SOLVED EXAMPLES

Ex. 1 A box of mass m is initially at rest on a horizontal surface. A constant horizontal force of mg/2 is applied to the box directed to the right. The coefficient of friction of the surface changes with the distance pushed as $m = m_0 x$ where x is the distance from the initial location. For what distance is the box pushed until it comes to rest again ?

(A) $\frac{2}{\mu_0}$ **(B)** $\frac{1}{\mu_0}$ **(C)** $\frac{1}{2\mu_0}$ **(D)** $\frac{1}{4\mu_0}$

Sol. Net change in kinetic energy $= 0 \Rightarrow$ net work $W = 0$

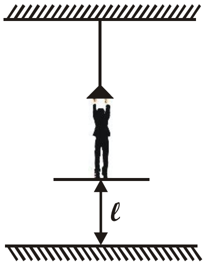
$$\int dW = \int F dx - \int \mu N dx = \frac{mg}{2}x - mg\mu_0 \int_0^x x dx = 0 \Rightarrow x = \frac{1}{\mu_0}$$

Ex. 2 When a conservative force does positive work on a body, then

(A) its potential energy must increase.
(B) its potential energy must decrease.
(C) its kinetic energy must increase.
(D) its total energy must decrease.

Sol. Work done by conservative force $= -\Delta U =$ positive $\Rightarrow \Delta U \downarrow$

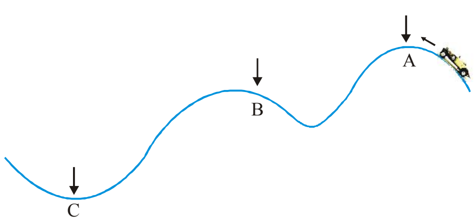
Ex. 3 One end of a light rope is tied directly to the ceiling. A man of mass M initially at rest on the ground starts climbing the rope hand over upto a height ℓ. From the time he starts at rest on the ground to the time he is hanging at rest at a height ℓ, how much work done on the man by the rope ?



(A) 0
(B) $Mg\ell$
(C) $-Mg\ell$
(D) It depends on how fast the man goes up.

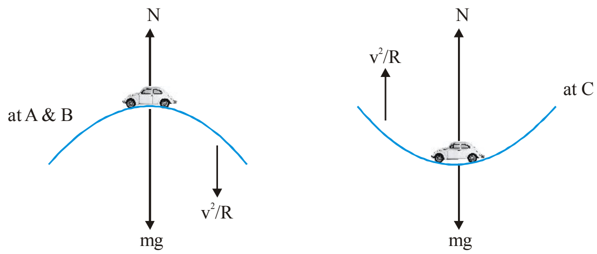
Sol. Total work done on man $= 0 \Rightarrow$ Work done by string $= -$ work done by gravity $= -(-Mg\ell) = Mg\ell$

Ex. 4 A car is moving along a hilly road as shown (side view). The coefficient of static friction between the tyres and pavement is constant and the car maintains a steady speed. If, at one of the points shown the driver applies the brakes as hard as possible without making the tyres slip, the magnitude of the frictional force immediately after the brakes are applied will be maximum if the car was at

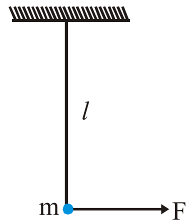


(A) point A
(B) point B
(C) point C
(D) friction force dame for positions A, B and C

Sol. At A & B, $N = mg - mv^2/R$ & at C, $N = mg + mv^2/R$ $\therefore$ $f_{max} = \mu_s N \rightarrow$ maximum for C

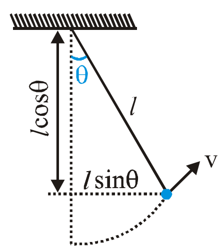


Ex. 5 A pendulum bob of mass m is suspended at rest. A constant horizontal force F = mg/2 starts acting on it. The maximum angular deflection of the string is



(A) 90° **(B)** 53° **(C)** 37° **(D)** 60°

Sol. Let at angular deflection θ its velocity be v then by work energy theorem W = ΔKE



$$\frac{1}{2}mv^2 = -mg(\ell - \ell\cos\theta) + F\ell\sin\theta$$

At maximum angular deflection, v = 0

$$0 = -mg\ell(1-\cos\theta) + \frac{mg}{2}\sin\theta \Rightarrow 2 - 2\cos\theta = \sin\theta$$

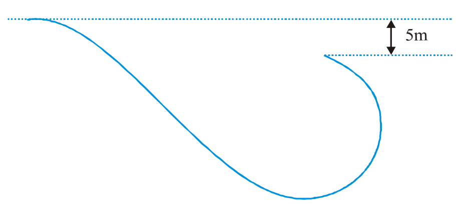
$$\Rightarrow 4 + 4\cos^2\theta - 8\cos\theta = \sin^2\theta = 1 - \cos^2\theta$$

$$\Rightarrow 5\cos^2\theta - 8\cos\theta + 3 = 0 \Rightarrow 5\cos^2\theta - 5\cos\theta - 3\cos\theta + 3 = 0$$

$$\Rightarrow 5\cos^2\theta(\cos\theta - 1) - 3(\cos\theta - 1) = 0 \Rightarrow (5\cos\theta - 3)(\cos\theta - 1) = 0$$

$$\Rightarrow \cos\theta = \frac{3}{5} \text{ or } \cos\theta = 1 \Rightarrow \theta = 37^\circ \text{ or } \theta = 0^\circ$$

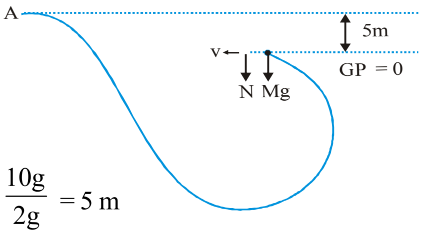
Ex. 6 Consider a roller coaster with a circular loop. A roller coaster car starts from rest from the top of a hill which is 5 m higher than the top of the loop. It rolls down the hill and through the loop. What must the radius of the loop be so that the passengers of the car will feel at highest point, as if they their normal weight ?



(A) 5 m **(B)** 10 m **(C)** 15 m **(D)** 20 m

Sol. According to mechanical energy conservation between A and B

$$mg(5) = O + \frac{1}{2}mv^2 \Rightarrow v^2 = 10g \quad ...(i)$$



According to centripetal force equation

$$N + mg = \frac{mv^2}{r} \text{ for } N = mg;\ 2mg = \frac{mv^2}{r} \Rightarrow r = \frac{v^2}{2g} = \frac{10g}{2g} = 5\text{ m}$$

Ex. 7 The potential energy for the force $\vec{F} = yz\hat{i} + xz\hat{j} + xy\hat{k}$, if the zero of the potential energy is to be chosen at the point (2, 2, 2) is

(A) 8 + xyz **(B)** 8 – xyz **(C)** 4 – xyz **(D)** 4 + xyz

Sol. $\because \vec{F} = -\frac{\partial U}{\partial x}\hat{i} - \frac{\partial U}{\partial y}\hat{j} - \frac{\partial U}{\partial z}\hat{k}$ $\therefore \frac{\partial U}{\partial x} = -yz, \frac{\partial U}{\partial y} - xz, \frac{\partial U}{\partial z} = -xy$

Therefore U = – xyz + C where C = constant As at (2, 2, 2), U = 0 so C = 8

OR

Objective question approach : Check that U = 0 at (2, 2, 2)

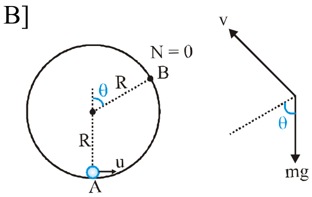
Ex. 8 A particle is projected along the inner surface of a smooth vertical circle of radius R, its velocity at the lowest point being $\frac{1}{5}\sqrt{95Rg}$. It will leaves the circle at an angular distance .... from the highest point.

(A) 37° **(B)** 53° **(C)** 60° **(D)** 30°

Sol. By conservation of mechanical energy [between point A and B]

$$\frac{1}{2}mu^2 = mgR(1 + \cos\theta) + \frac{1}{2}mv^2$$

$$\frac{1}{2}m\left(\frac{1}{5}\sqrt{95Rg}\right)^2 = mgR(1 + \cos\theta) + \frac{1}{2}mgR\cos\theta$$



$mg\cos\theta = mv^2/R (QN = 0)$

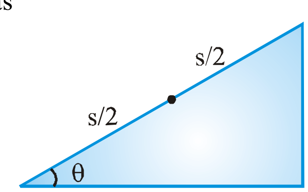
$$\Rightarrow \frac{95}{25} = 2 + 2\cos\theta + \cos\theta \Rightarrow 3\cos\theta = \frac{45}{25} \Rightarrow \cos\theta = \frac{15}{25} = \frac{3}{5} \Rightarrow \theta = 53°$$

Ex. 9 The upper half of an inclined plane with inclination q is perfectly smooth while the lower half is rough. A body starting from rest at the top will again come to rest at the bottom if the coefficient of friction for the lower half is given by

(A) tanθ **(B)** 2tanθ **(C)** 2cosθ **(D)** 2sinθ

Sol. Refer to figure. In the journey over the upper half of incline $v^2 - u^2 = 2as$

$$v^2 - 0 = 2(g\sin\theta)\frac{s}{2} = g\sin\theta.s$$



In the journey over the lower half of incline $v^2 - u^2 = 2as$

$$0 - g\sin\theta.s = 2g(\sin\theta - \mu\cos\theta)\frac{s}{2} \Rightarrow -\sin\theta = \sin\theta - \mu\cos\theta \Rightarrow \mu = \frac{2\sin\theta}{\cos\theta} = 2\tan\theta$$

Ex. 10 Simple pendulum P_1 and P_2 have lengths $\ell_1 = 80$ cm and $\ell_2 = 100$ cm. The bob are of masses m_1 and m_2. Initially both are at rest in equilibrium position. If each of the bobs is given a displacement of 2 cm, the work done is W_1 and W_2 respectively. Then,

(A) $W_1 > W_2$ if $m_1 = m_2$ **(B)** $W_1 < W_2$ if $m_1 = m2$

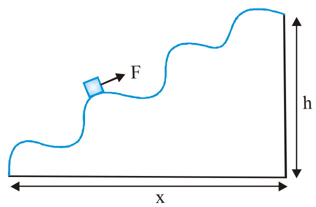
(C) $W_1 = W_2$ if $\frac{m_1}{m_2} = \frac{5}{4}$ **(D)** $W_1 = W_2$ if $\frac{m_1}{m_2} = \frac{4}{5}$

Sol. With usual notation, the height through which the bob falls is $h = \ell(1-\cos\theta) = \ell\left(2\sin^2\frac{\theta}{2}\right) = 2\ell\left(\frac{\theta^2}{4}\right)$

since θ is small. Therefore, we can write $h = \frac{\ell\theta^2}{2} = \frac{\ell}{2}\left(\frac{a}{\ell}\right)^2 = \frac{a^2}{2\ell}$, where a = amplitude

Thus, the work done $W = P.E. = mgh = \frac{mga^2}{2\ell} \Rightarrow W \propto \frac{1}{\ell}$

Ex. 11 A body of mass m is slowly halved up the rough hill by a force F at which each point is directed along a tangent to the hill.



Work done by the force

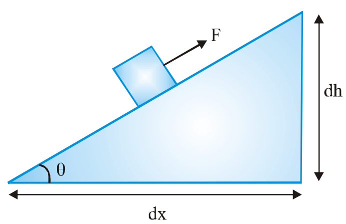
(A) independent of shape of trajectory. **(B)** depends upon x.

(C) depends upon h. **(D)** depends upon coefficient of friction (μ)

Sol. Work done by the force = Work done against gravity (W_g) + work done against friction (W_f)

$= Wg \int(mg\sin\theta)ds = mg\int ds\sin\theta = mg\int dh = mgh$

and $Wf \int(\mu mg\cos\theta)ds = \mu mg\int ds\cos\theta = \mu mg\int dx = \mu mgx$



Ex. 12 A particle moves in one dimensional field with total mechanical energy E. If potential energy of particle is U(x), then

(A) Particle has zero speed where U(x) = E **(B)** Particle has zero acceleration where U(x) = E

(C) Particle has zero velocity where $\frac{dU(x)}{dx} = 0$ **(D)** Particle has zero acceleration where $\frac{dU(x)}{dx} = 0$

Sol. Mechanical energy + potential energy $E = K + U(x)$ where $K = \frac{1}{2}mv^2$

If K = 0 then E = U(x)

If F = 0 then $F = -\frac{dU(x)}{dx} = 0 \Rightarrow \frac{dU(x)}{dx} = 0$

Ex. 13 The kinetic energy of a particle continuously increase with time. Then

(A) the magnitude of its linear momentum is increasing continuously.

(B) its height above the ground must continuously decrease.

(C) the work done by all forces acting on the particle must be positive.

(D) the resultant force on the particle must be parallel to the velocity at all times.

Sol. **For (A) :** $p = \sqrt{2mK}$ if K then p

For (B) : Its height may or

For (C) : W $= \Delta K$ if ΔK = positive then W = positive.

For (D) : The resultant force on the particle must be at an angle less than 90° all times

Ex. 14 A particle of mass m = 1 kg is moving along y-axis and a single conservative force F(y) acts on it. The potential energy of particle is given by $U(y) = (y^2 - 6y + 14)$ J where is in meters. At y = 3 m the particle has kinetic energy of 15 J.

(i) The total mechanical energy of the particle is

(A) 15 J **(B)** 5 J **(C)** 20 J **(D)** can`t be determined

(ii) The maximum speed of the particle is

(A) 5 m/s **(B)** $\sqrt{30}$ m/s **(C)** $\sqrt{40}$ m/s **(D)** $\sqrt{10}$ m/s

(iii) The largest value of y (position of particle) is

(A) $3 + \sqrt{5}$ **(B)** $3 - \sqrt{5}$ **(C)** $3 + \sqrt{15}$ **(D)** $6 + \sqrt{15}$

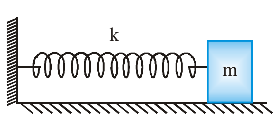
Sol.

(i) Total mechanical energy = kinetic energy + potential energy = $15 + [3^2 - 6(3) + 14] = 15 + 5 = 20$ J

(ii) At maximum speed (i.e. maximum kinetic energy), potential energy is minimum U = y2 – 6y + 14 = 5 + (y – 3)2 which is minimum at y = 3m so Umin = 5 J

(iii) For particle $K \geq 0 \Rightarrow E - U \geq 0 \Rightarrow 20 - (5 + (y-3)^2 \geq 0 \Rightarrow (y-3)^2 \leq 15 \Rightarrow y - 3 \leq \sqrt{15} \Rightarrow y \leq 3 + \sqrt{15}$

Ex. 15 A spring block system is placed on a rough horizontal surface having coefficient of friction μ. The spring is given initial elongation $\frac{3\mu mg}{k}$ and the block is released from rest. For the subsequent motion



(A) Initial acceleration of block is 2μg.

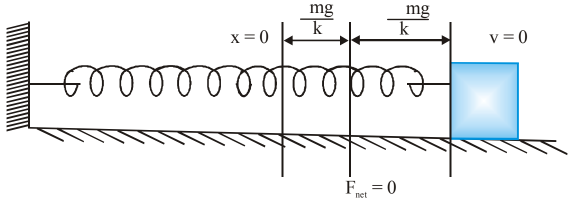
(B) Maximum compression in spring is $\frac{\mu mg}{k}$

(C) Minimum compression in spring is zero.

(D) Maximum speed of the block is $2\mu g\sqrt{\frac{m}{k}}$

Sol. **For (A) :** Initial acceleration $= \dfrac{k\left(\dfrac{3\mu mg}{k}\right) - \mu mg}{m} = 2\mu g$

For (B, C) :

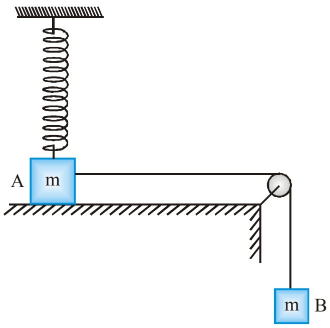


Therefore maximum compression $= \dfrac{2\mu mg}{k} - \dfrac{\mu mg}{k} = \dfrac{\mu mg}{k}$ and minimum compression $= 0$

For (D) : At maximum speed $F_{net} = 0$ so by using work energy theorem

$$\frac{1}{2}mv^2 = \frac{1}{2}k\left(\frac{3\mu mg}{k}\right) - \frac{1}{2}k\left(\frac{\mu mg}{k}\right)^2 - \mu mg\left(\frac{2\mu mg}{k}\right) \Rightarrow v = 2\mu g\sqrt{m/k}$$

Ex. 16 Two block A and B, each having a mass of 320 g connected by a light string passing over a smooth light pulley. The block A is attached to a spring of spring constant 40 N/m whose other end is fixed to a support 40 cm above the horizontal surface as shown. Initially, the spring is vertical and unstretched when the system is released to move. Find the velocity of the block A at the instant it breaks off the surface below it. Take $g = 10\ m/s^2$.

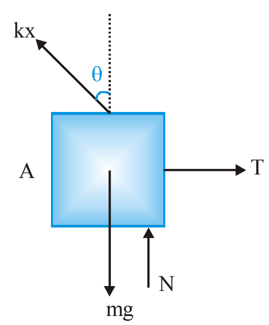


Sol. At the instant of break-off , N = 0

$\Rightarrow$ $kx\cos\theta = mg$

where extension in the spring

$$x = \ell - 0.4 = \frac{0.4}{\cos\theta} - 0.4$$



$\therefore$ $k\left(\dfrac{0.4}{\cos\theta} - 0.4\right)\cos\theta = mg$

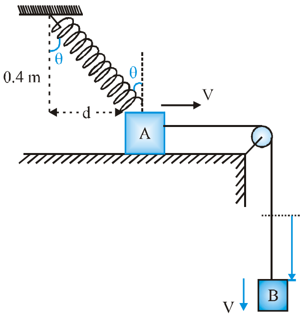
$k(0.4)(1 - \cos\theta) = mg$

$\Rightarrow$ $\cos\theta = 1 - \dfrac{mg}{0.4k}$

$= 1 - \dfrac{0.320 \times 10}{0.4 \times 40}$

$\cos\theta = \dfrac{4}{5}$ $\Rightarrow$ $x = \dfrac{0.4 \times 5}{4} - 0.4 = 0.1\,m$

Also $\tan\theta = \dfrac{3}{4} \Rightarrow$ $d = 0.4\tan\theta = 0.3\,m$



$\therefore$ By work energy theorem for motion of both the blocks.

$W_g + W_s = \Delta KE$

$\Rightarrow$ $mgd - \frac{1}{2}kx^2 = \left(\frac{1}{2}mv^2\right) \times 2$

$\Rightarrow$ $0.32 \times 10 \times 0.3 - \frac{1}{2}(40)(0.1)^2 = (0.32)v^2$

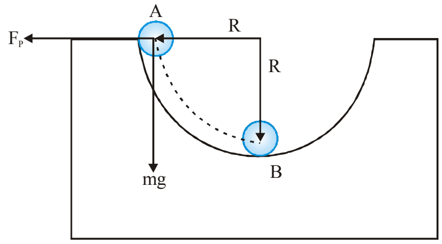
$\Rightarrow$ $v = 1.54$ m/s

Ex. 17 A small body is placed at rest the bottom B of a smooth hemispherical surface of wedge as shown. If the wedge is shifted horizontally towards right with acceleration $a_0 = 3g$, find speed of the body w.r.t. the wedge at the instant the body reaches points A.

Sol. Here we need calculation w.r.t. the wedge which is accelerated i.e. non-inertial frame of reference, so we have to consider Pseudo force (F_P) and work done by the Pseudo force (W_P) also.

where $F_P = ma_0 = 3mg$ and is towards left i.e. opposite to a_0

By work-energy theorem for motion from B to A

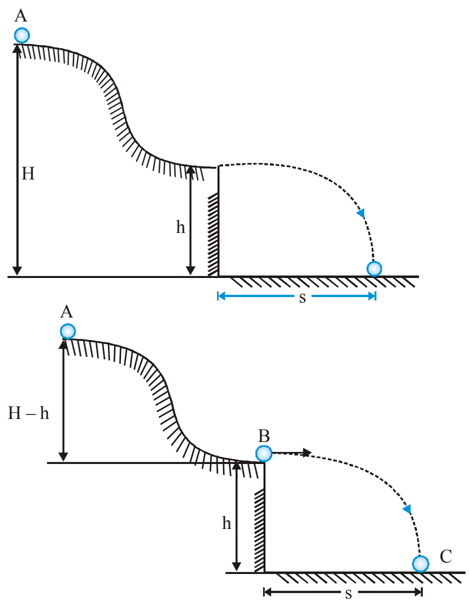


$F_PR - mgR = \frac{1}{2}m(v^2 - 0)$

$\Rightarrow$ $3\,mgR - mgR = \frac{1}{2}mv^2$

$\therefore$ $v = 2\sqrt{gR}$

Ex. 18 A small body starts sliding from the height H with zero velocity down a smooth hill which has horizontal portion as shown. What must be the height of the horizontal portion 'h' to ensure the maximum distance 's' covered by the body What is the maximum value of 's' ?



Sol.

Applying work energy theorem for motion from A to B

$mg(H-h) = \frac{1}{2}m(V^2 - 0)$ $\therefore$ $V = \sqrt{2g(H-h)}$

If time taken by the disc to move from point B to the point C on ground is t, then

$$\Delta y = u_y t - \frac{1}{2}gt^2 = h$$

$\therefore \quad 0 - \frac{1}{2}gt^2 = -h \quad \Rightarrow \quad t = \sqrt{\frac{2h}{g}}$

$$S = \Delta x = vt$$

$\therefore \quad S = \sqrt{2g(H-h)\times\frac{2h}{g}} = 2\sqrt{Hh - h^2} \qquad$ ....(i)

for s to be maximum, $(Hh - h^2)$ is maximum

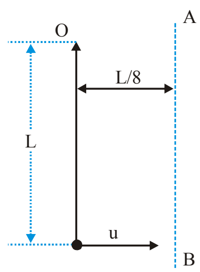
i.e. $\quad \frac{d}{dh}\left[Hh - h^2\right] = 0$

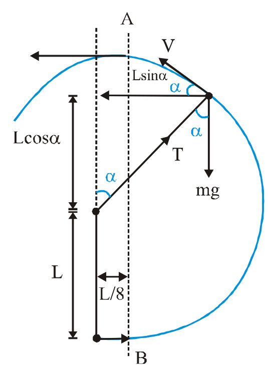
$\therefore \quad H - 2h = 0 \Rightarrow \quad h = \frac{H}{2}$

Putting this value of h in equation (i)

$\therefore \quad S_{max} = 2\sqrt{H\left(\frac{H}{2}\right) - \left(\frac{H}{2}\right)^2} = H$

Ex. 19 A particle is suspended vertically from a point O by an inextensible massless string of length L. A vertical line AB is at a distance L/8 from O as shown. The object given a horizontal velocity u. At some point, its motion ceases to be circular and eventually the object passes through the line AB. the instant of crossing AB, its velocity is horizontal. Find u.





Sol. Let the string slacks when the particle is at point P as shown

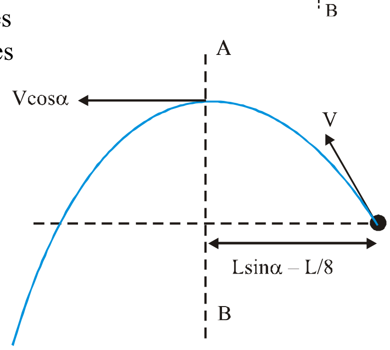
At point P, $T + mg\cos\alpha = \frac{mV^2}{L}$

where T = 0 (as string slacks)

$\therefore \quad mg\cos\alpha = \frac{mV^2}{L}$

$\Rightarrow \quad V^2 = gL\cos\alpha \qquad$ ....(i)

After this it undergoes parabolic path. When it passes through line AB its velocity is horizontal which implies that $(L\sin\alpha - L/8)$ is half of horizontal range.



i.e. $\quad L\sin\alpha - \frac{L}{8} = \frac{1}{2}\left[\frac{V^2\sin(2\alpha)}{g}\right]$

$\Rightarrow \quad$ from equation (i)

$$L\sin\alpha - \frac{L}{8} = \frac{1}{2}\left[\frac{gL\cos\alpha(2\sin\alpha\cos\alpha)}{g}\right]$$

$\therefore \quad \sin\alpha - \frac{1}{8} = \sin\alpha\cos^2\alpha$

$\Rightarrow \quad \sin\alpha\,(1 - \cos^2\alpha) = \frac{1}{8}$

$\Rightarrow \quad \sin^3\alpha = \frac{1}{8} \quad \Rightarrow \quad \sin\alpha = \frac{1}{2} \quad \Rightarrow \quad \alpha = 30^\circ$

$\therefore \quad V^2 = \frac{gL\sqrt{3}}{2}$

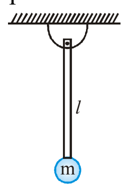
Also by applying work energy theorem

$$-mg\,L\,(1 + \cos\alpha) = \frac{1}{2}\,m\,(V^2 - u^2)$$

$$= -g\,L\left(1 + \frac{\sqrt{3}}{2}\right) = \frac{1}{2}\left(\frac{gL\sqrt{3}}{2} - u^2\right)$$

$\therefore$ On solving, we get $\quad u = \sqrt{\frac{gL}{2}\left(4 + 3\sqrt{3}\right)}$

Ex. 20 A rigid rod of length ℓ and negligible mass has a ball with mass m attached to one end and its other end fixed to form a pendulum as shown in figure. The pendulum is inverted, with the rod straight up, and then released.



(i) At the lowest point of trajectory, what is the ball`s speed ?

(A) $\sqrt{2g\ell}$ **(B)** $\sqrt{4g\ell}$ **(C)** $2\sqrt{2g\ell}$ **(D)** $\sqrt{8g\ell}$

(ii) What is the tension in the rod at the lowest point of trajectory of ball ?

(A) 6 mg **(B)** 3 mg **(C)** 4 mg **(D)** 5 mg

(iii) Now, if the pendulum is released from rest from a horizontal position. At what angle from the vertical does the tension in the rod equal to the weight of the ball ?

(A) $\cos^{-1}\left(\frac{2}{3}\right)$ **(B)** $\cos^{-1}\left(\frac{1}{3}\right)$ **(C)** $\cos^{-1}\left(\frac{1}{2}\right)$ **(D)** $\cos^{-1}\left(\frac{1}{4}\right)$

Sol.

(i) From COME : $2\,mg\,\ell = \frac{1}{2}mv^2 \Rightarrow v = \sqrt{4g\ell} = 2\sqrt{g\ell}$

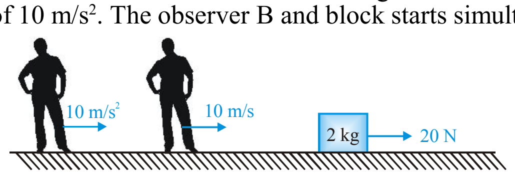
(ii) At the lowest point $T - mg = \frac{mv^2}{\ell} \Rightarrow T = mg + \frac{m}{\ell}(4g\ell) = 5\,mg$

(iii) Force equation $T - mg\cos\theta = \frac{mv^2}{\ell}$

Energy equation $mg\,\ell\cos\theta = \frac{1}{2}mv^2$

Therefore $mg - mg\cos\theta = 2\,mg\cos\theta \Rightarrow 3\cos\theta = 1 \Rightarrow \cos\theta = \frac{1}{3}$

Ex. 21 A block of mass 2 kg is dragged by a force of 20 N on a smooth horizontal surface. It is observed from there reference frames ground, observer A and observer B. Observer A is moving with constant velocity of 10 m/s and B is moving with constant acceleration of 10 m/s². The observer B and block starts simultaneously at t = 0.



	Column-I		Column-II
(A)	Work energy theorem is applicable in	(P)	100 J
(B)	Work done on block in 1 s as observed by ground is	(Q)	– 100 J
(C)	Work done on block is 1 s as observed by observer A is	(R)	zero
(D)	Work done on block in 1 s as observed by observer B is	(S)	only ground & A
		(T)	all frames ground, A & B

Sol. **For (A) :** Work energy theorem is applicable in all reference frames.

For (B) : w.r.t. ground : At t = 0, u = 0 t = 1s, v = at $= \left(\frac{20}{2}\right)(1) = 10$ m/s

Work done = change in kinetic energy $= \frac{1}{2}(2)(10)^2 - \frac{1}{2}(2)(0)^2 = 100$ J

For (C) : w.r.t. observer A : Initial velocity = 0 – 10 = – 10 m/s, Final velocity = 10 – 10 = 0

Work done $= \frac{1}{2}(2)(0)^2 - \frac{1}{2}(2)(-10)^2 = -100$ J

For (D) : w.r.t. observer B : Initial velocity = 0 – 0 = 0

Final velocity = 10 – 10 = 0; Work done = 0

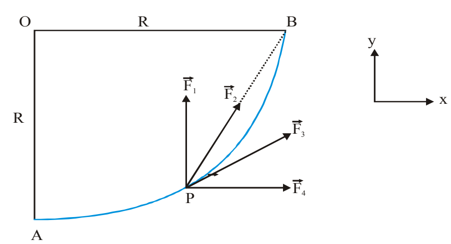
Ex. 22 AB is a quater of a smooth horizontal circular track of radius R. A particle P of mass m moves along the track from A to B under the action of following forces :

$\vec{F}_1$ = F (always towards y-axis)

$\vec{F}_2$ = F (always towards point B)

$\vec{F}_3$ = F (always along the tangent to path AB

$\vec{F}_4$ = F (always towards x-axis)



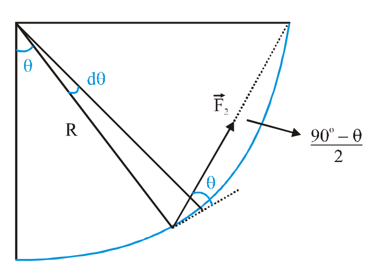
	Column-I		Column-II
(A)	Work done by $\vec{F}_1$	(P)	$\sqrt{2}$ FR
(B)	Work done by $\vec{F}_2$	(Q)	$\frac{1}{\sqrt{2}}$ FR
(C)	Work done by $\vec{F}_3$	(R)	FR
(D)	Work done by $\vec{F}_4$	(S)	$\frac{\pi FR}{2}$
		(T)	$\frac{2FR}{\pi}$

Sol.

For (A) : Work done by $\vec{F}$ = FR

For (B) : $dW = \vec{F}.d\vec{s} = (FRd\theta)\cos\left(45 - \frac{\theta}{2}\right) = FR\left(45 - \frac{\theta}{2}\right)d\theta$

$$W = \int_0^{\pi/4} FR\cos\left(45 - \frac{\theta}{2}\right) = -2FR\left(\sin 45^\circ - \frac{\theta}{2}\right)_0^{\pi/2} = \sqrt{2}FR$$



For (C) : $W = \int \vec{F}.d\vec{s} = F\left(\frac{\pi R}{2}\right) = \frac{\pi FR}{2}$

For (D) : $W = \int \vec{F}.d\vec{s} = (F)(R) = FR$

Exercise # 1

[Single Correct Choice Type Questions]

1. The work done by the frictional force on a pencil in drawing a complete circle of radius $r = 1/\pi$ metre on the surface by a pencil of negligible mass with a normal pressing force N = 5 N ($\mu = 0.5$) is :

(A) + 4J **(B)** –3 J **(C)** – 2 J **(D)** – 5J

2. A person A of 50 kg rests on a swing of length 1m making an angle 37^O with the vertical. Another person B pushes him to swing on other side at 53^O with vertical. The work done by person B is : [$g = 10\ m/s^2$]

(A) 50 J **(B)** 9.8 J **(C)** 100 J **(D)** 10 J

3. A rope is used to lower vertically a block of mass M by a distance x with a constant downward acceleration g/2. The work done by the rope on the block is :

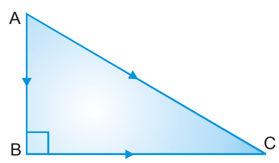
(A) Mgx **(B)** $\frac{1}{2}Mgx^2$ **(C)** $-\frac{1}{2}Mgx$ **(D)** Mgx^2

4. Work done in time t on a body of mass m which is accelerated from rest to a speed v in time t_1 as a function of time t is given by :

(A) $\frac{1}{2}m\frac{v}{t_1}t^2$ **(B)** $m\frac{v}{t_1}t^2$ **(C)** $\frac{1}{2}\left(\frac{mv}{t_1}t\right)^2 t^2$ **(D)** $\frac{1}{2}m\frac{v^2}{t_1^2}t^2$

5. The work done in moving a particle under the effect of a conservative force, from position A to B is 3 joule and from B to C is 4 joule. The work done in moving the particle from A to C is :

(A) 5 joule
(B) 7 joule
(C) 1 joule
(D) –1 joule



6. A block of mass m moving with speed v compresses a spring through distance x before its speed is halved. What is the value of spring constant ?

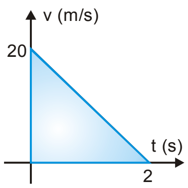
(A) $\frac{3mv^2}{4x^2}$ **(B)** $\frac{mv^2}{4x^2}$ **(C)** $\frac{mv^2}{2x^2}$ **(D)** $\frac{2mv^2}{x^2}$

7. A particle moves on a rough horizontal ground with some initial velocity say v_0. If $\frac{3}{4}$ of its kinetic energy is lost due to friction in time t_0 then coefficient of friction between the particle and the ground is :

(A) $\frac{v_0}{2gt_0}$ **(B)** $\frac{v_0}{4gt_0}$ **(C)** $\frac{3v_0}{4gt_0}$ **(D)** $\frac{v_0}{gt_0}$

8. Velocity–time graph of a particle of mass 2 kg moving in a straight line is as shown in figure. Work done by all the forces on the particle is :

(A) 400 J **(B)** –400 J
(C) –200 J **(D)** 200 J



9. An engine can pull 4 coaches at a maximum speed of 20 m/s. Mass of the engine is twice the mass of every coach. Assuming resistive forces proportional to the weight, approximate maximum speeds of the engine when it pulls 12 and 6 coaches are :

(A) 8.5 m/s and 15 m/s respectively **(B)** 6.5 m/s and 8 m/s respectively
(C) 8.5 m/s and 13 m/s respectively **(D)** 10.5 m/s and 15 m/s respectively

10. A body is moved along a straight line by a machine delivering constant power. The distance moved by the body in time t is proportional to :

(A) $t^{1/2}$ **(B)** $t^{3/4}$ **(C)** $t^{3/2}$ **(D)** t^2

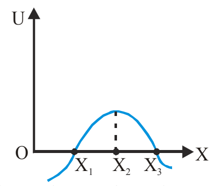
11 A small sphere starts falling from a very large height and after falling a distance of 100 m it attains the terminal velocity and continues to fall with this velocity. The work done by the atmosphere during the first fall of 100m is :

(A) Greater than the work done for next fall of 100 m
(B) Less than the work done for next fall of 100 m
(C) Equal to 100 mg
(D) Greater than 100 mg

12 A force acts on a 3 gm particle in such a way that the position of the particle as a function of time is given by $x= 3t - 4t^2 + t^3$, where x is in meters and t is in seconds. The work done during the first 4 second is:

(A) 384 mJ **(B)** 168 mJ **(C)** 528 mJ **(D)** 541 mJ

13. In the figure shown the potential energy (U) of a particle is plotted against its position 'x' from origin. Then which of the following statement is correct. A particle at :



(A) x_1 is in stable equilibrium **(B)** x_2 is in stable equilibrium

(C) x_3 is in stable equilibrium **(D)** None of these

14. A particle of mass m is moving in a circular path of constant radius r such that its centripetal acceleration a_C is varying with time t as $a_C = k^2rt^2$, where k is a constant. The power delivered to the particle by the force acting on it is :

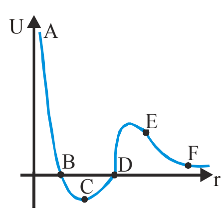
(A) $2\pi mk^2r^2$ **(B)** mk^2r^2t **(C)** $\frac{(mk^4r^2t^5)}{3}$ **(D)** zero

15. A weight is hung freely from the end of a spring. A boy then slowly pushes the weight upwards until the spring becomes slack. The gain in gravitational potential energy of the weight during this process is equal to :

(A) The work done by the boy against the gravitational force acting on the weight.
(B) The loss of the stored energy by the spring minus the work done by the tension in the spring.
(C) The work done on the weight by the boy plus the stored energy lost by the spring.
(D) The work done on the weight by the boy minus the work done by the tension in the spring plus the stored energy lost by the spring.

16. The given plot shows the variation, the potential energy (U) of interaction between two particles with the separating distance (r) between them. Which of the above statements are correct ?

(1) B and D are equilibrium points
(2) C is a point of stable equilibrium points
(3) The force of interaction between the two particles is attractive between points C and D and repulsive between points D and E on the curve.
(4) The force of interaction between the particles is repulsive between points E and F on the curve.



(A) 1 and 3 **(B)** 1 and 4 **(C)** 2 and 4 **(D)** 2 and 3

17. A rope ladder with a length ℓ carrying a man of mass m at its end is attached to the basket of balloon with a mass M. The entire system is in equilibrium in the air. As the man climbs up the ladder into the balloon, the balloon descends by a height h. Then the potential energy of the man :

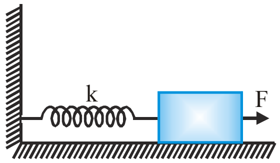
(A) Increases by mg $(\ell - h)$ **(B)** Increases by $mg\ell$

(C) Increases by mgh **(D)** Increases by mg $(2\ell - h)$

18. A simple pendulum has a string of length ℓ and bob of mass m. When the bob is at its lowest position, it is given the minimum horizontal speed necessary for it to move in a circular path about the point of suspension. The tension in the string at the lowest position of the bob is :

(A) 3mg **(B)** 4mg **(C)** 5mg **(D)** 6mg

19. A block attached to a spring, pulled by a constant horizontal force, is kept on a smooth surface as shown in the figure. Initially, the spring is in the natural state. Then the maximum positive work that the applied force F can do is : [Given that spring does not break]



(A) $\frac{F^2}{k}$ **(B)** $\frac{2F^2}{k}$ **(C)** ∞ **(D)** $\frac{F^2}{2k}$

20. A particle of mass m is fixed to one end of a light rigid rod of length ℓ and rotated in a vertical circular path about its other end. The minimum speed of the particle at its highest point must be :

(A) zero **(B)** $\sqrt{g\ell}$ **(C)** $\sqrt{1.5g\ell}$ **(D)** $\sqrt{2g\ell}$

21. In the previous question, when the string is horizontal, the net force on the bob is :

(A) mg **(B)** 3mg **(C)** $\sqrt{10}mg$ **(D)** 4mg

22. A marble of mass m and radius b is placed in a hemispherical bowl of radius r. The minimum velocity to be given to the marble so that it reaches the highest point is :

(A) $\sqrt{2g(r-b)}$ **(B)** $\sqrt{2gr}$ **(C)** $\sqrt{2g(r+b)}$ **(D)** $\sqrt{g(r-b)}$

23. A stone tied to a string of length L is whirled in a vertical circle, with the other end of the string at the centre. At a certain instant of time, the stone is at its lowest position and has a speed u. The magnitude of the change in its velocity as it reaches a position where the string is horizontal is :

(A) $\sqrt{u^2-2gL}$ **(B)** $\sqrt{2gL}$ **(C)** $\sqrt{u^2-gL}$ **(D)** $\sqrt{2(u^2-gL)}$

24. A particle is moving in a circular path with a constant speed v. If θ is the angular displacement, then starting from $\theta = 0^0$, the maximum and minimum change in the linear momentum will occur when value of θ is respectively:

(A) 45º & 90º **(B)** 90º & 180º **(C)** 180º & 360º **(D)** 90º & 270º

25. A particle is placed at the top of a sphere of radius r. It is given a little jerk so that it just starts slipping down. Find the point where it leaves the sphere.

(A) r/2 **(B)** r/3 **(C)** r/4 **(D)** r

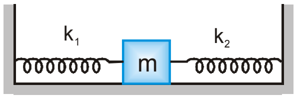
26. In a simple pendulum, the breaking strength of the string is double the weight of the bob. The bob is released from rest when the string is horizontal. The string breaks when it makes an angle θ with the vertical–

(A) $\theta = \cos^{-1}\left(\frac{1}{3}\right)$ **(B)** $\theta = 60°$ **(C)** $\theta = \cos^{-1}\left(\frac{2}{3}\right)$ **(D)** $\theta = 0$

Exercise # 2

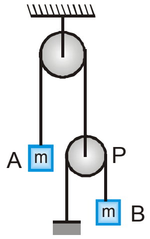
Part # I [Multiple Correct Choice Type Questions]

1. A block of mass m is attached to two spring of spring constant k_1 and k_2 as shown in figure. The block is displaced by x towards right and released. The velocity of the block when it is at x/2 will be :



(A) $\sqrt{\frac{(k_1+k_2)x^2}{2m}}$ **(B)** $\sqrt{\frac{3}{4}\frac{(k_1+k_2)x^2}{m}}$ **(C)** $\sqrt{\frac{(k_1+k_2)x^2}{m}}$ **(D)** $\sqrt{\frac{(k_1+k_2)x^2}{4m}}$

2. In the figure shown, the system is released from rest. Find the velocity of block A when block B has fallen a distance 'ℓ'. Assume all pulleys to be massless and frictionless.



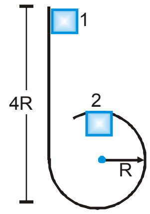
(A) $\sqrt{\frac{g\ell}{5}}$ **(B)** $\sqrt{g\ell}$

(C) $\sqrt{5g\ell}$ **(D)** None of these

3. An object of mass m slides down a hill of height h of arbitrary shape and after travelling a certain horizontal path stops because of friction. The friction coefficient is different for different segments for the entire path but is independent of the velocity and direction of motion. The work that a force must perform to return the object to its initial position along the same path is :

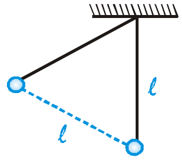
(A) mgh **(B)** 2mgh **(C)** 4mgh **(D)** –mgh

4. A cube of mass M starts at rest from point 1 at a height 4R, where R is the radius of the circular track. The cube slides down the frictionless track and around the loop. The force which the track exerts on the cube at point 2 is :



(A) 3 mg **(B)** mg
(C) 2 mg **(D)** cube will not reach the point 2.

5. A bob hangs from a rigid support by an inextensible string of length ℓ. If it is displaced through a distance ℓ (from the lowest position) keeping the string straight & released, the speed of the bob at the lowest position is:

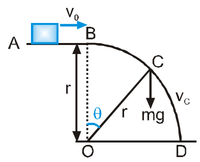


(A) $\sqrt{g\ell}$ **(B)** $\sqrt{3g\ell}$ **(C)** $\sqrt{2g\ell}$ **(D)** $\sqrt{5g\ell}$

6. A man places a chain of mass 'm' and length 'ℓ' on a table slowly. Initially the lower end of the chain just touches the table. The man drops the chain when half of the chain is in vertical position. Then work done by the man in this process is :

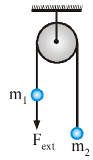
(A) $-mg\frac{\ell}{2}$ **(B)** $-\frac{mg\ell}{4}$ **(C)** $-\frac{3mg\ell}{8}$ **(D)** $-\frac{mg\ell}{8}$

7. A small block slides with velocity $0.5\sqrt{gr}$ on the horizontal frictionless surface as shown in the figure. The block leaves the surface at point C. The angle θ in the figure is :



(A) $\cos^{-1}\frac{4}{9}$ **(B)** $\cos^{-1}\frac{3}{4}$ **(C)** $\cos^{-1}\frac{1}{2}$ **(D)** $\cos^{-1}\frac{4}{5}$

8. Two bodies of mass m_1 and m_2 $(m_2 > m_1)$ are connected by a light inextensible string which passes through a smooth fixed pulley. The instantaneous power delivered by an external agent to pull m_1 with constant velocity v is :



(A) $(m_2 - m_1)\ g/v$ **(B)** $(m_2 - m_1)\ v/g$ **(C)** $(m_2 - m_1)\ gv$ **(D)** $(m_1 - m_2)\ gv$

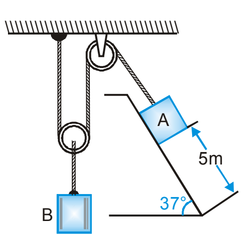
9. The potential energy of a particle of mass m free to move along x–axis is given by $U = \frac{1}{2}\ kx^2$ for $x < 0$ and $U = 0$ for $x \geq 0$ (x denotes the x–coordinate of the particle and k is a positive constant). If the total mechanical energy of the particle is E, then its speed at $x = -\sqrt{\frac{2E}{k}}$ is :

(A) zero **(B)** $\sqrt{\frac{2E}{m}}$ **(C)** $\sqrt{\frac{E}{m}}$ **(D)** $\sqrt{\frac{E}{2m}}$

10. A particle is projected along a horizontal field whose coefficient of friction varies as $\mu = \frac{A}{r^2}$ where r is the distance from the origin in meters and A is a positive constant. The initial distance of the particle is 1 m from the origin and its velocity is radially outwards. The minimum initial velocity at this point so that particle never stops is:

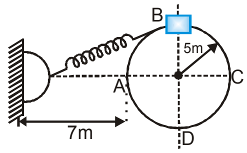
(A) ∞ **(B)** $2\sqrt{gA}$ **(C)** $\sqrt{2gA}$ **(D)** $4\sqrt{gA}$

11. The blocks A and B shown in the figure have masses $M_A = 5$ kg and $M_B = 4$ kg. The system is released from rest. The speed of B after A has travelled a distance 1 m along the incline is :



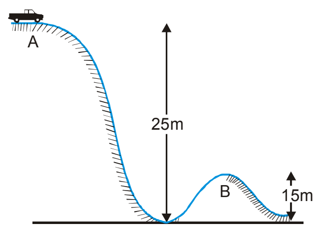
(A) $\frac{\sqrt{3}}{2}\sqrt{g}$ **(B)** $\frac{\sqrt{3}}{4}\sqrt{g}$ **(C)** $\frac{\sqrt{g}}{2\sqrt{3}}$ **(D)** $\frac{\sqrt{g}}{2}$

12. A collar 'B' of mass 2 kg is constrained to move along a horizontal smooth and fixed circular track of radius 5m. The spring lying in the plane of the circular track and having spring constant 200 N/m is undeformed when the collar is at 'A'. If the collar starts from rest at B' the normal reaction exerted by the track on the collar when it passes through 'A' is :



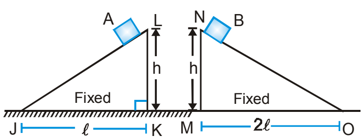
(A) 360 N **(B)** 720 N **(C)** 1440 N **(D)** 2880 N

13. Figure shows the roller coaster track. Each car will start from rest at point A and will roll with negligible friction. It is important that there should be at least some small positive normal force exerted by the track on the car at all points, otherwise the car would leave the track. With the above fact, the minimum safe value for the radius of curvature at point B is ($g = 10\ m/s^2$) :



(A) 20 m **(B)** 10 m **(C)** 40 m **(D)** 25 m

14. Two identical blocks A and B are placed on two inclined planes as shown in diagram. Neglect air resistance and other friction. Choose the correct statement :



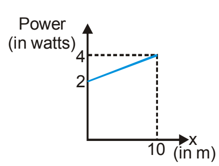
Statement I: Kinetic energy of 'A' on sliding to J will be greater than the kinetic energy of B on falling to M.
Statement II: Acceleration of 'A' will be greater than acceleration of 'B' when both are released to slide on inclined plane.
Statement III : Work done by external agent to move block slowly from position B to O is negative

(A) statement I is true **(B)** statement II is true
(C) statement I and III are true **(D)** statement II and III are true

15. A fire hose has a diameter of 2.5 cm and is required to direct a jet of water to a height of at least 40m. The minimum power of the pump needed for this hose is :

(A) 21.5 kW **(B)** 40 kW **(C)** 36.5 kW **(D)** 48 kW

16. A particle 'A' of mass $\frac{10}{7}$ kg is moving in the positive x–direction. Its initial position is x = 0 & initial velocity is 1 m/s. The velocity at x = 10m is : (use the graph given)

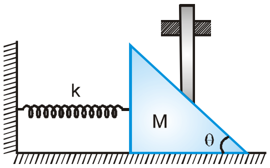


(A) 4 m/s **(B)** 2 m/s **(C)** $3\sqrt{2}m/s$ **(D)** 100/3 m/s

17. A particle is projected vertically upwards with a speed of 16 m/s, after some time, when it again passes through the point of projection, its speed is found to be 8 m/s. It is known that the work done by air resistance is same during upward and downward motion. Then the maximum height attained by the particle is : (Take g = 10 m/s^2)

(A) 8 m **(B)** 4.8 m **(C)** 17.6 m **(D)** 12.8 m

18. A wedge of mass M fitted with a spring of stiffness 'k' is kept on a smooth horizontal surface. A rod of mass m is kept on the wedge as shown in the figure. System is in equilibrium. Assuming that all surfaces are smooth, the potential energy stored in the spring is:

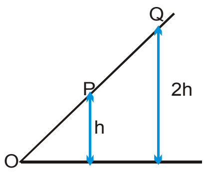


(A) $\frac{mg^2 \tan^2\theta}{2k}$ **(B)** $\frac{m^2 g \tan^2\theta}{2k}$ **(C)** $\frac{m^2 g^2 \tan^2\theta}{2k}$ **(D)** $\frac{m^2 g^2 \tan^2\theta}{k}$

19. A force $\vec{F} = (3\tilde{i} + 4\tilde{j})$ N acts on a 2 kg movable object that moves from an initial position $\vec{d_i} = (-3\tilde{i} - 2\tilde{j})$ m to final position $\vec{d_f} = (5\tilde{i} + 4\tilde{j})$ in 6s. The average power delivered by the force during the interval is equal to :

(A) 8 watt **(B)** $\frac{50}{6}$ watt **(C)** 15 watt **(D)** $\frac{50}{3}$ watt

20. A ball rolls down an inclined plane figure. The ball is first released from rest from P and then later from Q. Which of the following statement is/are correct ?



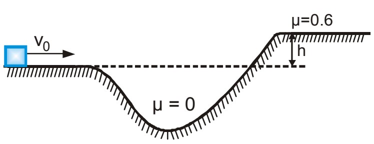
(A) The ball takes twice as much time to roll from Q to O as it does to roll from P to O.

(B) The acceleration of the ball at Q is twice as large as the acceleration at P.

(C) The ball has twice as much K.E. at O when rolling from Q as it does when rolling from P

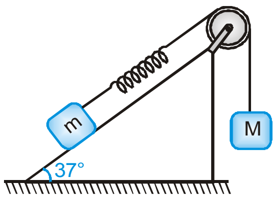
(D) None of the above

21. In the figure, a block slides along a track from one level to a higher level, by moving through an intermediate valley. The track is frictionless untill the block reaches the higher level. There a frictional force stops the block in a distance d. The block's initial speed v_0 is 6 m/s, the height difference h is 1.1 m and the coefficient of kinetic friction μ is 0.6. The value of d is



(A) 1.17 m **(B)** 1.71 m **(C)** 7.11 m **(D)** 11.7 m

22. A block of mass m is attached with a massless spring of force constant k. The block is placed over a rough inclined surface for which the coefficient of friction is $\mu = 3/4$. The minimum value of M required to move the block up the plane is : (Neglect mass of string and pulley and friction in pulley)

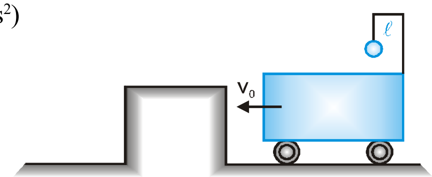


(A) $\frac{3}{5}$ m **(B)** $\frac{4}{5}$ m **(C)** 2 m **(D)** $\frac{3}{2}$ m

23. A car of mass m starts moving so that its velocity varies according to the law $v = a\sqrt{s}$, where a is a constant, and s is the distance covered. The total work performed by all the forces which are acting on the car during the first t seconds after the beginning of motion is :
(A) $ma^4t^2/8$ **(B)** $ma^2t^4/8$ **(C)** $ma^4t^2/4$ **(D)** $ma^2t^4/4$

24. If one of the forces acting on a particle is conservative then :
(A) Its work is zero when the particle moves exactly once around any closed path.
(B) Its work equals the change in the kinetic energy of the particle.
(C) It obeys Newton's second law.
(D) Its work depends on the end points of the motion, not on the path between.

25. A bob is suspended from a crane by a cable of length ℓ = 5 m. The crane and load are moving at a constant speed v_0. The crane is stopped by a bumper and the bob on the cable swings out an angle of 60°. The initial speed v_0 is– (g = 9.8 m/s^2)

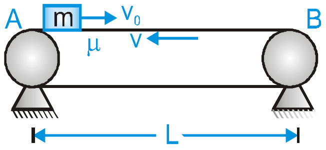


(A) 10 m/s **(B)** 7 m/s **(C)** 4 m/s **(D)** 2 m/s

26. A particle of mass m = 1 kg lying on x–axis experiences a force given by law F=x(3x–2) Newton, where x is the x–coordinate of the particle in meters. The points on x–axis where the particle is in equilibrium are :
(A) x = 0 **(B)** x = 1/3 **(C)** x = 2/3 **(D)** x = 1

27. A light spring of length 20 cm and force constant 2 N/cm is placed vertically on a table. A small block of mass 1 kg falls on it. The length h from the surface of the table at which the block will have the maximum velocity is :
(A) 20 cm **(B)** 15 cm **(C)** 10 cm **(D)** 5cm

28. With what minimum velocity v_0 should block be projected from left end A towards end B such that it reaches the other end B of conveyer belt moving with constant velocity v ? Friction coefficient between block and belt is μ.



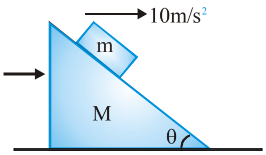
(A) $\sqrt{\mu gL}$ **(B)** $\sqrt{2\mu gL}$ **(C)** $\sqrt{3\mu gL}$ **(D)** $2\sqrt{\mu gL}$

29. When a conservative force does positive work on a body :

(A) The potential energy increases **(B)** The potential energy decreases

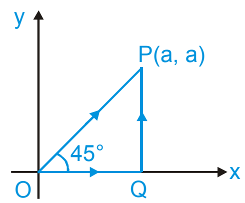
(C) Total energy increases **(D)** Total energy decreases

30. In the figure shown all the surfaces are frictionless, and mass of the block, m = 1 kg. The block and wedge are held initially at rest. Now wedge is given a horizontal acceleration of 10 m/s^2 by applying a force on the wedge, so that the block does not slip on the wedge. Then work done by the normal force in ground frame on the block in $\sqrt{3}$ seconds is :



(A) 30J **(B)** 60 J **(C)** 150 J **(D)** 100 $\sqrt{3}$ J

31. A particle is moved from (0, 0) to (a, a) under a force $\vec{F} = (3\hat{i} + 4\hat{j})$ from two paths. Path 1 is OP and path 2 is OQP. Let W_1 and W_2 be the work done by this force in these two paths. Then :

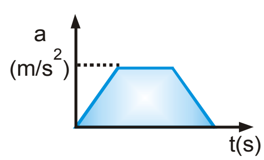


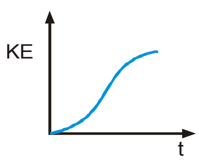
(A) $W_1 = W_2$ **(B)** $W_1 = 2W_2$ **(C)** $W_2 = 2W_1$ **(D)** $W_2 = 4W_1$

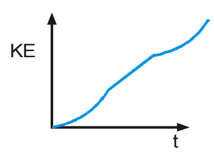
32. A 1.0 kg block collides with a horizontal weightless spring of force constant 2.75 Nm^{-1}. The block compresses the spring 4.0 m from the rest position. If the coefficient of kinetic friction between the block and horizontal surface is 0.25, the speed of the block at the instant of collision is :

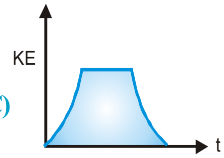
(A) 0.4 ms^{-1} **(B)** 4 ms^{-1} **(C)** 0.8 ms^{-1} **(D)** 8 ms^{-1}

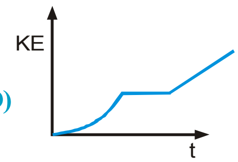
33. Acceleration versus time graph of a particle moving in a straight line is as shown in adjoining figure. If initially particle was at rest then corresponding kinetic energy versus time graph will be:



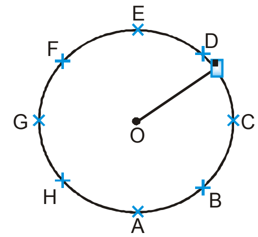
(A) 

(B) 

(C) 

(D) 

34. A machine, in an amusement park, consists of a cage of the end of one arm, hinged at O. The cage revolves along a vertical circle of radius r (ABCDEFGH) about its hinge O, at constant linear speed v= $\sqrt{gr}$. The cage is so attached that the man of weight 'W' standing on a weighing machine, inside the cage, is always vertical. Then which of the following is correct



(A) The weight reading at A is greater than the weight reading at E by 2W
(B) The weight reading at G = W
(C) The ratio of the weight reading at E to that at A = 0
(D) The ratio of the weight reading at A to that at C = 2

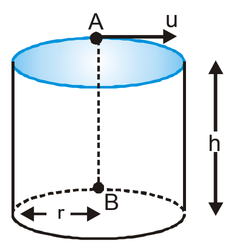
35. A particle of mass m begins to slide down a fixed smooth sphere from the top. What is the tangential acceleration when it breaks off the sphere?

(A) $\frac{2g}{3}$ **(B)** $\frac{\sqrt{5}g}{3}$ **(C)** g **(D)** $\frac{g}{3}$

36. The kinetic energy K of a particle moving along a circle of radius R depends upon the distance s, as $K = as^2$. The force acting on the particle is–

(A) $2a\frac{s}{R}$ **(B)** $2as\left(1+\frac{s}{R^2}\right)^{\frac{1}{2}}$ **(C)** 2as **(D)** 2a

37. A hollow vertical cylinder of radius r and height h has a smooth internal surface. A small particle is placed in contact with the inner side of the upper rim, at point A, and given a horizontal speed u, tangential to the rim. It leaves the lower rim at point B, vertically below A. If n is an integer then–



(A) $\frac{u}{2\pi r}\sqrt{\frac{2h}{g}} = n$ **(B)** $\frac{h}{2\pi r} = n$ **(C)** $\frac{2\pi r}{h} = n$ **(D)** $\frac{u}{\sqrt{2gh}} = n$

38. A simple pendulum of length L and mass (bob) M is oscillating in a plane about a vertical line between angular limits $-\phi$ and ϕ. For an angular displacement θ, $[|\theta|<\phi]$ the tension in the string and velocity of the bob are T and v respectively. The following relations hold good under the above conditions

(A) $T\cos\theta = Mg$ **(B)** $T - Mg\cos\theta = \frac{Mv^2}{L}$

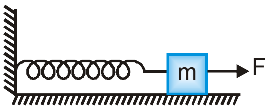
(C) Tangential acceleration $= g\sin\theta$ **(D)** $T = Mg\cos\theta$

Part # II [Assertion & Reason Type Questions]

These questions contains, Statement 1 (assertion) and Statement 2 (reason).

(A) Statement-I is true, Statement-II is true ; Statement- II is correct explanation for Statement-I.
(B) Statement-I is true, Statement-II is true; Statement-II is NOT a correct explanation for statement-I.
(C) Statement-I is true, Statement-II is false.
(D) Statement-I is false and Statement-II is true.
(E) Statement- I is false, Statement-II is false.

1. **Statement - I** One end of ideal massless spring is connected to fixed vertical wall and other end to a block of mass m initially at rest on smooth horizontal surface. The spring is initially in natural length. Now a horizontal force F acts on block as shown. Then the maximum extension in spring is equal to maximum compression in spring.



Statement - II To compress or to expand an ideal unstretched spring by equal amount, same work is to done on spring.

2. **Statement - I** The work done in pushing a block is more than the work done in pulling the block in a rough surface.
Statement - II In the pushing condition more normal reaction increases the frictional force.

3. **Statement - I** The work done by friction is always negative.
Statement - II If frictional force acts on a body its kinetic energy may decrease.

4. **Statement - I** A body can have energy without having momentum.
Statement - II A body can have momentum without having mechanical energy.

5. **Statement - I** A particle is rotated in a vertical circle with the help of a string. Power produced by tension in the string on the particle is zero.
Statement - II Tension is always perpendicular to instantaneous velocity.

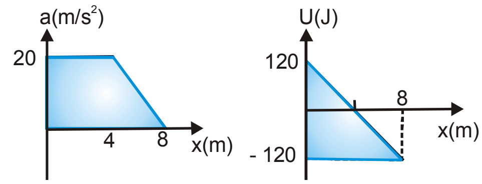
6. **Statement - I** A body at rest may be in equilibrium.
Statement - II A body in equilibrium is at rest.

7. **Statement - I** When a gas is allowed to expand, work done by gas is positive.
Statement - II In expansion of a gas the force due to gaseous pressure and displacement (of piston) are in the same direction.

8. **Statement - I** If the internal forces are conservative, the work done by the external force is equal to the change in mechanical energy.
Statement - II Work done on a system by all the (external and internal) force is equal to the change in its kinetic energy and the change in the potential energy of a system corresponding to conservative internal forces is equal to negative of the work done by these forces.

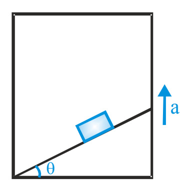
Exercise # 3 Part # I [Matrix Match Type Questions]

1. Acceleration 'a' versus x and potential energy 'U' versus x graph of a particle moving along x–axis is as shown in figure. Mass of the particle is 1kg and velocity at x = 0 is 4 m/s. At x = 8 m :–



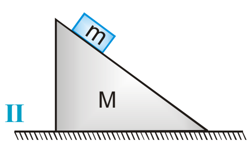
	Column I		Column II
(A)	Kinetic energy	(P)	120J
(B)	Work done by conservative forces	(Q)	240 J
(C)	Total work done	(R)	128 J
(D)	Work done by external forces	(S)	112 J
		(T)	–120 J

2. A block of mass m is stationary with respect to a rough wedge as shown in figure. Starting from rest, in time t work done on the block : (m = 1kg, $\theta = 30°$, a = 2m/s^2, t = 4s)



	Column I		Column II
(A)	By gravity	(P)	144 J
(B)	By normal reaction	(Q)	32 J
(C)	By friction	(R)	56 J
(D)	By all the forces	(S)	48 J
		(T)	None

3. A block of mass m lies on wedge of mass M. The wedge in turn lies on smooth



	Column I		Column II
(A)	Work done by normal reaction acting on the block is	(P)	Positive
(B)	Work done by normal reaction (exerted by block) acting on wedge is	(Q)	Negative
(C)	The sum of work done by normal reaction on block and work done by normal reaction (exerted by block) on wedge is	(R)	Zero
(D)	Net work done by all forces on block is	(S)	Less than mgh in magnitude

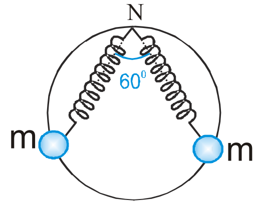
4. In vertical circular motion of a bob, match the entries of column–I with entries of column–II. Here v_0 is the velocity of bob at lowest point & T is tension in string.

	Column – I (Speed at lowest point)		Column–II (Possible situation)
(A)	$v_0 = \sqrt{5g\ell}$	(P)	$T_{lowest} - T_{highest} = 6mg$
(B)	$v_0 = \sqrt{g\ell}$	(Q)	String will slack for a finite time
(C)	$v_0 = 2\sqrt{g\ell}$	(R)	bob will oscillate
(D)	$v_0 = 3\sqrt{g\ell}$	(S)	bob will complete the circle

Part # II [Comprehension Type Questions]

Comprehension # 1

Two identical beads are attached to free ends of two identical springs of spring constant $k = \dfrac{(2+\sqrt{3})mg}{\sqrt{3}\ \ R}$. Initially both springs make an angle of 60° at the fixed point N. Normal length of each spring is 2R. Where R is the radius of smooth ring over which bead is sliding. Ring is placed on vertical plane and beads are at symmetry with respect to vertical line as diameter.



1. Normal reaction on one of the bead at initial moment due to ring is

(A) mg/2 **(B)** $\sqrt{3}$ mg/2 **(C)** mg **(D)** Insufficient data

2. Relative acceleration between two beads at the initial moment

(A) g/2 vertically away from each other **(B)** g/2 horizontally towards each other

(C) $2g/\sqrt{3}$ vertically away from each other **(D)** $2g/\sqrt{3}$ horizontally towards each other

3. The speed of bead when spring is at normal length

(A) $\sqrt{\dfrac{\left(2+\sqrt{3}\right)gR}{\sqrt{3}}}$ **(B)** $\sqrt{\dfrac{\left(2-\sqrt{3}\right)gR}{\sqrt{3}}}$ **(C)** $\sqrt{\dfrac{2gR}{\sqrt{3}}}$ **(D)** $\sqrt{3gR}$

4. Choose the correct statement

(A) Maximum angle made by spring after collision is same as that of initial moment

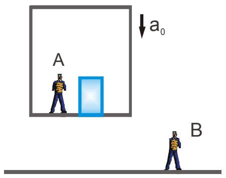
(B) If the collision is perfectly inelastic, the total energy is conserved

(C) If the collision is perfectly elastic, each bead undergoes SHM

(D) Both Linear momentum and angular momentum with respect to centre of smooth ring are conserved only at the instant of collision.

Comprehension # 2

A block of mass m is kept in an elevator which starts moving downward with an acceleration a_0 as shown in figure. The block is observed by two observers A and B for a time interval t_0.



1. The observer B finds that the work done by gravity is

(A) $\dfrac{1}{2}mg^2t_0^{\,2}$ **(B)** $-\dfrac{1}{2}mg^2t_0^{\,2}$ **(C)** $\dfrac{1}{2}mgat_0^{\,2}$ **(D)** $-\dfrac{1}{2}mgat_0^{\,2}$

2. The observer B finds that work done by normal reaction N is

(A) zero (B) $-Nat_0^2$ (C) $+\frac{Nat^2}{2}$ (D) None of these

3. The observer B finds that work done by pseudo force is

(A) zero (B) $-ma^2t_0$ (C) $+ ma^2t_0$ (D) $- mgat_0$

4. According to observer B, the net work done on the block is

(A) $-\frac{1}{2}ma^2t_0^2$ (B) $\frac{1}{2}ma^2t_0^2$ (C) $\frac{1}{2}mgat_0^2$ (D) $-\frac{1}{2}mgat_0^2$

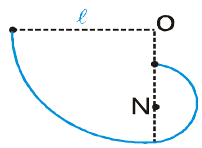
5. According to the observer A

(A) the work done by gravity is zero (B) the work done by normal reaction is zero

(C) the work done by pseudo force is zero (D) all the above

Comprehension # 3

The bob of simple pendulum of length ℓ is released from a point in the same horizontal line as the point of suspension (O) and at a distance ℓ from it.



1. The velocity of the bob at the lowest point of the string will be

(A) $v = \sqrt{2g\ell}$ (B) $v = \sqrt{g\ell}$ (C) $v = \sqrt{3g\ell}$ (D) $v = 2\sqrt{g\ell}$

2. If the string is catched by a nail located vertically below the point of suspension and the bob just swings around a complete circle around the nail, then the distance of the nail from point of suspension.

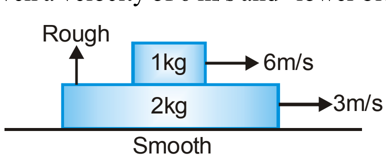
(A) $(2/5)\ell$ (B) $(2/3)\ell$ (C) $(3/5)\ell$ (D) $(1/3)\ell$

3. If the string of the pendulum is made of rubber then how much will it be stretched on reaching the bob at the lowest point.

(A) 2mg/k (B) 3mg/k (C) 5 mg/k (D) mg/k

Comprehension # 4

In the figure shown upper block is given a velocity of 6 m/s and lower block 3 m/s. When relative motion between them is stopped.



1. (A) Work done by friction on upper block is negative

(B) Work done by friction on both the blocks is positive

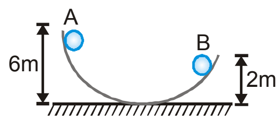
(C) Work done by friction on lower block is negative

(D) Work done by friction on both the blocks is negative

2. (A) Work done by friction on upper block is – 10 J
(B) Work done by friction on lower block is + 10 J
(C) Net work done by friction is zero
(D) All of the above

Comprehension # 5

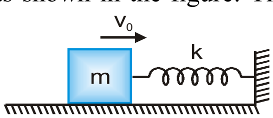
A ball is released from point A as shown in figure. The ball leaves the track at B. All surfaces are smooth.



1. Let h be the maximum height from ground reached by ball after leaving track at B. Then :–
(A) h = 6m (B) h < 6 m (C) h > 6m
(D) speed of ball at B will change if shape of track is changed keeping h_A and h_B constant
2. If track makes an angle 30° with horizontal at B then maximum height attained by ball will be :
(A) 3m (B) 4m (C) 4.5 m (D) 5m

Comprehension # 6

A block of mass m moving with a velocity v_0 on a smooth horizontal surface strikes and compresses a spring of stiffness k till mass comes to rest as shown in the figure. This phenomenon is observed by two observers :



A : Standing on the horizontal surface ;
B : Standing on the block
1. To an observer A, the work done by spring force is
(A) negative but nothing can be said about its magnitude (B) $-\frac{1}{2}mv_0^2$
(C) positive but nothing can be said about its magnitude (D) $+\frac{1}{2}mv_0^2$
2. To an observer A, the work done by the normal reaction N between the block and the spring on the block is
(A) zero (B) $-\frac{1}{2}mv_0^2$ (C) $+\frac{1}{2}mv_0^2$ (D) None of these
3. To an observing A, the net work done on the block is
(A) $-mv_0^2$ (B) $+mv_0^2$ (C) $-\frac{1}{2}mv_0^2$ (D) zero
4. According to the observer A
(A) the kinetic energy of the block is converted into the potential energy of the spring
(B) the mechanical energy of the spring–mass system is conserved
(C) the block loses its kinetic energy because of the negative work done by the conservative force of spring
(D) all the above
5. To an observer B, when the block is compressing the spring
(A) velocity of the block is decreasing (B) retardation of the block is increasing
(C) kinetic energy of the block is zero (D) all the above

6. According to observer B, the potential energy of the spring increases

(A) due to the positive work done by pseudo force

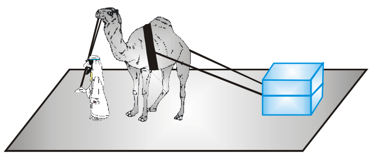
(B) due to the negative work done by pseudo force

(C) due to the decrease in the kinetic energy of the block

(D) all the above

Comprehension # 7

Ram and Shyam are two fast friends since childhood. Shyam neglected studies and now has no means to earn money other than a camel whereas Ram becomes an engineer. Now both are working in the same factory. Shyam uses camel to transport the load within the factory.



Due to low salary & degradation in health of camel, Shyam becomes worried and meet his friend Ram and discusses his problem. Ram collected some data & with some assumptions concluded the following:

(a) The load used in each trip is 1000 kg and has friction coefficient $\mu_k = 0.1$ and $\mu_s = 0.2$.

(b) Mass of camel is 500 kg.

(c) Load is accelerated for first 50 m with constant acceleration, then it is pulled at a constant speed of 5m/s for 2 km and at last stopped with constant retardation in 50 m.

(d) From biological data, the rate of consumption of energy of camel can be expressed as $P = 18 \times 10^3 v + 10^4$ J/s where P is the power and v is the velocity of the camel. After calculations on different issues Ram suggested proper food, speed of camel etc. to his friend. For the welfare of Shyam, Ram wrote a letter to the management to increase his salary.

(Assuming that the camel exerts a horizontal force on the load)

1. Sign of work done by the camel on the load during parts of motion : accelerated motion, uniform motion and retarted motion respectively are :

(A) +ve, +ve, +ve (B) +ve, +ve, –ve (C) +ve, zero, –ve (D) +ve, zero, +ve

2. The ratio of magnitude of work done by camel on the load during accelerated motion to retarded motion is–

(A) 3 : 5 (B) 2.2 : 1 (C) 1 : 1 (D) 5 : 3

3. Maximum power transmitted by the camel to load is–

(A) 6250 J/s (B) 5000 J/s (C) 10^5 J/s (D) 1250 J/s

4. The ratio of the energy consumed of the camel during uniform motion for the two cases when it moves with speed 5 m/s to the case when it moves with 10 m/s.

(A) $\frac{19}{20}$ (B) $\frac{19}{10}$ (C) $\frac{10}{19}$ (D) $\frac{20}{19}$

5. The total energy consumed of the camel during the trip of 2100 m is–

(A) 2.1×10^6 J (B) 4.22×10^7 J (C) 2.22×10^4 J (D) 4.22×10^6 J

Comprehension # 8

In a conservative force field we can find the radial component of force from the potential energy function by using $F = -\frac{dU}{dr}$. Here, a positive force means repulsion and a negative force means attraction. From the given potential energy function U(r) we can find the equilibrium position where force is zero. We can also find the ionisation energy which is the work done to move the particle from a certain position to infinity.

Let us consider a case in which a particle is bound to a certain point at a distance r from the centre of the force. The potential energy of the particle is : $U(r) = \frac{A}{r^2} - \frac{B}{r}$ where r is the distance from the centre of the force and A and B are positive constants.

1. The equilibrium distance is given by :

(A) $\frac{A}{B}$ **(B)** $\frac{2A}{B}$ **(C)** $\frac{3A}{B}$ **(D)** $\frac{B}{2A}$

2. The equilibrium is :

(A) Stable **(B)** Unstable **(C)** Neutral **(D)** Cannot be predicted

3. The work required to move the particle from equilibrium distance to infinity is :

(A) $\frac{B}{4A}$ **(B)** $\frac{4B}{A}$ **(C)** $\frac{B^2}{4A}$ **(D)** $\frac{4B^2}{A}$

4. If the total energy of the particle is $E = -\frac{3B^2}{16A}$, and it is known that the motion is radial only then the velocity is zero at : (here, r_0 = equilibrium distance)

(A) $\frac{r_0}{3}$ **(B)** $\frac{2r_0}{3}$ **(C)** r_0 **(D)** $\frac{2r_0}{5}$

Comprehension # 9

A small sphere of mass m suspended by a thread is first taken aside so that the thread forms the right angle with the vertical and then released, then

1. The total acceleration of the sphere and the thread tension as function of θ, the angle of deflection of the thread from the vertical will be

(A) $g\sqrt{1+3\cos^2\theta}$, T = 3 mg cosθ

(B) gcosθ, T = 3mg cosθ

(C) $g\sqrt{1+3\sin^2\theta}$, T = 5mg cosθ

(D) gsinθ, T = 5 mg cosθ

2. The thread tension at the moment when the vertical component of the sphere's velocity is maximum will be

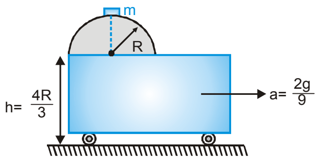
(A) mg **(B)** $mg\sqrt{2}$ **(C)** $mg\sqrt{3}$ **(D)** $\frac{mg}{\sqrt{3}}$

3. The angle θ between the thread and the vertical at the moment when the total acceleration vector of the sphere is directed horizontally will be

(A) $\cos\theta = \frac{1}{\sqrt{3}}$ **(B)** $\cos\theta = \frac{1}{3}$ **(C)** $\sin\theta = \frac{1}{\sqrt{3}}$ **(D)** $\sin\theta = \frac{1}{\sqrt{2}}$

Comprehension # 10

A vertical frictionless semicircular track of radius R is fixed on the edge of movable trolley. Initially the system is at rest and a mass m is kept at the top of the track. The trolley starts moving to the right with a uniform horizontal acceleration $a = \frac{2g}{9}$. The mass slides down the track, eventually losing contact with it and dropping to the floor h below the trolley.



1. The angle θ with vertical, at which it losses contact with the trolley is

(A) 37° **(B)** 53° **(C)** $\cos^{-1}\left(\frac{2}{3}\right)$ **(D)** $\frac{\pi}{2} - \cos^{-1}\left(\frac{2}{3}\right)$

2. The height at which mass m losing contact is

(A) $\frac{4}{5}R$ **(B)** $\frac{17}{15}R$ **(C)** R **(D)** $\frac{32}{15}R$

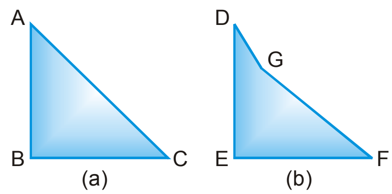
3. The time taken by the mass to drop on the floor, after losing contact is

(A) $\sqrt{\frac{2R}{3g}}$ **(B)** $\sqrt{\frac{2R}{g}}$ **(C)** $2\sqrt{\frac{2R}{3g}}$ **(D)** Can't be determined

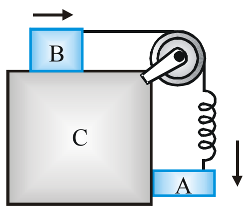
Exercise # 4 [Subjective Type Questions]

1. A body of mass 2 kg is being dragged with a uniform velocity of 2 m/s on a rough horizontal plane. The coefficient of friction between the body and the surface is 0.20, J = 4.2 J/cal and g = 9.8 m/s^2. Calculate the amount of heat generated in 5 s.

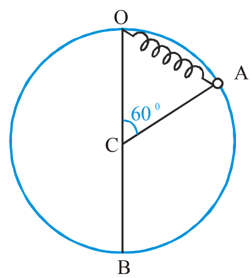
2. In the figure (A) and (B) AC, DG and GF are fixed inclined planes, BC = EF = x and AB = DE = y. A small block of mass M is released from the point A. It slides down AC and reaches C with a speed v_C. The same block is released from rest from the point D. It slides down DGF and reaches the point F with speed v_F. The coefficients of kinetic friction between the block and both the surfaces AC and DGF are μ. Calculate v_C and v_F.



3. Two blocks A and B are connected to each other by a string and a spring; the string pass overs a frictionless pulley as shown in the figure. Block B slides over the horizontal top surface of a stationary block C and the block A slides along the vertical side of C, both with the same uniform speed. The coefficient of friction between the surface and the block is 0.2. Force constant of the spring is 1960 N/m. If mass of block A is 2 kg, calculate the mass of block B and the energy stored in the spring.



4. A particle of mass 5 kg is free to slide on a smooth ring of radius r = 20 cm fixed in a vertical plane. The particle is attached to one end of a spring whose other end is fixed to the top point O of the ring. Initially the particle is at rest at a point A of the ring such that ∠ OCA = 60^0, C being the centre of the ring. The natural length of the spring is also equal to r = 20 cm. After the particle is released and slides down the ring the contact force between the particle & the ring becomes zero when it reaches the lowest position B. Determine the force constant of the spring.

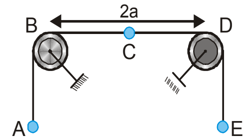


5. A particle is moving in x direction, under the influence of force F = πsinπx. Find the work done by another external agent in slowly moving a particle from x=0 to x = 0.5m.

6. The potential energy of a particle of mass 1kg free to move along x-axis is given by $V(x) = \left(\frac{x^2}{2} - x\right)$ joule.

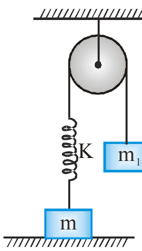
If total mechanical energy of the particle is 2J, then find the maximum speed of the particle.

7. A light string ABCDE whose mid point is C passes through smooth rings B and D, which are fixed in a horizontal plane distance 2a apart. To each of the points A, C and E is attached a mass m. Initially C is held at rest at O (mid point BD) and is then set free. What is the distance OC when C comes to instantaneous rest ?

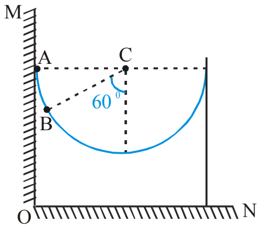


8. A particle of mass m moves along a circle of radius R with a normal acceleration varying with time as $a_n = bt^2$, where b is a constant. Find the time dependence of the power developed by all the forces acting on the particle, and the mean value of this power averaged over the first t seconds after the beginning of motion.

9. For what minimum value of m_1 the block of mass m will just leave the contact with surface ?

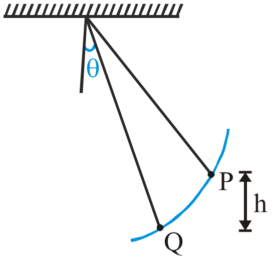


10. A ball of mass 1 kg is released from position, A inside a fixed wedge with a hemispherical cut of radius 0.5 m as shown in the figure. Find the force exerted by the vertical wall OM on wedge, when the ball is in position B. (neglect friction everywhere). (Take g = 10 m/s^2)

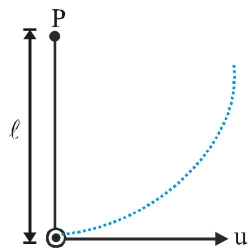


11. A particle of mass 3 kg is rotating in a circle of radius 1m such that the angle rotated by its radius is given by $\theta = 3$ (t + sint). Find the net force acting on the particle when t = $\pi/2$.

12. The bob of a simple pendulum of length ℓ is released from point P. What is the angle made by the direction of net acceleration of the bob with the string at point Q.

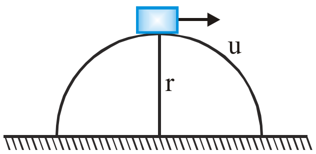


13. In the shown arrangement a bob of mass 'm' is suspended by means of a string connected to peg P. If the bob is given a horizontal velocity $\vec{u}$ having magnitude $\sqrt{3g\ell}$, find the minimum speed of the bob in subsequent motion.



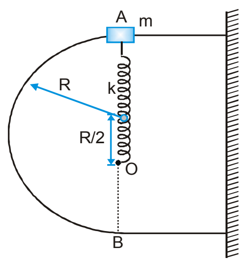
14. For a particle rotating in a vertical circle with uniform speed, the maximum and minimum tension in the string are in the ratio 5 : 3. If the radius of vertical circle is 2m, then find the speed of revolving body.

15. A small block of mass m is projected horizontally from the top of the smooth hemisphere of radius r with speed u as shown. For values of $u \geq u_0$, it does not slide on the hemisphere (i.e. leaves the surface at the top itself).



(a) For $u = 2u_0$, it lands at point P on the ground Find OP.
(b) For $u=u_0/3$, find the height from the ground at which it leaves the hemisphere.
(c) Find its net acceleration at the instant it leaves the hemisphere.

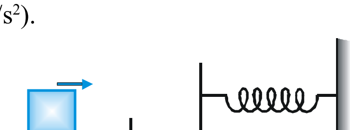
16. A bead of mass m is tied at one end of a spring of spring constant $\frac{mg}{R}$ and unstretched length $\frac{R}{2}$ and other end to fixed point O. The smooth semicircular wire frame is fixed in vertical plane. Find the normal reaction between bead and wire just before it reaches the lowest point.



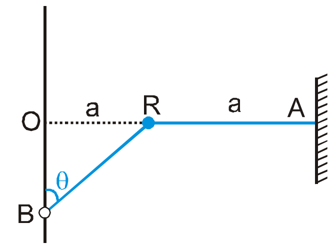
17. A particle of mass m is hanging with the help of an elastic string of unstretched length a and force constant $\frac{mg}{a}$. The other end is fixed to a peg on vertical wall. String is given an additional extension of 2a in vertical downward direction by pulling the mass and released from rest. Find the maximum height reached by it during its subsequent motion above point of release. (Neglect interaction with peg if any)

18. A body of mass 2 kg is moving under the influence of a central force whose potential energy is given by $U(r) = 2r^3$ J. If the body is moving in a circular orbit of radius 5m, then find its energy.

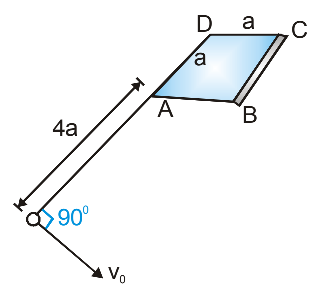
19. A 0.5 kg block slides from the point A (see figure) on a horizontal track with an initial speed of 3 m/s towards a weightless horizontal spring of length 1 m and force constant 2 N/m. The part AB of the track is frictionless and the part BC has the coefficients of static and kinetic friction as 0.22 and 0.2 respectively. If the distance AB and BD are 2m and 2.14 m respectively, find the total distance through which the block moves before it comes to rest completely. (Take $g = 10$ m/s^2).



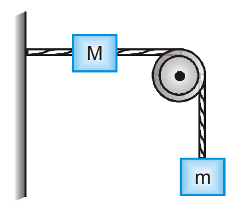
20. A small bead of mass m is free to slide on a fixed smooth vertical wire, as indicated in the diagram. One end of a light elastic string, of unstretched length a and force constant 2mg/a is attached to B. The string passes through a smooth fixed ring R and the other end of the string is attached to the fixed point A, AR being horizontal. The point O on the wire is at same horizontal level as R, and AR = RO =a. (i) In the equilibrium position, find OB. (ii) The bead B is raised to a point C of the wire above O, where OC =a, and is released from rest. Find the speed of the bead as it passes O, and find the greatest depth below O of the bead in the subsequent motion.



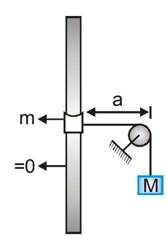
21. A square plate is firmly attached to a frictionless horizontal plane. One end of a taut cord is attached to point A of the plate and the other end is attached to a sphere of mass m. In the process, the cord gets wrapped around the plate. The sphere is given an initial velocity v_0 on the horizontal plane perpendicular to the cord which causes it to make a complete circle of the plate and return to point A. Find the velocity of the sphere when it hits point A again after moving in a circle on the horizontal plane. Also find the time taken by the sphere to complete the circle.



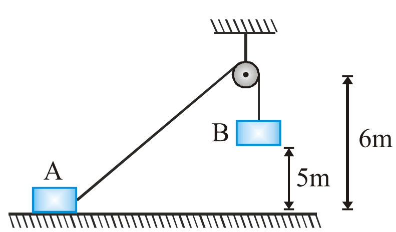
22. A string, with one end fixed on a rigid wall, passing over a fixed frictionless pulley at a distance of 2m from the wall, has a point mass M = 2kg attached to it at a distance of 1m from the wall. A mass m = 0.5 kg attached at the free end is held at rest so that the string is horizontal between the wall and the pulley and vertical beyond the pulley. What will be the speed with which the mass M will hit the wall when the mass m is released ?



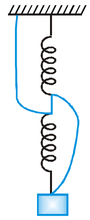
23. A ring of mass m slides on a smooth vertical rod. A light string is attached to the ring and is passing over a smooth peg distant a from the rod, and at the other end of the string is a mass M (M > m). The ring is held on a level with the peg and released. Show that it first comes to rest after falling a distance $\frac{2mMa}{M^2 - m^2}$



24. 'A' block of mass m is held at rest on a smooth horizontal floor. A light frictionless, small pulley is fixed at a height of 6 m from the floor. A light inextensible string of length 16m, connected with A passes over the pulley and another identical block B is hung from the string. Initial height of B is 5m from the floor as shown in figure. When the system is released from rest, B starts to move vertically downwards and A slides on the floor towards right. (i) If at an instant string makes an angle θ with horizontal, calculate relation between velocity u of A and v of B (ii) Calculate v when B strikes the floor.



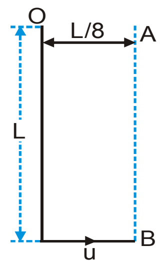
25. In figure two identical springs, each with a relaxed length of 50 cm and a spring constant of 500 N/m, are connected by a short cord of length 10 cm. The upper string is attached to the ceiling, a box that weighs 100N hangs from the lower spring. Two additional cords, each 85 cm long, are also tied to the assembly; they are limp (i.e. slack).



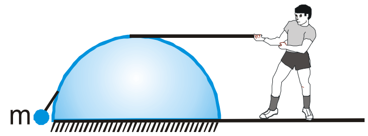
(i) If the short cord is cut, so that the box then hangs from the springs and the two longer cords, does the box move up or down ?

(ii) How far does the box move before coming to rest again ?

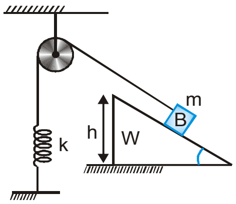
26. A particle is suspended vertically from a point O by an inextensible massless string of length L. A vertical line AB is at a distance $\frac{L}{8}$ from O as shown in figure. The object is given a horizontal velocity u. At some point, its motion ceases to be circular and eventually the object passes through the line AB. At the instant of crossing AB, its velocity is horizontal. Find u.



27. As shown in the figure a person is pulling a mass 'm' from ground on a fixed rough hemispherical surface upto the top of the hemisphere with the help of a light inextensible string. Find the work done by tension in the string if radius of hemisphere is R and friction co–efficient is μ. Assume that the block is pulled with negligible velocity.



28. In the figure shown the pulley is smooth. The spring and the string are light. The block 'B' slides down from the along the fixed rough wedge of inclination θ. Assuming that the block reaches the end of the wedge. Find the speed of the block at the end. Take the coefficient of friction between the block and the wedge to be μ and the spring was relaxed when the blockwas released from the top of the wedge.



29. A stone weighing 0.5 kg tied to a rope of length 0.5m revolves along a circular path in a vertical plane. The tension of the rope at the bottom point of the circle is 45 newtons. To what height will the stone rise if the rope breaks at moment the velocity is directed upwards? (g=10 m/s^2)

30. Starting from rest, a particle rotates in a circle of radius R = $\sqrt{2}$ m with an angular acceleration $\alpha = \frac{\pi}{4}$ rad/sec^2. Calculate the magnitude of average velocity of the particle over the time it rotates quarter circle.

Exercise # 5 Part # I [Previous Year Questions] [AIEEE/JEE-MAIN]

1. A spring of force constant 800 N/m has an extension of 5 cm. The work done in extending it from 5 cm to 15 cm is- **[AIEEE - 2002]**

(1) 16 J **(2)** 8 J **(3)** 32 J **(4)** 24 J

2. A spring of spring constant 5×10^3 N/m is stretched initially by 5 cm from the unstretched position. Then the work required to stretch it further by another 5 cm is- **[AIEEE - 2003]**

(1) 12.50 N-m **(2)** 18.75 N-m **(3)** 25.00 N-m **(4)** 6.25 N-m

3. A body is moved along a straight line by a machine delivering a constant power. The distance moved by the body in time t is proportional to- **[AIEEE - 2003]**

(1) $t^{3/4}$ **(2)** $t^{3/2}$ **(3)** $t^{1/4}$ **(4)** $t^{1/2}$

4. A particle moves in a straight line with retardation proportional to its displacement. Its loss of kinetic energy for any displacement x is proportional to- **[AIEEE - 2004]**

(1) x^2 **(2)** e^x **(3)** x **(4)** $\log_e x$

5. A body of mass m accelerates uniformly from rest to v_1 in time t_1. The instantaneous power delivered to the body as a function of time t is- **[AIEEE - 2004]**

(1) $\frac{mv_1 t}{t_1}$ **(2)** $\frac{mv_1^2 t}{t_1^2}$ **(3)** $\frac{mv_1 t^2}{t_1}$ **(4)** $\frac{mv_1^2 t}{t_1}$

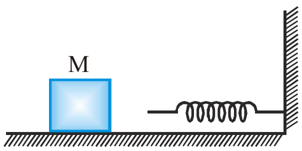
6. A uniform chain of length 2 m is kept on a table such that a length of 60 cm hangs freely from the edge of the table. The total mass of the chain is 4 kg. What is the work done in pulling the entire chain on the table **[AIEEE - 2004]**

(1) 7.2 J **(2)** 3.6 J **(3)** 120 J **(4)** 1200 J

7. A bullet fired into a fixed target loses half of its velocity after penetrating 3cm. How much further it will penetrate before coming to rest, assuming that it faces constant resistance to motion ? **[AIEEE - 2005]**

(1) 3.0 cm **(2)** 2.0 cm **(3)** 1.5 cm **(4)** 1.0 cm

8. The block of mass M moving on the frictionless horizontal surface collides with the spring of spring constant k and compresses it by length L. The maximum momentum of the block after collision is- **[AIEEE - 2005]**



(1) $\sqrt{Mk}\,L$ **(2)** $\frac{kL^2}{2M}$ **(3)** zero **(4)** $\frac{ML^2}{k}$

9. A particle of mass 100 g is thrown vertically upwards with a speed of 5 m/s. The work done by the force of gravity during the time the particle goes up is- **[AIEEE - 2006]**

(1) – 0.5 J **(2)** –1.25 J **(3)** 1.25 J **(4)** 0.5 J

10. The potential energy of a 1 kg particle free to move along the x-axis is given by $V(x) = \left(\frac{x^4}{4} - \frac{x^2}{2}\right)$ J. The total mechanical energy of the particle is 2 J. Then, the maximum speed (in m/s) is- **[AIEEE - 2006]**

(1) $3/\sqrt{2}$ **(2)** $\sqrt{2}$ **(3)** $1/\sqrt{2}$ **(4)** 2

11. A mass of M kg is suspended by a weightless string. The horizontal force that is required to displace it until the string makes an angle of 45° with the initial vertical direction is- **[AIEEE - 2006]**

(1) $Mg(\sqrt{2} + 1)$ **(2)** $Mg\sqrt{2}$ **(3)** $\frac{Mg}{\sqrt{2}}$ **(4)** $Mg(\sqrt{2} - 1)$

12. A 2 kg block slides on a horizontal floor with a speed of 4 m/s. It strikes an uncompressed spring, and compresses it till the block is motionless. The kinetic friction force is 15 N and spring constant is 10, 000 N/m. The spring compresses by :- **[AIEEE - 2007]**

(1) 5.5 cm **(2)** 2.5 cm **(3)** 11.0 cm **(4)** 8.5 cm

13. An athlete in the Olympic games covers distance of 100 m in 10 s. His kinetic energy can be estimated to be in the range :- **[AIEEE - 2008]**

(1) 200 J – 500 J **(2)** 2×10^5 J – 3×10^5 J
(3) 2×10^4 J – 3×10^4 J **(4)** 2×10^3 J – 5×10^3 J

14. The potential energy function for the force between two atoms in a diatomic molecule is approximately given by $U(x) = \frac{a}{x^{12}} - \frac{b}{x^6}$, where a and b are constant and x is the distance between the atoms. if the dissociation energy of the molecule is $D = [U(x = \infty) - U_{\text{at equilibrium}}]$, D is : **[AIEEE - 2010]**

(1) $\frac{b^2}{6a}$ **(2)** $\frac{b^2}{2a}$ **(3)** $\frac{b^2}{12a}$ **(4)** $\frac{b^2}{4a}$

15. At time t = 0s particle starts moving along the x-axis. If its kinetic energy increases uniformly with time 't', the net force acting on it must be proportional to :- **[AIEEE - 2011]**

(1) $\sqrt{t}$ **(2)** constant **(3)** t **(4)** $\frac{1}{\sqrt{t}}$

16. **This question has Statement-1 and Statement-2. Of the four choices given after the statements, choose the one that best describes the two statements.**
If two springs S_1 and S_2 of force constants k_1 and k_2, respectively, are stretched by the same force, it is found that more work is done on spring S_1 than on spring S_2. **[AIEEE - 2012]**
Statement-1: If stretched by the same amount, work done on S_1, will be more than that on S_2
Statement-2 : $k_1 < k_2$.
(1) Statement-1 is true, Statement-2 is true and Statement-2 is not the correct explanation of Statement-1.
(2) Statement-1 is false, Statement-2 is true
(3) Statement-1 is true, Statement-2 is false
(4) Statement-1 is true, Statement-2 is true and Statement-2 is the correct explanation of statement-1.

17. A person trying to lose weight by burning fat lifts a mass of 10 kg upto a height of 1 m 1000 times. Assume that the potential energy lost each time he lowers the mass is dissipated. How much fat will he use up considering the work done only when the weight is lifted up? Fat supplies 3.8×10^7 J of energy per kg which is converted to mechanical energy with a 20% efficiency rate. Tae $g = 9.8$ ms^{-2} : **[JEE (Main) - 2016]**

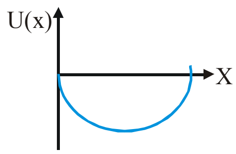
(1) 6.45×10^{-3} kg **(2)** 9.89×10^{-3} kg **(3)** 12.89×10^{-3} kg **(4)** 2.45×10^{-3} kg

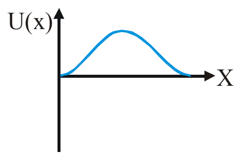
Part # II [Previous Year Questions][IIT-JEE ADVANCED]

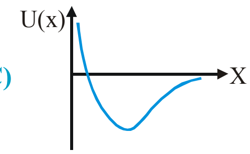
1. A wind–powered generator converts wind energy into electric energy. Assume that the generator converts a fixed fraction of the wind energy intercepted by its blades into electrical energy. For wind speed v, the electrical power output will be proportional to :– **[IIT-JEE 2000]**

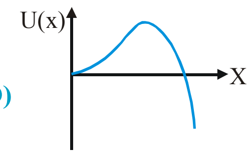
(A) v **(B)** v^2 **(C)** v^3 **(D)** v^4

2. A particle, which is constrained to move along x–axis, is subjected to a force in the same direction which varies with the distance x of the particle from the origin as $F(x) = -kx + ax^3$. Here, k and a are positive constant. For $x \geq 0$, the functional form of the potential energy U(x) of the particle is :– **[IIT-JEE 2002]**

(A) 

(B) 

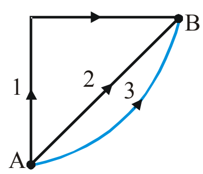
(C) 

(D) 

3. An ideal spring with spring–constant k is hung from the ceiling and a block of mass M is attached to its lower end. The mass is released with the spring initially unstretched. Then the maximum extension in the spring is :– **[IIT-JEE 2002]**

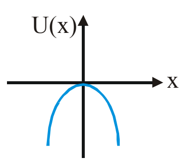
(A) $\frac{4Mg}{k}$ **(B)** $\frac{2Mg}{k}$ **(C)** $\frac{Mg}{k}$ **(D)** $\frac{Mg}{2k}$

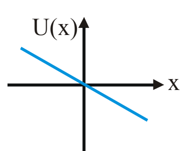
4. If W_1, W_2 and W_3 represent the work done in moving a particle from A to B along three different paths 1, 2 and 3 respectively (as shown) in the gravitational field of a point mass m. Find the correct relation between W_1, W_2 and W_3 :– **[IIT-JEE 2003]**

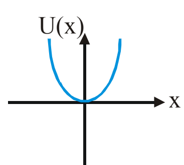


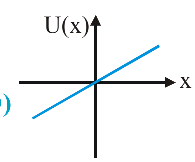
(A) $W_1 > W_2 > W_3$ **(B)** $W_1 = W_2 = W_3$
(C) $W_1 < W_2 < W_3$ **(D)** $W_2 > W_1 > W_3$

5. A particle is placed at the origin and a force F = kx is acting on it (where k is positive constant). If U(0)=0, the graph of U(x) versus x will be (where U is the potential energy function) :– **[IIT-JEE 2004]**

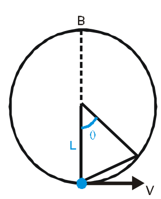
(A) 

(B) 

(C) 

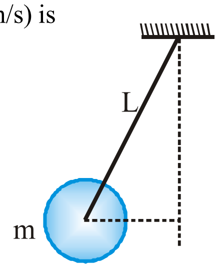
(D) 

6. A bob of mass M is suspended by a massless string of length L. The horizontal velocity v at position A is just sufficient to make it reach the point B. The angle θ at which the speed of the bob is half of that A, is **IIT-JEE 2008]**



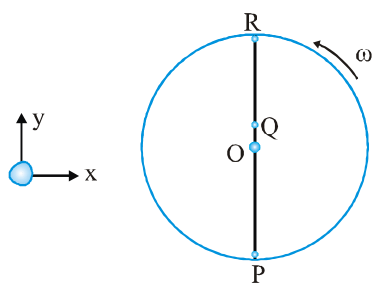
(A) $\theta = \frac{\pi}{4}$ **(B)** $\frac{\pi}{4} < \theta < \frac{\pi}{2}$ **(C)** $\frac{\pi}{2} < \theta < \frac{3\pi}{4}$ **(D)** $\frac{3\pi}{4} < \theta < \pi$

7. A ball of mass (m) 0.5 kg is attached to the end of a string having length (L) 0.5 m. The ball is rotated on a horizontal circular path about vertical axis. The maximum tension that the string can bear is 324 N. The maximum possible value of angular velocity of ball (in radian/s) is **[IIT-JEE-2011]**



(A) 9 **(B)** 18 **(C)** 27 **(D)** 36

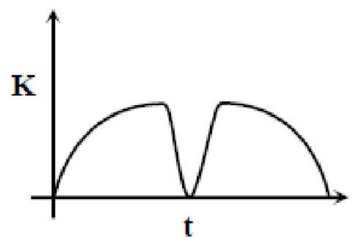
8. Consider a disc rotating in the horizontal plane with a constant angular speed ω about its centre O. The disc has a shaded region on one side of the diameter and an unshaded region on the other side as shown in the figure. When the disc is in the orientation as shown, two pebbles P and Q are simultaneously projected at an angle towards R. The velocity of projection is in the y-z plane and is same for both pebbles with respect to the disc. Assume that (i) they land back on the disc before the disc has completed $\frac{1}{8}$ rotation, (ii) their range is less than half the disc radius, and (iii) ω remains constant throughout. Then **[IIT-JEE-2012]**



(A) P lands in the shaded region and Q in the unshaded region.
(B) P lands in the unshaded region and Q in the shaded region.
(C) Both P and Q land in the unshaded region.
(D) Both P and Q land in the shaded region.

9. A tennis ball is dropped on a horizontal smooth surface. It bounces back to its original position after hitting the surface. The force on the ball during the collision is proportional to the length of compression of the ball. Which one of the following sketches describes the variation of its kinetic energy K with time t most appropriately? The figures are only illustrative and not to the scale. **[IIT-JEE-2014]**

(A)



(B)

(C)

(D)

MCQs with one or more than one correct answer

10. A particle is acted upon by a force of constant magnitude which is always perpendicular to the velocity of the particle. The motion of the particle takes place in a plane. It follows that :– **[IIT-JEE 1987]**

(A) its velocity is constant **(B)** its acceleration is constant

(C) its kinetic energy is constant **(D)** it moves in a circular path

Assertion & Reason

11. **Statement I :** A block of mass m starts moving on a rough horizontal surface with a velocity v. It stops due to friction between the block and the surface after moving through a certain distance. The surface is now tilted to an angle of 30° with the horizontal and the same block is made to go up on the surface with the same initial velocity v. The decrease in the mechanical energy in the second situation is smaller than that in the first situation. **[IIT-JEE 2007]**

Statement II : The coefficient of friction between the block and the surface decreases with the increase in the angle of inclination.

(A) statement–I is true, statement–II is true; statement–II is a correct explanation for statement–I

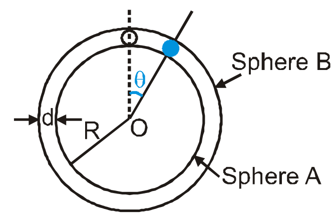
(B) statement–I is true, statement–II is true, statement–II is NOT a correct explanation for statement–I

(C) statement–I is true, statement–II is false

(D) statement–I is false, statement–II is true

Subjective Questions

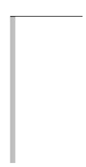
12. A spherical ball of mass m is kept at the highest point in the space between two fixed, concentric spheres A and B (see figure). The smaller sphere A has a radius R and the space between the two spheres has a width d. The ball has a diameter very slightly less then d. All surface are frictionless. Then ball is given a gentle push (towards the right in the figure). The angle made by the radius vector of the ball with the upward vertical is denoted by θ. **[IIT-JEE 2002]**



(i) Express the total normal reaction force exerted by the spheres on the ball as a function of angle θ.

(ii) Let N_A and N_B denote the magnitudes of the normal reaction forces on the ball exerted by the spheres A and B, respectively. Sketch the variations of N_A and N_B as function of cosθ in the range $0 \le \theta \le \pi$ by drawing two separate graphs in your answer book, taking cosθ on the horizontal axis.

13. A light inextensible string that goes over a smooth fixed pulley as shown in the figure connects two blocks of masses 0.36 kg and 0.72 kg. Taking $g = 10\ m/s^2$, find the work done (**in joules**) by the string on the block of mass 0.36 kg during the first second after the system is released from rest. **[IIT-JEE 2009]**



14. A block of mass 0.18 kg is attached to a spring of force-constant 2 N/m. The coefficient of friction between the block and the floor is 0.1. Initially the block is at rest and the spring is unstretched. An impulse is given to the block as shown in the figure. The block slides a distance of 0.06 m and comes to rest for the first time. The initial velocity of the block in m/s is V= N/10. Then N is **[IIT-JEE-2011]**