



Rewarding Learning

ADVANCED SUBSIDIARY (AS)  
General Certificate of Education  
January 2014

Centre Number

71

Candidate Number

## Physics

### Assessment Unit AS 2

*assessing*

Module 2: Waves, Photons and Medical Physics

[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.

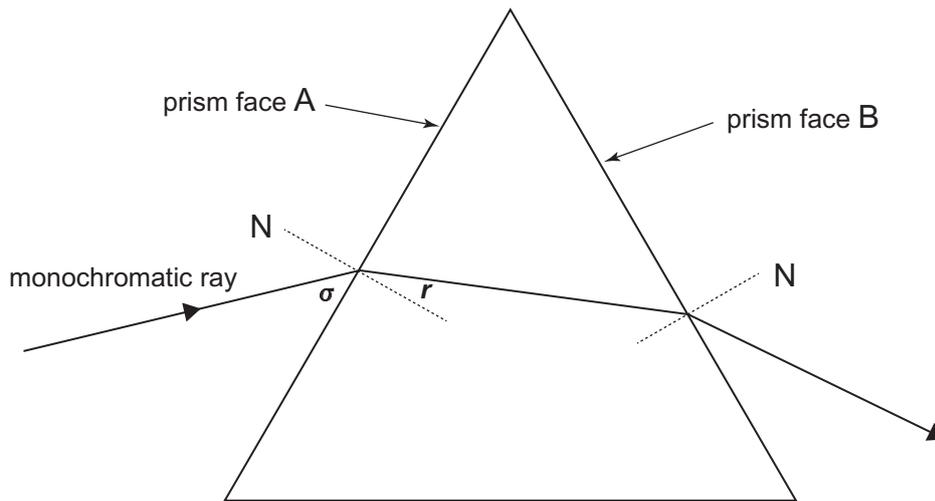
You may use an electronic calculator.

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.



**Fig. 1.1**

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

\_\_\_\_\_ [1]

- (ii) Calculate the angle marked  $\sigma$  if the refracted angle (labelled  $r$ ) is  $26.9^\circ$  and the refractive index of the glass is 1.54.

$\sigma =$  \_\_\_\_\_  $^\circ$  [3]

Examiner Only	
Marks	Remark

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

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[1]

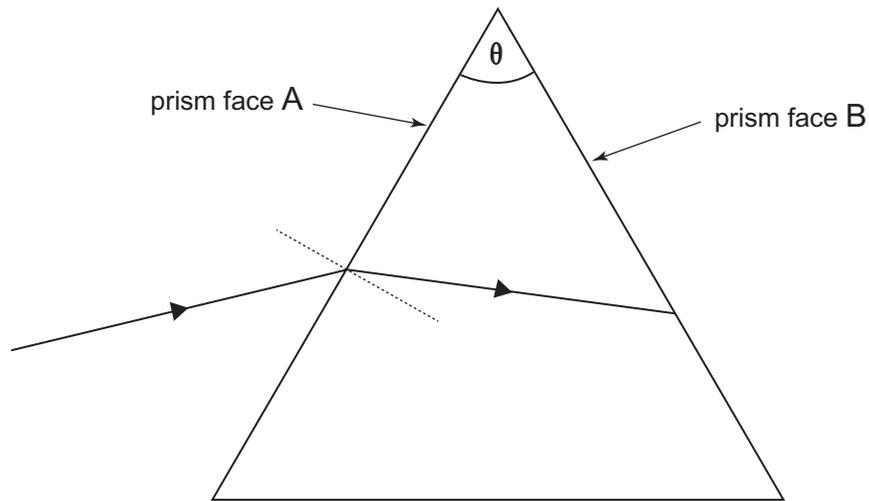


Fig. 1.2

(ii) Calculate the magnitude of angle  $\theta$ , 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.

$$\theta = \text{_____}^\circ$$

[3]

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.

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[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.

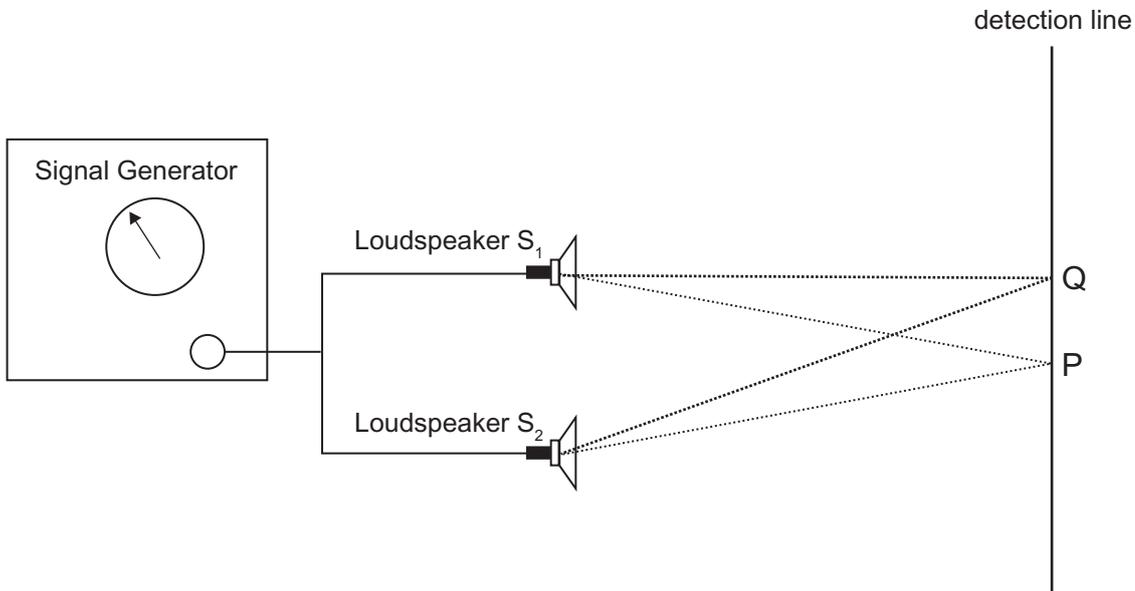
Focal length = \_\_\_\_\_

[4]

Examiner Only	
Marks	Remark



- 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.

- (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  $180^\circ$ . The sound waves have a frequency of 868 Hz and a velocity of  $330 \text{ m s}^{-1}$ . Calculate how much further the sound has to travel from  $S_2$  to location Q than the sound from  $S_1$ .

Distance = \_\_\_\_\_ m [4]

Examiner Only	
Marks	Remark

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

$$\text{Sound intensity level/dB} = 10 \lg_{10} \frac{I}{I_0} \quad \text{Equation 5.1}$$

- (a)  $I_0$  in **Equation 5.1** has a value of  $1.0 \times 10^{-12} \text{ W m}^{-2}$ . 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 = \_\_\_\_\_  $\text{W m}^{-2}$  [2]

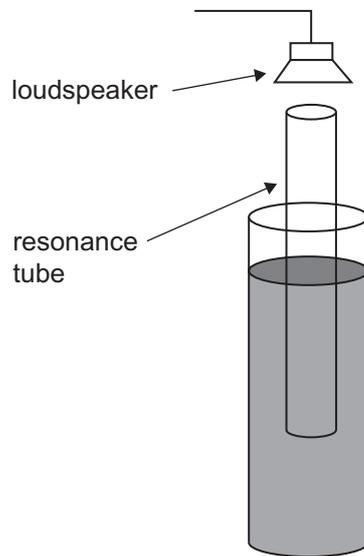
- (ii) At a distance of 2 km from the engine the intensity has fallen to  $\frac{1}{4 \times 10^4}$  of the value at a distance of 10 m. Calculate the sound intensity level 2 km from the engine.

Sound intensity level = \_\_\_\_\_ dB [2]

Examiner Only	
Marks	Remark

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- 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.



**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.

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[3]

Examiner Only	
Marks	Remark

- (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**.

**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  $\pm 10$  Hz. Explain why changing the frequency range would produce a more suitable set of results and suggest a better range.

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[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.

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[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.

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[3]

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

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[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]

Examiner Only	
Marks	Remark

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- 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.

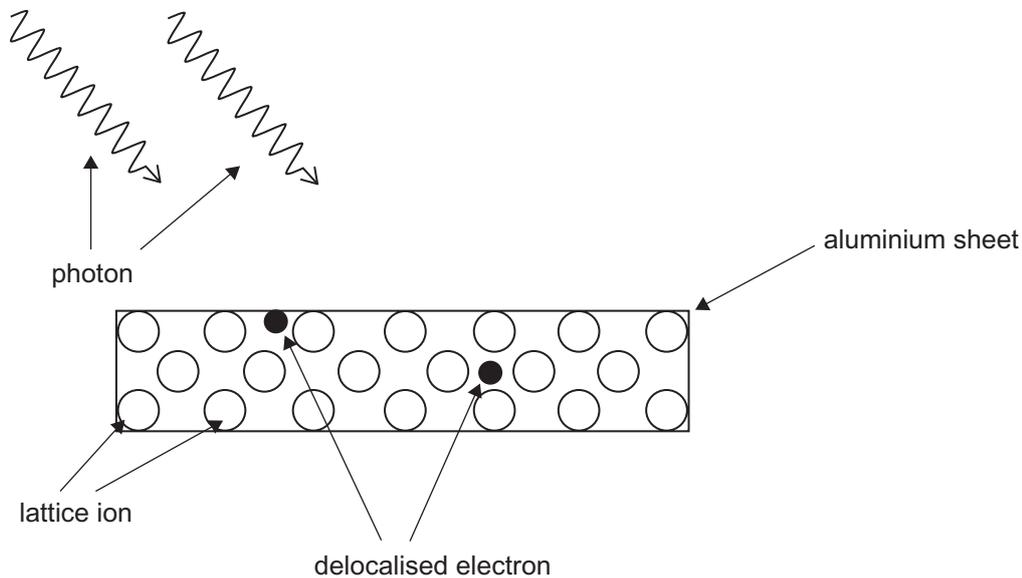


Fig. 8.1

- (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



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

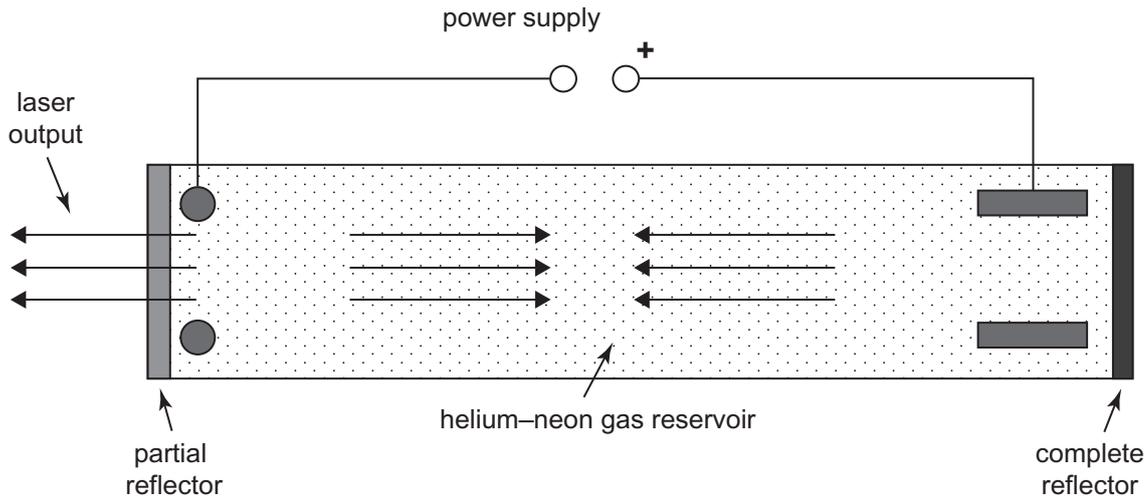


Fig. 9.1

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

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[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.

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[1]

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

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[1]

Examiner Only	
Marks	Remark

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- 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.

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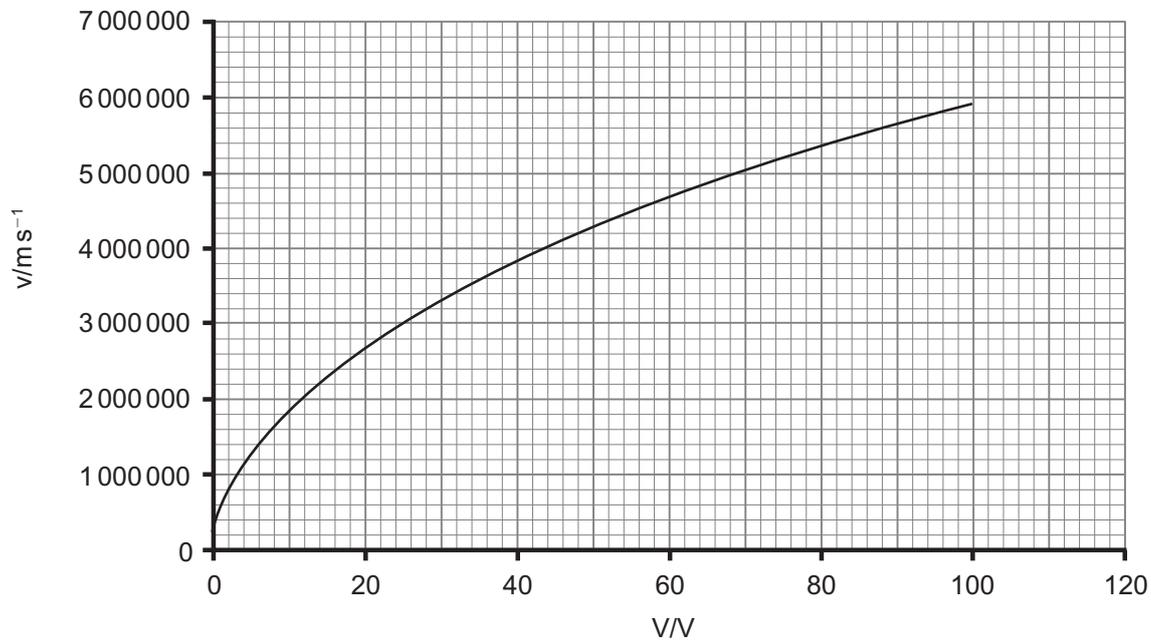


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[2]

Examiner Only	
Marks	Remark

- (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]

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**THIS IS THE END OF THE QUESTION PAPER**

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## GCE (Advanced Subsidiary) Physics

## Data and Formulae Sheet

## Values of constants

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

## 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	$= 10 \lg_{10} \frac{I}{I_0}$
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## Waves

Two-source interference	$\lambda = \frac{ay}{d}$
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## Light

Lens formula	$\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$
Magnification	$m = \frac{v}{u}$

## Electricity

Terminal potential difference	$V = E - Ir$ (e.m.f. $E$ ; Internal Resistance $r$ )
Potential divider	$V_{\text{out}} = \frac{R_1 V_{\text{in}}}{R_1 + R_2}$

## Particles and photons

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