Chapter 6

Work, Energy and Power

Solutions

SECTION - A

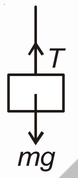
Objective Type Questions

(Work)

1. A string is used to pull a block of mass m vertically up by a distance h at a constant acceleration $\frac{g}{3}$. The work done by the tension in the string is

(1) $\frac{2}{3}mgh$ (2) $\frac{-mgh}{3}$ (3) mgh (4) $\frac{4}{3}mgh$

Sol. Answer (4)



$T - mg = ma$

$T = m(g + a)$

$= \frac{4}{3}mg$

Work (w) = $T.h$

$= \frac{4}{3}mgh$

2. A body constrained to move in z direction is subjected to a force given by $\vec{F} = (3\hat{i} - 10\hat{j} + 5\hat{k})$N. What is the work done by this force in moving the body through a distance of 5 m along z-axis?

(1) 15 J (2) – 15 J (3) –50 J (4) 25 J

Sol. Answer (4)

$W = \left(3\hat{i} - 10\hat{j} + 5\hat{k}\right).5\hat{k}$

$= 25$ J

3. If 250 J of work is done in sliding a 5 kg block up an inclined plane of height 4 m. Work done against friction is (g = 10 ms^{-2})

(1) 50 J (2) 100 J (3) 200 J (4) Zero

Sol. Answer (1)

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$W_{Total} = W_{friction} + W_{gravity}$

$-250 = W_f - 50(4)$

$W_f = -50$ J

4. A man carries a load on his head through a distance of 5 m. The maximum amount of work is done when he

(1) Moves it over an inclined plane (2) Moves it over a horizontal surface

(3) Lifts it vertically upwards (4) None of these

Sol. Answer (3)

Displacement is maximum while moving it vertically upwards.

5. A body moves a distance of 10 m along a straight line under the action of a force 5 N. If the work done is 25 joule, the angle which the force makes with the direction of motion of body is

(1) 0° (2) 30° (3) 60° (4) 90°

Sol. Answer (3)

$\vec{F}.\vec{S} = 25$

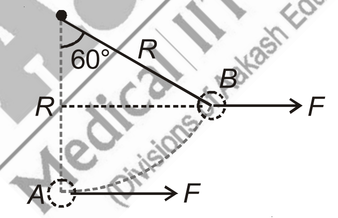
$FS \cos\theta = 25$

$(5)(10)\cos\theta = 25$

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

$\theta = 60°$

6. A block of mass m is pulled along a circular arc by means of a constant horizontal force F as shown. Work done by this force in pulling the block from A to B is

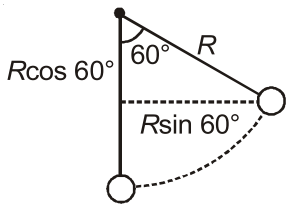


(1) $\frac{FR}{2}$ (2) FR (3) $\frac{\sqrt{3}}{2}FR$ (4) mgR

Sol. Answer (3)

Work = Force × (Displacement in the direction of force)

$= F(R\sin 60°) = \frac{\sqrt{3}}{2}FR$



7. A particle is displaced from a position $(2\hat{i} - \hat{j} + \hat{k})$ metre to another position $(3\hat{i} + 2\hat{j} - 2\hat{k})$ metre under the action of force $(2\hat{i} + \hat{j} - \hat{k})$ N. Work done by the force is

(1) 8 J (2) 10 J (3) 12 J (4) 36 J

Sol. Answer (1)

$W = \vec{F}\,.\,\vec{S}$

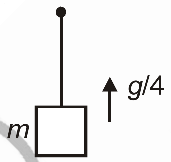
Displacement vector $\left(\vec{S}\right)$ = $(3i + 2j - 2k) - (2i - j + k)$

$= i + 3\hat{j} - 3\hat{k}$

W = $(2i + j - k)\,.\,(i + 3j - 3k)$

= 2 + 3 + 3 = 8J

8. A string is used to pull a block of mass m vertically up by a distance h at a constant acceleration $\frac{g}{4}$. The work done by the tension in the string is



(1) $+\frac{3mgh}{4}$ (2) $-\frac{mgh}{4}$ (3) $+\frac{5}{4}mgh$ (4) $+ mgh$

Sol. Answer (3)

$T - mg = ma$

$T = m(g + a) \;\Rightarrow T = m\left(g + \frac{g}{4}\right) = \frac{5}{4}mg$

$W = T.h = \frac{5}{4}mgh$

9. Work done by frictional force

(1) Is always negative (2) Is always positive

(3) Is zero (4) May be positive, negative or zero

Sol. Answer (4)

Frictional force can act in the direction of displacement, opposite to it and sometimes not let the body move. So the work can be positive, negative or zero.

(Kinetic Energy)

10. Two bodies of masses m_1 and m_2 have same kinetic energy. The ratio of their momentum is

(1) $\sqrt{\frac{m_2}{m_1}}$ (2) $\sqrt{\frac{m_1}{m_2}}$ (3) $\frac{m_1^2}{m_2^2}$ (4) $\frac{m_2^2}{m_1^2}$

Sol. Answer (2)

$\frac{P_1^2}{2m_1} = \frac{P_2^2}{2m_2}$

$\frac{P_1}{P_2} = \sqrt{\frac{m_1}{m_2}}$

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11. Two bodies of masses m_1 and m_2 have same momentum. The ratio of their KE is

(1) $\sqrt{\frac{m_2}{m_1}}$ (2) $\sqrt{\frac{m_1}{m_2}}$ (3) $\frac{m_1}{m_2}$ (4) $\frac{m_2}{m_1}$

Sol. Answer (4)

$$\sqrt{2m_1k_1} = \sqrt{2m_2k_2}$$

$$\frac{k_1}{k_2} = \frac{m_2}{m_1}$$

12. KE of a body is increased by 44%. What is the percent increase in the momentum?

(1) 10% (2) 20% (3) 30% (4) 44%

Sol. Answer (2)

$$1.44K = \frac{(P^1)^2}{2m}$$

$P^1 = 1.2\,P$

$$\frac{P^1 - P}{P} \times 100 = \frac{1.2P - P}{P} = 20\%$$

13. When momentum of a body increases by 200%, its KE increases by

(1) 200% (2) 300% (3) 400% (4) 800%

Sol. Answer (4)

$P^1 = 3P$

$$K^1 = \frac{(3P)^2}{2m} = \frac{9P^2}{2m}$$

$$\frac{K^1 - K}{K} \times 100 = \frac{\frac{9P^2}{2m} - \frac{P^2}{2m}}{\frac{P^2}{2m}} \times 100 = 800\%$$

14. Two bodies of masses m_1 and m_2 are moving with same kinetic energy. If P_1 and P_2 are their respective momentum, the ratio $\frac{P_1}{P_2}$ is equal to

(1) $\frac{m_1}{m_2}$ (2) $\sqrt{\frac{m_2}{m_1}}$ (3) $\sqrt{\frac{m_1}{m_2}}$ (4) $\frac{m_1^2}{m_2^2}$

Sol. Answer (3)

$$\frac{P_1^2}{2m_1} = \frac{P_2^2}{2m_2}$$

$$\frac{P_1}{P_2} = \sqrt{\frac{m_1}{m_2}}$$

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(Work Done by a Variable Force)

15. A particle moves along X-axis from x = 0 to x = 1 m under the influence of a force given by $F = 3x^2 + 2x - 10$. Work done in the process is

(1) +4 J (2) –4 J (3) +8 J (4) –8 J

Sol. Answer (4)

$$W = \int_0^1 \left(3x^2 + 2x - 10\right) dx$$

$$= \left[x^3 + x^2 - 10x\right]_0^1 = -8 \text{ J}$$

16. A particle moves along x-axis from x = 0 to x = 5 metre under the influence of a force $F = 7 - 2x + 3x^2$. The work done in the process is

(1) 70 (2) 135 (3) 270 (4) 35

Sol. Answer (2)

$$W = \int_0^5 \vec{F}.dx = \int_0^5 \left(7 - 2x + 3x^2\right) dx$$

$$= [7x - x^2 + x^3]_0^5 = 135$$

(Notion of Work and Kinetic Energy : The Work-Energy Theorem)

17. Under the action of a force, a 2 kg body moves such that its position x as a function of time t is given by $x = \frac{t^2}{3}$, where x is in metre and t in second. The work done by the force in first two seconds is

(1) 1600 J (2) 160 J (3) 16 J (4) $\frac{16}{9}$ J

Sol. Answer (4)

$$x = \frac{t^2}{3} \quad \Rightarrow \quad v = \frac{2t}{3}$$

$$W = \Delta\text{K.E.} = \frac{1}{2}(2)\left[\left(\frac{4}{3}\right)^2 - 0\right] = \frac{16}{9} \text{ J}$$

18. A rifle bullets loses $\left(\frac{1}{20}\right)$th of its velocity in passing through a plank. Assuming that the plank exerts a constant retarding force, the least number of such planks required just to stop the bullet is

(1) 11 (2) 20 (3) 21 (4) Infinite

Sol. Answer (1)

Let the retarding force by one block is F and displacement inside one block is x.

So using work energy theorem for one block

$$-F.x = \frac{1}{2}m\left[\left(\frac{19}{20}v\right)^2 - v^2\right] \quad \ldots(1)$$

Applying work energy theorem for n blocks, $-F.nx = \frac{1}{2}m\left[o - v^2\right]$

Using value of Fx from ...(1)

$$\frac{1}{2}m\left[v^2 - \left(\frac{19}{20}v\right)^2\right]n = \frac{1}{2}m\left[o - v^2\right]$$

Solving for n, n = 10.25

So, 11 planks

19. A particle of mass 2 kg travels along a straight line with velocity $v = a\sqrt{x}$, where a is a constant. The work done by net force during the displacement of particle from x = 0 to x = 4 m is

(1) a^2 (2) $2a^2$ (3) $4a^2$ (4) $\sqrt{2}a^2$

Sol. Answer (3)

$$v = a\sqrt{x}$$

$$W = \frac{1}{2}mv^2 - \frac{1}{2}mu^2$$

$$= \frac{1}{2}(2)\left[\left(a\sqrt{4}\right)^2 - 0\right]$$

$$= 4a^2$$

20. The position x of a particle moving along x-axis at time (t) is given by the equation $t = \sqrt{x} + 2$, where x is in metres and t in seconds. Find the work done by the force in first four seconds.

(1) Zero (2) 2 J (3) 4 J (4) 8 J

Sol. Answer (1)

$$x = (t - 2)^2$$

$$\frac{dx}{dt} = v = 2(t - 2)$$

$$W = \frac{1}{2}mv^2 - \frac{1}{2}mu^2$$

$$= \frac{m}{2}\left[4^2 - 4^2\right] = 0$$

21. KE acquired by a mass m in travelling a certain distance d, starting from rest, under the action of a constant force F is

(1) Directly proportional to $\sqrt{m}$ (2) Directly proportional to m

(3) Directly proportional to $\frac{1}{m}$ (4) None of these

Sol. Answer (4)

F.d = ΔK

F.d = K_f

K is independent of mass here.

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22. A simple pendulum with bob of mass *m* and length *x* is held in position at an angle θ_1 and then angle θ_2 with the vertical. When released from these positions, speeds with which it passes the lowest positions are v_1 & v_2 respectively. Then, $\frac{v_1}{v_2}$ is

(1) $\frac{1-\cos\theta_1}{1-\cos\theta_2}$ (2) $\sqrt{\frac{1-\cos\theta_1}{1-\cos\theta_2}}$ (3) $\sqrt{\frac{2gx(1-\cos\theta_1)}{1-\cos\theta_2}}$ (4) $\sqrt{\frac{1-\cos\theta_1}{2gx(1-\cos\theta_2)}}$

Sol. Answer (2)

$U_i + k_i = U_f + k_f$ (Mechanical energy conservation)

$$mgl(1-\cos\theta) = \frac{1}{2}mv^2$$

$$\frac{v_1^2}{v_2^2} = \frac{1-\cos\theta_1}{1-\cos\theta_2}$$

$$\frac{v_1}{v_2} = \sqrt{\frac{1-\cos\theta_1}{1-\cos\theta_2}}$$

23. The total work done on a particle is equal to the change in its kinetic energy. This is applicable

(1) Always (2) Only if the conservative forces are acting on it

(3) Only in inertial frames (4) Only when pseudo forces are absent

Sol. Answer (1)

$W = \Delta k$ is always applicable

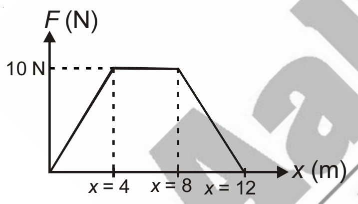
24. A particle of mass 0.1 kg is subjected to a force which varies with distance as shown. If it starts its journey from rest at $x = 0$, then its velocity at $x = 12$ m is

(1) 0 m/s

(2) $20\sqrt{2}$ m/s

(3) $20\sqrt{3}$ m/s

(4) 40 m/s



Sol. Answer (4)

Total work done = Area under $F - x$ curve

= ΔK.E.

$$\frac{1}{2}(4)(10) + \frac{1}{2}(4)10 + 40 = \Delta K$$

$$80\ J = \frac{1}{2}(0.1)v^2 \Rightarrow v = 40 \text{ m/s}$$

25. An unloaded bus can be stopped by applying brakes on straight road after covering a distance *x*. Suppose, the passenger add 50% of its weight as the load and the braking force remains unchanged, how far will the bus go after the application of the brakes? (Velocity of bus in both case is same)

(1) Zero (2) 1.5*x* (3) 2*x* (4) 2.5*x*

Sol. Answer (2)

$$F.x = \frac{1}{2}mv^2$$

$$F.x^1 = \frac{1}{2}(1.5m)v^2 \Rightarrow x^1 = 1.5\ x$$

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(The Concept of Potential Energy)

26. Potential energy is defined

    (1) Only in conservative fields

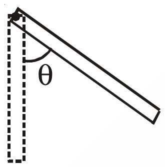
    (2) As the negative of work done by conservative forces

    (3) As the negative of workdone by external forces when $\Delta K = 0$

    (4) All of these

Sol. Answer (1)

27. A stick of mass m and length l is pivoted at one end and is displaced through an angle θ. The increase in potential energy is



(1) $mg\,\dfrac{l}{2}(1-\cos\theta)$ (2) $mg\,\dfrac{l}{2}(1+\cos\theta)$ (3) $mg\,\dfrac{l}{2}(1-\sin\theta)$ (4) $mg\,\dfrac{l}{2}(1+\sin\theta)$

Sol. Answer (1)

Using mechanical energy conservation, $U = \dfrac{mgl}{2}(1-\cos\theta)$

28. A spring with spring constants k when compressed by 1 cm, the potential energy stored is U. If it is further compressed by 3 cm, then change in its potential energy is

    (1) $3U$ (2) $9U$ (3) $8U$ (4) $15U$

Sol. Answer (4)

$$U = \frac{1}{2}k(1)^2 = \frac{k}{2}$$

$$U^1 = \frac{1}{2}k(4)^2 = \frac{1}{2}k(16) = 16U$$

$$\Delta U = U^1 - U = 16U - U = 15U$$

29. Two springs have force constant K_1 and K_2 $(K_1 > K_2)$. Each spring is extended by same force F. It their elastic potential energy are E_1 and E_2 then $\dfrac{E_1}{E_2}$ is

    (1) $\dfrac{K_1}{K_2}$ (2) $\dfrac{K_2}{K_1}$ (3) $\sqrt{\dfrac{K_1}{K_2}}$ (4) $\sqrt{\dfrac{K_2}{K_1}}$

Sol. Answer (2)

$$x = \frac{F}{K}$$

$$U = \frac{1}{2}Kx^2 = \frac{1}{2}K\left(\frac{F}{K}\right)^2$$

$$U = \frac{F^2}{2K}$$

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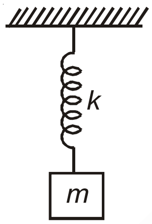
$$U \propto \frac{1}{K}$$

$$\frac{U_1}{U_2} = \frac{K_2}{K_1}$$

30. Initially mass m is held such that spring is in relaxed condition. If mass m is suddenly released, maximum elongation in spring will be



(1) $\frac{mg}{k}$ (2) $\frac{2mg}{k}$ (3) $\frac{mg}{2k}$ (4) $\frac{mg}{4k}$

Sol. Answer (2)

$E_i = E_f$

$$\Rightarrow 0 = -mgx + \frac{1}{2}kx^2$$

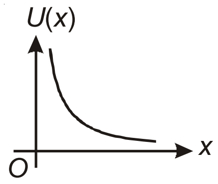
$$x = \frac{2mg}{k}$$

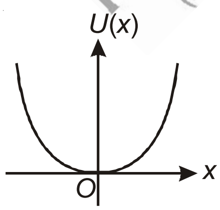
31. The potential energy of a particle of mass 5 kg moving in x-y plane is given by equation, $U = -7x + 24y$ joule. Here x and y are in metre at $t = 0$, the particle is at origin and moving with velocity $(2\hat{i} + 3\hat{j})$ m/s. The magnitude of acceleration of particle is

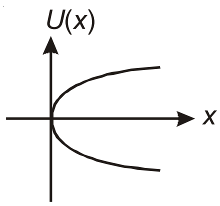
(1) 3 m/s^2 (2) 5 m/s^2 (3) 31 m/s^2 (4) 15 m/s^2

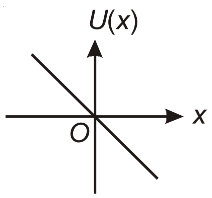
Sol. Answer (2)

32. On a particle placed at origin a variable force $F = -ax$ (where a is a positive constant) is applied. If $U(0) = 0$, the graph between potential energy of particle $U(x)$ and x is best represented by

(1) 

(2) 

(3) 

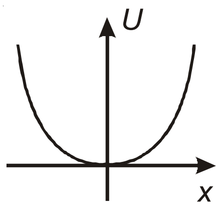
(4) 

Sol. Answer (2)

$$F = -ax = \frac{-dU}{dx}$$

Integrating both sides

$$U = \frac{ax^2}{2}$$



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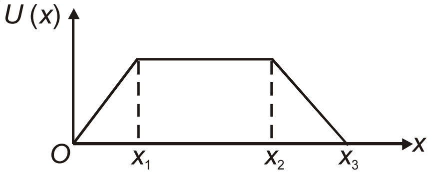
33. The variation of potential energy U of a system is shown in figure. The force acting on the system is best represented by



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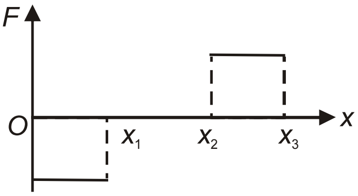

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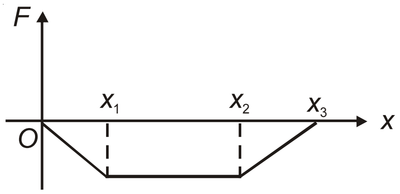

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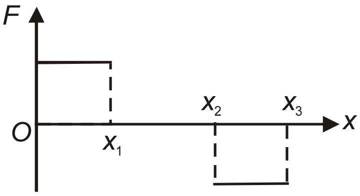

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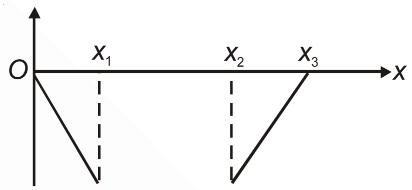


Sol. Answer (1)

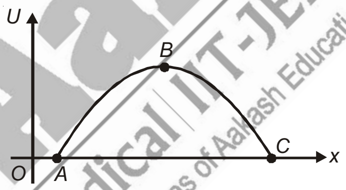
$F = \frac{-dU}{dx} \Rightarrow$ Slope of U–x curve will represent force

from $0 \rightarrow x_1$ Slope is positive and non zero

from $x_1 \rightarrow x_2$ Slope is zero

from $x_2 \rightarrow x_3$ Slope is negative and non zero

34. The variation of potential energy U of *a* body moving along x-axis varies with its position (x) as shown in figure



The body is in equilibrium state at

(1) A (2) B (3) C (4) Both A & C

Sol. Answer (2)

at B, $\frac{dU}{dx} = 0$ (Slope of $U - x$ curve)

$\Rightarrow F = 0$ at B, So its a position of equilibrium

(The Conservation of Mechanical Energy)

35. A uniform chain of length L and mass M is lying on a smooth table and one third of its length is hanging vertically down over the edge of the table. If g is acceleration due to gravity, the minimum work required to pull the hanging part of the chain on the table is

(1) MgL (2) $\frac{MgL}{3}$ (3) $\frac{MgL}{9}$ (4) $\frac{MgL}{18}$

Sol. Answer (4)

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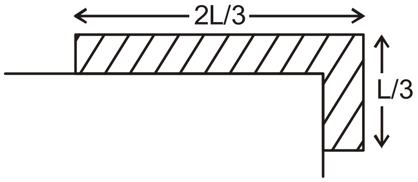
Mass of $\frac{L}{3}$ part will be $\frac{M}{3}$

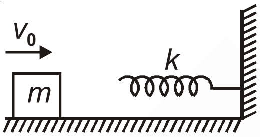


Centre of mass of $\frac{L}{3}$ part is $\frac{L}{6}$ below the table

So total displacement of C.M. to bring it on the table

$$W = \frac{M}{3} g \left(\frac{L}{6}\right) = \frac{MgL}{18}$$

36. A block of mass m moving with velocity v_0 on a smooth horizontal surface hits the spring of constant k as shown. The maximum compression in spring is



(1) $\sqrt{\frac{2m}{k}} \cdot v_0$ (2) $\sqrt{\frac{m}{k}} \cdot v_0$ (3) $\sqrt{\frac{m}{2k}} \cdot v_0$ (4) $\frac{m}{2k} \cdot v_0$

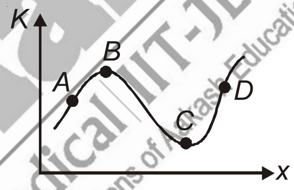
Sol. Answer (2)

$E_i = E_f$

$$\frac{1}{2} m v_0^2 = \frac{1}{2} k x^2$$

$$x = \sqrt{\frac{m}{k}} v_0$$

37. For a particle moving under the action of a variable force, kinetic energy-position graph is given, then



(1) At A particle is decelerating (2) At B particle is accelerating

(3) At C particle has maximum velocity (4) At D particle has maximum acceleration

Sol. Answer (4)

$F.dx = dK$

$$\frac{dK}{dx} = F$$

$\Rightarrow$ Slope of $K - x$ curve gives force

So slope is max at D, hence acceleration is maximum at D

38. A particle of mass 200 g is moving in a circle of radius 2 m. The particle is just 'looping the loop'. The speed of the particle and the tension in the string at highest point of the circular path are (g = 10 ms^{-2})

(1) 4 ms^{-1}, 5 N (2) 4.47 ms^{-1}, zero (3) 2.47 ms^{-1}, zero (4) 1 ms^{-1}, zero

Sol. Answer (2)

$v = \sqrt{gL} = 4.47$ m/s

$T = 0$

39. A particle of mass 200 g, is whirled into a vertical circle of radius 80 cm using a massless string. The speed of the particle when the string makes an angle of 60° with the vertical line is 1.5 ms^{-1}. The tension in the string at this position is

(1) 1 N (2) 1.56 N (3) 2 N (4) 3 N

Sol. Answer (2)

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

$\theta = 60°$

Solving this T = 1.56 N

40. A stone of mass 1 kg is tied with a string and it is whirled in a vertical circle of radius 1 m. If tension at the highest point is 14 N, then velocity at lowest point will be

(1) 3 m/s (2) 4 m/s (3) 6 m/s (4) 8 m/s

Sol. Answer (4)

$$T + mg = \frac{mv^2}{R} \text{ (at the highest point)}$$

$$14 = \frac{1(v^2)}{R(1)} + 10$$

$v^2 = 4 \Rightarrow v = 2$ m/s

Using mechanical energy conservation

$$\frac{1}{2}(1)u^2 = \frac{1}{2}(1)(2^2) + 1(10)(2)$$

$u^2 = 64 \Rightarrow u = 8$ m/s

(Power)

41. The power of water pump is 4 kW. If g = 10 ms^{-2}, the amount of water it can raise in 1 minute to a height of 20 m is

(1) 100 litre (2) 1000 litre

(3) 1200 litre (4) 2000 litre

Sol. Answer (3)

$$\text{Power} = \frac{\text{Work}}{\text{time}} = \frac{mgh}{t}$$

$$\frac{m(10)(20)}{60} = 4000 \Rightarrow m = 1200 \text{ litre}$$

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42. A particle moves with the velocity $\vec{v} = (5\hat{i} + 2\hat{j} - \hat{k})\text{ms}^{-1}$ under the influence of a constant force, $\vec{F} = (2\hat{i} + 5\hat{j} - 10\hat{k})$ N. The instantaneous power applied is

(1) 5 W (2) 10 W (3) 20 W (4) 30 W

Sol. Answer (4)

$$P = \vec{F}.\vec{V}$$

$= (2i + 5j - 10k) . (5i + 2j - k)$

$= 10 + 10 + 10 = 30$ W

43. A body is projected from ground obliquely. During downward motion, power delivered by gravity to it

(1) Increases (2) Decreases

(3) Remains constant (4) First decreases and then becomes constant

Sol. Answer (1)

Power = $Fv \cos\theta$ $\theta < 90°$

Velocity of particle will increase

So power will increase as F is constant

44. The blades of a wind mill sweep out a circle of area A. If wind flows with velocity v perpendicular to blades of wind mill and its density is ρ, then the mechanical power received by wind mill is

(1) $\frac{\rho A v^3}{2}$ (2) $\frac{\rho A v^2}{2}$ (3) $\rho A v^2$ (4) $2\rho A v^2$

Sol. Answer (1)

$$P = \frac{dk}{dt} = \frac{d}{dt}\left[\frac{1}{2}mv^2\right]$$

$$= \frac{1}{2}v^2\frac{dm}{dt} = \frac{PAv^3}{2}$$

45. A body of mass m accelerates uniformly from rest to velocity v_1 in time interval T_1. The instantaneous power delivered to the body as a function of time t is

(1) $\frac{mv_1^2}{T_1^2}t$ (2) $\frac{mv_1}{T_1^2}t$ (3) $\left(\frac{mv_1}{T_1}\right)^2 t$ (4) $\frac{mv_1^2}{T_1}t^2$

Sol. Answer (1)

$v_1 = u + at_1$ $\Rightarrow a = \frac{v_1}{t_1}$

again $v = u + at$

$$\Rightarrow v = 0 + \left(\frac{v_1}{T_1}\right)t$$

$$F = ma = \frac{mv_1}{T_1} \quad \Rightarrow P = \frac{mv_1}{T_1}\left(\frac{v_1}{T_1}t\right)$$

46. The power of a pump, which can pump 500 kg of water to height 100 m in 10 s is

(1) 75 kW (2) 25 kW (3) 50 kW (4) 500 kW

Sol. Answer (3)

$$P = \frac{500(1)(100)}{10} = 50{,}000 = 50\ \text{kW}$$

47. A pump is used to pump a liquid of density ρ continuously through a pipe of cross section area *A*. If liquid is flowing with speed *V*, then power of pump is

(1) $\frac{1}{3}\rho AV^2$ (2) $\frac{1}{2}\rho AV^2$ (3) $2\rho AV^2$ (4) $\frac{1}{2}\rho AV^3$

Sol. Answer (4)

$$P_{avg} = \frac{v^2}{2}\frac{dm}{dt} = \frac{1}{2}\rho Av^3$$

48. A car of mass *m* has an engine which can deliver power *P*. The minimum time in which car can be accelerated from rest to a speed *v* is

(1) $\frac{mv^2}{2P}$ (2) Pmv^2 (3) $2Pmv^2$ (4) $\frac{mv^2}{2}P$

Sol. Answer (1)

$$P = \frac{K.E.}{t}$$

$$Pt = \frac{m}{2}v^2$$

$$t = \frac{mv^2}{2P}$$

49. From a water fall, water is pouring down at the rate of 100 kg/s, on the blades of a turbine. If the height of the fall is 100 m, the power delivered to the turbine is approximately equal to

(1) 100 kW (2) 10 kW (3) 1 kW (4) 100 W

Sol. Answer (1)

$$P_{avg} = \frac{W}{t} = \frac{mgh}{t}$$

$$= \left(\frac{m}{t}\right)gh$$

$$= 100 \times 10 \times 100 = 100\ \text{kW}$$

(Collision)

50. A U–238 nucleus originally at rest, decays by emitting an α-particle, say with a velocity of *v* m/s. The recoil velocity (in ms^{-1}) of the residual nucleus is

(1) $\frac{4v}{238}$ (2) $-\frac{4v}{238}$ (3) $\frac{v}{4}$ (4) $-\frac{4v}{234}$

Sol. Answer (4)

Using momentum conservation, $0 = 4v + 234\,v' \Rightarrow v' = \frac{-4v}{234}$

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51. An object of mass 80 kg moving with velocity 2 ms^{-1} hit by collides with another object of mass 20 kg moving with velocity 4 ms^{-1}. Find the loss of energy assuming a perfectly inelastic collision

(1) 12 J (2) 24 J (3) 30 J (4) 32 J

Sol. Answer (4)

Loss in kinetic energy

$$\Delta k = \frac{m_1 m_2}{2(m_1+m_2)}(u_1-u_2)^2$$

Δk = 32 J

52. A ball of mass m moving with velocity v collides head-on with the second ball of mass m at rest. If the coefficient of restitution is e and velocity of first ball after collision is v_1 and velocity of second ball after collision is v_2 then

(1) $v_1 = \frac{(1-e)u}{2}, v_2 = \frac{(1+e)u}{2}$ (2) $v_1 = \frac{(1+e)u}{2}, v_2 = \frac{(1-e)u}{2}$

(3) $v_1 = \frac{u}{2}, v_2 = -\frac{u}{2}$ (4) $v_1 = (1+e)u$, $v_2 = (1-e)u$

Sol. Answer (1)

$$e = \frac{\text{Velocity of separation}}{\text{Velocity of approach}}$$

So, $V_1 = \frac{(1-e)u}{2}, v_2 = \frac{(1+e)}{2}u$

53. Particle A makes a perfectly elastic collision with another particle B at rest. They fly apart in opposite direction with equal speeds. If their masses are m_A & m_B respectively, then

(1) $2m_A = m_B$ (2) $3m_A = m_B$ (3) $4m_A = m_B$ (4) $\sqrt{3}m_A = m_B$

Sol. Answer (2)

From conservation of momentum and mechanical energy conservation

$3m_A = m_B$

54. A shell of mass m moving with a velocity v breakes up suddenly into two pieces. The part having mass $\frac{m}{3}$ remains stationary. The velocity of the other part will be

(1) v (2) 2 v (3) $\frac{2}{3}v$ (4) $\frac{3}{2}v$

Sol. Answer (4)

Momentum will be conserved, $P_i = P_f$

$$mv = \frac{m}{3}(0) + \frac{2m}{3}(v^1) \Rightarrow v^1 = \frac{3}{2}v$$

55. A particle of mass m moving towards west with speed v collides with another particle of mass m moving towards south. If two particles stick to each other, the speed of the new particle of mass 2 m will be

(1) $v\sqrt{2}$ (2) $\frac{v}{\sqrt{2}}$ (3) $\frac{v}{2}$ (4) v

Sol. Answer (2)

Using conservation of momentum, $P_i = P_f$

$$mv\left(-\hat{i}\right) + mv\left(-\hat{j}\right) = 2m\,\vec{v}^1$$

$$\left|v^1\right| = \frac{v}{\sqrt{2}}$$

56. A body of mass 10 kg moving with speed of 3 ms^{-1} collides with another stationary body of mass 5 kg. As a result, the two bodies stick together. The KE of composite mass will be

(1) 30 J (2) 60 J (3) 90 J (4) 120 J

Sol. Answer (1)

Using momentum conservation

10(3) = 15 V

V = 2 m/s

$$\text{K.E.} = \frac{1}{2}mv^2 = \frac{1}{2}(15)(2)^2 = 30\text{ J}$$

57. A stationary particle explodes into two particles of masses x and y, which move in opposite directions with velocity v_1 and v_2. The ratio of their kinetic energies ($E_1 : E_2$) is

(1) 1 (2) $\frac{xv_2}{yv_1}$ (3) $\frac{x}{y}$ (4) $\frac{y}{x}$

Sol. Answer (4)

Momentum will be conserved

$0 = xv_1 + yv_2$

$-xv_1 = yv_2$ ...(1)

$$\frac{k_1}{k_2} = \frac{\frac{1}{2}xv_1^2}{\frac{1}{2}yv_2^2}$$

Using (1) $\left(\frac{v_1}{v_2}\right)^2 = \frac{y^2}{x^2}$

$$\frac{k_1}{k_2} = \frac{x}{y}\cdot\left(\frac{y^2}{x^2}\right) = \frac{y}{x}$$

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58. Select the false statement

(1) In elastic collision, KE is not conserved during the collision

(2) The coefficient of restitution for a collision between two steel balls lies between 0 and 1

(3) The momentum of a ball colliding elastically with the floor is conserved

(4) In an oblique elastic collision between two identical bodies with one of them at rest initially, the final velocities are perpendicular

Sol. Answer (3)

Momentum will be conserved.

59. A bullet of mass *m* moving with a velocity *u* strikes a block of mass *M* at rest and gets embedded in the block. The loss of kinetic energy in the impact is

(1) $\frac{1}{2}mMu^2$ (2) $\frac{1}{2}(m+M)u^2$ (3) $\frac{mMu^2}{2(m+M)}$ (4) $\left(\frac{m+M}{2mM}\right)u^2$

Sol. Answer (3)

$$\Delta k = \frac{1}{2}\frac{m_1M_2}{(m_1+M_2)}(u_1-u_2)^2 = \frac{mMx^2}{2(m+M)}$$

60. A bullet of mass *m* moving with velocity *v* strikes a suspended wooden block of mass *M*. If the block rises to height *h*, the initial velocity of the bullet will be

(1) $\sqrt{2gh}$ (2) $\frac{M+m}{m}\sqrt{2gh}$ (3) $\frac{m}{M+m}\sqrt{2gh}$ (4) $\frac{M+m}{M}\sqrt{2gh}$

Sol. Answer (2)

$P_i = P_f$

$mv + 0 = mv^1 + Mv^1$

$mv = (m + M)v^1$

$$v^1 = \frac{mv}{m+M} = \sqrt{2gh}$$

$$v = \frac{(m+M)\sqrt{2gh}}{m}$$

61. A ball is allowed to fall from a height of 10 m. If there is 40% loss of energy due to impact, then after one impact ball will go up by

(1) 10 m (2) 8 m (3) 4 m (4) 6 m

Sol. Answer (4)

When ball just reaches the ground

k_1 = mg (10)

40 % of energy is lost after impact. Using mechanical energy conservation

$U_i + k_i = U_f + k_f$

$0 + (0.6)\, k_1 = mgh + 0$

(0.6) mg (10) = mgh

h = 6 m

62. A bullet weighing 10 g and moving with a velocity 300 m/s strikes a 5 kg block of ice and drop dead. The ice block is kept on smooth surface. The speed of the block after the collision is

(1) 6 cm/s (2) 60 cm/s (3) 6 m/s (4) 0.6 cm/s

Sol. Answer (2)

Using conservation of momentum

$P_i = P_f$

$$\frac{10}{1000}.(300) = \left(5 + \frac{10}{1000}\right)v$$

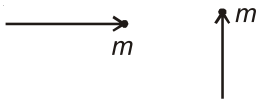
$$5 + \frac{10}{1000} \approx 5$$

So, v = 0.6 m/s Or 60 cm/s

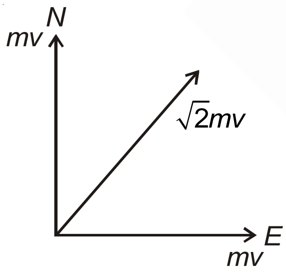
63. A particle of mass m moving eastward with a speed v collides with another particle of the same mass moving northwards with same speed v. The two particles coalesce on collision. The new particle of mass 2m will move with velocity.

(1) $\frac{v}{2}$ North-East (2) $\frac{v}{\sqrt{2}}$ South-West (3) $\frac{v}{2}$ North-West (4) $\frac{v}{\sqrt{2}}$ North-East

Sol. Answer (4)



Using momentum conservation



$$2mv^1 = \sqrt{2}mv$$

$$v^1 = \frac{v}{\sqrt{2}}$$ North-East

64. Two perfectly elastic particles A and B of equal masses travelling along the line joining them with velocity 15 m/s and 10 m/s respectively, collide. Their velocities after the elastic collision will be (in m/s), respectively

(1) 0, 25 (2) 3, 20 (3) 10, 15 (4) 20, 5

Sol. Answer (3)

Velocities will interchange as mass is same and collision is elastic

u_1 = 10 m/s , u_2 = 15 m/s

v_1 = 15 m/s , v_2 = 10 m/s

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65. Two balls of equal mass undergo head on collision while each was moving with speed 6 m/s. If the coefficient of restitution is $\frac{1}{3}$, the speed of each ball after impact will be

(1) 18 m/s (2) 2 m/s

(3) 6 m/s (4) 4 m/s

Sol. Answer (2)

$$v = \frac{u}{2}(1-e)$$

$$= \frac{6}{2}\left(1-\frac{1}{3}\right) = 2 \text{ m/s}$$

66. Select the false statement

(1) In elastic collision, kinetic energy during the collision is not conserved

(2) The coefficient of restitution for a collision between two steel balls lies between zero and one

(3) The momentum of a ball colliding elastically with the floor is conserved

(4) In an oblique elastic collision between two identical bodies with initially one of them at rest, final velocities are perpendicular

Sol. Answer (3)

67. A ball of mass M moving with speed v collides perfectly inelastically with another ball of mass m at rest. The magnitude of impulse imparted to the first ball is

(1) Mv (2) mv (3) $\frac{Mm}{M+m}v$ (4) $\frac{M^2}{M+m}v$

Sol. Answer (3)

Impulse = Change in momentum of first ball= $\frac{Mmv}{M+m}$

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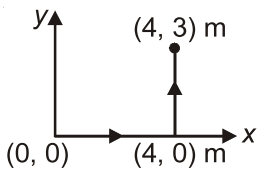
SECTION - B

Objective Type Questions

(Work)

1. A force $\vec{F} = (3\vec{i} + 4\vec{j})$N acts on a particle moving in x-y plane. Starting from origin, the particle first goes along x-axis to the point (4, 0)m and then parallel to the y-axis to the point (4, 3)m. The total work done by the force on the particle is



(1) + 12 J (2) – 6 J (3) + 24 J (4) – 12 J

Sol. Answer (3)

$\vec{F} = 3\hat{i} + 4\hat{j}$

Displacement vector $(\vec{x}) = 4\hat{i} + 3\hat{j}$

$\vec{F} \,.\, \vec{x} = (3i + 4\hat{j}).(4\hat{i} + 3\hat{j})$ = 12 + 12 = 24 J

2. A body of mass m is allowed to fall with the help of string with downward acceleration $\frac{g}{6}$ to a distance x. The work done by the string is

(1) $\frac{mgx}{6}$ (2) $-\frac{mgx}{6}$ (3) $\frac{5mgx}{6}$ (4) $-\frac{5mgx}{6}$

Sol. Answer (4)

$mg - T = \frac{mg}{6}$

$\Rightarrow T = \frac{5}{6}mg$

$W = \frac{-5}{6}mgx$

3. A particle of mass m is projected with speed u at angle θ with horizontal from ground. The work done by gravity on it during its upward motion is

(1) $\frac{-mu^2 \sin^2\theta}{2}$ (2) $\frac{mu^2 \cos^2\theta}{2}$ (3) $\frac{mu^2 \sin^2\theta}{2}$ (4) Zero

Sol. Answer (1)

Height covered by projectile $= \frac{u^2 \sin^2\theta}{2g}$

$W = -mg\left(\frac{u^2 \sin^2\theta}{2g}\right)$

$= \frac{-mu^2 \sin^2\theta}{2}$

(Kinetic Energy)

4. If net force on a system is zero then

(1) Its momentum is conserved

(2) Its kinetic energy may increase

(3) The acceleration of its a constituent particle may be non-zero

(4) All of these

Sol. Answer (4)

Due to internal forces kinetic energy or acceleration of its constituent particle may be non-zero.

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5. Internal forces acting within a system of particles can alter

(1) The linear momentum as well as the kinetic energy of the system

(2) The linear momentum of the system, but not the kinetic energy of the system

(3) The kinetic energy of the system, but not the linear momentum of the system

(4) Neither linear momentum nor kinetic energy of the system

Sol. Answer (3)

The kinetic energy of the system, but not the linear momentum of the system as

$F_{ext} = 0$. So momentum will be conserved.

(Notion of Work and Kinetic Energy : The Work-Energy Theorem)

6. A chain is on a frictionless table with one fifth of its length hanging over the edge. If the chain has length L and mass M, the work required to be done to pull the hanging part back onto the table is

(1) $\frac{MgL}{5}$ (2) $\frac{MgL}{50}$ (3) $\frac{MgL}{18}$ (4) $\frac{MgL}{10}$

Sol. Answer (2)

$\frac{1}{5}$ part is hanging, so C.M. is $\frac{L}{10}$ length below the table

$$W = \frac{m}{5}(8)\frac{L}{10} = \frac{MgL}{50}$$

7. A bullet of mass 20 g leaves a riffle at an initial speed 100 m/s and strikes a target at the same level with speed 50 m/s. The amount of work done by the resistance of air will be

(1) 100 J (2) 25 J (3) 75 J (4) 50 J

Sol. Answer (3)

$W = \Delta K$

$$W = \frac{1}{2}\frac{20}{1000}\left[(100)^2 - (50)^2\right] = (150)\left(\frac{50}{100}\right) = 75 \text{ J}$$

8. A stone with weight w is thrown vertically upward into the air from ground level with initial speed v_0. If a constant force f due to air drag acts on the stone throughout its flight. The maximum height attained by the stone is

(1) $h = \frac{v_0^2}{2g\left(1+\frac{f}{w}\right)}$ (2) $h = \frac{v_0^2}{2g\left(1-\frac{f}{w}\right)}$ (3) $h = \frac{v_0^2}{2g\left(1+\frac{w}{f}\right)}$ (4) $h = \frac{v_0^2}{2g\left(1-\frac{w}{f}\right)}$

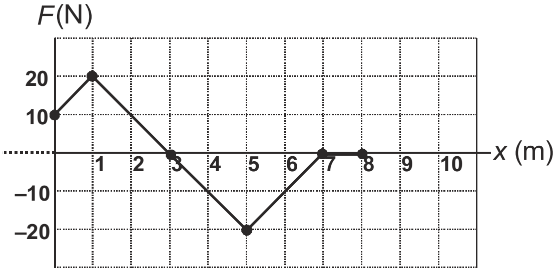
Sol. Answer (1)

Using work energy theorem, $W_f + W_g = \Delta K$

$$-f.h - Wh = 0 - \frac{1}{2}m\,v_0^2$$

$$h = \frac{v_0^2}{2g\left(1+\frac{f}{w}\right)}$$

9. Figure shows the variation of a force F acting on a particle along x-axis. If the particle begins at rest at $x = 0$, what is the particle's coordinate when it again has zero speed?



(1) $x = 3$ (2) $x = 6$ (3) $x = 5$ (4) $x = 7$

Sol. Answer (2)

Using work energy thorem

$W_F = \Delta K$

$\int F dx = \Delta K$

Given that $\Delta K = 0$

$\Rightarrow \int F dx = 0$ (Area under $F - x$ curve)

Positive area = Negative area

So at $x = 6$ Total area = 0

10. A spring of force constant K is first stretched by distance a from its natural length and then further by distance b. The work done in stretching the part b is

(1) $\frac{1}{2}Ka(a-b)$ (2) $\frac{1}{2}Ka(a+b)$ (3) $\frac{1}{2}Kb(a-b)$ (4) $\frac{1}{2}Kb(2a+b)$

Sol. Answer (4)

$$W_1 = \frac{1}{2}kx^2 = \frac{1}{2}ka^2$$

$$W_2 = \frac{1}{2}k(a+b)^2$$

$$\Delta W = W_2 - W_1 = \frac{1}{2}kb(2a+b)$$

11. A knife of mass m is at a height x from a large wooden block. The knife is allowed to fall freely, strikes the block and comes to rest after penetrating distance y. The work done by the wooden block to stop the knife is

(1) mgx (2) $-mgy$ (3) $-mg(x+y)$ (4) $mg(x-y)$

Sol. Answer (3)

$W_{all} = \Delta K$

$W_g + W_{block} = 0$

$+mg(x + y) + W_{block} = 0$

$W_{block} = -mg(x + y)$

12. A man is running on horizontal road has half the kinetic energy of a boy of half of his mass. When man speeds up by 1 m/s, then his KE becomes equal to KE of the boy, the original speed of the man is

(1) $\sqrt{2}$ m/s (2) $\left(\sqrt{2}-1\right)$ m/s (3) 2 m/s (4) $\left(\sqrt{2}+1\right)$ m/s

Sol. Answer (4)

According to problem

$K_B = 2K_m$

$$\frac{1}{2}m_B v_B^2 = 2\left(\frac{1}{2}m_m v_m^2\right)$$

$$\frac{1}{2}m_B v_B^2 = 2\left(\frac{1}{2}m_m \left(v_m+1\right)^2\right)$$

Solving

$$v_m = \sqrt{2}+1 \text{ m/s}$$

13. A particle of mass m starts moving from origin along x-axis and its velocity varies with position (x) as $v = k\sqrt{x}$. The work done by force acting on it during first "t" seconds is

(1) $\frac{mk^4t^2}{4}$ (2) $\frac{mk^2t}{2}$ (3) $\frac{mk^4t^2}{8}$ (4) $\frac{mk^2t^2}{4}$

Sol. Answer (3)

$v = k\sqrt{x}$

Square both sides

$v^2 = k^2 x$ …(1)

$v^2 = (0)^2 + 2ax$ …(2)

Compare (1) and (2)

$2a = k^2$

$$a = \frac{k^2}{2}$$

Displacement $x = \frac{1}{2}at^2$

$= \frac{1}{2}\frac{k^2}{2}t^2$

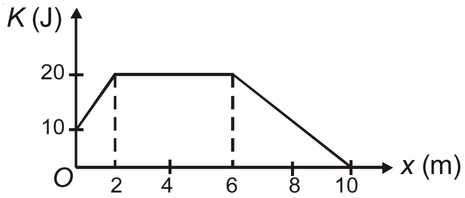
W = Fx

= ma x

$= \frac{mk^2}{2}\cdot\frac{1}{2}\frac{k^2}{2}t^2$

$= \frac{mk^4t^2}{8}$

14. The kinetic energy K of a particle moving along x-axis varies with its position (x) as shown in figure



The magnitude of force acting on particle at x = 9 m is

(1) Zero (2) 5 N (3) 20 N (4) 7.5 N

Sol. Answer (2)

Slope of K–x curve is F

$Fdx = dK$

$$F = \frac{dK}{dx}$$

at x = 9 m, Slope of the curve is 5

Hence F = 5 N

15. The rate of doing work by force acting on a particle moving along x-axis depends on position x of particle and is equal to $2x$. The velocity of particle is given by expression

(1) $\left[\frac{3x^2}{m}\right]^{1/3}$ (2) $\left[\frac{3x^2}{2m}\right]^{1/3}$ (3) $\left(\frac{2mx}{9}\right)^{1/2}$ (4) $\left[\frac{mx^2}{3}\right]^{1/2}$.

Sol. Answer (1)

$$P = \frac{F.dx}{dt}$$

$$= m\left(\frac{vdv}{dx}\right)v = 2x$$

$$m\int v^2 dv = \int 2x dx$$

$$\frac{mv^3}{3} = x^2$$

$$v = \left(\frac{3x^2}{m}\right)^{\frac{1}{3}}$$

(The Concept of Potential Energy)

16. If $F = 2x^2 - 3x - 2$, then select the correct statement

(1) $x = -\frac{1}{2}$ is the position of stable equilibrium (2) x = 2 is the position of stable equilibrium

(3) $x = -\frac{1}{2}$ is the position of unstable equilibrium (4) x = 2 is the position of neutral equilibrium

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Sol. Answer (1)

$F = 2x^2 - 3x - 2$

Putting $F = 0$

$2x^2 - 3x - 2 = 0$

$2x^2 - 4x + x - 2 = 0$

$2x(x - 2) + (x - 2) = 0$

$(x - 2)(2x + 1) = 0$

$\Rightarrow x = 2, \quad x = \frac{-1}{2}$

$\frac{d^2v}{dx^2} = \frac{-dF}{dx} = -(4x - 3)$

at $x = \frac{-1}{2}$

$\frac{d^2v}{dx^2} > 0 \quad \Rightarrow$ Stable equilibrium

17. When a conservative force does positive work on a body, then the

(1) Potential energy of body increases
(2) Potential energy of body decreases
(3) Total mechanical energy of body increases
(4) Total mechanical energy of body decreases

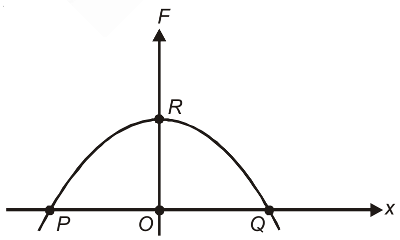
Sol. Answer (2)

$F = \frac{-dU}{dx}$

$\int dU = -\int F dr$

$\Rightarrow$ U will decrease

18. The variation of force F acting on a body moving along x-axis varies with its position (x) as shown in figure



The body is in stable equilibrium state at

(1) P
(2) Q
(3) R
(4) Both P & Q

Sol. Answer (2)

$F = \frac{-dU}{dx} \quad \Rightarrow \frac{dF}{dx} = \frac{-d^2U}{dx^2}$

If $\dfrac{dF}{dx} < 0 \quad \Rightarrow \quad \dfrac{d^2U}{dx^2} > 0$ Point of minima and stable equilibrium

at $Q \dfrac{dF}{dx} < 0$ (Slope of $F - x$ curve)

So Q is point of stable equilibrium

19. A particle located in one dimensional potential field has potential energy function $U(x) = \dfrac{a}{x^2} - \dfrac{b}{x^3}$, where a and b are positive constants. The position of equilibrium corresponds to x =

(1) $\dfrac{3a}{2b}$ (2) $\dfrac{2b}{3a}$ (3) $\dfrac{2a}{3b}$ (4) $\dfrac{3b}{2a}$

Sol. Answer (4)

$$U = \frac{a}{x^2} - \frac{b}{x^3}$$

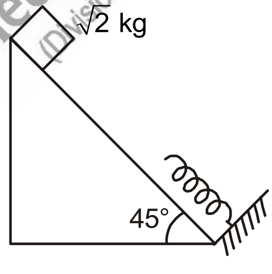
$F = \dfrac{-dU}{dx} = 0$ at equilibrium

$$\frac{dU}{dx} = \frac{-2a}{x^3} + \frac{3b}{x^4} = 0$$

$$x = \frac{3b}{2a}$$

(The Conservation of Mechanical Energy)

20. A block of mass $\sqrt{2}$ kg is released from the top of an inclined smooth surface as shown in figure. If spring constant of spring is 100 N/m and block comes to rest after compressing the spring by 1 m, then the distance travelled by block before it comes to rest is



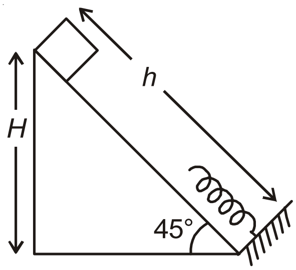
(1) 1 m (2) 1.25 m (3) 2.5 m (4) 5 m

Sol. Answer (4)

$U_i + k_i = U_f + k_f$

$(mgh \sin 45°) + 0 = \dfrac{1}{2} k(1)^2 + 0$

by solving h = 5 m



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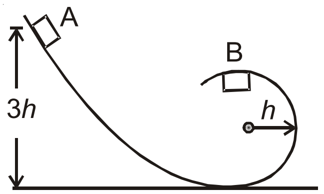
21. In the figure shown, a particle is released from the position A on a smooth track. When the particle reaches at B, then normal reaction on it by the track is



(1) mg (2) $2mg$ (3) $\frac{2}{3}mg$ (4) $\frac{m^2g}{h}$

Sol. Answer (1)

Using Mechanical energy conservation

$$mg(3h) = mg(2h) + \frac{1}{2}mv^2$$

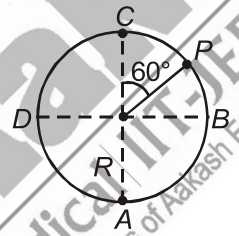
$$mgh = \frac{1}{2}mv^2$$

$$v^2 = 2gh$$

$$mg + N = \frac{mv^2}{h} = \frac{m(2gh)}{h}$$

$N = mg$

22. A particle is moving along a vertical circle of radius R. At P, what will be the velocity of particle (assume critical condition at C)?



(1) $\sqrt{gR}$ (2) $\sqrt{2gR}$ (3) $\sqrt{3gR}$ (4) $\sqrt{\frac{3}{2}gR}$

Sol. Answer (2)

At critical condition at C

$v = \sqrt{gR}$

Using mechanical energy conservation between points P and C (taking P.E. = 0 at P)

$U_i + k_i = U_f + k_f$

$$0 + \frac{1}{2}mv^2 = mgR(1 - \cos 60°) + \frac{1}{2}m\left(\sqrt{gR}\right)^2$$

$$\frac{1}{2}mv^2 = \frac{mgR}{2} + \frac{mgR}{2}$$

$v = \sqrt{2gR}$

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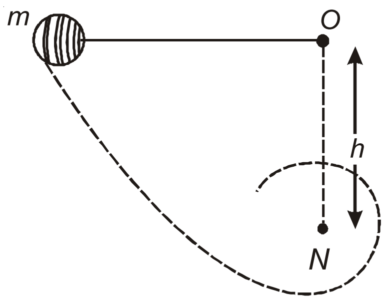
23. A particle of mass m attached to the end of string of length l is released from the horizontal position. The particle rotates in a circle about O as shown. When it is vertically below O, the string makes contact with a nail N placed directly below O at a distance h and rotates around it. For the particle to swing completely around the nail in a circle,



(1) $h < \frac{3}{5}l$ (2) $h \geq \frac{3}{5}l$ (3) $h < \frac{2}{5}l$ (4) $h \geq \frac{2}{5}l$

Sol. Answer (2)

Using mechanical energy conservation

$$mgl = \frac{1}{2}m\left(\sqrt{5g(l-h)}\right)^2$$

$$gl = \frac{5g(l-h)}{2}$$

$2gl = 5gl - 5gh$

$$h = \frac{3l}{5}$$

24. The PE of a 2 kg particle, free to move along x-axis is given by $V(x) = \left(\frac{x^3}{3} - \frac{x^2}{2}\right)\text{J}$. The total mechanical energy of the particle is 4 J. Maximum speed (in ms^{-1}) is

(1) $\frac{1}{\sqrt{2}}$ (2) $\sqrt{2}$ (3) $\frac{3}{\sqrt{2}}$ (4) $\frac{5}{\sqrt{6}}$

Sol. Answer (4)

$$U(x) = \frac{x^3}{3} - \frac{x^2}{2} \qquad \ldots(1)$$

$$F = \frac{-dU}{dx} = \frac{3x^2}{3} - \frac{2x}{2} = 0$$

$x^2 - x = 0$

$\Rightarrow x = 1, 0$

Potential energy is minimum at x = 1 m and the value of this minimum P.E. will be

U = $\frac{-1}{6}J$ (Putting x = 1 in (1))

Now, $E = U + K$

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Kinetic energy will be maximum, when potential energy will be minimum

$$4 = \frac{-1}{6} + K$$

$$K = \frac{25}{6}$$

$$\frac{1}{2}mv_m^2 = \frac{25}{6}$$

$$v_m = \frac{5}{\sqrt{6}}$$

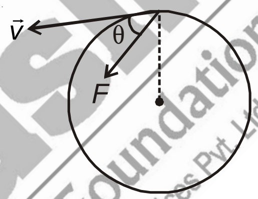
(Power)

25. A particle is moving in *a* circular path of radius *r* under the action of a force *F*. If at an instant velocity of particle is *v*, and speed of particle is increasing, then

(1) $\vec{F}.\vec{v} = 0$ (2) $\vec{F}.\vec{v} > 0$ (3) $\vec{F}.\vec{v} < 0$ (4) $\vec{F}.\vec{v} \geq 0$

Sol. Answer (2)

Net force will be in the direction of net acceleration.



Here accelerations are of two types

(i) Centripetal (ii) Tangential

$\theta < 90°$ always

$\Rightarrow \vec{F}.\vec{v} > 0$

26. The force required to row a boat at constant velocity is proportional to square of its speed. If a speed of *v* km/h requires 4 kW, how much power does a speed of 2*v* km/h require?

(1) 8 kW (2) 16 kW (3) 24 kW (4) 32 kW

Sol. Answer (4)

$F \propto v^2$

$P = F.v$, So $P \propto v^3$

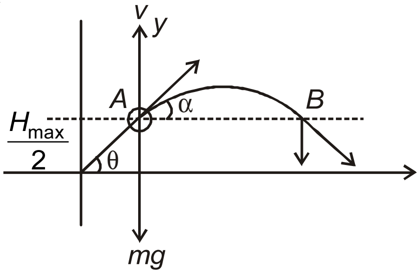
$$\frac{P_1}{P_2} = \frac{4}{P_2} = \frac{v^3}{8v^3}$$

$\Rightarrow P_2 = 32$ kW

27. A body of mass *m* is projected from ground with speed *u* at an angle θ with horizontal. The power delivered by gravity to it at half of maximum height from ground is

(1) $\frac{mgu\cos\theta}{\sqrt{2}}$ (2) $\frac{mgu\sin\theta}{\sqrt{2}}$ (3) $\frac{mgu\cos(90+\theta)}{\sqrt{2}}$ (4) Both (2) & (3)

Sol. Answer (4)



$$H_{max} = \frac{u^2 \sin^2\theta}{2g}$$

$$v_y^2 = (u\sin\theta)^2 - \frac{2gu^2\sin^2\theta}{4g}$$

$$v_y = \frac{u\sin\theta}{\sqrt{2}}$$

At point A, $\vec{P} = \vec{F}.\vec{V} = (mg)\left(\frac{u\sin\theta}{\sqrt{2}}\right)\cos\pi = \frac{-mgu\sin\theta}{\sqrt{2}}$

At point *B*, $\vec{P} = \frac{+umg\sin\theta}{\sqrt{2}}$

28. A particle of mass *m* moves in a circular path of radius *r*, under the action of force which delivers it constant power *p* and increases its speed. The angular acceleration of particle at time (*t*) is proportional

(1) $\frac{1}{\sqrt{t}}$ (2) $\sqrt{t}$

(3) t^0 (4) $t^{3/2}$

Sol. Answer (1)

Work = *Pt*

Using $W = \Delta K$

$$Pt = \frac{1}{2}m(rw)^2$$

$$Pt = \frac{1}{2}mr^2w^2$$

$$Pt = \frac{1}{2}mr^2\alpha^2t^2 \qquad \left(\because \alpha = \frac{w}{t}\right)$$

So $\alpha^2 \propto \frac{1}{t} \Rightarrow \alpha \propto \frac{1}{\sqrt{t}}$

(Collision)

29. A shell at rest on *a* smooth horizontal surface explodes into two fragments of masses m_1 and m_2. If just after explosion m_1 move with speed u, then work done by internal forces during explosion is

(1) $\frac{1}{2}(m_1+m_2)\frac{m_2}{m_1}u^2$ (2) $\frac{1}{2}(m_1+m_2)u^2$ (3) $\frac{1}{2}m_1u^2\left(1+\frac{m_1}{m_2}\right)$ (4) $\frac{1}{2}(m_2-m_1)u^2$

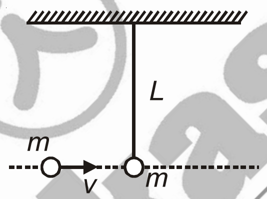
Sol. Answer (3)

Using momentum conservation, $m_1u = m_2v$

Now using work energy theorem, $W=\frac{P_1^2}{2m_1}+\frac{P_2^2}{2m_2}$

$$W=\frac{m_1^2u^2}{2}\left(\frac{m_1+m_2}{m_1m_2}\right)$$

30. A small ball of mass m moving with speed v ($<\sqrt{2gL}$) undergoes an elastic head on collision with a stationary bob of identical mass of a simple pendulum of length L. The maximum height h, from the equilibrium position, to which the bob rises after collision is



(1) $\frac{v^2}{2g}$ (2) $\frac{v^2}{4g}$ (3) $\frac{v^2}{8g}$ (4) $\frac{3v^2}{8g}$

Sol. Answer (1)

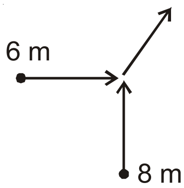
$$\frac{1}{2}mv^2 = mgh \Rightarrow h=\frac{v^2}{2g}$$

31. Two balls of masses m each are moving at right angle to each other with velocities 6 m/s and 8 m/s respectively. If collision between them is perfectly inelastic, the velocity of combined mass is

(1) 15 m/s (2) 10 m/s (3) 5 m/s (4) 2.5 m/s

Sol. Answer (3)

Using momentum conservation



$$m\sqrt{6^2+8^2} = 2mv^1$$

v^1 = 5 m/s

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32. A sphere of mass m moving with a constant velocity u hits another stationary sphere of the same mass. If e is the coefficient of restitution, then ratio of velocities of the two spheres after collision will be

(1) $\frac{1-e}{1+e}$ (2) $\frac{2+e}{2-e}$ (3) $\left(\frac{1+e}{1-e}\right)^2$ (4) $\left(\frac{1-e}{1+e}\right)^2$

Sol. Answer (1)

$$v_1 = \frac{u}{2}(1+e)$$

$$v_2 = \frac{u}{2}(1-e)$$

$$\frac{v_2}{v_1} = \frac{1-e}{1+e}$$

33. A neutron travelling with a velocity collides elastically, head on, with a nucleus of an atom of mass number A at rest. The fraction of total energy retained by neutron is

(1) $\left(\frac{A-1}{A+1}\right)^2$ (2) $\left(\frac{A+1}{A-1}\right)^2$ (3) $\left(\frac{A-1}{A}\right)^2$ (4) $\left(\frac{A+1}{A}\right)^2$

Sol. Answer (1)

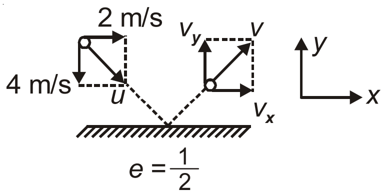
$$v_1 = \left(\frac{m_1 - m_2}{m_1 + m_2}\right)u = v\left(\frac{A-1}{A+1}\right)$$

Initial energy = $\frac{1}{2}(1)v^2$

Final energy = $\frac{1}{2}(1)v_1^2 = \frac{1}{2}(1)\left(\frac{A-1}{A+1}\right)^2$

Fraction of total energy retained = $\frac{\textit{Final energy}}{\textit{Initial energy}}$

34. In the figure shown, a small ball hits obliquely a smooth and horizontal surface with speed u whose x and y components are indicated. If the coefficient of restitution is $\frac{1}{2}$, then its x and y components v_x and v_y just after collision are respectively



(1) 4 m/s, 1 m/s (2) 2 m/s, 1 m/s (3) 2 m/s, 2 m/s (4) 4 m/s, 2 m/s

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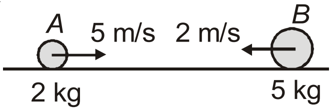
Sol. Answer (3)

$v_y = eu_y = \frac{1}{2} \times 4 = 2$ m/s

$v_x = u_x = 2$ m/s

35. Velocity of the ball A after collision with the ball B as shown in the figure is (Assume perfectly inelastic and head-on collision)



(1) $\frac{3}{7}$ m/s (2) $\frac{5}{7}$ m/s (3) $\frac{1}{7}$ m/s (4) Zero

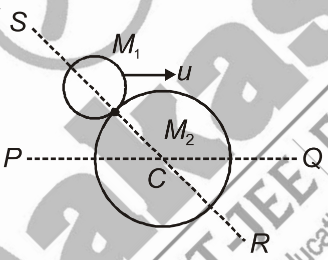
Sol. Answer (4)

Using momentum conservation

$10 - 10 = 2 mv^1$

$\Rightarrow v^1 = 0$

36. An object of mass M_1 moving horizontally with speed u collides elastically with another object of mass M_2 at rest. Select correct statement.



(1) The momentum of system is conserved only in direction PQ

(2) Momentum of M_1 is conserved in direction perpendicular to SR

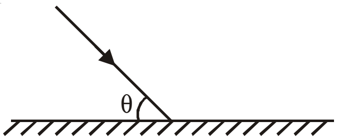
(3) Momentum of M_2 will change in direction normal to CR

(4) All of these

Sol. Answer (2)

Momentum $(\vec{P})$ of mass M_1 is conserved in direction $\perp$ to SR

37. A ball of mass m moving with speed u collides with a smooth horizontal surface at angle θ with it as shown in figure. The magnitude of impulse imparted to surface by ball is [Coefficient of restitution of collision is e]



(1) $mu(1 + e)\cos\theta$ (2) $mu(1 - e)\sin\theta$ (3) $mu(1 - e)\cos\theta$ (4) $mu(1 + e)\sin\theta$

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Sol. Answer (4)

$$u_y = -u\sin\theta\hat{j}$$

$$\vec{v}_y = +eu\sin\theta\hat{j}$$

$$\vec{I} = m\left(\vec{v}_y - \vec{u}_y\right)$$

$= mu(e+1)\sin\theta$

38. A body of mass m falls from height h on ground. If e be the coefficient of restitution of collision between the body and ground, then the distance travelled by body before it comes to rest is

(1) $h\left\{\dfrac{1+e^2}{1-e^2}\right\}$ (2) $h\left\{\dfrac{1-e^2}{1+e^2}\right\}$ (3) $\dfrac{2eh}{1+e^2}$ (4) $\dfrac{2eh}{1-e^2}$

Sol. Answer (1)

$S = h + 2e^2h + 2e^4h + ...$

$S = h + 2h\,[e^2 + e^4 + e^6 + ...]$

$$S = h + 2h\left[\frac{e^2}{1-e^2}\right]$$

Solving

$$S = \frac{h\left(1+e^2\right)}{\left(1-e^2\right)}$$

39. A bullet of mass m moving with velocity v strikes a suspended wooden block of mass M. If the block rises to height h, then the initial velocity v of the bullet must have been

(1) $\sqrt{2gh}$ (2) $\dfrac{M+m}{m}\sqrt{2gh}$ (3) $\dfrac{m}{M+m}\sqrt{2gh}$ (4) $\dfrac{M+m}{M}\sqrt{2gh}$

Sol. Answer (2)

Using momentum conservation

$mu + 0 = (M + m)\,v^1$

$$v^1 = \frac{mu}{M+m}$$

Now block reaches to height h, using energy conservation.

$$v^1 = \sqrt{2gh}$$

So in (1) $u = \dfrac{M+m}{m}\sqrt{2gh}$

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SECTION - C

Previous Years Questions

1. Consider a drop of rain water having mass 1 g falling from a height of 1 km. It hits the ground with a speed of 50 m/s. Take g constant with a value 10 m/s^2. The work done by the (i) gravitational force and the (ii) resistive force of air is **[NEET-2017]**

(1) (i) – 10 J (ii) –8.25 J

(2) (i) 1.25 J (ii) –8.25 J

(3) (i) 100 J (ii) 8.75 J

(4) (i) 10 J (ii) –8.75 J

Sol. Answer (4)

$w_g + w_a = K_f - K_i$

$mgh + w_a = \frac{1}{2}mv^2 - 0$

$10^{-3} \times 10 \times 10^3 + w_a = \frac{1}{2} \times 10^{-3} \times (50)^2$

$w_a = -8.75$ J i.e. work done due to air resistance and work done due to gravity = 10 J

2. A spring of force constant k is cut into lengths of ratio 1 : 2 : 3. They are connected in series and the new force constant is k'. Then they are connected in parallel and force constant is k''. Then $k' : k''$ is **[NEET-2017]**

(1) 1 : 6
(2) 1 : 9
(3) 1 : 11
(4) 1 : 14

Sol. Answer (3)

Spring constant $\propto \frac{1}{\text{length}}$

$k \propto \frac{1}{l}$

i.e, $k_1 = 6k$

$k_2 = 3k$

$k_3 = 2k$

In series, $\frac{1}{k'} = \frac{1}{6k} + \frac{1}{3k} + \frac{1}{2k}$

$\frac{1}{k'} = \frac{6}{6k}$

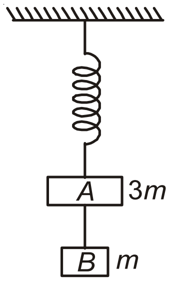
$k' = k$

$k'' = 6k + 3k + 2k$

$k'' = 11k$

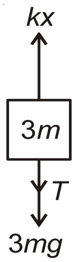
$\frac{k'}{k''} = \frac{1}{11}$ i.e $k' : k'' = 1 : 11$

3. Two blocks *A* and *B* of masses 3*m* and *m* respectively are connected by a massless and inextensible string. The whole system is suspended by a massless spring as shown in figure. The magnitudes of acceleration of *A* and *B* immediately after the string is cut, are respectively **[NEET-2017]**



(1) $g, \frac{g}{3}$ (2) $\frac{g}{3}, g$ (3) g, g (4) $\frac{g}{3}, \frac{g}{3}$

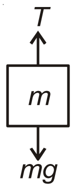
Sol. Answer (2)



Before the string is cut

$kx = T + 3mg$ ...(1)

$T = mg$ ...(2)



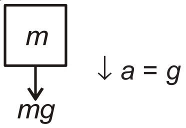
$\Rightarrow kx = 4mg$

After the string is cut, $T = 0$

$$a = \frac{kx - 3mg}{3m}$$

$$a = \frac{4mg - 3mg}{3m}$$

$$a = \frac{g}{3} \uparrow$$



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4. A particle moves from a point $(-2\hat{i} + 5\hat{j})$ to $(4\hat{j} + 3\hat{k})$ when a force of $(4\hat{i} + 3\hat{j})$ N is applied. How much work has been done by the force? **[NEET (Phase-2) 2016]**

(1) 8 J (2) 11 J (3) 5 J (4) 2 J

Sol. Answer (3)

$\vec{s} = \vec{r}_2 - \vec{r}_1 = (4\hat{j} + 3\hat{k}) - (-2\hat{i} + 5\hat{j}) = 2\hat{i} - \hat{j} + 3\hat{k}$

$\vec{F} = 4\hat{i} + 3\hat{j}$

$W = \vec{F} \cdot \vec{s} = 8 - 3 = 5$ J

5. A bullet of mass 10 g moving horizontally with a velocity of 400 ms^{-1} strikes a wood block of mass 2 kg which is suspended by light inextensible string of length 5 m. As a result, the centre of gravity of the block found to rise a vertical distance of 10 cm. The speed of the bullet after it emerges out horizontally from the block will be **[NEET (Phase-2) 2016]**

(1) 100 ms^{-1} (2) 80 ms^{-1}

(3) 120 ms^{-1} (4) 160 ms^{-1}

Sol. Answer (3)

Apply conservation of linear momentum.

CM rises through height h, so its velocity after collision = $\sqrt{2gh}$

$0.01\times 400 = 2\times\sqrt{2gh} + 0.01\times v \Rightarrow v$ = 120 m/s

6. Two identical balls A and B having velocities of 0.5 m/s and –0.3 m/s respectively collide elastically in one dimension. The velocities of B and A after the collision respectively will be **[NEET (Phase-2) 2016]**

(1) –0.5 m/s and 0.3 m/s (2) 0.5 m/s and –0.3 m/s

(3) –0.3 m/s and 0.5 m/s (4) 0.3 m/s and 0.5 m/s

Sol. Answer (2)

They will exchange their velocity, so v_B = 0.5 m/s and v_A = –0.3 m/s

7. What is the minimum velocity with which a body of mass m must enter a vertical loop of radius R so that it can complete the loop? **[NEET-2016]**

(1) $\sqrt{5gR}$ (2) $\sqrt{gR}$ (3) $\sqrt{2gR}$ (4) $\sqrt{3gR}$

Sol. Answer (1)

$v_{\min} = \sqrt{5\,gR}$

8. A body of mass 1 kg begins to move under the action of a time dependent force $F = (2t\hat{i} + 3t^2\hat{j})\text{N}$, where $\hat{i}$ and $\hat{j}$ are unit vectors along x and y axis. What power will be developed by the force at the time t?

[NEET-2016]

(1) $(2t^3 + 3t^5)$ W (2) $(2t^2 + 3t^2)$ W

(3) $(2t^2 + 4t^4)$ W (4) $(2t^3 + 3t^4)$ W

Sol. Answer (1)

$\vec{F} = \left(2t\hat{i} + 3t^2\hat{j}\right), \vec{a} = 2t\hat{i} + 3t^2\hat{j}$

$v = \int_0^t a\,dt = t^2\hat{i} + t^3\hat{j}$

$P = \vec{F}\cdot\vec{v} = 2t\cdot t^2 + 3t^2\cdot t^3 = 2t^3 + 3t^5$

9. If vectors $\vec{A} = \cos\omega t\,\hat{i} + \sin\omega t\,\hat{j}$ and $\vec{B} = \cos\frac{\omega t}{2}\hat{i} + \sin\frac{\omega t}{2}\hat{j}$ are functions of time, then the value of t at which they are orthogonal to each other is **[Re-AIPMT-2015]**

(1) $t = 0$ (2) $t = \frac{\pi}{4\omega}$ (3) $t = \frac{\pi}{2\omega}$ (4) $t = \frac{\pi}{\omega}$

Sol. Answer (4)

$$\vec{A} = \cos\omega t\,\hat{i} + \sin\omega t\,\hat{j}$$

$$\vec{B} = \cos\frac{\omega t}{2}\hat{i} + \sin\frac{\omega t}{2}\hat{j}$$

For $\vec{A}$ and $\vec{B}$ orthogonal, $\vec{A}.\vec{B} = 0$

$$(\cos\omega t\,\hat{i} + \sin\omega t\,\hat{j}).\left(\cos\frac{\omega t}{2}\hat{i} + \sin\frac{\omega t}{2}\hat{j}\right) = 0$$

$$\cos\omega t.\cos\frac{\omega t}{2} + \sin\omega t.\sin\frac{\omega t}{2} = 0$$

$$\cos\left(\omega t - \frac{\omega t}{2}\right) = 0$$

$$\cos\frac{\omega t}{2} = 0$$

$$\frac{\omega t}{2} = \frac{\pi}{2} \Rightarrow \omega t = \pi$$

$$t = \frac{\pi}{\omega}$$

10. A ball is thrown vertically downwards from a height of 20 m with an initial velocity v_0^2. It collides with the ground, loses 50 percent of its energy in collision and rebounds to the same height. The initial velocity v_0 is (Take g = 10 ms^{-2}) **[Re-AIPMT-2015]**

(1) 10 ms^{-1} (2) 14 ms^{-1} (3) 20 ms^{-1} (4) 28 ms^{-1}

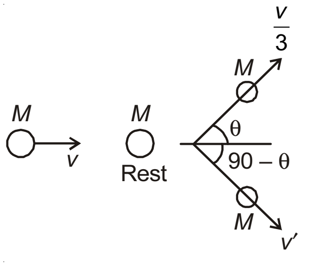
Sol. Answer (3)

$$mg(20) = \left[\frac{1}{2}mv_0^2 + mg(20)\right]\frac{50}{100} \Rightarrow v_0^2 = 400 \Rightarrow v_0 = 20\text{ m/s}$$

11. On a frictionless surface, a block of mass M moving at speed v collides elastically with another block of same mass M which is initially at rest. After collision the first block moves at an angle θ to its initial direction and has a speed $\frac{v}{3}$. The second blocks speed after the collision is **[Re-AIPMT-2015]**

(1) $\frac{\sqrt{3}}{2}v$ (2) $\frac{2\sqrt{2}}{3}v$ (3) $\frac{3}{4}v$ (4) $\frac{3}{\sqrt{2}}v$

Sol. Answer (2)



$$\frac{1}{2}Mv^2 = \frac{1}{2}M\left(\frac{v}{3}\right)^2 + \frac{1}{2}Mv'^2$$

$$v' = \frac{2\sqrt{2}}{3}v$$

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12. The heart of a man pumps 5 litres of blood through the arteries per minute at a pressure of 150 mm of mercury. If the density of mercury be 13.6×10^3 kg/m^3 and $g = 10$ m/s^2 then the power of heart in watt is **[Re-AIPMT-2015]**

(1) 1.50 (2) 1.70

(3) 2.35 (4) 3.0

Sol. Answer (2)

$$w = P\frac{dV}{dt} = (h\rho g)\frac{dV}{dt} = 0.15\text{ m} \times 13.6 \times 10^3 \times 10 \times \frac{5 \times 10^{-3}}{60}\text{ W} = 1.70\text{ W}$$

13. Two particles of masses m_1, m_2 move with initial velocities u_1 and u_2. On collision, one of the particles get excited to higher level, after absorbing energy ε. If final velocities of particles be v_1 and v_2 then we must have **[AIPMT-2015]**

(1) $\frac{1}{2}m_1^2u_1^2 + \frac{1}{2}m_2^2u_2^2 + \varepsilon = \frac{1}{2}m_1^2v_1^2 + \frac{1}{2}m_2^2v_2^2$ (2) $m_1^2u_1 + m_2^2u_2 - \varepsilon = m_1^2v_1 + m_2^2v_2$

(3) $\frac{1}{2}m_1u_1^2 + \frac{1}{2}m_2u_2^2 = \frac{1}{2}m_1v_1^2 + \frac{1}{2}m_2v_2^2 - \varepsilon$ (4) $\frac{1}{2}m_1u_1^2 + \frac{1}{2}m_2u_2^2 - \varepsilon = \frac{1}{2}m_1v_1^2 + \frac{1}{2}m_2v_2^2$

Sol. Answer (4)

14. Two similar springs P and Q have spring constants K_P and K_Q such that $K_P > K_Q$. They stretched first by the same amount (case a), then by the same force (case b). The work done by the springs W_P and W_Q are related as in case (a) and case (b), respectively **[AIPMT-2015]**

(1) $W_P < W_Q$; $W_Q < W_P$ (2) $W_P = W_Q$; $W_P > W_Q$

(3) $W_P = W_Q$; $W_P = W_Q$ (4) $W_P > W_Q$; $W_Q > W_P$

Sol. Answer (4)

15. A particle of mass m is driven by a machine that delivers a constant power k watts. If the particle starts from rest+ the force on the particle at time t is **[AIPMT-2015]**

(1) $\frac{1}{2}\sqrt{mk}\ t^{\frac{-1}{2}}$ (2) $\sqrt{\frac{mk}{2}}\ t^{\frac{-1}{2}}$ (3) $\sqrt{mk}\ t^{\frac{-1}{2}}$ (4) $\sqrt{2mk}\ t^{\frac{-1}{2}}$

Sol. Answer (2)

16. A block of mass 10 kg moving in x direction with a constant speed of 10 ms^{-1}, is subjected to a retarding force $F = 0.1x$ J/m during its travel from $x = 20$ m to 30 m. Its final KE will be **[AIPMT-2015]**

(1) 250 J (2) 475 J (3) 450 J (4) 275 J

Sol. Answer (2)

17. A body of mass ($4m$) is lying in x-y plane at rest. It suddenly explodes into three pieces. Two pieces, each of mass (m) move perpendicular to each other with equal speeds (v). The total kinetic energy generated due to explosion is **[AIPMT-2014]**

(1) mv^2 (2) $\frac{3}{2}mv^2$ (3) $2mv^2$ (4) $4mv^2$

Sol. Answer (2)

Momentum of the system will remain conserved

$$0 = mv\sqrt{2} - 2mv'$$

$$v' = \frac{v}{\sqrt{2}}$$

$$\text{Total K.E.} = \frac{1}{2}mv^2 + \frac{1}{2}mv^2 + \frac{1}{2}(2m)\left(\frac{v}{\sqrt{2}}\right)^2 = \frac{3}{2}mv^2$$

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18. A uniform force of $(3\hat{i}+\hat{j})$ newton acts on a particle of mass 2 kg. Hence the particle is displaced from position $(2\hat{i}+\hat{k})$ metre to position $(4\hat{i}+3\hat{j}-\hat{k})$ metre. The work done by the force on the particle is **[NEET-2013]**

(1) 6 J
(2) 13 J
(3) 15 J
(4) 9 J

Sol. Answer (4)

$$W=\left(3\hat{i}+\hat{j}\right).\left(2i+3\hat{j}-2\hat{k}\right) = 6 + 3 = 9\text{ J}$$

19. The potential energy of a particle in a force field is $U=\frac{A}{r^2}-\frac{B}{r}$, where A and B are positive constants and r is the distance of particle from the centre of the field. For stable equilibrium, the distance of the particle is **[AIPMT (Prelims)-2012]**

(1) $\frac{A}{B}$
(2) $\frac{B}{A}$
(3) $\frac{B}{2A}$
(4) $\frac{2A}{B}$

Sol. Answer (4)

$$U=\frac{A}{r^2}-\frac{B}{r}$$

$$F=\frac{-dU}{dr}=0$$

$$=\frac{-2A}{r^3}+\frac{B}{r^2}=0$$

$$r=\frac{2A}{B}$$

20. Two spheres A and B of masses m_1 and m_2 respectively collide. A is at rest initially and B is moving with velocity v along x-axis. After collision B has a velocity $\frac{v}{2}$ in a direction perpendicular to the original direction. The mass A moves after collision in the direction **[AIPMT (Prelims)-2012]**

(1) $\theta = \tan^{-1}\left(\frac{1}{2}\right)$ to the x-axis
(2) $\theta = \tan^{-1}\left(-\frac{1}{2}\right)$ to the y-axis
(3) Same as that of B
(4) Opposite to that of B

Sol. Answer (1)

Before collision After collision

Using momentum conservation, $m_2v\hat{i}+0=-m_2\frac{v}{2}\hat{j}+m_1\vec{v}$

$$m_1\vec{v}=m_2v\hat{i}+m_2\frac{v}{2}\hat{j}$$

$$\theta=\tan^{-1}\left(\frac{v}{2v}\right)=\tan^{-1}\left(\frac{1}{2}\right)$$

angle is from x-axis.

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21. A stone is dropped from a height h. It hits the ground with a certain momentum P. If the same stone is dropped from a height 100% more than the previous height, the momentum when it hits the ground will change by **[AIPMT (Mains)-2012]**

(1) 68% (2) 41% (3) 200% (4) 100%

Sol. Answer (2)

22. A car of mass m starts from rest and accelerates so that the instantaneous power delivered to the car has a constant magnitude P_0. The instantaneous velocity of this car is proportional to **[AIPMT (Mains)-2012]**

(1) t^2P_0 (2) $t^{1/2}$ (3) $t^{-1/2}$ (4) $\frac{1}{\sqrt{m}}$

Sol. Answer (2)

$$W = Pt = \frac{1}{2}mv^2$$

$$v^2 \propto t \Rightarrow v \propto t^{\frac{1}{2}}$$

23. The potential energy of a system increases if work is done **[AIPMT (Prelims)-2011]**

(1) Upon the system by a conservative force

(2) Upon the system by a nonconservative force

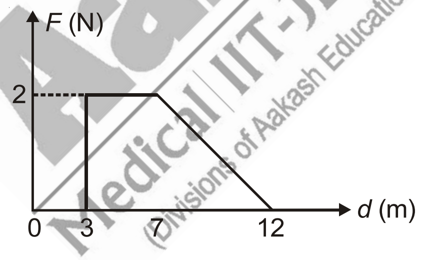
(3) By the system against a conservative force

(4) By the system against a non conservative force

Sol. Answer (3)

$dU = -\int \vec{F}_c.dx$, where $\vec{F}_c$ is conservative force.

24. Force F on a particle moving in a straight line varies with distance d as shown in the figure. The work done on the particle during its displacement of 12 m is **[AIPMT (Prelims)-2011]**



(1) 13 J (2) 18 J (3) 21 J (4) 26 J

Sol. Answer (1)

Work done will be area under F-x curve, $W = \frac{1}{2}\times 5(2) + 4\times 2$ = 13 J

25. A body projected vertically form the earth reaches a height equal to earth's radius before returning to the earth. The power exerted by the gravitational force is greatest **[AIPMT (Prelims)-2011]**

(1) At the instant just after the body is projected

(2) At the highest position of the body

(3) At the instant just before the body hits the earth

(4) It remains constant all through

Sol. Answer (3)

At the instant of projection velocity will be maximum and will be same just before the body hits the earth. But initially power will be negative, whereas the time of hitting it will be positive.

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26. An engine pumps water through a hose pipe. Water passes through the pipe and leaves it with a velocity of 2 m/s. The mass per unit length of water in the pipe is 100 kg/m. What is the power of the engine?

[AIPMT (Prelims)-2010]

(1) 800 W (2) 400 W

(3) 200 W (4) 100 W

Sol. Answer (1)

$$P = FV = v^2 \frac{dm}{dt} = (2)^2 (100 \times 2) = 800 \text{ W}$$

27. A particle of mass M starting from rest undergoes uniform acceleration. If the speed acquired in time T is V, the power delivered to the particle is **[AIPMT (Mains)-2010]**

(1) $\frac{MV^2}{T}$ (2) $\frac{1}{2}\frac{MV^2}{T^2}$ (3) $\frac{MV^2}{T^2}$ (4) $\frac{1}{2}\frac{MV^2}{T}$

Sol. Answer (4)

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

$$\frac{W}{T} = \frac{1}{2}\frac{mv^2}{T}$$

$$P = \frac{mv^2}{2T}$$

28. An engine pumps water continuously through a hose. Water leaves the hose with a velocity v and m is the mass per unit length of the water jet. What is the rate at which kinetic energy is imparted water?

[AIPMT (Prelims)-2009]

(1) mv^2 (2) $\frac{1}{2}mv^2$ (3) $\frac{1}{2}m^2v^2$ (4) mv^3

Sol. Answer (4)

$$F = \frac{dP}{dt} = \frac{vdM}{dt}$$

$$F.v = v^2\frac{dM}{dt}$$

$$= v^2\rho A\left(\frac{dx}{dt}\right) \quad (M = \rho Ax)$$

$$= v^3\rho A$$

$$= \frac{v^3\rho A(l)}{l} = mv^3 = \frac{dK}{dt} \left\{ \begin{aligned} \because \frac{dW}{dt} &= \frac{dK}{dt} \\ &= P \end{aligned} \right\} \quad (m : \text{mass per unit length})$$

29. A body of mass 1 kg is thrown upwards with a velocity 20 m/s. It momentarily comes to rest after attaining a height of 18 m. How much energy is lost due to air friction? (g = 10 m/s^2) **[AIPMT (Prelims)-2009]**

(1) 30 J (2) 40 J

(3) 10 J (4) 20 J

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Sol. Answer (4)

$W_{all} = \Delta k$

$$W_f + W_g = \frac{1}{2}(1)(20)^2$$

$W_f + mg(18) = 200$

$W_f = 200 - 180 = 20$ J

30. A block of mass M is attached to the lower end of a vertical spring. The spring is hung from a ceiling and has force constant value k. The mass is released from rest with the spring initially unstretched. The maximum extension produced in the length of the spirng will be: **[AIPMT (Prelims)-2009]**

(1) $\frac{2Mg}{k}$ (2) $\frac{4Mg}{k}$ (3) $\frac{Mg}{2k}$ (4) $\frac{Mg}{k}$

Sol. Answer (1)

31. Water falls from a height of 60 m at the rate of 15 kg/s to operate a turbine. The losses due to frictional forces are 10% of energy. How much power is generated by the turbine? (g = 10 m/s^2) **[AIPMT (Prelims)-2008]**

(1) 7.0 kW (2) 8.1 kW

(3) 10.2 kW (4) 12.3 kW

Sol. Answer (2)

Energy per unit time on the turbine = $\left(\frac{dm}{dt}\right)60(g)$ = 15(60)(10) = 9000 J/s

Losses per second = $9000 \times \frac{10}{100}$ = 900 J/s

So, net power supplied = 9000 – 900 = 8100 J/s

= 8.1 kW

32. A shell of mass 200 gm is ejected from a gun of mass 4 kg by an explosion that generates 1.05 kJ of energy. The initial velocity of the shell is **[AIPMT (Prelims)-2008]**

(1) 120 ms^{-1} (2) 100 ms^{-1}

(3) 80 ms^{-1} (4) 40 ms^{-1}

Sol. Answer (2)

Using momentum conservation

$0 = (0.2)v + 4v_1$

$$v_1 = \frac{-0.2v}{4}$$

Total energy produced = 1.05 kJ

$$\frac{1}{2}(0.2)v^2 + \frac{1}{2}(4)v_1^2 = 1050$$

$$\frac{1}{2}(0.2)v^2 + \frac{1}{2}(4)\left(\frac{0.2v}{4}\right)^2 = 1050$$

$\Rightarrow$ v =100 m/s

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33. A vertical spring with force constant K is fixed on a table. A ball of mass m at a height h above the free upper end of the spring falls vertically on the spring so that the spring is compressed by a distance d. The net work done in the process is **[AIPMT (Prelims)-2007]**

(1) $mg(h - d) + \frac{1}{2}Kd^2$ (2) $mg(h + d) + \frac{1}{2}Kd^2$ (3) $mg(h + d) - \frac{1}{2}Kd^2$ (4) $mg(h - d) - \frac{1}{2}Kd^2$

Sol. Answer (3)

$W = W_g + W_{spring}$

$= mg(h + d) - \frac{1}{2}Kd^2$

34. The potential energy of a long spring when stretched by 2 cm is U. If the spring is stretched by 8 cm the potential energy stored in it is : **[AIPMT (Prelims)-2006]**

(1) $4U$ (2) $8U$ (3) $16U$ (4) $\frac{U}{4}$

Sol. Answer (3)

$U = \frac{1}{2}K(2)^2 = 2K$

$U' = \frac{1}{2}K(8)^2 = 32K = 16U$

35. A body of mass 3 kg is under a constant force which causes a displacement s in metres in it, given by the relation $s = \frac{1}{3}t^2$, where t is in s. Workdone by the force in 2 s is **[AIPMT (Prelims)-2006]**

(1) $\frac{5}{19}$ J (2) $\frac{3}{8}$ J (3) $\frac{8}{3}$ J (4) $\frac{19}{5}$ J

Sol. Answer (3)

$S = \frac{1}{3}t^2 \qquad \Rightarrow v = \frac{2t}{3}$

$W = \frac{1}{2} \times 3\left(\frac{4}{3}\right)^2 = \frac{8}{3}$ J

36. 300 J of work is done in sliding a 2 kg block up an inclined plane of height 10 m. Taking $g = 10$ m/s^2, work done against friction is **[AIPMT (Prelims)-2006]**

(1) 200 J (2) 100 J (3) Zero (4) 1000 J

Sol. Answer (2)

$300 = w_f + 2\,(10)\,(10)$

$w_f = 100$ J

37. A bomb of mass 30 kg at rest explodes into two pieces of masses 18 kg and 12 kg. The velocity of 18 kg mass is 6 ms^{-1}. The kinetic energy of the other mass is **[AIPMT (Prelims)-2005]**

(1) 256 J (2) 486 J (3) 524 J (4) 324 J

Sol. Answer (2)

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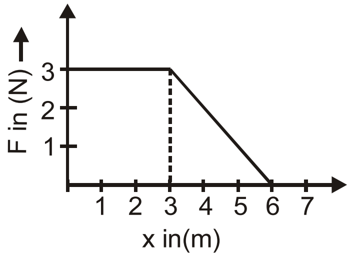
38. A force F acting on an object varies with distance x as shown here. The force is in N and x in m. The work done by the force in moving the object from x = 0 to x = 6 m is **[AIPMT (Prelims)-2005]**



(1) 4.5 J (2) 13.5 J (3) 9.0 J (4) 18.0 J

Sol. Answer (2)

Work will be area under F-x curve

So, $W = 3(3) + \frac{1}{2}(3)(3)$ = 13.5 J

39. The angle between the two vectors $\vec{A} = 3\hat{i} + 4\hat{j} + 5\hat{k}$ and $\vec{B} = 3\hat{i} + 4\hat{j} - 5\hat{k}$ will be

(1) 90° (2) 180° (3) Zero (4) 45°

Sol. Answer (1)

$cos\theta = \frac{\vec{a}.\vec{b}}{|\vec{a}||\vec{b}|}$

$\vec{A}.\vec{B} = (3\hat{i} + 4\hat{j} + 5\hat{k}).(3\hat{i} + 4\hat{j} - 5\hat{k})$ = 9 + 16 – 25 = 0

$\Rightarrow$ A and B are perpendicular

40. Vectors $\vec{A}, \vec{B}$ and $\vec{C}$ are such that $\vec{A}\cdot\vec{B}=0$ and $\vec{A}\cdot\vec{C}=0$. Then the vector parallel to $\vec{A}$ is

(1) $\vec{B}$ and $\vec{C}$ (2) $\vec{A}\times\vec{B}$ (3) $\vec{B}+\vec{C}$ (4) $\vec{B}\times\vec{C}$

Sol. Answer (4)

Given that

$\vec{A}\,.\,\vec{B} = 0,\ \vec{A}\,.\,\vec{C} = 0$

$\Rightarrow$ A is perpendicular to both $\vec{B}$ and $\vec{C}$ and $\vec{B}\times\vec{C}$ will be a vector

which is perpendicular to both $\vec{B}$ and $\vec{C}$, hence $\vec{A} \parallel \vec{B}\times\vec{C}$

41. If a unit vector is represented by $0.5\hat{i} - 0.8\hat{j} + c\hat{k}$ then the value of c is

(1) $\sqrt{0.01}$ (2) $\sqrt{0.11}$ (3) 1 (4) $\sqrt{0.39}$

Sol. Answer (2)

Magnitude of unit vector will be 1

$\sqrt{(0.5)^2 + (0.8)^2 + c^2} = 1$

0.25 + 0.64 + c^2 = 1

c^2 = 0.11

$c = \sqrt{0.11}$

42. If a vector $2\hat{i}+3\hat{j}+8\hat{k}$ is perpendicular to the vector $4\hat{j}-4\hat{i}+\alpha\hat{k}$, then the value of α is

(1) $\frac{1}{2}$ (2) $-\frac{1}{2}$ (3) 1 (4) –1

Sol. Answer (2)

$\vec{a}.\vec{b}=0$

$8-12+8\alpha=0$

$\alpha=-\frac{1}{2}$

43. The work done by an applied variable force $F = x + x^3$ from $x = 0$ m to $x = 2$ m, where x is displacement, is

(1) 6 J (2) 8 J (3) 10 J (4) 12 J

Sol. Answer (1)

$F=x+x^3$

$W=\int_0^2\left(x+x^3\right).dx$

$=\left[\frac{x^2}{2}+\frac{x^4}{4}\right]^2$

= 6 J

44. When a body moves with a constant speed along a circle

(1) No work is done on it (2) No acceleration is produced in it

(3) Its velocity remains constant (4) No force acts on it

Sol. Answer (1)

Displacement is zero, hence no work is done.

45. A position dependent force, $F = (7 - 2x + 3x^2)$ N acts on a small body of mass 2 kg and displaces it from $x = 0$ to $x = 5$ m. The work done in joules is

(1) 135 (2) 270 (3) 35 (4) 70

Sol. Answer (1)

$W=\int F.dx=\int\left(7-2x+3x^2\right).dx$

$=\left[7x-\frac{2x^2}{2}+\frac{3x^3}{3}\right]_0^5$

= 135 J

46. A body, constrained to move in y-direction, is subjected to a force given by $\vec{F}=\left(-2\hat{i}+15\hat{j}+6\hat{k}\right)$N. The work done by this force in moving the body through a distance of 10 m along positive y-axis, is

(1) 150 J (2) 20 J (3) 190 J (4) 160 J

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Sol. Answer (1)

$\vec{F} = -2\hat{i} + 15\hat{j} + 6\hat{k}$

$\vec{S} = 10\hat{j}$

$W = \vec{F}.\vec{S}$

$= \left(-2i + 15\hat{j} + 6\hat{k}\right).\left(10\hat{j}\right)$

= 150 J

47. A body moves a distance of 10 m along a straight line under the action of a 5 N force. If the work done is 25 J, then angle between the force and direction of motion of the body is

(1) 60° (2) 75° (3) 30° (4) 45°

Sol. Answer (1)

$Fs \cos\theta = 25$

$5(10) \cos\theta = 25$

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

$\theta = 60°$

48. A force acts on a 3 g 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 metres and t is in seconds. The work done during the first 4 second is

(1) 490 mJ (2) 450 mJ (3) 576 mJ (4) 528 mJ

Sol. Answer (4)

$x = 3t - 4t^2 + t^3$

$\frac{dx}{dt} = v = 3 - 8t + 3t^2$

$W = \Delta K$

$W = \frac{1}{2} \times \frac{3}{1000}\left[3 - 8(4) + 3(4)^2\right]^2 = 528 \text{ mJ}$

49. Two bodies of masses m and $4m$ are moving with equal K.E. The ratio of their linear momenta is

(1) 1 : 2 (2) 1 : 4 (3) 4 : 1 (4) 1 : 1

Sol. Answer (1)

$P = \sqrt{2mk}$

$\frac{P_1}{P_2} = \sqrt{\frac{m}{4m}} = 1:2$

50. One kilowatt hour is equal to

(1) 36×10^{-5} J (2) 36×10^{5} J (3) 36×10^{7} J (4) 36×10^{3} J

Sol. Answer (2)

1 kW hr = 36×10^{5} J

51. Two bodies with kinetic energies in the ratio of 4 : 1 are moving with equal linear momentum. The ratio of their masses is

(1) 4 : 1 (2) 1 : 1 (3) 1 : 2 (4) 1 : 4

Sol. Answer (4)

$$\frac{K_1}{K_2} = \frac{P_1^2 . 2m_2}{2m_1 . P_2^2} \qquad (P_1 = P_2 \text{ given})$$

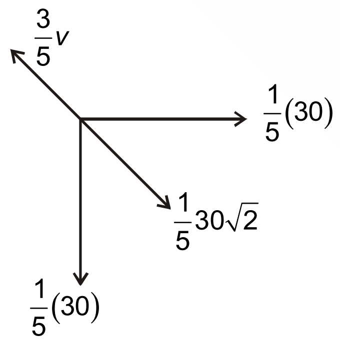
$$\Rightarrow \frac{K_1}{K_2} = \frac{m_2}{m_1} = \frac{4}{1} \quad \Rightarrow \frac{m_1}{m_2} = \frac{1}{4}$$

52. A 1 kg stationary bomb is exploded in three parts having masses in ratio 1 : 1 : 3 respectively. Parts having same mass move in perpendicular direction with velocity 30 m/s, then the velocity of bigger part will be

(1) $10\sqrt{2}$ m/s (2) $\frac{10}{\sqrt{2}}$ m/s (3) $15\sqrt{2}$ m/s (4) $\frac{15}{\sqrt{2}}$ m/s

Sol. Answer (1)

Momentum will be conserved.



$$\frac{3}{5}v = \frac{30}{5}\sqrt{2}$$

53. If kinetic energy of a body is increased by 300% then percentage change in momentum will be

(1) 100% (2) 150% (3) 265% (4) 73.2%

Sol. Answer (1)

$$k^1 = 4k = \frac{\left(P^1\right)^2}{2m}$$

$P^1 = 2P$

$\Rightarrow$ 100% increase

54. A stationary particle explodes into two particles of masses m_1 and m_2 which move in opposite directions with velocities v_1 and v_2. The ratio of their kinetic energies $\frac{E_1}{E_2}$ is

(1) $\frac{m_2}{m_1}$ (2) $\frac{m_1}{m_2}$ (3) 1 (4) $\frac{m_1 v_2}{m_2 v_1}$

Sol. Answer (1)

55. A particle of mass m_1 is moving with a velocity v_1 and another particle of mass m_2 is moving with a velocity v_2. Both of them have the same momentum but their different kinetic energies are E_1 and E_2 respectively. If $m_1 > m_2$, then

(1) $E_1 < E_2$ (2) $\frac{E_1}{E_2} = \frac{m_1}{m_2}$ (3) $E_1 > E_2$ (4) $E_1 = E_2$

Sol. Answer (1)

$E \propto \frac{1}{m}$ $m_1 > m_2 \Rightarrow E_1 < E_2$

56. A bomb of mass 30 kg at rest explodes into two pieces of masses 18 kg and 12 kg. The velocity of 18 kg mass is 6 ms^{-1}. The kinetic energy of the other mass is

(1) 324 J (2) 486 J (3) 256 J (4) 524 J

Sol. Answer (2)

Using momentum conservation

$0 = 18(6) + 12(v)$

$$v = \frac{-18(6)}{12} = -9 \text{ m/s}$$

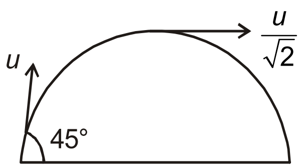
$$K.E. = \frac{1}{2}(12)(9)^2 = 486 \text{ J}$$

57. A ball whose kinetic energy is E is thrown at an angle of 45° with the horizontal. Its K.E. at the highest point of its flight will be

(1) $\frac{E}{\sqrt{2}}$ (2) Zero (3) E (4) $\frac{E}{2}$

Sol. Answer (4)

$$E = \frac{1}{2}mu^2$$



$$E^1 = \frac{1}{2}m\left(\frac{u}{\sqrt{2}}\right)^2$$

$$= \frac{E}{2}$$

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58. A body dropped from a height h with initial velocity zero, strikes the ground with a velocity 3 m/s. Another body of same mass is thrown from the same height h with an initial velocity of 4 m/s. Find the final velocity of second mass, with which it strikes the ground.

(1) 5 m/s (2) 12 m/s (3) 3 m/s (4) 4 m/s

Sol. Answer (1)

$v = \sqrt{2gh} \qquad h = \frac{v^2}{20} = \frac{9}{20}$

Now for second case

$v^2 = u^2 + 2(-g)(-h)$

$= 16 + 20 \times \frac{9}{20}$

$= 25$

$v = 5$ m/s

59. A particle with total energy E is moving in a potential energy region $U(x)$. Motion of the particle is restricted to the region when

(1) $U(x) > E$ (2) $U(x) < E$ (3) $U(x) = 0$ (4) $U(x) \leq E$

Sol. Answer (4)

Particle will be restricted to the region till when K.E. > 0

Using mechanical energy conservation

$E = k + U$

$E - U = k \geq 0$

$E \geq U$

60. The kinetic energy acquired by a mass m in travelling distance d, starting from rest, under the action of a constant force is directly proportional to

(1) m (2) m^0 (3) $\sqrt{m}$ (4) $1/\sqrt{m}$

Sol. Answer (2)

$v^2 = u^2 + 2as$

$u = 0,\ a = \frac{F}{m}$

$v^2 = \frac{2F}{m}d$

$K.E. = \frac{1}{2}mv^2 = \frac{1}{2}.m\frac{2F}{m}d = Fd$

So $K.E. \propto m^0$

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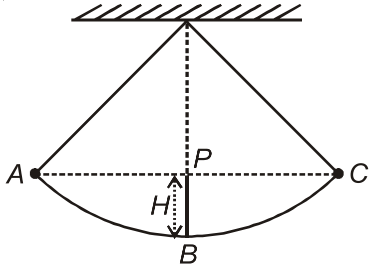
61. A simple pendulum with a bob of mass m oscillates from A to C and back to A such that PB is H. If the acceleration due to gravity is g, then the velocity of the bob as it passes through B is



(1) mgH (2) $\sqrt{2gH}$ (3) Zero (4) $2gH$

Sol. Answer (2)

Using energy conservation

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

$$v = \sqrt{2gH}$$

62. A car moving with a speed of 40 km/h can be stopped by applying brakes after at least 2 m. If the same car is moving with a speed of 80 km/h, what is the minimum stopping distance?

(1) 4 m (2) 6 m (3) 8 m (4) 2 m

Sol. Answer (3)

$v^2 = u^2 - 2as$

$0 = 1600 - 2a\ (2)$

$$a = \frac{1600}{4}\left(\frac{5}{18}\right)^2 \qquad \ldots(1)$$

Again using $v^2 = u^2 - 2as$

Using a from (1)

$S = 8\text{m}$

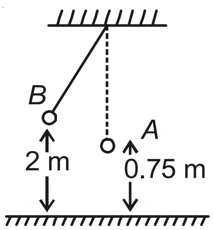
63. A child is sitting on a swing. Its minimum and maximum heights from the ground are 0.75 m and 2 m respectively, its maximum speed will be

(1) 10 m/s (2) 5 m/s

(3) 8 m/s (4) 15 m/s

Sol. Answer (2)

Using energy conservation at A and B



$U_i + k_i = U_f + k_f$

$$0 + \frac{1}{2}mv^2 = mg(2 - 0.75) + 0$$

$v^2 = 2g\ (1.25)$

$v^2 = 25 \Rightarrow v = 5$ m/s

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64. When a long spring is stretched by 2 cm, its potential energy is U. If the spring is stretched by 10 cm, the potential energy stored in it will

(1) $\frac{U}{5}$ (2) $5U$ (3) $10U$ (4) $25U$

Sol. Answer (4)

$$U = \frac{1}{2}kx^2$$

$$U = \frac{1}{2}k(4) \Rightarrow k = \frac{U}{2}$$

$$U' = \frac{1}{2}k(10)^2 = \frac{1}{2}.\frac{U}{2}.100 = 25\text{ U}$$

65. A ball of mass 2 kg and another of mass 4 kg are dropped together from a 60 feet tall building. After a fall of 30 feet each towards earth, their respective kinetic energies will be in the ratio of

(1) $\sqrt{2}:1$ (2) 1 : 4 (3) 1 : 2 (4) $1:\sqrt{2}$

Sol. Answer (3)

$$\frac{v_1}{v_2} = \frac{\sqrt{2gh}}{\sqrt{2gh}} \Rightarrow v_1 = v_2$$

$$\frac{K.E_1}{K.E_2} = \frac{\frac{1}{2}m_1v_1^2}{\frac{1}{2}m_2v_2^2} = \frac{2}{4} = \frac{1}{2}$$

66. A mass of 0.5 kg moving with a speed of 1.5 m/s on a horizontal smooth surface, collides with a nearly weightless spring of force constant k = 50 N/m. The maximum compression of the spring would be

(1) 0.15 m (2) 0.12 m (3) 1.5 m (4) 0.5 m

Sol. Answer (1)

$U_i + k_i = U_f + k_f$

$$0 + \frac{1}{2}(0.5)(1.5)^2 = \frac{1}{2}(50)x^2 + 0$$

x = 0.15 m

67. One coolie takes 1 minute to raise a suitcase through a height of 2 m but the second coolie takes 30 s to raise the same suitcase to the same height. The powers of two coolies are in the ratio

(1) 1 : 2 (2) 1 : 3 (3) 2 : 1 (4) 3 : 1

Sol. Answer (1)

$$\frac{P_1}{P_2} = \frac{\frac{W}{t_1}}{\frac{W}{t_2}} = \frac{t_2}{t_1} = \frac{1}{2}$$

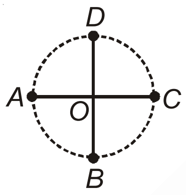
68. If a force of 9 N is acting on a body, then find instantaneous power supplied to the body when its velocity is 5 m/s in the direction of force

(1) 195 watt (2) 45 watt (3) 75 watt (4) 100 watt

Sol. Answer (2)

$P = FV = 9(5) = 45$ W

69. As shown in figure, a particle of mass *m* is performing vertical circular motion. The velocity of the particle is increased, then at which point will the string break?



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

Sol. Answer (2)

Tension will be maximum at *B*

So increasing velocity increases centripetal force and tension.

70. The bob of simple pendulum having length *l*, is displaced from mean position to an angular position θ with respect to vertical. If it is released, then velocity of bob at equilibrium position

(1) $\sqrt{2gl(1-\cos\theta)}$ (2) $\sqrt{2gl(1+\cos\theta)}$

(3) $\sqrt{2gl\cos\theta}$ (4) $\sqrt{2gl}$

Sol. Answer (1)

Using energy conservation

$$mgl(1-\cos\theta) = \frac{1}{2}mv^2$$

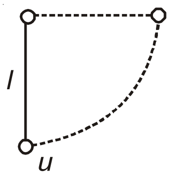
$$v = \sqrt{2gl(1-\cos\theta)}$$

71. A stone is tied to a string of length '*l*' and is whirled in a vertical circle with the other end of the string as 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 velocity as it reaches a position where the string is horizontal (*g* being acceleration due to gravity) is

(1) $\sqrt{2(u^2-gl)}$ (2) $\sqrt{u^2-gl}$ (3) $u-\sqrt{u^2-2gl}$ (4) $\sqrt{2gl}$

Sol. Answer (1)

Using conservation of energy



$U_i + k_i + U_f + k_f$

$$0+\frac{1}{2}mu^2 = mgl + \frac{1}{2}mv'^2$$

$$\sqrt{u^2-2gl} = v'$$

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Change in velocity (Δv) = $v'\hat{j} - u\hat{i}$

$$|\Delta v| = \sqrt{v'^2 + u^2}$$

$$= \sqrt{u^2 - 2gl + u^2}$$

$$= \sqrt{2(u^2 - gl)}$$

72. The potential energy between two atoms, in a molecule, is given by $U(x) = \frac{a}{x^{12}} - \frac{b}{x^6}$; where a and b are positive constants and x is the distance between the atoms. The atom is in stable equilibrium, when

(1) $x = \left(\frac{2a}{b}\right)^{1/6}$ (2) $x = \left(\frac{11a}{5b}\right)^{1/6}$ (3) $x = 0$ (4) $x = \left(\frac{a}{2b}\right)^{1/6}$

Sol. Answer (1)

$$U = \frac{a}{x^{12}} - \frac{b}{x^6}$$

$$F = \frac{-dU}{dx} = 0$$

$$\frac{-12a}{x^{13}} + \frac{6b}{x^7} = 0$$

$$x = \left(\frac{2a}{b}\right)^{\frac{1}{6}}$$

73. The coefficient of restitution, e, for a perfectly elastic collision is

(1) 0 (2) –1 (3) 1 (4) ∞

Sol. Answer (3)

e = 1

74. A particle of mass m_1 moves with velocity v_1 and collides with another particle at rest of equal mass. The velocity of the second particle after the elastic collision is

(1) $2v_1$ (2) v_1 (3) $-v_1$ (4) 0

Sol. Answer (2)

Velocity will be interchanged as mass of colliding particles is same.

75. Two identical balls A and B collide head-on elastically. If velocities of A and B, before the collision, are +0.5 m/s and –0.3 m/s respectively then their velocities, after the collision, are respectively

(1) – 0.5 m/s and + 0.3 m/s (2) + 0.5 m/s and + 0.3 m/s

(3) + 0.3 m/s and – 0.5 m/s (4) – 0.3 m/s and + 0.5 m/s

Sol. Answer (4)

Velocities will be exchanged

u_1 = 0.5 m/s u_2 = –0.3 m/s

v_1 = –0.3 m/s v_2 = 0.5 m/s

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76. A moving body of mass m and velocity 3 km/h collides with a rest body of mass $2m$ and sticks to it. Now the combined mass starts to move. What will be the combined velocity?

(1) 3 km/h (2) 4 km/h

(3) 1 km/h (4) 2 km/h

Sol. Answer (3)

Using momentum conservation

$m(3) + 0 = 3\text{ mv}$

$v = 1$ km/h

77. A rubber ball is dropped from a height of 5 m on a plane, where the acceleration due to gravity is not known. On bouncing, it rises to 1.8 m. The ball loses its velocity on bouncing by a factor of

(1) $\frac{3}{5}$ (2) $\frac{2}{5}$ (3) $\frac{16}{25}$ (4) $\frac{9}{25}$

Sol. Answer (2)

$h_2 = e^2 h_1$

$1.8 = e^2 (5)$

$$e^2 = \frac{18}{50} = \frac{9}{25} \Rightarrow e = \frac{3}{5}$$

$$v = eu = \frac{3}{5}u$$

$$\text{Velocity lost} = u - v = u - \frac{3u}{5} = \frac{2u}{5}$$

$$\text{Lost by a factor } \frac{\frac{2u}{5}}{u} = \frac{2}{5}$$

78. A ball moving with velocity 2 m/s collides head on with another stationary ball of double the mass. If the coefficient of restitution is 0.5 then their velocities (in m/s) after collision will be

(1) 0, 2 (2) 0, 1

(3) 1, 1 (4) 1, 0.5

Sol. Answer (2)

Using momentum conservation

$2m = mv_1 + 2mv_2$

and $e = \frac{v_2 - v_1}{2}$

Solving (1) and (2)

$v_1 = 0,\quad v_2 = 1$

79. A metal ball of mass 2 kg moving with speed of 36 km/h has a head on collision with a stationary ball of mass 3 kg. If after collision, both the balls move together, then the loss in K.E. due to collision is

(1) 100 J (2) 140 J (3) 40 J (4) 60 J

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Sol. Answer (4)

$$\Delta K = \frac{1}{2}\frac{m_1 m_2}{m_1 + m_2}(u_1 - u_2)^2$$

$$= \frac{1}{2}\frac{(2)(3)}{(2+3)}(10)^2$$

= 60 J

80. Two springs A and B having spring constant K_A and K_B ($K_A = 2K_B$) are stretched by applying force of equal magnitude. If energy stored in spring A is E_A then energy stored in B will be

(1) $2E_A$

(2) $\frac{E_A}{4}$

(3) $\frac{E_A}{2}$

(4) $4E_A$

Sol. Answer (1)

$K_A = 2K_B$

$$x_A = \frac{F}{K_A} \quad , \quad x_B = \frac{F}{K_B}$$

$$v_A = \frac{1}{2}K_A \frac{F^2}{K_A^2}$$

$$v_B = \frac{1}{2}K_B \frac{F^2}{K_B^2} = \frac{F^2}{K_A}$$

$\Rightarrow U_B = 2U_A$

SECTION - D

Assertion-Reason Type Questions

1. A : The work done by a force during round trip is always zero.

   R : The average value of force in round trip is zero.

Sol. Answer (4)

2. A : The change in kinetic energy of a particle is equal to the work done on it by the net force.

   R : The work-energy theorem can be used only in conservative field.

Sol. Answer (3)

3. A : Internal forces can change the kinetic energy but not the momentum of the system.

   R : The net internal force on a system is always zero.

Sol. Answer (1)

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4. A : The potential energy can be defined only in conservative field.

   R : The value of potential energy depends on the reference level (level of zero potential energy).

Sol. Answer (2)

5. A : When a body moves in a circle the work done by the centripetal force is always zero.

   R : Centripetal force is perpendicular to displacement at every instant.

Sol. Answer (1)

6. A : If net force acting on a system is zero, then work done on the system may be nonzero.

   R : Internal forces acting on a system can increase its kinetic energy.

Sol. Answer (1)

7. A : During collision between two objects, the momentum of colliding objects is conserved only in direction perpendicular to line of impact.

   R : The force on colliding objects in direction perpendicular to line of impact is zero.

Sol. Answer (1)

8. A : The potential energy of a system increases when work is done by conservative force.

   R : Kinetic energy can change into potential energy and vice-versa.

Sol. Answer (2)

9. A : In inelastic collision, a part of kinetic energy convert into heat energy, sound energy and light energy etc.

   R : The force of interaction in an inelastic collision is non-conservative in nature.

Sol. Answer (1)

10. A : Energy dissipated against friction depends on the path followed.

    R : Friction force is non-conservative force.

Sol. Answer (1)

11. A : Work done by the frictional force can't be positive.

    R : Frictional force is a conservative force.

Sol. Answer (4)

12. A : Impulse generated on one body by another body in a perfectly elastic collision is not zero.

    R : In a perfectly elastic collision, momentum of the system is always conserved and not the momentum of the individual bodies.

Sol. Answer (1)

13. A : Power of the gravitational force on the body in a projectile motion is zero, once during its motion.

    R : At the highest point only, the component of velocity along the gravitational force is zero.

Sol. Answer (1)

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14. A : Power delivered by the tension in the wire to a body in vertical circle is always zero.

    R : Tension in the wire is equal to the centripetal force acting on the body doing vertical circular motion.

Sol. Answer (3)

15. A : When a man is walking on a rough road, the work done by frictional force is zero.

    R : Frictional force acts in the direction of the motion of the man in this case.

Sol. Answer (2)

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