Rewarding Learning

ADVANCED SUBSIDIARY (AS)
General Certificate of Education
2022

Centre Number

Candidate Number

Physics

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

SPH21

[SPH21]

MONDAY 6 JUNE, 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 eleven** 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.

13119

1 **(a)** A surface water wave is classified as a transverse wave. Explain what is meant by a transverse wave.

____

____

____ [2]

(b) Transverse waves can be polarised. Explain what is meant by a polarised wave.

____

____

____ [1]

(c) A surface water wave of wavelength 2.24 m is moving at a speed of 56.0 m s^{-1}. The amplitude of the wave is 15.0 cm.

(i) Calculate the frequency of the wave.

Frequency = ____________ Hz [3]

(ii) On **Fig. 1.1**, sketch a graph showing two full cycles of the wave. Include values on both axes. Show any working out clearly.

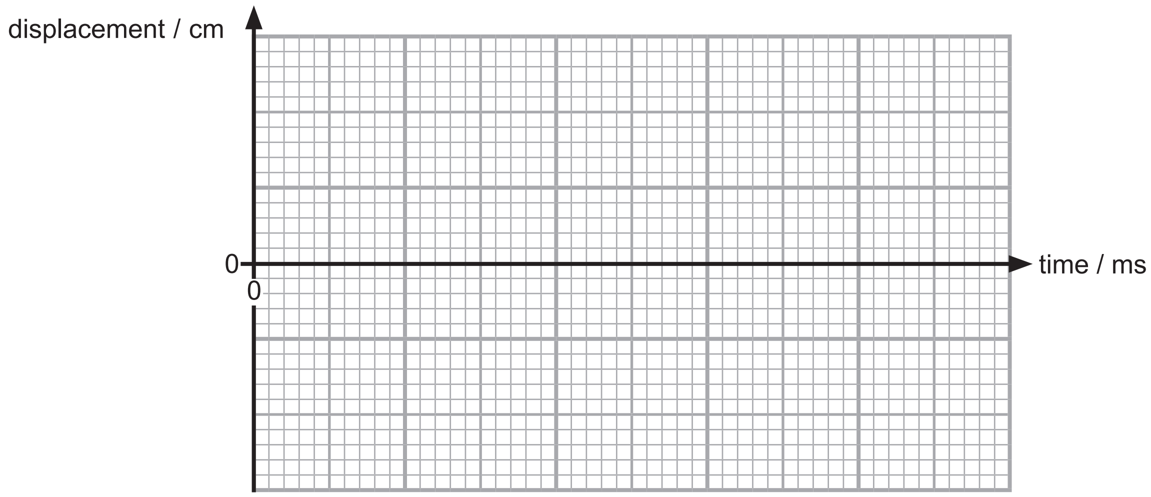

Fig. 1.1

[5]

2 The spiral galaxy NGC 2403 is estimated to be at a distance of 8 million light years from the Earth. One light year is the distance travelled by light in one year.

(a) Show that the NGC 2403 galaxy is approximately 7.6×10^{22} m from the Earth.

[3]

(b) (i) Calculate the recession speed of the NGC 2403 galaxy.

Recession speed = ____________ m s^{-1} [2]

(ii) Calculate the redshift parameter z for the NGC 2403 galaxy.

z = __________________ [2]

(c) One of the lines of the emission spectrum of hydrogen has wavelength 656 nm.

(i) Calculate the wavelength redshift $\Delta\lambda$ of this spectral line when emitted from the NGC 2403 galaxy and observed on Earth.

$\Delta\lambda$ = ____________________ nm [2]

(ii) How does your answer to **(c)(i)** compare to the $\Delta\lambda$ value for the 656 nm spectral line emitted from a galaxy 1000 times more distant than the NGC 2403 galaxy?

____

____ [1]

3 Sodium metal has a work function of 2.00 eV.

(a) Explain what is meant by the 'work function' of sodium.

____

____

____ [2]

(b) Calculate the threshold frequency of sodium.

Frequency = ____________________ Hz [3]

(c) **(i)** Use Einstein's photoelectric equation to calculate the maximum velocity of electrons emitted from the surface of sodium when it is illuminated by light of wavelength 330 nm.

Maximum velocity = ______________ m s^{-1} [6]

(ii) The intensity of the incident light of wavelength 330 nm is increased. What effect, if any, will this have on the maximum velocity of the emitted electrons?

____

____ [1]

(iii) State what would be observed if light of frequency 4.55×10^{14} Hz and of the original intensity is incident on the surface of sodium. Explain your reasoning.

____

____

____ [2]

4 **Fig. 4.1** shows the emission line spectrum for excited hydrogen gas. Explain how the spectrum is produced in terms of energy levels within the atom of hydrogen. Numerical values are not required in your answer.

Fig. 4.1

____

____

____

____

____

____

____

____

____ [5]

5 **(a)** A converging lens is used to produce a real, magnified image of an object. Draw a ray diagram on **Fig. 5.1** to locate the position of the object O when the focused image I is formed as shown. The points labelled F are the principal foci of the lens.

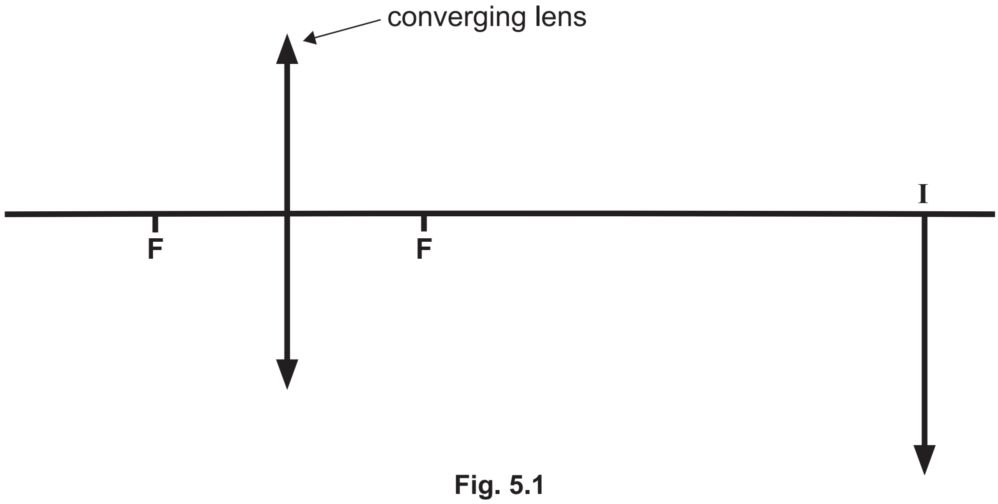

Fig. 5.1

[4]

(b) A projector is used to produce a real, magnified image of a square microscope slide on a screen placed at a distance of 3.5 m from the lens. The length of one side of the slide is 4.0 cm and the focused image on the screen is a square of side 88 cm.

Calculate the focal length of the lens being used in the projector.

Focal length = ________________ m [4]

[Turn over

6 Lasers produce light which is monochromatic and coherent. In relation to laser action, explain the terms below.

(a) Metastable state

____

____

____ [2]

(b) Population inversion

____

____

____ [2]

(c) Coherent light

____

____ [1]

(d) Monochromatic light

____

____ [1]

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7 An electron diffraction tube, as shown in **Fig. 7.1**, is used to demonstrate the wave–particle duality of electrons.

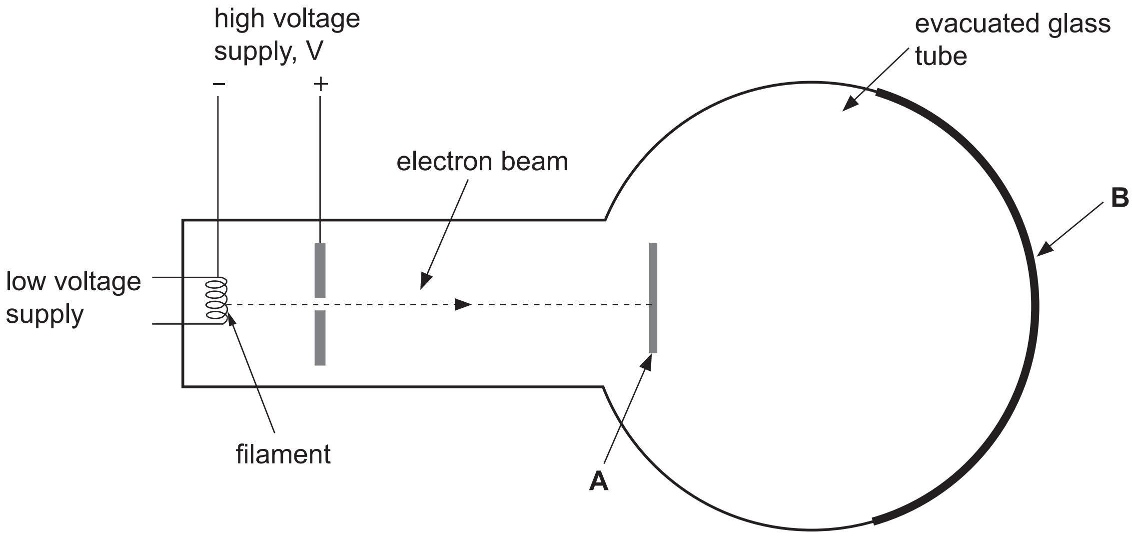

Fig. 7.1

(a) **(i)** Name the piece of apparatus labelled **A**.

____ [1]

(ii) Name the piece of apparatus labelled **B** and describe what is observed at **B**.

____

____

____

____ [3]

(iii) Explain how the diffraction apparatus in **Fig. 7.1** demonstrates both the wave nature and the particle nature of electrons.

____

____

____

____ [2]

(b) **(i)** In an electron diffraction tube, a high voltage supply accelerates the electrons to a velocity of 1.39×10^{7} m s^{-1}.
Determine the de Broglie wavelength of these electrons.

Wavelength = ____________________ m [4]

(ii) What region of the electromagnetic spectrum would a photon of the wavelength calculated in **(b)(i)** belong to?

____________________________ [1]

8 A diffraction grating may be used to experimentally determine the wavelength of visible laser light, using the arrangement shown in **Fig. 8.1**.

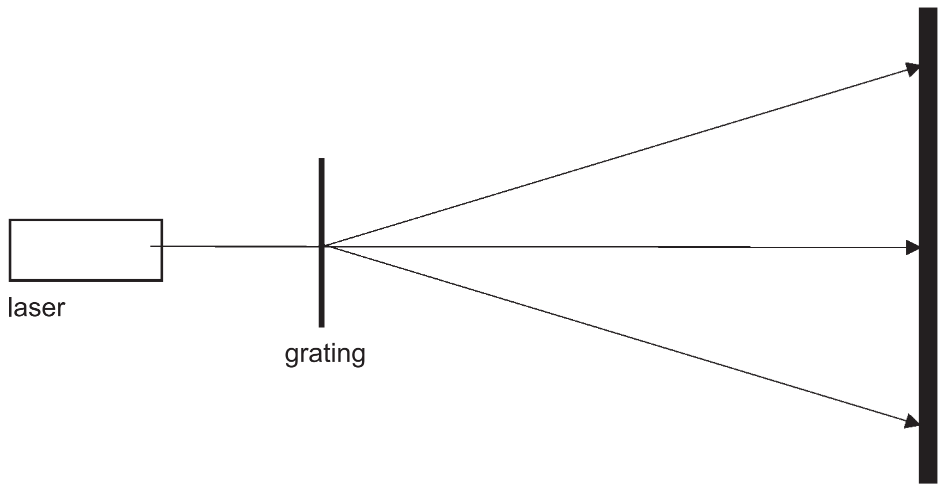

Fig. 8.1

The diffraction equation is given by **Equation 8.1**.

$$d \sin \theta = n \lambda$$ **Equation 8.1**

(a) Define the terms used in **Equation 8.1**.

n: ______________________________

____

d: ______________________________

____

θ: ______________________________

______________________________ [3]

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(b) In one such experiment, the laser emits light of wavelength 660×10^{-9} m, the grating has 200 lines per mm and a sheet of white paper of width 296 mm is being used as the screen. Use the diffraction grating formula to calculate a minimum grating to screen distance in order for both the first order fringes to be observed on the edges of the paper.

Minimum distance from grating to screen = ____________________ m [6]

9 A child wears spectacle lenses of focal length +0.56 m in order to correct the near point to a normal distance of 25 cm from their eye.

(a) (i) What defect of vision is being corrected by a lens of focal length +0.56 m?

____ [1]

(ii) What could cause the defect you have named in **(i)**?

____

____ [1]

(iii) What is meant by the near point?

____

____ [1]

(b) With the correcting lens in place, complete a ray diagram on **Fig. 9.1** to illustrate the path of two rays from an object placed 25 cm from the eye of the child. Draw the correct shape of the correcting lens on the dotted line shown and two rays passing through the correcting lens and the eye lens to the retina.

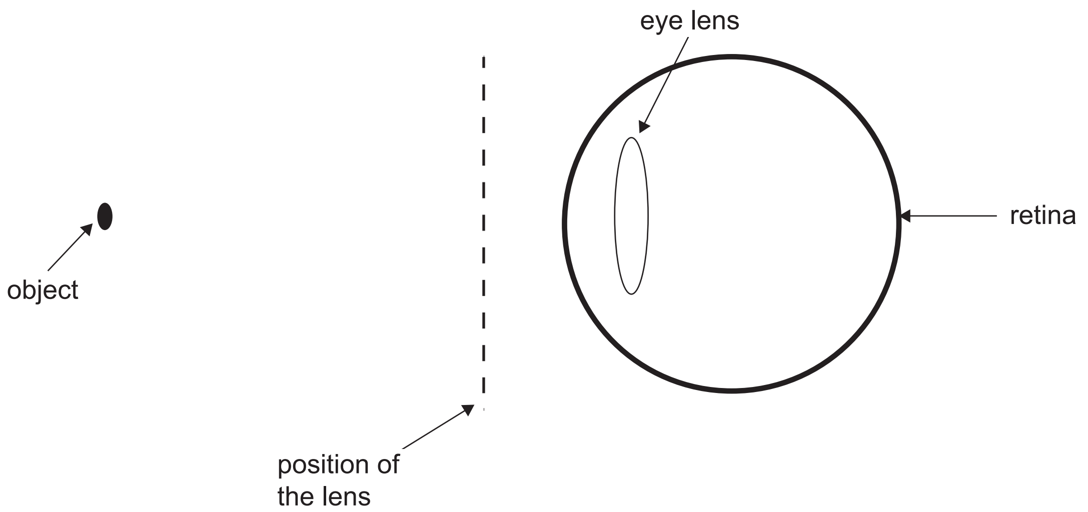

Fig. 9.1

[4]

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(Questions continue overleaf)

10 (a) State the principle of superposition.

____

____

____

____ [2]

(b) Interference effects can be demonstrated using sound waves.

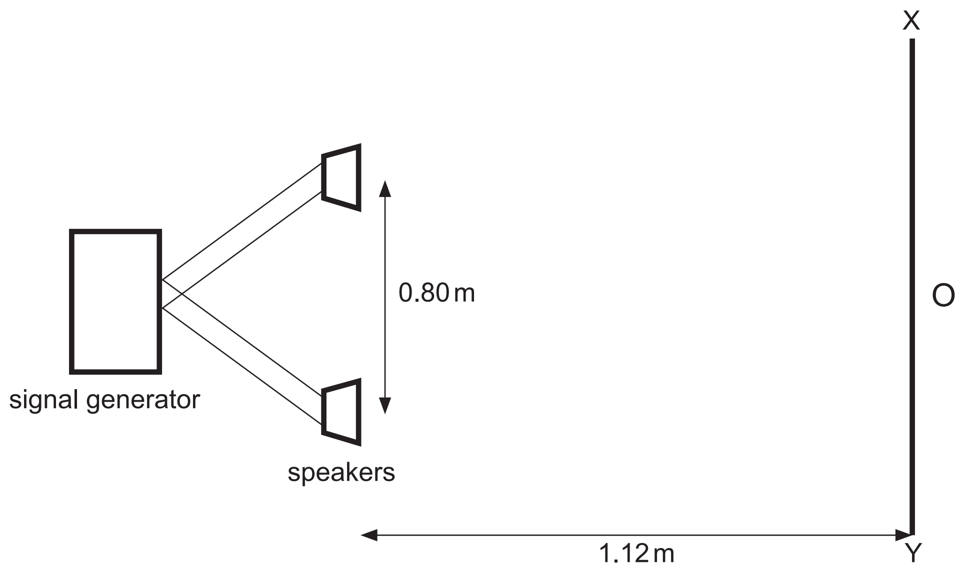

Fig. 10.1

Two loudspeakers connected to the same signal generator are placed 0.80 m apart as in **Fig. 10.1**. Students walking along the line XY at a distance of 1.12 m from the speakers can hear variations in the loudness of the sound.

Student A reports hearing loud sounds at 42 cm intervals and Student B at 44 cm intervals. Both agree that the loudest sound can be heard at point O, equidistant from both speakers.

(i) Explain why a loud sound is heard at point O.

____

____

____

____ [2]

(ii) By averaging the results of the two students, estimate the frequency of the sound being generated. The speed of sound in air is 334 m s^{-1}.
Give your answer to two significant figures.

Frequency = ______________ Hz [6]

11 Diamond has a refractive index of 2.42.

(a) Show that the critical angle for diamond is 24°.

[2]

(b) Pieces of diamond are cut so as to 'sparkle'. This is partly due to the phenomenon of total internal reflection of light within the stone. A ray of white light incident at 90° to the surface of a cut diamond is shown in **Fig. 11.1**.

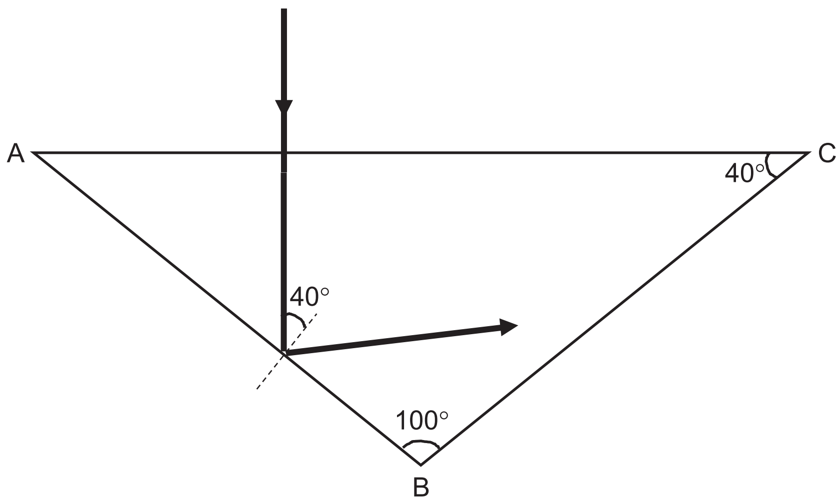

Fig. 11.1

(i) Explain why the ray has taken the path shown after striking boundary AB.

____

____

____ [2]

(ii) Continue the path of the ray on **Fig. 11.1** to show the path it follows before and just after striking boundary BC. Draw the normal line and include a value for the angle of incidence at the boundary BC. [3]

(iii) Diamonds which are 'shallow cut', such as the one in **Fig. 11.2**, would not sparkle in the same manner. Explain why this is the case. You may illustrate your answer by continuing the path of the ray after striking boundary EF on **Fig. 11.2**.

____

____

____ [2]

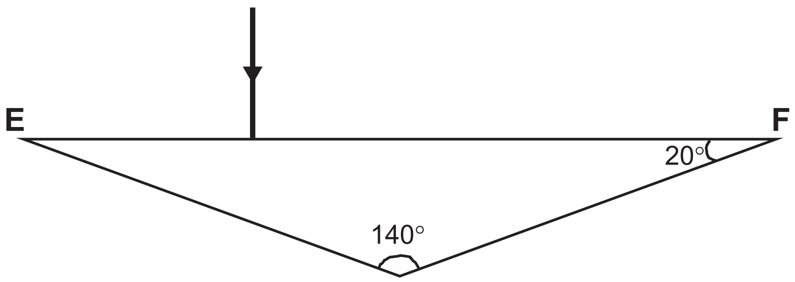

Fig. 11.2

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For Examiner's use only	
Question Number	Marks
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Examiner Number

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Rewarding Learning

ADVANCED SUBSIDIARY
General Certificate of Education

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 $v = H_0 d$