2.1 Forces work and power

Name: _____ Class: _____ Date: _____ **Total: 27 marks**

KEY WORDS kinetic energy • gravitational potential energy

Objective

Build the skills to answer exam questions on **work and energy** : work done by a force, elastic, gravitational and kinetic energy, power, and energy changes in moving objects.

You must be able to:

- calculate work done and explain heating by friction
- calculate elastic, gravitational potential and kinetic energy
- calculate power
- use conservation of energy for falling and moving objects

1 Key knowledge and worked examples

■ Work, energy and power

idea	equation or rule
work done	$W = Fs$ (J), s = distance moved along the force; work against friction heats the surfaces
elastic potential energy	$E_e = \frac{1}{2}ke^2$
gravitational potential energy	$E_p = mgh$, $g = 9.8$ N/kg
kinetic energy	$E_k = \frac{1}{2}mv^2$: double the speed and the energy is four times as big
power	$P = \frac{E}{t}$ or $P = \frac{W}{t}$ (W)
conservation	energy is never made or destroyed; a falling object: E_p lost $= E_k$ gained if there is no air resistance

Worked example 1: kinetic energy. A 900 kg car moves at 20 m/s. Find its kinetic energy.

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1. Known: $m = 900$ kg, $v = 20$ m/s.
2. Rule: $E_k = \frac{1}{2}mv^2$.
3. Numbers: $\frac{1}{2} \times 900 \times 20^2$.
4. Result: $E_k = 180\,000$ **J**.

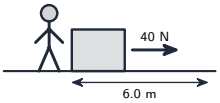
Worked example 2: a falling ball. A ball falls 5.0 m from rest. Find its speed at the bottom. Ignore air resistance.

1. Known: $h = 5.0$ m; E_p lost $= E_k$ gained.
2. Rule: $mgh = \frac{1}{2}mv^2$, so $v = \sqrt{2gh}$.
3. Numbers: $\sqrt{2 \times 9.8 \times 5.0} = \sqrt{98}$.
4. Result: $v = 9.9$ **m/s**.

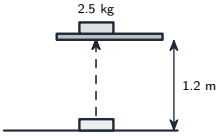
Answer shapes: say which energy store goes down and which goes up before you calculate.

2 Practice

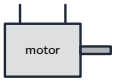
2.1 A girl pushes a box 6.0 m across the floor with a force of 40 N. Calculate the work she does. [2]



2.2 A 2.5 kg book is lifted 1.2 m onto a shelf. Calculate the gain in gravitational potential energy. [2]



2.3 A motor transfers 1800 J of energy in 15 s. Calculate its power. [2]



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3 Exam-style questions

3.1 A cyclist and bicycle have a total mass of 70 kg and move at 4.0 m/s. Calculate their kinetic energy. What is the kinetic energy if the speed doubles? [3]

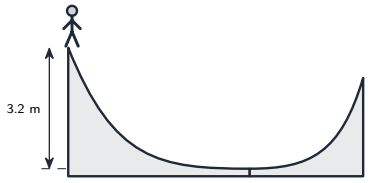


3.2 The elastic band of a catapult has spring constant 200 N/m. It is stretched by 0.15 m and fires a stone of mass 0.050 kg. Calculate the speed of the stone. Assume all the elastic energy becomes kinetic energy. [3]



3.3 A skateboarder of mass 50 kg starts at rest at the top of a ramp. The top is 3.2 m above the bottom. The ramp is 8.0 m long.

(a) Calculate the gravitational potential energy she loses from the top to the bottom. [3]



(b) Calculate her greatest possible speed at the bottom. Assume there is no friction. [3]

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(c) Her actual speed at the bottom is 7.0 m/s. Calculate the average friction force on her along the ramp. [3]

(d) She rolls up a ramp on the other side. Explain the energy changes as she goes down and up, and why she cannot reach a height of 3.2 m on the other side. Suggest how she could go higher. [6]

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Solutions

Marking: **M1** a correct method, **A1** the correct answer, **B1** an independent mark.

Each answer shows the steps, then the **result**.

2.1

- $W = Fs = 40 \times 6.0$
- $=$ **240** J

2.2

- $E_p = mgh = 2.5 \times 9.8 \times 1.2$
- $=$ **29** J

2.3

- $P = E \div t = 1800 \div 15$
- $=$ **120** W

3.1

- $E_k = \frac{1}{2} \times 70 \times 4.0^2$
- $=$ **560** J
- at double the speed, $4 \times 560 =$ **2240** J

3.2

- $E_e = \frac{1}{2} \times 200 \times 0.15^2 = 2.25$ J
- $\frac{1}{2} \times 0.050 \times v^2 = 2.25$
- $v =$ **9.5** m/s

3.3

(a) $E_p = mgh$; $50 \times 9.8 \times 3.2 =$ **1570** J

(b) $\frac{1}{2} \times 50 \times v^2 = 1568$; $v^2 = 62.7$; $v =$ **7.9** m/s

(c) actual $E_k = \frac{1}{2} \times 50 \times 7.0^2 = 1225$ J; work against friction $= 1568 - 1225 = 343$ J; $F = 343 \div 8.0 =$ **43** N

(d) points to include:

- down: E_p store decreases, E_k store increases; up: E_k back to E_p
- friction and air resistance do work against her motion
- this energy is dissipated to the thermal store of the surroundings, and as sound
- so she has less energy on the second ramp and cannot reach 3.2 m
- to go higher: push off at the start, oil the wheels, or crouch to reduce air resistance

Levels: **5–6** a full, logical answer with correct physics and correct terms; **3–4** several correct points, partly linked; **1–2** one or two relevant points.

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