Rewarding Learning

ADVANCED SUBSIDIARY (AS)
General Certificate of Education
2018

Centre Number

Candidate Number

Physics

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

SPH21

[SPH21]

FRIDAY 18 MAY, MORNING

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 nine** 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.
Your attention is drawn to the Data and Formulae Sheet which is inside this question paper.
You may use an electronic calculator.

1 A student observes the spectrum emitted by a mercury vapour lamp and notices that each line has a different colour, as represented by **Fig. 1.1**.

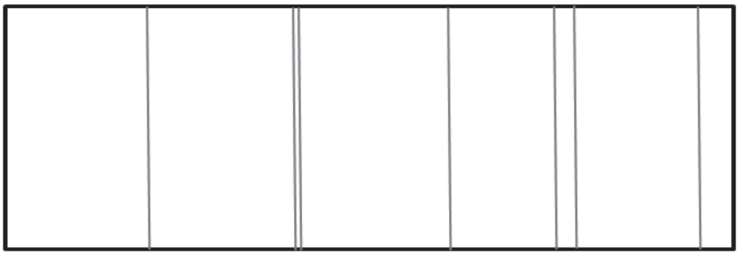

Fig. 1.1

(a) Explain the origin of the different colours observed.

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____ [2]

(b) **Fig. 1.2** shows some of the energy levels for a hydrogen atom.

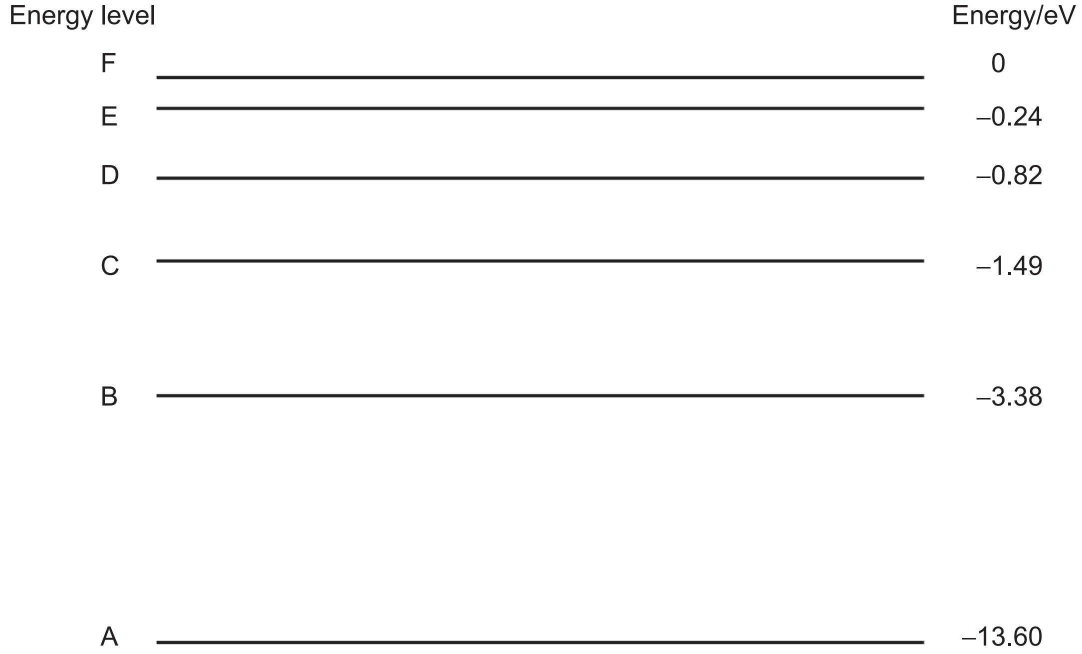

Fig. 1.2

(i) State the magnitude of the energy level value of the ground state of the hydrogen atom shown in **Fig. 1.2**.

Energy level value = ______________________________ eV [1]

(ii) Write down the expression for the wavelength **λ** of the radiation emitted during a transition between two energy levels. The two energy levels are separated by an energy difference **ΔE**. Identify any other symbols used.

[3]

(iii) Calculate the wavelength of the photons emitted when electrons fall from level **D** to **B** in **Fig. 1.2**.

Wavelength = ______________________________ m [3]

(iv) Are the photons emitted during the transition from energy level **D** to energy level **B** visible? Explain your answer.

____

____ [1]

(c) Explain how a laser works. In your explanation, use and describe the terms **population inversion**, **metastable state** and **stimulated emission**.

[4]

2 (a) Explain the meaning of the term **diffraction**.

____

____ [1]

(b) **Fig. 2.1** shows diagrams of wavefronts as they approach two different sized apertures. Carefully complete the diagrams to show how aperture size affects the diffraction pattern observed for water waves.

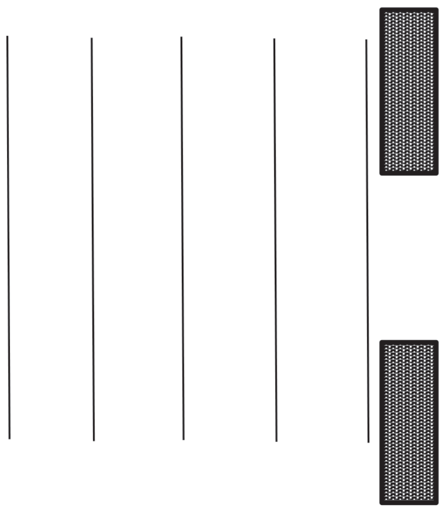

Fig. 2.1a

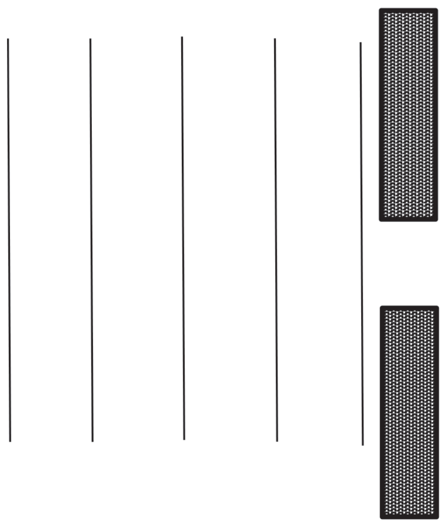

Fig. 2.1b

[3]

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(Questions continue overleaf)

(c) Light from a laser is incident normally on a diffraction grating with 200 lines per millimetre. **Fig. 2.2** shows a schematic diagram of the apparatus and the observed pattern on the screen. The distance along the screen between both third order maxima was measured to be 60.6 cm. The distance between the diffraction grating and the screen was 84.2 cm.

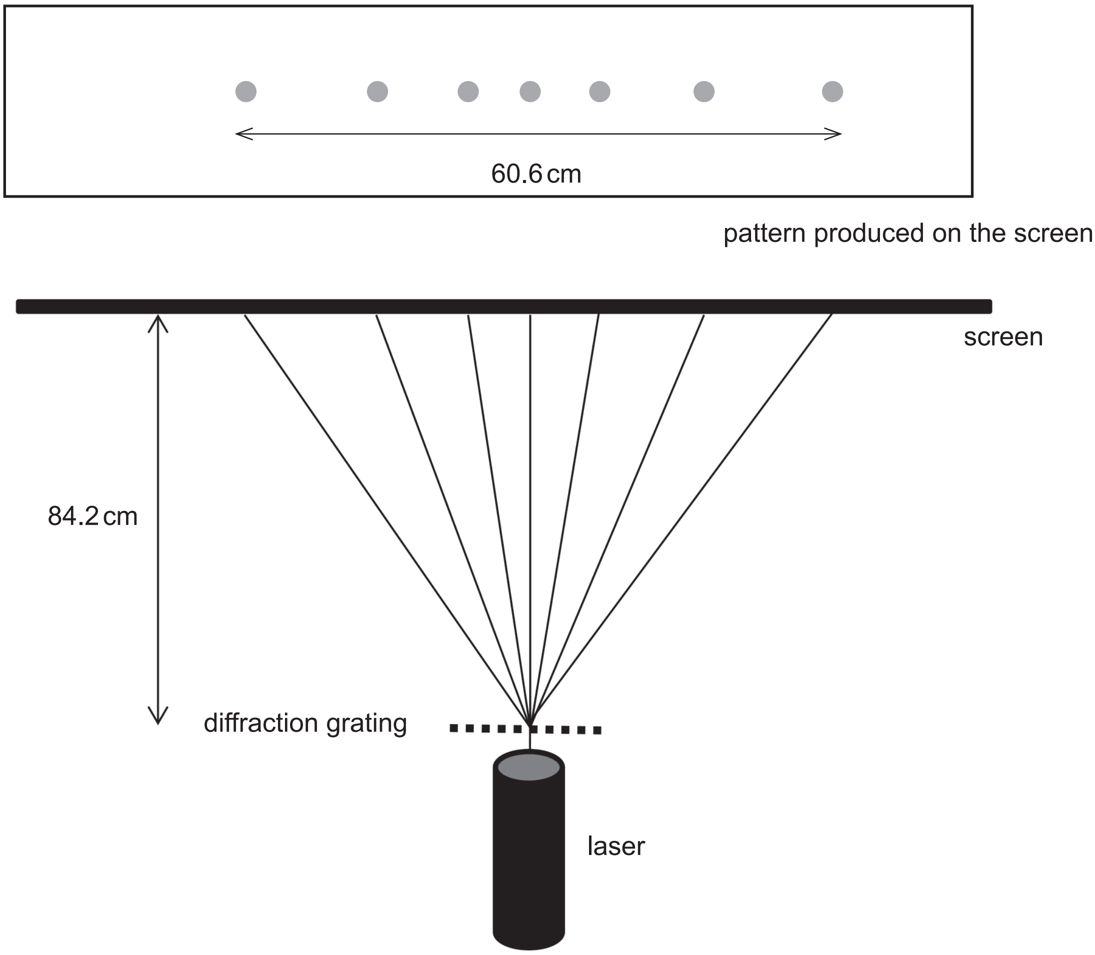

Fig. 2.2

(i) Use this information to show that the angle of diffraction for the third order maximum was 20°.

[2]

(ii) Calculate the wavelength of the laser light used in this experiment, in nanometres.

Wavelength of light = ____________________________ nm [4]

3 Electrons, of mass **m** and charge **e** are emitted at a hot cathode. They are accelerated to a speed v by applying a potential difference $\boldsymbol{V}$ between the hot cathode and anode. The arrangement is shown in **Fig. 3.1**.

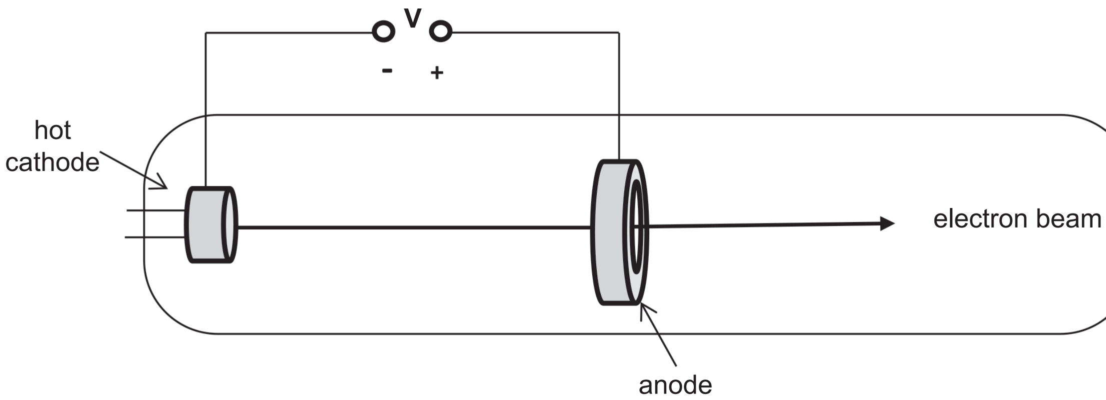

Fig. 3.1

(a) The speed of the electrons can be given by the expression $v = \boldsymbol{K}\sqrt{\boldsymbol{V}}$ where **K** is a constant. Find an expression for **K** in terms of **e** and **m**.

K = ____________

[3]

(b) The moving electrons each have a kinetic energy of 1.55×10^{-15} J.

(i) Calculate the momentum of these moving electrons.

Momentum = ____________________ $kg\ m\ s^{-1}$ [3]

(ii) Calculate the de Broglie wavelength of these moving electrons.

de Broglie wavelength = ____________________ m [2]

(c) In an electron diffraction tube, fast moving electrons pass through a very thin metal foil target before striking a fluorescent screen. The arrangement is shown in **Fig. 3.2**.

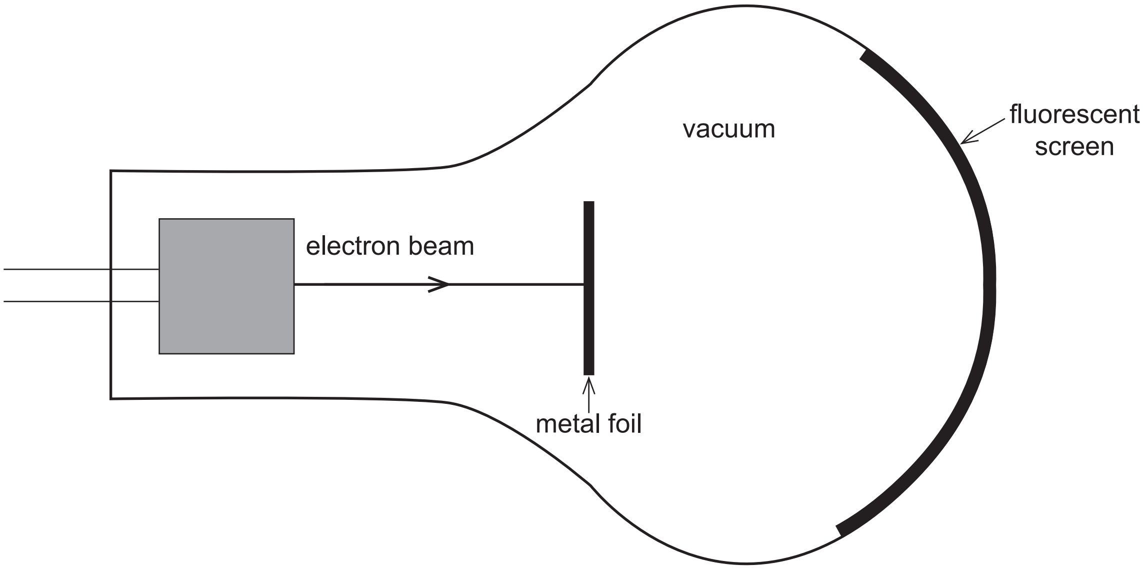

Fig. 3.2

(i) Sketch, in the space below, the diffraction pattern obtained using the electron diffraction tube apparatus.

[1]

(ii) State how the pattern changes when the accelerating voltage is increased.

____

____ [1]

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4 **Fig. 4.1** shows a loudspeaker placed over the open end of a cylinder of length 1.20 m. The loudspeaker is connected to a signal generator which can be used to vary the frequency.

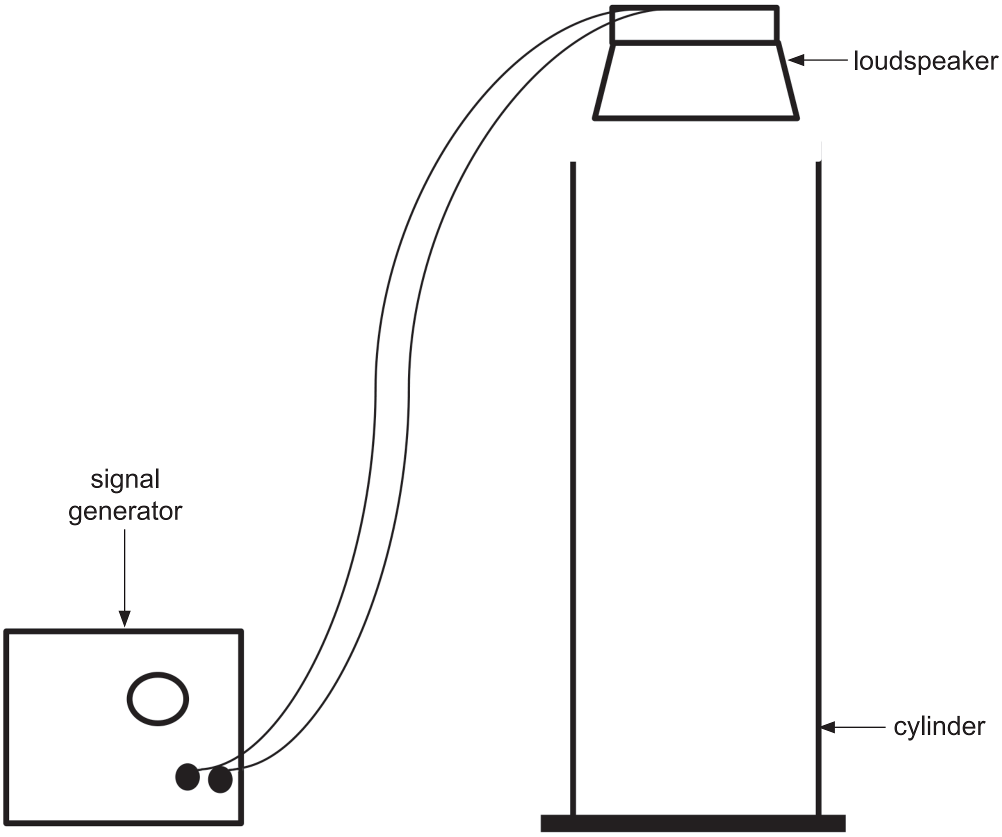

Fig. 4.1

(a) **(i)** Describe how you would use this apparatus to obtain the **first** mode of vibration of a standing wave in the air column.

____

____

____ [2]

(ii) On **Fig. 4.1** sketch the standing wave pattern formed in the tube in this mode of vibration. Mark the positions of all nodes N and antinodes A. [2]

(b) (i) At the first mode of vibration, the frequency reading on the signal generator was 70.0 Hz. What is the value of the speed of sound that can be obtained from this result?

Speed of sound = ________________ m s^{-1} [2]

(ii) Determine the values of frequency, f_1 and f_2, at which the next two modes of vibration occur.

f_1 = ________________ Hz f_2 = ________________ Hz [2]

(c) Water is now added to the cylinder until it is one quarter full. The signal generator is switched on and it is noticed that the first mode of vibration is no longer at 70.0 Hz. Calculate by how much the reading on the signal generator must be changed to observe the first mode of vibration again.

Change in frequency = ________________ Hz [4]

5 An observer sitting on a platform at a train station listens to the sound produced by a train moving through the station at a constant speed.

(a) Discuss the changes in the observed sound. Include in your discussion:

- the frequency of the sound as the train moves towards, and away from, the observer;
- the Doppler equations to describe the frequency or wavelength of the sound as the train moves towards, and away from, the observer.

Include an explanation of any symbols used.

[3]

(b) (i) When astronomers observe distant galaxies, they notice the light is red shifted. What is red shift and how do astronomers explain the red shift observed in light from **distant** galaxies?

____

____

____ [2]

(ii) The shift in the wavelength of light from a distant galaxy is 2.2×10^{-9} m. The wavelength of the light observed is 550×10^{-9} m. Calculate the recession speed of this galaxy in kilometres per second.

Recession speed = ______________________ km s^{-1} [3]

(c) Calculate a value for the estimated age of the universe in years.

Estimated age of the universe = _________________ years [3]

6 Describe an experiment to obtain the results needed to draw a graph from which an accurate value for the focal length of a converging lens can be determined.

(a) In the space below, draw a labelled sketch of the apparatus you would use. Clearly identify on the diagram the measurements to be taken.

[3]

(b) Outline how you would use the equipment to collect data for this experiment.

____

____

____ [2]

(c) On **Fig. 6.1**, label both axes and sketch a line graph which can be used to determine an accurate value for the focal length of the lens.

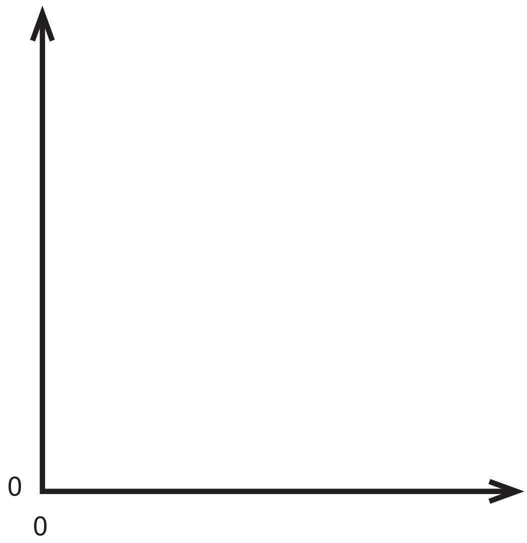

Fig. 6.1

[2]

(d) Describe how an accurate value of the focal length of the lens can be determined from the graph you have sketched in **Fig. 6.1**.

____

____

____ [1]

7 A diverging lens can be used to produce an image of a real object.

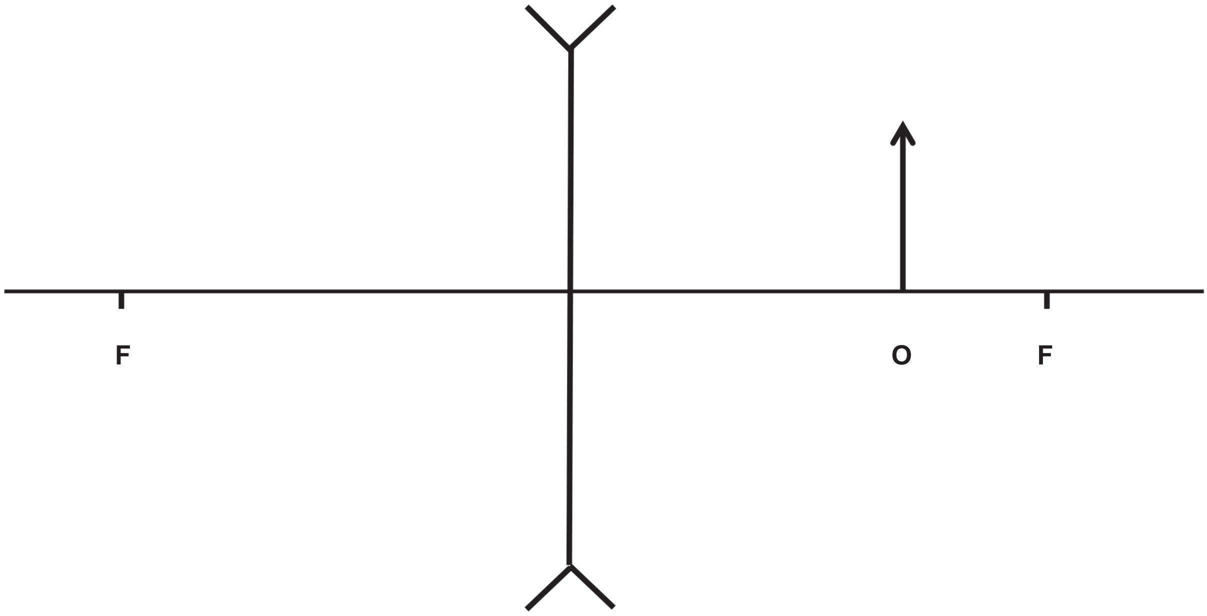

Fig. 7.1

(a) (i) Draw the ray diagram for the diverging lens in **Fig. 7.1** to locate the image of object **O**. Label the image **I**. Show where the eye should be positioned to view the image. [4]

(ii) Describe the image by placing ticks in the appropriate boxes in **Table 7.1**.

Table 7.1

Real		Virtual	
Magnified		Diminished	
Inverted		Upright	

[1]

11212

(b) (i) An object is placed in front of a diverging lens of focal length 15.0 cm. The height of the object is 14.0 cm and the linear magnification of the image is 0.42. Calculate the distance of the object from the lens and the height of the image formed.

Object distance from the lens = ____________________ cm

Image height = ____________________ cm [6]

(ii) How far is the image from the object?

Distance from image to object = ____________________ cm [2]

8 (a) (i) Waves may be categorised as either transverse or longitudinal. Describe, in terms of particle movement, how to distinguish between these two categories.

____

____

____ [2]

(ii) Explain what is meant by polarisation. State which category of waves can be polarised.

____

____

____ [2]

(b) A student writes the equation for the period **T** of a wave as shown in **Equation 8.1**.

$$\mathbf{T = \frac{\lambda}{v}} \qquad \textbf{Equation 8.1}$$

where **λ** is the wavelength and **v** is the wave speed. Show that **Equation 8.1** is valid.

[2]

(c) **Fig. 8.1** shows a graph of displacement against time for a wave.

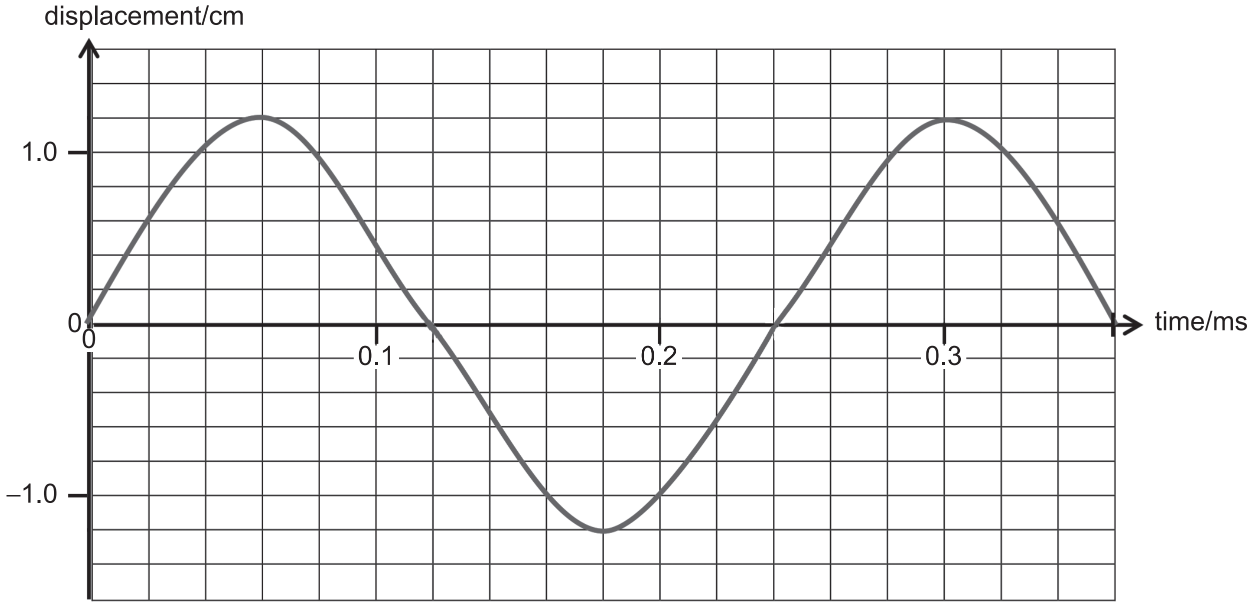

Fig. 8.1

(i) Calculate the frequency of the wave shown in **Fig. 8.1**.

Frequency = _______________ Hz [2]

(ii) On **Fig. 8.1**, sketch a wave which has half the amplitude and a phase difference of 120° from the original wave. [3]

[Turn over

9 **Fig. 9.1** shows a section through part of a typical optical fibre. The core is a glass fibre that allows light to travel through. The cladding is also made from a transparent material. In practical uses, the fibres themselves are as thin as a human hair, and many of them are bundled together to make a fibre optic cable.

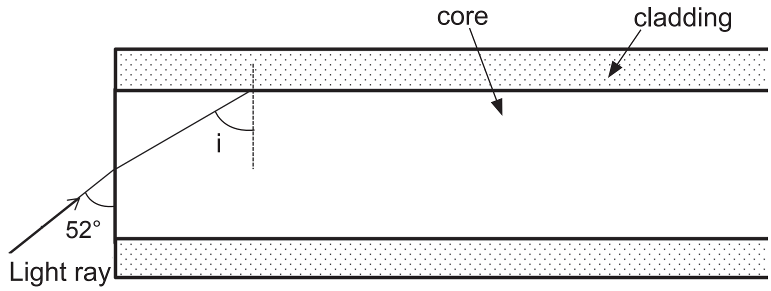

Fig. 9.1

(a) **(i)** Tick a box in **Table 9.1** to show which of the following statements describes the relationship between the refractive index of the cladding and the refractive index of the core.

Table 9.1

The refractive index of the cladding is larger than the refractive index of the core	
The refractive index of the cladding is the same as the refractive index of the core	
The refractive index of the cladding is smaller than the refractive index of the core	

[1]

(ii) The angle between the end of the glass fibre and the incident ray is 52° as shown in **Fig. 9.1**. The refractive index of the core is 1.52. Use these values to calculate the angle of incidence **i** at the boundary between the core and cladding.

Angle of incidence = _______________ ° [3]

(b) **(i)** The shortest time for a ray of light to travel through an optical fibre is when there is axial transmission. This is when the ray of light enters the optical fibre along the normal.
Calculate the shortest time taken for a ray of light to travel through 3 km of this optical fibre.

Shortest time = ____________________________ s [4]

(ii) Calculate the percentage increase in time for a ray travelling through the optical fibre at an angle of incidence at the core/cladding boundary of 70° compared to the shortest time for the light to travel through the optical fibre.

Percentage increase in time = ____________________ % [3]

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For Examiner's use only	
Question Number	**Marks**
1	
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Total Marks	

Examiner Number

Rewarding Learning

ADVANCED SUBSIDIARY
General Certificate of Education

Physics

Assessment Units AS 1 and AS 2

[SPH11/SPH21]

DATA AND FORMULAE SHEET

for use from 2017 onwards

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 $\quad \frac{1}{2}mv^2 - \frac{1}{2}mu^2 = Fs$ for a constant force

Waves

two-source interference $\quad \lambda = \frac{ay}{d}$

diffraction grating $\quad d \sin\theta = n\lambda$

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 $$v = H_0 d$$