Rewarding Learning

**ADVANCED SUBSIDIARY (AS)**
**General Certification of Education**
**2023**

**Centre Number**

**Candidate Number**

# Physics

## Assessment Unit AS 2
*assessing*
## Module 2: Waves, Photons and Astronomy

## [SPH21]

*SPH21*

## WEDNESDAY 24 MAY, AFTERNOON

**TIME**

1 hour 45 minutes.

**INSTRUCTIONS TO CANDIDATES**

Write your Centre Number and Candidate Number in the spaces provided at the top of this page.
**You must answer the questions in the spaces provided.**
**Do not write outside the boxed area on each page or on blank pages.**
Complete in black ink only. **Do not write with a gel pen.**
Answer **all ten** questions.

**INFORMATION FOR CANDIDATES**

The total mark for this paper is 100.
Figures in brackets printed down the right-hand side of pages indicate the marks awarded to each question or part question.
Your attention is drawn to the Data and Formulae Sheet which is inside this question paper.
You may use an electronic calculator.

13548

**1** **(a)** Water waves are classified as transverse waves.

**(i)** State another example of a transverse wave.

_____ [1]

**(ii)** State an example of a longitudinal wave.

_____ [1]

**(iii)** With reference to the motion of the particles of the medium through which the wave passes, what distinguishes a transverse wave from a longitudinal wave?

_____

_____

_____ [3]

**(b)** A graph of displacement against time for a water wave is shown in **Fig. 1.1**.

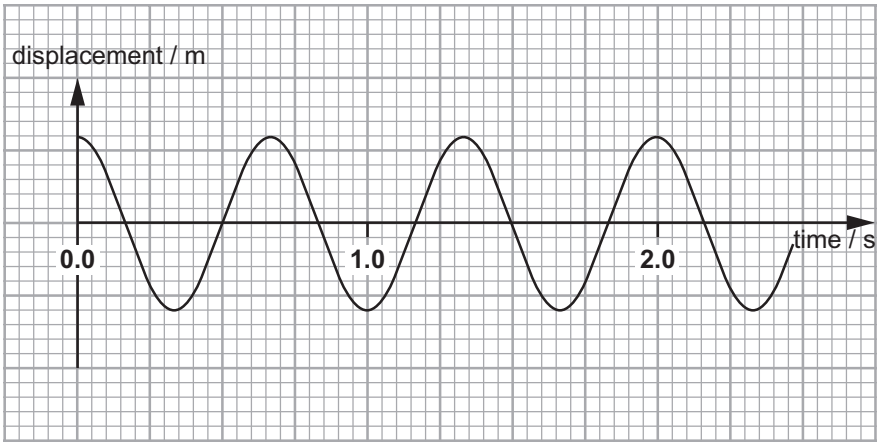


**Fig. 1.1**

**(i)** On **Fig. 1.1**, label the amplitude A of the wave. [1]

**(ii)** Use the graph in **Fig. 1.1** to determine an accurate value for the period of the wave.

Period = _____ s [2]

**(iii)** The wave is travelling at a speed of 3.50 m $s^{-1}$. Calculate the wavelength of the wave.

Wavelength = _____ m [3]

**(iv)** On **Fig. 1.1**, draw a wave of the same amplitude and period but 90° out of phase with the wave shown. [2]

**[Turn over**



**2** Describe an investigation that will allow you to accurately determine the focal length of a converging lens using a graphical method.

Include in your answer:

- a labelled sketch of the apparatus required;
- the measurements which should be taken;
- the graph that you would draw using your results;
- how the graph is used to find an accurate value for the focal length of the lens.

**(a)** A labelled sketch of the apparatus required:

[2]

**(b)** The measurements which should be taken;

[3]

**(c)** The graph you would draw using your results;

_____

_____ [1]

**(d)** How the graph is used to find an accurate value for the focal length of the lens.

_____

_____

_____ [2]

**[Turn over**

**3** **(a)** Explain the difference between Doppler red-shift and cosmological red-shift of light from distant galaxies. Refer to the source and the observer in each case.

_____

_____

_____

_____

_____ [2]

**(b)** The spectrum of light from a distant galaxy contains a spectral line of wavelength 398.6 nm. The same line, when measured in the laboratory, has a wavelength of 393.3 nm.

**(i)** Calculate the recession speed of the galaxy. Give your answer to three significant figures.

Recession speed = _____ m $s^{-1}$ [3]

**(ii)** Use Hubble's law to estimate the distance to this galaxy.

Distance = _____ m [2]

**(iii)** Why is this considered to be an estimate of the distance?

_____

_____ [1]

**[Turn over**

**4** The wavelength of monochromatic laser light can be calculated using Young's double-slit interference experiment. An arrangement for carrying out the experiment is shown in **Fig. 4.1**.

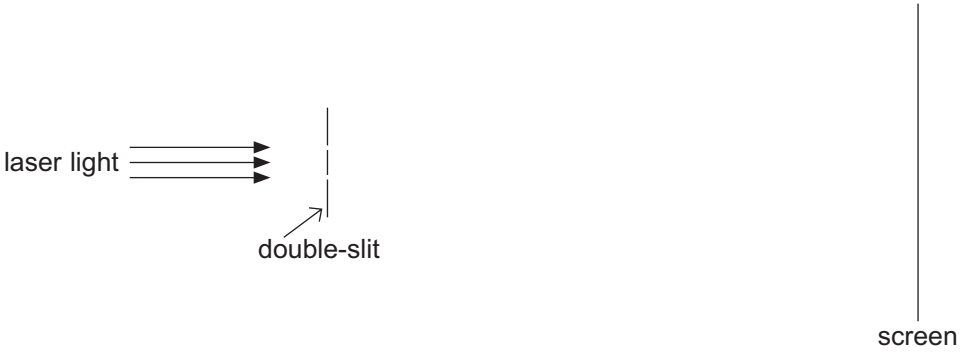


**Fig. 4.1**

**(a)** The light emerging from a laser is coherent. Explain what is meant by coherent in this context.

_____

_____ [1]

In one such experiment, the interference pattern of bright and dark fringes, shown in **Fig. 4.2**, is observed on a screen placed 2.50 m from the double-slit. The separation of the slits is 0.27 mm.

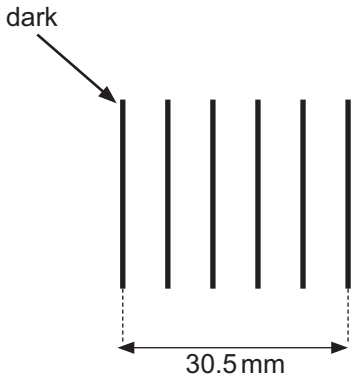


**Fig. 4.2**

**(b)** Use the data to calculate the wavelength of the laser light.

Wavelength = _____ m [4]

**[Turn over**

**5** **(a)** A person uses 'reading glasses' in order to correct hypermetropia (long sight). Each lens has a power +2.0 dioptres. While wearing the glasses, the person's near point is 25 cm.

**(i)** Show that the focal length of each lens in the glasses is +50 cm.

[2]

**(ii)** When an object is placed at a distance of 25 cm from the glasses, describe the image produced.

_____

_____

_____ [3]

**(iii)** Complete **Table 5.1** to show the range of vision with and without the glasses. Show any calculations in the space below.

**Table 5.1**

| | **near point** | **far point** |
|---|---|---|
| without the glasses | _____ cm | infinity |
| with the glasses | 25 cm | _____ cm |

[3]

**(b)** **Fig. 5.2** shows a diverging lens with an object OA placed perpendicular to the principal axis. The points F and F' are the principal foci of the lens.

On **Fig. 5.2**, draw suitable construction rays to locate the image of OA. Label the image IB. Show a suitable position of the eye for viewing the image.

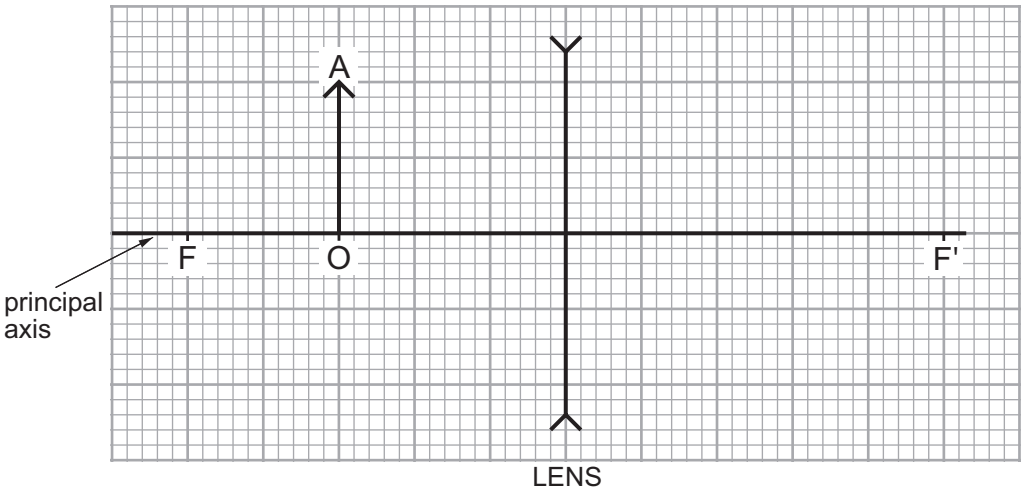


**Fig. 5.2**

[5]

**[Turn over**

**6** **(a)** Explain what is meant by the photoelectric effect.

_____

_____

_____

_____ [3]

**(b)** A piece of zinc metal is represented in **Fig. 6.1**. It contains fixed ions and delocalised electrons as shown. The threshold frequency of zinc is $1.04 \times 10^{15}$ Hz.

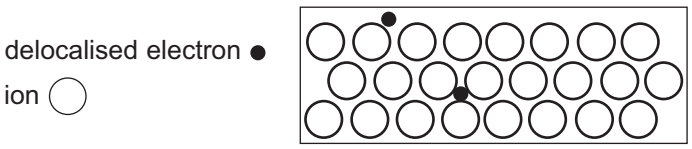


**Fig. 6.1**

**(i)** Calculate the work function of zinc, giving your answer in eV.

Work function = _____ eV [4]

**(ii)** When a piece of zinc is illuminated by radiation of a single frequency, the emitted particles have a range of kinetic energies. Explain why this is the case.

_____

_____

_____

_____ [2]

**[Turn over**

**7** A simplified energy level diagram for an atom of hydrogen is shown in **Fig. 7.1**.

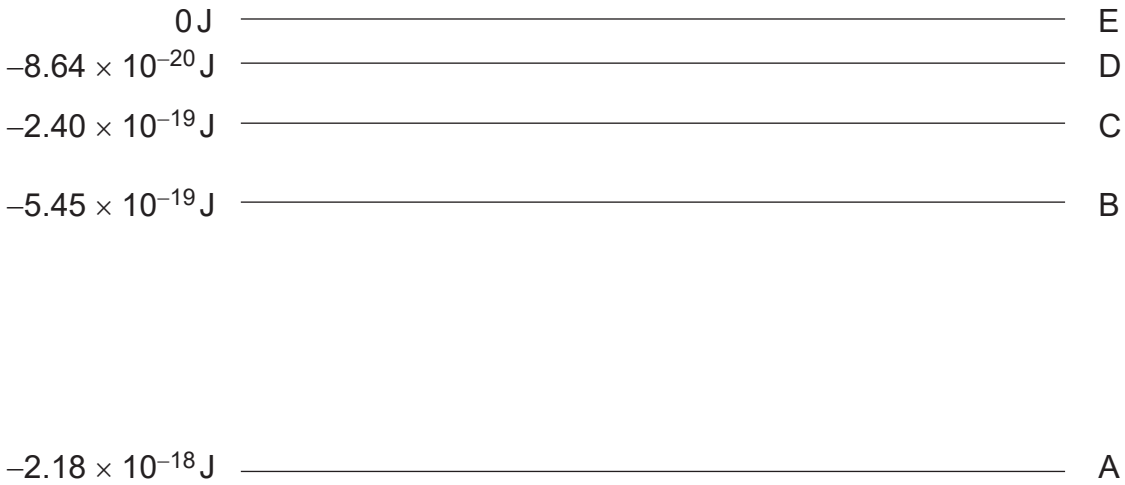


**Fig. 7.1**

**(a)** Explain why the energy levels have negative values.

_____

_____ [2]

**(b)** An electron can move between energy levels within the atom.

**(i)** If a photon of wavelength 652 nm is emitted, between which energy levels has the electron moved?

Electron moved from _____ to _____ [5]

**(ii)** An electron in level A is struck by a photon of energy $1.75 \times 10^{-18}$ J. State which transition might occur, if any, and why?

_____

_____ [2]

**(c)** Electron transitions between energy levels are involved in the production of X-rays for medical imaging. This is a result of high energy electrons striking a metal anode.

**(i)** What do the letters CT represent in CT scanning?

_____ [1]

**(ii)** State three differences between CT scanning and conventional X-ray imaging.

_____

_____

_____

_____

_____ [3]

**[Turn over**

**8** **(a)** Calculate **(i)** the momentum and **(ii)** the velocity of an electron with a de Broglie wavelength $3.17 \times 10^{-11}$ m.

**(i)** Momentum = _____ kg m $s^{-1}$ [2]

**(ii)** Velocity = _____ m $s^{-1}$ [2]

**(b)** Diffraction is the name given to the spreading of waves after they pass through an opening. What is the condition under which maximum diffraction occurs?

_____

_____ [1]

**(c)** In an experiment to demonstrate electron diffraction, a narrow beam of electrons is directed at a thin metal foil.

**(i)** The beam of electrons is produced by an 'electron gun', where a high voltage is applied between a cathode and an anode in order to accelerate the electrons.
Describe and explain the effect on the diffraction pattern when the accelerating voltage is increased.

_____

_____

_____

_____ [2]

**(ii)** In this demonstration, the thin foil acts as a diffraction grating. What is the effective number of lines per mm if the second order diffraction occurs at an angle of 40°?
The de Broglie wavelength of the electron is $3.17 \times 10^{-11}$ m.

Lines per mm _____ [4]

**[Turn over**

**9** **(a)** State Snell's law of refraction.

_____

_____

_____ [2]

**(b)** In an experiment to verify Snell's law, the path of a ray of light was traced as it passed from air through a rectangular glass block and out into the air. This is shown in **Fig. 9.1**.

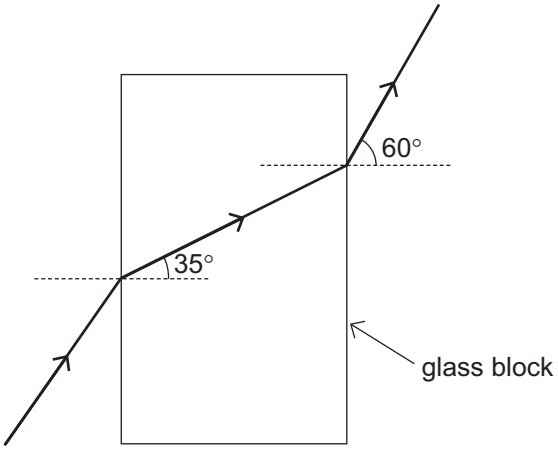


**Fig. 9.1**

Use the angles given to show that the refractive index of the glass is 1.51.

[2]

**(c)** A ray of monochromatic light passing through a section of an optical fibre is shown in **Fig. 9.2**. The ray travels from air into the core material with an incident angle A.
The core material is glass of refractive index 1.51 and the cladding material surrounding the core is of refractive index 1.45.
The ray is incident on the core–cladding boundary at the critical angle C for this pair of materials.

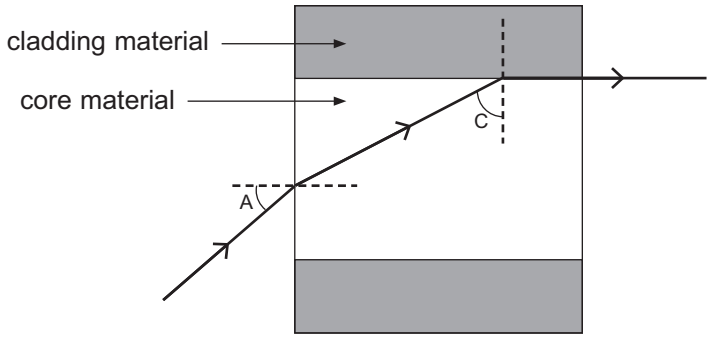


**Fig. 9.2**

**(i)** What is the speed of light in the core material?

Speed = _____ m $s^{-1}$ [3]

**(ii)** What is the refractive index for light travelling from the core to the cladding?

Refractive index = _____ [3]

**[Turn over**

**10** The speed of sound was measured using a resonance tube arrangement as shown in **Fig. 10.1**. A loudspeaker was placed above the open end of the tube. The length L of the tube is 75 cm. The signal frequency was raised from 0 Hz until an exceptionally loud sound was heard for the first time. This frequency is called the fundamental frequency $f_o$.

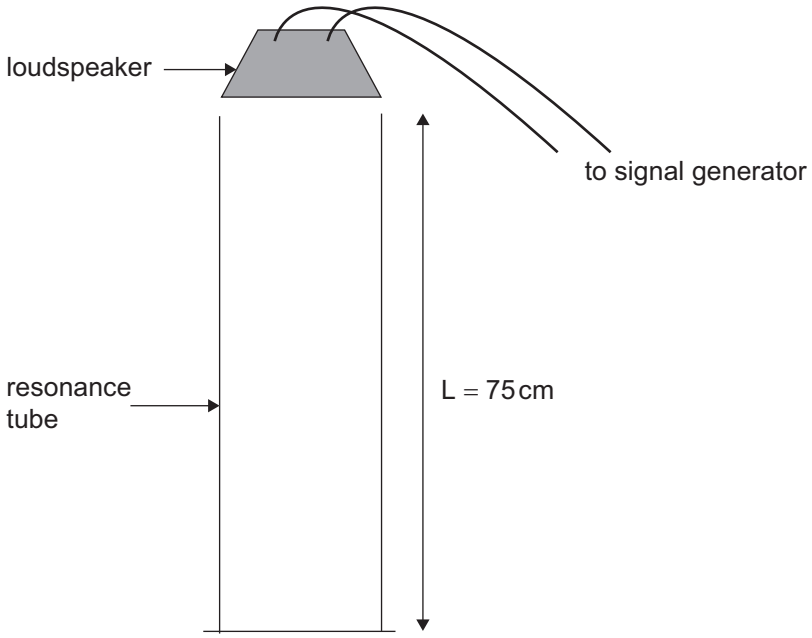


**Fig. 10.1**

**(a)** Resonance is the effect which results in an exceptionally loud sound being heard. Explain why resonance occurs.

_____

_____

_____ [2]

**(b)** The method described will identify the first position of resonance.

**(i)** On **Fig. 10.1** label the position of a node with the letter N and the position of an antinode with the letter A for the first position of resonance. [1]

**(ii)** Describe how the air particles in the resonance tube are behaving at N and A.

N _____

A _____ [2]

**(iii)** The fundamental frequency $f_o$ is 114 Hz when the first position of resonance is identified. Use this information to calculate the speed of sound in air.

Speed = _____ $m\ s^{-1}$ [3]

**(iv)** The frequency is increased from 114 Hz until the next position of resonance is identified. Calculate the frequency at which this will occur.

Frequency = _____ Hz [2]

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| For Examiner's use only | |
|---|---|
| **Question Number** | **Marks** |
| 1 | |
| 2 | |
| 3 | |
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| 7 | |
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| 9 | |
| 10 | |
| **Total Marks** | |

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# Physics

Assessment Units AS 1 and AS 2

**[SPH11/SPH21]**

# DATA AND FORMULAE SHEET

# Data and Formulae Sheet for AS 1 and AS 2

## Values of constants

| | |
|---|---|
| speed of light in a vacuum | $c = 3.00 \times 10^{8}$ m s$^{-1}$ |
| elementary charge | $e = 1.60 \times 10^{-19}$ C |
| the Planck constant | $h = 6.63 \times 10^{-34}$ J s |
| mass of electron | $m_e = 9.11 \times 10^{-31}$ kg |
| mass of proton | $m_p = 1.67 \times 10^{-27}$ kg |
| acceleration of free fall on the Earth's surface | $g = 9.81$ m s$^{-2}$ |
| electron volt | 1 eV $= 1.60 \times 10^{-19}$ J |
| the Hubble constant | $H_0 \approx 2.4 \times 10^{-18}$ s$^{-1}$ |

## Useful formulae

The following equations may be useful in answering some of the questions in the examination:

## Mechanics

| | |
|---|---|
| conservation of energy | $\frac{1}{2}mv^2 - \frac{1}{2}mu^2 = Fs$ for a constant force |

## Waves

| | |
|---|---|
| two-source interference | $\lambda = \frac{ay}{d}$ |
| diffraction grating | $d \sin\theta = n\lambda$ |

## Light

lens equation $\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$

## Electricity

terminal potential difference $V = E - Ir$ (e.m.f., $E$; Internal Resistance, $r$)

potential divider $V_{out} = \frac{R_1 V_{in}}{R_1 + R_2}$

## Particles and photons

Einstein's equation $\frac{1}{2} m v_{max}^2 = hf - hf_0$

de Broglie equation $\lambda = \frac{h}{p}$

## Astronomy

red shift $z = \frac{\Delta\lambda}{\lambda}$

recession speed $z = \frac{v}{c}$

Hubble's law $v = H_0 d$