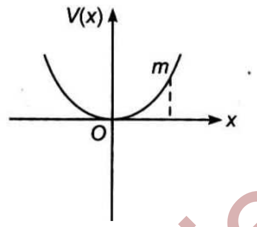
Circular Motion

2011

1. A particle moves in a circle of radius 5 cm with constant speed and time period $0.2\pi\, s$. The acceleration of the particle is

a) $25 m/s^2$ b) $36 m/s^2$ c) $5 m/s^2$ d) $15 m/s^2$

2. A particle of mass m is released from rest and follows a parabolic path as shown. Assuming that the displacement of the mass from the origin is small, which graph correctly depicts the position of the particle as a function of time?



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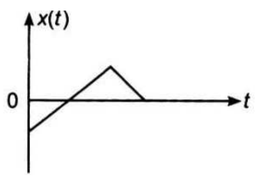

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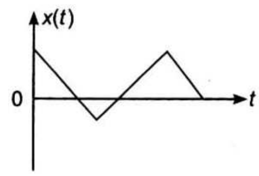

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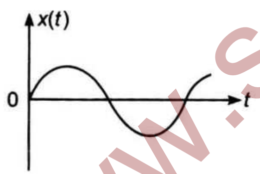

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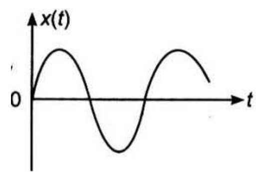

4. A ball of mass 0.12kg is being whirled in a horizontal circle at the end of string 0.5m long. It is capable of making 231 revolutions in one minute. The breaking tension of the string is

a) 3 N b) 15.1N c) 31.5N d) 35.1N

6. The motor of an angle is rotating about its axis with an angular velocity of 100 rev/m. It comes to rest in 15s, after being switched off. Assuming constant angular deceleration. What are the numbers of revolutions made by it before coming to rest?

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a) 12.5 b) 40 c) 32.6 d) 15.6

7. A stone of mass m is tied to a string and is moved in a vertical circle of radius r making n rev/min. The total tension in the string when the stone is at the lowest point is

a) mg b) $m(g+\pi nr^2)$ c) m (g + nr) d) $m\left\{g+\frac{\pi^2 n^2 r}{900}\right\}$

6. A string is wound round the rim of a mounted flywheel of mass 20kg and radius 20cm. A steady pull of 25N is applied on the cord. Neglecting friction and mass of the string, the angular acceleration of the wheel is

a) $50s^{-2}$ b) $25s^{-2}$ c) $12.5s^{-2}$ d) $6.25s^{-2}$

7. A wheel is rotating at 900 rpm about its axis. When the power is cut off it comes to rest in 1min. The angular retardation in rad/s^2 is

a) $\frac{\pi}{2}$ b) $\frac{\pi}{4}$ c) $\frac{\pi}{6}$ d) $\frac{\pi}{8}$

8. A car is moving in a circular horizontal track of radius 10.0 m with a constant speed of $10.0ms^{-1}$. A plumb bob is suspended from the roof of the car by a light rigid rod of length 1.00 m. The angle made by the rod with the track is $(g=10ms^{-2})$

a) Zero b) 30^0 c) 45^0 d) 60^0

2008

9. A roller coaster is designed such that riders experience 'weightlessness' as they go round the top of a hill whose radius of curvature is 20m. The speed of the car at the top of the hill is between

a) $14ms^{-1}$ and $15ms^{-1}$ b) $15ms^{-1}$ and $16ms^{-1}$

c) $16ms^{-1}$ and $17ms^{-1}$ d) $13ms^{-1}$ and $14ms^{-1}$

10. Assertion: A body of mass 1kg is making 1rps in a circle of radius 1m. Centrifugal force acting on it is $4\pi^2 N$.

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Reason: Centrifugal force is given by $F = \frac{mv^2}{r}$

a) Both assertion and reason are true and reason is the correct explanation of assertion.

b) Both assertion and reason are true but reason is not the correct explanation of assertion.

c) Assertion is true but reason is false.

d) Both assertion and reason are false.

11. A particle is moving along a circular path of radius 4m with a uniform speed $5ms^{-1}$**. What will be the average acceleration when the particle completes half revolution?**

a) Zero b) $10ms^{-2}$ c) $10\pi ms^{-2}$ d) $\frac{10}{\pi}ms^{-2}$

12. A car of mass m moves in a horizontal circular path of radius r m. at an instant its speed is $v\,ms^{-1}$ **and is increasing at a rate of** $a\,ms^{-2}$**. Then the acceleration of the car is**

a) $\frac{v^2}{r}$ b) a c) $\sqrt{a^2 + \left(\frac{v^2}{r}\right)^2}$ d) $\sqrt{u + \frac{v^2}{r}}$

13. A body of mass 1kg is rotating in a vertical circle of radius 1m. What will be the difference in its kinetic energy at the top and bottom of the circle (take $g = 10ms^{-2}$**)**

a) 10 J b) 20 J c) 30 J d) 50 J

14. A particle moves through angular displacement θ **on a circular path of radius r. The linear displacement will be**

a) $2r\sin(\theta/2)$ b) $2r\cos(\theta/2)$ c) $2r\tan(\theta/2)$ d) $2r\cot(\theta/2)$

2006

15. A body moves along a circular path of radius 10m and the coefficient of friction is 0.5. What should be its angular speed in $rads^{-1}$ **if it is not to slip from the surface?** $(g = 9.8ms^{-2})$

a) 5 b) 10 c) 0.1 d) 0.7

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16. 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

a) T b) $T - \frac{mv^2}{l}$ c) $T + \frac{mv^2}{l}$ d) Zero

17. If a_r and a_t represent radial and tangential accelerations, the motion of a particle will be uniformly circular if

a) $a_r = 0$ and $a_t = 0$ b) $a_r = 0$ but $a_t \neq 0$ c) $a_r \neq 0$ but $a_t = 0$ d) $a_r \neq 0$ and $a_t \neq 0$

2005

18. A stone tied to the end of a string of 1m long is whirled in a horizontal circle with a constant speed. If the stone makes 22 revolutions in 44s, what is the magnitude and direction of acceleration the centre?

a) $\frac{\pi^2}{4} ms^{-2}$ and direction along the radius towards the centre

b) $\pi^2 ms^{-2}$ and direction along the radius towards from centre

c) $\pi^2 ms^{-2}$ and direction along the radius towards the centre

d) $\pi^2 ms^{-2}$ and direction along the tangent to the circle

19. What determines the nature of the path followed by the particle?

a) Speed b) Velocity c) Acceleration d) Both b and c

20. A ball of mass 0.25kg attached to the ends of a string of length 1.96m is rotating in a horizontal circle. The string will break, if tension is more than 25N. What is the maximum velocity with which the ball can be rotated?

a) $3ms^{-1}$ b) $5ms^{-1}$ c) $9ms^{-1}$ d) $14ms^{-1}$

21. When a body moves with constant speed in a circular path, then

a) Work done will be zero b) Acceleration will be zero

c) No force acts on the body d) Its velocity remains constant

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22. **A stone of mass m tied to a string of length l is rotated a circle with the other end of the string as the centre. The speed of the stone is v. If the string breaks, the stone will**

a) Move towards the centre
b) Move away from the centre
c) Move along tangent
d) Stop

2004

23. **The direction of the angular velocity vector is along**

a) The tangent to the circular path
b) The inward radius
c) The outward radius
d) The axis of rotation

24. **In an orbital motion, the angular momentum vector is**

a) Along the radius vector
b) Parallel to the linear momentum
c) In the orbital plane
d) Perpendicular to the orbital plane.

2003

25. **A particle moves a long a circle of radius** $\left(\frac{20}{\pi}\right)m$ **with constant tangential acceleration. If the velocity of the particle is** $80ms^{-1}$ **at the end of the second revolution after motion has begun, the tangential acceleration is**

a) $160\pi ms^{-2}$
b) $40ms^{-2}$
c) $40\pi ms^{-2}$
d) $640\pi ms^{-2}$

26. **Force responsible for the circular motion of the body is**

a) Centripetal Force
b) Centrifugal Force
c) Gravitational Force
d) None of these

27. **A cyclist moving at a speed of** $20ms^{-1}$ **takes a turn, if the doubles his speed then chance of overturn**

a) Is doubled
b) Is halved
c) Becomes four times
d) Becomes ¼ times

28. **A particle originally at rest at the highest point of a smooth circle in a vertical plane, is gently pushed and starts sliding along the circle in a vertical plane, is gently pushed and starts sliding along the circle. It will leave the circle at a vertical distance h below the highest point such that**

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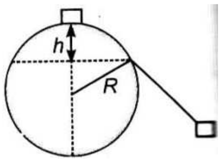


a) h = 2R b) $h = \frac{R}{2}$ c) h =R d) $h = \frac{R}{3}$

Key

1) **c**	2) **d**	3) **d**	4) **a**	5) **d**	6) **c**	7) **a**	8) **c**	9) **a**	10) **a**
11) **d**	12) **c**	13) **b**	14) **a**	15) **d**	16) **a**	17) **c**	18) **c**	19) **d**	20) **d**
21) **a**	22) **c**	23) **d**	24) **d**	25) **b**	26) **a**	27) **d**	28) **d**		

Hints

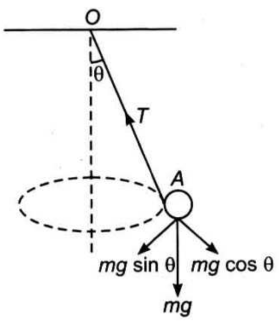
1. r =5cm $= 5\times10^{-2}m$ and $T = 0.2\pi s$

$$a = r\omega^2 = \frac{4\pi^2}{T^2}r = \frac{4\times\pi^2\times5\times10^{-2}}{(0.2\pi)^2} = 5ms^{-2}$$

2. Concept

3. $F = \frac{mv^2}{r}$

Where, m is mass, v the velocity and r the radius



Since, $v = r\omega$

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$F = mr\omega^2$

But, m = 0.1kg, r = 0.5m,

$\omega = 231 rpm = \frac{2\pi \times 231}{60} rad\ s^{-1}$ = 24.2 rad/s

$\therefore F = 0.12 \times 0.5 \times (24.2)^2 = 35.1N$

4. $0 = \omega_0 - \alpha t$

$\alpha = \frac{\omega_0}{t} = \frac{(100 \times 2\pi)/60}{15} = 0.6 rad/s^2$

Now, $\theta = \frac{\omega_0^2}{2\alpha}$

Or $\theta = \frac{\left(\frac{100 \times 2\pi}{60}\right)^2}{2 \times 0.7} = 78.25 rad$

Number of rotations

$n = \frac{\theta}{2\pi} = 12.5$

5. $T_{net} = \frac{mv^2}{r} + mg = mr\omega^2 + mg = mg\left(\frac{2\pi n}{60}\right)^2 + mg = m\left[\frac{\pi^2 n^2 r}{900} + g\right]$

6. m = 20kg

R = 20cm = $\frac{1}{5}$

But, $I = \frac{1}{2} MR^2 = \frac{1}{2} \times 20 \times \frac{1}{5}$

$I = 0.4 kg - m^2$

Angular acceleration $\alpha = \frac{\tau}{I} = \frac{FR}{I} = \frac{25 \times \frac{1}{5}}{0.4} = 12.5 s^{-2}$

7. $\omega = \omega_0 + \alpha t$

$\omega_0 = 900 rpm = \frac{(2\pi \times 900)}{60} rad/s$

$\omega = 0$ and t = 60

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$$0=\frac{2\pi\times 900}{60}+\alpha\times 60$$

$$\alpha=\frac{2\pi\times 900}{60\times 60}=\frac{\pi}{2}$$

8. $\tan\theta=\frac{v^2}{rg}\Rightarrow\tan\theta=\frac{(10)^2}{10\times 10}=1$

$\Rightarrow\theta=45^0$

9. $Mg-N=M\frac{v^2}{R}$

For weightlessness, N = 0

$\therefore\frac{Mv^2}{R}=Mg$

Where R is the radius of curvature and v is the speed of car

Therefore, $v=\sqrt{Rg}$

But, R =20m, $g=10.0ms^{-2}$

$v=\sqrt{20\times 10.0}=14.14ms^{-2}$

10. $F=\frac{mv^2}{r}=\frac{n(r\omega)^2}{r}=mr\omega^2=mr(2\pi v)^2=4\pi^2mrv^2$

$F=4\pi^2\times 1\times 1\times 1^2=4\pi^2N$

11. Change in velocity

$\Delta v=[5-(-5)]ms^{-1}=10ms^{-1}$

Time taken to complete the half revolution is

$t=\frac{\pi r}{v}=\frac{\pi\times 5}{5}=\pi\text{second}$

Average acceleration $a_v=\frac{\Delta v}{t}=\frac{10}{\pi}ms^{-2}$

12. Radial acceleration $a_r=\frac{v^2}{r}$

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Tangential acceleration $a_t = a$

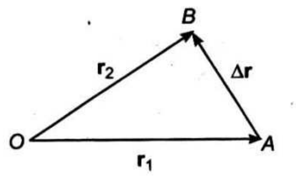
$\therefore$ Resultant acceleration $a' = \sqrt{a_r^2 + a_t^2 + 2a_r a_t \cos\theta}$

But $\theta = 90^0$

And $a' = \sqrt{a_r^2 + a_t^2} = \sqrt{\left(\frac{v^2}{r}\right)^2 + a^2}$

13. Difference in kinetic energy $= \frac{1}{2}m[5gr - gr] = 2gmr$ = 2 x 10 x 1 x 1 =20J

14. $\Delta r = r_2 - r_1$; where $r_2 = r_1 = r$



$\Delta r = \sqrt{r_2^2 + r_1^2 - 2r_2 r_1 \cos\theta} = 2r\sin\frac{\theta}{2}$

15. $mr\omega^2 = \mu mg$

Or $r\omega^2 = \mu g$

Or $\omega = \sqrt{\frac{0.5\times 9.8}{10}} = 0.7 rad\, s^{-1}$

16. Concept

17. a) if $a_r = 0$ and $a_t = 0$ then motion is uniform translatory

b) if $a_r = 0$ but $a_t \neq 0$ then motion is acceleration translatory

c) if $a_r \neq 0$ and $a_t \neq 0$, then motion is a uniform circular

d) if $a_r \neq 0$ and $a_t \neq 0$ then motion is a non uniform circular

18. $a = r\omega^2 = r\left(\frac{2\pi n}{t}\right)^2 = r\times\frac{4\pi^2 n^2}{t^2} = \frac{1\times 4\times\pi^2\times(22)^2}{(44)^2} = \pi^2 ms^{-2}$

This acceleration is directed along radius of circle

19. Concept

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20. $F = \frac{mv^2}{r}$

Or $v^2 = \frac{Fr}{m}$

$\therefore v^2 = \frac{25 \times 1.96}{0.25} = 196$

Or $v = \sqrt{196} = 14 ms^{-1}$

21. Concept
22. Concep
23. Concept
24. Concept
25. The tangential acceleration

$a_T = r\alpha$

But from ,

$\omega^2 = \omega_0^2 + 2\alpha\theta$

$\omega_0 = 0$, $\omega = \frac{v}{r} = \frac{80}{20/\pi} = 4\pi \, rad \, s^{-1}$

$\theta = 2 \times 2\pi \, rad$

$\alpha = \frac{\omega^2}{20} = \frac{(4\pi)^2}{2 \times (2 \times 2\pi)} = \frac{16\pi^2}{8\pi} = 2\pi$

$\therefore a_T = r\alpha = \frac{20}{\pi} \times 2\pi = 40 ms^{-2}$

26. Concept
27. $F = \frac{mv^2}{r}$

$\Rightarrow F \propto v^2$

Hence chance of overturning becomes $\frac{1}{4}$ times

28. From law of conservation of energy,

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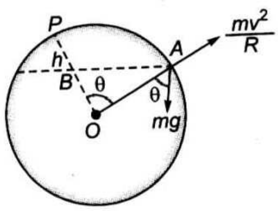
$\therefore PE = KE$

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

$\Rightarrow v = \sqrt{2gh}$ .... (i)

Also the horizontal component of force is equal centrifugal force



$\therefore mg\cos\theta = \frac{mv^2}{R}$ .... (ii)

From eq (i)

$v = \sqrt{2gh}$

$\therefore mg\cos\theta = \frac{2mgh}{R}$ .... (iii)

From ΔAOB,

$\cos\theta = \frac{2R - h}{R}$

$\Rightarrow mg\left(\frac{R-h}{R}\right) = \frac{2mgh}{R} \Rightarrow 3h = R$

$\Rightarrow h = \frac{R}{3}$

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