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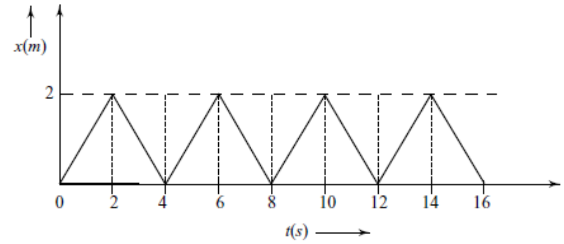
Class: XI
Subject: Physics
Topic: Laws of motion
No. of Questions: 29

Q1. The given figure shows the position–time (x–t) graph of one-dimensional motion of a body of mass 0.4 kg.
What is the time interval between consecutive impulses received by the body?



A. 2 s

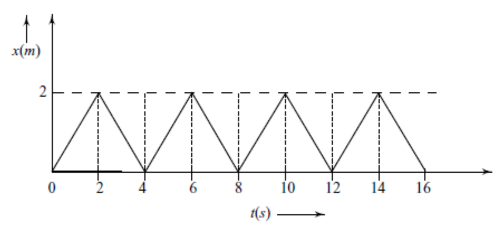
B. 4 s

C. 8 s

D. 16 s

Sol: A
Terval from t = 0 to 2 s. Between t = 2 s and t = 4 s, the slope of the graph is constant but negative. This implies that at t = 2s, the velocity of the body is re-versed and it retraces its path and returns to $x = 0$ at t = 4 s; and so on. Thus, the body receives impulses at t = 0, 2 s, 4 s, … , etc. Therefore, the interval be-tween two consecutive impulses is 2 s. Hence, the correct choice is (1).

Q2. The given figure shows the position–time (x–t) graph of one-dimensional motion of a body of mass 0.4 kg.
What is the magnitude of each impulse?



A. 0.2 Ns

B. 0.4 Ns

C. 0.8 Ns

D. 1.6 Ns

Sol: C

Between $t = 0$ and $t = 2$s, the speed of the body is v = slope of the (x–t) graph between $t = 0$ and $t = 2$s, i.e.

$$v = \frac{(2-0)\text{m}}{(2-0)\text{s}} = 1 \text{ ms}^{-1}$$

At $t = 2$ s, the velocity of the body is reversed and it moves in the opposite direction with a speed = -1 ms^{-1}. Therefore,

$$\begin{aligned}\text{Impulse} &= \text{change in momentum} \\ &= mv - (-mv) = 2\,mv \\ &= 2 \times 0.4 \text{ kg} \times 1 \text{ ms}^{-1} \\ &= 0.8 \text{ kg ms}^{-1} = 0.8 \text{ Ns}\end{aligned}$$

Hence, the correct choice is (3).

Q3. An aeroplane of mass M requires a speed v for takeoff. The length of the runway is s and the coefficient of friction between the tyres and the ground is μ. Assuming that the plane accelerates uniformly during the takeoff, the minimum force required by the engine of the plane for takeoff is given by

A. $M\left(\frac{v^2}{2s} + \mu g\right)$

B. $\left(\frac{v^2}{2s} - \mu g\right)$

C. $M\left(\frac{2v^2}{s} + 2\mu g\right)$

D. $M\left(\frac{2v^2}{s} - 2\mu g\right)$

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Sol: A

The required force is to (i) accelerate the plane from rest to a speed v over a distance s and (ii) to overcome the force of friction ($= \mu R = \mu Mg$). The acceleration a required to impart a speed v in a distance s is given by $v^2 - u^2 = 2as$. Since, $u = 0$, we have $v^2 = 2\,as$ or $a = v^2/2s$. The force needed to produce this acceleration is

$$F_1 = \text{mass} \times \text{acceleration} = \frac{Mv^2}{2s}$$

The force needed to overcome the force of friction is

$$F_2 = \mu Mg$$

$$\therefore \text{ Total force needed} = F_1 + F_2 = M\left(\frac{v^2}{2s} + \mu g\right)$$

Hence, the correct choice is (1)

Q4. A block of mass 5 kg is resting on an inclined plane. The inclination of the plane to the horizontal direction is gradually increased. It is found that when the angle of inclination is 30°, the block just begins to slide down the plane. The coefficient of sliding friction μ_s between the block and the plane is

A. μ_s = sin 30°

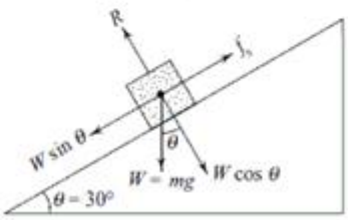
B. μ_s = cos 30°

C. μ_s = tan 30°

D. μ_s = cot 30°

Sol: C

The weight $W = mg$ of the block can be resolved into two rectangular components: one along the plane ($W \sin\theta$) and the other perpendicular to it ($W \cos\theta$). Let R be the magnitude of the normal reaction and f_s be the force of sliding friction



When these forces are in equilibrium, the block just begins to slide, i.e.

$f_s = W \sin\theta$

Also $R = W \cos\theta$

$\therefore$ Coefficient of sliding friction is $\mu_s = \frac{f_s}{R} = \frac{W\sin\theta}{W\cos\theta}$

$= \tan\theta = \tan 30°$.

Hence, the correct choice is (3).

Q5. Ten coins are placed on top of each other on a horizontal table. If the mass of each coin is 10 g and acceleration due to gravity is 10 ms^{-2}, what is the magnitude and direction of the force on the 7^{th} coin (counted from the bottom) due to all the coins above it?

A. 0.3 N downwards

B. 0.3 N upwards

C. 0.7 N downwards

D. 0.7 N upwards

Sol: A

Mass of each coin (m) = 10 g = 0.01 kg. The 7^{th} coin from the bottom has 3 coins above it. Hence, the force on the 7^{th} coin = weight of 3 coins = 3 mg = $3 \times 0.01 \times 10 = 0.3$ N, vertically downwards. Thus, the correct choice is (1).

Q6. A given object takes as much time to slide down a 45° rough incline as it takes to slide down a perfectly smooth 45° incline. The coefficient of kinetic friction between the object and the incline is given by

A. $\mu_k = 1/(1-n^2)$

B. $\mu_k = 1 - 1/n^2$

C. $\mu_k = \sqrt{1/(1-n^2)}$

D. $\mu_k = \sqrt{(1-1/n^2)}$

Sol: B

The square of the time of slide is inversely proportional to the acceleration. The accelerations in the two cases are

$$a_1 = g\sin 45° = \frac{g}{\sqrt{2}} \text{ and } a_2$$
$$= (g\sin 45° - \mu_k g\cos 45°)$$
$$= \frac{g}{\sqrt{2}}(1-\mu_k)$$

$\therefore$ $$\frac{t_2^2}{t_1^2} = n^2 = \frac{a_1}{a_2} = \frac{1}{1-\mu_k}$$

or $$\mu_k = 1 - \frac{1}{n^2}.$$

Hence, the correct choice is (2).

Q7. A body is moving down a long inclined plane of angle of inclination θ. The coefficient of friction between the body and the plane varies as μ = 0.5 x, where x is the distance moved down the plane. The body will have the maximum velocity when it has travelled a distance x given by

A. $x = 2\tan\theta$

B. $x = \frac{2}{\tan\theta}$

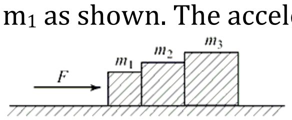
C. $x = \sqrt{2}\cot\theta$

D. $x = \frac{\sqrt{2}}{\cot\theta}$

Sol: A

The acceleration of the body down the plane is $g\sin\theta - \mu g\cos\theta = g(\sin\theta - \mu\cos\theta) = g(\sin\theta - 0.5x\cos\theta)$. Therefore, the body will first accelerate up to $x < 2\tan\theta$. The velocity will be maximum at $x = 2\tan\theta$, because for $x > 2\tan\theta$, the body starts decelerating. Hence, the correct choice is (1).

Q8. Three blocks of masses m_1 = 1 kg, m_2 = 2 kg and m_3 = 3 kg are placed in contact on a horizontal frictionless surface as shown in the figure. A force F = 12 N is applied to mass m_1 as shown. The acceleration of the system is



A. 12 ms^{-2}

B. 6 ms^{-2}

C. 4 ms^{-2}

D. 2 ms^{-2}

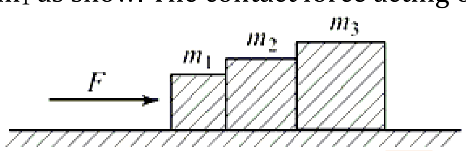
Sol: D

The acceleration of the system is

$$a = \frac{\text{net force}}{\text{total mass}} = \frac{12}{1+2+3} = 2 \text{ ms}^{-2}$$

Hence the correct choice is (4).

Q9. Three blocks of masses m_1 = 1 kg, m_2 = 2 kg and m_3 = 3 kg are placed in contact on a horizontal frictionless surface as shown in the figure. A force F = 12 N is applied to mass m_1 as show. The contact force acting on mass m_2 is



A. 12 N

B. 10 N

C. 8 N

D. 6 N

Sol: B

The contact force on mass m_2 is

$$F_2 = (m_2 + m_3)a = (2+3) \times 2 = 10 \text{ N}$$

Hence the correct choice is (2).

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Q10. A car moving at a speed 'v' is stopped by a retarding force F over a distance 's'. If the retarding force were 3F, the car could have been stopped over a distance of

A. $\frac{s}{3}$

B. $\frac{s}{6}$

C. $\frac{s}{9}$

D. $\frac{s}{12}$

Sol: A

Now, $F = \frac{mv^2}{2s}$, which implies that $s \propto \frac{1}{F}$, i.e. s is inversely proportional to F. Thus, the correct choice is (1).

Q11. A simple pendulum of length r = 1 m and bob of mass 100 g is swinging with an angular amplitude of 60°. What is the tension in the string when the bob passes through the equilibrium position? Take g = 10 ms^{-2}

A. 1 N

B. 2 N

C. 3 N

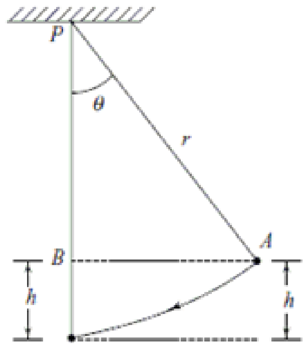
D. 4 N

Sol: B

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

where v is the speed of the bob at O. Now, the potential energy of the bob at the extreme position $A = mgh$ which is converted into kinetic energy $\frac{1}{2}mv^2$ when it reaches O. Therefore

$$\frac{1}{2}mv^2 = mgh$$



Q12. The pilot of an aircraft, who is not tied to his seat, can loop a vertical circle in air without falling out at the top of the loop. What is the minimum speed required so that he can successfully negotiate a loop or radius 4 km? Take g = 10 ms^{-2}.

A. 100 ms^{-1}

B. 300 ms^{-1}

C. 200 ms^{-1}

D. 400 ms^{-1}

Sol: C

The pilot does not drop down when he is at the top of the loop because his weight mg is less than the centripetal force $m\,v^2/R$ required to keep him in the loop. The rest of the centripetal force is balanced by the reaction of the seat. Hence, he is stuck to the seat without being tied to it. If the speed of the aircraft is reduced so that $mg > mv^2/R$, he will fall off from his seat. Therefore, the minimum speed v_{min} required to successfully negotiate the vertical loop is given by

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

or

$$v_{min} = \sqrt{gR} = \sqrt{10 \times 4000}$$

$$= 200\ ms^{-1}$$

Thus, the correct choice is (2).

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Q13. A block of weight 200 N is pulled along a rough horizontal surface at a constant speed by a force of 100 N acting at an angle of 30° above the horizontal. The coefficient of friction between the block and the surface is

A. 0.43

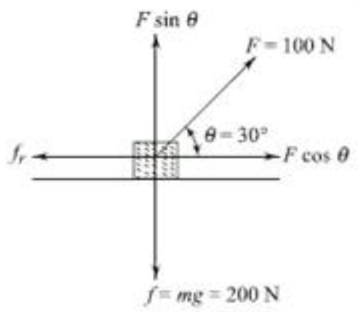
B. 0.58

C. 0.75

D. 0.85

Sol: B

Refer to Fig. Since the block moves with a constant velocity, no net force acts on it. Therefore, the horizontal component $F \cos \theta$ of force F must balance with the friction force, i.e. $f_r = F \cos \theta$. Also



$$f_r = \mu (mg - F \sin \theta)$$
$$= \mu (f - F \sin \theta)$$

$\therefore \quad \mu (f - F \sin \theta) = F \cos \theta$

or $\quad \mu (200 - 100 \sin 30°) = 100 \cos 30°$

or $\quad \mu \left(200 - 100 \times \frac{1}{2}\right) = 100 \times 0.866 = 86.6$

or $\quad \mu = \frac{86.6}{150} = 0.58,$

which is choice (2).

Q14. A body of mass M kg is on the top point of a smooth hemisphere of radius 5 m. It is released to slide down the surface of the hemisphere. It leaves the surface when its velocity is 5 m/s. At this instant, the angle made by the radius vector of the body with the vertical is (Take acceleration due to gravity = 10 ms^{-2})

A. 30°

B. 45°

C. 60°

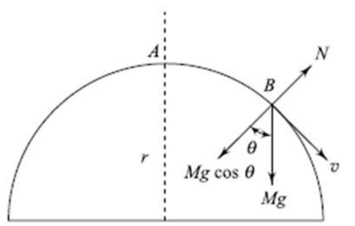
D. 90°

Sol: C

Let the body leave the surface at point B as shown in Fig. 3.95. When the body is between points A and B, we have

$$Mg\cos\theta - N = \frac{Mv^2}{r}$$

When the body leaves the surface at point B, the normal reaction N becomes zero. Thus



$$Mg\cos\theta = \frac{Mv^2}{r}$$

$$\text{or} \quad \cos\theta = \frac{v^2}{rg} = \frac{(5)^2}{5\times 10} = \frac{1}{2} \quad \text{or} \quad \theta = 60°$$

Q15. A body of mass 0.5 kg is whirled in a vertical circle at an angular frequency of 10 rad s^{-1}. If the radius of the circle is 0.5 m, what is the tension in the string when the body is at the top of the circle? Take g = 10 ms^{-2}.

A. 10 N

B. 20 N

C. 30 N

D. 40 N

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Sol: B

It is clear from Fig. that when the body at the top point A of the circle, its weight mg and tension T_1 in the string act downwards towards the centre O of the circle and the sum of the two provides the necessary centripetal force. Thus

$$T_1 + mg = mR\omega^2$$

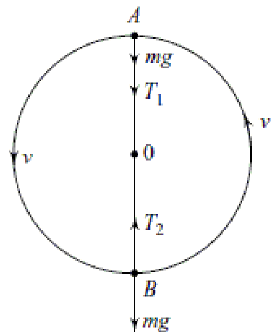
or

$$T_1 = m(R\omega^2 - g)$$

$$= 0.5 \times (0.5 \times 10^2 - 10)$$

$$= 20\text{ N}$$

Thus, the correct choice is (2)



Q16. A body of mass 0.5 kg is whirled in a vertical circle at an angular frequency of 10 rad s^{-1}. If the radius of the circle is 0.5 m, what will be the tension in the string when the body is at the bottom of the circle?

A. 10 N

B. 30 N

C. 20 N

D. 40 N

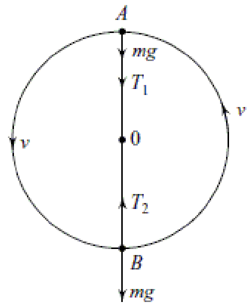
Sol: B

When the body is at the bottom of the circle (point B in Fig.), the tension T_2 is opposite to weight mg and the difference $(T_2 - mg)$ provides the necessary centripetal force. Therefore, we have

$$T_2 = m(R\omega^2 + g)$$

$$= 0.5 \times (0.5 \times 10^2 + 10) = 30\text{ N}$$

Thus, the correct choice is (3).



Q17. A simple pendulum having a bob of mass m swings with an angular amplitude of 40°. When its angular displacement is 20°, the tension in the string is

A. mg cos 20°

B. mg sin 20°

C. greater than mg cos 20°

D. greater than mg sin 20°

Sol: C

The tension in the string is given by

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

where r is the length of the string and v, the velocity of the bob when its angular displacement is θ. When the angular displacement is maximum, i.e. when $\theta = 40°$, $v = 0$. Tension at $\theta = 20°$ is given by

$$T = mg\cos 20° + \frac{mv^2}{r}$$

where v is the velocity when $\theta = 20°$. Hence the correct choice is (3).

Q18. A cylinder rolls up an inclined plane, reaches some height, and then rolls down (without slipping throughout these motions). The directions of the frictional force acting on the cylinder are

A. up the incline while ascending and down the incline while descending

B. up the incline while ascending as well as descending

C. down the incline while ascending and up the incline while descending

D. down the incline while ascending as well as descending

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Sol: B

When a cylinder rolls up or down an inclined plane, its angular acceleration is always directed down the plane. Hence, the frictional force acts up the inclined plane when the cylinder rolls up or down the plane. Thus, the correct choice is (2).

Q19. A uniform chain of length L is lying on the horizontal surface of a table. If the coefficient of friction between the chain and the table top is μ = 0.25, what is the maximum percentage of the length of the chain that can hang over the edge of the table without disturbing the rest of the chain on the table?

A. 8%

B. $\frac{40}{3}\%$

C. 20%

D. 25%

Sol: C

$\frac{l}{L}=\frac{\mu}{1+\mu}=\frac{0.25}{1+0.25}=\frac{1}{5}$ or 20%, which is choice (3).

Q20. A smooth inclined plane of angle of inclination 30° is placed on the floor of a compartment of a train moving with a constant acceleration a. When a block is placed on the inclined plane, it does not slide down or up the plane. The acceleration a must be

A. g

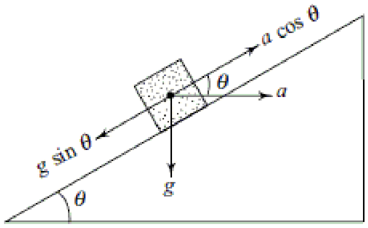
B. $\frac{g}{2}$

C. $\frac{g}{\sqrt{2}}$

D. $\frac{g}{\sqrt{3}}$

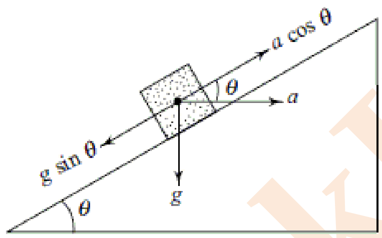
Sol: D

Refer to Fig. The component of acceleration vector **a** along the plane is $a \cos \theta$. The component of acceleration due to gravity **g** along the plane is $g \sin \theta$. The block will stay at rest if $a \cos \theta = g \sin \theta$ or $a = g \tan \theta$



Now $\theta = 30°$. Therefore, $a = g \tan 30° = \frac{g}{\sqrt{3}}$. Hence the correct choice is (4).

Refer to Fig. The component of acceleration vector **a** along the plane is $a \cos \theta$. The component of acceleration due to gravity **g** along the plane is $g \sin \theta$. The block will stay at rest if $a \cos \theta = g \sin \theta$ or $a = g \tan \theta$



Now $\theta = 30°$. Therefore, $a = g \tan 30° = \frac{g}{\sqrt{3}}$. Hence the correct choice is (4).

Q21. What is the unit of coefficient of friction?

Ans. It has no unit.

Q22. Name the factor on which coefficient of friction depends?

Ans. Coefficient of friction $us = F/R$ depends on the nature of surfaces in contact and nature of motion.

Q23. What provides the centripetal force to a car taking a turn on a level road?

Ans. Centripetal force is provided by the force of friction between the tyres and the road.

Q24. Give the magnitude and direction of the net force acting on

(a) A drop of rain falling down with constant speed.

(b) A kite skillfully held stationary in the sky.

Ans.

(1) According to first law of motion F = 0 as a = 0 (particle moves with constant speed)
(2) Since kite is stationary net force on the kite is also zero.

Q25. Two blocks of masses m1, m2 are connected by light spring on a smooth horizontal surface. The two masses are pulled apart and then released. Prove that the ratio of their acceleration is inversely proportional to their masses.

Ans. The forces F_1 and F_2 due to masses m_1 and m_2 acts in opposite directions
Thus $F_1 + F_2 = 0$
$m_1 a_1 + m_2 a_2 = 0$
$m_1 a_1 = - m_2 a_2$
$\frac{a_1}{a_2} = -\frac{m_1}{m_2}$ Hence proved

Q26. A shell of mass 0.020kg is fired by a gun of mass 100kg. If the muzzle speed of the shell is 80m/s, what is the recoil speed of the gun?

Ans. Momentum before firing = 0
Momentum after firing = momentum of (bullet + gun)
Momentum after firing $= mbv_b - m_g v_g$
According to law of conservation of linear momentum
$0 = m_b v_b - m_g v_g$
$m_b v_b - m_g v_g$
$\Longrightarrow v_g = \frac{m_b v_b}{m_g}$
$v_g = \frac{m_b v_b}{m_g} = \frac{0.02\times 80}{100}$ $\qquad v_g = 0.016 m / s$

Q27. A train runs along an unbanked circular bend of radius 30m at a speed of 54km/hr. The mass of the train is 106kg. What provides the necessary centripetal force required for this purpose? The engine or the rails? What is the angle of banking required to prevent wearing out of the rail?

Ans.

(1) The centripetal force is provided by the lateral force acting due to rails on the wheels of the train.
(2) Outer rails

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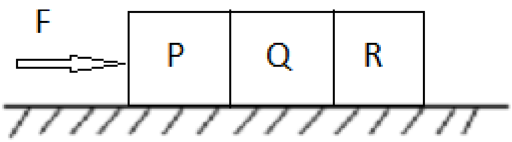
(3) $\tan\theta = \frac{v^2}{rg} = \frac{(15)^2}{30\times 9.8}$

$\tan\theta = 0.7653$

$\theta = 37.4^o$

Q28. Three identical blocks each having a mass m, are pushed by a force F on a frictionless table as shown in figure



What is the acceleration of the blocks? What is the net force on the block P? What force does P apply on Q. What force does Q apply on R?

Ans. If a is the acceleration

Then F = (3m)a

$a = F/3m$

(1) Net force on P

$F_1 = ma = m\times \frac{F}{3m}$ $\qquad F_1 = F/3$

(2) Force applied on

$F_2 = (m + m)a$

$F_2 = 2m \times a = 2m \times \frac{F}{3m}$ $\qquad F_2 = \frac{2F}{3}$

(3) Force applied on R by Q

$F_3 = m \times a = m \times \frac{F}{3m}$ $\qquad F_3 = \frac{F}{3}$

Q29. (a) Define impulse. State its S.I. unit?

(b) State and prove impulse momentum theorem?

Ans.

(a) Force which are exerted over a short time intervals are called impulsive forces.

Impulse I=F×t

Unit – NS

Impulse is a vector quantity directed along the average force $\overrightarrow{F\ av.}$

(b) Impulse of a force is equal to the change in momentum of the body.

According to Newton's second law

$$\vec{F} = \frac{d\vec{p}}{dt}$$

$$or\ d\vec{p} = \vec{F}dt$$

$$At\ t = 0\ \vec{P} = \vec{P_1}\ and\ at$$

$$t = t\ \vec{P} = \vec{P_2}$$

$$\int_{\vec{P_1}}^{\vec{P_2}} dp = \int_{v}^{t} Fdt$$

$$\vec{P_2} - \vec{P_1} = Ft$$

$$\boxed{\vec{P_2} - \vec{P_1} = I} \qquad [\because Ft = I\,(\text{Impulse})]$$

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