

Exercise walk-through

7.4

Energy of Simple Harmonic Oscillators

AP Physics 1

Energy of an oscillator

Energy sloshes between two forms, but the total is constant:

Set by the amplitude

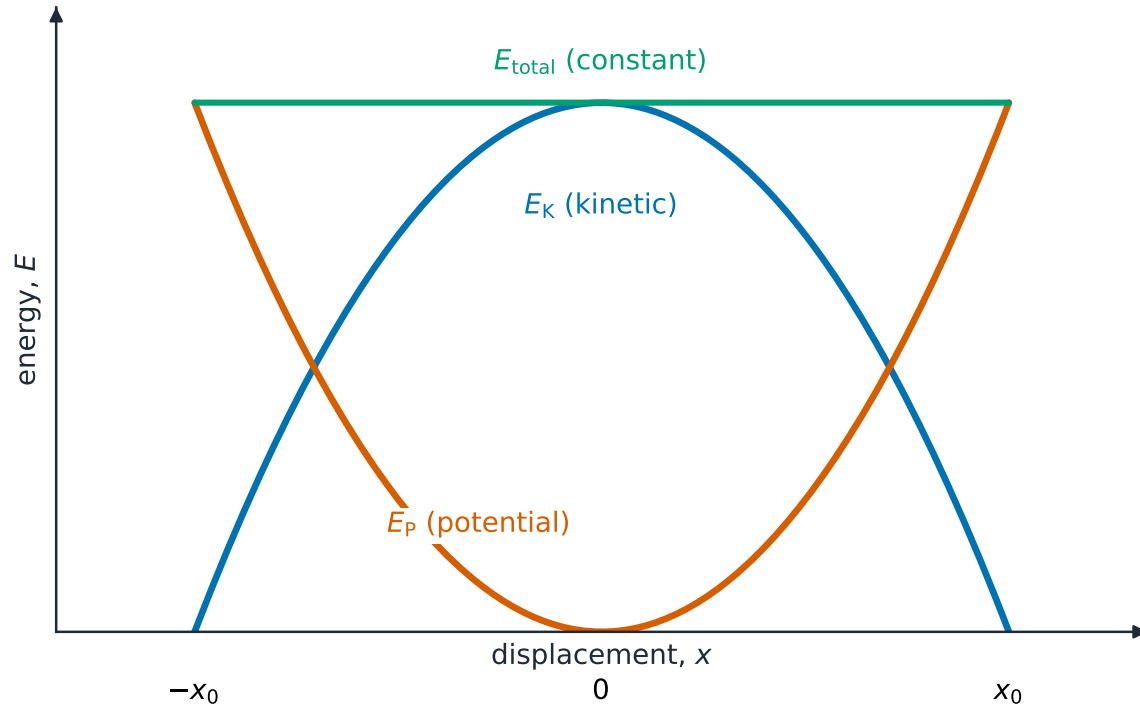
$$E = \frac{1}{2}kA^2$$

- **kinetic energy** greatest in the middle
- **potential energy** greatest at the extremes



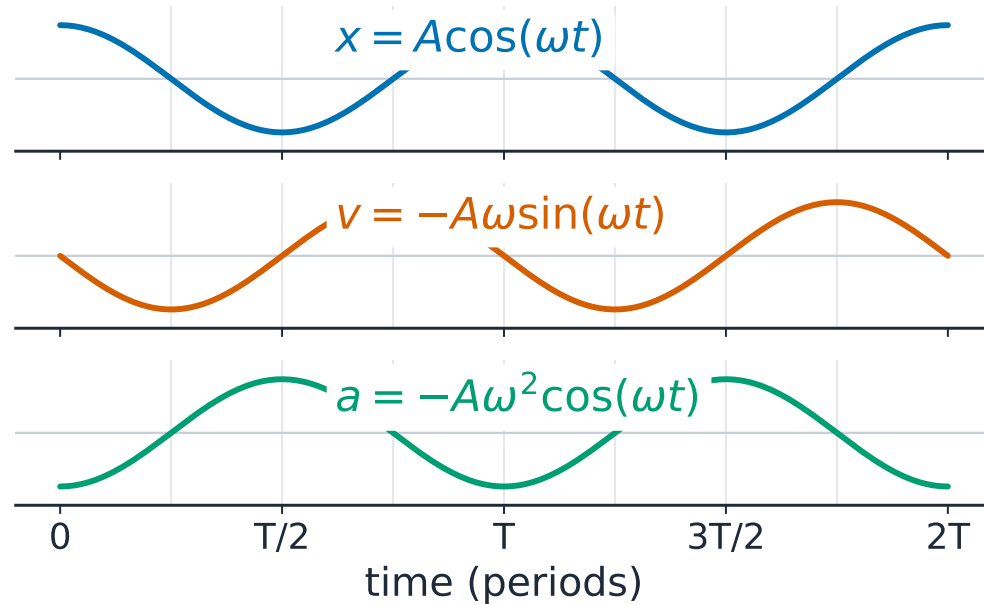
Oscillators store and exchange energy

Energy of an oscillator, continued



Kinetic and potential energy swap over a cycle while the total energy stays constant

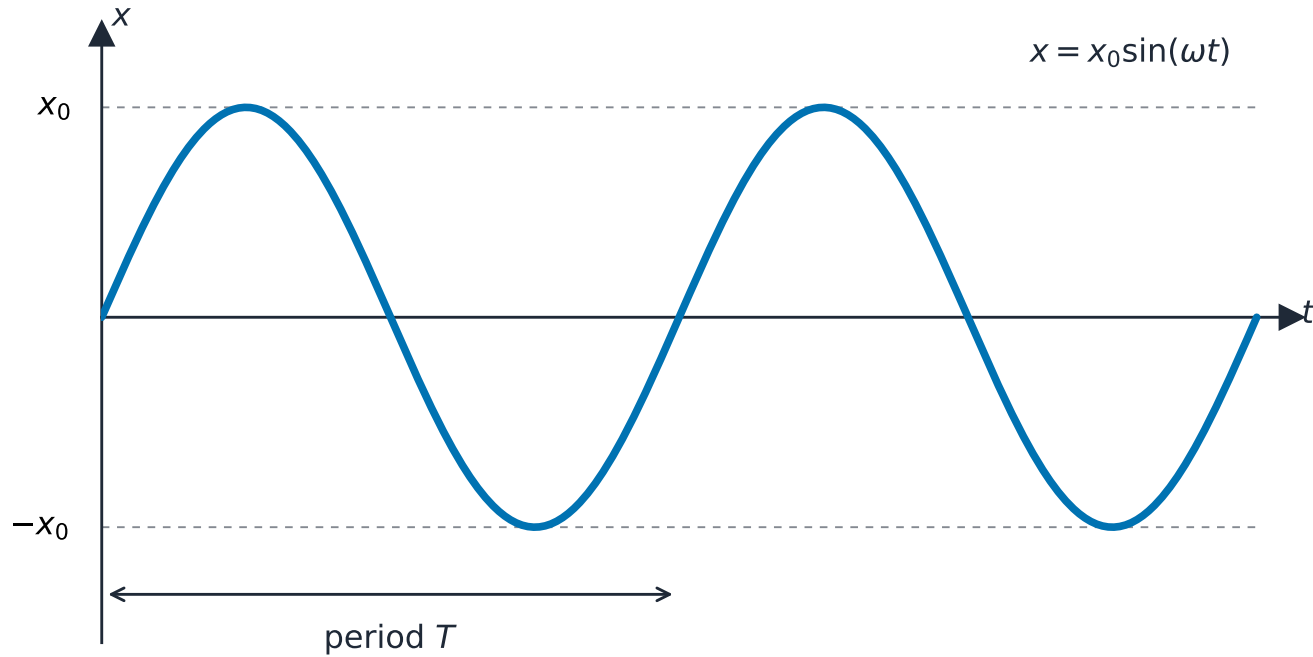
Displacement – one



$a = -\omega^2 x$ · v leads x by $T/4$ · a is in antiphase with x

Displacement, velocity, and acceleration in SHM, each a quarter-cycle apart

Displacement – two



Displacement varies sinusoidally with time in simple harmonic motion

Exam tips

- Test for **SHM**: the acceleration must be proportional to the displacement and directed back toward the middle ($a = -\frac{k}{m}x$).
- The **period does not depend on amplitude** – use $T = 2\pi\sqrt{m/k}$ (spring) or $T = 2\pi\sqrt{L/g}$ (pendulum, small angles).
- Speed is **maximum at the middle** (all kinetic) and **zero at the extremes** (all potential); acceleration is largest at the extremes.
- Use energy ($\frac{1}{2}kA^2 = \frac{1}{2}kx^2 + \frac{1}{2}mv^2$) to find the maximum speed quickly:
 $v_{\max} = A\sqrt{k/m}$.
- Total energy $\propto A^2$, so doubling the amplitude quadruples the energy.

Exercises 2.1-2.3

2.1 A spring of constant 100 N m^{-1} oscillates with amplitude 0.20 m . Find the total energy. [2]

2.2 State where in the motion the kinetic energy is greatest. [1]

2.3 State the potential energy at the amplitude, in terms of the total energy E . [1]

Exercises 2.1-2.3

2.1 A spring of constant 100 N m^{-1} oscillates with amplitude 0.20 m . Find the total energy. [2]

2.1

- $E = \frac{1}{2}kA^2 = \frac{1}{2}(100)(0.20)^2 = 2.0 \text{ J}$

2.2 State where in the motion the kinetic energy is greatest. [1]

2.2

- at the equilibrium position

2.3 State the potential energy at the amplitude, in terms of the total energy E . [1]

2.3

- all of it – E

Exercises 3.1-3.2

3.1 The total energy of a mass-spring oscillator is

[1]

☐

A $\frac{1}{2}kA$

B $\frac{1}{2}kA^2$

C kA^2

D $\frac{1}{2}mA^2$

3.2 At the amplitude of SHM, the energy is entirely

[1]

☐

A kinetic

B potential

C thermal

D zero

Exercises 3.1-3.2

3.1 The total energy of a mass-spring oscillator is

[1]

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A $\frac{1}{2}kA$

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C kA^2

D $\frac{1}{2}mA^2$

3.1 B

- $\frac{1}{2}kA^2$.

3.2 At the amplitude of SHM, the energy is entirely

[1]

☐

A kinetic

B potential

C thermal

D zero

3.2 B

- potential.

Exercise 3.3 (a)

3.3 A 0.50 kg mass on a spring of constant 200 N m^{-1} oscillates with amplitude 0.10 m.

(a) Find the total energy.

[2]

Exercise 3.3 (a)

3.3 A 0.50 kg mass on a spring of constant 200 N m^{-1} oscillates with amplitude 0.10 m.

(a) Find the total energy. [2]

(a)

- $E = \frac{1}{2}(200)(0.10)^2 = 1.0 \text{ J}$

Exercise 3.3 (b)

3.3 A 0.50 kg mass on a spring of constant 200 N m^{-1} oscillates with amplitude 0.10 m.

(b) Find the maximum speed.

[2]

Exercise 3.3 (b)

3.3 A 0.50 kg mass on a spring of constant 200 N m^{-1} oscillates with amplitude 0.10 m.

(b) Find the maximum speed.

[2]

(b)

- at equilibrium all energy is kinetic: $\frac{1}{2}mv^2 = 1.0 \Rightarrow v = \sqrt{\frac{2(1.0)}{0.50}} = 2.0 \text{ m s}^{-1}$