

CBSE Test Paper 01
Chapter 6 Work Energy & Power

1. A 0.800-kg ball is tied to the end of a string 1.60 m long and swung in a vertical circle. Calculate the total work done on the ball by (i) the tension in the string and (ii) gravity for motion along the semicircle from the lowest to the highest point on the path. **1**
 - a. 0, -281 J
 - b. 0, -251 J
 - c. 0, -2.51 J
 - d. 0, -25.1 J
2. A bullet of mass 0.012 kg and horizontal speed 70 m s^{-1} strikes a block of wood of mass 0.4 kg and instantly comes to rest with respect to the block. The block is suspended from the ceiling by means of thin wires. Calculate the height to which the block rises. Also, estimate the amount of heat produced in the block. **1**
 - a. 72.2 cm, 28.5 J
 - b. 21.2 cm, 28.5 J
 - c. 29.2 cm, 29.5 J
 - d. 23.2 cm, 38.5 J
3. A rain drop of mass 2.00 g falls from a height 1.00 km. It hits the ground with a speed of 50.0 m/s. What is the work done by the resistive forces if any? (Take $g = 10 \text{ m s}^{-2}$) **1**
 - a. - 27.5 J
 - b. - 22.5 J
 - c. - 19.5 J
 - d. - 17.5 J
4. A 0.800-kg ball is tied to the end of a string 1.60 m long and swung in a vertical circle. (a) During one complete circle, starting anywhere, calculate the total work done on the ball by (i) the tension in the string and (ii) gravity **1**
 - a. 25 J, -25 J
 - b. 10 J, 10 J
 - c. 30 J, 30 J
 - d. 0, 0 J
5. A block having a mass of 0.80 kg is given an initial velocity 1.2 m/s to the right and

collides with a spring of negligible mass and force constant $k = 50 \text{ N/m}$. Assuming the surface to be frictionless, calculate the maximum compression of the spring after the collision. **1**

- a. 0.15 m
- b. 0.20 m
- c. 0.10 m
- d. 0.25 m

- 6. Does the amount of work done depend upon the fact that how fast is a load raised or moved in the direction of force? **1**
- 7. Write the characteristics of displacement? **1**
- 8. Is a collision between two particles possible even without any physical contact between them? **1**
- 9. What is the work done by the centripetal force? Explain. **2**
- 10. If one mole of a monatomic gas is mixed with 3 moles of a diatomic gas. What is the molecular specific heat of the mixture at constant volume? **2**
- 11. If the volume of block of metal changes by 0.12% when it is heated through 200°C . What is the co-efficient of linear expansion of the metal? **2**
- 12. Prove that in an elastic collision in one dimension the relative velocity of approach before impact is equal to the relative velocity of separation after impact. **3**
- 13. State work-kinetic energy theorem and prove it analytically. **3**
- 14. The nucleus Fe^{57} emits a γ -ray of energy 14.4 keV. If the mass of the nucleus is 56.935 amu, calculate the recoil energy of the nucleus. [Take, $1 \text{ amu} = 1.66 \times 10^{-27} \text{ kg}$] **3**
- 15. Prove that when a particle suffers an oblique elastic collision with another particle of equal mass and initially at rest, the two particles would move in mutually perpendicular directions after collisions. **5**

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Answer

1. d. 0, -25.1 J

Explanation: work done by tension will be zero because tension is perpendicular to displacement.

$$W = Ts \cos 90^\circ = 0$$

work done by gravity in semicircle from the lowest to the highest point on the path

$$W = mgh \cos 180^\circ = 0.8 \times 9.8 \times 3.2 \times (-1) = -25.1 \text{ J}$$

2. b. 21.2 cm, 28.5 J

Explanation: mass of bullet $m = 0.012 \text{ kg}$

mass of block $= 0.4 \text{ kg}$

Initial speed of bullet, $u = 70 \text{ m/s}$

Let the final speed of block and bullet which move together $= v \text{ m/s}$

According to law of conservation of momentum,

$$mu = (m + M)v$$

$$v = \frac{mu}{M+m} \\ = \frac{0.012 \times 70}{0.412} = 2.04 \text{ m/s}$$

Let block rises to a height h after collision, then

Loss in K.E. of block and bullet = Gain in P.E. after collision.

$$\frac{1}{2} (m + M) v^2 = (m + M) gh$$

$$h = \frac{v^2}{2g} = \frac{2.04 \times 2.04}{2 \times 9.8} = 0.212 \text{ m} = 21.2 \text{ cm}$$

Heat produced in the block = loss of K.E. = K.E. of bullet - K.E. of block and bullet

$$\begin{aligned} \text{Heat produced in the block} &= \frac{1}{2} mu^2 - \frac{1}{2} (m + M) v^2 \\ &= \left(\frac{1}{2} \times 0.012 \times 70 \times 70 \right) - \left(\frac{1}{2} \times 0.412 \times 2.04 \times 2.04 \right) = 28.5 \text{ J} \end{aligned}$$

3. d. -17.5 J

Explanation: from work kinetic energy theorem

$$\Delta K = W_{mg} + W_{air}$$

$$W_{mg} = Fs \cos \theta = mgh \cos 0^\circ$$

$$W_{mg} = 2 \times 10^{-3} \times 10 \times 1000 \times 1 = 20J$$

$$\frac{1}{2} \times 2 \times 10^{-3} (50^2 - 0) = 20 + W_{air}$$

$$2.5 = 20 + W_{air}$$

$$W_{air} = -17.5 J$$

4. d. 0, 0

Explanation: Work done by conservative force in round trip will be zero (displacement = 0).

So that work done by tension and gravity will be zero.

5. a. 0.15 m

Explanation: for maximum compression

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

$$x = \sqrt{\frac{mv^2}{k}}$$

$$= \sqrt{\frac{0.8 \times 1.2 \times 1.2}{50}} = 0.15m$$

the maximum compression of the spring after the collision = 0.15m

6. No, the amount of work does not depend on how fast an object is raised up in the direction of the force.
7. 1. Displacement is a vector quantity. Thus it has both magnitude and direction.
2. Displacement of a given body can be positive, negative or zero.
8. Yes, in collision of atomic and subatomic particles, the particles come near each other to a distance of closest approach, without any physical contact between them. e.g. Rutherford's alpha particles scattering where alpha particles collide with the nucleus of gold atoms.
9. Work done by the centripetal force is zero. For a particle in a circular motion, the centripetal force acts radially inwards but displacement is along the tangential path. As force and displacement are in mutually perpendicular directions, hence work done is zero.
10. For a monatomic gas, Specific heat at constant volume = $C_{V1} = \frac{3}{2}R$; R = Universal Gas Constant

No. of moles of monatomic gas = $n_1 = 1$ mole

No. of moles of diatomic gas = $n_2 = 3$ moles.

For, diatomic gas, specific heat at constant volume $C_{V_2} = \frac{5}{2}R$

Applying, conservation of energy.

Let C_V = Specific heat of the mixture;

$$C_V = \frac{n_1 C_{v1} + n_2 C_{v2}}{n_1 + n_2}$$

$$C_V = \frac{1 \times \frac{3}{2}R + 3 \times \frac{5}{2}R}{1 + 3}$$

$$C_V = \frac{\frac{3}{2}R + \frac{15}{2}R}{4}$$

R = Universal Gas constant

$$C_V = \frac{18R}{2 \times 4}$$

$$C_V = \frac{9R}{4}$$

$$C_V = \frac{9}{4} \times 8.31$$

$$C_V = 18.7 J |mol|^{-1} K$$

11. The co-efficient of cubical expansion γ of the metal is given by:-

$$\gamma = \frac{1}{V} \times \frac{\Delta V}{\Delta T}$$

$$\gamma = \frac{\Delta V}{V} \times \frac{1}{\Delta T}$$

$$\text{Here, } \frac{\Delta V}{V} = \frac{0.12}{100}$$

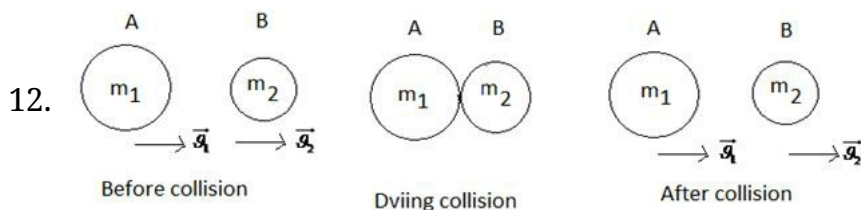
$$\Delta T = 20^\circ C$$

$$\gamma = \frac{0.12}{100} \times \frac{1}{20} \quad \gamma = 6 \times 10^{-5} |^\circ C|^{-1}$$

\therefore Co-efficient of linear expansion of the metal is :-

$$\alpha = \frac{\gamma}{3} = \frac{6.0 \times 10^{-5}}{3}$$

$$\alpha = 2.0 \times 10^{-5} |^\circ C|^{-1}$$



According to the question the collision is elastic in nature

so, $P_i = P_f$ (as per law of conservation of momentum)

and $(K.E)_i = (K.E)_f$ (Kinetic Energy remains conserved during elastic collision)

As per conservation of momentum

$$m_1 u_1 + m_2 u_2 = m_1 v_1 + m_2 v_2$$

$$m_1 (u_1 - v_1) = m_2 (v_2 - u_2) \dots (i)$$

K.E. also remains conserved during the elastic collision

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

$$m_1 (u_1^2 - v_1^2) = m_2 (v_2^2 - u_2^2) \dots (ii)$$

Dividing equation (2) by equation (1), we get

$$u_1 - v_1 = v_2 + u_2$$

$$u_1 - u_2 = v_2 - v_1$$

Relative velocity of approach = Relative velocity of separation.

13. The work-energy theorem states that the work done by a force acting on a body is equal to the change produced in its kinetic energy. If work W is being done on a body of mass m and due to the work done, the speed of the body changes from u to v, then Work done is given by:

W = Change in its kinetic energy

$$\text{Therefore, } W = \Delta K = K_2 - K_1 = \frac{1}{2} m v^2 - \frac{1}{2} m u^2$$

To derive the work-kinetic energy theorem analytically consider a body of mass m moving with a velocity u. Let a force \vec{F} be applied on the body and under its effect body be displaced by \vec{ds} , so that we can write work done as:

$$dW = \vec{F} \cdot \vec{ds}$$

But we know that, $\vec{F} = m\vec{a} = m \frac{d\vec{v}}{dt}$

$$\text{Therefore, } dW = m \frac{d\vec{v}}{dt} \cdot \vec{ds} = m \frac{ds}{dt} dv = m v dv$$

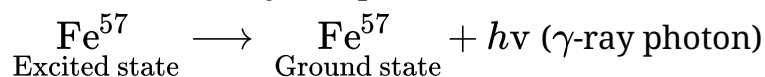
On integrating above equation, we obtain

$$\begin{aligned} \int_0^W dW &= W = \int_u^v m v dv \\ &= m \left[\frac{v^2 - u^2}{2} \right] = \frac{1}{2} m v^2 - \frac{1}{2} m u^2 \end{aligned}$$

Obviously, $\frac{1}{2} m v^2 - \frac{1}{2} m u^2 = \text{change in K.E.} = K_f - K_i$.

Thus, $W = K_f - K_i$ which is the work-kinetic energy theorem.

14. The nuclear decay is represented as follows:



According to the de-Broglie hypothesis, the linear momentum of a photon of energy E is given by:

$$p = \frac{E}{c} = \frac{14.4 \text{ keV}}{c} = \frac{14.4 \times 1.6 \times 10^{-16} \text{ J}}{3 \times 10^8 \text{ ms}^{-1}}$$

$$\text{or } p = 7.68 \times 10^{-24} \text{ kg ms}^{-1}$$

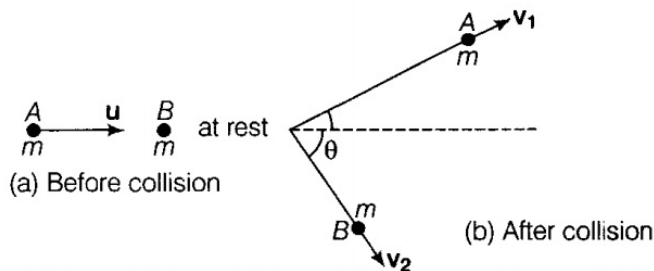
According to the law of conservation of linear momentum, the momentum of

daughter nucleus, p = momentum of γ -ray photon = $7.68 \times 10^{-24} \text{ kg ms}^{-1}$

$$\begin{aligned} \text{Now, } K &= \frac{p^2}{2m} = \frac{(7.68 \times 10^{-24})^2}{2 \times 56.935 \times 1.66 \times 10^{-27}} \\ &= 0.32 \times 10^{-21} \text{ J} = \frac{0.312 \times 10^{-21}}{1.6 \times 10^{-16}} \text{ keV} \end{aligned}$$

$K = 1.95 \times 10^{-6} \text{ keV}$, which is the required recoil energy of the nucleus.

15. Assume that a particle A of mass m and having velocity u collides with particle B (which is at rest) of equal mass. Let the collision be oblique elastic collision and after collision the balls A and B move with velocities V_1 and V_2 respectively inclined at an angle θ from each other.



Applying the principle of conservation of linear momentum, we have

$$mu = mv_1 + mv_2 \text{ or } u = v_1 + v_2$$

$$\text{or } u^2 = (v_1 + v_2) \cdot (v_1 + v_2)$$

$$= v_1^2 + v_2^2 + 2v_1 v_2 \cos \theta \dots\dots\dots (i)$$

Again as total KE before collision = total KE after collision

$$\therefore \frac{1}{2}mu^2 = \frac{1}{2}mv_1^2 + \frac{1}{2}mv_2^2$$

$$\Rightarrow u^2 = v_1^2 + v_2^2 \dots\dots\dots (ii)$$

By comparing Equations (i) and (ii), we obtain

$$2v_1 v_2 \cos \theta = 0$$

As in an oblique collision both v_1 and v_2 are finite, hence $\cos \theta = 0$

$$\Rightarrow \theta = \cos^{-1}(0) = \frac{\pi}{2}$$

Thus, the particles A and B are moving in mutually perpendicular directions after the collision.