PHYSICS – CLASS XI

Chapter 5 : Work, Energy and Power

SOLUTIONS AND MARKING SCHEME (Step-by-Step)

Marks for each step are shown in brackets. Alternative correct methods carry full marks.

Quick answer key – Section A

Q	1	2	3	4	5	6	7	8
Ans	(b)	(c)	(b)	(a)	(b)	1000 W	10 m s^{-1}	(b)

SECTION A

1. **Ans: (b) 50 J.** **(1)**

$W = Fd\cos\theta = 20 \times 5 \times \cos 60° = 20 \times 5 \times ½ =$ **50 J**.

2. **Ans: (c) 90°.** **(1)**

$\mathbf{A}\cdot\mathbf{B} = (2)(3) + (3)(-2) = 6 - 6 = 0$, so $\cos\theta = 0$ and $\theta =$ **90°** (the vectors are perpendicular).

3. **Ans: (b) 60 J.** **(1)**

Work = area under the F–x graph = rectangle (0–4 m) + triangle (4–8 m) $= 10 \times 4 + ½ \times 4 \times 10 = 40 + 20 =$ **60 J**.

4. **Ans: (a).** **(1)**

Both are true. A potential energy can be defined only for a conservative force, i.e. one whose work over a closed path is zero. Friction does non-zero work over a closed path, so R explains A.

5. **Ans: (b) 1 J.** **(1)**

$V = ½kx^2 = ½ \times 200 \times (0.1)^2 = ½ \times 200 \times 0.01 =$ **1 J**.

6. **Ans: 1000 W.** **(1)**

At constant speed the crane force equals the weight: $F = mg = 200 \times 10 = 2000$ N.
$P = Fv = 2000 \times 0.5 =$ **1000 W** (1 kW).

7. **Ans: 10 m s^{-1}.** **(1)**

$mgh = ½mv^2 \rightarrow v = \sqrt{(2gh)} = \sqrt{(2 \times 10 \times 5)} = \sqrt{100} =$ **10 m s^{-1}**.

8. **Ans: (b) zero and v.** **(1)**

For equal masses in a head-on elastic collision the velocities are exchanged: $v_{1f} = 0$, $v_{2f} = v$.

SECTION B

9. **(i)** $k = F/x = 80/0.2 =$ **400 N m^{-1}**. (1) **(2)**

(ii) $W = ½kx^2 = ½ \times 400 \times (0.2)^2 =$ **8 J** (= area of the triangle $½ \times 0.2 \times 80$). (1)

10. $W_F = 26 \times 5 = 130$ J; $W_f = -6 \times 5 = -30$ J. Net work = 100 J. (1) **(2)**

Work–energy theorem: $100 = ½ \times 2 \times v^2 - 0 \rightarrow v^2 = 100 \rightarrow v =$ **10 m s^{-1}**. (1)

11. Net force F gives acceleration $a = F/m$, and $v^2 - u^2 = 2ad$. (½) **(2)**
Multiply by $m/2$: $\frac{1}{2}mv^2 - \frac{1}{2}mu^2 = mad = Fd$. (1)
i.e. $K_f - K_i = W$: the change in kinetic energy equals the work done by the net force. (½)

OR

Work–energy theorem: $W = K_f - K_i = 0 - \frac{1}{2} \times 0.02 \times (300)^2 = -900$ J. (1)
$-F \times 0.03 = -900 \rightarrow F = 900/0.03 =$ **30 000 N** (3×10^4 N). (1)

12. **(i)** Tension does no work, so mechanical energy is conserved: $mgL = \frac{1}{2}mv^2 \rightarrow v = \sqrt{(2gL)} = \sqrt{(2 \times 10 \times 1.25)} =$ **5 m s⁻¹**. (1) **(2)**
(ii) At A: $T - mg = mv^2/L \rightarrow T = 0.2 \times 10 + 0.2 \times 25/1.25 = 2 + 4 =$ **6 N**. (1)

SECTION C

13. Work = area under the F–x graph. **(3)**
(i) 0–4 m: ½ × 4 × 20 = **40 J**; 4–8 m: 4 × 20 = **80 J**; 8–12 m: ½ × 4 × 20 = **40 J**. (1½)
(ii) Total work = 40 + 80 + 40 = **160 J**. (½)
(iii) By the work–energy theorem $160 = \frac{1}{2} \times 5 \times v^2 \rightarrow v^2 = 64 \rightarrow v =$ **8 m s⁻¹**. (1)

14. **(i)** The incline is smooth, so mechanical energy is conserved: $mgh = \frac{1}{2}mv^2 \rightarrow v = \sqrt{(2 \times 10 \times 3.2)} = \sqrt{64} =$ **8 m s⁻¹**. (1) **(3)**
(ii) On the floor, work done by friction = change in kinetic energy: $-\mu_k mg \times s = 0 - \frac{1}{2}mv^2$. (1)
$s = v^2/(2\mu_k g) = 64/(2 \times 0.4 \times 10) =$ **8 m**. (1)

OR

(i) $K = \frac{1}{2}mv^2 = \frac{1}{2} \times 0.5 \times 16 =$ **4 J**. (1)
(ii) At maximum compression all the kinetic energy is stored in the spring: $\frac{1}{2}kx_m^2 = 4 \rightarrow x_m^2 = 8/200 = 0.04 \rightarrow x_m =$ **0.2 m**. (1)
(iii) At $x = 0.1$ m: $V = \frac{1}{2} \times 200 \times (0.1)^2 =$ **1 J**; by conservation of mechanical energy $K = 4 - 1 =$ **3 J**. (1)

15. Work done per minute = $mgh = 600 \times 10 \times 20 = 1.2 \times 10^5$ J. **(3)**
(i) Useful power = $1.2 \times 10^5/60 =$ **2000 W**. (1)
(ii) Electrical power = useful power/efficiency = 2000/0.5 = **4000 W**. (1)
(iii) Energy in 1 h = 4 kW × 1 h = **4 kWh** (= 1.44×10^7 J). (1)

SECTION D

16. **(5)**

(a) An elastic collision is one in which the total kinetic energy (as well as the total momentum) is conserved. **Linear momentum** is conserved in every collision. (1)

(b) $v_{1f} = (m_1 - m_2)v_{1i}/(m_1 + m_2) = (2 - 4) \times 6/6 =$ **-2 m s^{-1}**. (1)

(c) $v_{2f} = 2m_1v_{1i}/(m_1 + m_2) = 2 \times 2 \times 6/6 =$ **4 m s^{-1}**. (Check momentum: $12 = 2(-2) + 4(4) = 12$.) (1)

(d) Before: ½ × 2 × 36 = 36 J. After: ½ × 2 × 4 + ½ × 4 × 16 = 4 + 32 = 36 J. Equal, so kinetic energy is conserved. (1)

(e) A rebounds (moves backwards, negative velocity) because it is lighter than the target B it collides with. (1)

OR

(a) A **completely inelastic** collision (the bodies move together after impact). (1)

(b) $0.02 \times 300 = (0.02 + 1.98)v \rightarrow v = 6/2 =$ **3 m s^{-1}**. (1)

(c) $\frac{1}{2}mv^2 = mgh \rightarrow h = v^2/2g = 9/20 =$ **0.45 m**. (1)

(d) Initial $K = \frac{1}{2} \times 0.02 \times 300^2 =$ **900 J**. After impact: $K = \frac{1}{2} \times 2 \times 3^2 =$ **9 J**. (1) Loss = 891 J, i.e. 891/900 = **99%**. (1)

17. **(5)**

(a) The tension is always along the string, i.e. perpendicular to the velocity (displacement), so $W = Fd \cos 90° = 0$. (1)

(b) At the top the string just goes slack, so $T_C = 0$ and gravity alone gives the centripetal force: $mg = mv_C^2/L \rightarrow v_C = \sqrt{(gL)} = \sqrt{5}$ m s^{-1}. (1)

(c) Energy at A = energy at C: $\frac{1}{2}mv_0^2 = \frac{1}{2}mv_C^2 + mg(2L)$. (1)

$v_0^2 = gL + 4gL = 5gL = 5 \times 10 \times 0.5 = 25 \rightarrow v_0 =$ **5 m s^{-1}**. (1)

(d) At A: $T - mg = mv_0^2/L \rightarrow T = 0.2 \times 10 + 0.2 \times 25/0.5 = 2 + 10 =$ **12 N**. (1)

OR

(a) Constant speed means zero net force: $F = mg + f = 8000 + 2000 =$ **10 000 N**. (1)

(b) $P = Fv = 10\,000 \times 1.5 =$ **15 000 W** (15 kW). (1)

(c) Electrical power = 15 000/0.8 = **18 750 W** (18.75 kW). (1)

(d) Time = 2 min = 1/30 h. Energy = 18.75 kW × (1/30) h = **0.625 kWh**. (2)

— END OF SOLUTIONS —