Class 11 Physics · Chapter 5: Work, Energy and Power

Answer key and marking scheme · 20 marks · about 40 minutes · based on NCERT

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1. The component of $\vec{A} = 4\hat{i} + 2\hat{j} + 4\hat{k}$ along the direction of $\vec{B} = 2\hat{i} - \hat{j} + 2\hat{k}$ is [1]

(a) 14 (b) 7/3

(c) 2 (d) 14/3

Answer: (d) Component of $\vec{A}$ along $\vec{B}$ = $\vec{A}\cdot\vec{B} / B = (8 - 2 + 8)/\sqrt{(4 + 1 + 4)} = 14/3$. Not dividing by B gives 14; dividing by $B^2 = 9$ gives 14/9, and by $A = 6$ gives 7/3.

2. A child pulls a toy cart with a string that makes 60° with the horizontal. The tension in the string is 10 N and the cart moves 5 m along the level floor. The work done by the tension is [1]

(a) 50 J (b) 43.3 J

(c) 0 J (d) 25 J

Answer: (d) $W = Fd\cos\theta = 10 \times 5 \times \cos 60° = 25$ J. Using sin 60° gives 43.3 J; leaving out the angle gives 50 J.

3. Two vectors $\vec{A}$ and $\vec{B}$ have magnitudes 4 units and 6 units, and the angle between them is 120°. The scalar product $\vec{A}\cdot\vec{B}$ is [1]

(a) 12 (b) −12

(c) 24 (d) −24

Answer: (b) $\vec{A}\cdot\vec{B} = AB\cos\theta = 4 \times 6 \times \cos 120° = 24 \times (-½) = -12$. Taking cos 120° as +½ gives 12; leaving out cos θ gives 24.

4. The dimensions of the spring constant k are [1]

(a) $[MT^{-2}]$ (b) $[MLT^{-2}]$

(c) $[ML^2T^{-2}]$ (d) $[ML^{-1}T^{-2}]$

Answer: (a) k = force/extension = $[MLT^{-2}]/[L] = [MT^{-2}]$; its unit is N m^{-1}. $[MLT^{-2}]$ is force and $[ML^2T^{-2}]$ is energy.

5. A 2 kW geyser is used for 45 minutes every day. The electrical energy it uses in 30 days is [1]

(a) 2700 kWh (b) 60 kWh

(c) 45 kWh (d) 4.5 kWh

Answer: (c) Energy = power × time = 2 kW × 0.75 h × 30 = 45 kWh. Using 45 h instead of 0.75 h each day gives 2700 kWh; using 1 h each day gives 60 kWh.

6. A 2 kg book rests on a shelf 1.5 m above the floor. A table top is 0.8 m above the floor. Find the gravitational potential energy of the book (i) taking the floor as zero and (ii) taking the table top as zero. Show that the change in potential energy when the book is moved from the shelf to the table top is the same in both cases. ($g = 10$ m s^{-2}) [2]

(i) $V = mgh = 2 \times 10 \times 1.5 = 30$ J. (ii) $V = 2 \times 10 \times (1.5 - 0.8) = 14$ J. Shelf to table: with the floor as zero, $\Delta V = 2 \times 10 \times 0.8 - 30 = 16 - 30 = -14$ J; with the table top as zero, $\Delta V = 0 - 14 = -14$ J. The zero is arbitrary; only changes in potential energy matter.

- 30 J and 14 J (1)
- $\Delta V = -14$ J in both cases (1)

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7. A stone tied to a string is whirled in a horizontal circle at constant speed. What is the work done by the tension in the string during one revolution? Give a reason, and check that your answer agrees with the work-energy theorem. [2]

Zero. The tension acts along the string, towards the centre, while the stone's displacement at every instant is along the tangent; $\theta = 90°$, so the tension does no work. The speed is constant, so the kinetic energy does not change, $\Delta K = 0$, which the work-energy theorem requires for zero net work.

- work is zero, tension perpendicular to the displacement (1)
- $\Delta K = 0$ at constant speed, consistent with the theorem (1)

8. An electric iron rated 1.5 kW is used for 40 minutes every day. Find the electrical energy it uses in 30 days in kWh, and the cost at ₹8 per kWh. [2]

Energy each day = 1.5 kW × (40/60) h = 1.0 kWh. In 30 days: 1.0 × 30 = 30 kWh. Cost = 30 × ₹8 = ₹240.

- energy = 30 kWh (1)
- cost = ₹240 (1)

9. Prove the work-energy theorem for a variable force acting on a particle moving in one dimension. [3]

$K = \tfrac{1}{2}mv^2$, so $dK/dt = mv\,(dv/dt) = (m\,dv/dt)\,v$. By Newton's second law $m\,dv/dt = F$, so $dK/dt = Fv = F\,dx/dt$, giving $dK = F\,dx$. Integrating from x_i to x_f: $K_f - K_i = \int F\,dx$ (from x_i to x_f). The right side is, by definition, the work W done by the variable force, so $K_f - K_i = W$: the change in kinetic energy equals the work done by the net force.

- $dK/dt = mv\,dv/dt = Fv$ (1)
- $dK = F\,dx$ (1)
- integration gives $K_f - K_i = \int F\,dx = W$ (1)

10. A car of mass 1200 kg has an engine that delivers a maximum power of 30 kW. On a level road the total resistive force on it is 1500 N. (a) Find its maximum speed on the level road. (b) Find its maximum speed up a slope that rises 1 m for every 20 m travelled along it, with the same resistive force. ($g = 10$ m s^{-2}) [3]

(a) At the maximum speed the engine force balances the resistance: $P = Fv$, $v = 30000/1500 = 20$ m s^{-1}. (b) Up the slope the engine must also balance $mg \sin\theta = 1200 \times 10 \times (1/20) = 600$ N, so $F = 1500 + 600 = 2100$ N and $v = 30000/2100 = 14.3$ m s^{-1}.

- $v = P/F = 20$ m s^{-1} on the level (1)
- extra force $mg \sin\theta = 600$ N (1)
- $v = 14.3$ m s^{-1} up the slope (1)

11. A block of mass 0.2 kg is attached to a spring of spring constant 80 N m^{-1} and rests on a smooth horizontal surface. It is pulled 5 cm from its equilibrium position and released from rest. Find (a) the total mechanical energy of the system, (b) the maximum speed of the block, and (c) the displacement at which the kinetic energy equals the potential energy. [3]

(a) $E = \tfrac{1}{2}kx_m^2 = \tfrac{1}{2} \times 80 \times (0.05)^2 = 0.1$ J. (b) At $x = 0$ all of it is kinetic: $\tfrac{1}{2}mv_m^2 = 0.1$ J, $v_m = \sqrt{(2 \times 0.1/0.2)} = 1$ m s^{-1}. (c) $K = V$ means $V = E/2$: $\tfrac{1}{2}kx^2 = \tfrac{1}{2} \times \tfrac{1}{2}kx_m^2$, so $x = x_m/\sqrt{2} = 5/1.414 = 3.54$ cm on either side of the equilibrium position.

- $E = 0.1$ J (1)
- $v_m = 1$ m s^{-1} (1)
- $x = \pm 3.54$ cm (1)

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