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Class	9th	Chapter	05
Subject	Physics	Board	Punjab

Chapter 05: Work, Energy and Power

A. Multiple Choice Questions

- **5.1. Work done is maximum when the angle between the force F and the displacement d is:**
  - **Options:** (a) **0°** *(Correct Answer)* | (b) 30° | (c) 60° | (d) 90°
  - *Explanation:* Work $W = Fd\cos\theta$. Since $\cos(0°) = 1$, work done is maximum when force and displacement are in the same direction (0°).
- **5.2. A joule can also be written as:**
  - **Options:** (a) $\text{kg} \cdot \text{m} \cdot \text{s}^{-2}$ | (b) $\text{kg} \cdot \text{m} \cdot \text{s}^{-1}$ | (c) $\text{kg} \cdot \text{m}^2 \cdot \text{s}^{-3}$ | (d) $\text{kg} \cdot \text{m}^2 \cdot \text{s}^{-2}$ *(Correct Answer)*
  - *Explanation:* Work = Force × distance = $(\text{kg} \cdot \text{m} \cdot \text{s}^{-2}) \times \text{m} = \text{kg} \cdot \text{m}^2 \cdot \text{s}^{-2}$.
- **5.3. The SI unit of power is:**
  - **Options:** (a) joule | (b) newton | (c) **watt** *(Correct Answer)* | (d) second
  - *Explanation:* Power is measured in watts (W), which is joules per second (J/s).
- **5.4. The power of a water pump is 2 kW. The amount of water it can raise in one minute to a height of 5 metres is:**
  - **Options:** (a) 1000 litres | (b) 1200 litres | (c) 2000 litres | (d) 2400 litres *(Correct Answer)*
  - *Explanation:* Power $P = \frac{W}{t} \Rightarrow W = P \times t = 2000\ \text{W} \times 60\ \text{s} = 120{,}000\ \text{J}$. Work $W = mgh \Rightarrow 120{,}000 = m \times 10 \times 5 \Rightarrow m = 2400\ \text{kg} = 2400$ litres.
- **5.5. A bullet of mass 0.05 kg has a speed of 300 m s^{-1}. Its kinetic energy will be:**
  - **Options:** (a) **2250 J** *(Correct Answer)* | (b) 4500 J | (c) 1500 J | (d) 1125 J
  - *Explanation:* KE $= \frac{1}{2}mv^2 = \frac{1}{2} \times 0.05 \times (300)^2 = 0.025 \times 90{,}000 = 2250$ J.
- **5.6. If a car doubles its speed, its kinetic energy will be:**
  - **Options:** (a) the same | (b) doubled | (c) increased to three times | (d) **increased to four times** *(Correct Answer)*

- *Explanation:* KE $\propto v^2$. If speed v is doubled $(2v)$, KE becomes $(2v)^2 = 4v^2$ (four times).

- **5.7. The energy possessed by a body by virtue of its position is:**
  - **Options:** (a) kinetic energy | (b) **potential energy** *(Correct Answer)* | (c) chemical energy | (d) solar energy
  - *Explanation:* Potential energy is energy stored due to position or configuration.
- **5.8. The magnitude of momentum of an object is doubled, the kinetic energy of the object will:**
  - **Options:** (a) double | (b) **increase to four times** *(Correct Answer)* | (c) reduce to one-half | (d) remain the same
  - *Explanation:* KE $= \frac{p^2}{2m}$. If momentum p is doubled $(2p)$, KE becomes $\frac{(2p)^2}{2m} = 4\left(\frac{p^2}{2m}\right)$ (four times).
- **5.9. Which of the following is not renewable energy source?**
  - **Options:** (a) Hydroelectric energy | (b) **Fossil fuels** *(Correct Answer)* | (c) Wind energy | (d) Solar energy
  - *Explanation:* Fossil fuels (coal, petroleum, gas) are exhaustible and non-renewable.

B. Short Answer Questions

- **5.1. What is the work done on an object that remains at rest when a force is applied on it?**
  - **Answer:** Zero work is done because displacement $d = 0$ $(W = F \times 0 = 0)$.
- **5.2. A slow-moving car may have more kinetic energy than a fast-moving motorcycle. How is this possible?**
  - **Answer:** Kinetic energy depends on both mass and velocity $(\text{KE} = \frac{1}{2}mv^2)$. Even if a car moves slowly, its exceptionally large mass compared to a motorcycle can result in a higher kinetic energy.
- **5.3. A force F_1 does 5 J of work in 10 s. Another force F_2 does 3 J of work in 5 s. Which force delivers greater power?**
  - **Answer:** Power $P_1 = \frac{5\text{ J}}{10\text{ s}} = 0.5$ W. Power $P_2 = \frac{3\text{ J}}{5\text{ s}} = 0.6$ W. Force F_2 delivers greater power.
- **5.4. A woman runs up a flight of stairs. The gain in her gravitational potential energy is 4500 J. If she runs up the same stairs with twice the speed, what will be her gain in potential energy?**

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- **Answer:** Gravitational potential energy depends only on mass, gravity, and height (PE $= mgh$). Speed does not affect potential energy gain; hence the gain remains 4500 J.

- **5.5. Define work and its SI unit.**
  - **Answer:** Work is defined as the product of force applied on an object and the displacement in the direction of the force ($W = Fd\cos\theta$). Its SI unit is the joule (J).
- **5.6. What is the potential energy of a body of mass m when it is raised through a height h?**
  - **Answer:** Potential energy PE $= mgh$, where m is mass, g is gravitational acceleration, and h is height.
- **5.7. Find an expression for the kinetic energy of a moving body.**
  - **Answer:** Consider a body of mass m at rest ($v_i = 0$) accelerated to velocity v by force F over distance s. $W = Fs = mas$. Since $v_f^2 = v_i^2 + 2as \Longrightarrow as = \frac{v^2}{2}$. Thus KE $= m\left(\frac{v^2}{2}\right) = \frac{1}{2}mv^2$.
- **5.8. Define efficiency of a working system. Why a system cannot have 100% efficiency?**
  - **Answer:** Efficiency is the ratio of useful work output to total energy input (Efficiency $= \frac{\text{Output}}{\text{Input}} \times 100\%$). No system can have 100% efficiency due to inevitable energy losses as heat, sound, and friction.
- **5.9. What is power? Define the unit used for it.**
  - **Answer:** Power is the rate of doing work ($P = \frac{W}{t}$). Its SI unit is the watt (W), defined as the power when one joule of work is done in one second.
- **5.10. Differentiate between renewable and non-renewable energy sources.**
  - **Answer:**
    - *Renewable energy sources* are inexhaustible and naturally replenished (e.g., solar, wind, hydro).
    - *Non-renewable energy sources* are finite and exhaustible (e.g., coal, oil, natural gas).

C. Constructed Response Questions

- **5.1. Can the kinetic energy of a body ever be negative?**
  - **Answer:** No. Kinetic energy (KE $= \frac{1}{2}mv^2$) depends on mass (always positive) and the square of velocity (v^2 is always positive). Thus, kinetic energy can never be negative.
- **5.2. Which one has the greater kinetic energy; an object travelling with a velocity v or an object twice as heavy travelling with a velocity of ½ v?**

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- **Answer:**
  - Object 1: $\mathrm{KE}_1 = \frac{1}{2}mv^2$.
  - Object 2: $\mathrm{KE}_2 = \frac{1}{2}(2m)\left(\frac{1}{2}v\right)^2 = m\left(\frac{v^2}{4}\right) = \frac{1}{4}mv^2 = 0.5\,\mathrm{KE}_1$.
  - Therefore, the first object has greater kinetic energy.

- **5.3. A car is moving along a curved road at constant speed. Does its kinetic energy change?**
  - **Answer:** No. Kinetic energy is a scalar quantity depending only on the magnitude of velocity (speed). Since speed is constant, kinetic energy remains constant even though direction (and velocity vector) changes.
- **5.4. Comment on the statement. 'An object has one joule of potential energy.'**
  - **Answer:** It means an amount of work equal to one joule was done against gravity to raise the object to its current position (e.g., lifting a mass of approximately 100 g through a height of 1 metre).
- **5.5. While driving on a motorway, tyre of a vehicle sometimes bursts. What may be its cause?**
  - **Answer:** Rapid friction generating high temperatures, overloading, under-inflation causing excessive flexing, or high-speed driving on hot pavement.
- **5.6. While playing cricket on a street, the ball smashes a window pane. Describe the energy changes in this event.**
  - **Answer:** Chemical energy in the batter's muscles is converted into kinetic energy of the bat, then kinetic energy of the moving ball. Upon impact, ball kinetic energy is converted into sound energy, thermal energy, and strain/fracture energy breaking the glass.
- **5.7. A man rowing boat upstream is at rest with respect to the shore. Is he doing work?**
  - **Answer:** Physically, work done is zero with respect to the shore because displacement relative to the shore is zero ($W = F \times 0 = 0$). However, muscular/chemical work is being expended internally to fight the water current.
- **5.8. A cyclist goes downhill from the top of a steep hill without pedalling and takes it to the top of the next hill. (i) Draw a diagram... (ii) Analyse this event in terms of potential and kinetic energy...**
  - **Answer:** At the top of the first hill, the cyclist has maximum gravitational potential energy and zero kinetic energy. As they go downhill, potential energy decreases while kinetic energy increases to a maximum at the bottom. As they coast up the next hill, kinetic energy converts back into potential energy, reaching a stop at the top.

D. Comprehensive Questions

- **5.1. What is meant by kinetic energy? State its unit. Describe how it is determined.**

- **Answer:** Kinetic energy is the energy possessed by a body due to its motion ($\text{KE} = \frac{1}{2}mv^2$). Its unit is the joule (J). It is determined by calculating the work done in accelerating the body from rest to velocity v.

- **5.2. State the law of conservation of energy. Explain it with the help of an example of a body falling from certain height in terms of its potential energy and kinetic energy.**
  - **Answer:** Energy cannot be created nor destroyed; it can only be converted from one form to another. For a freely falling body, total mechanical energy (PE + KE) remains constant at all points along its fall.
- **5.3. Differentiate between renewable and non-renewable sources of energy. Give three examples for each.**
  - **Answer:**
    - *Renewable:* Solar, wind, hydroelectric (inexhaustible).
    - *Non-renewable:* Coal, petroleum, natural gas (finite).
- **5.4. Explain what is meant by efficiency of a machine. How is it calculated? Why there is a limit for the efficiency of a machine?**
  - **Answer:** Efficiency is the ratio of useful output energy to total input energy ($\text{Efficiency} = \frac{\text{Output}}{\text{Input}} \times 100\%$). It is limited to under 100% because friction and thermal losses are unavoidable in real machines.
- **5.5. Describe the process of electricity generation by drawing a block diagram of the process in the following cases: (i) Hydroelectric power generations (ii) Fossil fuels**
  - **Answer:**
    - (i) *Hydroelectric:* Water reservoir → Penstock → Turbine → Generator → Electrical energy.
    - (ii) *Fossil fuels:* Fuel combustion → Boiler (Steam) → Turbine → Generator → Electrical energy.

E. Numerical Problems

- **5.1. A force of 20 N acting at an angle of 60° to the horizontal is used to pull a box through a distance of 3 m across a floor. How much work is done?**
  - **Answer:**
    - $F = 20$ N, $\theta = 60°$, $d = 3$ m
    - $W = Fd\cos\theta = 20 \times 3 \times \cos(60°) = 60 \times 0.5 = \mathbf{30}$ J.
- **5.2. A body moves a distance of 5 metres in a straight line under the action of a force of 8 newtons. If the work done is 20 joules, find the angle which the force makes with the direction of motion of the body.**
  - **Answer:**
    - $d = 5$ m, $F = 8$ N, $W = 20$ J

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- $W = Fd\cos\theta \Rightarrow 20 = 8 \times 5 \times \cos\theta \Rightarrow 20 = 40\cos\theta \Rightarrow \cos\theta = \frac{20}{40} = 0.5 \Rightarrow \mathbf{\theta = 60}°$.

- **5.3. An engine raises 100 kg of water through a height of 80 m in 25 s. What is the power of the engine?**
  - **Answer:**
    - $m = 100$ kg, $h = 80$ m, $t = 25$ s, $g = 10$ m/s^2
    - $W = mgh = 100 \times 10 \times 80 = 80{,}000$ J
    - $P = \frac{W}{t} = \frac{80{,}000}{25} = \mathbf{3200}$ W.
- **5.4. A body of mass 20 kg is at rest. A 40 N force acts on it for 5 seconds. What is the kinetic energy of the body at the end of this time?**
  - **Answer:**
    - $m = 20$ kg, $v_i = 0$, $F = 40$ N, $t = 5$ s
    - Acceleration $a = \frac{F}{m} = \frac{40}{20} = 2$ m/s^2
    - Final velocity $v_f = v_i + at = 0 + (2 \times 5) = 10$ m/s
    - KE $= \frac{1}{2}mv^2 = \frac{1}{2} \times 20 \times (10)^2 = 10 \times 100 = \mathbf{1000}$ J.
- **5.5. A ball of mass 160 g is thrown vertically upward. The ball reaches a height of 20 m. Find the potential energy gained by the ball at this height.**
  - **Answer:**
    - $m = 160$ g $= 0.16$ kg, $h = 20$ m, $g = 10$ m/s^2
    - PE $= mgh = 0.16 \times 10 \times 20 = \mathbf{32}$ J.
- **5.6. A 0.14 kg ball is thrown vertically upward with an initial velocity of 35 m s^{-1}. Find the maximum height reached by the ball.**
  - **Answer:**
    - $m = 0.14$ kg, $v_i = 35$ m/s, $v_f = 0$, $g = 10$ m/s^2
    - Using $2gh = v_f^2 - v_i^2 \Rightarrow 2(10)h = 0^2 - (35)^2 \Rightarrow 20h = 1225 \Rightarrow h = \frac{1225}{20} = \mathbf{61.25}$ m.
- **5.7. A girl is swinging on a swing. At the lowest point of her swing, she is 1.2 m from the ground, and at the highest point she is 2.0 m from the ground. What is her maximum velocity and where?**
  - **Answer:**
    - Height difference $\Delta h = 2.0 - 1.2 = 0.8$ m.
    - By conservation of energy: Loss in PE = Gain in KE $\Rightarrow mg(\Delta h) = \frac{1}{2}mv^2 \Rightarrow v = \sqrt{2g\Delta h} = \sqrt{2 \times 10 \times 0.8} = \sqrt{16} =$ **4** m/s at the lowest position.

- **5.8. A person pushes a lawn mower with a force of 50 N making an angle of 45° with the horizontal. If the mower is moved through a distance of 20 m, how much work is done?**
  - **Answer:**
    - $F = 50$ N, $\theta = 45°$, $d = 20$ m
    - $W = Fd\cos\theta = 50 \times 20 \times \cos(45°) = 1000 \times 0.7071 \approx \mathbf{707}$ J.
- **5.9. Calculate the work done in: (i) Pushing a 5 kg box up a frictionless inclined plane 10 m long that makes an angle of 30° with the horizontal. (ii) Lifting the box vertically up from the ground to the top of the inclined plane.**
  - **Answer:**
    - (i) $W = Fd = (mg\sin\theta) \times d = (5 \times 10 \times \sin(30°)) \times 10 = (50 \times 0.5) \times 10 = \mathbf{250}$ J.
    - (ii) Height $h = 10\sin(30°) = 5$ m. $W = mgh = 5 \times 10 \times 5 = \mathbf{250}$ J.
- **5.10. A box of mass 10 kg is pushed up along a ramp 15 m long with a force of 80 N. If the box rises up a height of 5 m, what is the efficiency of the system?**
  - **Answer:**
    - $m = 10$ kg, $h = 5$ m, Output work $= mgh = 10 \times 10 \times 5 = 500$ J.
    - Input work = Force × distance = 80 N × 15 m = 1200 J.
    - Efficiency $= \left(\frac{\text{Output}}{\text{Input}}\right) \times 100\% = \left(\frac{500}{1200}\right) \times 100\% = \mathbf{41.7}\%$.
- **5.11. A force of 600 N acts on a box to push it 5 m in 15 s. Calculate the power.**
  - **Answer:**
    - $F = 600$ N, $d = 5$ m, $t = 15$ s
    - $W = F \times d = 600 \times 5 = 3000$ J
    - $P = \frac{W}{t} = \frac{3000}{15} = \mathbf{200}$ W.
- **5.12. A 40 kg boy runs up-stair 10 m high in 8 s. What power he developed.**
  - **Answer:**
    - $m = 40$ kg, $h = 10$ m, $t = 8$ s, $g = 10$ m/s^2
    - $W = mgh = 40 \times 10 \times 10 = 4000$ J
    - $P = \frac{W}{t} = \frac{4000}{8} = \mathbf{500}$ W.
- **5.13. A force F acts through a distance L on a body. The force is then increased to 2F that further acts through 2L. Sketch a force-displacement graph and calculate the total work done.**
  - **Answer:**
    - Work done = Area under the force-displacement graph.
    - Part 1: $W_1 = F \times L = FL$.
    - Part 2: $W_2 = 2F \times 2L = 4FL$.
    - Total work done $= FL + 4FL = \mathbf{5FL}$ (or 5 units).

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