IB DP PHYSICS

Theme C · Wave Behaviour

TOPICAL WORKSHEET

C.1 Simple Harmonic Motion · C.2 Wave Model · C.3 Wave Phenomena
C.4 Standing Waves and Resonance · C.5 Doppler Effect

Standard and Higher Level · Syllabus 2025

Fahad H. Ahmad

+92 323 509 4443 | Megalecture.com

Original exam-style questions written for the IB Diploma Programme Physics course (first assessment 2025)

Section A — Multiple Choice (15 marks)

Circle the letter of the best answer to each question. Each question is worth 1 mark.

1. In simple harmonic motion, the acceleration of the oscillator is always **[1]**

A constant in magnitude and direction

B directed away from the equilibrium position, proportional to displacement

C directed towards the equilibrium position, proportional to displacement

D zero at the extremes of the oscillation

2. A 0.50 kg mass on a spring of force constant k = 20 N m^{-1} oscillates in SHM. What is the period of oscillation? **[1]**

A 0.16 s

B 0.50 s

C 0.99 s

D 3.14 s

3. An SHM oscillator with force constant k = 20 N m^{-1} has amplitude 0.10 m. What is its total mechanical energy? **[1]**

A 0.020 J

B 0.10 J

C 0.20 J

D 2.0 J

4. A wave has frequency 50 Hz and wavelength 0.020 m. What is its speed? **[1]**

A 0.40 m s^{-1}

B 1.0 m s^{-1}

C 2.5 m s^{-1}

D 1000 m s^{-1}

5. In a longitudinal wave, the direction of particle oscillation is **[1]**

A parallel to the direction of energy transfer

B perpendicular to the direction of energy transfer

C always vertical, regardless of the direction of travel

D random, with no fixed relationship to the direction of travel

6. Two electromagnetic waves, one of frequency 100 MHz and one of frequency 100 THz, both travel through a vacuum. Which statement is correct? **[1]**

A The higher-frequency wave travels faster

B The lower-frequency wave travels faster

C Both waves travel at the same speed, c

D Their relative speed depends on their amplitudes

7. A light ray travels from air (n = 1.00) into water (n = 1.33) at an angle of incidence of 30°. What is the angle of refraction? **[1]**

A 22.1°

B 30.0°

C 39.7°

D 41.8°

8. Diffraction effects (significant spreading of a wave around an obstacle or through a gap) are most pronounced when **[1]**

A the wavelength is much smaller than the size of the gap or obstacle

B the wavelength is comparable to, or larger than, the size of the gap or obstacle

C the wave has a very high frequency

D the wave is travelling through a vacuum

9. Two coherent light sources illuminate a screen. At a point where the path difference between the two waves is a whole number of wavelengths ($n\lambda$), the interference is **[1]**

A always destructive

B always constructive

C neither, it depends on the intensities only

D destructive only if n is even

10. A string of length 0.50 m, fixed at both ends, carries transverse waves at 200 m s^{-1}. What is its fundamental frequency? **[1]**

A 100 Hz

B 200 Hz

C 400 Hz

D 800 Hz

11. At a node in a standing wave, the amplitude of oscillation of the medium is **[1]**

A at its maximum value

B zero

C equal to the amplitude of each component travelling wave

D dependent on the driving frequency only

12. Which harmonics can be present in an air column in a pipe that is closed at one end and open at the other? **[1]**

A All integer harmonics (1st, 2nd, 3rd, ...)

B Only even harmonics (2nd, 4th, 6th, ...)

C Only odd harmonics (1st, 3rd, 5th, ...)

D Only the fundamental (1st harmonic)

13. A source of sound (f_0 = 1000 Hz) moves towards a stationary observer at 20 m s^{-1} through still air (speed of sound = 340 m s^{-1}). What frequency does the observer hear? **[1]**

A 943.8 Hz

B 1000 Hz

C 1062.5 Hz

D 1200 Hz

14. The Doppler effect (a shift in observed frequency) for sound waves arises because **[1]**

A the speed of sound changes when the source moves

B relative motion between source and observer changes the wavelength (or the rate of wavefront arrival) received by the observer

C sound waves slow down as they travel further from the source

D the observer's ear physically compresses at high frequencies

15. Light from a distant galaxy is observed to have a longer wavelength (redshifted) than the same spectral lines measured in a laboratory. This indicates that the galaxy is **[1]**

A moving towards Earth

B stationary relative to Earth

C moving away from Earth

D rotating, with no radial motion

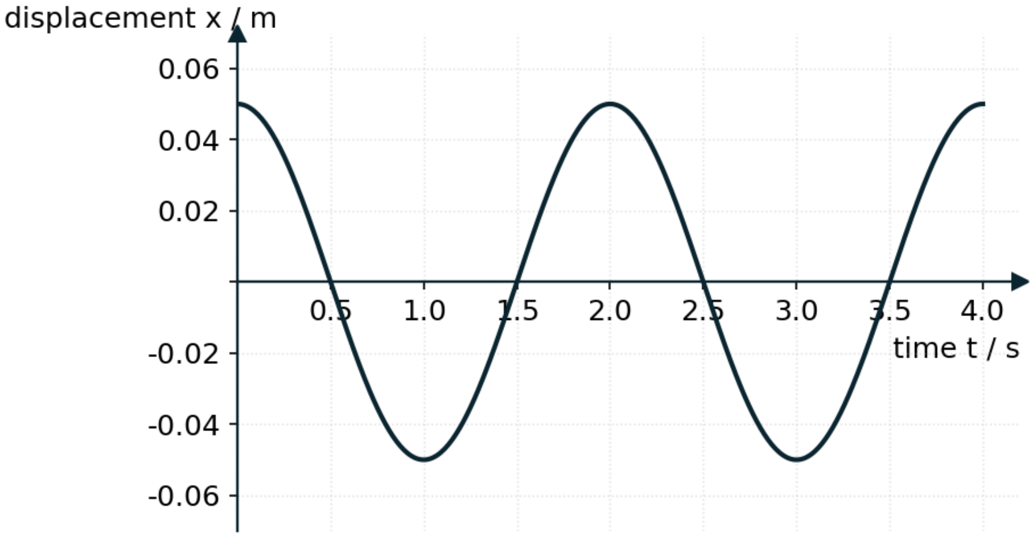
Section B — Structured Questions (66 marks)

Answer all questions in the space provided. Working must be shown for full marks.

C.1 Simple Harmonic Motion

Question 1 [6 marks]

A small object undergoes simple harmonic motion. The graph shows its displacement x from the equilibrium position as a function of time t.



Displacement–time graph for the SHM oscillator (amplitude and period are the given data for this question).

(a) Use the graph to determine the amplitude and period of the oscillation, and hence calculate the angular frequency ω. **[2]**

(b) Calculate the maximum speed of the object during the oscillation. **[2]**

(c) Calculate the magnitude of the maximum acceleration of the object. **[2]**

Question 2 [6 marks]

A simple pendulum of length 0.80 m swings with amplitude 0.030 m and bob mass 0.20 kg. Take g = 9.8 m s^{-2}. For small oscillations, a simple pendulum undergoes approximately simple harmonic motion with $T = 2\pi\sqrt{(L/g)}$.

(a) Calculate the period of oscillation of the pendulum. **[2]**

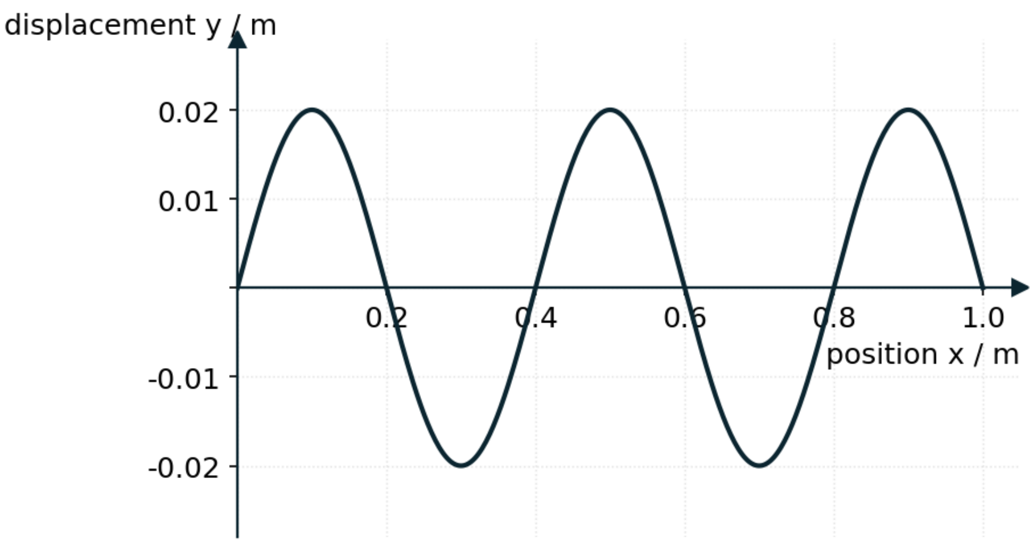
(b) Calculate the maximum speed of the pendulum bob as it swings through the equilibrium position. **[2]**

(c) Calculate the maximum kinetic energy of the bob during the swing. **[2]**

C.2 Wave Model

Question 3 [7 marks]

A transverse wave travels along a stretched string. The graph shows a snapshot of the string's shape at one instant. The wave source oscillates at a frequency of 5.0 Hz.



Displacement–position snapshot of the wave (wavelength and amplitude are given data).

(a) Read the wavelength from the graph, and calculate the speed of the wave. **[2]**

(b) Calculate the period of oscillation of a particle on the string. **[2]**

(c) Calculate the maximum transverse speed of a particle on the string as the wave passes. **[3]**

Question 4 [6 marks]

A small point source radiates sound energy uniformly in all directions. At a distance of 2.0 m from the source, the intensity is 20 W m^{-2}.

(a) State how intensity varies with distance from a point source, and hence calculate the intensity at a distance of 6.0 m. **[3]**

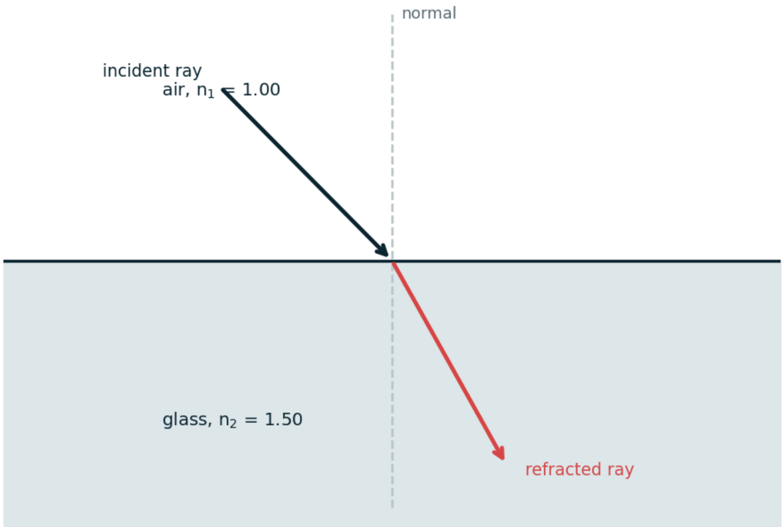
(b) Calculate the total power radiated by the source. **[3]**

C.3 Wave Phenomena

Question 5 [7 marks]

A ray of light travelling in air (n_1 = 1.00) is incident on a glass surface (n_2 = 1.50) at an angle of incidence of 40°, as shown.

Refraction of a light ray at an air–glass boundary



Refraction of the ray as it enters the glass.

(a) State Snell's law, and use it to calculate the angle of refraction in the glass. **[3]**

(b) Calculate the critical angle for total internal reflection at this glass–air boundary. **[3]**

(c) State what happens to a ray travelling from glass into air at an angle of incidence greater than the critical angle. **[1]**

Question 6 [6 marks]

In a Young's double-slit experiment, the slit separation is 5.0×10^{-4} m and the screen is 2.0 m from the slits. Red light of wavelength 6.0×10^{-7} m is used.

(a) Calculate the fringe spacing observed on the screen. **[2]**

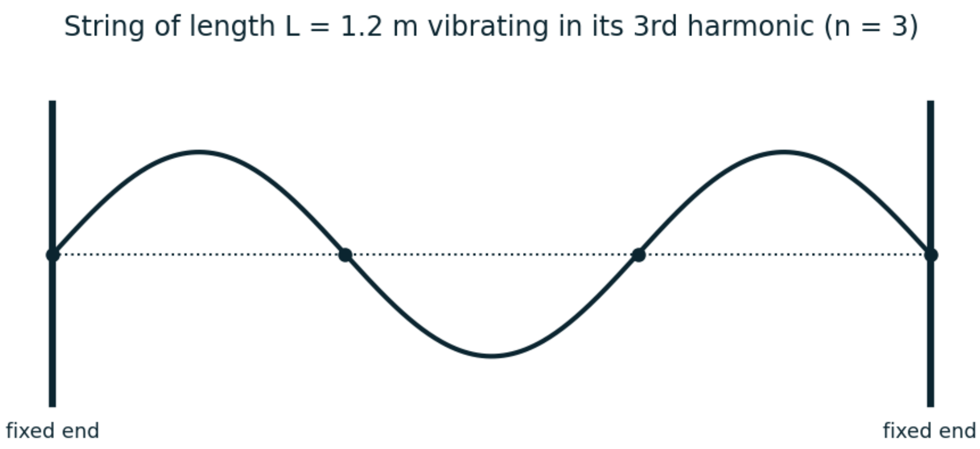
(b) The red light is replaced with blue light of wavelength 4.5×10^{-7} m, with d and D unchanged. Calculate the new fringe spacing. **[2]**

(c) State one condition necessary for the two slits to produce a stable (observable) interference pattern. **[2]**

C.4 Standing Waves and Resonance

Question 7 [7 marks]

A string of length L = 1.2 m, fixed at both ends, is set vibrating in the pattern shown, corresponding to its 3rd harmonic (n = 3). The transverse wave speed on the string is 40 m s^{-1}.



Standing wave pattern for the 3rd harmonic on the fixed string.

(a) Determine the wavelength of the standing wave pattern shown. **[2]**

(b) Calculate the frequency of this 3rd-harmonic oscillation. **[2]**

(c) Calculate the fundamental frequency (1st harmonic, n = 1) of the string, and state the relationship between the harmonic frequencies. **[3]**

Question 8 [7 marks]

A tube of air, closed at one end and open at the other, has length 0.85 m. The speed of sound in air is 340 m s^{-1}. For a pipe closed at one end, $\lambda_n = 4L/n$ for odd n only.

(a) Calculate the wavelength and frequency of the fundamental (1st harmonic) note produced by the tube. **[3]**

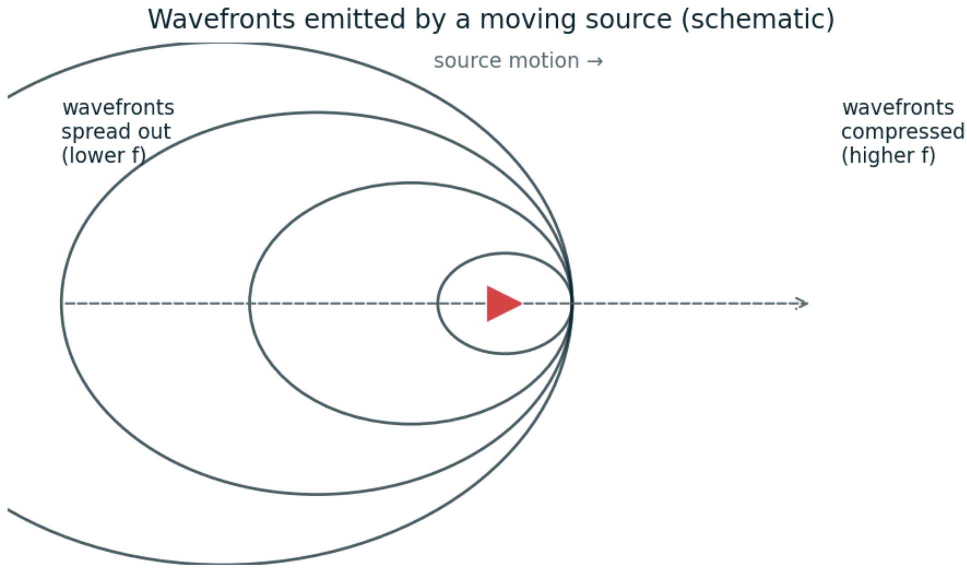
(b) Calculate the frequency of the next higher resonant note (the next harmonic) the tube can produce. **[2]**

(c) State the boundary conditions on displacement that apply at the closed end and at the open end of the tube. **[2]**

C.5 Doppler Effect

Question 9 [8 marks]

A police siren emits sound at a source frequency f_0 = 500 Hz. The car moves at a constant speed of 30 m s^{-1} through still air, in which the speed of sound is 340 m s^{-1}. The diagram shows the resulting wavefront pattern.



Wavefronts emitted by the moving source are compressed ahead of it and spread out behind it.

(a) Calculate the frequency heard by a stationary observer that the car is approaching. **[3]**

(b) Calculate the frequency heard by a stationary observer that the car has just passed and is now moving away from. **[3]**

(c) State whether the wavelength directly in front of the moving source is longer or shorter than the source's stationary wavelength, and explain why. **[2]**

Question 10 [6 marks]

A particular spectral line of hydrogen has a laboratory (rest-frame) wavelength of 656.3 nm. The same line, observed in the spectrum of a distant galaxy, is measured at 661.1 nm. Take $c = 3.0 \times 10^8$ m s^{-1}.

(a) Calculate the wavelength shift, Δλ, between the observed and laboratory wavelengths. **[2]**

(b) Using the non-relativistic Doppler approximation $\Delta\lambda/\lambda = v/c$, calculate the recession velocity of the galaxy. **[2]**

(c) State whether the galaxy is moving towards or away from Earth, and explain how you know. **[2]**