Unit 5 · Work, Energy and Power

ANSWER KEY · FOR TEACHERS

Full marks 31

Give the marks for the points in the marking scheme; an answer in other words that says the same is right.

1 Key words

1. joules
2. power
3. horsepower
4. kinetic energy
5. potential energy
6. conservative
7. elastic
8. coefficient of restitution

Each carries 0.5 mark. **K · 4**

2 Multiple choice

i. **b.** 3.6×10^6 J of energy **K · 1**

1 kWh = 1000 W × 3600 s = 3.6×10^6 J: it is energy, not power.

ii. **a.** zero **U · 1**

The pull is towards the center, always at 90° to the stone's motion, so W = Fd cos 90° = 0. That is why the speed doesn't change.

iii. **c.** 9 J **A · 1**

$K = \frac{1}{2}mv^2 = \frac{1}{2} \times 2 \times 3^2 = 9$ J.

iv. **c.** four times as large **A · 1**

$K \propto v^2$, so $2^2 = 4$ times. (Its braking distance, for the same braking force, is also four times as long.)

v. **b.** the bodies stick together, momentum is conserved, and kinetic energy is lost **U · 1**

In every collision momentum is conserved. Perfectly inelastic means they move off together (e = 0), with the most kinetic energy lost.

3 Short answers

a. **MARKING SCHEME** **K · 2**

- ✓ Any one, e.g. the work done by a conservative force doesn't depend on the path, but a non-conservative force's does.
- ✓ Any second, e.g. a conservative force's work round a closed path is zero (and can be recovered); a non-conservative force's isn't (it is lost as heat); gravity is conservative, friction isn't.

b. **MARKING SCHEME** **U · 2**

- ✓ The bounce is inelastic: kinetic energy is lost in the collision.
- ✓ It changes into heat, sound and deformation (total energy still conserved).

c. **MARKING SCHEME** **A · 3**

- ✓ W = mgh = 88 200 J.
- ✓ P = 4410 W.
- ✓ About 5.9 hp.

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4 Long answer

ANSWER U · 4

Momentum is conserved: $m_1u = (m_1 + m_2)v$, so $v = \dfrac{m_1u}{m_1 + m_2}$.

KE before: $K_1 = \dfrac{1}{2}\,m_1u^2$. KE after: $K_2 = \dfrac{1}{2}(m_1 + m_2)v^2 = \dfrac{m_1{}^2u^2}{2(m_1 + m_2)} = K_1 \cdot \dfrac{m_1}{m_1 + m_2}$.

Fraction lost: $\dfrac{K_1 - K_2}{K_1} = 1 - \dfrac{m_1}{m_1 + m_2} = \dfrac{m_2}{m_1 + m_2}$.

So the heavier the body at rest, the more of the energy is lost (all of it, nearly, against a wall).

MARKING SCHEME

- ✓ Momentum conserved: $v = m_1u/(m_1 + m_2)$.
- ✓ KE before $\tfrac{1}{2}m_1u^2$.
- ✓ KE after $= K_1 \times m_1/(m_1 + m_2)$.
- ✓ Fraction lost $m_2/(m_1 + m_2)$.

5 Numerical problems

a. **ANSWER** A · 4

i. Before: $v = \sqrt{(2gh)} = \sqrt{(2 \times 9.8 \times 5.0)} = \mathbf{9.9\ m/s}$. After: $\sqrt{(2 \times 9.8 \times 3.2)} = \mathbf{7.9\ m/s}$.

ii. The floor doesn't move, so $e = 7.92 \div 9.90 = \mathbf{0.8}$.

iii. Energy lost $= mg(5.0 - 3.2) = 0.5 \times 9.8 \times 1.8 = \mathbf{8.8\ J}$.

MARKING SCHEME

- ✓ 9.9 m/s before and 7.9 m/s after.
- ✓ e = speed after ÷ speed before.
- ✓ e = 0.8.
- ✓ Energy lost 8.8 J.

b. **ANSWER** A · 4

The graph: a straight line from (0 m, 0 N) to (4 m, 20 N), then flat at 20 N to 6 m.

Work = area $= \tfrac{1}{2} \times 4 \times 20 + 2 \times 20 = 40 + 40 = \mathbf{80\ J}$.

By the work–energy theorem, $\tfrac{1}{2} \times 2 \times v^2 = 80$, so $v = \sqrt{80} = \mathbf{8.9\ m/s}$.

MARKING SCHEME

- ✓ The graph drawn (a sloping line, then flat).
- ✓ Work as the area under the graph.
- ✓ 80 J.
- ✓ v = 8.9 m/s from the work–energy theorem.

6 Think

ANSWER HA · 3

Two balls at half speed would conserve momentum: $m\,u = 2m \times u/2$. But their kinetic energy would be $\tfrac{1}{2}(2m)(u/2)^2 = \tfrac{1}{4}mu^2$, only half of the $\tfrac{1}{2}mu^2$ that came in. In an elastic collision both momentum and kinetic energy must be conserved, and only one ball leaving at u does both.

MARKING SCHEME

- ✓ Two balls at u/2 conserve momentum.
- ✓ But their kinetic energy would be $\tfrac{1}{4}mu^2$, half of what came in.
- ✓ Elastic collisions conserve both, so only one ball at u fits.

7 Activity: Your power on the stairs

(not marked)

WHAT STUDENTS SHOULD FIND

The work against gravity, mgh, is the same walking or running: the same mass is lifted through the same height. Only the time differs, so running needs more power: a student of 50 kg running up 3 m in 3 s gives about 490 W, walking in 8 s about 180 W (more is used by the body, which is far from 100% efficient).

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See it at Science Playground

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- **Coupled Pendulums** (exhibit): Start just one pendulum: its swing dies away as the other's grows, then returns, the energy passing between them while their total stays nearly constant.
- **Newton's Cradle** (exhibit): Nearly elastic collisions: almost all the kinetic energy passes along the row, and the little lost each time, to sound and air, slowly stops the balls.
- **Pulley Systems** (exhibit): Lift the same load with each pulley arrangement: halve the force and you pull twice as much rope, so the work done, Fd, stays about the same.

Marks by level	Knowledge	Understanding	Application	Higher ability	Total
Marks	7	8	13	3	**31**