

17.2 Energy in simple harmonic motion

Name: _____ Class: _____ Date: _____ **Total: 29 marks**

KEY WORDS kinetic energy 动能 • damping 阻尼 • displacement 位移 • equilibrium 平衡
• amplitude 振幅

Objective

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

You must be able to:

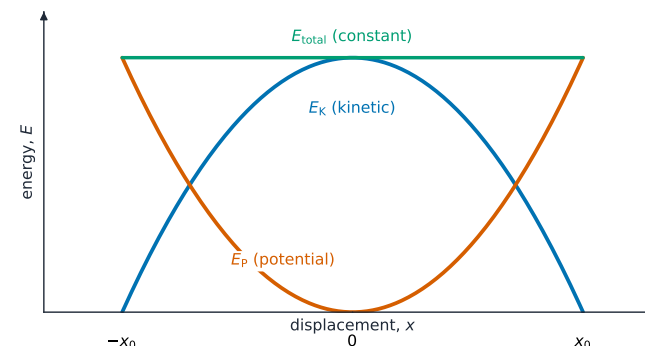
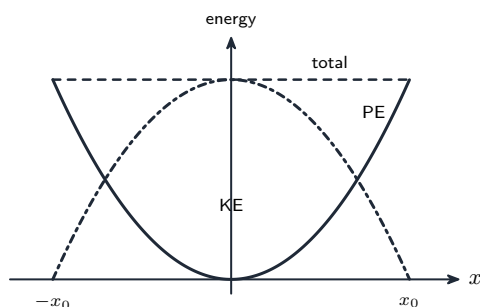
- describe the **KE** ↔ **PE** interchange during SHM
- use $E = \frac{1}{2}m\omega^2x_0^2$ for the total energy

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**:



SHM: $E_k + E_p = \text{const} \cdot \text{max } E_k \text{ at centre}$

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

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

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 | B |
| C | D |
- 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 $\omega = 10 \text{ rad s}^{-1}$ 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]

3.6 A mass hangs on a spring and oscillates vertically with simple harmonic motion. A data logger records its **kinetic energy** against time, giving a curve that repeats every 0.40 s. The mass is 0.25 kg and the amplitude of the oscillation is 4.0 cm.

(a) **Determine** the period of the oscillation of the **mass**, and explain why it is not 0.40 s. [2]

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

(c) **Determine** the total energy of the oscillation. [3]

(d) **Determine** the speed of the mass when its displacement is 2.0 cm. [3]

(e) The oscillation is **lightly damped**. **State and explain** what happens to the time between successive maxima of the kinetic-energy curve, and to the height of those maxima. [3]