Rewarding Learning

Centre Number

71	

Candidate Number

ADVANCED SUBSIDIARY (AS)
General Certificate of Education
January 2014

Physics

Assessment Unit AS 2

assessing

Module 2: Waves, Photons and Medical Physics

[AY121]

AY121

WEDNESDAY 22 JANUARY, AFTERNOON

TIME

1 hour 30 minutes.

INSTRUCTIONS TO CANDIDATES

Write your Centre Number and Candidate Number in the spaces provided at the top of this page.
Answer **all ten** questions.
Write your answers in the spaces provided in this question paper.

INFORMATION FOR CANDIDATES

The total mark for this paper is 75.
Quality of written communication will be assessed in Question **3**.
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.

For Examiner's use only	
Question Number	Marks
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
Total Marks	

1 A monochromatic ray of light is incident on face A of a triangular glass prism. **Fig. 1.1** shows the path of the ray incident on the prism, through the prism and back into the air. "Normals" have been included and are labelled N.

Examiner Only	
Marks	Remark

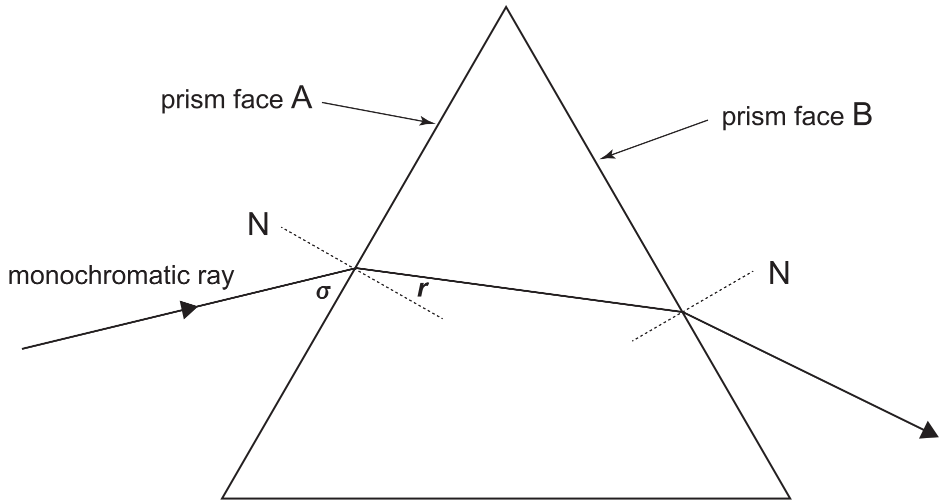

Fig. 1.1

(a) (i) What does "monochromatic" mean?

____

____ [1]

(ii) Calculate the angle marked ***σ*** if the refracted angle (labelled ***r***) is 26.9° and the refractive index of the glass is 1.54.

σ = __________ ° [3]

(b) (i) State the meaning of the term “critical angle”.

____

____ [1]

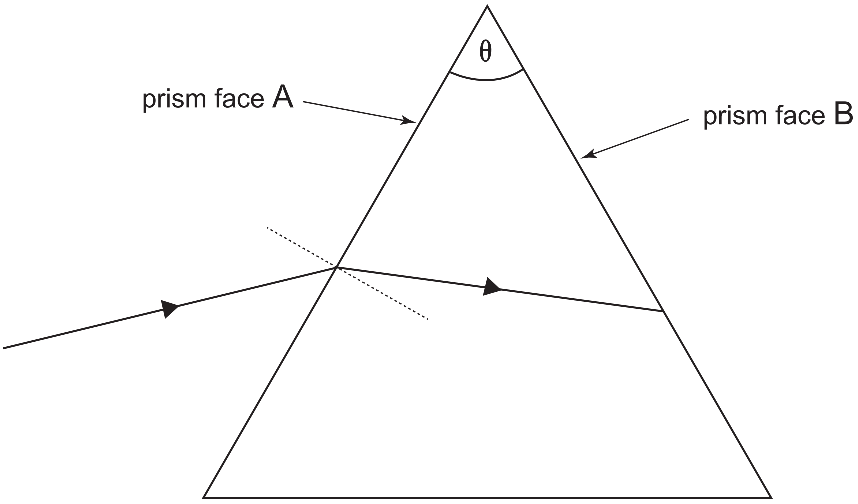

Fig. 1.2

(ii) Calculate the magnitude of angle θ, in **Fig. 1.2**, that would just result in the total internal reflection of the monochromatic ray at face B. The incident angle on face A remains unchanged from part **(a)** of this question.

$\theta =$ __________ ° [3]

Examiner Only

Marks	Remark

Examiner Only	
Marks	Remark

2 **(a)** **(i)** In the space below, draw a labelled sketch of the **apparatus** you would use to perform an experiment to obtain the raw data from which to determine the value of the focal length of a converging lens.

[2]

(ii) Using the apparatus sketched in **(a)(i)**, outline the procedure you would follow to obtain reliable data.

____

____

____

____

____ [2]

(b) A converging lens produces an **upright** image of size 2.4 cm, of an object of size 4 mm, when the lens is placed 6.7 cm from the object. Calculate the focal length of the converging lens.

Focal length = __________ [4]

Examiner Only	
Marks	Remark

Where appropriate in this question you should answer in continuous prose. You will be assessed on the quality of your written communication.

3 **Fig. 3.1** shows a photograph of the screen of a liquid crystal display (LCD) with a pair of sunglasses between the screen and camera. **Fig. 3.2** is a photograph of the same scene as **Fig 3.1** under identical circumstances except that the sunglasses have been rotated through 90°.

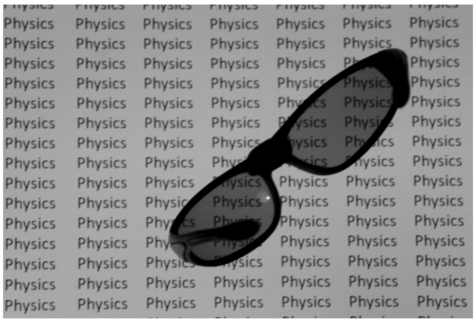

Fig. 3.1

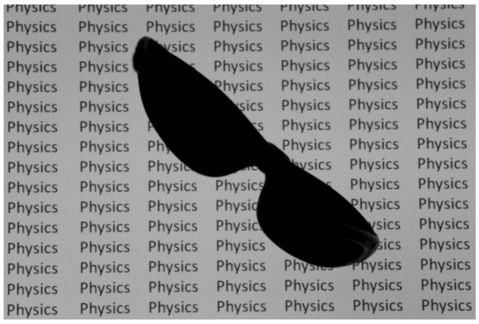

Fig. 3.2

Explain the difference in the view through the sunglasses in **Figs. 3.1** and **3.2**. In your answer you should comment on the nature of the light emitted from the LCD and the nature of the lenses in the sunglasses.

[6]

Quality of written communication [2]

4 Two loudspeakers S_1 and S_2 are connected to a signal generator and produce coherent waves that are **in phase**. A microphone, connected to a cathode ray oscilloscope (CRO), is moved along a straight line (the detection line) in front of both speakers to detect the resultant sound wave at different locations. The path taken by the sound waves from S_1 and S_2 to the microphone when it is at positions P and Q is shown in **Fig. 4.1**.

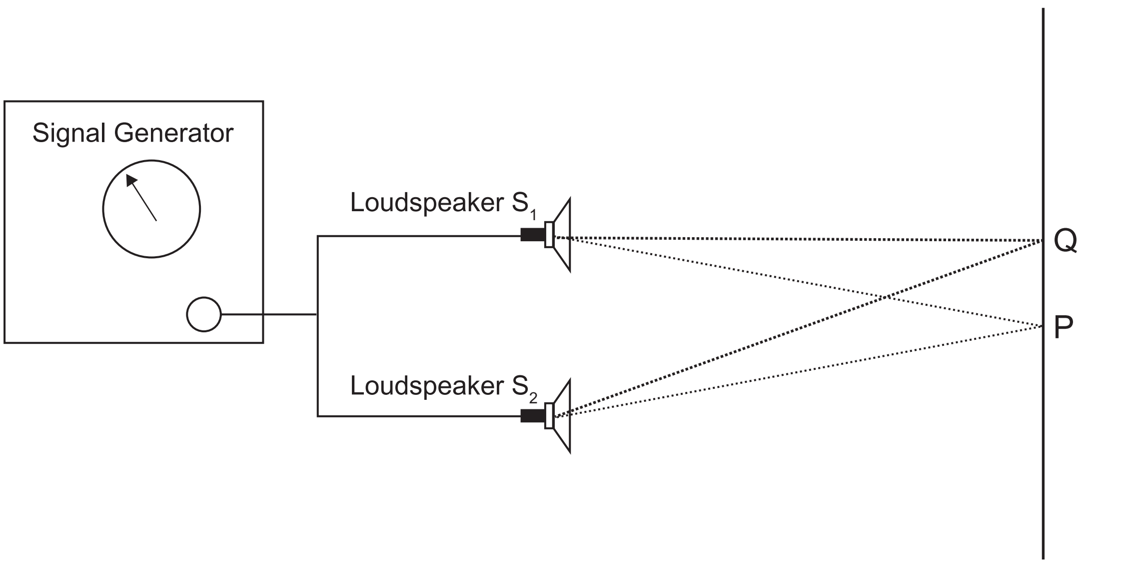

Fig. 4.1

(a) (i) Sound waves from S_1 and S_2 are coherent. Explain the meaning of the term "coherent" in this context.

____

____ [1]

(ii) The sound waves emitted from loudspeakers S_1 and S_2 are described as being "in phase". Explain the meaning of this phrase.

____

____ [1]

Examiner Only	
Marks	Remark

(b) As the microphone moves along the detection line, the CRO display rises and falls periodically.

Examiner Only

Marks	Remark

(i) Position P represents the point, on the detection line, equidistant from the loudspeakers, see **Fig. 4.1**. Comment on the loudness of the sound detected by the microphone and explain your answer.

____

____ [2]

(ii) What variation would a person detect if they move along the detection line?

____

____ [1]

(iii) Location Q is the closest point to location P at which the waves arrive from S_1 and S_2 with a phase difference of 180°. The sound waves have a frequency of 868 Hz and a velocity of 330 m s^{-1}. Calculate how much further the sound has to travel from S_2 to location Q than the sound from S_1.

Distance = _________ m [4]

5 The Data and Formulae Sheet gives **Equation 5.1** for sound intensity level.

$$\textit{Sound intensity level/dB} = 10\lg_{10}\frac{I}{I_0} \qquad \textbf{Equation 5.1}$$

Examiner Only	
Marks	Remark

(a) I_0 in **Equation 5.1** has a value of $1.0 \times 10^{-12}\,\mathrm{W\,m^{-2}}$. What does I_0 represent?

____

____ [1]

(b) At a distance of 10 m, the sound intensity level of a jet engine is 140 dB.

(i) Calculate the intensity of sound energy from the engine at a distance of 10 m.

Intensity = __________ $\mathrm{W\,m^{-2}}$ [2]

(ii) At a distance of 2 km from the engine the intensity has fallen to $\dfrac{1}{4 \times 10^4}$ of the value at a distance of 10 m. Calculate the sound intensity level 2 km from the engine.

Sound intensity level = __________ dB [2]

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(Questions continue overleaf)

6 **Fig. 6.1** illustrates a loudspeaker being sounded over the open end of a 50 cm long resonance tube which is free to move vertically within a tall beaker of water. For a range of sound frequencies, resonance tube length data from the apparatus in **Fig. 6.1** is required to determine the speed of sound in air.

Examiner Only	
Marks	Remark

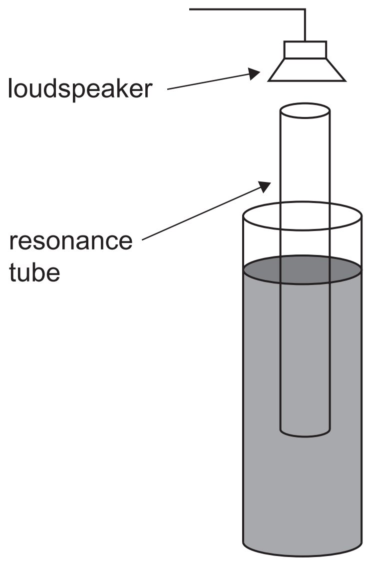

Fig. 6.1

(a) Describe how this apparatus is manipulated and identify the length to be measured to enable the speed of sound in air to be determined.

____

____

____

____

____

____ [3]

(b) **Table 6.1** shows the relevant results obtained from the experiment using a **resonance tube 50 cm long** as shown in **Fig. 6.1**.

Examiner Only

Marks | Remark

Table 6.1

frequency/Hz	length/cm
2000	4.1
3000	2.8
4000	2.1
5000	1.7
6000	1.4

(i) The lengths are measured using a metre rule and the frequency values are accurate to ±10 Hz. Explain why changing the frequency range would produce a more suitable set of results and suggest a better range.

____

____

____

____

____

____ [3]

(ii) Explain how an accurate value for the speed of sound in air could be calculated from the data in **Table 6.1**. The data is relevant for the **first mode of vibration** at each frequency.

____

____

____

____ [2]

Examiner Only	
Marks	Remark

7 Magnetic Resonance Imaging (MRI) is a powerful diagnostic tool requiring complex analysis of data based on atoms in the human body which have experienced nuclear magnetic resonance (NMR).

(a) Describe the nuclear magnetic resonance phenomenon.

____

____

____

____

____

____

____

____ [3]

(b) One component in the magnetic resonance system requires a current of around 700 A to flow. Name this component and state the main design feature it incorporates to reduce power losses.

____

____

____ [2]

(c) Explain why each of the following must be removed before undergoing an MRI scan:

(i) A credit card: ____

____ [1]

(ii) Gold chain: ____

____ [1]

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(Questions continue overleaf)

8 **Fig. 8.1** shows identical photons incident on a sheet of aluminium. The aluminium has a regular arrangement of lattice ions and contains TWO delocalised electrons, one **just below the surface** of the aluminium and the other at some **distance below the surface**. The work function of aluminium is 4.2 eV.

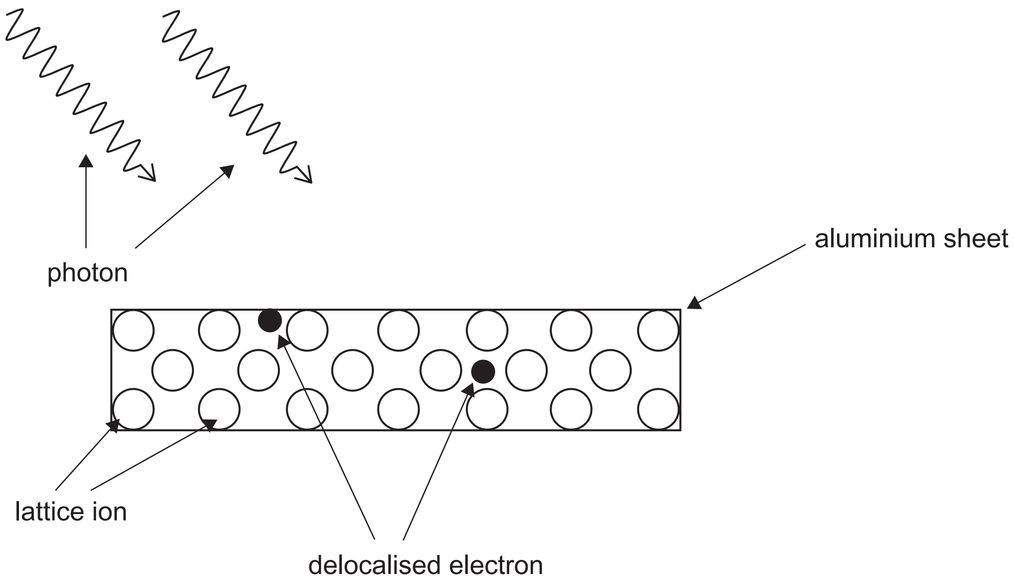

Fig. 8.1

(a) What is a photon?

____

____ [2]

(b) If each delocalised electron absorbs a photon, state which electron will be emitted with the greatest kinetic energy and explain why.

____

____

____ [2]

Examiner Only	
Marks	Remark

(c) (i) Calculate the minimum frequency of electromagnetic wave that could cause photoelectric emission.

Frequency = ___________________ Hz [3]

(ii) Hence, calculate the wavelength of the electromagnetic wave. State your answer in nanometres.

Wavelength = ___________________ nm [2]

(iii) To which region of the electromagnetic spectrum does this wave belong?

Region = ___________________ [1]

Examiner Only	
Marks	Remark

9 **Fig. 9.1** is a diagram of the main components in a laser.

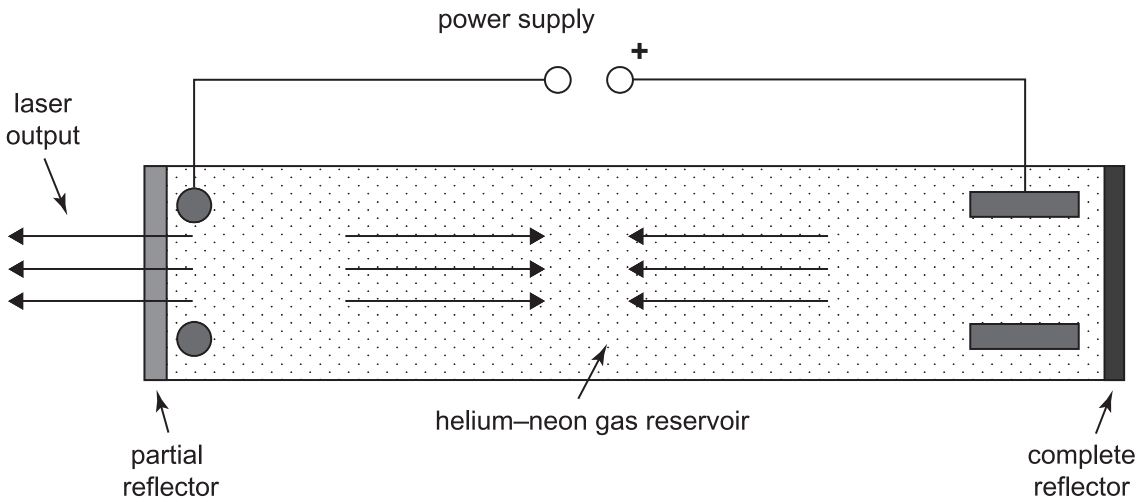

Fig. 9.1

(a) With reference to laser action, define the term “population inversion”.

____

____

____

____

____ [2]

(b) The reflectors at either end of the laser cause a continuous stream of photons to move through the helium–neon gas reservoir. Explain why this is vital for laser action.

____

____

____ [1]

(c) State one common use of lasers in an everyday context.

____

____ [1]

Examiner Only	
Marks	Remark

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(Questions continue overleaf)

Examiner Only

Marks	Remark

10 (a) (i) Light undergoes a number of phenomena and two theories, the wave theory and the particle theory, are used to explain these phenomena. Complete **Table 10.1** by marking with a tick (✓) if the phenomenon can be explained by that theory and with a cross (✗) if it cannot.

Table 10.1

Phenomenon	Wave theory	Particle theory
Diffraction		
Photoelectric effect		
Polarisation		
Reflection		

[2]

(ii) Explain how the de Broglie equation embodies the wave-particle duality that exists in the nature of light.

____

____

____ [2]

(b) Electron diffraction is used to determine the separation of molecules within a sample. (Molecular separation is analogous to aperture size in conventional diffraction.) One such experiment involves accelerating electrons using a voltage V to a variety of kinetic energies and measuring the extent of diffraction that results. The conversion chart in **Fig. 10.1** allows the accelerating voltage required to produce electrons with a particular velocity to be found and vice versa.

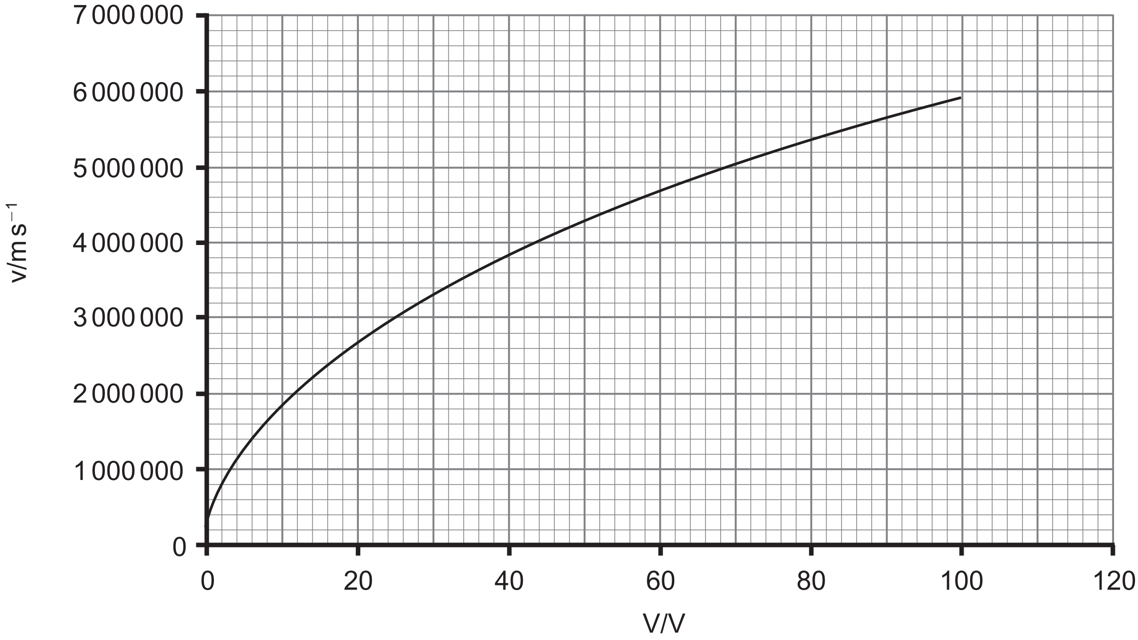

Fig. 10.1

If maximum diffraction occurs when the voltage is 68 V determine the molecular separation of the molecules in the sample.

Separation of molecules = ____________________ m [4]

THIS IS THE END OF THE QUESTION PAPER

Examiner Only

Marks	Remark

GCE (Advanced Subsidiary) Physics

Data and Formulae Sheet

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

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

Hooke's Law $F = kx$ (spring constant k)

Sound

Sound intensity level/dB $= 10 \lg_{10} \dfrac{I}{I_0}$

Waves

Two-source interference $\lambda = \dfrac{ay}{d}$

Light

Lens formula $\dfrac{1}{u} + \dfrac{1}{v} = \dfrac{1}{f}$

Magnification $m = \dfrac{v}{u}$

Electricity

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

Potential divider $V_{out} = \dfrac{R_1 V_{in}}{R_1 + R_2}$

Particles and photons

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