OCR
Oxford Cambridge and RSA

Thursday 9 June 2016 – Afternoon

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 number(s) 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.

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Answer **all** the questions.

1 **(a)** Write a suitable word equation to define the *resistivity* of a material.

.....

..... **[1]**

(b) A student investigates the electrical properties of the graphite 'lead' in a pencil.

(i) The pencil is 150 mm long. The 'lead' is a cylindrical graphite rod of diameter 2.0 mm. The resistance of the rod is 8.0 Ω. Calculate the resistivity ρ of graphite.

ρ = ... unit ..... **[4]**

(ii) The graphite rod is removed from the pencil and used as a variable resistor, labelled 8.0 Ω in the circuit of Fig. 1.1. At a particular point **X** the current in ammeter $\mathbf{A_1}$ is twice the current in ammeter $\mathbf{A_2}$.

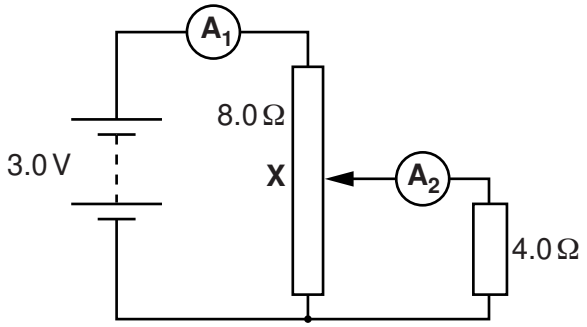


Fig. 1.1

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1 Explain why **X** must be the mid point of the graphite rod.

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..... **[3]**

2 Calculate the current in $\mathbf{A_1}$.

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

(c) Calculate the mean drift velocity v of the free electrons in the graphite rod when there is a current of 0.40 A in it.

number of charge carriers per unit volume = $3.6 \times 10^{26}\,\text{m}^{-3}$

v = ... m s^{-1} **[3]**

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(d) A metal such as copper is classified as a *conductor*. Graphite behaves as a *semiconductor*.

(i) Describe why the resistivity of copper is less than that of graphite.

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..... **[2]**

(ii) State with a reason what effect an increase in temperature has on the electrical properties of each of these two types of material.

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..... **[2]**

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2 Fig. 2.1 shows the *I-V* characteristic of a light-emitting diode (LED) which is designed to light normally at a current of 30 mA.

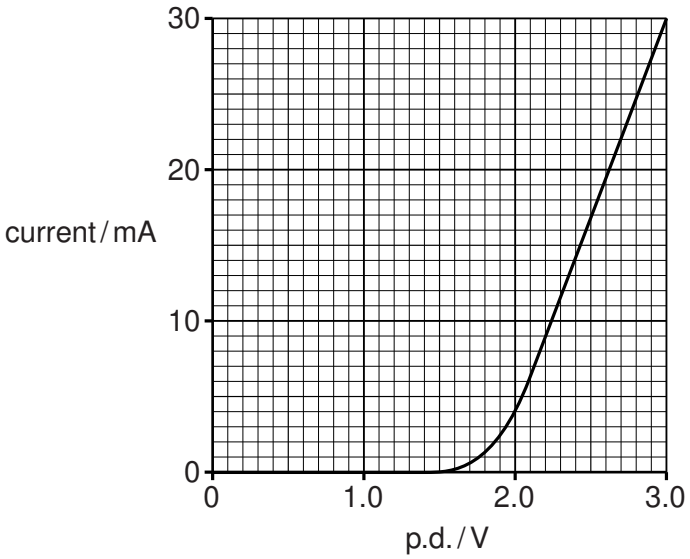


Fig. 2.1

(a) (i) On Fig. 2.1 draw the *I-V* characteristic of a fixed resistor of resistance 67 Ω. **[2]**

(ii) Explain how the *I-V* characteristics show that the resistor obeys Ohm's law but the LED does not.

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..... **[2]**

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(b) The LED and 67 Ω resistor are connected in **series** to a 5.0 V d.c. supply of negligible internal resistance.

(i) Show that the LED lights normally, i.e. with a current of 30 mA.

[3]

(ii) Calculate

1 the charge Q passing through the LED each second

Q = ... C **[1]**

2 the energy required to light the LED each second

energy = ... J **[2]**

3 the energy dissipated in the resistor each second.

energy = ... J **[2]**

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(iii) Seven of these LEDs, each with its 67 Ω series resistor, are arranged in a unit as shown in Fig. 2.2 to display any number from 0 to 9.



Fig. 2.2

Three of these units enable numbers up to 999 to be displayed. The three number display is connected to the 5.0 V supply so that all the LED-resistor combinations are in parallel. Each three number display is provided with a fuse.
Circle the most suitable value for the fuse from the list below and give a reason for your choice.

50 mA 500 mA 1.0 A 3.0 A

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..... **[2]**

(c) Give **one** other example where LEDs are now commonly used. Suggest **one** advantage of using LEDs in place of filament lamps.

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..... **[2]**

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3 **(a)** Circle the quantity, in the list below, that is conserved in Kirchhoff's second law.

charge **e.m.f.** **energy** **current** **[1]**

(b) Explain the meaning of the following terms which are often used when referring to a d.c. supply

(i) *terminal potential difference*

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.....

..... **[2]**

(ii) *internal resistance.*

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.....

..... **[1]**

(c) Fig. 3.1 shows a d.c. supply labelled 6.0 V connected to a circuit containing an ammeter, a voltmeter, a fixed 3.0 Ω resistor and a 0 to 15 Ω variable resistor. You are to carry out an experiment to show that the internal resistance *r* of the d.c. supply is constant for a range of currents and to find the value of *r*.

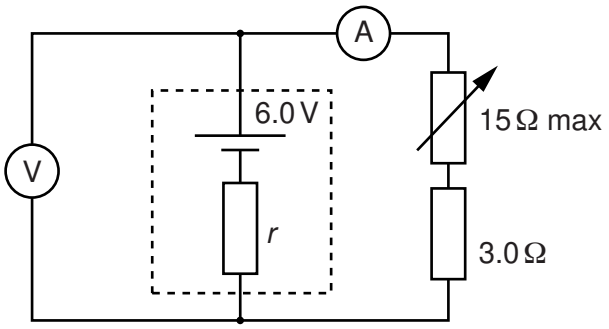


Fig. 3.1

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(i) Describe how you would carry out the experiment. Explain how you would determine the value of the internal resistance of the d.c. supply and show that it is constant.

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..... **[5]**

(ii) Suggest why the 3.0 Ω resistor is included in the circuit.

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..... **[1]**

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(d) Two cells **X** and **Y** each have an e.m.f. and internal resistance as shown in Fig. 3.2. They are connected in series to a resistor **R** of resistance 2.0 Ω.

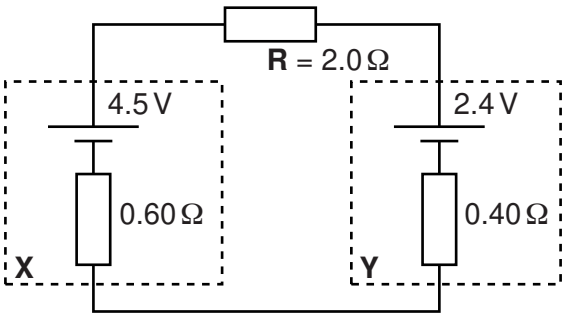


Fig. 3.2

(i) Note that the positive terminals of the cells are connected together. Draw a single arrow on Fig. 3.2 to show the direction of the current in **R**. **[1]**

(ii) Calculate the current in **R**.

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

(iii) Calculate

1 the p.d. V_R across **R**

V_R = ... V **[1]**

2 the terminal p.d. V_X across **X**.

V_X = ... V **[2]**

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4 **(a)** A diffraction grating is used to determine the wavelengths emitted by a light source.

Fig. 4.1 shows light being diffracted through an angle θ at a tiny length of a grating.

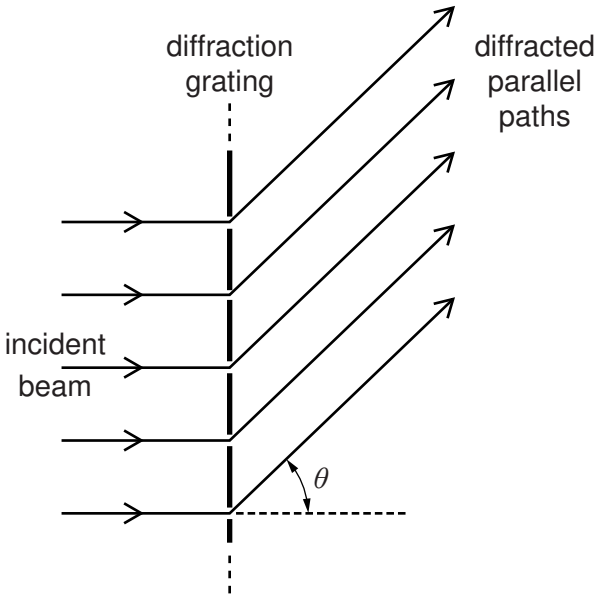


Fig. 4.1

Light of a given wavelength is observed only at particular angles through the grating. Use the ideas of wave superposition and interference to explain why light of that wavelength is observed only at certain angles.
You may find it useful to use Fig. 4.1 to illustrate your answer.

In your answer you should state clearly the conditions for the beam of coherent light at angle θ to produce a bright spectral line.

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..... **[4]**

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(b) Fig. 4.2 shows the positions of the five strongest lines in the emission spectrum of mercury when light from a mercury lamp is passed through a diffraction grating. The lines are labelled **A** to **E** and their wavelengths are shown on the diagram in nanometres.

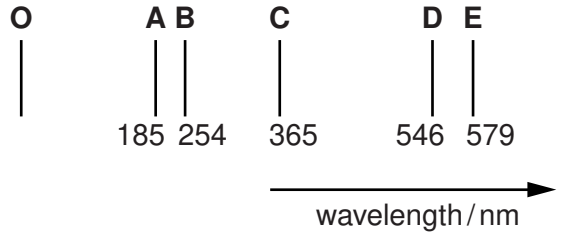


Fig. 4.2

(i) Fig. 4.3 shows the angular position of line **E** in the first order spectrum and the bright central beam **O** caused by the incident beam of mercury light passing through the grating.

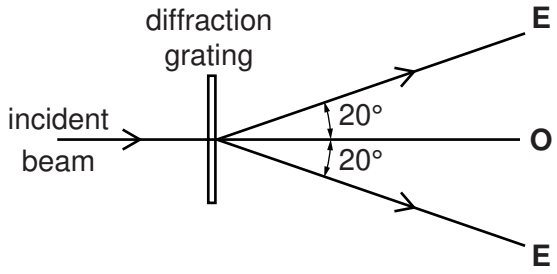


Fig. 4.3

1 On Fig. 4.3 add and label the approximate angular position of spectral line **C** in the first order spectrum. **[1]**

2 Use data from Figs 4.2 and 4.3 to calculate the line separation *d* for the grating.

d = ... m **[3]**

(ii) State which **one** of the wavelengths, **A** to **E**, in Fig. 4.2 has the lowest photon energy.

..... **[1]**

(iii) State which of the wavelengths, **A** to **E**, in Fig. 4.2 are in the visible region of the spectrum.

..... **[1]**

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(iv) Fig. 4.4 is an energy level diagram showing the electron transition for mercury atoms which results in one of the wavelengths **A** to **E** in Fig. 4.2.

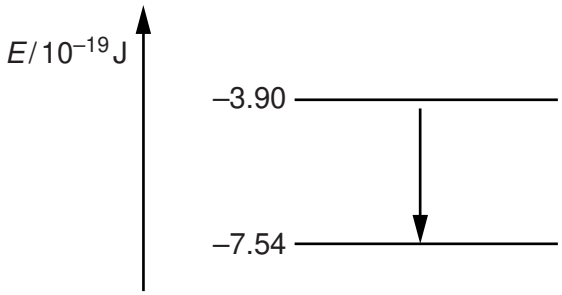


Fig. 4.4

Determine by calculation which one of the wavelengths corresponds to this transition.

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

(v) State **one** similarity and **one** difference between a line emission spectrum and a line absorption spectrum for mercury.

similarity .....

.....

difference .....

..... **[2]**

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(vi) Light from a mercury lamp is incident on a calcium surface. The work function of calcium is 4.7×10^{-19} J. Show that a photon of wavelength 254 nm, spectral line **B** in Fig. 4.2, can cause the emission of an electron with maximum kinetic energy 3.1×10^{-19} J.

[3]

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5 (a) (i) Define the terms *wavelength*, *frequency* and *period* used to describe wave motion.

wavelength, λ .....

.....

frequency, f .....

.....

period, T .....

..... **[3]**

(ii) Starting from the definition of speed v, derive the wave equation which relates λ, f and v. Explain your reasoning clearly.

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..... **[3]**

Question 5 continues on page 16

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(b) Fig. 5.1 shows a long plastic tube immersed in a deep tank of water. A loudspeaker emitting a sound of constant frequency 512 Hz is fixed to the end of the tube. The tube is raised out of the water until a loud sound is first heard, position **P**. The tube is raised again until a loud sound is heard for a second time, position **Q**. The distance that the tube is raised between the two positions of loud sound is shown in the diagram.

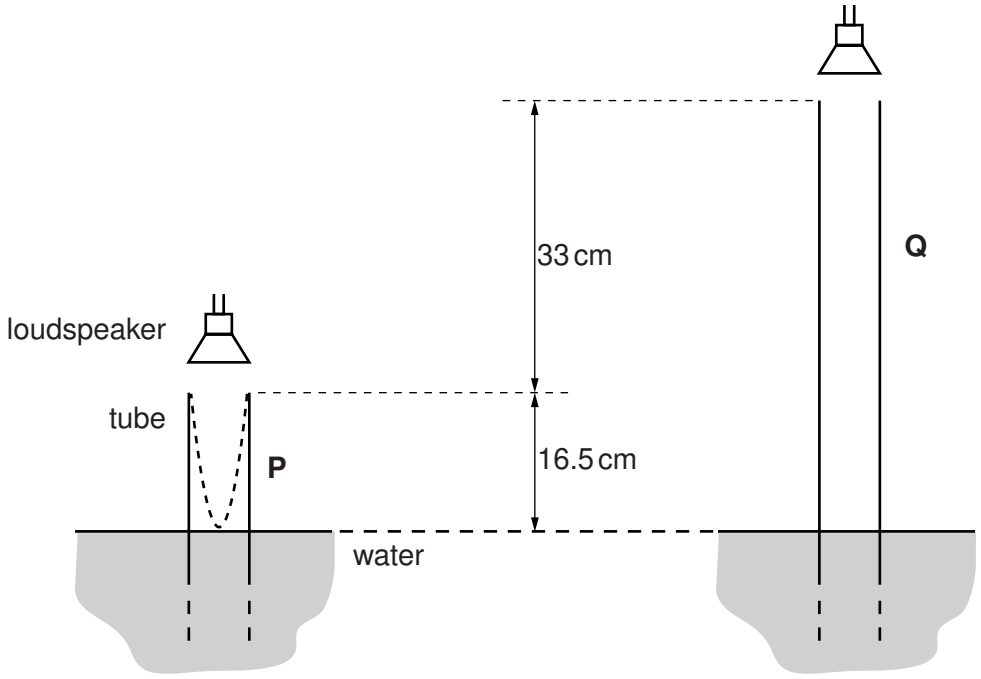


Fig. 5.1

The tube is narrow enough for end corrections to be ignored.

(i) The dotted line in the tube when at position **P** illustrates the stationary wave produced in the tube.

1 Sketch on Fig. 5.1 the stationary wave formed in the tube when at position **Q**. **[1]**

2 On your sketch, label the positions of all nodes with the letter **N**, and all antinodes with the letter **A**. **[2]**

(ii) Calculate the speed v of sound in the tube.

v = ... $m\,s^{-1}$ **[3]**

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(c) The length of the tube is 66 cm. The tube is removed completely from the water with the loudspeaker continuing to emit the same frequency of 512 Hz. A loud sound is again heard.

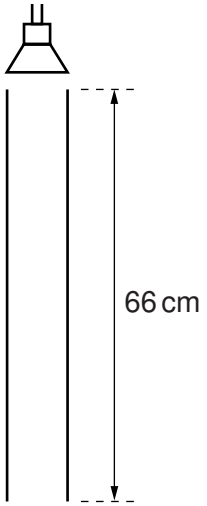


Fig. 5.2

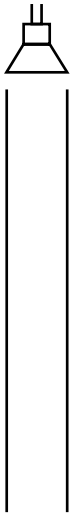


Fig. 5.3

(i) Sketch on Fig. 5.2 the stationary wave now produced in the tube. **[1]**

(ii) **1** State the fundamental frequency f_0 of the stationary wave in the open tube.

f_0 = ... Hz **[1]**

2 On Fig. 5.3 sketch the fundamental mode of vibration in the open tube. **[1]**

(iii) Explain why the stationary wave in Fig. 5.2 is the second harmonic for an open pipe.

.....

.....

..... **[2]**

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6 (a) (i) The de Broglie equation is often written in the form

$$\lambda = \frac{h}{mv}.$$

Explain the meaning of each symbol used in the equation.

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..... **[3]**

(ii) Describe briefly **one** piece of evidence for believing that electrons sometimes behave like waves.

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..... **[2]**

(iii) The electrons in a typical electron microscope are accelerated through a potential difference of 5.0×10^4 V.

1 Show that the final speed of an accelerated electron is about $1.3 \times 10^8\,\text{m}\,\text{s}^{-1}$.

Ignore any relativistic effects.

[3]

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2 Calculate the de Broglie wavelength of an electron moving at $1.3 \times 10^8\,m\,s^{-1}$.

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

3 Calculate by how many powers of 10 this is shorter than the wavelength of visible light used in optical microscopes.

powers of ten = ... **[2]**

(b) Electromagnetic waves sometimes behave like particles, called photons. Name and describe briefly **one** piece of evidence which supports this particle-like behaviour.

In your answer you should name the experiment and make clear how the observations are explained using a photon model of electromagnetic radiation.

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..... **[4]**

END OF QUESTION PAPER

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ADDITIONAL ANSWER SPACE

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

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