A-LEVEL PHYSICS • EXERCISE SHEET

5.2 Gravitational potential energy and kinetic energy

Name: _____ Class: _____ Date: _____ **Total: 18 marks**

Objective

Build the skills to answer exam questions on **gravitational potential energy and kinetic energy** —the formulae, their derivations, and energy exchange.

You must be able to:

- use $\Delta E_{\mathrm{P}} = mg\Delta h$ and derive it from $W = Fs$
- use $E_{\mathrm{K}} = \frac{1}{2}mv^2$ and derive it from the equations of motion
- solve problems where GPE and KE exchange

1 Worked examples

Study these first. Each one shows the method for a question type used later —follow the steps and you can do the Practice and Exam-style questions yourself.

GPE change

Lifting mass m slowly through height Δh needs an upward force mg, so the work done (= GPE gained) is

$$\Delta E_{\mathrm{P}} = W = (mg)(\Delta h) = mg\Delta h.$$

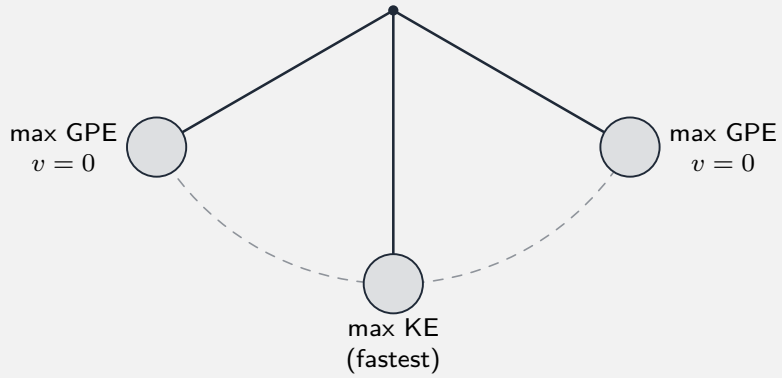
Kinetic energy

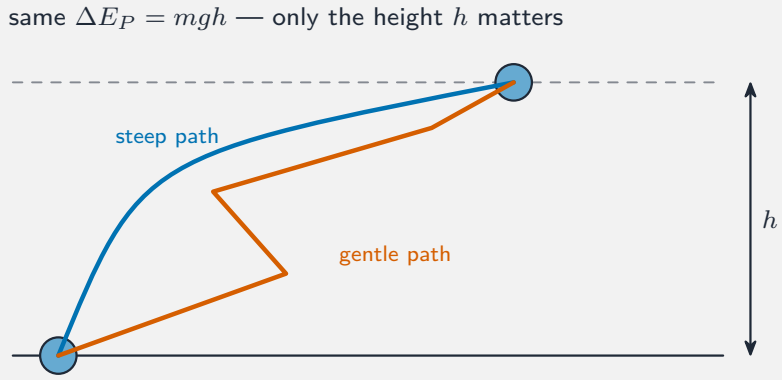
A force F accelerates a mass from rest to speed v over distance s. With $u = 0$, $v^2 = 2as$, so $s = v^2/2a$, and

$$E_{\mathrm{K}} = W = Fs = (ma)\frac{v^2}{2a} = \tfrac{1}{2}mv^2.$$

Energy exchange (pendulum)

A pendulum bob trades GPE and KE: **max GPE** (and $v = 0$) at the ends, **max KE** at the bottom:





GPE depends only on height, not the path

Energy is conserved: $mgh = \frac{1}{2}mv^2$, so the bob's speed at the bottom is $v = \sqrt{2gh}$.

2 Practice

Now apply the methods above.

2.1 Write the formula for **GPE change** and for **kinetic energy**. [2]

2.2 Find the **kinetic energy** of a 1200 kg car moving at 15 m s^{-1}. [2]

2.3 Find the **GPE gained** by a 2.0 kg book lifted 1.5 m ($g = 9.81$ m s^{-2}). [2]

2.4 At the **bottom** of a pendulum swing, which energy is at a maximum? [1]

3 Exam-style questions

3.1 An object's speed **doubles**. Its kinetic energy: [1]

- **A** doubles
- **B** halves
- **C** becomes four times larger
- **D** stays the same

3.2 Derive $E_K = \frac{1}{2}mv^2$ using the equations of motion. [3]

3.3 A 0.50 kg ball is dropped from a height of 1.8 m. Calculate its speed just before it hits the ground (ignore air resistance). [3]

3.4 A pendulum bob is released from a point 0.20 m above its lowest point. Calculate

its **maximum speed**. [2]

3.5 A 0.20 kg ball is dropped from a height of 1.6 m and rebounds to a height of 1.2 m. Calculate the energy **transferred to other forms** during the bounce. [3]

4 Go further

You are now ready for the real exam questions on this subtopic. Open the **5.2 Gravitational PE and kinetic energy** past-paper sheet in the Library, or try these in **Practice mode**:

- 9702/22 N25 —Q6 (GPE and KE exchange)
- 9702/21 N25 —Q1 (energy and motion)
- 9702/24 J25 —Q3 (kinetic energy calculation)
- 9702/11 N25 —Q17 (KE and GPE)

Solutions

2.1 $\Delta E_{\mathrm{P}} = mg\Delta h$; $E_{\mathrm{K}} = \frac{1}{2}mv^2$.

2.2 $E_{\mathrm{K}} = \frac{1}{2}(1200)(15)^2 = 1.35 \times 10^5$ J.

2.3 $\Delta E_{\mathrm{P}} = mg\Delta h = 2.0 \times 9.81 \times 1.5 = 29$ J.

2.4 Kinetic energy.

3.1 C —KE $\propto v^2$, so doubling v makes KE four times larger.

3.2 Work done $W = Fs = mas$; with $u = 0$, $v^2 = 2as \Rightarrow s = v^2/2a$; $W = ma \cdot \dfrac{v^2}{2a} = \frac{1}{2}mv^2 = E_{\mathrm{K}}$.

3.3 $\frac{1}{2}mv^2 = mgh$; $v = \sqrt{2gh} = \sqrt{2 \times 9.81 \times 1.8} = 5.9$ m s^{-1}.

3.4 $v = \sqrt{2gh} = \sqrt{2 \times 9.81 \times 0.20} = 2.0$ m s^{-1}.

3.5 GPE before $= mgh_1 = 0.20 \times 9.81 \times 1.6 = 3.1$ J; GPE after $= mgh_2 = 0.20 \times 9.81 \times 1.2 = 2.4$ J; energy transferred $= 3.1 - 2.4 = 0.79$ J.