

# Work , Energy and Power

## Self-Assessment

### Module 1 Work and Power

**Q.6.1.1** A cyclist, while in motion, applies brakes and comes to rest over a distance of 10 m. Assuming that the average force exerted by the road on the cycle to be 500 N, The work done (i) by the road on the cycle and (ii) by the cycle on the road are respectively equal to

- (A) -5000 J and + 5000 J
- (B) +5000 J and - 5000 J
- (C) -5000 J and zero
- (D) zero and -5000 J

**Q.6.1.2** A body of mass 2 kg is initially at rest, and it moves under the action of an applied horizontal force of 18 N on a horizontal table. The coefficient of kinetic friction between the body and the table is 0.1. Taking  $g = 10 \text{ m/s}^2$ , the work done by the applied force and the force of friction on the body, in 10 s are respectively equal to

- (A) 7200 J and -800 J
- (B) -7200 J and +800J
- (C) 8100 J and -900J
- (D) -8100 J and +900J

**Q.6.1.3** A variable force  $\vec{F}(t)$ , acts on an object of mass  $m$ , initially at rest. The instantaneous power, associated with the force, varies as  $t^{\frac{3}{2}}$ .

$|\vec{F}(t)|$  i.e., the dependence of  $|\vec{F}|$ , on time, can be expressed as

- (A)  $|\vec{F}(t)| = (\text{a constant}) (t^{\frac{1}{2}})$
- (B)  $|\vec{F}(t)| = (\text{a constant}) (t^{\frac{1}{4}})$
- (C)  $|\vec{F}(t)| = (\text{a constant}) (t^{\frac{3}{2}})$
- (D)  $|\vec{F}(t)| = (\text{a constant})(- t^{\frac{3}{4}})$

**Q.6.1.4** A particle is moved from point P (1, 2, 3) to point Q (3, 4, 5) by the application of a constant force  $\vec{F}$  given by  $\vec{F} = (-2\hat{i} + 3\hat{j} + 4\hat{k})$  newton. The work done by the force on the particle is

- (A) 4 J
- (B) 6 J
- (C) 8 J
- (D) 10 J

**Q.6.1.5** An object of mass  $m$  is raised from the surface of the earth to a height  $H$ . If the height  $H$  is comparable to the radius  $R$  of the earth, the work done, against the force of gravity, is

- (A)  $m \frac{GM}{R^2} H$
- (B)  $m \frac{GMH}{R^2} \left(1 + \frac{H}{R}\right)^{-2}$
- (C)  $m \frac{GMH}{R^2} \left(1 + \frac{H}{R}\right)^{-1}$
- (D)  $m \frac{GMH}{R^2} \left(1 + \frac{H}{R}\right)$

**Q.6.1.6** An object of mass 100 kg is raised from the surface of the earth (assume to be a sphere of radius  $\approx 6400$  km) to a point at a height of 3200 km above the surface. Taking  $g = 10\text{m/s}^2$ , the work done by the gravitational force in raising this object is

- (A)  $3.2 \times 10^9 \text{ J}$
- (B)  $-3.2 \times 10^9 \text{ J}$
- (C)  $-2.13 \times 10^9 \text{ J}$
- (D)  $2.13 \times 10^9 \text{ J}$

**Q.6.1.7** A body is moving in a particular direction under the influence of a source of constant power supplying energy. If it starts from rest from its origin, then which of the following represents the correct variation of displacement as a function of time for its motion?

- (A)  $s \propto t$
- (B)  $s \propto t^{3/2}$
- (C)  $s = \text{a constant}$
- (D)  $s \propto t^{2/3}$

**Q.6.1.8** A body of mass 0.5 kg travels in a straight line with velocity  $v = ax^{3/2}$  where  $a = 5 \text{ m}^{-1/2} \text{ s}^{-1}$  and  $x$  is the displacement of the body. The work done by the net force, during its displacement from  $x = 0$  to  $x = 2 \text{ m}$ , is

- (A) 1.5 J
- (B) 50 J
- (C) 10 J
- (D) 100 J

**Q.6.1.9** An object of mass  $m$  initially at rest, falls from a height  $H$  ( $H \ll R$ ,  $R = \text{radius of the earth}$ ), under the influence of the gravitational force of the earth and the opposing resistive force due to earth's atmosphere.

Assuming this resistive force to be directly proportional to the instantaneous speed ( $v$ ) of the particle ( $F_{\text{resistive}} = kv$ ), the work done by the net force, on the object, when it reaches the surface of the earth, is [Hint: As a first approximation we may take velocity  $v \approx \sqrt{2gx}$ ]

- (A)  $mgH - \frac{2}{3}\sqrt{2gk^2H^3}$
- (B)  $mgH - \frac{2}{3}\sqrt{gk^2H^3}$
- (C)  $mgH - \frac{3}{2}\sqrt{gk^2H^3}$
- (D)  $mgH + \frac{2}{3}\sqrt{2gk^2H^3}$

**Q.6.1.10** An object of mass  $m$ , initially at rest at the origin, is acted upon by a variable force  $\vec{F}(t)$ , where  $\vec{F}(t) = kti^{\wedge}$

The instantaneous displacement  $\vec{x}(t)$ , of the object, and the instantaneous power  $P(t)$ , associated with the force  $\vec{F}(t)$ , would then be given, respectively, by

- (A)  $\left(\frac{k}{2m}t^2\right)i^{\wedge}$  and  $\frac{k^2}{2m}t^3$
- (B)  $\left(\frac{k}{2m}t^2\right)i^{\wedge}$  and  $\frac{k^2}{4m}t^3$
- (C)  $\left(\frac{k}{m} \frac{t^3}{6}\right)i^{\wedge}$  and  $\frac{k^2}{2m}t^3$

(D)  $\left(\frac{k}{m} \frac{t^3}{6}\right)^{\wedge} i$  and  $\frac{k^2}{4m} t^3$

## Module 2 Work Energy Theorem

**Q.6.2.1** A ball of mass  $m$  when pushed down from the point P, with a speed  $v$ , just manages to reach the top end Q of the smooth hemispherical bowl of radius  $R$  (Fig.Q.6.2.1)

. The velocity  $v$  is equal to

- (A)  $\sqrt{2g(R)}$
- (B)  $\sqrt{2g(R - h)}$
- (C)  $\sqrt{2g(R + h)}$
- (D)  $\sqrt{2gh}$

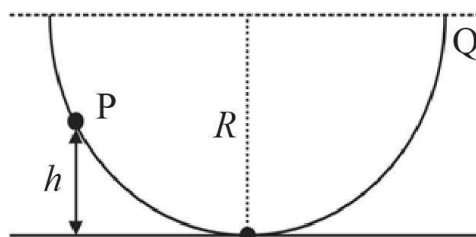
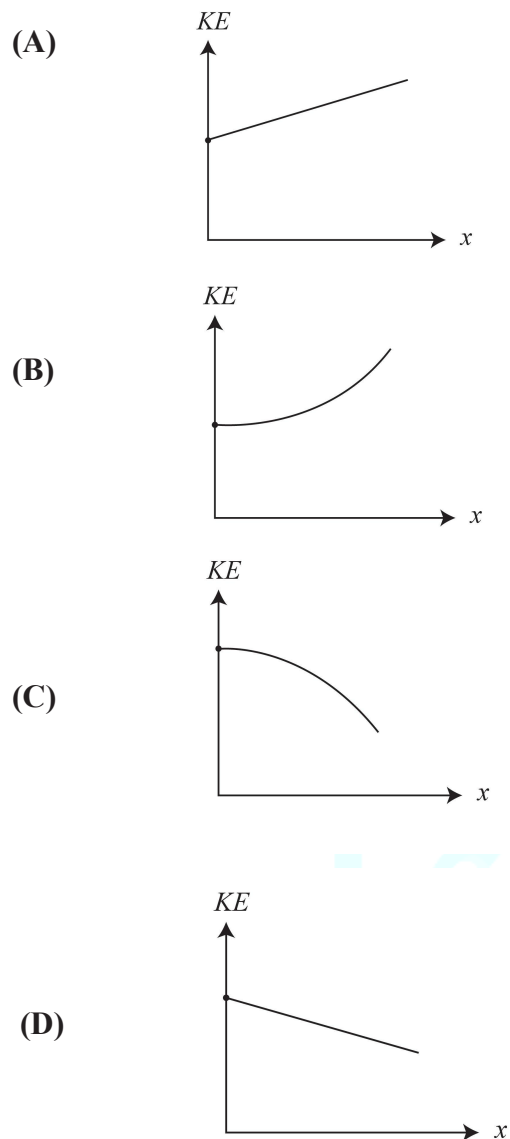


Fig.Q.6.2.1

**Q.6.2.2** An arrow of mass  $m$  is shot from a bow, whose string exerts an average force  $F$  on the arrow over a length  $l$ . The speed of arrow as it leaves the bow is

- (A)  $\left(\frac{Fl}{m}\right)^{\frac{1}{2}}$
- (B)  $\left(\frac{2Fl}{m}\right)^{\frac{1}{2}}$
- (C)  $\left(\frac{Fl}{2m}\right)^{\frac{1}{2}}$
- (D)  $2\left(\frac{Fl}{m}\right)^{\frac{1}{2}}$

**Q.6.2.3** A particle is sliding down an inclined plane having a uniform dynamic friction, from a height  $h$ . The variation in Kinetic Energy with  $x$  which is the distance through which the particle moves is given by which one among the following?



**Q.6.2.4** A body of mass 2 kg initially at rest moves under the action of an applied horizontal force of 7 N on a table. The coefficient of kinetic friction between the body and the table is 0.1.

Using  $g = 10 \text{ ms}^{-2}$ , the

(i) work done by the applied force in 10 s,

(ii) work done by the force of friction in 10 s,  
(iii) work done by the net force on the body in 10 s,  
(iv) change in kinetic energy of the body in 10 s,  
are respectively equal to

- (A) 875 J, -250 J, 625 J, 625 J
- (B) -875 J, +250 J, -625 J, 625 J
- (C) 1225 J, -350 J, 875 J, 875 J
- (D) -1225 J, +350 J, -875 J, 875 J

**Q.6.2.5** When a cloud mass at a height of 5 km above the ground condenses, it inundated an area of  $10^5 \text{ m}^2$  with ankle deep (10 cm) water. If  $g = 10 \text{ ms}^{-2}$ , and density of water is  $1 \text{ gcm}^{-3}$ , the loss of potential energy (in joules) of the cloud mass is  $5 \times 10^n$  where  $n$  is equal to

- (A) 8
- (B) 9
- (C) 10
- (D) 11

**Q.6.2.6** A rain drop of radius 2 mm falls from a height of 500 m above the ground. Due to the viscous resistance of the air, it falls with decreasing acceleration and soon attains a uniform terminal speed. It reaches the ground with a speed of  $10 \text{ ms}^{-1}$ .

Taking  $g = 9.8 \text{ ms}^{-2}$ , the work done by the gravitational and the resistive forces on the drop, are respectively (nearly) equal to

- (A)  $-0.1642 \text{ J}$  and  $+0.0017 \text{ J}$
- (B)  $+0.1642 \text{ J}$  and  $-0.1625 \text{ J}$
- (C)  $+0.1642 \text{ J}$  and  $-0.0017 \text{ J}$
- (D)  $-0.1642 \text{ J}$  and  $+0.1625 \text{ J}$

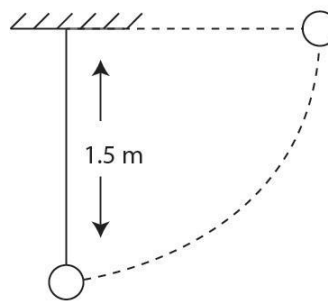
**Q.6.2.7** A particle starts with a non-zero initial velocity and moves along a straight line with uniform acceleration. The plot of the variation of its kinetic energy ( $KE$ ) with time will have an intercept on the  $KE$ -axis and will be

- (A) a straight line inclined at an acute angle with the time axis
- (B) a straight line inclined at an obtuse angle with the time axis
- (C) a parabola with positive slope at its point of intersection with the KE axis
- (D) a parabola with zero slope at the point of intersection with the KE axis

**Q.6.2.8** A simple pendulum, having a length of 1.5 m, has its bob pulled to a horizontal position (Fig.Q.6.2.2). 5% of the total energy of the bomb dissipates as it comes down to its lowest position.

Taking  $g = 9.8 \text{ ms}^{-2}$ , the speed of the bob when it (first) comes back at its lowest position would be (nearly)

- (A)  $5.42 \text{ ms}^{-1}$
- (B)  $5.28 \text{ ms}^{-1}$
- (C)  $5.15 \text{ ms}^{-1}$
- (D)  $5.08 \text{ ms}^{-1}$



**Fig.Q.6.2.2**

**Q.6.2.9** The electron, in a hydrogen atom, is orbiting around the nucleus in a circular orbit of radius  $r$  with a speed  $v$ . The needed centripetal force  $\left(\frac{mv^2}{r}\right)$  is provided by the attractive coulomb force  $(= k \cdot \frac{e \cdot e}{r^2})$  between the electron and the proton of the hydrogen nucleus.

If the radius of the electron orbit were to decrease to  $r/2$ , the kinetic energy of the electron would

- (A) increase by an amount of  $(ke^2/r)$
- (B) increase by an amount of  $(ke^2/2r)$
- (C) decrease by an amount of  $(ke^2/r)$
- (D) decrease by an amount of  $(ke^2/2r)$

**Q.6.2.10** It is well known that a raindrop (assumed to be at rest, to start with) falls under the influence of the downward gravitational force and the opposing resistive force. The latter is known to be proportional to the speed of the drop but is otherwise undetermined. Consider a drop of mass 1.00 g falling from a height of 1.00 km. It hits the ground with a speed of  $50.0 \text{ ms}^{-1}$ . Taking  $g = 10 \text{ m/s}^2$  work done by the gravitational force and

the work done by the unknown resistive force are respectively equal to

- (A)  $-10.0 \text{ J}$  and  $+8.75 \text{ J}$
- (B)  $+10.0 \text{ J}$  and  $-8.75 \text{ J}$
- (C)  $+10.0 \text{ J}$  and  $-1.25 \text{ J}$
- (D)  $-10.0 \text{ J}$  and  $+1.25 \text{ J}$

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### Module 3 Potential Energy and Energy of spring

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**Q.6.3.1** A construction worker has to supply bricks to his partner at a height of 3 m vertically above him. He throws them up so that they reach his partner with a velocity of  $2 \text{ ms}^{-1}$ . What percentage of his work could be saved if he threw them away so that they might just reach his partner? (Take  $g = 10 \text{ ms}^{-2}$ )

- (A) 5
- (B) 6.25
- (C) 7.5
- (D) 8

**Q.6.3.2** Two springs, (1) and (2), have spring constant  $k_1$  and  $k_2$ , respectively, with  $k_1 < k_2$ . The springs are stretched

- (a) by applying equal force on them and
- (b) so that their lengths increase by the same amount.

Let the work done on the two springs, in cases (a) and (b), be  $(W_{1a}$  and  $W_{2a})$  and  $(W_{1b}$  and  $W_{2b})$ , respectively. We would then have

- (A)  $(W_{1a} > W_{2a})$  and  $(W_{1b} = W_{2b})$
- (B)  $(W_{1a} = W_{2a})$  and  $(W_{1b} < W_{2b})$
- (C)  $(W_{1a} < W_{2a})$  and  $(W_{1b} > W_{2b})$
- (D)  $(W_{1a} > W_{2a})$  and  $(W_{1b} < W_{2b})$

**Q.6.3.3** Imagine a mass  $m$  to be moved from the centre of the earth to a point on the surface of the earth. The work done (by some external agency) against the gravitational pull of the earth, would then be equal to ( $g$  = acceleration due to gravity on the surface of the earth)

- (A)  $mgR$
- (B)  $mgR/2$
- (C)  $mgR/3$
- (D)  $mgR/4$

**Q.6.3.4** Let a conservative (inverse square) force do positive work on a particle while displacing it towards the source of this force. If the instantaneous distance, between the origin of the source of this force and the particle is  $r$ , we say that the potential energy of the particle

- (A) decreases with a decrease in  $r$ , and it is taken as zero as  $r \rightarrow 0$ .
- (B) decreases with a decrease in  $r$ , and it is taken as zero as  $r \rightarrow \infty$ .
- (C) increases with a decrease in  $r$ , and it is taken as zero as  $r \rightarrow 0$ .
- (D) increases with a decrease in  $r$ , and it is taken as zero as  $r \rightarrow \infty$ .

**Q.6.3.5** A given spring, when compressed by an amount  $x_0$ , can cause an object of mass  $m$ , kept on it, to get 'thrown up' through a maximum vertical height  $H$ . The spring constant,  $k$ , of this spring, equals

- (A)  $\frac{mgh}{x_0^2}$
- (B)  $\frac{mgh}{2x_0^2}$
- (C)  $\frac{2mgh}{3x_0^2}$
- (D)  $\frac{2mgh}{x_0^2}$

**Q.6.3.6** Four springs (1, 2, 3, and 4) are made from the same material but

- (i) Springs (1) and (2) have the same diameter but different lengths, say  $l_1$  and  $l_2$ , with  $l_1 > l_2$ .
- (ii) Springs (3) and (4) have the same length but different diameters, say  $d_1$  and  $d_2$ , with  $d_1 > d_2$ .

The potential energies, stored in the four springs, when they are stretched by equal amounts (say  $x$  each) are  $U_1$ ,  $U_2$ ,  $U_3$  and  $U_4$  respectively. We would then have

- (A)  $U_1 < U_2$  and  $U_3 < U_4$
- (B)  $U_1 > U_2$  and  $U_3 > U_4$
- (C)  $U_1 < U_2$  and  $U_3 > U_4$
- (D)  $U_1 > U_2$  and  $U_3 < U_4$

**Q.6.3.7** A Particle is moving along the  $x$ -axis under the action of a variable force  $F(x)$ . The PE associated with the particle, is then expressed by the function  $U(x)$ . if  $F(x)$  is conservative then which among the following is/are possible?

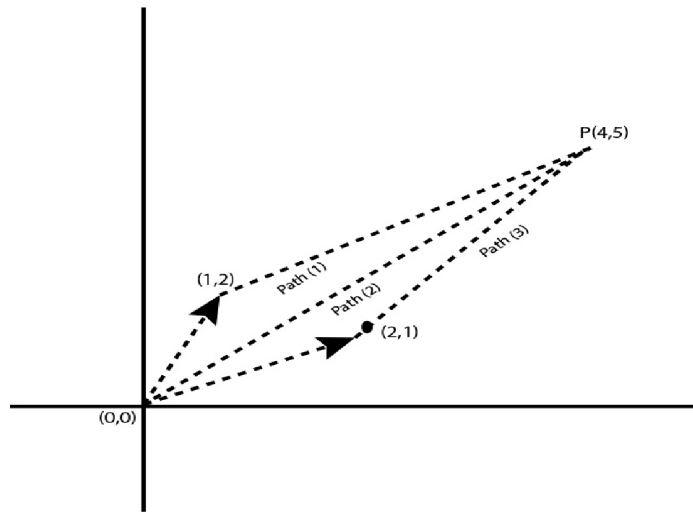
I .  $F(x) = - \frac{du}{dx}$

II .  $F(x) = - \frac{du}{dx}$

- (A) Only I
- (B) Only II
- (C) Both I and II
- (D) Neither I , nor II

**Q.6.3.8** A given charged particle, having a charge  $q$ , is moved from the origin, to the point  $P(4, 5)$ , via three different paths (1), (2), (3), as shown, in the  $XY$  plane (Fig.Q.6.3.2). Let there be a uniform electric field  $\vec{E}$ , in the  $XY$  plane given by  $\vec{E} = C_1 \hat{i} + C_2 \hat{j}$ , where  $(C_1, C_2)$  are constants having the same dimensions as that of the electric field.

Let the work done, on the charged particles, by the electric field in the three cases, be  $W_1$ ,  $W_2$  and  $W_3$  respectively. A direct calculation of  $W_1$ ,  $W_2$ ,  $W_3$  would then show that



**Fig.Q.6.3.2**

- (A)  $W_1 \neq W_2 = W_3$ ; the force is non-conservative
- (B)  $W_2 \neq W_3 = W_1$ ; force is non-conservative
- (C)  $W_3 \neq W_1 = W_2$ ; force is non-conservative
- (D)  $W_1 = W_2 = W_3$ ; force is conservative

**Q.6.3.9** It is known that comets move around the Sun in elliptical orbits of very high eccentricity. In general, the instantaneous gravitational force, on the comet, due to the Sun is not normal to its instantaneous velocity.

The net work done, by the gravitational force of the Sun, on the comet, over one complete orbit, of the comet, would then be

- (A) A non-zero positive work; dependent on the eccentricity of the orbit
- (B) A non-zero negative work; dependent on the eccentricity of the orbit
- (C) Zero only if the elliptical orbit approaches a circular shape.
- (D) Zero; irrespective of the eccentricity of the orbit.

**Q.6.3.10** Ernst Rutherford, in his nuclear model of the hydrogen atom, assumed that the electron orbits around

the nucleus in a circular orbit of radius  $r$ , the required centripetal force being provided by the electric force of attraction between the electron and the nucleus.

This motion of the electron around the nucleus is, therefore, an accelerated motion and as per the electromagnetic theory, the electron must continuously radiate energy as it orbits around the nucleus. This continuous loss of energy would then cause the electron to continuously move

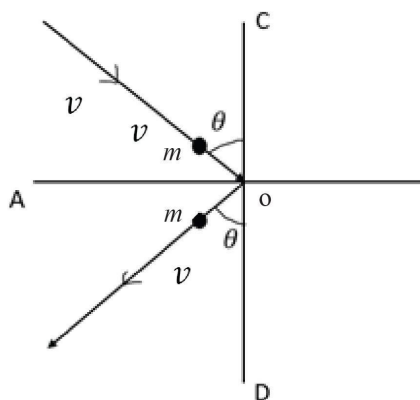
- (A) away from the nucleus with a continuous decrease in its kinetic energy.
- (B) towards the nucleus with a continuous decrease in its kinetic energy
- (C) towards the nucleus with a continuous increase in its kinetic energy.
- (D) away from the nucleus with a continuous increase in its kinetic energy.

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## Module 4 : Elastic and Inelastic Collision

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**Q.6.4.1** A gas molecule of mass  $m$  moving with velocity  $v$  undergoes an elastic collision with the wall of the container as shown schematically in Fig.Q.6.4.1. If the time of impact of collision is  $\tau$ . Then the force exerted by the molecule on the wall is given by

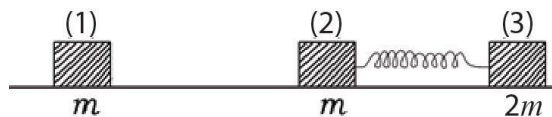


**Fig.Q.6.4.1**

- (A)  $2mv \sin \theta / \tau$  along OA
- (B)  $2mv \cos \theta / \tau$  along OA
- (C)  $2mv \sin \theta / \tau$  along AO

- (D)  $2mv \cos \theta / \tau$  along AO

**Q.6.4.2** Three objects of masses  $m$ ,  $m$  and  $2m$  are kept on a smooth horizontal floor (Fig. Q.6.4.2). The spring constant of the spring, connected between objects (2) and (3) is  $k$ .



**Fig.Q.6.4.2**

The object (1), is set moving with a velocity  $v_0$  and undergoes an elastic collision with object (2) at time  $t = 0$ .

At some instant ( $t = t_0$ , say), after the collision, the spring is compressed by an amount  $x_0$  and the instantaneous velocities of objects (2) and (3), are equal to each other.

The relation, between  $k$ ,  $v_0$  and  $x_0$ , is

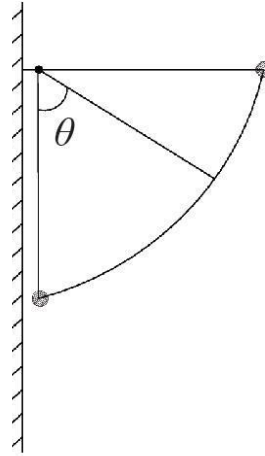
- (A)  $k = \frac{mv_0^2}{x_0^2}$
- (B)  $k = \frac{1}{2} \frac{mv_0^2}{x_0^2}$
- (C)  $k = \frac{2}{3} \frac{mv_0^2}{x_0^2}$
- (D)  $k = \frac{3}{4} \frac{mv_0^2}{x_0^2}$

**Q.6.4.3** A bob of mass  $M$  is suspended from a wall, on a small peg, using an ideal string of length  $L$ . The bob is pulled up to a horizontal position and 'let-go'. It hits the wall, rebounds, rises up and again comes back to hit the wall (Fig.Q.6.4.3). The coefficient of restitution for the bob-wall collision equals  $\frac{2}{\sqrt{5}}$ .

It is given that  $\log \sqrt{5} = 0.35$  and  $\log 2 = 0.3$ . Then after nearly how many collisions will the angular amplitude ( $\theta$ ) of the bob be  $60^\circ$ ?

- (A) 2
- (B) 3

- (C) 4  
(D) 5



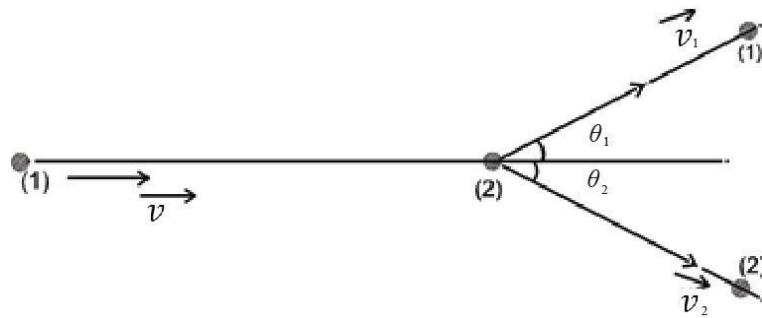
**Fig.Q.6.4.3**

**Q.6.4.4** A ball initially at rest, is dropped (at  $t = 0$ ) from a height  $H$  onto a floor. If the coefficient of restitution between the ball and the floor is  $e$ , the time instant, at which the ball would be just making its second impact on the floor, would be

- (A)  $\sqrt{\frac{2H}{g}}(1 + 2e)$   
 (B)  $\sqrt{\frac{2H}{g}}(1 - 2e)$   
 (C)  $\sqrt{\frac{2H}{g}}(1 - e)$   
 (D)  $\sqrt{\frac{2H}{g}}(1 + e)$

**Q.6.4.5** Two balls, of equal masses ( $m$  each), are kept on a smooth table (Fig.Q.6.4.4). One of these balls is given a velocity  $\vec{v}$  and made an elastic collision with the other ball which is at rest. The two balls move along directions inclined at angles  $\theta_1$  and  $\theta_2$  to the initial direction of  $\vec{v}$  is as shown in the figure. If  $\theta_1 = \frac{\pi}{6}$ , then  $\theta_2$  is equal to

- (A)  $\frac{\pi}{12}$
- (B)  $\frac{\pi}{4}$
- (C)  $\frac{\pi}{3}$
- (D)  $\frac{5\pi}{12}$



**Fig.Q.6.4.4**

**Q.6.4.6** A ball falls from a height of 200 cm onto a rough floor and rises back after impact to a height of 162 cm. The coefficient of restitution between the ball and the floor, and the height to which the ball rises after the second impact, are respectively (nearly) equal to

- (A) 0.9 and 131 cm
- (B) 0.81 and 131 cm
- (C) 0.81 and 106 cm
- (D) 0.9 and 106 cm

**Q.6.4.7** A ball initially at rest is dropped vertically from a height of  $H$  onto a floor. If the coefficient of restitution between the ball and the floor equals  $e$ . The height to which the ball would rise after its third impact, would be

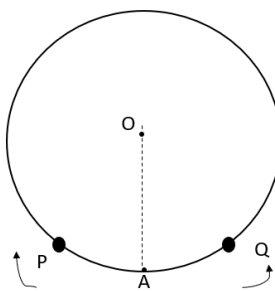
- (A)  $e^3 H$

- (B)  $e^6 H$
- (C)  $e^2 H$
- (D)  $e^4 H$

**Q.6.4.8** In the game of cricket, a player hits a ball of mass 0.16 kg horizontally square of the wicket, which means perpendicular to the direction of the ball which was also traveling horizontally at the time of impact with the bat. The ball was traveling at a speed of 144 km/h when it was hit and the speed acquired by the ball was 270 km/h immediately after the impact. If the change in momentum (in kg m/s) and its direction are  $\Delta p$  and  $\theta$  respectively, then their values are:

- (A) 13.6 kg m/s, at an angle of  $(\frac{\pi}{2} + \tan^{-1} \frac{8}{15})$  with the original direction of the ball.
- (B) 13.6 kg m/s, at an angle of  $(\tan^{-1} \frac{8}{15})$  with original direction of ball
- (C) 5.6 kg m/s, at an angle of  $(\tan^{-1} \frac{8}{15})$  with original direction of ball
- (D) 5.6 kg m/s, at an angle of  $(\frac{\pi}{2} + \tan^{-1} \frac{8}{15})$  with original direction of ball

**Q.6.4.9** Two particles P and Q, each of mass  $m$  start simultaneously from point A on a frictionless circular track and move in opposite directions with velocities having their magnitudes in the ratio of 3:2 (Fig.Q.6.4.5). If the two particles collide at a point such that particle P comes to rest instantaneously, then what will be the component of change in momentum of particle Q along OA.



**Fig.Q.6.4.5**

- (A)  $5 mu \cos 54^\circ$
- (B)  $mu \sin 54^\circ$
- (C)  $mu \sin 36^\circ$

(D)  $\sqrt{13} mu \cos 36^\circ$

**Q.6.4.10** A bullet of mass  $m$  moving with a velocity  $u$  strikes a greater mass  $M$  at rest and gets embedded into it. The composite mass starts moving with a velocity  $v$ . There will be a decrease in kinetic energy, and the difference can be expressed as being equivalent to the  $KE$  of a mass  $m_0$  moving with a velocity  $w$ , where

- (A)  $m_0 < m$  &  $w = v$
- (B)  $m_0 > M$  &  $v < w < u$
- (C)  $m_0 < m$  &  $w = u$
- (D)  $m < m_0 < M$  &  $w = v$



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