by the tension produced in the string. Hence, in the given case, the net force on the particle is the tension *T*, i.e.,

$F = T = mv^2 / l$

Where F is the net force acting on the particle.

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 ms^{-1}. How long does the body take to stop?

Answer

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, $v = 0$

Using Newton's second law of motion, the acceleration (a) produced in the body can be calculated as:

$F = ma$

$-50 = 20 \times a$

$\therefore a = -50/20 = -2.5\ ms^{-2}$

Using the first equation of motion, the time (t) taken by the body to come to rest can be calculated as:

$v = u + at$

$\therefore t = -u / a = -15 / -2.5 = 6$ s

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^{-1} in 25 s. The direction of the motion of the body remains unchanged. What is the magnitude and direction of the force?

Answer

Mass of the body, m = 3 kg

Initial speed of the body, u = 2 m/s

Final speed of the body, v = 3.5 m/s

Time, t = 25 s

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

$v = u + at$

$\therefore a = (v - u) / t$

$= (3.5 - 2) / 25 = 0.06 \text{ ms}^{-2}$

As per Newton's second law of motion, force is given as:

$F = ma$

$= 3 \times 0.06 = 0.18$ N

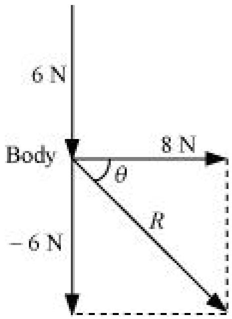
Since the application of force does not change the direction of the body, the net force acting on the body is in the direction of its motion.

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.

Answer

Mass of the body, m = 5 kg

The given situation can be represented as follows:



The resultant of two forces is given as:

$$R = \sqrt{(8)^2 + (-6)^2} = \sqrt{64 + 36} = 10 \text{ N}$$

θ is the angle made by *R* with the force of 8 N

$\therefore \theta = tan^{-1}(-6/8) = -36.87^{o}$

The negative sign indicates that *θ* 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:

$F = ma$

$\therefore a = F / m = 10 / 5 = 2 \text{ ms}^{-2}$

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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.

Answer

Initial speed of the three-wheeler, u = 36 km/h = 10 m/s

Final speed of the three-wheeler, v = 0 m/s

Time, t = 4 s

Mass of the three-wheeler, m = 400 kg

Mass of the driver, m' = 65 kg

Total mass of the system, M = 400 + 65 = 465 kg

Using the first law of motion, the acceleration (a) of the three-wheeler can be calculated as:

$v = u + at$

$\therefore a = (v - u) / t = (0 - 10) / 4 = -2.5 \text{ ms}^{-2}$

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:

$F = Ma$

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

The negative sign indicates that the force is acting against the direction of motion of the three-wheeler.

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

Answer

Mass of the rocket, m = 20,000 kg

Initial acceleration, a = 5 m/s^2

Acceleration due to gravity, g = 10 m/s^2

Using Newton's second law of motion, the net force (thrust) acting on the rocket is given by the relation:

$F - mg = ma$

$F = m(g + a)$

$= 20000 \times (10 + 5)$

$= 20000 \times 15 = 3 \times 10^5$ N

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5.10. A body of mass 0.40 kg moving initially with a constant speed of 10 m s^{-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.

Answer

Mass of the body, m = 0.40 kg

Initial speed of the body, u = 10 m/s due north

Force acting on the body, F = –8.0 N

Acceleration produced in the body, $a = F / m = -8.0 / 0.40 = -20\ ms^{-2}$

(i) At t = –5 s

Acceleration, a' = 0 and u = 10 m/s

s = $ut + (1/2)\, a'\, t^2$

= 10 × (−5) = −50 m

(ii) At t = 25 s

Acceleration, a'' = −20 m/s^2 and u = 10 m/s

$s' = ut' + (1/2)\, a''\, t^2$

= 10 × 25 + (1/2) × (-20) × $(25)^2$

= 250 - 6250 = -6000 m

(iii) At t = 100 s

For 0 ≤ t ≤ 30 s

a = -20 ms^{-2}

u = 10 m/s

$s_1 = ut + (1/2)a''t^2$

= 10 × 30 + (1/2) × (-20) × $(30)^2$

= 300 - 9000 = -8700 m

For 30 < t ≤ 100 s

As per the first equation of motion, for t = 30 s, final velocity is given as:

$v = u + at$

= 10 + (−20) × 30 = −590 m/s

Velocity of the body after 30 s = −590 m/s

For motion between 30 s to 100 s, i.e., in 70 s:

$s_2 = vt + (1/2)\, a'' t^2$

= -590 × 70 = -41300 m

∴ Total distance, s'' = $s_1 + s_2$ = -8700 -41300 = -50000 m = -50 km.

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

Answer

(a) Initial velocity of the truck, $u = 0$

Acceleration, $a = 2\ m/s^2$

Time, $t = 10$ s

As per the first equation of motion, final velocity is given as:

$v = u + at$

= 0 + 2 × 10 = 20 m/s

The final velocity of the truck and hence, of the stone is 20 m/s.

At $t = 11$ s, the horizontal component (v_x) of velocity, in the absence of air resistance, remains unchanged, i.e.,

$v_x = 20$ m/s

The vertical component (v_y) of velocity of the stone is given by the first equation of motion as:

$v_y = u + a_y \delta t$

Where, $\delta t = 11 - 10 = 1$ s and $a_y = g = 10\ m/s^2$

$\therefore v_y = 0 + 10 \times 1 = 10$ m/s

The resultant velocity (v) of the stone is given as:

Let θ be the angle made by the resultant velocity with the horizontal component of velocity, v_x

$\therefore\ tan\ \theta = (v_y / v_x)$

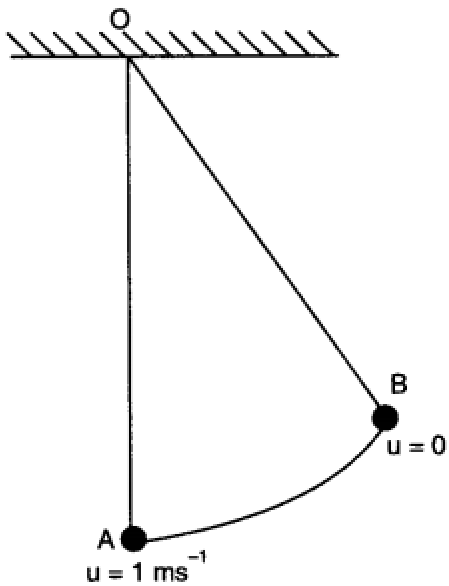
$\theta = tan^{-1} (10 / 20)$

$= 26.57^o$

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

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⁻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.

when the bob is (a) at one of its extreme positions, (b) at 0 its mean position ?



Answer

Let the bob be oscillating as shown in the figure.

(a) When the bob is at its extreme position (say B), then its velocity is zero. Hence on cutting the string the bob will fall vertically downward under the force of its weight F = mg.

(b) When the bob is at its mean position (say A), it has a horizontal velocity of v = 1 ms^{-1} and on cutting the string it will experience an acceleration a = g = 10 ms^{-2} in vertical downward direction. Consequently, the bob will behave like a projectile and will fall on ground after describing a parabolic path.

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Question 5. 13. A man of mass 70 kg, stands on a weighing machine in a lift, which is moving

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

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

(c) upwards with a uniform acceleration of 5 ms^{-2}.

What would be the readings on the scale in each case?

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

Answer:

Here, m = 70 kg, g = 10 m/s^2

The weighing machine in each case measures the reaction R i.e., the apparent weight.

(a) When the lift moves upwards with a uniform speed, its acceleration is zero.

R = mg = 70 x 10 = 700 N

(b) When the lift moves downwards with a = 5 ms^{-2}

R = m (g – a) = 70 (10 – 5) = 350 N

(c) When the lift moves upwards with a = 5 ms^{-2}

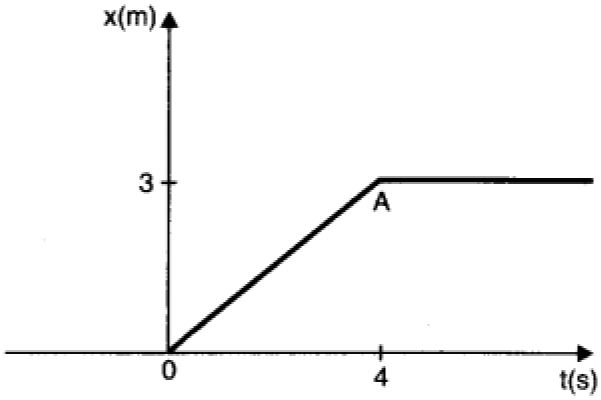
R = m (g + a) = 70 (10 + 5) = 1050 N

(d) If the lift were to come down freely under gravity, downward acc. a = g

:. R = m(g -a) = m(g-g) = Zero.

Question 5. 14. Figure shows the position-time graph of a particle of mass 4 kg. What is the (a) force on the particle for t < 0, t > 4 s,

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



Answer

(a) When $t < 0$. As this part is horizontal, thus it can be concluded that distance covered by the particle is zero and hence force on the particle is zero.

When $0 < t < 4$s. As OA has a constant slope, hence in this interval, particle moves with constant velocity $\left(\frac{3}{4} = 0.75 \text{ ms}^{-1}\right)$. Hence force on the particle is zero.

When $t > 4$s. As this portion shows that particle always remains at a distance of 3 m from the origin *i.e.*, the particle is at rest. Hence force on the particle is zero.

(b) Impulse at $t = 0$. Here $u = 0$, $v = 0.75 \text{ ms}^{-1}$, $M = 4$ kg

$\therefore$ Impulse = total change in momentum = $Mv - Mu$

$= M(v - u) = 4(0.75 - 0) = 3 \text{ kg ms}^{-1}$

Impulse at $t = 4$s. Here $u = 0.75 \text{ ms}^{-1}$, $v = 0$

$\therefore$ Impulse $= M(v - u) = 4(0 - 0.75) = -3 \text{ kg ms}^{-1}$.

Question 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 tight 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?

Answer

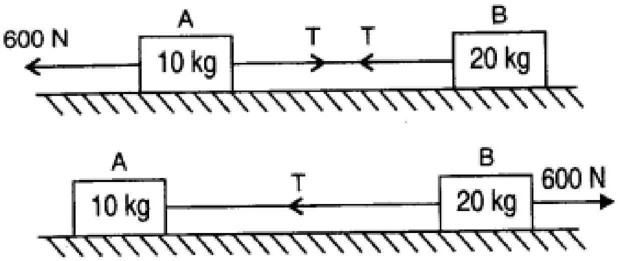
$$\text{Acceleration} = \frac{600\text{ N}}{10\text{ kg} + 20\text{ kg}} = 20\text{ ms}^{-2}$$

(*i*) When force is applied on 10 kg mass

$$600 - T = 10 \times 20 \quad \text{or}$$
$$T = 400\text{ N}$$

(*ii*) When force is applied on 20 kg mass,

$$600 - T = 20 \times 20 \quad \text{or}$$
$$T = 200\text{ N}$$



Question 5. 16. Two masses 8 kg and 12 kg are connected at the two ends of a light in extensible string that goes over a friction less pulley. Find the acceleration of the masses, and the tension in the string when the masses are released.

Answer

For block $m_2 \to m_2 g - T = m_2 a$ ...(*i*)

and for block $m_1 \to T - m_1 g = m_1 a$ ...(*ii*)

Adding (*i*) and (*ii*), we obtain

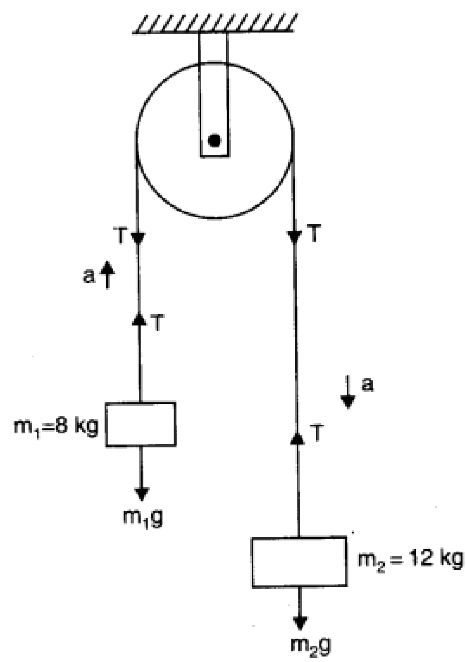
$$(m_2 - m_1) g = (m_2 + m_1) a$$

or

$$a = \left(\frac{m_2 - m_1}{m_2 + m_1}\right) g$$
$$= \frac{12 - 8}{12 + 8} \times 10$$
$$= \frac{4 \times 10}{20} = 2\text{ ms}^{-2}$$

Substituting value of a in equation (*ii*), we obtain

$$T = m_1 (g + a)$$
$$= 8 \times (10 + 2)$$
$$= 8 \times 12 = 96\text{ N.}$$



Question 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.

Answer

Let m1, m2 be the masses of products and v_1,v_2 be their respective velocities. Therefore, total linear momentum after disintegration = m_1v_1 +m_2 v_2. Before disintegration, the nucleus is at rest.

Therefore, its linear momentum before disintegration is zero.

According to the principle of conservation of linear momentum,

$$m_1\vec{v}_1 + m_2\vec{v}_2 = 0 \quad \text{or} \quad \vec{v}_2 = -\frac{m_1\vec{v}_1}{m_2}$$

Negative sign shows that v_1 and $_2$ are in opposite directions.

Question 5. 18. Two billiard balls, each of mass 0.05 kg, moving in opposite directions with speed 6 ms^{-1} collide and rebound with the same speed. What is the impulse imparted to each ball due to the other?

Answer

Initial momentum of each ball before collision

= 0.05 x 6 kg ms^{-1} = 0.3 kg ms^{-1}

Final momentum of each ball after collision

= – 0.05 x 6 kg ms^{-1} = – 0.3 kg ms^{-1} Impulse imparted to each ball due to the other

= final momentum – initial momentum = 0.3 kg m s-1 – 0.3 kg ms^{-1}

= – 0.6 kg ms^{-1} = 0.6 kg ms^{-1} (in magnitude)

The two impulses are opposite in direction.

Question 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 ms^{-1} what is the recoil speed of the gun?

Answer

m = 0.02 kg, M = 100 kg, v = 80 ms^{-1}, V = ?

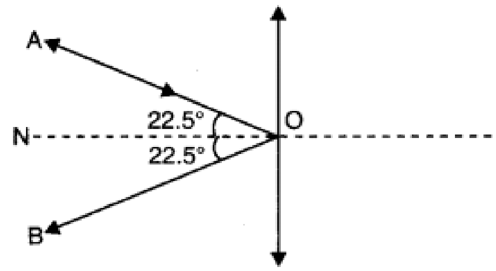
$$V = -\frac{mv}{M} = -\frac{0.020 \text{ kg} \times 80 \text{ m s}^{-1}}{100 \text{ kg}}$$
$$= -0.016 \text{ m s}^{-1} = \mathbf{-1.6 \text{ cm s}^{-1}}$$

Negative sign indicates that the gun moves in a direction opposite to the direction of motion of the bullet.

Question 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.)

Answer

Suppose the point O as the position of bat. AO line shows the path along which the ball strikes the bat with velocity u and OB is the path showing deflection such that $\angle AOB = 45°$. Now initial momentum of ball



$$= mu \cos\theta$$

$$= \frac{0.15 \times 54 \times 1000 \times \cos 22.5}{3600}$$

$$= 0.15 \times 15 \times 0.9239 \text{ along } NO$$

Final momentum of ball $= mu\cos\theta$ along ON

$$\text{Impulse} = \text{change in momentum} = mu\cos\theta - (-mu\cos\theta)$$

$$= 2\,mu\cos\theta = 2 \times 0.15 \times 15 \times 0.9239 = 4.16 \text{ kg m}^{-1}.$$

Question 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?

Answer

Here, $m = 0.25 \text{ kg}, \quad r = 1.5 \text{ m}$

$$n = 40 \text{ rpm} = \frac{40}{60}\text{ rps} = \frac{2}{3}\text{ rps}$$

Now $T = mr\omega^2 = mr\,(2\pi n)^2 = 4\pi^2\, mrn^2$

$$T = 4 \times \frac{22}{7} \times \frac{22}{7} \times 0.25 \times 1.5 \times \left(\frac{2}{3}\right)^2 = 6.6 \text{ N}$$

If $T_{max} = 200$ N, then from

$$T_{max} = \frac{mv_{max}^2}{r} \Rightarrow v_{max}^2 = \frac{T_{max} \times r}{m}$$

or $$v_{max}^2 = \frac{200 \times 1.5}{0.25} = 1200 \Rightarrow v_{max} = \sqrt{1200} = 34.6 \text{ ms}^{-1}.$$

Question 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 stoneflies off at an angle with the tangent whose magnitude depends on the speed of the particle?

Answer

(b) The velocity is tangential at each point of circular motion. At the time the string breaks, the particle continues to move in the tangential direction according to Newton's first law of motion.

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Question 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.

Answer

(a) A horse by itself cannot move in space due to law of inertia and so cannot pull a cart in space.

(b) The passengers in a speeding bus have inertia of motion. When the bus is suddenly stopped the passengers are thrown forward due to this inertia of motion.

(c) In the case of pull, the effective weight is reduced due to the vertical component of the pull. In the case of push, the vertical component increases the effective weight.

(d) The ball comes with large momentum after being hit by the batsman. When the player takes catch it causes large impulse on his palms which may hurt the cricketer. When he moves his hands backward the time of contact of ball and hand is increased so the force is reduced.

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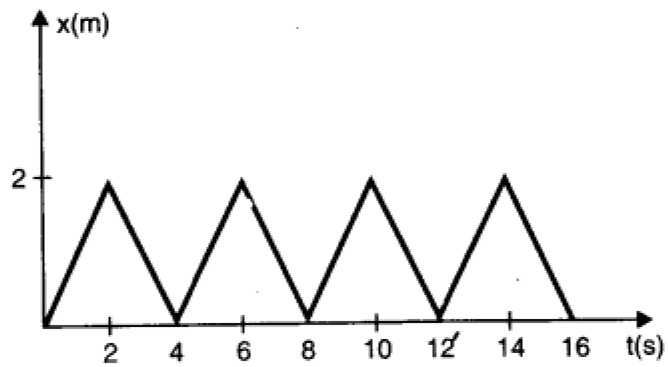
Question 5. 24. Figure shaws the position-time graph of a particle of mass 0.04 kg. Suggest a suitable physical context for this motion. What is the time between two consecutive impulses received by the particle ? What is the magnitude of each impulse?

Answer

This graph can be of a ball rebounding between two walls situated at position 0 cm and 2 cm. The ball is rebounding from one wall to another, time and again every 2 s with uniform velocity.



Impulse. Here, Velocity $= \frac{\text{displacement}}{\text{time}} = \frac{2}{100 \times 2} = 0.01 \text{ ms}^{-1}$

Initial momentum $= mu = 0.04 \times 0.01 = 4 \times 10^{-4}$ kg ms^{-1}

Final momentum $= mv = 0.04 \times (-0.01) = -4 \times 10^{-4}$ kg ms^{-1}

Magnitude of Impulse = Change in momentum

$= (4 \times 10^{-4}) - (-4 \times 10^{-4}) = 8 \times 10^{-4}$ kg ms^{-1}

Time between two consecutive impulses is 2 s *i.e.*, the ball receives an impulse every 2 *s*.

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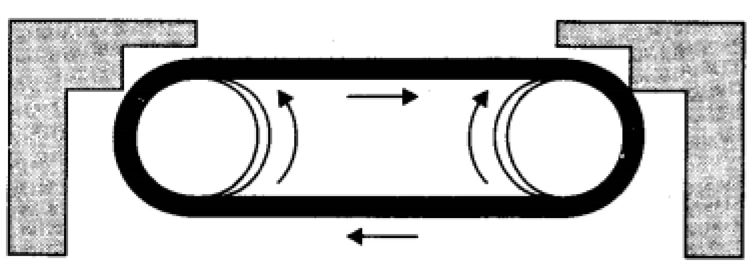
Question 5. 25. Figure shows a man standing stationary with respect to a horizontal conveyor belt that is accelerating with 1 ms^{-2}. What is the net force on the man ? If the coefficient of static friction , between the man's shoes and the belt is 0.2, up to what acceleration of the belt can the man continue to be stationary relative to the belt? (Mass of the man = 65 kg.)



Answer

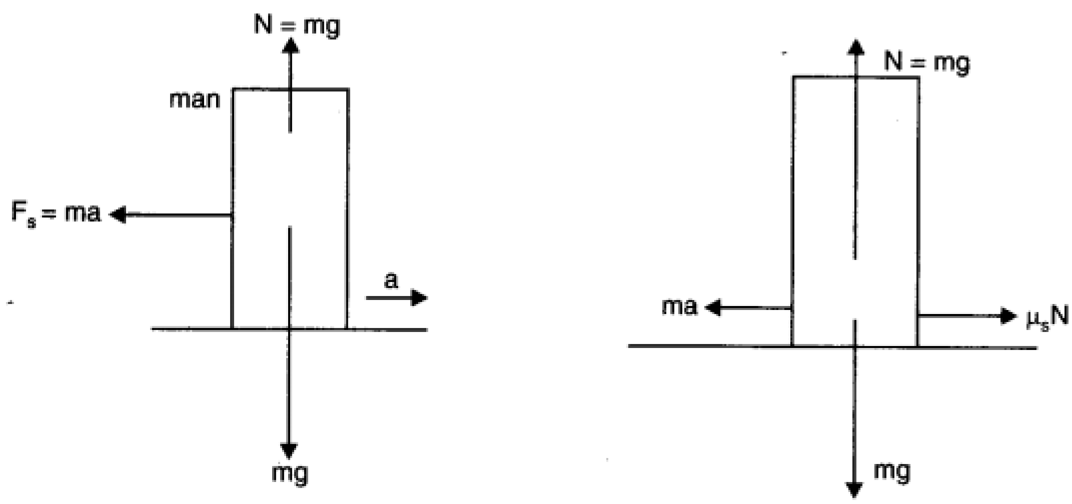
Here acceleration of conveyor belt a = 1 ms^{-2}, μ_s= 0.2 and mass of man m = 65 kg. t As the man is in an accelerating frame, he experiences a pseudo force F_s = ma as shown

in fig. (a). Hence to maintain his equilibrium, he exerts a force F = – F_s = ma = 65 x 1 = 65 N in forward direction i.e., direction of motion of belt.

∴ Net force acting on man = 65 N (forward)

As shown in fig. (b), the man can continue to be stationary with respect to belt, if force of friction

$$\mu_s N = \mu_s mg = ma_{max}$$
$$a_{max} = \mu_s \cdot g = 0.2 \times 10 = 2 \text{ m s}^{-2}$$



(a) (b)

Question 5. 26. A stone of mass m tied to the end of a string is revolving in a vertical circle of radius R. The net force 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)	$mg + T_1 - (mv_1^2)/R$	$mg - T_2 + (mv_1^2)/R$
(d)	$mg - T_1 - (mv_1^2)/R$	$mg + T_1 + (mv_1^2)/R$

T_1 and v_1 denote the tension and speed at the lowest point. T_2 and v_2 denote corresponding values at the highest point.

Answer

The net force at the lowest point is ($mg – T_1$) and the net force at the highest point is ($mg + T_2$). Therefore, alternative (a) is correct.

Since mg and T_1 are in mutually opposite directions at lowest point and mg and T_2 are in same direction at the highest point.

NCERT 11th Physics Chapter 5, class 11 Physics chapter 5 solutions

Question 5. 27. A helicopter of mass 1000 kg rises with a vertical acceleration of 15 ms^{-2}. The crew and the passengers weigh 300 kg. Give the magnitude and direction of

(a) force on the floor by the crew and passengers,

(b) action of the rotor of the helicopter on surrounding air,

(c) force on the helicopter due to the surrounding air

Answer

Here, mass of helicopter, m_1= 1000 kg

Mass of the crew and passengers, m_2 = 300 kg upward acceleration, a = 15 ms^{-2} and g = 10 ms^{-2}

(a)Force on the floor of helicopter by the crew and passengers = apparent weight of crew and passengers

= m_2 (g + a) = 300 (10 + 15) N = 7500 N

(b)Action of rotor of helicopter on surrounding air is obviously vertically downwards, because helicopter rises on account of reaction to this force. Thus, force of action

F = (m_1+ m_2) (g + a) = (1000 + 300) (10 + 15) = 1300 x 25 = 32500 N

(c)Force on the helicopter due to surrounding air is the reaction. As action and reaction are equal and opposite, therefore, force of reaction, F = 32500 N, vertically upwards.

5.28.A stream of water flowing horizontally with a speed of 15 ms^{-1} pushes out of a tube of cross sectional area 10^{-2} m^2, and hits at a vertical wall nearby. What is the force exerted on the wall by the impact of water, assuming that it does not rebound?

Answer

In one second, the distance travelled is equal to the velocity v.

Volume of water hitting the wall per second, V = av where a is the cross-sectional area of the tube and v is the speed of water coming out of the tube.

V = 10^{-2} m^2 x 15 ms^{-1} = 15 x 10^{-2} m^3 s^{-1}

Mass of water hitting the wall per second

$= 15 \times 10^{-2} \times 10^{3}$ kg s^{-1} = 150 kg s^{-1} [v density of water = 1000 kg m^{-3}] Initial momentum of water hitting the wall per second

= 150 kg s^{-1} x 15 ms^{-1} = 2250 kg ms^{-2} or 2250 N Final momentum per second = 0 Force exerted by the wall = 0 – 2250 N = – 2250 N Force exerted on the wall = – (- 2250) N = 2250 N.

NCERT 11th Physics Chapter 5

Question 5. 29. Ten one rupee coins are put on top of one another on a table. Each coin has a mass m kg. Give the magnitude and direction of

(a) the force on the 7th coin (counted from the bottom) due to all coins above it.

(b) the force on the 7th coin by the eighth coin and

(c) the reaction of the sixth coin on the seventh coin.

Answer

(a) The force on 7th coin is due to weight of the three coins lying above it. Therefore,

F = (3 m) kgf = (3 mg) N

where g is acceleration due to gravity. This force acts vertically downwards.

(b) The eighth coin is already under the weight of two coins above it and it has its own weight too. Hence force on 7th coin due to 8th coin is sum of the two forces i.e.

F = 2 m + m = (3 m) kg f = (3 mg) N The force acts vertically downwards.

(c) The sixth coin is under the weight of four coins above it.

Reaction, R = – F = – 4 m (kg) = – (4 mgf) N Minus sign indicates that the reaction acts vertically upwards, opposite to the weight.

Question 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?

Answer:

Here $v = 720 \text{ km/h} = 720 \times \frac{5}{18} \text{ m/s} = 200 \text{ m/s}$ and angle of banking $\theta = 15°$

From the relation

$$\tan\theta = \frac{v^2}{rg} \quad \text{we have}$$

$$r = \frac{v^2}{g\tan\theta} = \frac{200 \times 200}{10 \times \tan 15°} = \frac{200 \times 200}{10 \times 0.2679}$$

$$\Rightarrow \quad r = 14931 \text{ m} = 14.9 \text{ km.}$$

NCERT 11th Physics Chapter 5, class 11 Physics chapter 5 solutions

Question 5. 31. A train runs along an un banked circular track of radius 30 m at a speed of 54 km/h. The mass of the train is 10^6 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?

Answer:

Here $r = 30$ m, $v = 54$ km/h $= 54 \times \frac{5}{18}$ m/s $= 15$ m/s, mass of train $m = 10^6$ kg.

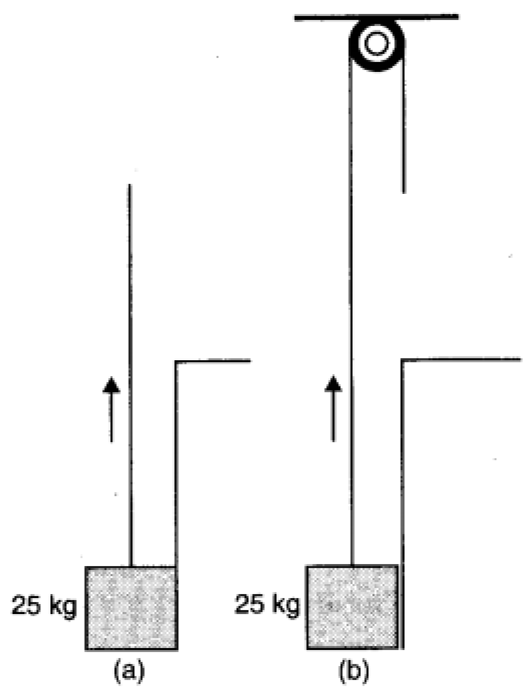
The centripetal force $F = \frac{mv^2}{r}$ for negotiating the circular track is provided by the force of lateral friction due to rails on the wheels of the train.

To prevent wearing out of rails, the angle of banking θ is given by

$$\tan\theta = \frac{v^2}{rg} = \frac{15 \times 15}{30 \times 10} = 0.75$$

$$\Rightarrow \quad \theta = \tan^{-1}(0.75) \simeq 37°.$$

Question 5. 32. A block of mass 25 kg is raised by a 50 kg man in two different ways as shown in Fig. 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?



Answer

In 1st case, man applies an upward force of 25 kg wt.r (same as the weight of the block). According to Newton's third law of motion, there will be a downward reaction on the floor.

The action on the floor by the man.

= 50 kg wt. + 25 kg wt. = 75 kg wt = 75 kg x 10 m/s^2 = 750 N.

In case II, the man applies a downward force of 25 kg wt. According to Newton's third law, the reaction is in the upward direction.

In this case, action on the floor by the man

= 50 kg wt – 25 kg wt. = 25 kg wt. = 25 kg x 10 m/s^2 = 250 N.

Therefore, the man should adopt the second method.

Question 5. 33. A monkey of mass 40 kg climbs on a rope (Fig.) 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 ms^{-2}

(b) climbs down with an acceleration of 4 ms^{-2}

(c) climbs up with a uniform speed of 5 ms^{-1}

(d) falls down the rope nearly freely under gravity?

(Ignore the mass of the rope).

Answer

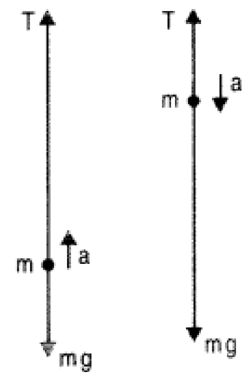
(a) When the monkey climbs up with an acceleration a, then T – mg = ma

where T represents the tension (figure a).

$\therefore \quad T = mg + ma = m(g + a)$

or $\quad T = 40 \text{ kg } (10 + 6) \text{ ms}^{-2} = 640 \text{ N}$

But the rope can withstand a maximum tension of 600 N. So the rope will break.



(a) (b)

(b) When the monkey is climbing down with an acceleration, then

$mg - T = ma$ (Figure (b)

$\Rightarrow \quad T = mg - ma = m(g - a)$

or $\quad T = 40 \text{ kg} \times (10 - 4) \text{ ms}^{-2} = 240 \text{ N}$

The rope will not break.

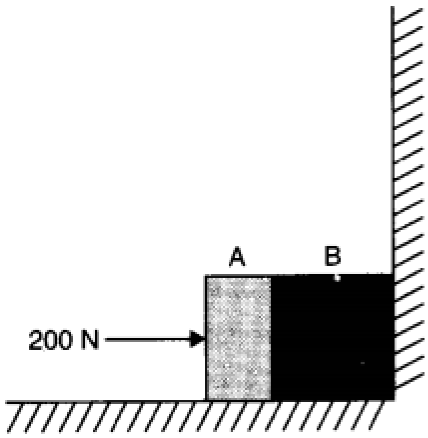
(c) When the monkey climbs up with uniform speed, then

T mg = 40 kg x 10 ms^{-2} = 400 N The rope will hot break.

(d) When the monkey is falling freely, it would be a state of weightlessness. So, tension will be zero and the rope will not break.

Question 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.). 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.



Answer

(i) When the wall exists and blocks A and B are pushing the wall, there can't be any motion i.e., blocks are at rest. Hence,

(a) reaction of the partition = – (force applied on A) = 200 N towards left.

(b) action-reaction forces between A and B are 200 N each. A presses B towards right with an action force 200 N and B exerts a reaction force on A towards left having magnitude 200 N.

(ii) When the wall is removed, motion can take place such that net pushing force provides the acceleration to the block system. Hence, taking kinetic friction into account, we have

$$200 - \mu(m_1 + m_2)g = (m_1 + m_2)a$$

$$\Rightarrow \quad a = \frac{200 - \mu(m_1 + m_2)g}{(m_1 + m_2)} = \frac{200 - 0.15 \times (5 + 10) \times 10}{(5 + 10)}$$

$$= \frac{200 - 22.5}{15} = \frac{177.5}{15} = 11.8 \text{ ms}^{-2}$$

∴ If force exerted by A on B be F_{BA}, then considering equilibrium (or free body diagram) of only block A, we have

$$200 - f_{k_1} = m_1 a + F_{BA} \quad \text{or} \quad 200 - \mu m_1 g = m_1 a + F_{BA}$$

$$\Rightarrow \quad F_{BA} = 200 - \mu m_1 g - m_1 a = 200 - (0.15 \times 5 \times 10) - (5 \times 11.8)$$

$$= 200 - 7.5 - 59$$

$$= 200 - 66.5 = 133.5 \text{ N} \simeq 1.3 \times 10^2 \text{ N towards right}$$

∴ Force exerted on A by B $F_{AB} = -F_{BA} = 1.3 \times 10^2$ N towards left.

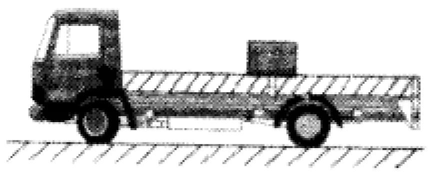
Question 5. 35. A block of mass 15 kg is placed on a long trolley. The coefficient of static friction between the block and the trolley is 0.18. The trolley accelerates from rest with 0.5 ms^{-1} for 20 s and then moves with uniform velocity. Discuss the motion of the block as viewed by (a) a stationary observer on the ground, (b) an observer moving with the trolley.

Answer:

(a) Force experienced by block, F = ma = 15 x 0.5 = 7.5 N Force of friction,F_f= p mg = 0.18 x 15 x 10 = 27 N. i.e., force experienced by block will be less than the friction.So the block will not move. It will remain stationary w.r.t. trolley for a stationary observer on ground.

(b) The observer moving with trolley has an accelerated motion i.e., he forms non-inertial frame in which Newton's laws of motion are not applicable. The box will be at rest relative to the observer.

Question 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. 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 ms^{-2}. At what distance from the starting point does the box fall off the truck? (Ignore the size of the box).



Answer

Force experienced by box, $F = ma = 40 \times 2 = 80$ N

Frictional force $F_f = \mu mg = 0.15 \times 40 \times 10 = 60$ N.

Net force $= F - F_f = 80 - 60 = 20$ N.

Backward acceleration produced in the box, $a = \frac{20}{40}\left(\frac{\text{Net force}}{m}\right)$

$$\Rightarrow \quad a = 0.5 \text{ ms}^{-2}$$

If t is time taken by the box to travel $s = 5$ metre and fall off the truck, then from

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

$$5 = 0 \times t + \frac{1}{2} \times 0.5\, t^2$$

$$t = \sqrt{\frac{5 \times 2}{0.5}} = 4.47 \text{ s.}$$

If the truck travels a distance x during this time, then again from

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

$$x = 0 \times 4.47 + \frac{1}{2} \times 2\,(4.47)^2 = 19.98 \text{ m.}$$

Question 5. 37. A disc revolves with a speed of 33 1/3 rpm 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 record is 0.15, which of the coins will revolve with the record?

Answer

If the coin is to revolve with the record, then the force of friction must be enough to provide the necessary centripetal force.

$$\therefore \quad mr\,\omega^2 \le \mu_s mg \quad \text{or} \quad r \le \frac{\mu_s mg}{m\,\omega^2} \quad \text{or} \quad r \le \frac{\mu_s g}{\omega^2}$$

$$\text{frequency} = 33\frac{1}{3}\text{ rpm} = \frac{100}{3}\text{ rpm} = \frac{100}{3\times 60}\text{ rps}$$

The problems in which centripetal force is obtained from force of friction, start with the following equation:

$$m\,r\omega^2 \le \mu_s mg$$

$$\omega = 2\pi \times \frac{100}{3\times 60}\text{ rad s}^{-1} = \frac{10}{9}\pi\text{ rad s}^{-1}$$

$$\frac{\mu_s g}{\omega^2} = \frac{0.15\times 10}{\left(\frac{10}{9}\pi\right)^2}\text{ m} = 0.12\text{ m} = 12\text{ cm}$$

The condition ($r \le 12$ cm) is satisfied by the coin placed at 4 cm from the centre of the record. So, **the coin at 4 cm will revolve with the record.**

Question 5. 38. You may have seen in a circus a motorcyclist driving in vertical loops inside a 'death well' (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?

Answer

When the motorcyclist is at the highest point of the death-well, the normal reaction R on the motorcyclist by the ceiling of the chamber acts downwards. His weight mg also acts downwards. These two forces are balanced by the outward centrifugal force acting on him.

$$\therefore \quad R + mg = \frac{mv^2}{r} \qquad ...(1)$$

Here v is the speed of the motorcyclist and m is the mass of the motorcyclist (including the mass of the motor cycle). Because of the balancing of the forces, the motorcyclist does not fall down.

The minimum speed required to perform a vertical loop is given by equation (1) when R = 0.

$$\therefore \quad mg = \frac{mv_{min}^2}{r} \quad \text{or} \quad v^2_{min.} = gr$$

$$\text{or} \quad v = \sqrt{gr} = \sqrt{10 \times 25}\ \text{m s}^{-1} = 15.8\ \text{m s}^{-1}$$

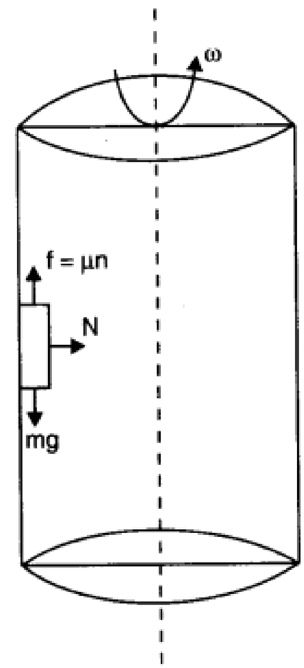
Question 5. 39. A 70 kg man stands in contact against the inner wall of a hollow cylindrical drum of radius 3 m rotating about its vertical axis with 200 rev/min. The coefficient of friction between the wall and his clothing is 0.15. What is the minimum rotational speed of the cylinder to enable the man to remain stuck to the wall (without falling) when the floor is suddenly removed?

Answer

$R = 3$ m, $\omega = 200$ rev/min $= 2 \times \frac{22}{7} \times \frac{200}{60}$ rad/s

$$= \frac{440}{21} \text{ rad/s}$$

and $\mu = 0.15$



As shown in the figure, the normal reaction (N) of the wall on the man acts in the horizontal direction towards the axis of the cylinder while the force of friction (f) acts vertically upwards. The required centripetal force will be provided by the horizontal reaction N of the wall on the man, *i.e.*,

$$N = \frac{mv^2}{R} = m\omega^2 R$$

The frictional force f acting vertically upwards will be balanced by the weight of the man. Hence, the man remains stuck to the wall after the floor is removed if $mg \leq$ limiting frictional force f_e (or μN)

or if $mg \leq \mu\, m\omega^2 R$

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

or $\mu\, \omega^2\, R \geq g$ or $\omega \geq \frac{g}{R\mu}$

Hence, for minimum rotational speed of the cylinder

$$\omega^2 = \frac{g}{\mu R} = \frac{10}{0.15 \times 3} = 22.2$$

$\Rightarrow$ $\omega = \sqrt{22.2} = 4.7$ rad/s.

Question 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 $\omega \leq \sqrt{g/R}$. What is the angle made by the radius vector joining the centre to the bead with the vertical downward direction for $\omega = \sqrt{2g/R}$? Neglect friction.

Answer:

Let the radius vector joining the bead to the centre of the wire make an angle θ with the vertical downward direction. If N is normal reaction, then from fig,

$$mg = N\cos\theta \quad ...(i)$$

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

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

or $$mR\omega^2 = N$$

From equation (*i*), $mg = mR\omega^2\cos\theta$

or $$\cos\theta = \frac{g}{R\omega^2} \quad ...(iii)$$

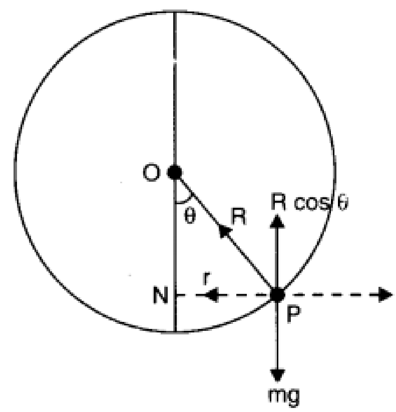
As $|\cos\theta| \leq 1$, therefore bead will remain at its lowermost point for

$$\frac{g}{R\omega^2} \leq 1 \quad \text{or} \quad \omega \leq \sqrt{\frac{g}{R}}$$

When $$\omega = \sqrt{\frac{2g}{R}}$$ from equation (*iii*),

$$\cos\theta = \frac{g}{R}\left(\frac{R}{2g}\right) = \frac{1}{2}$$

$\therefore$ $$\theta = 60°.$$



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