

Oscillations, springs, pendulums and resonance

Physics grades 11-12 (A Level · IB · Class 11-12) · Worksheet

Name: _____ Date: _____ Class: _____

These twenty problems move from reading graphs and using $T = 2\pi\sqrt{m/k}$ to energy, damping and resonance. They suit A Level, IB physics and Class 11-12 students and train unit handling, rearranging equations and checking answers for sense. Problems 16 to 20 combine several ideas.

Level: Physics grades 11-12 (A Level · IB · Class 11-12) · **Curriculum:** IB C.1

Problem 1 Recognising SHM (easy)

Aarav in Pune studies four moving objects. Their accelerations are given in SI units: (A) $a = -16x$, (B) $a = +16x$, (C) $a = -16x^2$, (D) $a = -16$.

1. State which one describes simple harmonic motion and explain why.
2. Calculate the angular frequency and the period for that motion.
3. State the direction of the acceleration when x is positive.

Problem 2 Swing in the park (easy)

Chiamaka counts 15 complete swings of a playground swing in Lagos in 36 s.

1. Calculate the period.
2. Calculate the frequency.
3. Calculate the angular frequency.

Problem 3 Phone vibration motor (easy)

The vibration unit of a phone shakes at 160 Hz.

1. Calculate the angular frequency.
2. Calculate the period in milliseconds.
3. State how many oscillations occur in 0.25 s.

Problem 4 Pendulum in Accra (easy)

Kofi hangs a small steel bob on a string so the distance from the pivot to the centre of the bob is 0.80 m. Take $g = 9.81 \text{ m/s}^2$.

1. Calculate the period for small swings.
2. Calculate the time for 25 complete swings.

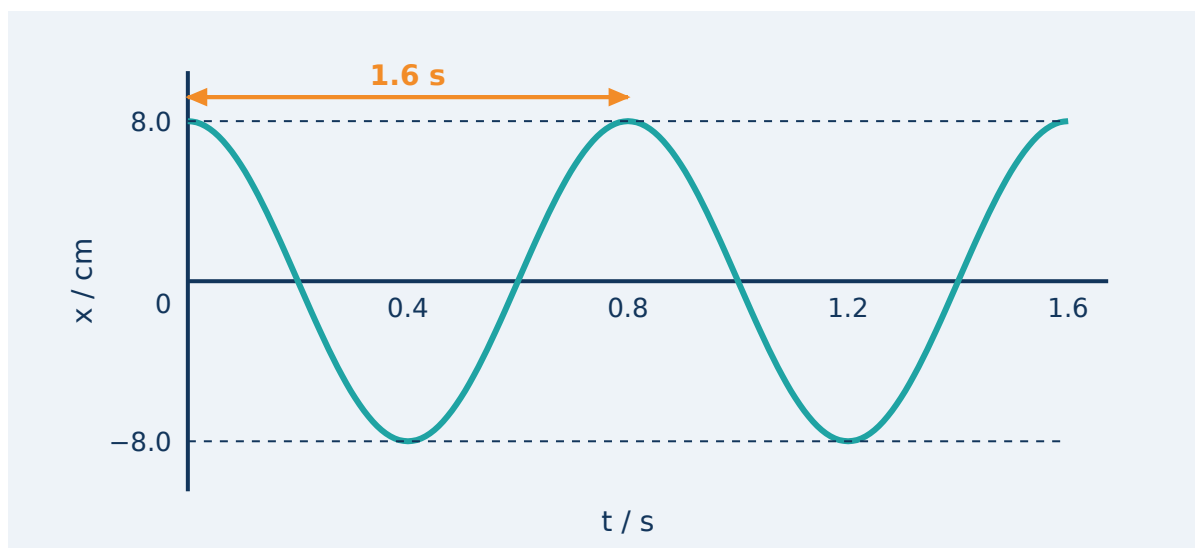
Problem 5 Spring balance (easy)

A mass of 0.40 kg hangs from a spring of stiffness 25 N/m and is pulled down and released.

1. Calculate the period.
2. State what happens to the period if the amplitude is doubled.
3. Calculate the frequency.

Problem 6 Reading a displacement graph (easy)

The graph shows the vertical displacement of a fishing float on a Kenyan lake.



Displacement of a float against time.

1. State the amplitude, in cm.
2. State the period and calculate the frequency.
3. State two times between 0 and 1.6 s when the speed is a maximum.
4. Calculate the maximum speed.

Problem 7 Maximum speed and acceleration (easy)

An oscillator has amplitude 0.030 m and angular frequency 20 rad/s.

1. Calculate its maximum speed.
2. Calculate its maximum acceleration.
3. State where in the motion each maximum occurs.

Problem 8 Stiffness from the period (medium)

A 0.50 kg trolley on a horizontal air track oscillates between two identical springs with a period of 0.90 s. Together the springs act as one spring of stiffness k .

1. Rearrange the period equation to make k the subject.
2. Calculate k .
3. Calculate the period if the trolley mass is increased to 2.0 kg.

Problem 9 Measuring g with a pendulum (medium)

Emma in Leeds times 20 complete swings of a pendulum and records 40.0 s. The length from pivot to the centre of the bob is 0.995 m.

1. Calculate the period.
2. Rearrange $T = 2\pi\sqrt{L/g}$ to give g and calculate its value.
3. Suggest one reason why timing 20 swings is better than timing 1 swing.

Problem 10 Speed at a given displacement (medium)

A float on a rippling pond oscillates with amplitude 5.0 cm and period 0.80 s.

1. Calculate the angular frequency.
2. Calculate the speed when the displacement is 3.0 cm from the centre.
3. Calculate the speed at the centre and compare it with your answer to part 2.

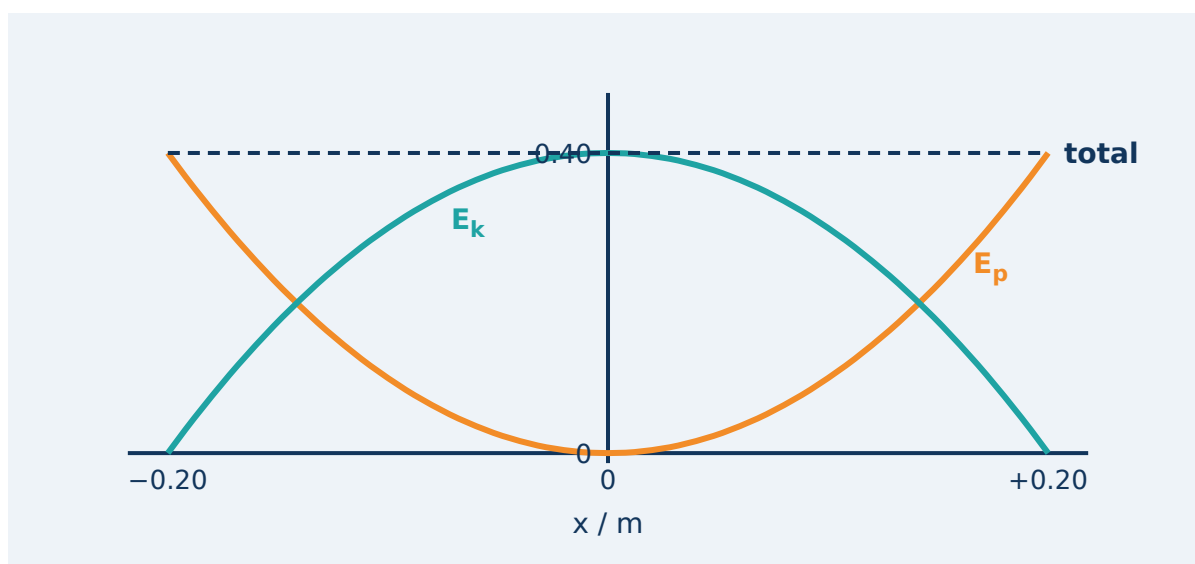
Problem 11 Energy of a spring oscillator (medium)

A 0.30 kg block on a smooth table is attached to a spring of stiffness 60 N/m and oscillates with amplitude 0.10 m.

1. Calculate the total energy.
2. Calculate the maximum speed.
3. Calculate the kinetic energy when the displacement is 0.060 m.

Problem 12 Reading an energy graph (medium)

The graph shows the energy of a spring oscillator in a school lab.



Energy against displacement for a spring oscillator.

1. State the total energy and the amplitude.
2. Calculate the spring stiffness.
3. Calculate the kinetic energy at $x = 0.10$ m.

Problem 13 Hanging mass (medium)

Bilal in Lahore hangs a 0.20 kg mass from a spring. It stretches the spring by 4.9 cm at equilibrium. Take $g = 9.81 \text{ m/s}^2$.

1. Calculate the spring stiffness.
2. Calculate the period of vertical oscillations.
3. Show that the period can also be found from $T = 2\pi\sqrt{e/g}$, where e is the extension.

Problem 14 Displacement at a given time (medium)

A small speaker cone vibrates with displacement $x = A \cos \omega t$, amplitude 4.0 mm and frequency 2.5 Hz.

1. Calculate ω .
2. Calculate the displacement at $t = 0.050 \text{ s}$.
3. Calculate the first time at which the cone is at $x = 0$.

Problem 15 Clock on the Moon (medium)

A pendulum clock beats with a period of 1.00 s on Earth ($g = 9.81 \text{ N/kg}$). It is taken to the Moon, where $g = 1.62 \text{ N/kg}$.

1. Calculate the period on the Moon.
2. Compare this with a mass on a spring of the same mass and stiffness taken to the Moon.
3. Explain the difference.

Problem 16 Two springs combined (hard)

Mei in Singapore has two identical springs, each of stiffness 30 N/m, and a 0.60 kg mass.

1. State the combined stiffness when the springs are connected side by side (parallel) to carry the mass.
2. State the combined stiffness when they are connected end to end (series).
3. Calculate the period of the mass in each arrangement.

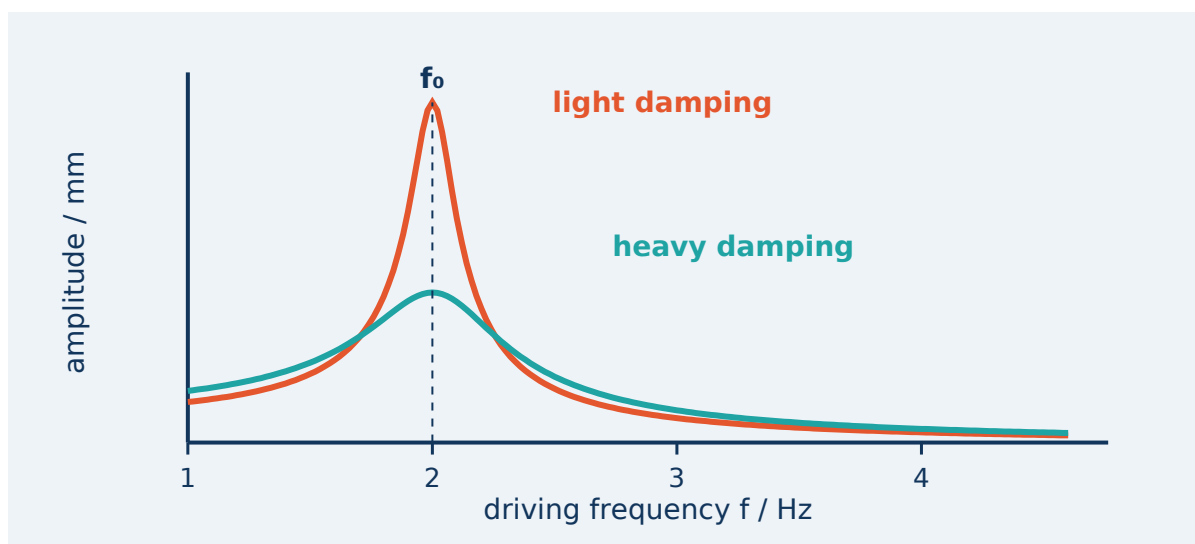
Problem 17 Phone on a shaking shelf (hard)

A phone rests on a shelf that moves vertically in SHM at 2.0 Hz. The amplitude of the shelf is slowly increased.

1. Explain why the phone loses contact when the downward acceleration of the shelf exceeds g .
2. Calculate the amplitude at which the phone just leaves the shelf. Take $g = 9.81 \text{ m/s}^2$.
3. State at which point of the motion the phone leaves the shelf.

Problem 18 Driven oscillator data (hard)

A student drives a spring-mass system with a motor of variable frequency and plots amplitude against driving frequency for light and heavy damping.



Resonance curves for two levels of damping.

1. Read the natural frequency from the graph and calculate the natural period.
2. The oscillating mass is 0.25 kg. Calculate the spring stiffness.
3. Describe the effect of heavier damping on the peak.
4. Predict the amplitude of the system when driven at 4 Hz compared with the amplitude at 2 Hz.

Problem 19 Decaying swings (hard)

The amplitude of a damped oscillation falls by 5.0 % every complete cycle. The initial amplitude is 8.0 cm. Energy is proportional to amplitude squared.

1. Calculate the amplitude after 10 cycles.
2. Calculate the percentage of the initial energy lost after 10 cycles.
3. Calculate the number of cycles for the energy to halve.

Problem 20 Putty on the block (hard)

A 2.0 kg block on a smooth horizontal surface is fixed to a spring of stiffness 200 N/m and oscillates with amplitude 0.15 m. As it passes through the equilibrium position, a 1.0 kg lump of putty drops on to it and sticks.

1. Calculate the speed of the block just before the putty lands.
2. Calculate the speed just after.
3. Calculate the new amplitude and the new period.