A-LEVEL PHYSICS • EXERCISE SHEET

17.2 Energy in simple harmonic motion

Name: ______________ Class: __________ Date: ____________ **Total: 15 marks**

Objective

Build the skills to answer exam questions on **energy in simple harmonic motion**.

You must be able to:

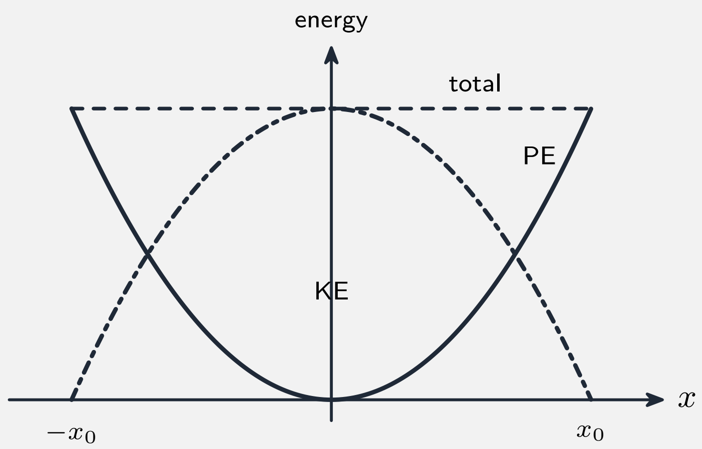
- describe the **KE**   **PE** interchange during SHM
- use $E = \frac{1}{2}m\omega^2 x_0^2$ for the total energy

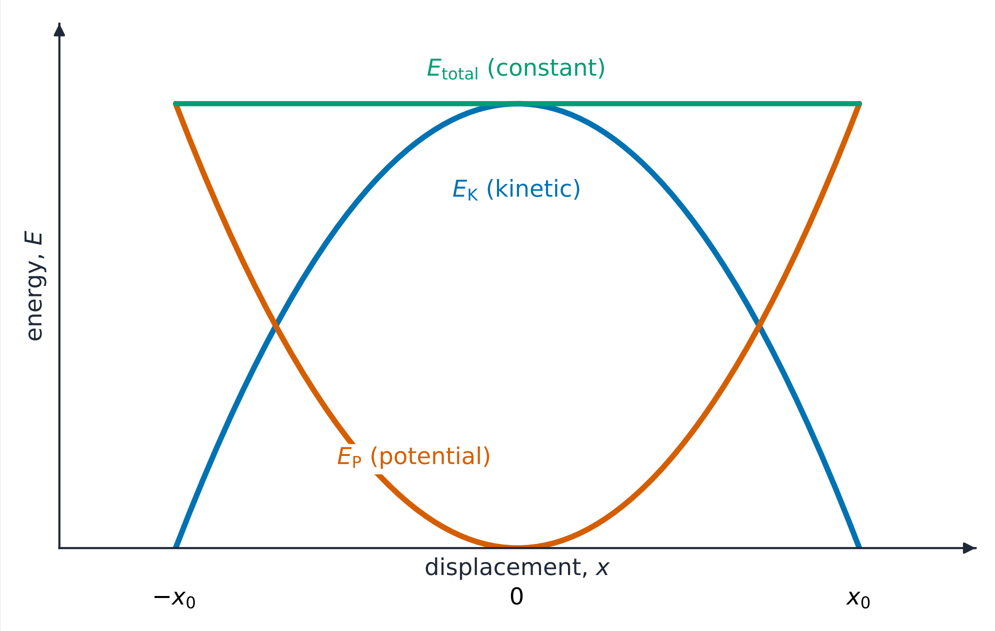
1 Worked examples

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.

■ Energy interchange

KE and PE swap as the oscillator moves; with no damping the **total energy is constant**:





Energy interchange in simple harmonic motion

- at $x = 0$: KE is **maximum**, PE minimum;
- at $x = \pm x_0$: KE $= 0$, PE **maximum**.

■ Total energy

$$E = \tfrac{1}{2}mv_{\max}^2 = \tfrac{1}{2}m\omega^2 x_0^2.$$

So $E \propto x_0^2$ (doubling the amplitude gives **four times** the energy) and $E \propto \omega^2$.

■ Energy varies at twice the frequency

In one full oscillation the object passes through the centre (KE maximum) **twice**, so the **KE and PE vary at twice** the frequency of the displacement. On a graph of KE against **time**, one repeat of the KE pattern takes **half** the oscillation period — so if the KE graph repeats every t_E, the oscillation period is $T = 2t_E$.

2 Practice

Now apply the methods above.

2.1 Describe the **energy interchange** during SHM. [2]

2.2 State where the **kinetic energy** is maximum and where the **potential energy** is maximum. [2]

2.3 Write the formula for the **total energy** of a simple harmonic oscillator. [1]

3 Exam-style questions

3.1 In SHM, the total energy is proportional to: [1]

- **A** the amplitude x_0
- **B** the amplitude squared x_0^2
- **C** $1/x_0$
- **D** the period T

3.2 A 0.20 kg mass oscillates with $\omega = 10$ rad s^{-1} and amplitude 0.050 m. Calculate the **total energy**. [3]

3.3 Sketch how the **kinetic energy** and **potential energy** vary with displacement in SHM. [2]

3.4 State what happens to the total energy if the **amplitude is doubled**. [1]

3.5 A graph of the **kinetic energy** of an oscillator against **time** repeats every 0.40 s.

(a) State the **period** of the oscillation, explaining your answer. [2]

(b) Calculate the **angular frequency** ω of the oscillation. [2]

4 Go further

You are now ready for the real exam questions on this subtopic. Open the **17.2 Energy in simple harmonic motion** past-paper sheet in the Library, or try these in **Practice mode**:

- 9702/44 N25 —Q4 (energy in SHM)
- 9702/42 M25 —Q4 (KE–time graph, ω)
- 9702/43 J25 —Q5 (energy in SHM)

Solutions

2.1 Energy is continually transferred between **kinetic** and **potential** forms; with no damping the **total** stays constant.

2.2 KE is maximum at the **equilibrium** ($x = 0$); PE is maximum at the **extremes** ($x = \pm x_0$).

2.3 $E = \frac{1}{2}m\omega^2 x_0^2$.

3.1 **B** —the amplitude squared.

3.2 $E = \frac{1}{2}m\omega^2 x_0^2 = \frac{1}{2}(0.20)(10)^2(0.050)^2 = 0.025$ J.

3.3 KE: a **downward** parabola, maximum at $x = 0$, zero at $\pm x_0$; PE: an **upward** parabola, zero at $x = 0$, maximum at $\pm x_0$; their sum is constant.

3.4 It becomes **four times** larger ($E \propto x_0^2$).

3.5 (a) The KE varies at **twice** the oscillation frequency (the object passes the centre twice per cycle), so the oscillation period is **twice** the KE-graph period: $T = 2 \times 0.40 = 0.80$ s.

3.5 (b) $\omega = \dfrac{2\pi}{T} = \dfrac{2\pi}{0.80} = 7.9$ rad s^{-1}.