OCR

Monday 9 June 2014 – Morning

AS GCE PHYSICS A

G482/01 Electrons, Waves and Photons

Candidates answer on the Question Paper.

OCR supplied materials:
- Data, Formulae and Relationships Booklet (sent with general stationery)

Other materials required:
- Electronic calculator

Duration: 1 hour 45 minutes

Candidate forename		Candidate surname	

Centre number						Candidate number				

INSTRUCTIONS TO CANDIDATES

- Write your name, centre number and candidate number in the boxes above. Please write clearly and in capital letters.
- Use black ink. HB pencil may be used for graphs and diagrams only.
- Answer **all** the questions.
- Read each question carefully. Make sure you know what you have to do before starting your answer.
- Write your answer to each question in the space provided. If additional space is required, you should use the lined page at the end of this booklet. The question numbers must be clearly shown.
- Do **not** write in the bar codes.

INFORMATION FOR CANDIDATES

- The number of marks is given in brackets **[ ]** at the end of each question or part question.
- The total number of marks for this paper is **100**.
- You may use an electronic calculator.
- You are advised to show all the steps in any calculations.
- Where you see this icon you will be awarded marks for the quality of written communication in your answer.
  This means for example you should:
  - ensure that text is legible and that spelling, punctuation and grammar are accurate so that meaning is clear;
  - organise information clearly and coherently, using specialist vocabulary when appropriate.
- This document consists of **20** pages. Any blank pages are indicated.

OCR is an exempt Charity

Turn over

Answer **all** the questions.

1 Fig. 1.1 shows the *I*-*V* characteristic of a 6.0 V 1.5 W filament lamp.

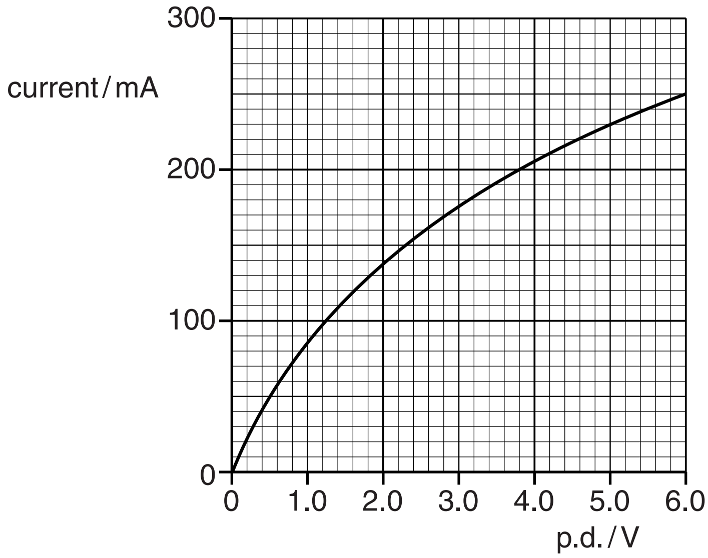

Fig. 1.1

(a) **(i)** State how Fig. 1.1 shows that the filament lamp does not obey Ohm's law.

....

.... **[1]**

(ii) Explain how Fig. 1.1 shows that the resistance of the filament lamp is about 10 Ω when the current is between zero and 50 mA.

[2]

(iii) Explain why the resistance of the filament lamp is much larger (about 25 Ω) at 6.0 V.

....

....

....

.... **[2]**

(b) A student designs a circuit for a night light using the filament lamp of part **(a)** and a light-dependent resistor (LDR). The circuit is shown in Fig. 1.2.

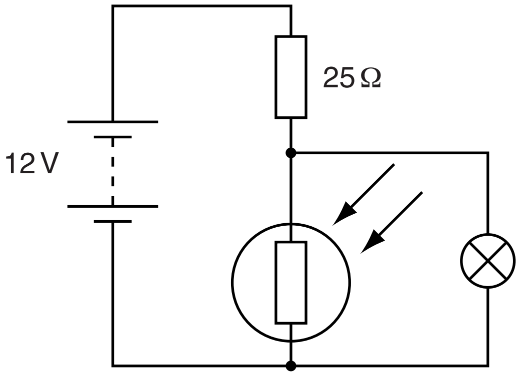

Fig. 1.2

This LDR has a resistance of about 1 Ω in daylight and 1000 Ω in the dark.

Show that the circuit will cause the lamp to be off in the day and on at night as long as the light from the lamp does not shine on the LDR.

In your answer you should explain clearly with or without calculation how the circuit functions to cause the lamp to be off in daylight and on in the dark.

....

....

....

....

....

....

....

....

....

....

....

....

....

.... **[5]**

[Total: 10]

2 **(a)** The following electrical quantities are often used when analysing circuits. The units given are alternatives to the units normally used for the quantities below. Draw a straight line from each quantity on the left to its correct unit on the right.

electromotive force	A s
resistance	V C
energy	$V A^{-1}$
charge	$J C^{-1}$

[2]

(b) The circuit in Fig. 2.1 consists of a cell and five resistors.

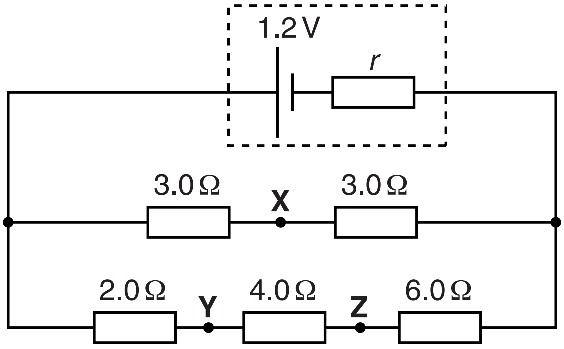

Fig. 2.1

The cell has e.m.f. 1.2 V and internal resistance *r*. The current at point **X** is 0.16 A.

(i) Define *potential difference*.

....

....

.... **[2]**

(ii) Explain what is meant by *internal resistance*.

....

.... **[1]**

(iii) Explain why the current at **X** must be twice the current at **Y** or **Z**.

....

....

....

....

.... **[2]**

(iv) Calculate the p.d. across the 6.0 Ω resistor.

p.d. = ... V **[2]**

(v) Suggest why the p.d. V_{XZ} between **X** and **Z** is zero.

....

....

....

....

.... **[2]**

(vi) Calculate the value of the internal resistance *r*.

r = ... Ω **[4]**

[Total: 15]

3 **(a)** Define *resistance*.

....

.... **[1]**

(b) The smallest conductor within a computer processing chip can be represented as a rectangular block that is one atom high, four atoms wide and twenty atoms long. One such block is shown in Fig. 3.1.

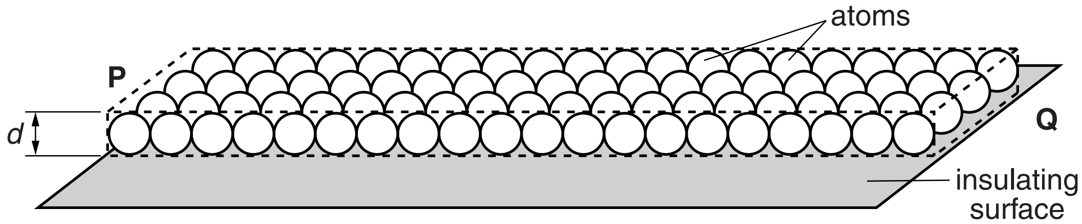

Fig. 3.1

The block is made from phosphorus atoms of diameter $d = 3.8 \times 10^{-10}$ m. The atoms are deposited on an insulating surface. This ensures that the atoms touch each other.

(i) Show that the resistance between the ends **P** and **Q** of this block is greater than 200 Ω. The resistivity of phosphorus is $1.7 \times 10^{-8}\,\Omega$ m.

[3]

(ii) Show that the number density of free electrons within the block is about $2 \times 10^{28}\,\text{m}^{-3}$. Assume that each phosphorus atom contributes one free electron.

[1]

(iii) Calculate the current between **P** and **Q** when the mean drift velocity of free electrons in the block is $1.9 \times 10^{-5}\,\mathrm{m\,s^{-1}}$.

current = ... A **[2]**

(iv) There are about 10^9 of these tiny conductors in a single chip each carrying the current calculated in **(iii)**. Estimate the total power dissipated in these conductors in a single chip.

power = ... W **[3]**

(c) It takes about 4×10^{-4} s for an electron to pass from **P** to **Q** but the electrical signal, an electromagnetic wave, is transmitted across the block in about 3×10^{-17} s. Explain why these times are so different.

....

....

....

.... **[2]**

[Total: 12]

4 Fig. 4.1 shows the *I-V* characteristic of a blue light-emitting diode (LED).

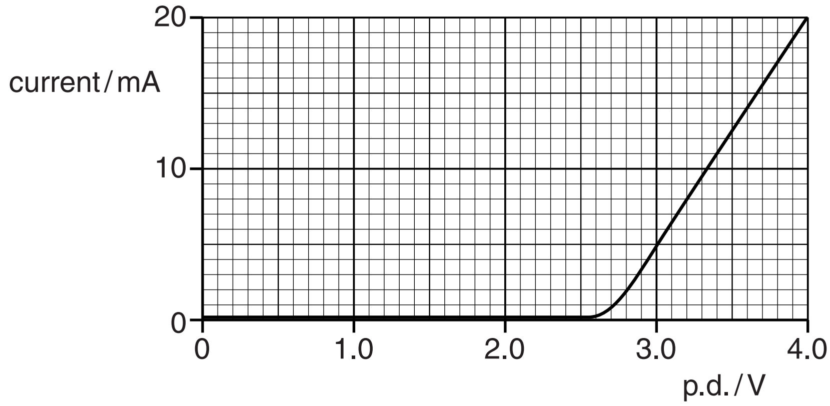

Fig. 4.1

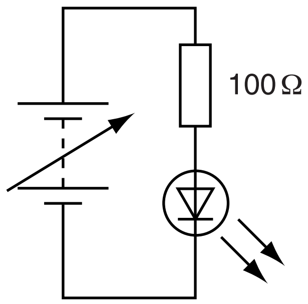

Fig. 4.2

(a) (i) The data for plotting the *I-V* characteristic is collected using the components shown in Fig. 4.2. By drawing on Fig. 4.2 complete the circuit showing how you would connect the two meters needed to collect these data. **[1]**

(ii) When the current in the circuit of Fig. 4.2 is 20 mA calculate the terminal potential difference across the supply.

terminal p.d. = ... V **[3]**

(b) The energy of each photon emitted by the LED comes from an electron passing through the LED. The energy of each blue photon emitted by the LED is 4.1×10^{-19} J.

(i) Calculate the energy of a blue photon in electron volts.

energy = ... eV **[1]**

(ii) Explain how your answer to **(i)** is related to the shape of the curve in Fig. 4.1.

....

....

....

.... **[2]**

(c) Calculate for a current of 20 mA

(i) the number *n* of electrons passing through the LED per second

n = ... s^{-1} **[2]**

(ii) the total energy of the light emitted per second

energy per second = ... J s^{-1} **[2]**

(iii) the efficiency of the LED in transforming electrical energy into light energy.

efficiency = ... **[2]**

(d) The energy of a photon emitted by a red LED is 2.0 eV. The current in this LED is 20 mA when the p.d. across it is 3.4 V. Draw the *I*-*V* characteristic of this LED on Fig. 4.1. **[2]**

[Total: 15]

5 Fig. 5.1 shows two loudspeakers **S** and **T** connected to a signal generator, emitting sound of a single frequency but with different amplitudes. A person walks in the direction from **O** to **Q**. The line **OQ** is at a distance D from the loudspeakers.

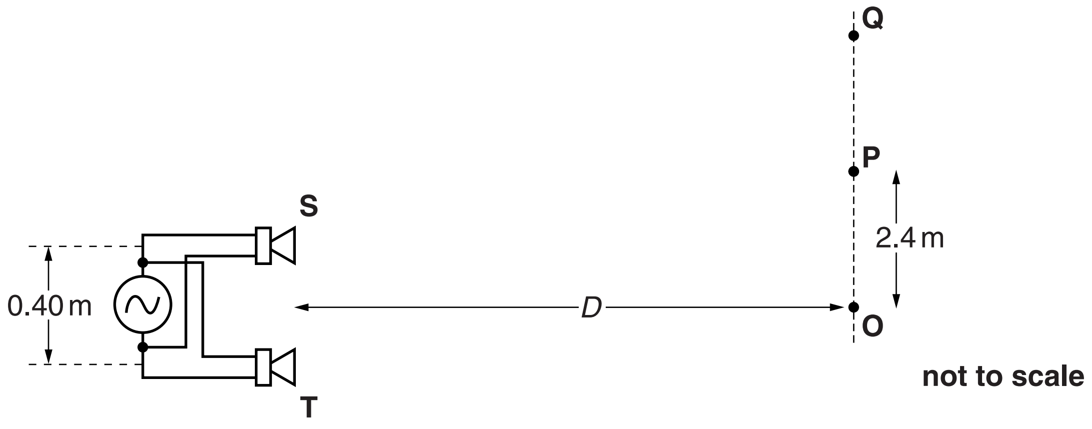

Fig. 5.1

The sound waves emitted individually by **S** and **T** have displacements x_S and x_T at the point **P**. Fig. 5.2 shows the variation with time t of each of these displacements. Note that the amplitude of the wave from **T** is twice that of the wave from **S**.

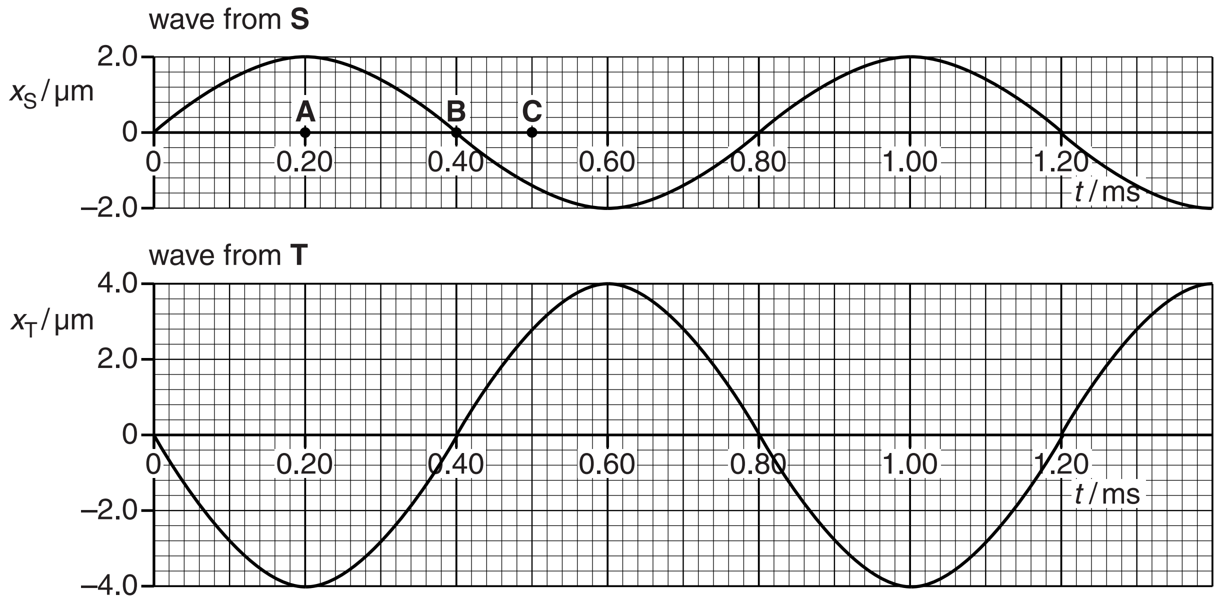

Fig. 5.2

(a) Explain whether or not the two waves are coherent.

....

.... **[1]**

(b) Explain why the sound heard at **P** will be of minimum but not zero intensity.

....

....

....

.... **[2]**

(c) State the phase difference between the oscillation at time **A**, labelled on the t–axis of the x_S against t curve in Fig. 5.2, and the oscillation

(i) at time **B** ....

(ii) at time **C** .... **[2]**

(d) **(i)** Calculate the wavelength λ of the sound waves emitted from the loudspeakers.

speed of sound in air = $340\,\mathrm{m\,s^{-1}}$

λ = ... m **[3]**

(ii) Maximum intensity of sound is heard at point **O**. The loudspeakers are 0.40 m apart and the distance **OP** is 2.4 m. **P** is the position of the first minimum.
Calculate the distance D from the loudspeakers to the line **OQ**. Assume that the equation used for the interference of light from a double-slit also applies for the sound from these two loudspeakers.

D = ... m **[3]**

(e) **(i)** Explain the term *intensity*.

....

.... **[1]**

(ii) The intensity of the sound at point **P**, the minimum, is $4.0 \times 10^{-6}\,W\,m^{-2}$. Use data from Fig. 5.2 to calculate the maximum intensity of sound, at point **O**.

maximum intensity = ... $W\,m^{-2}$ **[3]**

[Total: 15]

Question 6 begins on page 14

BLANK PAGE

Question 6 begins on page 14

PLEASE DO NOT WRITE ON THIS PAGE

6 **(a)** State **two** properties which distinguish electromagnetic waves from other transverse waves.

....

....

....

.... **[2]**

(b) **(i)** Describe what is meant by *a plane polarised wave*.

....

....

....

.... **[2]**

(ii) Light from a filament lamp is viewed through two polarising filters, shown in Fig. 6.1. The arrow beside each filter indicates the transmission axis of that polarising filter.

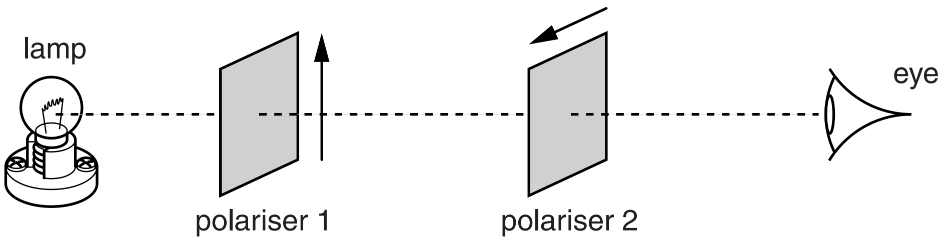

Fig. 6.1

Explain why the lamp cannot be seen by the eye.

....

....

....

....

....

....

.... **[2]**

(iii) A third polarising filter is placed between the first two with its transmission axis at 45° to each of the others as shown in Fig. 6.2.

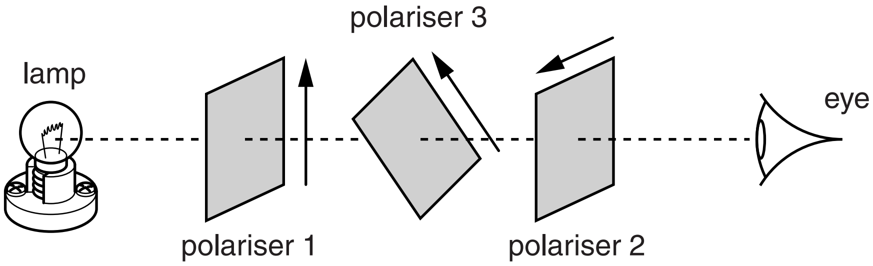

Fig. 6.2

Explain whether or not any light reaches the eye through the three filters.

In your answer you should state clearly the condition for light to be transmitted by a polarising filter.

....

....

....

....

....

....

....

....

....

.... **[3]**

[Total: 9]

7 An estimation of the speed of electromagnetic waves can be made using the hot spots inside a microwave oven. Microwaves are emitted in all directions inside the metal walls of the oven at a frequency of 2.5×10^9 Hz causing stationary waves to be set up. Fig. 7.1 shows a typical pattern of the centres of the hot spots marked **X** in the central area of the floor of the oven.

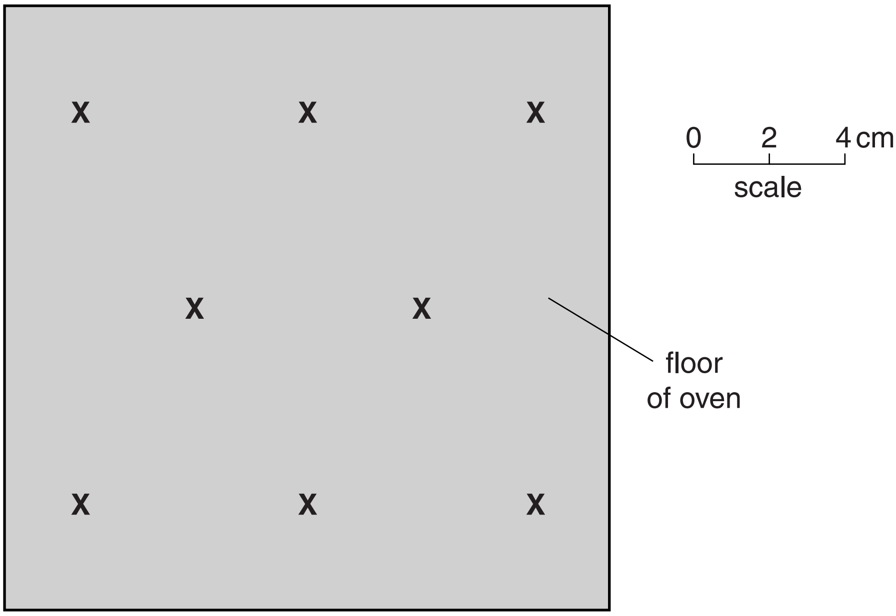

Fig. 7.1

These positions can be located to within a few millimetres by melting small areas in a bar of chocolate placed on the floor of the oven for a few seconds.

(a) Explain how a stationary microwave pattern is set up in the oven.

....

....

....

....

....

....

....

....

....

....

.... **[3]**

(b) Explain whether the points marked **X** on Fig. 7.1 are at nodes or antinodes in the wave pattern.

....

....

....

....

.... **[2]**

(c) Fig. 7.1 is drawn to **half scale**. By using measurements taken from the diagram make an estimate of the speed *c* of the microwaves. Make your reasoning clear.

c = ... $m\,s^{-1}$ **[4]**

[Total: 9]

8 In a demonstration experiment of the photoelectric effect, light of wavelength 440 nm incident on a clean metal surface causes electrons to be emitted. No electrons are emitted from the surface when the wavelength of the incident light is greater than 550 nm.

(a) **(i)** Define the term *work function*.

....

.... **[2]**

(ii) Explain how the work function is related to the threshold frequency.

....

....

.... **[2]**

(iii) Calculate the value of the work function for this metal.

work function = ... J **[2]**

(b) **(i)** Show that the maximum speed of the emitted electrons in the experiment is about $4.5 \times 10^{5}\,\mathrm{m\,s^{-1}}$.

[3]

(ii) Calculate the minimum de Broglie wavelength of an emitted electron.

wavelength = ... m **[2]**

(c) The light source for this experiment is a discharge lamp containing excited atoms which emit light at several wavelengths. Fig. 8.1 shows the three lowest energy levels of one of these atoms, labelled $n = 1$, 2 and 3.

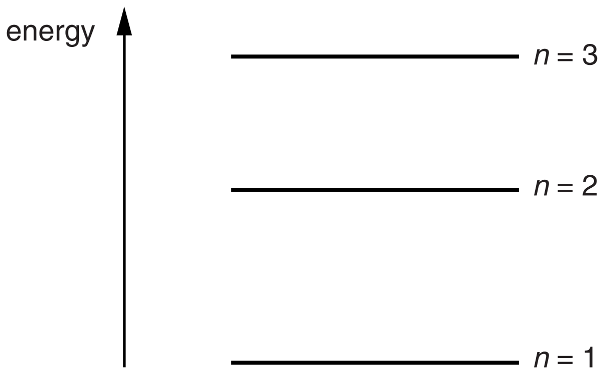

Fig. 8.1

Electron transitions between these energy levels can produce three different wavelengths of radiation. The transition between $n = 2$ and $n = 1$ causes the 440 nm photons.

(i) Photons at 590 nm are also emitted. Which transition causes these photons?

.... **[1]**

(ii) Hence calculate the wavelength of the photons emitted by the third transition.

wavelength = ... m **[3]**

[Total: 15]

END OF QUESTION PAPER

ADDITIONAL ANSWER SPACE

If additional answer space is required, you should use the following lined page(s). The question number(s) must be clearly shown in the margins.