

HC VERMA Solutions for Class 11 Physics Chapter 7 Circular Motion

Question 1

Find the acceleration of the moon with respect to the earth from the following data: Distance between the earth and the moon = 3.85×10^5 km and the time taken by the moon to complete one revolution around the earth = 27.3 days.

Solution 1

Speed of the moon = distance/time

$$\begin{aligned} &= \frac{2\pi r}{T} \\ &= \frac{2 \times 3.14 \times (3.85 \times 10^5)}{27.3 \times 86400} \end{aligned}$$

$$= 1025.4 \text{ m/s}$$

Acceleration of moon =

$$A_r = \frac{v^2}{r} = \frac{(1025.4)^2}{(3.85 \times 10^8)}$$

$$A_r = 2.73 \times 10^{-3} \text{ m/s}^2$$

Question 2

Find the acceleration of a particle placed on the surface of the earth at the equator due to earth's rotation. The diameter of earth = 12800 km and it takes 24 hours for the earth to complete one revolution about its axis.

Solution 2

Speed of particle at equator = distance/time

$$\begin{aligned} &= \frac{2\pi R}{T} \\ &= \frac{2 \times 3.14 \times 6400 \times 10^3}{24 \times 60 \times 60} \end{aligned}$$

$$= 465.1 \text{ m/s}$$

Acceleration of particle =

$$\begin{aligned} A_r &= \frac{v^2}{R} \\ A_r &= \frac{(465.1)^2}{(6400 \times 10^3)} \end{aligned}$$

$$A_r = 0.038 \text{ m/s}^2$$

Question 3

A particle moves in a circle of radius 1.0 cm at a speed given by $v = 2.0 t$ where v is in cm/s and t in seconds. (a) Find the radial acceleration of the particle at $t = 1$ s. (b) Find the tangential acceleration at $t = 1$ s. (c) Find the magnitude of the acceleration at $t = 1$ s.

Solution 3

(a)

Velocity of particle at $t=1$ sec

$$V=2t$$

$$V=2(1)$$

$$V=2\text{cm/s}$$

Radial acceleration

$$A_r = \frac{V^2}{R} = \frac{(2)^2}{1}$$

$$A_r = 4\text{cm/s}^2$$

(b)

Tangential acceleration

$$A_t = \frac{dv}{dt} = \frac{d(2t)}{dt}$$

$$A_t = 2\text{cm/s}^2$$

(c)

$$A_n = \sqrt{A_r^2 + A_t^2}$$

$$A_n = \sqrt{(4)^2 + (2)^2}$$

$$A_n = \sqrt{20} \text{ cm/s}$$

Question 4

A scooter weighing 150 kg together with its rider moving at 36 km/hr is to take a turn of radius 30 m. What horizontal force on the scooter is needed to make the turn possible?

Solution 4

Horizontal force required = Centrifugal force

$$= \frac{mv^2}{R}$$
$$= \frac{(150)(36 \times \frac{5}{18})^2}{30}$$

$$F = 500\text{N}$$

Question 5

If the horizontal force needed for the turn in the previous problem is to be supplied by the normal force by the road, what should be the proper angle of banking?

Solution 5

Let banking angle be θ

$$\tan \theta = \frac{v^2}{Rg}$$
$$\tan \theta = \frac{(36 \times \frac{5}{18})^2}{30 \times 10} = \frac{1}{3}$$

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

Question 6

A park has a radius of 10 m. If a vehicle goes round it at an average speed of 18 km/hr, what should be the proper angle of banking?

Solution 6

Let banking angle be θ

$$\tan \theta = \frac{v^2}{Rg}$$

$$\tan \theta = \frac{(18 \times \frac{5}{18})^2}{10 \times 10}$$

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

Question 7

If the road of the previous problem is horizontal (no banking), what should be the minimum friction coefficient so that a scooter going at 18 km/hr. does not skid?

Solution 7

Centrifugal force = Frictional force

$$\frac{mv^2}{R} = \mu N$$

$$\frac{mv^2}{R} = \mu mg$$

$$\mu = \frac{v^2}{Rg} = \frac{(18 \times \frac{5}{18})^2}{10 \times 10}$$

$$\mu = 0.25$$

Question 8

A circular road of radius 50 m has the angle of banking equal to 30° . At what speed should a vehicle go on this road so that the friction is not used?

Solution 8

$$\tan \theta = \frac{v^2}{Rg}$$

$$\tan 30^\circ = \frac{v^2}{(50)(10)}$$

$$v \cong 17 \text{ m/s}$$

Question 9

In the Bohr model of hydrogen atom, the electron is treated as a particle going in a circle with the centre at the proton. The proton itself is assumed to be fixed in an inertial frame. The centripetal force is provided by the Coulomb attraction. In the ground state, the electron goes round the proton in a circle of radius $5.3 \times 10^{-11} \text{ m}$. Find the speed of the electron in the ground state. Mass of the electron = $9.1 \times 10^{-31} \text{ kg}$ and charge of the electron = $1.6 \times 10^{-19} \text{ C}$.

Solution 9

Coulomb force = Centrifugal force

$$\frac{Kq_p q_e}{r^2} = \frac{m_e v^2}{r}$$

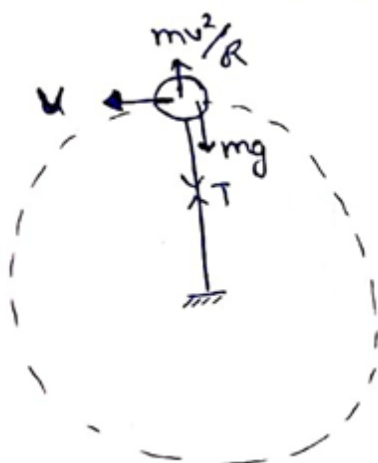
$$\frac{(9 \times 10^9)(1.6 \times 10^{-19})^2}{5.3 \times 10^{-11}} = (9.1 \times 10^{-31}) v^2$$

$$V = 2.2 \times 10^6 \text{ m/s}$$

Question 10

A stone is fastened to one end of a string and is whirled in a vertical circle of radius R. Find the minimum speed the stone can have at the highest point of the circle.

Solution 10



At highest point

$$T + mg = \frac{mv^2}{R}$$

For minimum speed, $T=0$

$$mg = \frac{mv^2}{R}$$

$$V = \sqrt{Rg}$$

Question 11

A ceiling fan has a diameter (of the circle through the outer edges of the three blades) of 120 cm and rpm 1500 at full speed. Consider a particle of mass 1 g sticking at the outer end of a blade. How much force does it experience when the fan runs at full speed? Who exerts this force on the particle? How much force does the particle exert on the blade along its surface?

Solution 11

$$\text{Radius of the circle} = \frac{120}{2} \text{ cm} = 60 \text{ cm}$$

Angular speed = 1500 rpm

$$\omega = 1500 \times \frac{2\pi}{60}$$

$$\omega = 157 \text{ rad/sec}$$

$$\text{Force} = mR\omega^2$$

$$= \left(\frac{1}{1000} \right) (0.6) (157)^2$$

$$F = 14.8 \text{ N}$$

This force is exerted by friction. On particle it acts towards the centre of the circle and on fan blade outside the circle due to action-reaction pair.

So, force along the surface = 14.8 N

Question 12

A mosquito is sitting on an L.P. record disc rotating on a turn table at 333 per minute. The distance 3 of the mosquito from the centre of the turn table is 10 cm. Show that the friction coefficient between the record and the mosquito is greater than $\frac{\pi^2}{81}$. Take $g = 10 \text{ m/s}^2$.

Solution 12

$$\omega = 33 \frac{1}{3} \text{ rpm} = \frac{100}{3} \text{ rpm}$$

$$= \left(\frac{100}{3} \right) \times \frac{(2\pi)}{60}$$

$$= \frac{10\pi}{9} \text{ rad/sec}$$

For mosquito to remain at rest on L.P record.

Frictional force $\geq$ Centrifugal force

$$\mu N \geq mR\omega^2$$

$$\mu mg \geq mR\omega^2$$

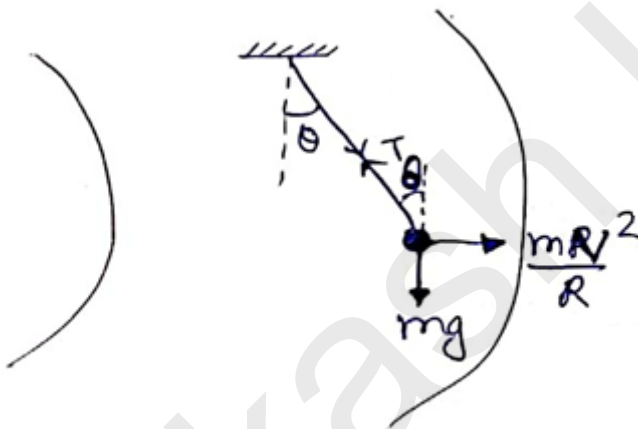
$$\mu \geq \frac{(0.1)}{(10)} \left(\frac{10\pi}{9} \right)^2$$

$$\mu \geq \frac{\pi^2}{81}$$

Question 13

A simple pendulum is suspended from the ceiling of a car taking a turn of radius 10 m at a speed of 36 km/h. Find the angle made by the string of the pendulum with the vertical if this angle does not change during the turn. Take $g = 10 \text{ m/s}^2$.

Solution 13



$$T \sin \theta = \frac{mv^2}{R} \text{ ----- (1)}$$

$$T \cos \theta = mg \text{ ----- (2)}$$

Divide,

$$\tan \theta = \frac{v^2}{Rg}$$

$$= \frac{(36 \times \frac{5}{18})^2}{10 \times 10}$$

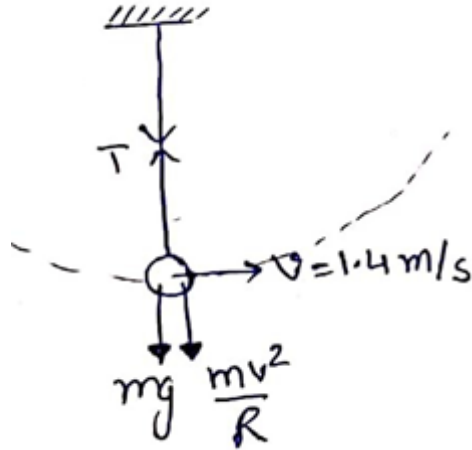
$$\tan \theta = \frac{10 \times 10}{10 \times 10}$$

$$\theta = 45^\circ$$

Question 14

The bob of a simple pendulum of length 1 m has mass 100 g and a speed of 1.4 m/s at the lowest point in its path. Find the tension in the string at this instant.

Solution 14



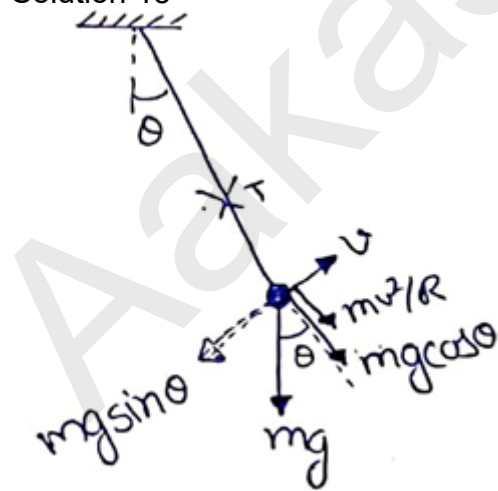
At lowest point

$$T = mg + \frac{mv^2}{R}$$
$$= (0.1)(10) + \frac{(0.1)(1.4)^2}{(1)}$$
$$T = 1.2\text{N}$$

Question 15

Suppose the bob of the previous problem has a speed of 1.4 m/s when the string makes an angle of 0.20 radian with the vertical. Find the tension at this instant. You can use $\cos \theta = 1 - \theta^2/2$ and $\sin \theta = \theta$ for small θ .

Solution 15



At angle θ

$$T = mg \cos \theta + \frac{mv^2}{R}$$

$$T = mg(1 - \frac{\theta^2}{2}) + \frac{mv^2}{R}$$

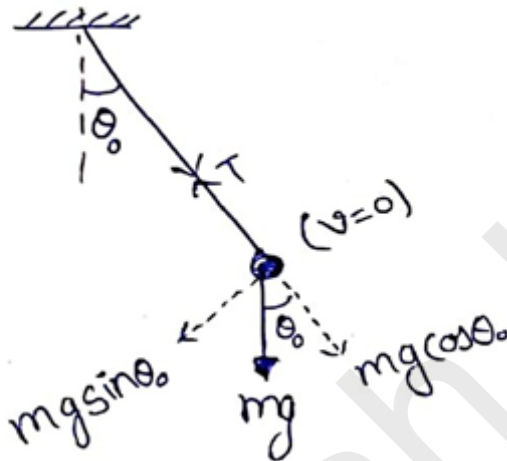
$$T = (0.1)(10)(1 - \frac{(0.2)^2}{2}) + \frac{(0.1)(14)^2}{(1)}$$

$$T \approx 1.16$$

Question 16

Suppose the amplitude of a simple pendulum having a bob of mass m is θ_0 . Find the tension in the string when the bob is at its extreme position.

Solution 16



At extreme position,

$$T = mg \cos \theta_0$$

(No centrifugal force as $v=0$ at extreme position.)

Question 18

A turn of radius 20 m is banked for the vehicles going at a speed of 36 km/h. If the coefficient of static friction between the road and the tyre is 0.4, what are the possible speeds of a vehicle so that it neither slips down nor skids up?

Solution 18

For banking angle,

$$\tan \theta = \frac{v^2}{Rg}$$

$$= \frac{(36 \times \frac{5}{18})^2}{(20)(10)}$$

$$\tan \theta = 0.5$$

$$V_{max} = \sqrt{Rg \frac{(\mu + \tan \theta)}{(1 - \mu \tan \theta)}}$$

$$= \sqrt{\frac{20 \times 10 \times (0.4 + 0.5)}{(1 - 0.4 \times 0.5)}}$$

$$= 15 \text{ m/s}$$

$$15 \times \frac{18}{5} \text{ kmph}$$

$$= 54 \text{ kmph}$$

$$V_{\min} = \sqrt{\frac{Rg(\tan\theta - \mu)}{(1 + \mu \tan\theta)}}$$

$$= \sqrt{\frac{20 \times 10 \times (0.5 - 0.4)}{(1 + 0.4 \times 0.5)}}$$

$$= 4 \text{ m/s}$$

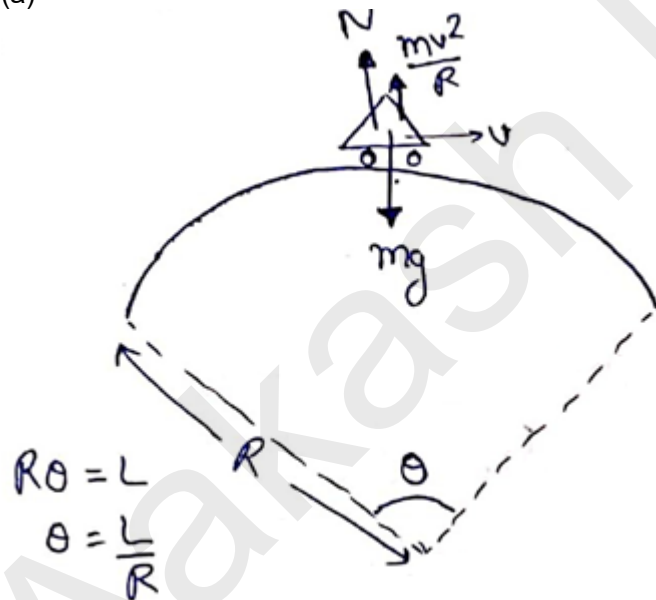
$$V_{\min} = 14.7 \text{ kmph}$$

Question 19

A motorcycle has to move with a constant speed on an overbridge which is in the form of a circular arc of radius R and has a total length L . Suppose the motorcycle starts from the highest point. (a) What can its maximum velocity be for which the contact with the road is not broken at the highest point? (b) If the motorcycle goes at speed $1/42$ times the maximum found in part (a), where will it lose the contact with the road? (c) What maximum uniform speed can it maintain on the bridge if it does not lose contact anywhere on the bridge?

Solution 19

(a)



At highest point,

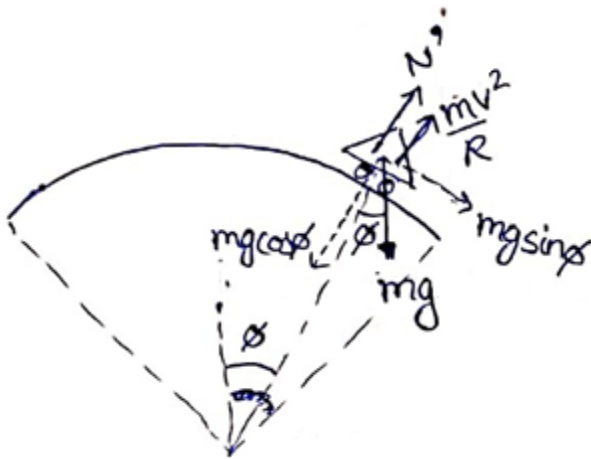
$$N + \frac{mv^2}{R} = mg$$

For maximum speed, $N=0$

$$\frac{mv_{\max}^2}{R} = mg$$

$$V_{\max} = \sqrt{Rg}$$

(b)



$$V = \frac{V_{\max}}{\sqrt{2}} = \sqrt{\frac{Rg}{2}}$$

Let at angle Φ it loses its contact with road

$$N' = 0$$

$$N' + \frac{mv^2}{R} = mg \cos \Phi$$

$$0 + \frac{m \left(\sqrt{\frac{Rg}{2}} \right)^2}{R} = mg \cos \Phi$$

$$\cos \Phi = \frac{1}{2}$$

$$\Phi = 60^\circ \text{ or } \frac{\pi}{3} \text{ rad.}$$

So it loses contact after a distance $\pi R/3$ along the bridge from the highest point.

(c)

Normal contact at any angle Φ

$$N' = mg \cos \Phi - \frac{mv^2}{R} \text{ ----> (1)}$$

So, as motorcycle moves along the curve Φ increases, so $\cos \Phi$ decreases and hence N' decreases.

Normal contact will be minimum at the extreme point.

At extreme point

$$\Phi = \frac{\theta}{2} = \frac{L}{2R} \text{ and } N' = 0$$

From equation (1),

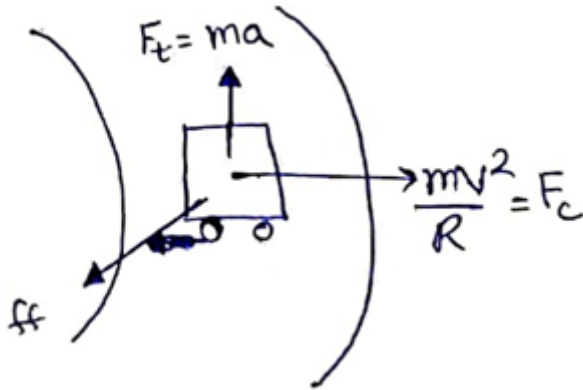
$$0 = mg \cos \left(\frac{L}{2R} \right) - \frac{mv^2}{R}$$

$$V = \sqrt{gR \cos \left(\frac{L}{2R} \right)}$$

Question 20

A car goes on a horizontal circular road of radius R , the speed increasing at a constant rate $dv/dt = a$. The friction coefficient between the road and the tyre is μ . Find the speed at which the car will skid.

Solution 20



From free body diagram

$$ff = \sqrt{F_t^2 + F_c^2}$$

$$\mu N = \sqrt{(ma)^2 + \left(\frac{mv^2}{R}\right)^2}$$

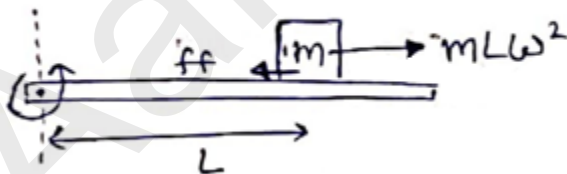
$$(\mu mg) = \sqrt{(ma)^2 + \left(\frac{mv^2}{R}\right)^2}$$

Squaring and solving,
 $v = [(\mu^2 g^2 - a^2) R^2]^{1/4}$

Question 21

A block of mass m is kept on a horizontal ruler. The friction coefficient between the ruler and the block is μ . The ruler is fixed at one end and the block is at a distance L from the fixed end. The ruler is rotated about the fixed end in the horizontal plane through the fixed end. (a) What can the maximum angular speed be for which the block does not slip? (b) If the angular speed of the ruler is uniformly increased from zero at an angular acceleration a , at what angular speed will the block slip?

Solution 21



(a)

For block not to slip

$$ff \geq mL\omega^2$$

$$\mu N \geq mL\omega^2$$

$$\mu mg \geq mL\omega^2$$

$$\omega^2 \leq \frac{\mu g}{L}$$

$$\omega_{\max} = \sqrt{\frac{\mu g}{L}}$$

(b)

Now, ruler makes uniformly accelerated circular motion at angular acceleration of α , so **tangential acceleration**

$$A_t = L\alpha$$

$$F_t = ma_t$$

$$F_t = mL\alpha$$

$$\text{Radial force } F_c = mL\omega^2$$

Where ω is maximum angular speed at which it slips

$$\mu N = \sqrt{(F_c^2 + F_t^2)}$$

$$\mu mg = \sqrt{(mL\omega^2)^2 + (mL\alpha^2)^2}$$

squaring and solving,

$$\omega = \left[\left(\frac{\mu g}{L} \right)^2 \cdot \alpha^2 \right]^{1/4}$$

Question 22

A track consists of two circular parts ABC and CDE of equal radius 100 m and joined smoothly as shown in figure (7-E1). Each part subtends a right angle at its centre. A cycle weighing 100 kg together with the rider travels at a constant speed of 18 km/h on the track. (a) Find the normal contact force by the road on the cycle when it is at B and at D. (b) Find the force of friction exerted by the track on the tyres when the cycle is at B, C and D. (c) Find the normal force between the road and the cycle just before and just after the cycle crosses C. (d) What should be the minimum friction coefficient between the road and the tyre, which will ensure that the cyclist can move with constant speed? Take $g = 10 \text{ m/s}^2$.

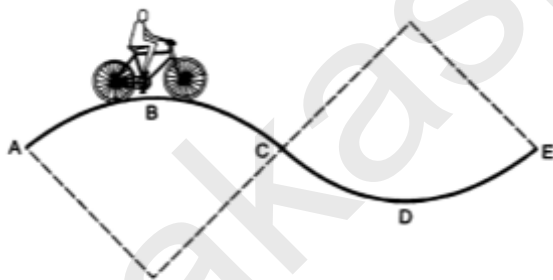
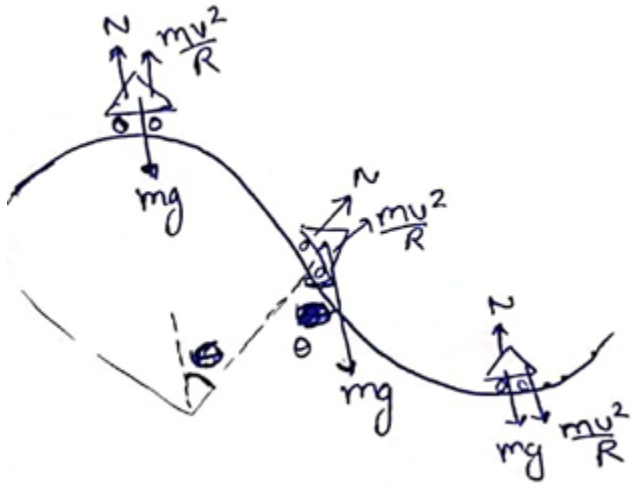


Figure 7-E1

Solution 22



(a)

Velocity of cyclist = $\frac{(18 \times 5)}{18} = 5 \text{ m/s}$

At point B

$$N_B + \frac{mv^2}{R} = mg$$

$$N_B = (100)(10) - \frac{(100)(5)^2}{100}$$

$$N_B = 975 \text{ N}$$

At point D

$$N_D = mg + \frac{mv^2}{R}$$

$$N_D = (100)(10) + \frac{(100)(5)^2}{100}$$

$$N_D = 1025 \text{ N}$$

(b)

No force acts along surface at point B and D

$$\text{So, } f_B = f_D = 0$$

At point C,

$$\therefore \text{acceleration} = 0$$

$$\text{So, } f_c = mg \sin \theta$$

$$f_c = (100)(10) \sin 45^\circ$$

$$f_c = 707 \text{ N}$$

(C)

Before C,

$$N_c + \frac{mv^2}{R} = mg \cos 45^\circ$$

$$N_c = (100)(10) \left(\frac{1}{\sqrt{2}} \right) - \frac{(100)(5)^2}{(100)}$$

$$N_c = 682 \text{ N}$$

After C,

$$N'_c = \frac{mv^2}{R} + mg \cos 45^\circ$$

$$N'_c = \frac{(100)(5)^2}{100} + (100)(10) \left(\frac{1}{\sqrt{2}} \right)$$

$$N'_C = 732\text{N}$$

$$(d) \text{ } f_f = \mu N$$

For minimum friction force normal contact should be minimum.

Normal contact is minimum at point just before C.

$$f_f = mg \sin \theta = \mu N$$

$$(100)(10) \sin 45^\circ = \mu(682)$$

$$\mu = 1.037$$

Question 23

In a children's park a heavy rod is pivoted at the centre and is made to rotate about the pivot so that the rod always remains horizontal. Two kids hold the rod near the ends and thus rotate with the rod (figure 7-E2). Let the mass of each kid be 15 kg, the distance between the points of the rod where the two kids hold it be 3.0 m and suppose that the rod rotates at the rate of 20 revolutions per minute. Find the force of friction exerted by the rod on one of the kids.

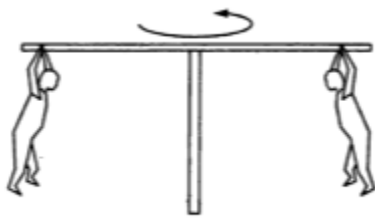
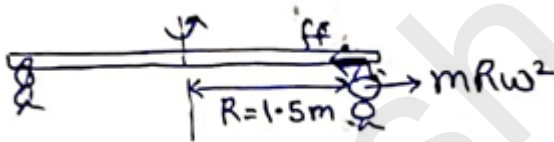


Figure 7-E2

Solution 23



$$\omega = 20 \text{ rpm} = 20 \times \frac{2\pi}{60}$$

$$\omega = \frac{2\pi}{3} \text{ (rad/sec)}$$

$$R = 1.5\text{m}$$

$$\text{Frictional force} = mR \omega^2$$

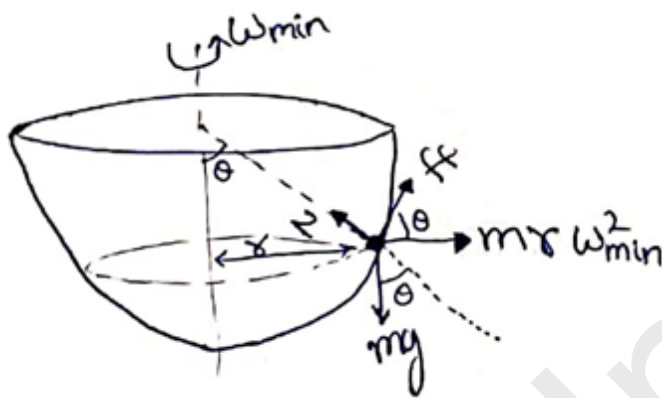
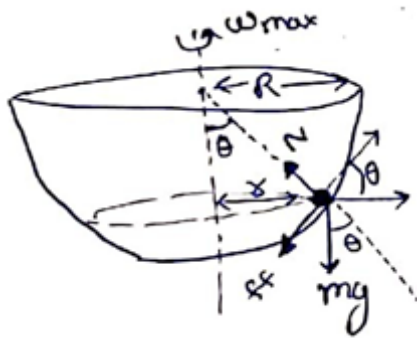
$$= (15)(1.5) \left(\frac{2\pi}{3} \right)^2$$

$$f_f = 10 \pi^2$$

Question 24

A hemispherical bowl of radius R is rotated about its axis of symmetry which is kept vertical. A small block is kept in the bowl at a position where the radius makes an angle θ with the vertical. The block rotates with the bowl without any slipping. The friction coefficient between the block and the bowl surface is μ . Find the range of the angular speed for which the block will not slip.

Solution 24



Particle will have tendency to move up. So, frictional force is in downward direction.

$$r = R \sin \theta \text{----->(i)}$$

$$N = mg \cos \theta + \frac{m r \omega_{\max}^2}{R} \sin \theta \text{----->(ii)}$$

$$f + mg \sin \theta = \frac{m r \omega_{\max}^2}{R} \cos \theta \text{----->(iii)}$$

$$f = \mu N \text{----->(iv)}$$

on solving,

$$\omega_{\max} = \left[\frac{g(\sin \theta + \mu \cos \theta)}{R \sin \theta (\cos \theta - \mu \sin \theta)} \right]$$

For $\omega_{\min}$, particle will have tendency to move down. So, frictional force acting upward direction.

$$r = R \sin \theta \text{----->(1)}$$

$$N = mg \cos \theta + \frac{m r \omega_{\min}^2}{R} \sin \theta \text{----->(ii)}$$

$$Mg \sin \theta = f + \frac{m r \omega_{\min}^2}{R} \cos \theta \text{----->(iii)}$$

$$f = \mu N \text{----->(iv)}$$

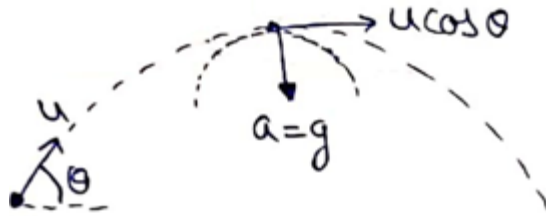
on solving,

$$\omega_{\min} = \left[\frac{g(\sin \theta - \mu \cos \theta)}{R \sin \theta (\cos \theta + \mu \sin \theta)} \right]$$

Question 25

A particle is projected with a speed u at an angle θ with the horizontal. Consider a small part of its path near the highest position and take it approximately to be a circular arc. What is the radius of this circle? This radius is called the radius of curvature of the curve at the point.

Solution 25



At highest point

$$a_{\text{radial}} = \frac{v^2}{R}$$

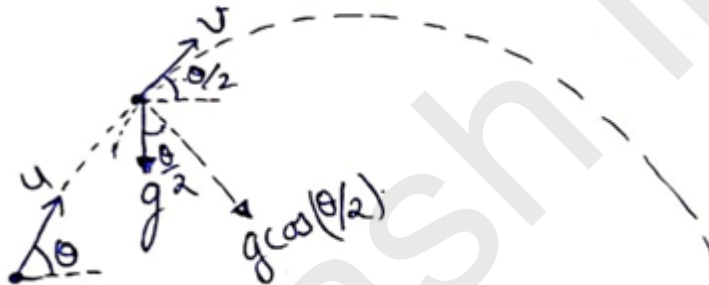
$$g = \frac{(u \cos \theta)^2}{R}$$

$$R = \frac{u^2 \cos^2 \theta}{g}$$

Question 26

What is the radius of curvature of the parabola traced out by the projectile in the previous problem at a point where the particle velocity makes an angle $\theta/2$ with the horizontal?

Solution 26



Since acceleration in horizontal direction is zero

$$u \cos \theta = v \cos \left(\frac{\theta}{2} \right)$$

$$v = \frac{u \cos \theta}{\cos \frac{\theta}{2}}$$

$$a_{\text{radial}} = \frac{v^2}{R}$$

$$R = \frac{\frac{u^2 \cos^2 \theta}{\cos^2 \frac{\theta}{2}}}{g \cos \frac{\theta}{2}}$$

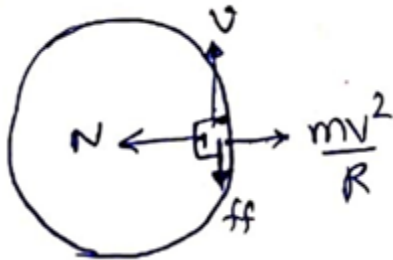
$$R = \frac{u^2 \cos^2 \theta}{g \cos^3 \left(\frac{\theta}{2} \right)}$$

Question 27

A block of mass m moves on a horizontal circle against the wall of a cylindrical room of radius R . The floor of the room on which the block moves is smooth but the friction coefficient between the

wall and the block is μ . The block is given an initial speed v_0 . As a function of the speed v write (a) the normal force by the wall on the block, (b) the frictional force by the wall and (c) the tangential acceleration of the block. (d) Integrate the tangential acceleration ($dv/dt = v dv/ds$) to obtain the speed of the block after one revolution.

Solution 27



Top View of Cylinder

(a)

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

(b)

$$ff = \mu N = \frac{\mu mv^2}{R}$$

(c)

Let acceleration along velocity be a_t for the block

$$0 - ff = m a_t$$

$$\frac{-\mu mv^2}{R} = m a_t$$

$$a_t = -\frac{\mu v^2}{R}$$

(d)

$$v \frac{dv}{dx} = -\frac{\mu v^2}{R}$$

$$\int_{v_0}^v \frac{dv}{v} = -\frac{\mu}{R} \int_0^{2\pi R} dx$$

$$\ln v - \ln v_0 = -\frac{\mu}{R} (2\pi R)$$

$$v = v_0 e^{-2\pi\mu}$$

Question 28

A table with smooth horizontal surface is fixed in a cabin that rotates with a uniform angular velocity ω in a circular path of radius R (figure 7-E3). A smooth groove AB of length L ($\ll R$) is made on the surface of the table. The groove makes an angle θ with the radius OA of the circle in which the cabin rotates. A small particle is kept at the point A in the groove and is released to move along AB. Find the time taken by the particle to reach the point B.

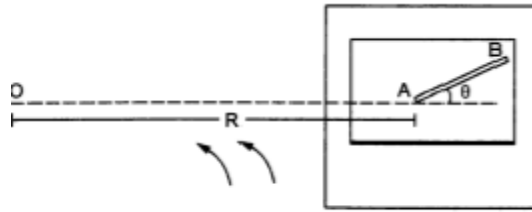


Figure 7-E3

Solution 28

Component of force $mR\omega^2$ along the line AB will be responsible for motion of particle

$$\text{Force} = mR\omega^2 \cos \theta$$

$$ma = mR\omega^2 \cos \theta$$

$$a = R\omega^2 \cos \theta$$

$$u = 0$$

$$s = L$$

$$\text{using } s = ut + \frac{1}{2}at^2$$

$$L = \frac{1}{2}(R\omega^2 \cos \theta) t^2$$

$$t = \frac{2L}{R\omega^2 \cos \theta}$$

Question 29

A car moving at a speed of 36 km/hr is taking a turn on a circular road of radius 50 m. A small wooden plate is kept on the seat with its plane perpendicular to the radius of the circular road (figure 7-E4). A small block of mass 100 g is kept on the seat which rests against the plate. The friction coefficient between the block and the plate is $1.1 = 0.58$. (a) Find the normal contact force exerted by the plate on the block. (b) The plate is slowly turned so that the angle between the normal to the plate and the radius of the road slowly increases. Find the angle at which the block will just start sliding on the plate.

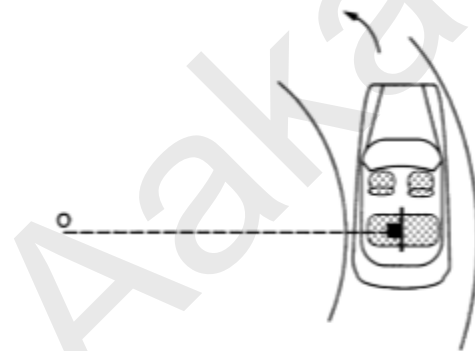
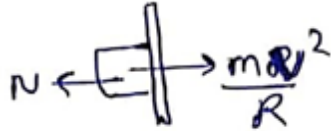


Figure 7-E4

Solution 29

(a)

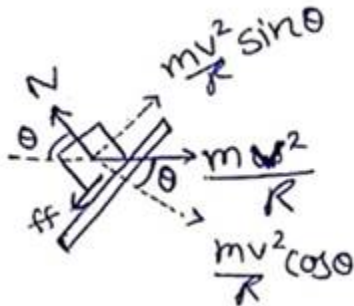


$$N = \frac{mv^2}{R}$$

$$= \frac{(0.1)(36 \times \frac{5}{18})^2}{50}$$

$$N = 0.2$$

(b)



At the time of just sliding

$$ff = \frac{mv^2}{R} \sin \theta$$

$$\mu N = \frac{mv^2}{R} \sin \theta$$

$$\frac{\mu mv^2}{R} \cos \theta = \frac{mv^2}{R} \sin \theta$$

$$\mu = \tan \theta$$

$$\theta = \tan^{-1}(0.58)$$

$$\theta = 30^\circ$$

Question 30

A table with smooth horizontal surface is placed in a cabin which moves in a circle of a large radius R (figure 7-E5). A smooth pulley of small radius is fastened to the table. Two masses m and $2m$ placed on the table are connected through a string going over the pulley. Initially the masses are held by a person with the strings along the outward radius and then the system is released from rest (with respect to the cabin). Find the magnitude of the initial acceleration of the masses as seen from the cabin and the tension in the string.

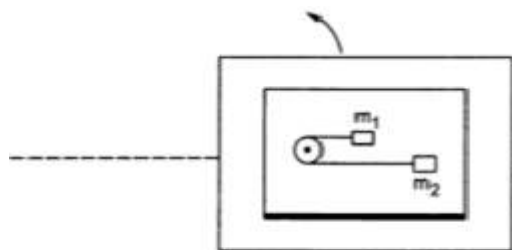
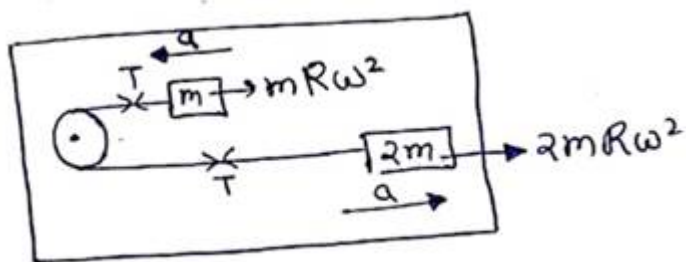


Figure 7-E5

Solution 30



$$2mR\omega^2 - T = 2ma$$

$$T - mR\omega^2 = ma$$

Adding both,

$$mR\omega^2 = 3ma$$

$$a = \frac{R\omega^2}{3}$$

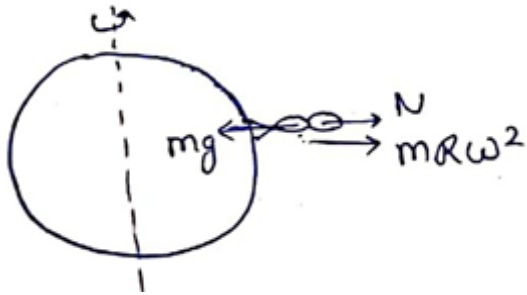
$$T - mR\omega^2 = \frac{m(R\omega^2)}{3}$$

$$T = \frac{4}{3} mR\omega^2$$

Question 17

A person stands on a spring balance at the equator. (a) By what fraction is the balance reading less than his true weight? (b) If the speed of earth's rotation is increased by such an amount that the balance reading is half the true weight, what will be the length of the day in this case?

Solution 17



(a)

At equator, normal contact force

$$N + mR\omega^2 = mg$$

$$\text{Reading } N = mg - mR\omega^2$$

$$\text{So, fraction less than true weight} = \frac{mg - (mg - mR\omega^2)}{mg}$$

$$= \frac{R\omega^2}{g}$$

$$= \frac{g}{g}$$

$$= \frac{(6400 \times 10^3)}{(10)} \left(\frac{2\pi}{86400} \right)^2$$

$$= 3.5 \times 10^{-3}$$

(b)

$$\text{Balance reading} = \frac{1}{2} (\text{True weight})$$

$$mg - mR\omega^2 = \frac{1}{2} (mg)$$

$$mR\omega^2 = \frac{1}{2} mg$$

$$\omega = \sqrt{\frac{g}{2R}} = \frac{2\pi}{T'}$$

$$T' = 2 \times 3.14 \times \frac{\sqrt{(2 \times 6400 \times 10^3)}}{\sqrt{(9.8)}}$$

$$T' = \frac{2 \times 3.14 \times \sqrt{(6.4 \times 10^7)}}{\sqrt{49}} \quad (\text{in hrs.})$$

$$T' = \frac{(60 \times 60)}{2} \quad (\text{in hrs.})$$

$$T' = 2 \text{ hrs}$$