OCR A-LEVEL PHYSICS A

PHYSICS



EXAM QUESTION PACK

UNIT G482 OLD SPECIFICATION PAPERS

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OCR
Oxford Cambridge and RSA

Thursday 8 June 2017 – 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

* G 4 8 2 0 1 *

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 barcodes.

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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Turn over

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Answer **all** the questions.

1 Many filament lamps are now obsolete. They have been replaced by light-emitting diode (LED) technology. For example, an 8.7 W LED lamp has replaced the 60 W mains filament lamp.

(a) A 60 W filament lamp is connected to the 230 V supply.
Calculate

(i) the current I drawn from the supply

I = ... A **[2]**

(ii) the resistance R of the filament.

R = ... Ω **[1]**

(b) The filament temperature is 2800 K when the lamp is lit. At this temperature, the cross-sectional area of the filament wire is $4.8 \times 10^{-8}\,m^2$. The material of the filament has resistivity $7.0 \times 10^{-5}\,\Omega\,m$.

(i) Calculate the length of the filament wire using your value for R from **(a)(ii)**.

length = ... m **[3]**

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(ii) At the end of its lifetime, the filament of the lamp usually breaks immediately after the lamp is switched on, rather than after glowing for some time. Suggest a reason for this behaviour.

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

(c) An 8.7 W LED lamp is left on for 3.0 hours.
Calculate the charge passing though the lamp in this time.

charge = ... unit ..... **[3]**

(d) The lifetime of the 60 W filament lamp is advertised to be 1500 hours, whilst for the 8.7 W LED lamp the figure is 15000 hours. Each lamp costs £1.00.
The cost of 1 kWh is 12 p.
Calculate the saving made by changing from a filament lamp to an LED lamp over the lifetime of the LED lamp.

saving = £ ..... **[3]**

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2 A 120 V power supply with negligible internal resistance is connected to four resistors, as shown in Fig. 2.1.

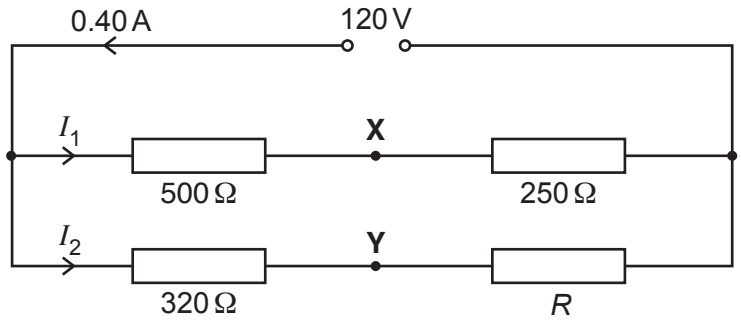


Fig. 2.1

The resistance values of the four resistors are 500 Ω, 250 Ω, 320 Ω and *R*.
The current from the supply is 0.40 A. The currents in the two branches are I_1 and I_2 as shown.

(a) Calculate

(i) current I_1

I_1 = ... A **[2]**

(ii) resistance *R*.

R = ... Ω **[2]**

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(b) Two points in Fig. 2.1 are labelled **X** and **Y**.

(i) Calculate the potential difference V_{XY} between **X** and **Y**.

V_{XY} = ... V **[2]**

(ii) The resistor of resistance R in Fig. 2.1 is changed to one with a lower resistance. The rest of the circuit remains unchanged.
State and explain the effect on

current I_1

.....

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

current I_2

.....

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

potential difference V_{XY}.

.....

.....

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

Question 2 is continued on page 6

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(c) The resistor of resistance *R* is now replaced by a thermistor. The variation of resistance with temperature for the thermistor is shown in Fig. 2.2.

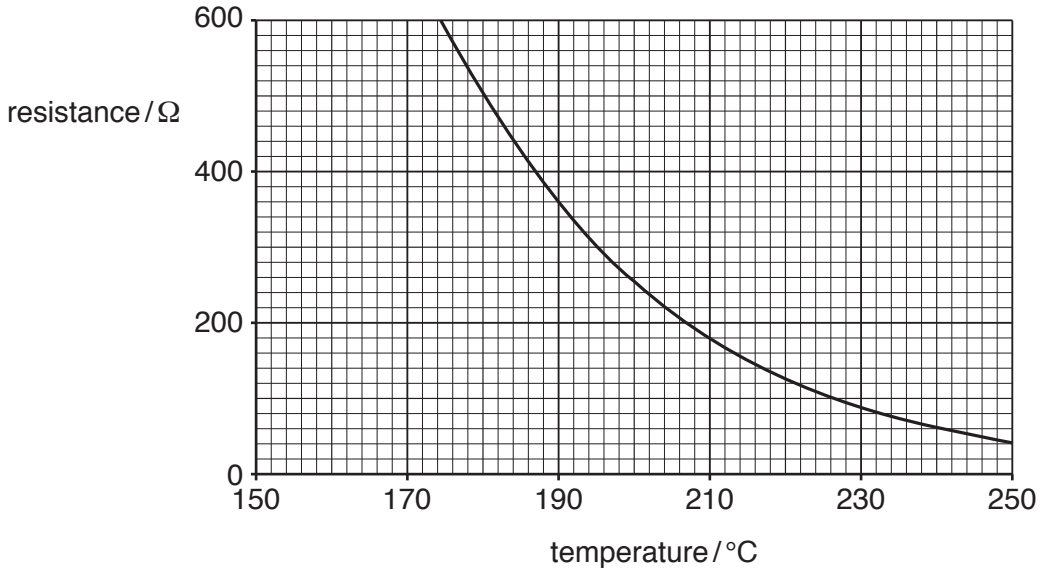


Fig. 2.2

(i) Complete the circuit symbol for a thermistor on the symbol labelled *R* in Fig. 2.1. **[1]**

(ii) In an experiment the thermistor is mounted (on long conducting leads) in an oven. The temperature of the oven must be kept between 200 °C and 220 °C. The temperature can be monitored by an ammeter placed at **Y** or by a voltmeter placed between **X** and **Y**.

1 Show that the ratio $\frac{\text{change in current}}{\text{change in temperature}}$ is $3\,\text{mA}\,\text{K}^{-1}$ between 200 °C and 220 °C.

[3]

2 Hence show that the ratio $\frac{\text{change in voltage}}{\text{change in temperature}}$ is $1\,\text{V}\,\text{K}^{-1}$ between 200 °C and 220 °C.

[2]

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3 Explain why it is better to measure the voltage across **XY** than the current at **Y**.

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

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3 **(a)** **(i)** Define the term *electromotive force*.

.....

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

(ii) Explain, in the context of energy transfer, the meaning of the term *internal resistance*.

.....

.....

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

(b) You are asked to plan an experiment to determine the e.m.f. E and internal resistance r of a cell. The plan is to include a circuit diagram with two meters and a variable resistor. The data collected is to be plotted on a graph from which E and r can be determined.

The e.m.f. of the cell is about 6 V and r is about 2 Ω. The maximum resistance of the variable resistor is 18 Ω. Suggest a maximum scale reading for each of the meters to be used in the experiment.

In your answer you should state how the graph is used to determine the values of E and r.

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

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(c) Fig. 3.1 shows the I-V characteristic of a 6.0 V 1.5 W filament lamp.

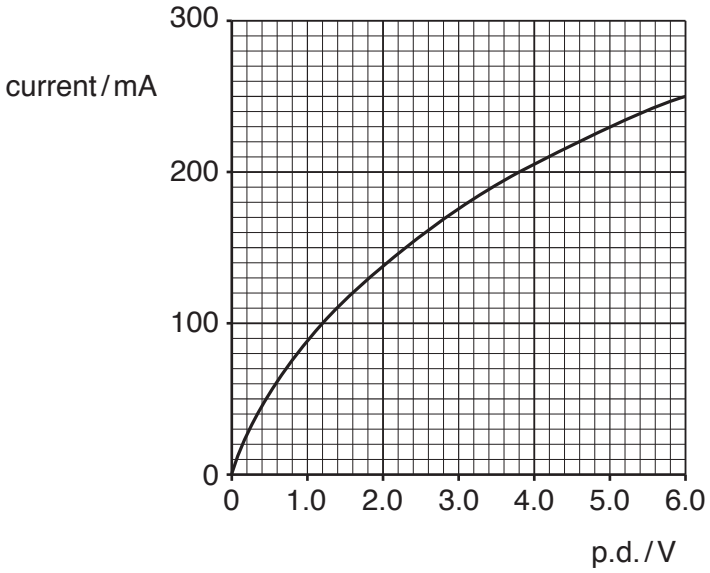


Fig. 3.1

(i) The student is asked to verify that these data are correct using a lamp with the equipment that has just been used for **(b)** above. On Fig. 3.2(a) complete the circuit required to perform this task.

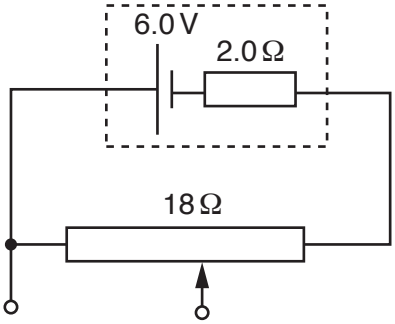


Fig. 3.2(a)

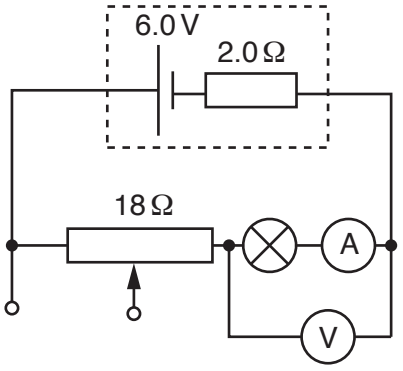


Fig. 3.2(b)

[2]

(ii) The student mistakenly connects the circuit shown in Fig. 3.2(b). By drawing a I-V characteristic for the resistors of total resistance 20 Ω on Fig. 3.1, or otherwise, determine the reading on each meter. Make your reasoning clear.

ammeter reading = ... A

voltmeter reading = ... V

[5]

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4 Fig. 4.1 shows a loudspeaker mounted on a bench and connected to a signal generator.

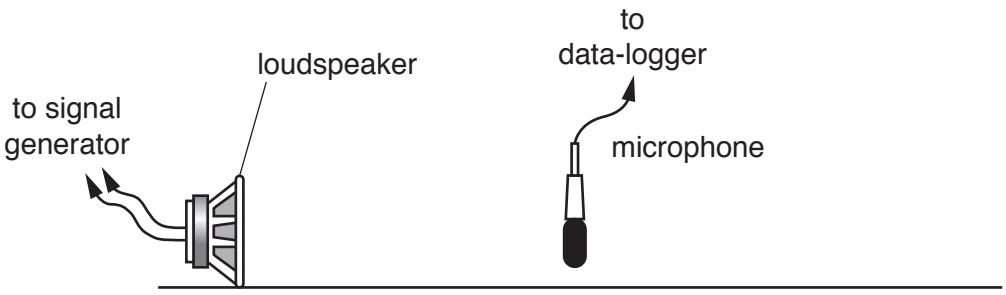


Fig. 4.1

The voltage output from a microphone placed as shown is processed through a data-logger to produce the displacement y of the air against time t graph shown in Fig. 4.2.

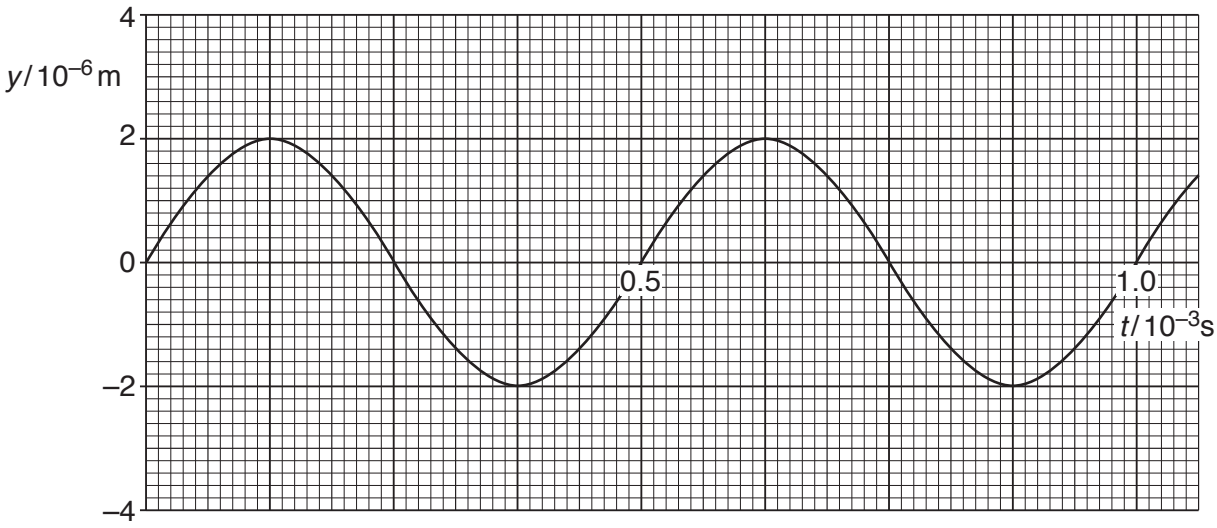


Fig. 4.2

(a) The speed of sound in air is 340 m s^{-1}.
Calculate

(i) the frequency f of oscillation of the air

f = ... Hz **[2]**

(ii) the wavelength λ of the sound.

λ = ... m **[2]**

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(b) The microphone detects the presence of a longitudinal rather than a transverse wave. Explain the difference between the two types of wave motion.

.....

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

(c) **(i)** Explain the meaning of the term *phase difference*.

.....

.....

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

(ii) A second microphone is connected to the data-logger and placed 0.043 m to the right of the one shown in Fig. 4.1. Draw on Fig. 4.2 the variation of the displacement of the air with time at the position of the second microphone. Assume that the data-logger can record both sets of data on the same time scale to produce a graph displaying both curves. **[2]**

(iii) State the phase difference between the two oscillations in degrees or radians.

phase difference ..... unit ..... **[1]**

Question 4 is continued on page 12

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(d) A second loudspeaker is connected to the **same** signal generator and mounted on the bench facing the first as shown in Fig. 4.3. The microphone is at the midpoint along the line joining the two loudspeakers.

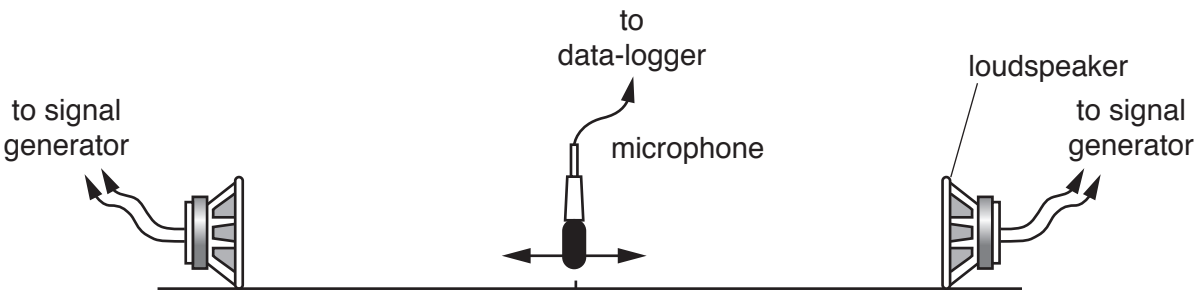


Fig. 4.3

When the microphone is moved to the left, or to the right, the amplitude of the detected signal changes.

(i) Explain why the amplitude varies between maximum and minimum values.

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

(ii) State, with a reason, the distance between adjacent minima.

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distance: ..... m **[2]**

(iii) When the microphone is at the mid-point between the two loudspeakers explain why the amplitude of the detected signal is either a maximum or a minimum.

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

Question 5 begins on page 14

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5 **(a)** Name one common property of electromagnetic waves not shared by other waves.

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

(b) Fig. 5.1 shows a diagram of the seven regions of the electromagnetic spectrum, labelled **A** to **G**.

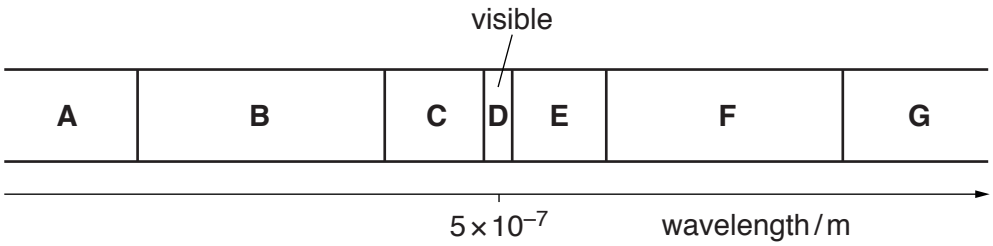


Fig. 5.1

Name the principal radiation in each of the regions **B** and **F**.

B ..... **F** ..... **[2]**

(c) A narrow beam of sunlight is incident on the surface of a flat horizontal glass plate. The reflected beam passes through a polarising filter as shown in Fig. 5.2. The filter is held with its plane perpendicular to the reflected beam.

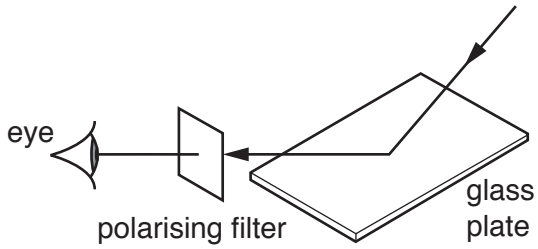


Fig. 5.2

(i) Describe and explain what is observed as the filter is rotated through 360° in the plane perpendicular to the reflected beam.

In your answer you should make clear how the transmission axis of the filter is orientated to explain each of the observations that you describe.

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

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(ii) Suggest how the observations from this experiment help to decide the orientation of the transmission axis in the lenses of Polaroid sunglasses.

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

(d) Ultraviolet radiation from the Sun is divided into three regions UV-A, UV-B and UV-C.

(i) Explain why UV-B is more dangerous to sunbathers than the other two.

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

(ii) Explain how sunscreen protects the human skin.

.....

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

(e) When an electron is accelerated from rest through a potential difference of 500 V it has a de Broglie wavelength equal to that of a gamma ray photon.

Calculate this wavelength in picometres (pm).

wavelength = ... pm **[5]**

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6 The spectrum of light from a sodium vapour lamp consists of a line spectrum. The wavelengths of three spectral lines are shown in the table below.

spectral line	wavelength / nm
R	615
Y	589
G	570

(a) Explain what is meant by a *line* spectrum.

.....

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

(b) The **Y** spectral line has about double the intensity of the other two which are approximately equal. On Fig. 6.1, sketch a graph to represent the relative intensity-wavelength relation for these three lines. Label them **R**, **Y** and **G**.

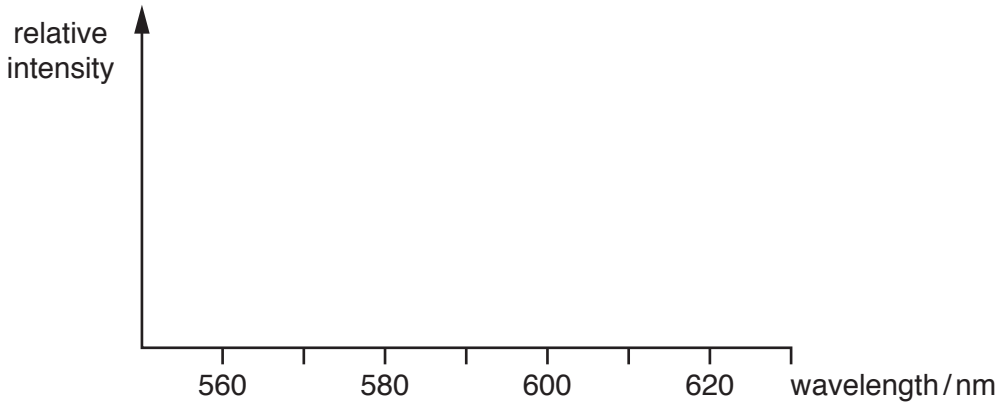


Fig. 6.1

[2]

(c) Calculate, clearly showing your working, the ratio

$$\frac{\text{energy of a photon producing } \mathbf{G}}{\text{energy of a photon producing } \mathbf{Y}}.$$

ratio = ... **[2]**

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(d) The energy level diagram shown in Fig. 6.2 is for the atoms in the lamp emitting light at the three spectral lines **R**, **Y** and **G**. The three electron transitions shown between the four levels **A**, **B**, **C** and **D** produce the three different photons. The energy E of an electron bound to an atom is negative.

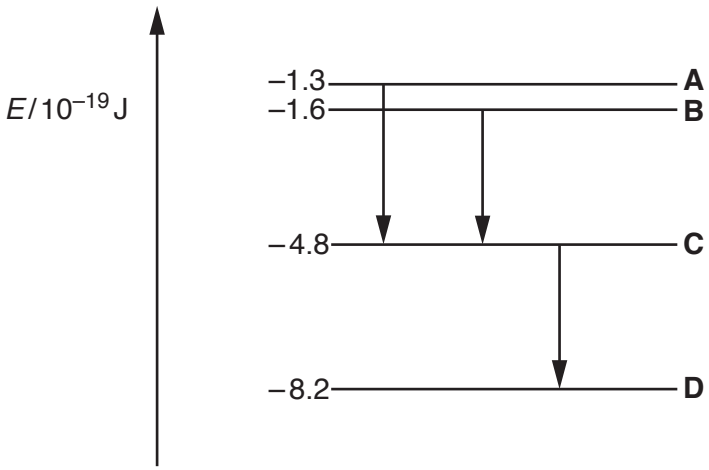


Fig. 6.2 (not to scale)

Label the arrows on Fig. 6.2 **R**, **Y** and **G** to indicate which transition results in which photon. **[2]**

(e) Light from the sodium lamp is analysed by passing it through a diffraction grating.

The line separation d of the grating is 1.67×10^{-6} m.

(i) Calculate the angular spread of the first order spectrum, that is, the angle between the outer lines in Fig. 6.1.

angle = ... ° **[4]**

Question 6 is continued on page 18

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(ii) Calculate how many **R** lines appear over the 180° in front of the grating. Ignore the zeroth order spectral line.

number of **R** lines = ... **[2]**

(f) Fig. 6.3 shows a circuit containing a photoelectric cell. Light from the sodium lamp falls on its cathode and photoelectrons are emitted from the cathode.

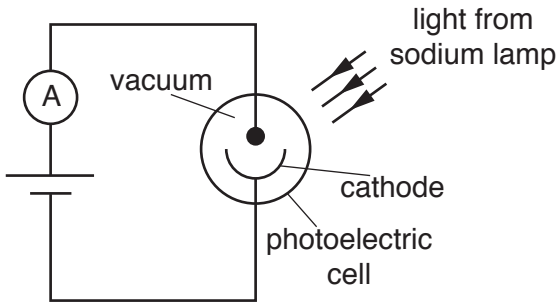


Fig. 6.3

(i) Explain, in terms of the photoelectric effect, why there is a current in this circuit.

.....

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

(ii) Each of the component wavelengths, **R**, **Y** and **G**, is shone in turn on the cathode of the photocell. Predict which wavelength is least likely to produce electron emission. Give a reason for your answer.

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.....

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

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END OF QUESTION PAPER

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ADDITIONAL ANSWER SPACE

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

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GCE

Physics A

Unit **G482**: Electrons, Waves and Photons

Advanced Subsidiary GCE

Mark Scheme for June 2017

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Annotations

Annotation	Meaning
BOD	Benefit of doubt given
CON	Contradiction
	Incorrect response
ECF	Error carried forward
FT	Follow through
NAQ	Not answered question
NBOD	Benefit of doubt not given
POT	Power of 10 error
^	Omission mark
RE	Rounding error ONLY APPLIED ONCE IN THE PAPER; also use as Repeated error
SF	Error in number of significant figures ONLY APPLIED ONCE IN THE PAPER
	Correct response
AE	Arithmetic error
	Wrong physics or equation
/	alternative and acceptable answers for the same marking point
(1)	Separates marking points
reject	Answers which are not worthy of credit

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Annotation	Meaning
not	Answers which are not worthy of credit
IGNORE	Statements which are irrelevant
ALLOW	Answers that can be accepted
( )	Words which are not essential to gain credit
__	Underlined words must be present in answer to score a mark
ecf	Error carried forward
AW	Alternative wording
ORA	Or reverse argument

Subject-specific Marking Instructions

CATEGORISATION OF MARKS

The marking scheme categorises marks on the MABC scheme

B marks: These are awarded as <u>independent</u> marks, which do not depend on other marks. For a **B**-mark to be scored, the point to which it refers must be seen specifically in the candidate's answer.

M marks: These are <u>method</u> marks upon which **A**-marks (accuracy marks) later depend. For an **M**-mark to be scored, the point to which it refers must be seen in the candidate's answer. If a candidate fails to score a particular **M**-mark, then none of the dependent **A**-marks can be scored.

C marks: These are <u>compensatory</u> method marks which can be scored even if the points to which they refer are not written down by the candidate, providing subsequent working gives evidence that they must have known it. For example, if an equation carries a **C**-mark and the candidate does not write down the actual equation but does correct working which shows that the candidate knew the equation, then the **C**-mark is given.

A marks: These are <u>accuracy</u> or <u>answer</u> marks, which either depend on an **M**-mark, or allow a **C**-mark to be scored.

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Note about significant figures:
If the data given in a question is to 2 sf, then allow answers to 2 or more sf.
If an answer is given to fewer than 2 sf, then penalise once only in the entire paper.
Any exception to this rule will be mentioned in the Guidance.
Please put a tick for every mark awarded in the body of the text at the point where the mark is given.

Question			Answer	M	Guidance
1					
	a	i	P = VI I = 60/230 = 0.26 (A)	C1 A1	**allow** 0.261, etc.
		ii	R = V/I = 230/ 0.26 = 882 (Ω)	A1	**ecf ai; allow** 880 Ω to 885 Ω **or** 890 Ω
	b	i	ρ = RA/l or R = ρl/A l = 885 x 4.8 x 10^{-8}/ 7.0 x 10^{-5} ρ = 0.61 (m)	C1 C1 A1	 **ecf aii** **accept** 0.60 to 0.61
		ii	resistivity of filament is temperature dependent/ R of filament is much less/low when cold so initial I large heating effect is I^2R so more likely to melt	B1 B1 B1	**allow** resistance is proportional to temperature/AW
	c		I = P/V = 8.7/230 = 0.038 A Q = It = 0.038 x 3.0 x 3600 = 410 unit C	C1 A1 B1	**allow** 38 mA accept 408, 409 **accept** A s
	d		power difference 51.3 W power cost = 51.3 x 15 x 0.12 = £92.34 9 extra bulbs required = £9.00 so total is £101.34	C1 C1 A1	**alt** bulb £108, LED £15.66; difference; add in £9 **allow** ± 10p **accept** answer to 2 sf
			Total question 1	**15**	

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Question			Answer	M	Guidance
2					
	a	i	$I_1 = V/R$ $I_1 = 120 / 750 = 0.16$ (A)	C1 A1	allow V = IR
		ii	$I_2 = 0.40 – 0.16$ (= 0.24) $0.24(320 + R) = 120$ $R = 180$ (Ω)	C1 A1	**ecf ai** but not if $I_2<0$ or $I_2= I_1$. **alt** $R_{tot} = 300$; $1/300 = 1/750 + 1/(320 + R)$
	b	i	$V_X = 0.16 \times 500 = 80.0$; $V_Y = 0.24 \times 320 = 76.8$ $V_{XY} = 3.2$ (V)	C1 A1	**ecf a; allow** 0.16 x 250 = 40; 0.24 x 180 = 43.2
		ii	I_1 is unchanged as same resistance across supply/AW I_2 increases as (branch) resistance falls (and supply p.d. is constant)/AW V_{XY} decreases as p.d. across 320 Ω increases **or** potential at Y increases (and p.d. at X is constant)	M1 M1 A1	no M mark without justification **ignore** M status of marks above if I_1 is unchanged and I_2 increases have been stated
	c	i	correct symbol	B1	
		ii1	$R_{200} = 575$ Ω; $R_{220} = 445$ Ω $I_{200} = 0.21$ A; $I_{220} = 0.27$ A so $\Delta I/\Delta\theta = 0.06/20$ (= 3 mA K^{-1})	C1 M1 A1	tolerance ± 5 Ω; **allow** 255 Ω and 125 Ω for 1 mark using I = 120/R **accept** answers which become 3 mA K^{-1} to 1 SF
		ii2	$\Delta V/\Delta\theta = 320\ \Delta I/\Delta\theta$ $\Delta V/\Delta\theta = 320 \times 0.003 = 0.96$ (V K^{-1})	M1 A1	$V_{Y200} = 67.2$ V with $V_{XY200} = 12.8$ V; $V_{Y220} = 86.4$ V with $V_{XY220} = -6.4$ V giving $\Delta V/\Delta\theta = 19.2/20$ **accept ecf cii1** x 320
		ii3	fsd of ammeter must be 300 mA so 1/100 of fsd change per K/AW fsd for voltmeter can be ± 10 V so 1/10 of fsd change per K/AW so measurement of V_{XY} better	 B1 B1 A0	**allow** one mark for a simpler/qualitative answer which contrasts the ability to detect a small temperature change using an ammeter or voltmeter.
		•	• **Total question 2**	17	

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Question			Answer	M	Guidance
3					
	(a)	(i)	energy transferred from source/changed from some form to electrical energy; per unit charge (to drive charge round a complete circuit)	M1 A1	
		(ii)	(some) energy is transferred into thermal energy /lost as heat in (driving charge through) the battery/cell/supply (which behaves as if it has a resistance inside)	B1	**allow** there is a voltage drop across/decrease in voltage from the battery when a current is drawn from it/AW **or** any description which uses E = V + Ir but not just the formula alone.
	b		**1.**cell across variable resistor R ammeter in series and voltmeter in parallel across R or cell **2.** y-intercept of graph of V against I gives E **3.** the gradient of line on this graph gives the magnitude of r **4**. range of ammeter 0 to 3 (A**)** **5.** range of voltmeter 0 to 6 (V)	B1 B1 B1 B1 B1	QWC only given if marking points **2** and **3** are present **ignore** sign of gradient in determining r **allow** 0 to 5 A **or** just I_{max} = 3 A **allow** 0 to 10 V **or** just V_{max} = 6 V
	c	i	ammeter in series with lamp across terminals voltmeter in parallel with lamp	B1 B1	correct symbols must be used **allow** across lamp and ammeter
		ii	straight line through origin and 300,6 appreciation that current is the same in both components appreciation that p.d.s across components add to 6 V I = 0.16 to 0.17 (A) V = 2.7 ± 0.1 (V)	B1 B1 B1 B1 B1	if wrong line drawn **allow ecf** for rest of answer **accept** answers in terms of lines drawn on fig.3.1 **or** description of using ruler horizontally on graph and adding squares across graph,etc. **allow** 165 ± 5 x 10^{-3} (A) **or** 165 m(A) **allow** mark for consistent values of V for incorrect I
		•	• **Total question 3**	**15**	

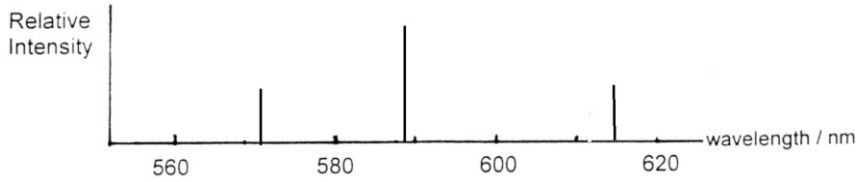
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Question			Answer	M	Guidance
4					
	a	i	f = 1000/0.5 f = 2000 (Hz)	C1 A1	**give** 1 mark for 2 (POT error) **allow** 2 kHz or 2 x 10^3 Hz; no SF penalty
		ii	v = fλ giving 340 = 2000 x λ λ = 0.17 (m)	C1 A1	**ecf(a)(i)**
	b		displacement/oscillation (of particles) is normal/perpendicular to direction of energy transfer in transverse wave displacement/oscillation (of particles) is parallel to direction of energy transfer in longitudinal wave	 B1 B1	**allow** vibrations **allow** direction of wave motion/propagation/velocity/travel **NOT** transverse wave can travel through a vacuum give max 1 mark for 2 similar poor definitions, e.g. direction of travel, waves oscillate, etc. (two such errors scores zero)
	c	i	relates to (the oscillation of) two points on the same wave how far 'out of step' one oscillation is from the other/AW	B1 B1	**allow** terms like the angular separation of the oscillations
		ii	identical curve with any phase shift correct phase, i.e. y= - 2 x 10^{-6} at t = 0	M1 A1	**do not** penalise if curve is not drawn the full width of the diagram, e.g. curve starts on x-axis after 1/4 cycle
		iii	90 degrees or π/2 rad	A1	**accept** symbols for units; **allow** 91° or 1.6 rad
	d	i	two coherent/identical waves travelling in opposite directions interfere/superpose to produce a resultant wave with nodes and antinodes	B1 B1	**allow** with the same speed and frequency/wavelength in place of coherent/identical
		ii	nodes (or antinodes) are λ/2 apart 0.085 (m)	B1 B1	**ecf aii** **allow** 8.5 cm, 85 mm, etc.
		iii	the path lengths from each speaker to microphone are equal the speaker connections to the signal generator cause their vibrations/oscillations to be in phase or in antiphase AW in phase will produce a maximum; in antiphase a minimum	B1 B1 B1	 **allow** rotate one loudspeaker 180°; facing maximum, opposed minimum
			Total question 4	**18**	

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Question			Answer	M	Guidance
5					
	a		travel through a vacuum **and/or** at the speed of light c **or** are caused by accelerating charges	B1	
	b		B are X-rays F are microwaves	B1 B1	if answers are reversed score 1 mark
	c	i	**1** Reflected sunbeam/light is (partially plane) polarised **2** Light transmitted by the filter will vary between max and min **3** Two max & min per rotation **4** Max with axis of transmission of filter parallel to glass plate **5** because amplitude of light in plane of glass unaffected by reflection **6** Min with axis of transmission of filter in plane of light beam **7** because amplitude of light perpendicular to plane of glass is diminished	B1 B1 B1 B1	**max** 4 marks from 7 marking points one of which (QWC) must be **4** or **6**
		ii	Polaroid sunglasses reduce glare (reflected sunlight from sea/surfaces) **or** ground acts like glass plate in Fig. 5.2 (so) axis of transmission of (lens) filter in plane of light beam **or** in direction to minimise light reaching eye from glare/reflection	B1 B1	
	d	i	UV-B is more energetic/shorter wavelength than UV-A UV-C is absorbed by the atmosphere (so does NOT reach the skin)	B1 B1	**accept** any two suitable statements **allow** one mark out of two for **A** and **C** reversed
		ii	filters out/blocks/reflects/absorbs UV(-B)	B1	**allow** chemicals prevent sunburn/skin cancer **not** stops UV penetrating skin
	e		energy = eV = $1.6 \times 10^{-19} \times 500 = 8.0 \times 10^{-17}$ J $\frac{1}{2}mv^2 = 8.0 \times 10^{-17}$ $v^2 = 1.76 \times 10^{+14}$ $v = 1.3(2) \times 10^7$ m s^{-1} $\lambda = h/mv$ $\lambda = 6.63 \times 10^{-34}/(9.11 \times 10^{-31} \times 1.3 \times 10^7)$ $= 5.5 \times 10^{-11} = 55$ (pm)	C1 C1 C1 C1 A1	**accept** eV = $p^2/2m$; $\lambda = h/p = h/\sqrt{(2meV)}$ **ecf** with incorrect (sensible) energy; e.g. not values giving v > c or very small v last mark for answer in pm, accept 56
			• **Total question 5**	**17**	

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Question			Answer	M	Guidance
6					
	a		A spectrum containing only a (few) discrete wavelengths or colours	B1	**accept** some idea of discreteness, e.g. mechanism: atomic state changes, energy level changes, fingerprint of element idea
	b		 Sketch with correct positions; and relative intensities	B2	**allow** only a few nm for width of lines if not drawn as sharp vertical lines; otherwise max 1 mark. **ignore** requirement for labels
	c		$E = hc/\lambda$ + attempt to use; **or** $E_g/E_y = \lambda_y/\lambda_g$ Ratio= 589/570 = 1.03	C1 A1	 **require** at least 3 SF
	d		from left to right on diagram **G**, **R** and **Y**	B1 B1	**allow** 1 mark for only 1 correct
	e	i	$\lambda = d \sin\theta$ $615 \times 10^{-9} = 1.67 \times 10^{-6} \sin\theta$ gives $\theta = 21.61^o$ $570 \times 10^{-9} = 1.67 \times 10^{-6} \sin\theta$ gives $\theta = 19.96^o$ $\Delta\theta = 1.65^o$.	C1 C1 C1 A1	 for θ rounded to 20.0^o allow $\Delta\theta = 1.6^o$; **allow** answer to 2 SF
		ii	$n\lambda = d \sin\theta$ with $\theta = 90^o$ or $\sin\theta = 1$ $n = 1.67 \times 10^{-6} / 615 \times 10^{-9} = 2.7$ so answer is 4	C1 B1	 no marks if no working shown
	f	i	the energy of some of the photons of the sodium light are greater than the work function of the cathode (surface) any of these photons absorbed by a (surface) electron can release it from the metal (surface) photoelectrons are attracted to the positive (collector) electrode, completing the circuit /causing a current	B1 B1 B1	**alt** photon(s) absorbed by (surface) electron(s) (in metal surface); electron (can be) emitted when (photon) energy is greater than work function (**allow** symbol for w.f.); released electron(s) complete(s) circuit/AW
		ii	red light has the least <u>energy</u> as it has the longest wavelength/lowest frequency (and hence the least probability of releasing electrons)	B1 B1	**allow R** or 615 nm
			Total question 6	**18**	

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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 $\mathbf{A_2}$.

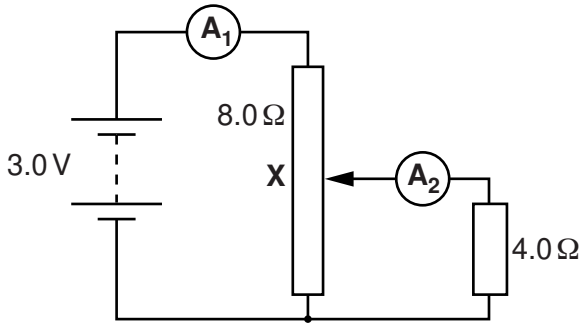


Fig. 1.1

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

.....

.....

.....

.....

.....

..... **[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 = $3.6 \times 10^{26}\,m^{-3}$

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.

.....

.....

.....

..... **[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.

.....

.....

.....

.....

.....

..... **[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.

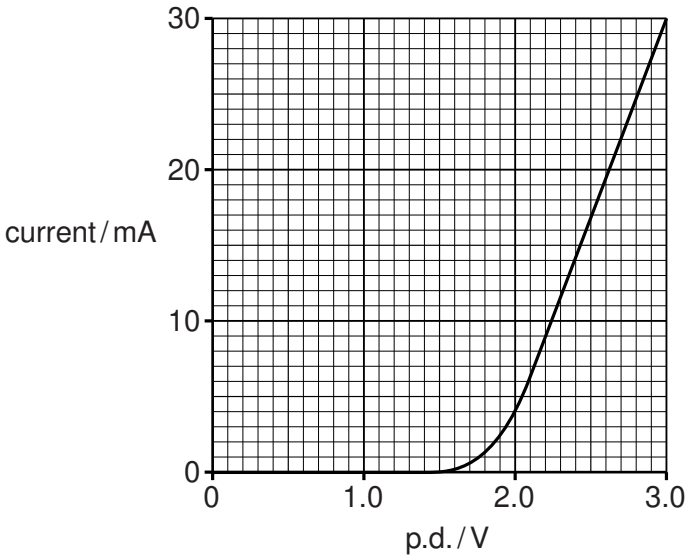


Fig. 2.1

(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.

.....

.....

.....

..... **[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

.....

.....

.....

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

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

.....

.....

.....

..... **[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*

.....

.....

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

(ii) *internal resistance.*

.....

.....

..... **[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*.

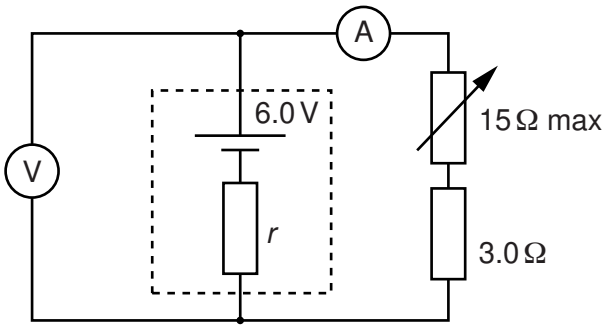


Fig. 3.1

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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.

.....

.....

..... **[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.

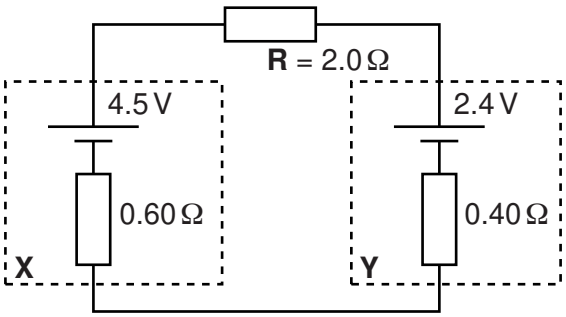


Fig. 3.2

(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.

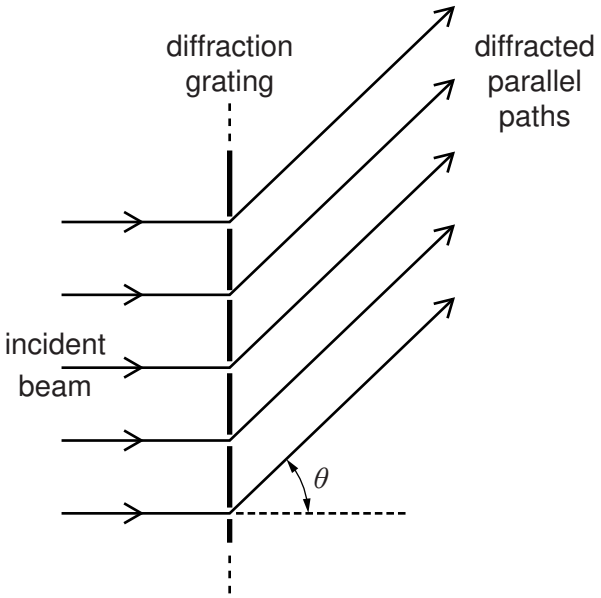


Fig. 4.1

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.

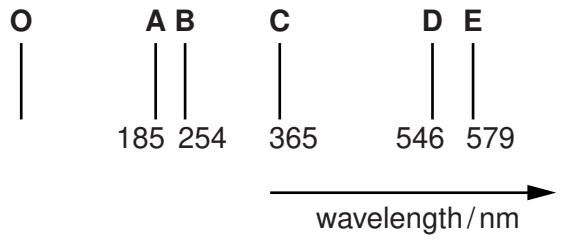


Fig. 4.2

(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.

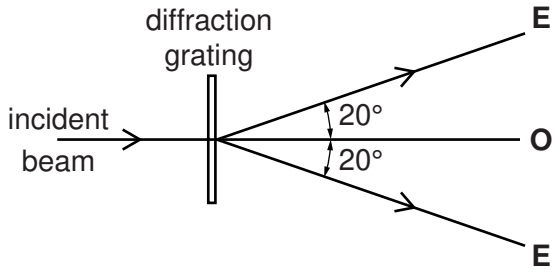


Fig. 4.3

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.

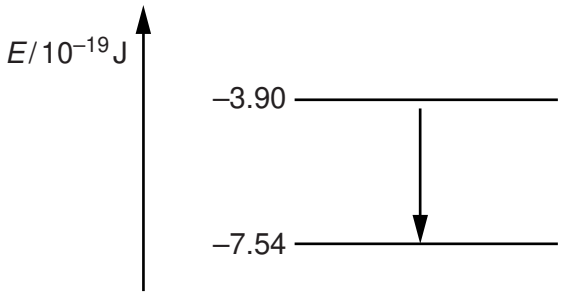


Fig. 4.4

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.

.....

.....

.....

.....

..... **[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.

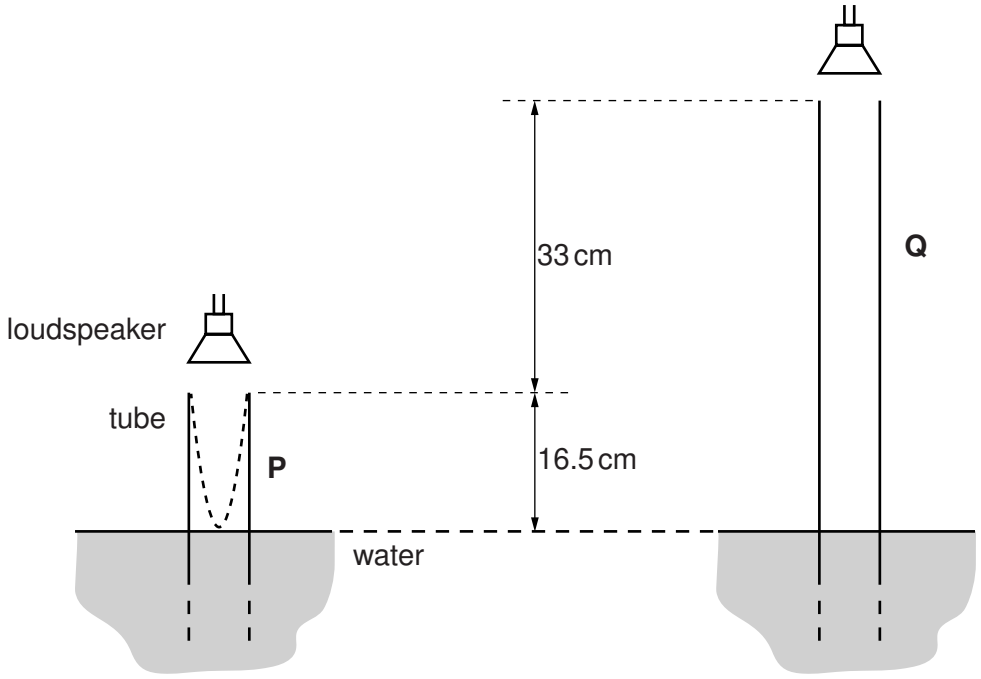


Fig. 5.1

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.

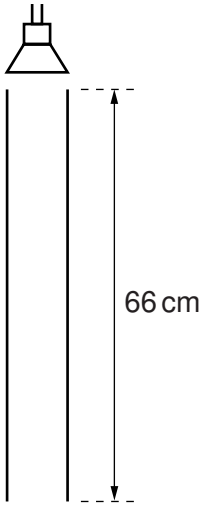


Fig. 5.2

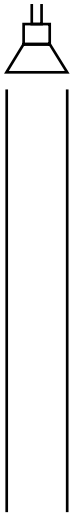


Fig. 5.3

(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.

.....

.....

.....

.....

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

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

.....

.....

.....

..... **[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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GCE

Physics A

Unit **G482**: Electrons, Waves and Photons

Advanced Subsidiary GCE

Mark Scheme for June 2016

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All examiners are instructed that alternative correct answers and unexpected approaches in candidates' scripts must be given marks that fairly reflect the relevant knowledge and skills demonstrated.

Mark schemes should be read in conjunction with the published question papers and the report on the examination.

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Annotations

Annotation	Meaning
BOD	Benefit of doubt given
CON	Contradiction
	Incorrect response
ECF	Error carried forward
FT	Follow through
NAQ	Not answered question
NBOD	Benefit of doubt not given
POT	Power of 10 error
^	Omission mark
RE	Rounding error ONLY APPLIED ONCE IN THE PAPER; also use as Repeated error
SF	Error in number of significant figures ONLY APPLIED ONCE IN THE PAPER
	Correct response
AE	Arithmetic error
	Wrong physics or equation
/	alternative and acceptable answers for the same marking point
(1)	Separates marking points
reject	Answers which are not worthy of credit

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Annotation	Meaning
not	Answers which are not worthy of credit
IGNORE	Statements which are irrelevant
ALLOW	Answers that can be accepted
( )	Words which are not essential to gain credit
__	Underlined words must be present in answer to score a mark
ecf	Error carried forward
AW	Alternative wording
ORA	Or reverse argument

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Subject-specific Marking Instructions

CATEGORISATION OF MARKS

The marking scheme categorises marks on the MABC scheme

B marks: These are awarded as independent marks, which do not depend on other marks. For a **B**-mark to be scored, the point to which it refers must be seen specifically in the candidate's answer.

M marks: These are method marks upon which **A**-marks (accuracy marks) later depend. For an **M**-mark to be scored, the point to which it refers must be seen in the candidate's answer. If a candidate fails to score a particular **M**-mark, then none of the dependent **A**-marks can be scored.

C marks: These are compensatory method marks which can be scored even if the points to which they refer are not written down by the candidate, providing subsequent working gives evidence that they must have known it. For example, if an equation carries a **C**-mark and the candidate does not write down the actual equation but does correct working which shows that the candidate knew the equation, then the **C**-mark is given.

A marks: These are accuracy or answer marks, which either depend on an **M**-mark, or allow a **C**-mark to be scored.

Note about significant figures:
If the data given in a question is to 2 SF, then allow answers to 2 or more SF.
If the answer is given to fewer than 2 SF, then penalise once only in the entire paper. **N.B**. Also penalise RE only once per paper.
Any exception to this rule will be mentioned in the Guidance.
A tick should be placed in the body of the script at the point where each mark is awarded.

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Question			Answer	M	Guidance
1	a		resistivity = resistance x (cross-sectional) area / length	B1	**accept** equation with *resistance* as subject **allow** *over* for divide by; do **NOT** allow algebraic formula followed by a word definition of each symbol
	b	i	$A = \pi d^2/4 = 3.14 \times 10^{-6}$ m^2 $\rho = RA/l = 8.0 \times 3.14 \times 10^{-6}/ 0.15$ $\rho = 1.7 \times 10^{-4}$ unit Ω m	C1 C1 A1 B1	**apply** POT error as many times as occurs correct substitution with **ecf** for A **accept** 1.68×10^{-4} **accept** Ω mm or mΩ m, etc.
		ii 1	current below X in 'lead' equals current in 4 Ω same V across 'lead' below X and 4 Ω **or** they are in parallel (so) X is the mid point of the 'lead'/ 4 Ω is half of 8 Ω	B1 B1 B1	**allow** reverse argument starting from 4 Ω as resistance of half of 'lead' **allow** references to A_1 & A_2 possibly to indicate branches of circuit rather than meters
		ii 2	sum of R's in parallel = 2 Ω total R = 6 Ω so I = 0.50 A	C1 A1	incorrect working with correct answer cannot score second mark **allow** 0.5 A;
	c		select I = nAev = 0.40 A $v = 0.40/3.6 \times 10^{26} \times 3.14 \times 10^{-6} \times 1.6 \times 10^{-19}$ $= 2.2 \times 10^{-3}$ (m s^{-1})	C1 C1 A1	 correct substitutions into formula with **ecf** for A answer to be given to 2 or more SF
	d	i	reference to differences in <u>number density</u> of (free) electrons/charge carriers conductors have n a (few) powers of 10 <u>greater</u> than semiconductors/AW	 B1 B1	allow n, number per m^3 or unit volume **allow** <u>much</u> greater than
		ii	*conductor*: R or ρ rises because of (increase in) electron ion collisions/ v falls *semiconductor*: R or ρ falls because of (large) increase in n/free electrons	 B1 B1	**allow** R or resistivity rises for conductors and falls for semiconductors for 1 mark **allow** current decreases for same p.d. /AW **allow** current increases for same p.d. /AW
			Total question 1	**17**	

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Question			Answer	M	Guidance
2	a	i	straight line through origin passing through (2, 30)	B1 B1	 **allow** 2.0 ± 0.05, i.e. half a square
		ii	V is <u>proportional</u> to I for the resistor R but the LED the characteristic/line is a curve/not a straight line	B1 B1	**accept** statement of Ohm's law **allow** V α I **NOT** gradient changes **nor** gradient not constant
	b	i	From Fig. 2.1, V <u>across R</u> at 30 mA = 2.0 V **or** 0.03 x 67 = 2.0 V V <u>across LED</u> = 5.0 – 2.0 = 3.0 V I in LED at 3.0 V is 30 mA	 B1 B1 B1	**allow** 1 SF answers in **b(i)** and **(ii)** at 30 mA R of LED = 100 Ω total R = 167 Ω I in LED = 5.0/167 = 30 mA **or** in reverse
		ii 1	0.030 (C)	A1	**allow** 30 mC or 3.0 x 10^{-2} C
		ii 2	QV or VI = 3.0 x 0.03 **or** $I^2R = 0.03^2$ x 100 energy = 0.090 (J)	C1 A1	**possible ecf from (ii)1** **allow** 90 mJ or 9.0 x 10^{-2} J **allow** 1 mark for 0.15 (J), i.e. taking V = 5 V
		ii 3	P = $I^2R = 0.03^2$ x 67 = 0.060 (J)	C1 A1	**possible ecf from b(i) for R value** **allow** P = VI = 2.0 x 0.03 = 0.060 J **or** P = $V^2/R = 2.0^2/67$ = 0.0597 J
		iii	current required is 0.63 A so nearest larger value is best 1.0 A	M1 A1	
	c		suitable example, e.g. torch bulb, traffic light, car rear lamp,etc. (replaced by cluster of LEDs) advantage, e.g. draws a lower current/ more efficient (at converting electrical energy into light)/if one LED fails others are still lit/greater lifetime/more robust	B1 B1	**accept** TV screens etc. **allow** size e.g. back lighting in mobile **NOT** cost
			Total question 2	**16**	

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Question			Answer	M	Guidance
3	a		energy	A1	
	b	i	energy (**available) to be** transferred from electrical to other forms **per unit charge** **or** energy transferred **across the terminals** from the supply **per unit charge**	B1 B1	**award** 1 mark for only one of the two bold phrases; 2 marks for both present **allow** 1 mark for answer which uses V = E - Ir with explanation **or** the p.d. across (the terminals of) the supply when it is delivering a current (to an external circuit)
		ii	The supply behaves as if it has an (internal) resistance causing (some) energy to be *transferred into thermal energy/lost as heat* **or** there is a *voltage drop across/decrease in voltage* from the supply when a current is drawn from it/AW	 B1	**NOT** the energy lost as heat inside the supply **allow** (causes) 'lost volts' per unit current (in the supply)
	c	i	Take readings of V and I for several (five or more) positions/values of the variable resistor plot a graph of V against I the internal resistance is constant if the graph of V against I is a straight line measure the gradient of the V against I graph which equals the internal resistance **or** find y-intercept = E; find one pair of values of V,I substitute into equation E = V + Ir to find r	 B1 B1 B1 B1 B1	**Do not allow** any analysis with E assumed to be 6 V **allow** 2 pairs of values of V and I to be substituted into equation to find r (non-graph method max 2/5) **allow** find or similar word ignore problem of minus sign, i.e. assume value only
		ii	as a safety/limiting resistor **or** so the supply is not short-circuited (when variable resistor is reduced to zero)/AW	B1	**allow** e.g. to stop the current becoming too large/AW
	d	i	arrow pointing clockwise	A1	arrow need not be on circuit wire
		ii	e.m.f = 4.5 – 2.4 (= 2.1 V) I = 2.1/(0.6 + 0.4 + 2.0) = 2.1/3.0 = 0.70 A	C1 A1	 **allow** 0.7 A
		iii 1	1.4 (V)	A1	**ecf(d)(ii)** i.e. answer = 2 x ans(d)(ii) **NOT** ecf when I = 1.05 A/3.45 A giving 2.1 V/6.9 V
		iii 2	V_x = 4.5 – 0.70 x 0.6 4.1 (V)	C1 A1	**ecf(d)(ii)**
			Total question 3	**16**	

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Question			Answer	M	Guidance
4	a		All of the r*ays/wavefronts/waves* are added together (at each point on the screen) when the path difference is an exact number of wavelengths the *rays/waves* interfere constructively giving maximum amplitude/intensity (at all other angles) when the path difference between rays is not an exact number of wavelengths the *rays/waves interfere destructively/cancel out* giving *a dark background/little to no intensity*	B1 B1 B1 B1 B1 B1	**max** 4 marks to include the second marking point **NOT** *superpose* or *interfere* for *added* as in stem of Q **allow** nλ **QWC mark** **allow** bright *line/light* **NOT** bright fringes **nor** maxima **NOT** when the path difference is (2n +1)λ/2 there is destructive interference/AW **allow** suitable annotation of diagram to score marks
	b	i 1	two lines between 5 and 15 degrees (judge by eye)	B1	**allow** with label C missing; actual value is 12.5°
		i 2	select nλ = d sin θ 579 x 10^{-9} = d sin 20 = 0.342 d d = 1.7 x 10^{-6} (m)	C1 C1 A1	**allow** n = 1 in initial equation allow 1.69 x 10^{-6}
		ii	**E**	B1	
		iii	**D,E**	B1	
		iv	E = 3.64 x 10^{-19} J select E = hc/ λ , λ = 6.63 x 10^{-34} x 3.0 x 10^{8}/3.64 x 10^{-19} λ = 5.46 x 10^{-7} m **D**	C1 B1 A1 A0	**accept** 546 nm; **N.B.** a correct unit must be present
		v	lines appear at the same *positions/frequencies* in the spectrum **emission**: *bright/coloured* lines (on dark background) **absorption**: *dark/black* lines (on *bright background/continuous spectrum*)	B1 B1	**allow** comparison of backgrounds only **or** just a full description of absorption spectrum
		vi	E = (3.1 + 4.7) x 10^{-19} J = 7.8 x 10^{-19} J select E = hc/ λ , λ = 6.63 x 10^{-34} x 3.0 x 10^{8}/7.8 x 10^{-19} λ = 2.55 x 10^{-7} m	B1 B1 A1	E = 6.63 x 10^{-34} x 3.0 x 10^{8}/2.54 x 10^{-7} giving E = 7.8(3) x 10^{-19} J (f = 1.18 x 10^{15} Hz) which equals (3.1 + 4.7) x 10^{-19} J
			Total question 4	**18**	

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Question			Answer	M	Guidance
5	a	i	λ **minimum** distance between ***neighbouring/adjacent*** identical points on the wave f number of (complete) *oscillations/cycles/vibrations* (at a point) per unit time **or** produced by the wave source per unit time T time for one complete oscillation **or** time for one complete oscillation <u>at a point</u> on the wave	B1 B1 B1	**N.B.** one of the two emboldened words must be present ;**allow** e.g distance from one peak to the next peak of the wave **allow** number of <u>wavelengths</u> passing a point per unit time; **allow** per second **NOT** amount **NOT** in a second **nor** f = 1/T **allow** time for one <u>wavelength</u> to pass a (given) point **NOT** time for one oscillation to pass **nor** T = 1/f **N.B.** if f=1/T or T = 1/f is included in an otherwise correct definition ignore, do not CON
		ii	speed = (distance of) one wavelength travelled per period where period equals 1/frequency so v = λ/(1/f) =f λ **or** in 1 second f wavelengths λ are produced distance travelled by first wavelength in one second is f λ = v	M1 M1 A1	**allow** v = λ/T but T = I/f so v = λ/(1/f) =f λ **NOT** derivation in terms of units
	b	i 1	¾ λ with node at closed end and antinode at open end	B1	**allow** poorly proportioned sketches which reach both ends
		i 2	all nodes and antinodes drawn in **bi1** correctly labelled N and A only two N and two A present	B1 B1	positions of labels must be accurate to the eye **allow** max of one mark for only 3 out of the 4 labelled
		ii	λ/2 = 33 cm v = fλ = 512 x 0.66 v = 338 or 340 (m s^{-1})	C1 C1 A1	**or** λ/4 = 16.5 cm **N.B.** an incorrect value of λ/4 or λ/2 scores 0/3
	c	i	the pipe is one wavelength long with both ends antinodes so sketch must have 3 antinodes and 2 nodes <u>with reasonably correct proportions</u>	B1	
		ii1	256 (Hz)	B1	
		ii2	λ/2 with antinodes at both ends	B1	
		iii	v is the same in the pipe at all f/length is fixed = $\lambda_0/2 = \lambda_1$ so as $f_1 \lambda_1 = f_0 \lambda_0$ then $f_1 = 2f_0$ **or** harmonics must have antinodes at both ends of the pipe so <u>next</u> possible pattern is *one wavelength/has 3A and 2N*	B1 B1	**allow** 1 mark for: as $f_1 = 2f_0$ then f_1 is the second harmonic **or** halving the wavelength doubles the frequency
			Total question 5	**17**	

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Question			Answer	M	Guidance
6	a	i	λ is the (de Broglie) wavelength <u>associated with a particle</u> h is (a constant known as) the Planck constant mv is the momentum/mass x speed of <u>the particle</u>	B1 B1 B1	**allow** object/electron for particle **accept** velocity for speed **accept** m and v separately but the particle must appear with one of the quantities to score the mark
		ii	electrons passing through a (thin) sheet of graphite are diffracted producing *rings/pattern* (on a fluorescent screen)	B1 A1	any suitable situation **NOT** Au or Al, etc. what is observed + interpretation 1 mark. **Do not** award the A mark alone unless a plausible situation has been suggested. *Young slits* type experiments etc score 0/2
		iii 1	$eV = ½ mv^2$ $2eV/m = v^2$ so $v = \sqrt{(2 \times 1.6 \times 10^{-19} \times 5.0 \times 10^4/9.1 \times 10^{-31})}$ so $v = 1.3 \times 10^8$ (m s^{-1})	C1 C1 B1 A0	**allow** $eV = 8.0 \times 10^{-15}$ J for 1 mark **allow** $\sqrt{(2 \times 8.0 \times 10^{-15}/9.1 \times 10^{-31})}$ **or** evidence of correct calculation, e.g. $v = 1.325 \times 10^8$
		iii 2	$\lambda = h/mv = 6.63 \times 10^{-34}/ 1.3 \times 10^8 \times 9.1 \times 10^{-31}$ $\lambda = 5.6 \times 10^{-12}$ (m)	C1 A1	 **allow** 5.5×10^{-12} if 1.325×10^8 is used
		iii 3	λ of visible light 5.6×10^{-7} m so power of 10 = 5 or -5	B1 B1	**ecf aiii2**; **accept** 4 to 7 $\times 10^{-7}$ m **NOT** 10^{-7} **NOT** 10^5 on the answer line
	b		The photoelectric effect Individual photons are absorbed by individual electrons in the metal surface, i.e. one to one interaction. Only photons with energies above the work function energy will cause photoelectron emission/idea of threshold frequency Hence u-v photons or blue photons will cause photoemission but red photons will not. Number of electrons emitted depends on light intensity A wave model does not explain instantaneous emission of electrons. A wave model does not explain a threshold frequency/wavelength for emission to occur	B1 B1 B1 B1 B1 B1 B1	QWC mark **allow** exp't description: uv light shone on a zinc plate connected to a gle **max** 3 from 6 marking points **allow** wave model does not explain no emission however bright the light if energy of photon below work function
			Total question 6	**16**	

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Thursday 4 June 2015 – 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

* G 4 8 2 0 1 *

* 4 8 6 5 6 3 7 3 7 2 *

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.

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Answer **all** the questions.

1 The maximum power input to a domestic fan heater is 2.6 kW when connected to the 230 V mains supply. The electric circuit of the fan heater consists of two heating elements (resistors) rated at 1.5 kW and 1.0 kW, a motor rated at 100 W and three switches.

(a) (i) Show that the resistance of the 1.5 kW heating element is about 35 Ω.

[2]

(ii) The 1.5 kW heating element is made from a wire of cross-sectional area $7.8 \times 10^{-8}\,m^2$ and resistivity $1.1 \times 10^{-6}\,\Omega m$. Calculate the length of the wire.

length = ... m **[3]**

(b) With only the first switch closed, the fan rotates; closing the second switch gives the heater an output of 1.5 kW and closing the third switch increases the output to 2.5 kW. The elements will not heat up unless the fan is switched on. The heater cannot give an output of 1.0 kW.

Complete the circuit diagram of Fig. 1.1 to show the fan, the heating elements and the switches connected so that the heater will work as described. Label the switches and the elements.

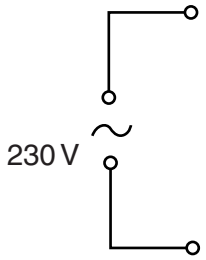


Fig. 1.1

[3]

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(c) Both heating elements are made of wire of the same resistivity and length.

(i) Explain, without calculation, why the diameter *d* of the 1.0 kW heater wire must be less than the diameter *D* of the 1.5 kW heater wire, designed for use with a 230 V supply.

.....

.....

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

(ii) Show that *d* is approximately equal to 0.8 *D*.

[3]

(d) Circle the correct fuse for the plug of this appliance from the values below.

3 A **5 A** **10 A** **13 A**

Justify your choice.

.....

.....

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

(e) **(i)** Define the *kilowatt-hour*.

.....

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

(ii) Calculate, to the nearest penny, the cost of using the heater for 4.0 hours with only **one** of the heating elements switched on. The cost of 1 kWh is 18 p.

cost = ... p **[2]**

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2 This question is about the use of a thermistor fitted inside a domestic oven as a temperature sensor in a potential divider circuit.

Fig. 2.1 shows the potential divider circuit in which the component $\mathbf{R_2}$ is connected in parallel to the input of an electronic circuit that switches the mains supply to the heating element in the oven on or off.

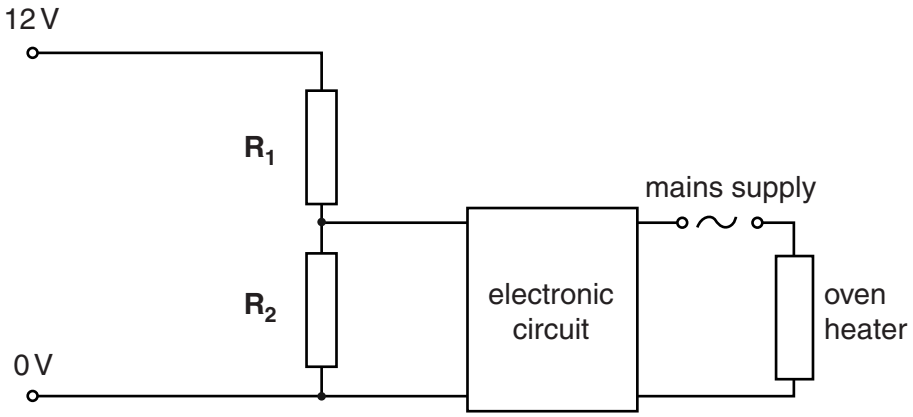


Fig. 2.1

(a) $\mathbf{R_1}$ is a variable resistor and $\mathbf{R_2}$ is the thermistor. The circuit symbols for $\mathbf{R_1}$ and $\mathbf{R_2}$ are incomplete. Complete these circuit symbols on Fig. 2.1. **[2]**

(b) It is required that the p.d. across the thermistor $\mathbf{R_2}$ is 7.0 V when at a temperature of 180 °C. The variation of resistance with temperature for $\mathbf{R_2}$ is shown in Fig. 2.2.

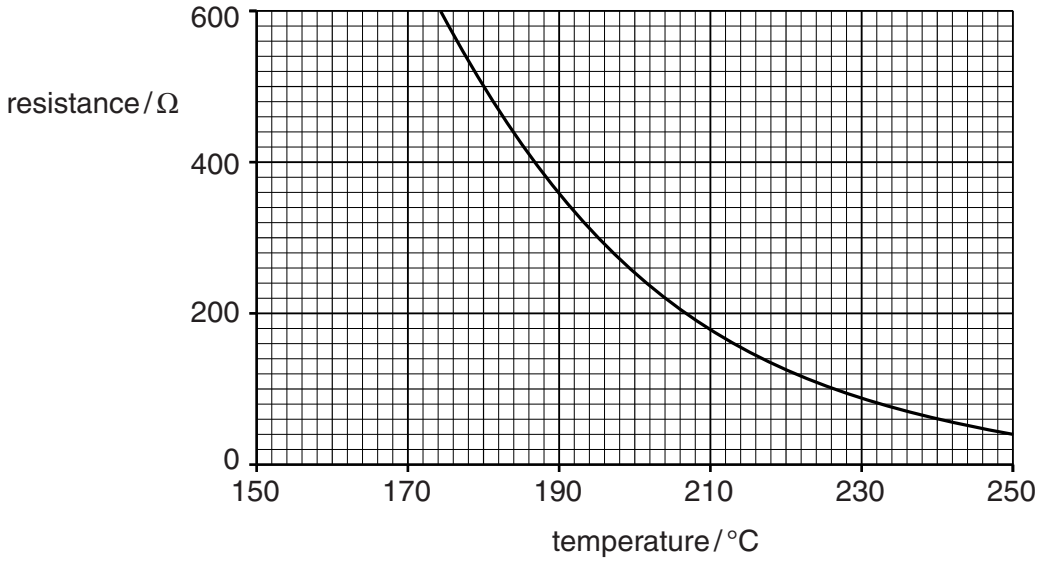


Fig. 2.2

(i) Use Fig. 2.2 to determine the resistance of $\mathbf{R_2}$ at a temperature of 180 °C.

resistance = ... Ω **[1]**

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(ii) When the temperature is 180 °C the p.d. across $\mathbf{R_2}$ is 7.0 V. Calculate the current in $\mathbf{R_2}$.

current = ... A **[1]**

(iii) The electronic circuit draws a negligible current. Show that the resistance of the variable resistor $\mathbf{R_1}$ must be about 350 Ω.

[2]

(iv) $\mathbf{R_2}$ is heated slowly. Show that the p.d. across $\mathbf{R_2}$ must fall to about 5.0 V when the temperature of $\mathbf{R_2}$ reaches 200 °C.

[2]

(c) The thermistor $\mathbf{R_2}$ is fitted inside the oven. When the p.d. across $\mathbf{R_2}$ falls to 5.0 V the oven heater switches off. The oven cools until the p.d. across $\mathbf{R_2}$ rises to 7.0 V when the heater switches on again.

$\mathbf{R_1}$ is adjusted to 250 Ω. Calculate the temperatures at which the oven heater is switched on and off.

temperature on ..... °C

temperature off ..... °C **[4]**

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3 **(a)** A battery charger contains a microprocessor circuit so that it can charge an AA rechargeable cell at a constant current of 450 mA. It takes 4 hours 40 minutes to charge a 1.5 V cell from a fully discharged state.

(i) Calculate the charge Q passing through the cell during the charging process.

Q = ... unit ..... **[3]**

(ii) Fig. 3.1 shows the cell of internal resistance 0.90 Ω connected to the battery charger. Assume that the e.m.f. of the cell is 1.5 V.

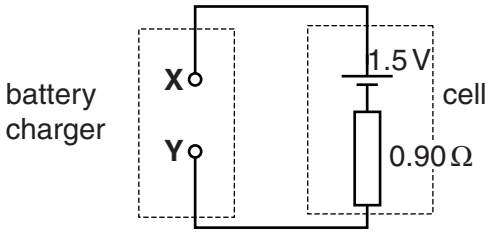


Fig. 3.1

1 State whether the terminal **X** of the battery charger is positive or negative.

.....

2 Mark the direction of the current in the circuit on Fig. 3.1. Label your arrow I. Give a reason for your choice.

.....

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

3 Calculate the terminal p.d. V_{XY} between **X** and **Y** during the charging process.

V_{XY} = ... V **[2]**

4 Show that the mean rate of increase of energy stored in the cell during the charging process is about 0.7 J s^{-1}.

[2]

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(b) Explain how you would determine experimentally the e.m.f. *E* and internal resistance *r* of the charged cell. Include a circuit diagram with meters and a variable load resistor.



In your answer you should state how the data collected is used to determine the values of E and r.

.....

.....

.....

.....

.....

.....

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

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(c) A 6.0V 2.0W filament lamp has a resistance of 18Ω when lit to normal brightness. It is connected in series to four 1.5V cells each of internal resistance 0.90Ω.

(i) Explain, using calculations, why the lamp does not light to normal brightness.

[3]

(ii) It is found that by adding more cells in series it is possible to make the lamp light to normal brightness. Calculate the total number of cells needed in the circuit for this to occur. Show your working clearly.

number of cells = ... **[2]**

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4 **(a)** Fig. 4.1 shows a section of a uniform string under tension at one instant of time. A progressive wave of wavelength 80 cm is moving along the string from left to right. At the instant shown, the displacement of the string is zero at the point opposite the zero mark on the scale beneath the string.

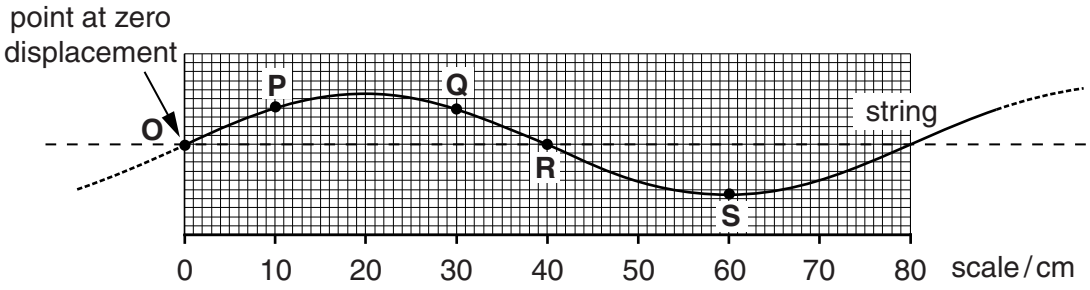


Fig. 4.1

Four points **P**, **Q**, **R** and **S** at 10, 30, 40 and 60 cm respectively, are marked on the string. The oscillatory motion of each point can be described in terms of amplitude, frequency and phase difference from **O**.

(i) State the meaning of each of the terms

1 *amplitude*

.....

.....

2 *frequency*

.....

.....

3 *phase difference*.

.....

.....

[3]

(ii) Describe using these three terms how the motion of points **P**, **Q**, **R** and **S**

1 is similar,

.....

.....

2 is different.

.....

.....

[2]

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(b) Fig. 4.2 shows the same section of string now held under tension between a clamp and a pulley, 80 cm apart. A mechanical oscillator is attached to the string close to the clamped end. The frequency of the mechanical oscillator is varied until the stationary wave shown is set up between the clamp and the pulley. The same four points as in Fig. 4.1 are marked on the string.

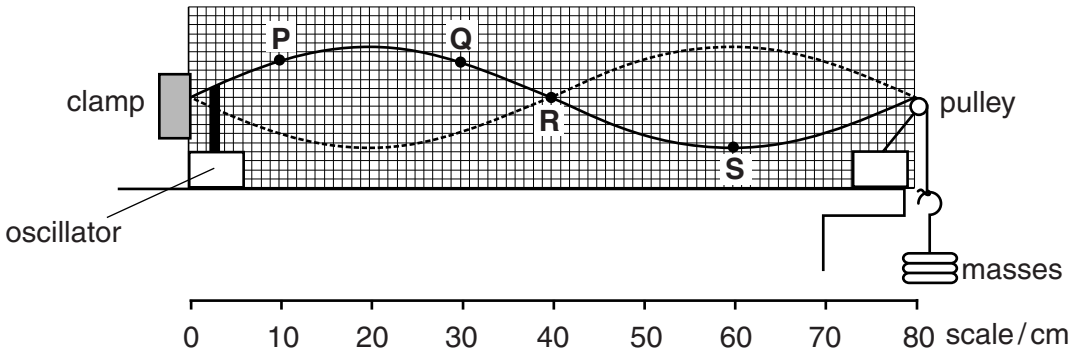


Fig. 4.2

(i) Describe how a stationary wave is different from a progressive wave.

.....

.....

.....

.....

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

(ii) Explain how the stationary wave is formed on this string.

.....

.....

.....

.....

.....

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

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(iii) Describe, using the terms amplitude, frequency and phase difference, how the motions of the points **P**, **Q** and **S**

1 are similar,

.....

.....

2 are different.

.....

.....

[3]

(iv) In Fig. 4.2 the frequency of oscillation is 30 Hz. State, with a reason, the lowest frequency of oscillation of the string at which the motions of all of the points **P**, **Q**, **R** and **S** are

1 in phase,

.....

.....

2 all at rest.

.....

.....

[4]

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5 Fig. 5.1 shows two microwave transmitters **A** and **B** 0.20 m apart. The transmitters emit microwaves of frequency 10 GHz, of equal amplitude and in phase. A microwave detector is placed at **O** a distance of 4.0 m from **AB**.

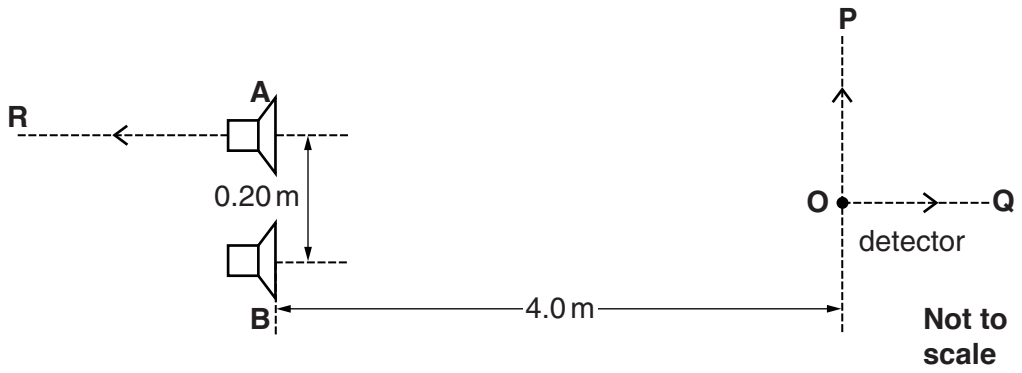


Fig. 5.1

(a) Interference of the waves from the two transmitters is detected only when the transmitters are coherent. Explain the meaning of

(i) *interference*

.....

.....

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

(ii) *coherent.*

.....

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

(b) The length of the detector aerial is half a wavelength. Calculate the length of the aerial.

Show your working.

aerial length = ... m **[2]**

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(c) (i) 1 Explain why the amplitude of the detected signal changes when the detector is moved in the direction **OP**.

.....

.....

.....

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

2 Calculate the distance between adjacent **maximum** and **minimum** signals.

distance = ... m **[2]**

(ii) Explain why the amplitude of the detected signal changes when the detector is moved in the direction **OQ**.

.....

.....

.....

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

(iii) Explain why the amplitude of the detected signal decreases to a minimum before increasing again as transmitter **A** is moved a small distance in the direction **AR** with the detector fixed at **O**. Calculate the distance **A** is moved to cause this minimum signal at **O**.

.....

.....

.....

.....

.....

.....

distance = ... m **[2]**

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(d) State, with a reason, the effect on the intensity of the signal detected at **O** when each of the following changes is made.

(i) The amplitude of the waves emitted from **A** and **B** is doubled.

.....

.....

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

(ii) The detector **O** is rotated 90° about the axis through **OQ**.

.....

.....

.....

.....

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

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Question 6 begins on page 16

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6 In an experiment it is observed that when blue light is shone on a clean metal surface electrons are emitted, but with red light there is no electron emission.

(a) State the name of the effect observed in this experiment.

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

(b) Describe Einstein's theory to explain these observations.



In your answer you should include technical terms to explain how the physics of quantum behaviour is used to explain the observations.

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

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

(c) The longest wavelength of light incident on the metal surface which causes electrons to be emitted is 480 nm.

(i) Show that the work function of the metal is about 4×10^{-19} J.

[3]

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(ii) Calculate the maximum speed of an emitted electron when a photon of energy 5.2×10^{-19} J is incident on the metal surface.

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

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

.....

.....

.....

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

(ii) Calculate the de Broglie wavelength of an electron moving at 500 $km\,s^{-1}$.

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

END OF QUESTION PAPER

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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.

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GCE

Physics A

Unit **G482**: Electrons, Waves and Photons

Advanced Subsidiary GCE

Mark Scheme for June 2015

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This mark scheme is published as an aid to teachers and students, to indicate the requirements of the examination. It shows the basis on which marks were awarded by examiners. It does not indicate the details of the discussions which took place at an examiners' meeting before marking commenced.

All examiners are instructed that alternative correct answers and unexpected approaches in candidates' scripts must be given marks that fairly reflect the relevant knowledge and skills demonstrated.

Mark schemes should be read in conjunction with the published question papers and the report on the examination.

OCR will not enter into any discussion or correspondence in connection with this mark scheme.

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Annotations

Available in Scoris

Annotation	Meaning
BOD	Benefit of doubt given
CON	Contradiction
	Incorrect response
ECF	Error carried forward
FT	Follow through
NAQ	Not answered question
NBOD	Benefit of doubt not given
POT	Power of 10 error
^	Omission mark
RE	Rounding error or repeat error
SF	Error in number of significant figures
	Correct response
AE	Arithmetic error
	Wrong physics or equation

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The abbreviations, annotations and conventions used in the detailed Mark Scheme are:

Annotation	Meaning
/	Alternative and acceptable answers for the same marking point
(1)	Separates marking points
reject	Answers which are not worthy of credit
not	Answers which are not worthy of credit
IGNORE	Statements which are irrelevant
ALLOW	Answers that can be accepted
( )	Words which are not essential to gain credit
__	Underlined words must be present in answer to score a mark
ecf	Error carried forward
AW	Alternative wording
ORA	Or reverse argument

Subject-specific Marking Instructions

CATEGORISATION OF MARKS

The marking scheme categorises marks on the MABC scheme

B marks: These are awarded as <u>independent</u> marks, which do not depend on other marks. For a **B**-mark to be scored, the point to which it refers must be seen specifically in the candidate's answer.

M marks: These are <u>method</u> marks upon which **A**-marks (accuracy marks) later depend. For an **M**-mark to be scored, the point to which it refers must be seen in the candidate's answer. If a candidate fails to score a particular **M**-mark, then none of the dependent **A**-marks can be scored.

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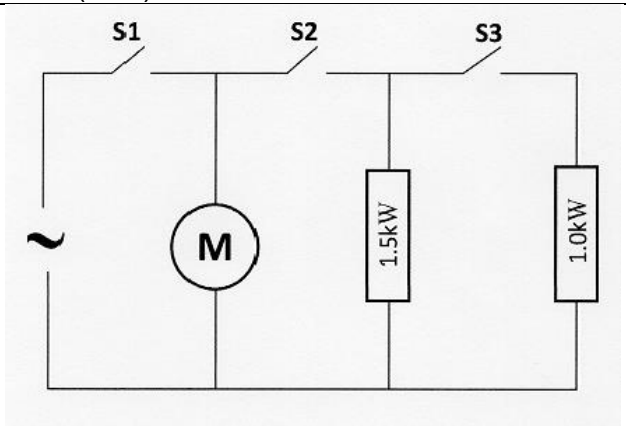
C marks: These are compensatory method marks which can be scored even if the points to which they refer are not written down by the candidate, providing subsequent working gives evidence that they must have known it. For example, if an equation carries a **C**-mark and the candidate does not write down the actual equation but does correct working which shows that the candidate knew the equation, then the **C**-mark is given.

A marks: These are accuracy or answer marks, which either depend on an **M**-mark, or allow a **C**-mark to be scored.

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Note about significant figures:
If the data given in a question is to 2 SF, then allow answers to 2 or more SF.
If an answer is given to fewer than 2 SF, then penalise once only in the entire paper. **N.B.** Also penalise RE only once per paper.
Any exception to this rule will be mentioned in the Guidance.

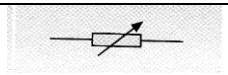
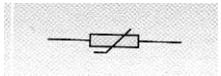
A tick should be placed in the body of the script at the point where each mark is awarded.

Question			Answer	M	Guidance
1					
	a	i	$P = V^2/R = 230^2/R = 1500$ $R = 35.3\ \Omega$	C1 A1	**accept** $I = P/V = 6.52$ A and $R = 230/6.52$ **allow** $52900/1500 = 35\ \Omega$, i.e. some working shown
		ii	use of $\rho = RA/l$ or $R = \rho l/A$ $l = 35 \times 7.8 \times 10^{-8}/1.1 \times 10^{-6}$ $l = 2.5$ (m)	C1 C1 A1	formula correct substitution answer (2.48)
	b		resistors and motor wired in parallel to supply switches correctly placed (open or closed) any suitably labelled symbols; components in correct order	B1 M1 A1	 do not expect switches to be labelled
	c	i	power is inversely proportional resistance (for same V) resistance of wire is inversely proportional to c-s area/diameter squared (as I and ρ are fixed/same)	B1 B1	**accept**: (same V so for) larger/smaller power need (larger/smaller I and so) smaller/larger resistance **accept** smaller c-s area/diameter (of wire) causes larger resistance or vice versa
		ii	P α A (because $P = V^2/R = V^2A/\rho l$) **or** P α d^2 (because $A = \pi d^2/4$) $1.0/1.5 = (d/D)^2 = 2/3$ so $d = 0.82\ D$	B1 M1 A1	**accept** $R_{1000} = 52.9\ \Omega$ and R α 1/A [where $A_d = 5.2 \times 10^{-8}$ & $A_D = 7.8 \times 10^{-8}$] so $35.3 / 52.9 = [(d/D)^2$ or $A_d/A_D] = 2/3$ [where $d = 2.57 \times 10^{-4}$ & $D = 3.15 \times 10^{-4}$]

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Question			Answer	M	Guidance
	d		total current in circuit = 2600/230 = 11.3 A so 13 A fuse required	M1 A1	**accept** I = 2500/230 = 10.9 A
	e	**i**	(a unit of) energy equal to 3.6 MJ **or** 1 kW for 1 h/AW	B1	**e.g.** 1000 W for 3600 s or similar; **NOT** 1 kW **per** hour
		ii	1.6 x 4 x 18 115 (p)	C1 A1	**allow** 1 mark for 108 p; i.e. using 1.5 x 4 x 18 **or** 1 mark for 79 p; i.e. using 1.1 x 4 x 18 **NOT** 72 p
			Total question 1	**18**	

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Question			Answer	M	Guidance
2					
	a		 for R_1  for R_2	B1 B1	
	b	i	500 Ω	B1	**accept** ± 20 Ω
		ii	7.0 = I x 500; I 0.014 (A)	B1	**ecf b(i)**
		iii	5.0 = 0.014 x R or 12 = 0.014(500 + R) R = 360 Ω	M1 A1	**ecf b(i)(ii)** **allow** R = 500 x 5/7 = 360 Ω
		iv	(at 200°C) R_{th} = 250 Ω V across thermistor =12 x 250/(250 + 350) = 5.0 V **alt** 5.0 = 12 x R/(R + 350) **or** I = 7.0/350 = 0.02 A; V_{th} = 5.0 = 0.02 x R R = 250 Ω which occurs at 200°C	B1 B1	**allow** R_{th} = 250 ± 10 giving 4.8 to 5.1 V **expect** 350 or 360; **allow** 1 SF where answer is 5.0 **NOT** 250 x 0.02 = 5.0 V; 0.02 A must be justified **allow** 7.0 = 12 x 350/(350 + R)
	c		**switch on** 5.0 = 12 x 250/(250 + R) or 7.0 = 12 x R/(250 + R) giving R = 350 Ω which is 190°C **switch off** 7.0 = 12 x 250/(250 + R) or 5.0 = 12 x R/(250 + R) giving R = 180 Ω which is 210°C **or** Switch on, R2 / R1 = 7/5 giving R2 - 250 x 7/5 = 350 ohm Switch off, R2 / R1 = 5/7 giving R2 = 250 x 5/7 = 179 ohm	M1 A1 M1 A1	**accept** solution in 2 stages first calculating currents on I = 0.02 and R = 7/0.02 off I = 0.028 and R = 5/0.028 **allow** ± 5°C in reading from graph **N.B.** zero marks for correct temperatures quoted without some correct working/justification
			Total question 2	**12**	

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Question			Answer	M	Guidance
3					
	a	i	Q = It= 0.45 x 4.67 x 60 x 60 = 7600 C or As	C1 A1 B1	**accept** 7560 or 7570
		ii 1,2	**1** positive; **2** clockwise energy must be transferred to the cell **or** current in opposite direction transfers energy from the cell to the circuit/AW	M1 A1	positive plus correct direction of arrow for first mark; do not penalise if arrow not labelled I. **allow** (conventional) current is from positive to negative ; **or** electron flow from – to + [but current must be clockwise in **1**]
		3	V_{XY} = 1.5 + 0.45 x 0.90 V_{XY} = 1.9 (V)	C1 A1	**accept** 1.905 or 1.91
		4	P = VI = 0.45 x 1.5 P = 0.675 (J s^{-1})	C1 A1	**allow** QV/t with **ecf a(i)** if necessary (11340/16800) **allow** 0.7 as final line if 0.675 appears above
	b		**1.**cell across variable resistor R ammeter in series and voltmeter in parallel across R or cell **2.**Take (set of) readings of V and I for different positions/values of the variable resistor **3.**plot a graph of V against I **4.**(find) y-intercept = E **5.**(find) the gradient of the V against I graph which equals the internal resistance in magnitude **or 4 or 5** take one pair of values of V,I and substitute into equation E = V + Ir to find r or E	B1 B1 B1 B1 B1	QWC last marking point needed for full marks **allow** use (digital) voltmeter across unloaded cell to find E; add R and find one value of V and I; then use equation to find r (points 2 to 5) **ignore** sign of gradient in determining r **allow** for no graph plot, using 2 pairs of values of V and I substituted into equation allows r and E to be found.(points 2 to 5)
	c	i	4 x 1.5 V cells gives 6.0 V with r of 3.6 Ω so current is 6.0/(3.6 + 18) = 0.28 A requires (2 W/6 V =) 0.33 A to light normally or power delivered = (0.28^2 x 18 or 5.0 x 0.28)= 1.4 W **alt**: use 0.33 A & 6 V to show need emf of 7.2 V (1.8 V per cell)	B1 B1 B1	**allow** AW such as: 6 V but total R now 21.6 Ω; 6 V across 21.6 Ω gives 5 V across 18 Ω; requires 6 V to light normally **allow** P = 1.(6)7 W for 2 marks; only give the third mark if P labelled as power delivered by cell
		ii	1.5 n = 0.33 (18 + 0.9 n) **or** 1.5n = 6 + 0.3n so 3.6 n = 18 **or** 1.2n = 6 giving n = 5	M1 A1	**alt:** lamp needs V = 6V and I = 0.33 A terminal p.d per cell is 1.5 = V + 0.9 x 0.33 giving V = 1.2 V so n = 6/1.2 = 5 **allow** trial and error method but working must be shown to score any marks
			Total question 3	**19**	

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Question			Answer	M	Guidance
4					
	a	i 1	the maximum displacement from equilibrium or rest position	B1	**allow** *zero* or *undisturbed* for *equilibrium*
		2	number of oscillations/vibrations (at a point) per unit time	B1	number of wavelengths passing a point or produced by the wave source per unit time **allow** per second **NOT** *amount* for *number*
		3	how far 'out of step' (out of sync) the oscillations at two points on the wave/string are/AW	B1	**alt e.g.** the fraction of a cycle between the oscillations at the two points
		ii 1	all have same frequency **or** same amplitude	B1	**N.B.** withhold mark if extra incorrect answers given
		2	all have different phases/ phase differences	B1	**allow** *not in phase* or *all out of phase*
	b	i	*progressive* a wave which transfers energy *stationary* a wave which traps/stores energy (in pockets) **or** *progressive* : transfers shape/information from one place to another *stationary* where the shape does not move along/which has nodes and antinodes/AW	B1 B1	**accept** phase relationship descriptions between different points on wave; must be a comparison for same property to score both marks
		ii	the wave reflected (at the fixed end of the wire) interferes/superposes with the incident wave to produce a resultant wave with nodes and antinodes/no energy transfer	B1 B1 B1	
		iii 1	**(all** points have) same frequency	B1	
			P and **Q** have same amplitude and (are in) phase	B1	**allow** *same phase difference* here
		2	**S** has larger amplitude than **P** and **Q**	B1	**allow** *different to*
			S has a phase difference of π/in antiphase to **P** and **Q**	B1	**or** 180° **max** any 3 out of 4 marking points
		iv 1	15 Hz	B1	
			as all points in the fundamental/first harmonic mode move in phase	B1	**accept** string is ½ λ long/between ends
		2	120 Hz	B1	
			for every 10 cm to be at rest λ = 20 cm (so 4 x frequency of Fig. 4.2)	B1	**accept** as all points are nodes **or** $f = 8f_0$ **or** is 8th harmonic
			Total question 4	**17**	

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Question			Answer	M	Guidance
5					
	a	i	when two (or more) waves meet/superpose/overlap (at a point) there is a change in overall displacement	M1 A1	**NOT** interact,combine, join, connect, collide, hit**,** intersect, pass through, etc. **allow** the resultant displacement equals the sum of the individual displacements
		ii	constant phase difference/relationship (between the waves)	B1	**allow** fixed **not** same
	b		$\lambda = c/f = 3.0 \times 10^{8} / 1.0 \times 10^{10}$ $\lambda = 3.0 \times 10^{-2}$ so aerial length = 1.5×10^{-2} (m)	M1 A1	 **accept** 1.5 c(m)
	c	i1	the path difference between the signals (from the two transmitters) changes (along OP) causing the detected signal to vary between maximum and minimum values/AW **or** when signals (at the point on OP) are in phase there is a maximum when (π) out of phase there is a minimum	B1 B1	**give** 1 mark out of 2 for maxima and minima occur (because of interference)
		2	$x = \lambda D/a = 3.0 \times 10^{-2} \times 4.0/0.20$ (= 0.60) so distance = x/2 = 0.30 (m)	C1 A1	**ecf (b)** 20 times answer to **(b)** **allow** 1 SF answer here
		ii	amplitude of signal decreases (inversely) with distance because energy emitted by the transmitters spreads out (so less is collected by the receiver the further away it is)	B1 B1	**allow** intensity; **no mark if** any suspicion of decrease being caused by interference effect **accept** any statement which conveys the idea of energy spreading correctly,e.g. $I \propto 1/d^2$
		iii	when AO – BO = λ/2 a minimum occurs/AW **or** phase difference of π (180°) between detected signals from A and B so distance = λ/2 = 1.5×10^{-2} (m)	B1 B1	idea that movement of λ/2 will change maximum to minimum or vice versa **ecf (b)** same answer as **(b); accept** 1.5 c(m)
	d	i	intensity increases by factor of 4 as intensity α (amplitude)^2	B1 B1	
		ii	intensity falls to zero (emitted) signal is (vertically) polarised receiver in position only to detect horizontally polarised signal	B1 B1 B1	 **allow** transmitter and detector act like 'crossed polarisers' or quoting Malus' law correctly
			Total question 5	**18**	

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Question			Answer	M	Guidance
6					
	a		photoelectric effect	B1	
	b		**1.**Individual photons are absorbed by individual electrons (in the metal surface)/ one to one interaction/AW **2.**Only photon with energy above the work function energy will cause photoelectron emission/idea of threshold frequency **3.**Photon energy is proportional to frequency **4.**(therefore) blue photons with higher f/shorter λ will cause photoemission but red photons will not. **5.**$hf - \phi = KE_{max}$ is the equation resulting from conservation of energy **or** resulting from the meaning of each term **6.**A wave model does not explain instantaneous emission	B1 B1 B1 B1 B1 B1	**max** 4 from 6 marking points **allow** work function (of a metal surface) is minimum energy for photoemission **allow** shorter wavelength light has higher energy (hc/ λ) or higher frequency higher energy (hf) **or** ….red photons with lower f/longer λ..... *max* must be present to score mark; equation stated in words: photon e. – w.f. = max ke of *e* to score full marks (4) the answer **must include** two terms out of *photon, work function* and *threshold frequency/wavelength* (QWC mark)
	c	i	work function = $\phi = hc/\lambda$ $\varphi = 6.6 \times 10^{-34} \times 3.0 \times 10^{8} / 4.8 \times 10^{-7}$ $= 4.1(4) \times 10^{-19}$ (J)	C1 M1 A1	allow $\phi = hf$ ($f = 6.25 \times 10^{14}$) and $f = c/\lambda$ must show answer initially to 2 or 3 SF; ignore any final rounding down to 1 SF
		ii	$E - \phi = ½ mv^2$ $(5.2 - 4.1) \times 10^{-19} = 1.1 \times 10^{-19} = ½ mv^2$ $v = \sqrt{(2 \times 1.1 \times 10^{-19} / 9.1 \times 10^{-31})}$ $v = 4.9 \times 10^{5}$ (m s^{-1})	C1 C1 A1	can use 4.14 or 4 instead of 4.1 **allow** 5.1×10^{5} (m s^{-1}) using $\phi = 4 \times 10^{-19}$ or 4.8×10^{5} (m s^{-1}) using $\phi = 4.14 \times 10^{-19}$
	d	i	electrons passing through a thin sheet of graphite are diffracted/produce diffraction rings on a fluorescent screen	M1 A1	any suitable/reasonably plausible situation what is observed/ interpretation
		ii	$\lambda = h/mv$ $\lambda = 6.63 \times 10^{-34} / 5.0 \times 10^{5} \times 9.1 \times 10^{-31}$ $\lambda = 1.5 \times 10^{-9}$ (m)	C1 C1 A1	 1.46 to 3 SF
			Total question 6	**16**	

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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.

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Answer **all** the questions.

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

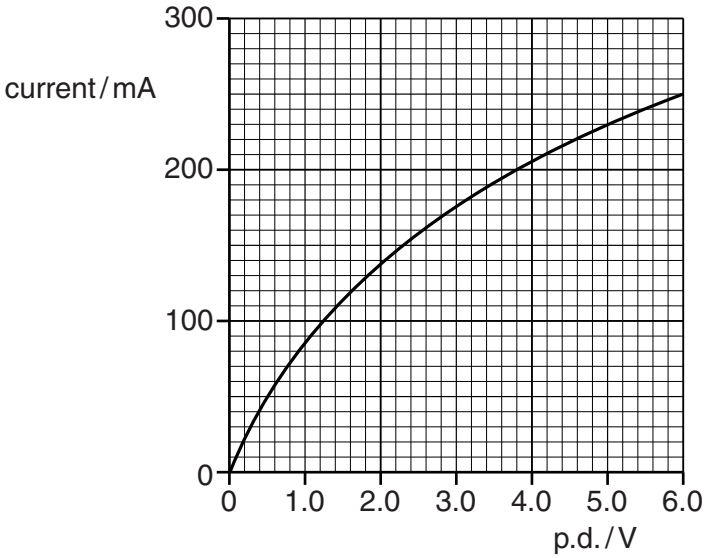


Fig. 1.1

(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]**

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(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.

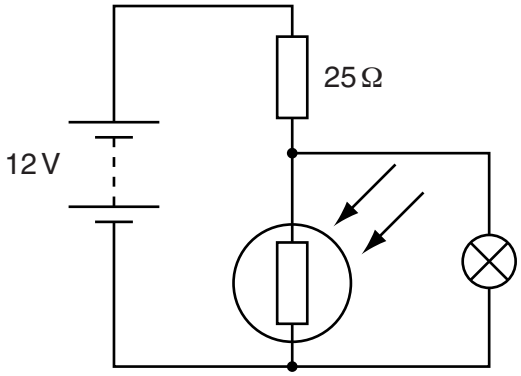


Fig. 1.2

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.

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

[Total: 10]

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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.

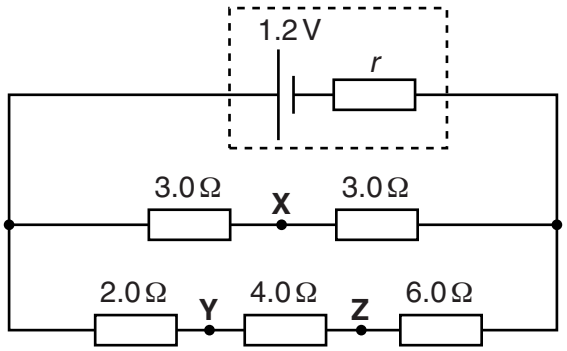


Fig. 2.1

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]**

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(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]

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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.

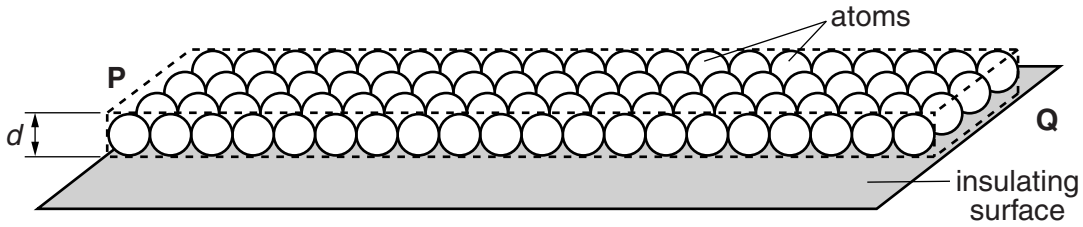


Fig. 3.1

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 1.7×10^{-8} Ω m.

[3]

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

[1]

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

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

.....

.....

.....

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

[Total: 12]

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

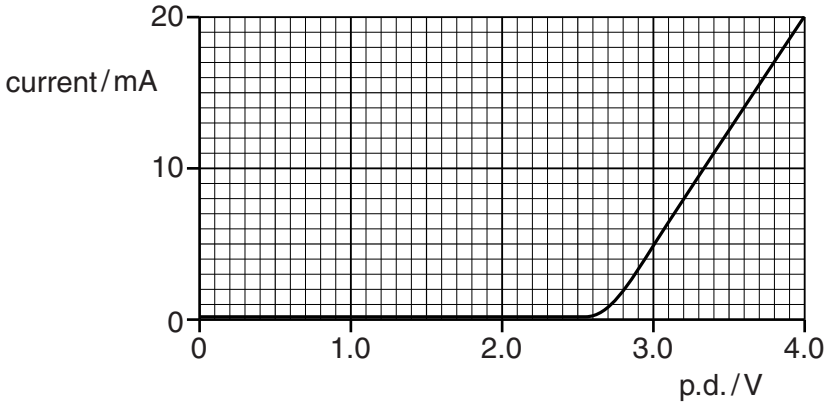


Fig. 4.1

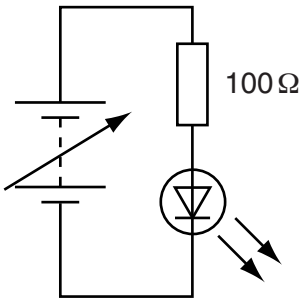


Fig. 4.2

(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]**

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(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]

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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.

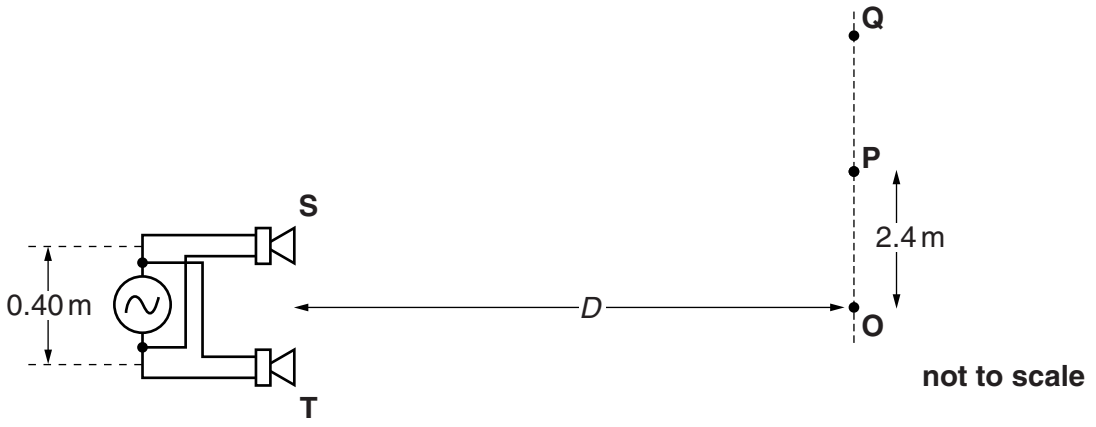


Fig. 5.1

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**.

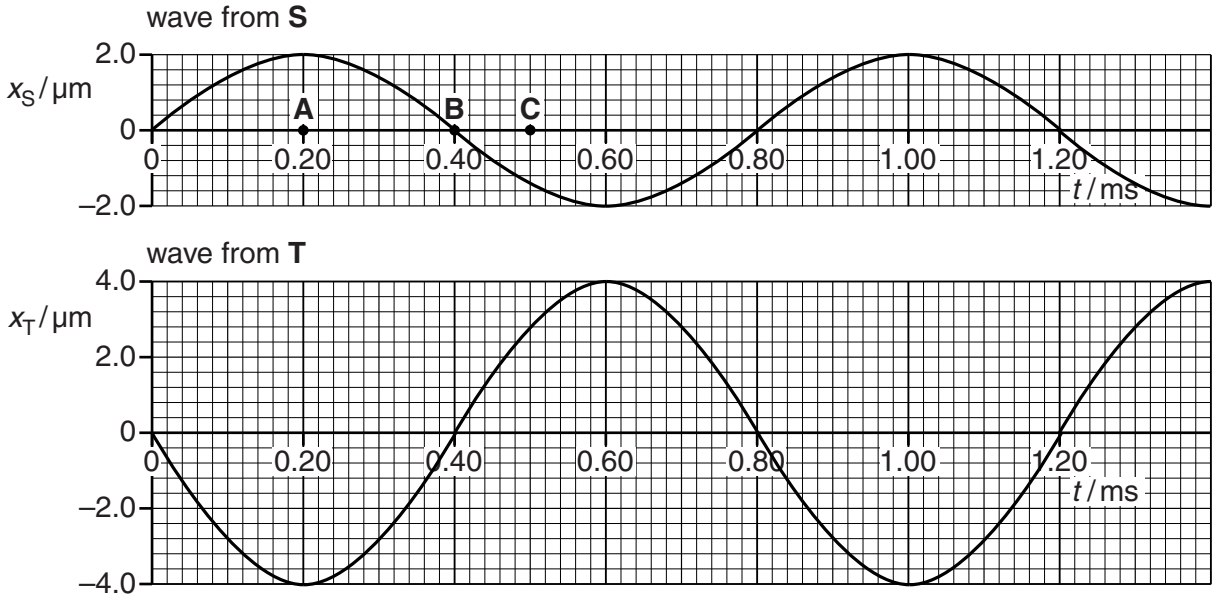


Fig. 5.2

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

.....

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

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(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 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]**

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(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

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Question 6 begins on page 14

PLEASE DO NOT WRITE ON THIS PAGE

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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.

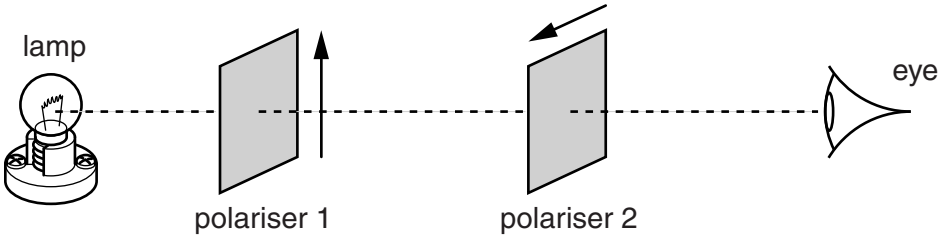


Fig. 6.1

Explain why the lamp cannot be seen by the eye.

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

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(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.

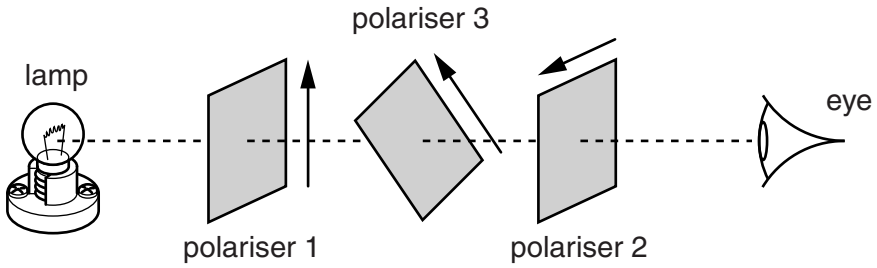


Fig. 6.2

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.

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

[Total: 9]

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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.

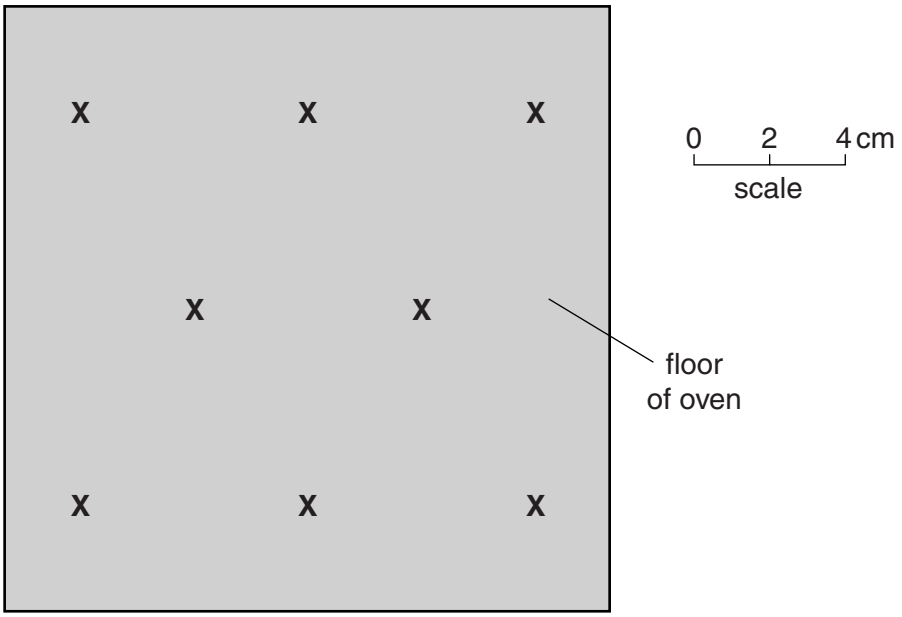


Fig. 7.1

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.

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

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(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]

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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 $4.5 \times 10^5\,m\,s^{-1}$.

[3]

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(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.

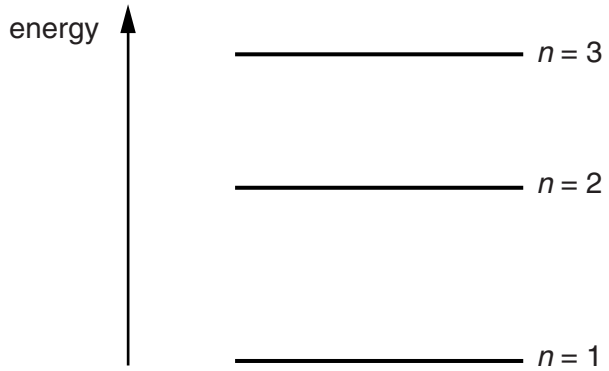


Fig. 8.1

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

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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.

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OCR
Oxford Cambridge and RSA

GCE

Physics A

Unit **G482**: Electrons, Waves and Photons

Advanced Subsidiary GCE

Mark Scheme for June 2014

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It is also responsible for developing new specifications to meet national requirements and the needs of students and teachers. OCR is a not-for-profit organisation; any surplus made is invested back into the establishment to help towards the development of qualifications and support, which keep pace with the changing needs of today's society.

This mark scheme is published as an aid to teachers and students, to indicate the requirements of the examination. It shows the basis on which marks were awarded by examiners. It does not indicate the details of the discussions which took place at an examiners' meeting before marking commenced.

All examiners are instructed that alternative correct answers and unexpected approaches in candidates' scripts must be given marks that fairly reflect the relevant knowledge and skills demonstrated.

Mark schemes should be read in conjunction with the published question papers and the report on the examination.

OCR will not enter into any discussion or correspondence in connection with this mark scheme.

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These are the annotations, (including abbreviations), including those used in scoris, which are used when marking

Annotation	Meaning
BP	Blank Page – this annotation **must** be used on all blank pages within an answer booklet (structured or unstructured) and on each page of an additional object where there is no candidate response.
BOD	Benefit of doubt given
CON	Contradiction
	Incorrect response
ECF	Error carried forward
FT	Follow through
NAQ	Not answered question
NBOD	Benefit of doubt not given
POT	Power of 10 error
^	Omission mark
RE	Rounding error or repeated error
SF	Error in number of significant figures
	Correct response
AE	Arithmetic error
	Wrong physics or equation

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Abbreviations, annotations and conventions used in the detailed Mark Scheme

Annotation	Meaning
/	alternative and acceptable answers for the same marking point
(1)	Separates marking points
reject	Answers which are not worthy of credit
not	Answers which are not worthy of credit
IGNORE	Statements which are irrelevant
ALLOW	Answers that can be accepted
( )	Words which are not essential to gain credit
__	Underlined words must be present in answer to score a mark
ecf	Error carried forward
AW	Alternative wording
ORA	Or reverse argument

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Subject-specific Marking Instructions

CATEGORISATION OF MARKS

The marking scheme categorises marks on the MABC scheme

B marks: These are awarded as independent marks, which do not depend on other marks. For a **B**-mark to be scored, the point to which it refers must be seen specifically in the candidate's answer.

M marks: These are method marks upon which **A**-marks (accuracy marks) later depend. For an **M**-mark to be scored, the point to which it refers must be seen in the candidate's answer. If a candidate fails to score a particular **M**-mark, then none of the dependent **A**-marks can be scored.

C marks: These are compensatory method marks which can be scored even if the points to which they refer are not written down by the candidate, providing subsequent working gives evidence that they must have known it. For example, if an equation carries a **C**-mark and the candidate does not write down the actual equation but does correct working which shows that the candidate knew the equation, then the **C**-mark is given.

A marks: These are accuracy or answer marks, which either depend on an **M**-mark, or allow a **C**-mark to be scored.

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IMPORTANT UPDATE:

ADDITIONAL OBJECTS: You **must** annotate the additional objects for each script you mark. If no credit is to be awarded for the additional object, please use annotation as agreed at the SSU, likely to be 'seen', a cross or the highlighting tool.

CROSSED OUT, RUBRIC ERROR (OPTIONAL QUESTIONS) AND MULTIPLE RESPONSES

Crossed-out Responses: Where a candidate has crossed out a response and provided a clear alternative then the crossed out response is not marked. Where no alternative response has been provided, examiners may give candidates the benefit of the doubt and mark the crossed out response where legible.

Rubric Error Responses – Optional Questions: Where candidates have a choice of question across a whole paper or a whole section and have provided more answers than required, then all responses are marked and the highest mark allowable within the rubric is given. *(The underlying assumption is that the candidate has penalised themselves by attempting more questions than necessary in the time allowed.)*

Multiple Choice Question Responses: When a multiple choice question has only a single, correct response and a candidate provides two responses (even if one of these responses is correct), then no mark should be awarded (as it is not possible to determine which was the first response selected by the candidate).
When a question requires candidates to select more than one option/multiple options, then local marking arrangements need to ensure consistency of approach.

Contradictory Responses: When a candidate provides contradictory responses, then no mark should be awarded, even if one of the answers is correct.

Short Answer Questions (requiring only a list by way of a response, usually worth only **one mark per response**): Where candidates are required to provide a set number of short answer responses then only the set number of responses should be marked. The response space should be marked from left to right on each line and then line by line until the required number of responses have been considered. The remaining responses should not then be marked. Examiners will have to apply judgement as to whether a 'second response' on a line is a development of the 'first response', rather than a separate, discrete response. *(The underlying assumption is that the candidate is attempting to hedge their bets and therefore getting undue benefit rather than engaging with the question and giving the most relevant/correct responses.)*

Short Answer Questions (requiring a more developed response, worth **two or more marks**): If the candidates are required to provide a description of, say, three items or factors and four items or factors are provided, then mark on a similar basis – that is downwards (as it is unlikely in this situation that a candidate will provide more than one response in each section of the response space.)

Longer Answer Questions (requiring a developed response): Where candidates have provided two (or more) responses to a medium or high tariff question which only required a single (developed) response and not crossed out the first response, then only the first response should be marked.

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Examiners will need to apply professional judgement as to whether the second (or a subsequent) response is a 'new start' or simply a poorly expressed continuation of the first response.

Note about significant figures:

If the data given in a question is to 2 sf, then allow answers to 2 or more sf.
If an answer is given to fewer than 2 sf, then penalise once only in the entire paper.
Any exception to this rule will be mentioned in the Guidance.

Please put a tick for every mark awarded in the body of the text at the point where the mark is given.

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Question			Answer	Marks	Guidance
1	a	i	V is not proportional to I	B1	**accept** not a straight line; R is not constant
		ii	R (approximately) constant up to V = 0.5 V and I = 50 mA so R = 0.5/0.05 = 10 (Ω)	B1 B1	**allow** graph is (almost) linear/straight (to V = 0.5 V) or constant gradient **allow** any correct calculation, e.g. 0.2/0.02
		iii	the resistivity/resistance of the (metal) filament increases with temperature the larger the current in the filament the hotter it becomes/AW	B1 B1	larger current heats filament so resistance increases **or** electron-ion collisions increase/AW; **allow** atom for ion
	b		Any potential divider argument or calculation *In the light* parallel combination less than or about 1 Ω/AW so V across lamp less than 0.5 V (so lamp out)/ small compared to V across 25 Ω	B1 B1 B1	**QWC** the arguments must be clear for full marks **allow** R_{lamp} = 10 to 25 Ω for any calculation **or** comparison of voltage across 25 Ω to 1 Ω **N.B.** answers given in terms of current are likely to score zero
			In the dark parallel combination about 25 Ω/AW so V across lamp approximately 6.0 V so lamp on	B1 B1	
			Total	**10**	

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Question			Answer	Marks	Guidance
2	a		emf – J C^{-1}, resistance – V A^{-1}, energy – V C, charge – A s	**B1** **B1**	4 correct 2 marks; 2 correct 1 mark
	b	i	energy per unit charge transferred from electrical to other forms	**B1** **B1**	**NOT** coulomb **allow** any other form e.g. heat, light, etc
		ii	(some) energy is transferred into thermal energy /lost as heat in (driving charge through) the battery. It behaves as if it has an (internal) resistance/AW **or** there is a voltage drop across/decrease in voltage from the battery (when a current is drawn from it)/AW	**B1**	**allow** any description which uses E = V + Ir but not just the formula alone, e.g. 'lost volts' per unit current is just accepable
		iii	p.d. across each branch is the same/branches in parallel resistance in X branch is 6 Ω, in YZ branch is 12 Ω so current in X branch is twice that in YZ branch/ as V = IR	**B1** **B1** **A0**	**allow** R in X branch is half that in YZ branch/AW
		iv	V = IR = 0.08 x 6 V = 0.48 (V)	**C1** **A1**	
		v	the p.d. across each 3 Ω resistor is terminal p.d./2 **or** 0.48 V at Z there is 6 Ω either way to the supply/AW so p.d. across each 6 Ω is terminal p.d./2 so p.d. between X and Z is zero	**B1** **B1** **A0**	p.d./voltage across 3 Ω and 6 Ω are equal with justification
		vi	terminal p.d. = 0.96 V current in r = 0.16 + 0.08 = 0.24 A use of E = V + Ir 1.2 = 0.96 + 0.24 r giving r = 1.0 (Ω)	**C1** **C1** **C1** **A1**	**or** V = 0.24 x 4 **or** = 0.08 x 12 **or** 0.16 x 6 **or (iv)** x 2 **alt**: R in parallel gives 4.0 Ω; total R = 1.2/0.24 = 5.0 Ω r = 5.0 - 4.0 = 1.0 (Ω) **allow** 1SF
			Total	**15**	

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Question			Answer	Marks	Guidance
3	a		p.d./voltage (across component) divided by current (in it)	B1	**accept** V/I with V and I defined; per (unit) current, etc
	b	i	R = ρl/A = $1.7 \times 10^{-8} \times 20 \times d/4d^2 = 1.7 \times 10^{-8} \times 5/3.8 \times 10^{-10}$ =220 (Ω)	C1 C1 A1	 **allow** $A = 4\pi r^2 = 4.5 \times 10^{-19}$ giving 285 Ω **accept** 220 to 230 Ω
		ii	$n = 1/d^3 = (1.8 \times 10^{28})$	A1	**accept** alternatives, e.g. 80/volume
		iii	I = nAev $= 1.8 \times 10^{28} \times 4 \times (3.8 \times 10^{-10})^2 \times 1.6 \times 10^{-19} \times 1.9 \times 10^{-5}$ $= 3.2 \times 10^{-14}$ (A)	C1 A1	1 mark for substitution into formula, **ecf** n, A values accept 3.16 and 3.5 (using $n = 2 \times 10^{28}$) accept 2.48 and 2.76 (for 285 Ω)
		iv	$P = I^2R$ $= (3.2 \times 10^{-14})^2 \times 200 \times 10^9$ $= 2.0 \times 10^{-16}$ (W)	C1 C1 A1	**ecf b(i) & (iii)** **accept** 1 SF as estimate; can obtain 1.2 to 2.8 using all values possible in **(iii)**
	c		electron moves at drift velocity signal travels at/close to the speed of light	B1 B1	**accept** answers explaining idea of drift velocity
			Total	12	

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Question			Answer	Marks	Guidance
4	a	i	ammeter in series voltmeter in parallel with LED	B1	both correct to score 1 mark
		ii	(at 20 mA) V_{led} = 4.0 V V_R = 0.020 x 100 = 2.0 V so p.d. = 6.0 V	B1 C1 A1	**allow** R_{led} = (4.0/ 0.02) = 200 Ω p.d. = 0.020 (200 + 100) **allow** answer to 1 SF
	b	i	energy in eV = $4.1 \times 10^{-19}/1.6 \times 10^{-19}$ = 2.6 (eV)	B1	**expect** 2.56 eV
		ii	LED strikes at 2.6 V/ only conducts above 2.6 V an electron must pass through a p.d. of 2.6 V to lose energy as a photon of blue light/AW.	M1 A1	
	c	i	n = I/e = $0.02/1.6 \times 10^{-19}$ = 1.3×10^{17}	C1 A1	**expect** 1.25×10^{17}
		ii	energy/s = $1.25 \times 10^{17} \times 4.1 \times 10^{-19}$ or 2.6 V x 0.020 A = 0.051 to 0.053 (J s^{-1})	C1 A1	**ecf (c)(i); NOT** 4.0 x 0.020 answer is 0.053 using 1.3×10^{17}
		iii	efficiency = $0.052/(4.0 \times 20 \times 10^{-3})$ = 0.64	C1 A1	**ecf (c)(ii)** **accept** $V_{strike}/V_{operate}$ = 2.6/4.0 or any other correct (P or W out)/ (P or W in) calculation **accept** 64 %
	d		shape similar to the curve drawn leaving x-axis at close to 2.0 V and passing through (3.4, 20)	B1 B1	Within half a square
			Total	**15**	

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Question			Answer	Marks	Guidance
5	a		constant phase difference/relationship (between the waves) **or** always at π radians/180° **or** because they are generated by the same source/AW	**B1**	**allow** fixed **NOT** same
	b		(for a minimum) the two oscillations/amplitudes add in antiphase/ are π (rad) out of phase/completely out of phase there is a resultant amplitude (of 2.0 μm) so a sound will still be heard	**B1** **B1**	for zero intensity the two oscillations must have equal amplitudes/AW and be in antiphase **allow** the word waves for oscillations
	c		**B** π/2 radians/90° **C** 3π/4 radians/135°	**B1** **B1**	**max** 1 out of 2 marks if unit omitted
	d	i	$f = 10^3/0.8 = 1.25$ kHz **or** $T = 0.8 \times 10^{-3}$ s $\lambda = v/f$ **or** $vT = 340 \times 0.8 \times 10^{-3}$ $\lambda = 0.27$ m	**C1** **C1** **A1**	if T value from graph incorrect **ecf** with max 2/3
		ii	select $\lambda = ax/D$ $D = 0.4 \times 4.8/ 0.27$ D = 7.1 (m)	**C1** **C1** **A1**	**ecf (d)(i)** **expect** 7.06 m if using $\lambda =$ 0.272 m 3.5 m or 3.6 m scores 2 marks
	e	i	energy per unit time/power per unit area (perpendicular to the direction of energy transfer)	**B1**	**accept** per second as a special case
		ii	ratio of amplitudes = 3 intensity is proportional to (amplitude)^2 ratio of intensities = 9 so intensity at **O** = $4.0 \times 10^{-6} \times 9$ $I = 3.6 \times 10^{-5}$ (W m^{-2})	**C1** **C1** **A1**	**or** A at **P** = 2.0 μm and A at **O** = 6.0 μm clearly stated **allow** $I \propto A^2$ i.e. symbols only
			Total	**15**	

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Question			Answer	Marks	Guidance
6	a		all travel at speed of light through a vacuum are oscillating E and B fields **or** are caused by accelerating charges/AW	**B1** **B1**	**max** 2 marks from 3 marking points if 3 properties are given withhold one mark for each incorrect property so 2 correct and 1 incorrect would score 1 mark ;1 correct and 2 incorrect would score zero, etc
	b	**i**	oscillations (of particles/e-m fields along the wave) are in one direction only perpendicular to the direction of wave propagation/of travel of the wave/of energy transfer	**B1** **B1**	
		ii	light passing through polariser 1 is <u>vertically</u> polarised/ only vertical oscillations of the light exist beyond the polariser 1/AW only (the component of) light in the <u>horizontal</u> plane can pass through polariser 2 so no light reaches the eye	**B1** **B1**	**allow** any words indicating <u>vertical</u>, e.g. up and down; for <u>horizontal</u>, e.g. at 90° to vertical or crossed polarisers **accept** using Malus' law $I_{trans} = I_{incident}\cos^2\theta$ with $\theta = 90^o$ gives $I_{trans} = 0$
		iii	after polariser 1 the component of the vertically polarised light at 45° passes through polariser 3 the polarised light beyond polariser 3 has a component at 45° which passes through polariser 2 so light reaches the eye **or mark a typical answer of the form (max 2) as follows** some of the vertically polarised light passes through polariser 3 and some of this passes through polariser 2 because in each case the polarised light is not at right angles to the transmission axis of the polariser	**B1** **B1** **B1**	**QWC** statement to the effect that component of light along polarising axis of filter is transmitted **accept** using Malus' law $I_{trans} = I_{incident}\cos^2\theta$ with $\theta = 45^o$ gives $I_{trans} = I_{incident}/2$ same process gives $I_{trans} = I_{incident}/2$ again so ¼ of light after polariser 1 reaches eye (assuming no absorption) accept answers in terms of amplitudes rather than intensities, i.e. $A = A_0 \cos\theta$, etc.
			Total	**9**	

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Question			Answer	Marks	Guidance
7	a		(micro)waves are <u>reflected</u> (at the metal walls) reflected waves interfere/superpose with the incident waves to produce nodes and antinodes (– a stationary wave pattern)	**B1** **B1** **B1**	**allow** points of constructive and destructive interference
	b		X are the points of <u>maximum</u> energy/intensity/amplitude so are antinodes	**M1** **A1**	**allow** displacement in this case
	c		measurement = 3 cm **or** λ/2 = 6 cm so λ = 0.12 m c = fλ = 2.5 x 10^9 x 0.12 = 3.0 x 10^8 (m s^{-1})	**B1** **C1** **M1** **A1**	measurement to within ± 1 mm **ecf** measurement, i.e. λ = 4 x measurement there must be a valid calculation shown scores 1 out of final 3 for answer of 1.5 x 10^8 **allow** 1 SF, i.e. 3 x 10^8
			Total	**9**	

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Question			Answer	Marks	Guidance
8	a	i	energy φ required for an electron to escape from <u>metal surface</u> the minimum energy.....	**M1** **A1**	inclusion of the word minimum in the sentence scores the second mark
		ii	a <u>photon</u> with less than the threshold frequency f_0 cannot cause electron emission/AW so work function = h (threshold frequency)	**B1** **B1**	**allow** $\varphi = hf_0$ when the symbols φ and f_0 have been defined somewhere in the question
		iii	$\varphi = hc/\lambda$ $= 6.63 \times 10^{-34} \times 3.0 \times 10^{8}/550 \times 10^{-9}$ $= 3.6 \times 10^{-19}$ (J)	**C1** **A1**	
	b	i	$KE_{max} = hf - \varphi$ or $hf = \varphi + KE_{max}$ $hf = 6.63 \times 10^{-34} \times 3.0 \times 10^{8}/440 \times 10^{-9} = 4.5 \times 10^{-19}$ J $½mv^2 = 9 \times 10^{-20}$ giving $v^2 = 1.8 \times 10^{-19}/9.1 \times 10^{-31}$ $v = 4.45 \times 10^{5}$ (m s^{-1})	**C1** **B1** **B1** **A0**	**ecf (a)(iii)** allow 4.5 or 4.4×10^{5}
		ii	$\lambda = h/mv = 6.63 \times 10^{-34}/9.1 \times 10^{-31} \times 4.5 \times 10^{5}$ $\lambda = 1.6 \times 10^{-9}$ (m)	**C1** **A1**	allow 1.7×10^{-9} for $v = 4.4 \times 10^{5}$
	c	i	n = 3 <u>to</u> n = 2	**B1**	**allow** between **or** and **when** there is a downward arrow on Fig. 8.1
		ii	$E_{32} + E_{21} = E_{31}$ $hc/\lambda_{32} + hc/\lambda_{21} = hc/\lambda_{31}$ 1/590 + 1/440 = 1/252 so $\lambda_{31} = 250 \times 10^{-9}$ (m)	**C1** **C1** **A1**	**accept** equation using 1/λ **or** $1/590 + 1/440 = 1/\lambda_{31}$ **allow** 2 or 3 sf **allow** 2/3 for using 550 for 590 nm giving 244 nm
			Total	**15**	

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RECOGNISING ACHIEVEMENT

Wednesday 5 June 2013 – Morning

AS GCE PHYSICS A

G482/01 Electrons, Waves and Photons

G411720613

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

G 4 8 2 0 1

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, your should use the lined pages at the end of the 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.

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Answer **all** the questions.

1 Fig. 1.1 shows the $I-V$ characteristic of a slice of semiconducting material.

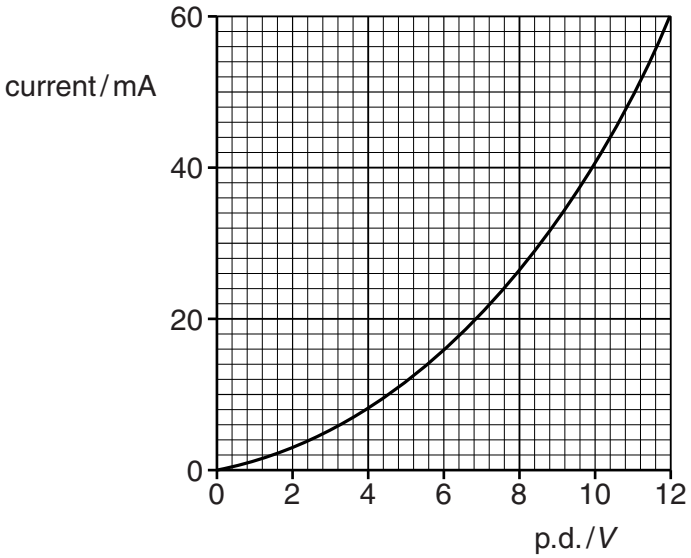


Fig. 1.1

(a) (i) Define *resistance*.

.....

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

(ii) Show that the resistance of the slice is about 250 Ω when there is a current of 40 mA in it.

[2]

(b) The dimensions of the slice are shown in Fig. 1.2.

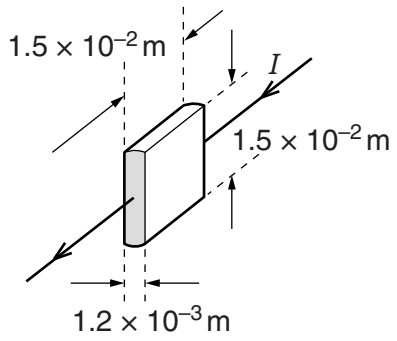


Fig. 1.2

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Calculate the resistivity ρ of the semiconducting material when there is a current I of 40 mA in the slice.

ρ = ... Ω m **[3]**

(c) Explain how the $I-V$ characteristic shows that the resistivity of the semiconducting material decreases with increasing temperature.



In your answer you should explain how you are aware that the temperature of the slice changes.

.....

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

[Total: 10]

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2 **(a)** The battery in an electric car has an e.m.f. of 24 V. It can provide a current of 200 A to the motor for a period of 4.0 hours.

(i) Define the term *electromotive force* (e.m.f.) for the battery.

.....

.....

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

(ii) Show that the total charge Q that can be delivered by the battery is about 3×10^6 C.

[2]

(iii) Calculate the total energy E that can be supplied by the battery at a constant e.m.f. of 24 V.

E = ... J **[2]**

(b) The charger for the battery has a 30 V output supplying a current I. The total resistance of the circuit is indicated by one resistor **R** in Fig. 2.1. The positive terminal of the battery is connected to **X**.

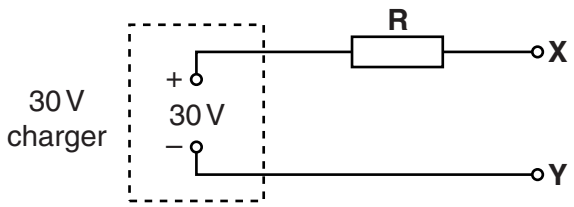


Fig. 2.1

(i) Complete the circuit by drawing the correct symbol for the battery between **X** and **Y** on Fig. 2.1. The battery has negligible internal resistance. **[1]**

(ii) The potential difference across the battery remains at 24 V. The current I provided by the battery charger is constant at 120 A. Show that the value of the resistance of **R** is 0.050 Ω.

[2]

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(iii) Calculate the power lost in **R** as the battery is charging.

power lost = ... W **[2]**

(iv) The efficiency of the charging process is given by the equation

$$\text{efficiency} = \frac{\text{input power from charger} - \text{power loss in } \mathbf{R}}{\text{input power from charger}}.$$

Calculate its value as a percentage.

efficiency = ... % **[3]**

(c) (i) Show that it takes about 7 hours to charge a completely flat battery.

[2]

(ii) Calculate the cost of charging the battery at 26p per kWh.

cost = ... p **[1]**

[Total: 17]

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3 **(a)** Kirchhoff's laws can be used to analyse any electrical circuit. State each of Kirchhoff's laws and the physical quantity associated with each law that is conserved in the circuit.

(i) Kirchhoff's first law

.....

.....

.....

.....

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

(ii) Kirchhoff's second law

.....

.....

.....

.....

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

(b) The circuit in Fig. 3.1 consists of a battery of e.m.f. 45 V and negligible internal resistance and three resistors.

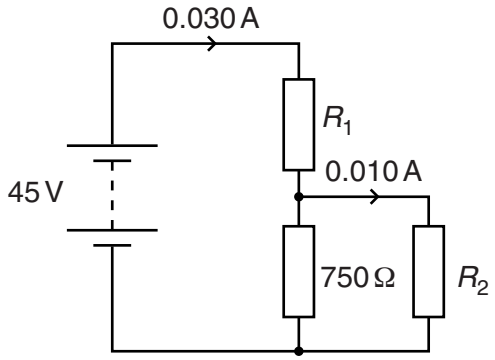


Fig. 3.1

The resistors have resistances R_1, R_2 and 750 Ω. The current in the resistor of resistance R_1 is 0.030 A. The current in the resistor of resistance R_2 is 0.010 A.

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Calculate

(i) the current I in the 750 Ω resistor

I = ... A **[1]**

(ii) the p.d. V across the 750 Ω resistor

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

(iii) the resistances R_1 and R_2.

R_1 = ... Ω

R_2 = ... Ω
[2]

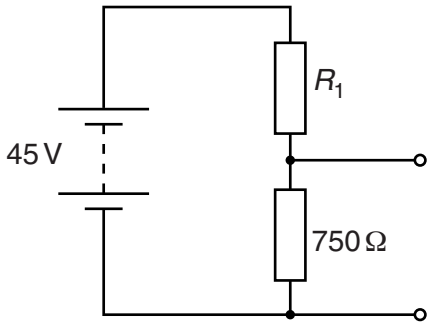
Question 3 is continued on page 8

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(c) The resistor of resistance R_2 is replaced in Fig. 3.1 by a light dependent resistor (LDR).

(i) Draw the circuit symbol for an LDR on Fig. 3.2 to complete this new circuit.



[1]

Fig. 3.2

(ii) The resistance of the LDR falls from about 1.5 kΩ to about 400 Ω as the light intensity increases. State and explain, without calculation, how the potential difference across the 750 Ω resistor varies as the intensity of the light incident on the LDR increases.

.....

.....

.....

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

(iii) It is suggested that the LDR in the circuit of Fig. 3.2 is used to monitor changes in the light intensity.

1 Draw a suitable electrical meter in the LDR branch of the circuit on Fig. 3.2 to measure these changes.

2 State the electrical meter that you have chosen and suggest a sensible maximum scale reading.

.....

.....

.....

[3]

[Total: 15]

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Question 4 begins on page 10

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4 **(a)** **(i)** Explain what is meant by a *progressive wave*.

.....

.....

.....

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

(ii) State **two** differences between a *progressive* and a *stationary* wave.

1 .....

.....

2 .....

.....

[2]

(b) Fig. 4.1 shows, at time $t = 0$, the shape of a section of stretched cord along which a transverse wave is **travelling** from left to right. **W**, **X**, **Y** and **Z** are four marked points on the cord.

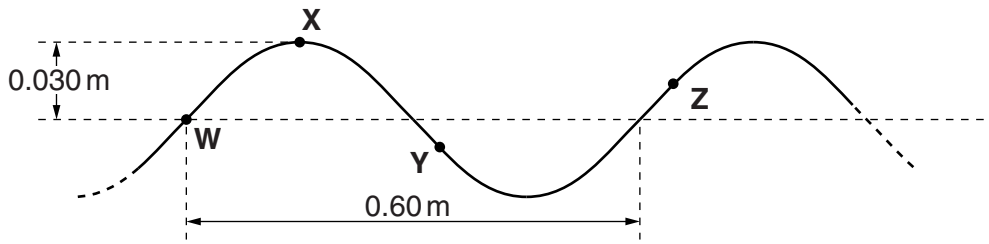


Fig. 4.1

A mechanical oscillator is causing the wave by oscillating the end of the cord at a steady frequency of 5.0 Hz. The wave has a wavelength of 0.60 m and amplitude of 0.030 m.

(i) On the axes of Fig. 4.2 sketch the graph of the displacement of point **X** over the period $t = 0$ to 0.40 s. Add suitable scales to the axes. **[4]**

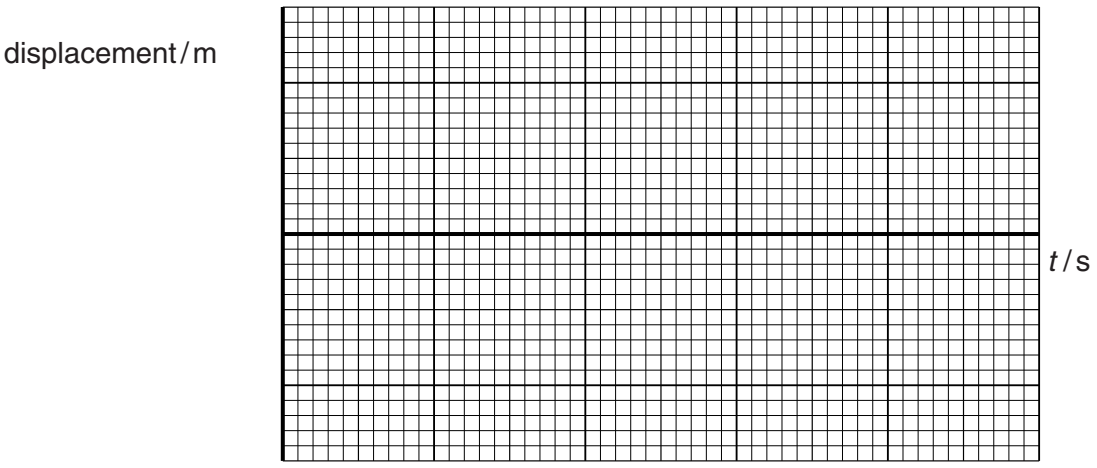


Fig. 4.2

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(ii) State which of the points **W**, **X**, **Y** and **Z** at $t = 0$

1 is instantaneously at rest .....

2 has the greatest speed .....

3 are moving 90° out of phase with each other. .....

[3]

(iii) On Fig. 4.1 draw arrows to show the directions in which the points **Y** and **Z** are moving. **[2]**

(c) The speed v of the wave on the stretched cord is given by the formula

$$v = k\sqrt{T}$$

where T is the tension in the cord and k is a constant.

Calculate the wavelength λ of the wave after the tension in the cord has been **quadrupled** (×4) but the frequency of oscillation is unchanged.

$\lambda =$ ..... m **[2]**

(d) The speed of point **W** on the cord at $t = 0$ is $0.94\,\text{m s}^{-1}$. With the cord at its original tension, the frequency of oscillation is now **doubled** to 10 Hz. The amplitude is kept at 0.030 m. Calculate the new speed of point **W** at $t = 0$. Explain your reasoning.

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

[Total: 17]

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5 This question is about the superposition of electromagnetic waves.

(a) **(i)** State the *principle of superposition of waves*.

.....

.....

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

(ii) State **one** property of electromagnetic waves that distinguishes them from **all** other waves.

.....

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

(iii) State why electromagnetic waves can be polarised but sound waves cannot be polarised.

.....

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

(b) In Fig. 5.1 $\mathbf{T_1}$ and $\mathbf{T_2}$ are two adjacent transmitters 1.0 m apart with a receiving aerial **R** halfway between them. The transmitters are set up to emit coherent electromagnetic waves of wavelength 3.0 cm.

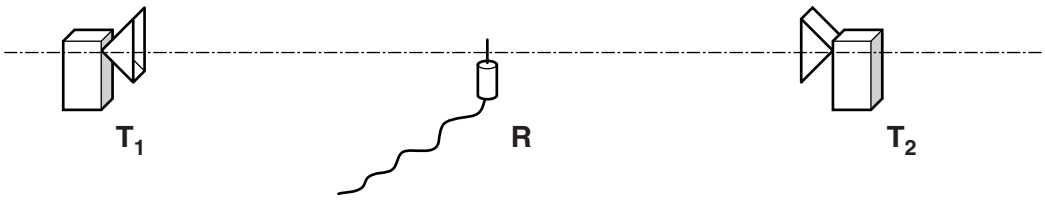


Fig. 5.1

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(i) The student finds that the signal at the receiver **R** falls from maximum to zero when **R** is moved 0.75 cm towards a transmitter. Explain this observation.

In your answer you should make clear how the signal can be zero and why the distance moved should be 0.75 cm.

.....

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.....

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

(ii) With **R** at the mid-point between $\mathbf{T_1}$ and $\mathbf{T_2}$, the student rotates $\mathbf{T_2}$ through 90° about an axis through $\mathbf{T_1}$ and $\mathbf{T_2}$. See Fig. 5.2.

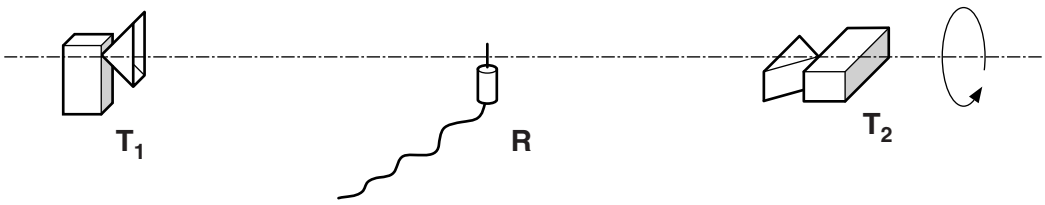


Fig. 5.2

The student finds that the amplitude of the signal at **R** falls to about one half. The detected signal now remains the same when **R** is moved 0.75 cm. Explain these observations.

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

[Total: 11]

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6 **(a)** A 5.0 eV photon can cause the photoelectric effect from most metals.

(i) State what is meant by the *photoelectric effect*.

.....

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

(ii) State what is meant by an *electron volt* (eV).

.....

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

(iii) Calculate the value of 5.0 eV in SI units.

value = ... unit ..... **[1]**

(b) A photon of energy 8.0×10^{-19} J incident on a clean zinc surface can cause photoelectric emission. The maximum kinetic energy of an electron emitted from the surface is 1.1×10^{-19} J.

(i) **1** Define the term *work function* of a metal.

.....

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

2 Calculate the work function for zinc.

work function = ... unit ..... **[1]**

(ii) **1** Show that the maximum speed v of an electron emitted from the surface is about $5 \times 10^5\,\text{m s}^{-1}$.

[2]

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2 Calculate the de Broglie wavelength of an electron emitted from the surface at the maximum speed.

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

(c) The spacing between atoms in a thin sheet of graphite is about 2.5×10^{-10} m.

(i) A beam of electrons in a vacuum can travel through a thin sheet of graphite placed perpendicular to the beam to produce a pattern of **rings** on a fluorescent screen beyond the graphite sheet. Explain why this pattern is produced.

.....

.....

.....

.....

.....

.....

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

(ii) Explain whether or not the electrons in **(b)(ii)** would be suitable for use in such an experiment.

.....

.....

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

[Total: 14]

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7 This question is about the Young double slit experiment. See Fig. 7.1. The fringe pattern seen on the screen is shown to the right.

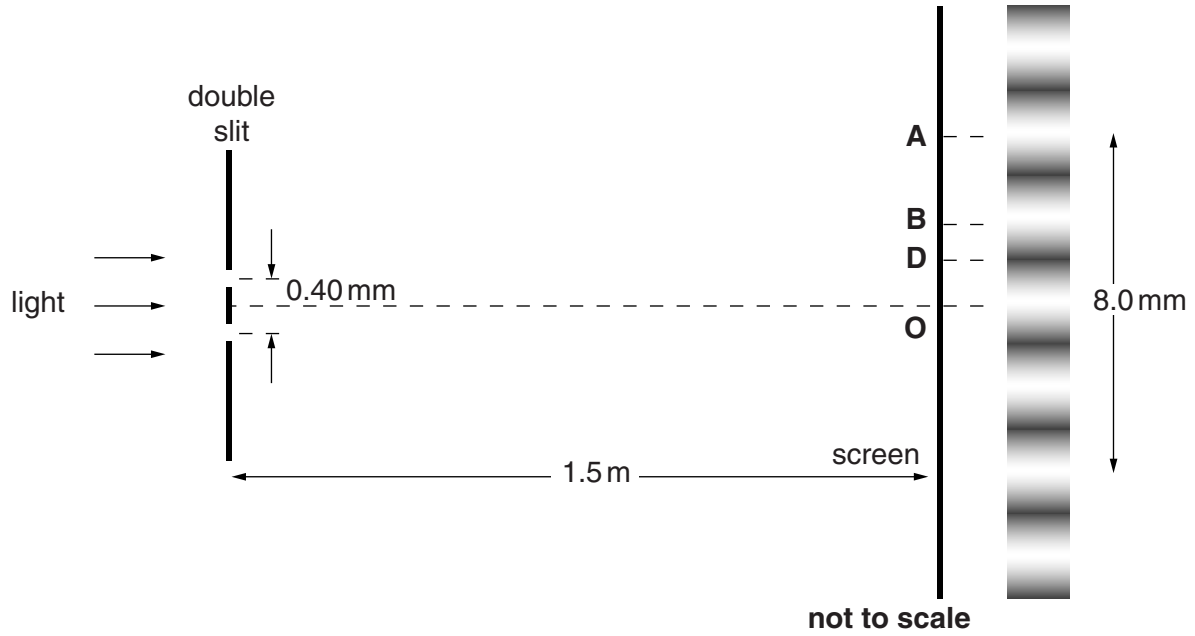


Fig. 7.1

Two parallel clear lines are scratched on a darkened glass slide 0.40 mm apart. When a beam of monochromatic visible light is shone through these slits, interference fringes are observed on a screen placed 1.5 m from the slide. The fringe at point **B** is bright and the fringe at point **D** is dark.

(a) Explain why this arrangement with two slits is used to produce visible fringes on the screen rather than two separate identical light sources.

.....

.....

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

(b) State the **phase difference** between the light waves from the two slits that meet on the screen in Fig. 7.1 at point

D .....

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

(c) **(i)** Use Fig. 7.1 to calculate the separation of adjacent bright fringes, the distance between **O** and **B**.

fringe separation = ... m **[1]**

(ii) Show that the wavelength λ of the monochromatic light is about 5×10^{-7} m.

[3]

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(d) Calculate the **path difference**, in nanometres, between the light waves from the two slits that meet on the screen in Fig. 7.1 at point **A**.

path difference = ... nm **[2]**

(e) The energy level diagram of Fig. 7.2 is for the atoms emitting photons in the light source. Electron transitions between the three levels shown produce three photons of different wavelength. The energy E of an electron bound to an atom is negative.

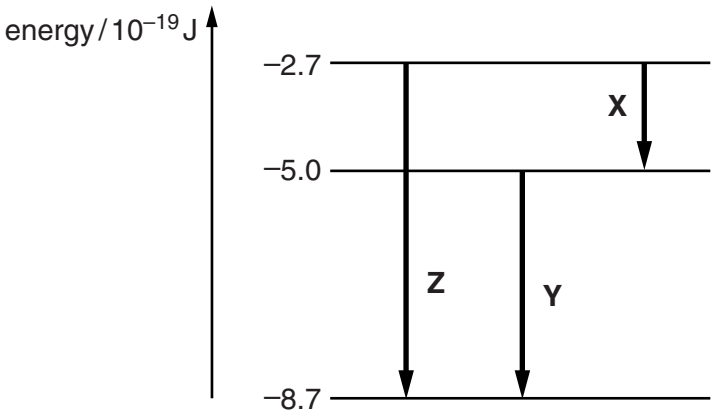


Fig. 7.2

(i) Use data from Fig. 7.2 to justify that the arrow labelled **Y** produces the photons of wavelength about 5×10^{-7} m used in the interference experiment.

[4]

(ii) Neither of the photons shown by the other transitions can be used for the experiment because they are not visible. State in which region of the electromagnetic spectrum each photon is produced, by the other transitions, **X** and **Z**.

X .....

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

[Total: 16]

END OF QUESTION PAPER

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ADDITIONAL ANSWER PAGE

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.

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ADDITIONAL ANSWER SPACE

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RECOGNISING ACHIEVEMENT

GCE

Physics A

Advanced Subsidiary GCE

Unit **G482:** Electrons, Waves and Photons

Mark Scheme for June 2013

Oxford Cambridge and RSA Examinations

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This mark scheme is published as an aid to teachers and students, to indicate the requirements of the examination. It shows the basis on which marks were awarded by examiners. It does not indicate the details of the discussions which took place at an examiners' meeting before marking commenced.

All examiners are instructed that alternative correct answers and unexpected approaches in candidates' scripts must be given marks that fairly reflect the relevant knowledge and skills demonstrated.

Mark schemes should be read in conjunction with the published question papers and the report on the examination.

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1. **Annotations**

Annotation	Meaning
	Benefit of doubt given
	Contradiction
	Incorrect response
	Error carried forward
	Follow through
	Not answered question
	Benefit of doubt not given
	Power of 10 error
	Omission mark
	Rounding error or repeated error
	Error in number of significant figures
	Correct response
	Arithmetic error
	Wrong physics or equation

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Abbreviations, annotations and conventions used in the detailed Mark Scheme (to include abbreviations and subject–specific conventions).

Annotation	Meaning
/	alternative and acceptable answers for the same marking point
(1)	Separates marking points
reject	Answers which are not worthy of credit
not	Answers which are not worthy of credit
IGNORE	Statements which are irrelevant
ALLOW	Answers that can be accepted
( )	Words which are not essential to gain credit
__	Underlined words must be present in answer to score a mark
ecf	Error carried forward
AW	Alternative wording
ORA	Or reverse argument

Highlighting is also available to highlight any particular points on the script.

2. **Subject-specific Marking Instructions**

CATEGORISATION OF MARKS

The marking scheme categorises marks on the MABC scheme

B marks: These are awarded as independent marks, which do not depend on other marks. For a **B**-mark to be scored, the point to which it refers must be seen specifically in the candidate's answer.

M marks: These are method marks upon which **A**-marks (accuracy marks) later depend. For an **M**-mark to be scored, the point to which it refers must be seen in the candidate's answer. If a candidate fails to score a particular **M**-mark, then none of the dependent **A**-marks can be scored.

C marks: These are compensatory method marks which can be scored even if the points to which they refer are not written down by the candidate, providing subsequent working gives evidence that they must have known it. For example, if an equation carries a **C**-mark and the candidate does not write down the actual equation but does correct working which shows that the candidate knew the equation, then the **C**-mark is given.

A marks: These are accuracy or answer marks, which either depend on an **M**-mark, or allow a **C**-mark to be scored.

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Note about significant figures:

If the data given in a question is to 2 sf, then allow answers to 2 or more sf.
If an answer is given to fewer than 2 sf, then penalise once only in the entire paper and annotate with SF.
Any exception to this rule will be mentioned in the Guidance.

Note about rounding errors

Only penalise rounding errors once in the entire paper and annotate with RE.

Please put ticks and crosses against all sub-sections marked AAA (9 in total) in the body of the text where the mark is given

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Question			Answer	Marks	Guidance
1	(a)	(i)	potential difference (across a component)/current (in it)	B1	**allow** symbols if symbols defined; voltage or p.d.; **allow** per **not** over
		(ii)	read 10 V from graph (R = V/I =) 10/ 0.04 = 250 (Ω)	C1 M1 A0	**allow** 9.8 or 9.9 **ecf** reading from graph
	(b)		R = ρl/A **or** ρ =RA/l ρ = 250 x 1.2 x 10^{-3} ρ = 0.30 (Ω m)	C1 C1 A1	select formula mark **ecf(a)(ii)**; a correct substitution correct answer **allow** 0.3
A **A** **A**	(c)		(graph curves so) R changes qualification: I increases faster than V **increased temperature is caused by (larger) <u>current</u> in slice** qualification: P = I^2R as R decreases ρ decreases	B1 B1 B1 B1 B1	**allow** R increases or decreases **allow**: by calculating two values of R **do not allow** either of the first two marking points if reference made linking gradient and R value **QWC mark; allow** heating effect is caused by.... **allow** 'R decreases' already stated earlier in answer **max** 3 out of 4 + QWC mark
			Total	**10**	

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Question			Answer	Marks	Guidance
2	(a)	(i)	energy transfer per unit charge from chemical/other to electrical form	B1 B1	**allow** energy per unit charge
		(ii)	(Q = It =) 200 x 4 x 60 x 60 = 2.9 x 10^6 (C)	M1 A1	**accept** 200 x 14400 **accept** 2.88 x 10^6
		(iii)	E = QV = 2.88 x 10^6 x 24 = 6.9 x 10^7 (J)	C1 A1	**accept** 72 MJ if using 3 MC or 69.6 or 70 if using 2.9 MC
	(b)	(i)	correct symbol and polarity connected to X and Y	B1	**allow** one cell or more or two cells with dotted lines between
A A A		(ii)	V = 30 – 24 = 6 V R = V/I = 6/120 = 0.05 (Ω)	M1 M1 A0	evidence of the V subtraction needed **do not allow** use of E = V + I**r**; it must be I**R**
		(iii)	P = VI = 6 x 120 = 720 (J s^{-1})	C1 A1	**or** $I^2R = 120^2$ x 0.05 **or** $V^2/R = 6^2$ /0.05
		(iv)	(3600 – 720)/3600 = 2880/3600 = 0.8 = 80 (%)	C1 C1 A1	**ecf b(iii)**; using 2880 instead of 3600 gives 75%; scores zero **allow** (30 – 6)I/30I = 24/30 = 0.8 = 80 (%)
	(c)	(i)	t = Q/I = 2.88 x 10^6/120 **or** E/VI = 69 x 10^6/(24 x 120) t = 2.4 x 10^4/3600 = 6.7 h	M1 A1	**ecf (a)(iii); accept** 3 x 10^6 giving 2.5 x 10^4 s and 6.9 h **allow ora** using 7.0 h giving E = 72.5 MJ
		(ii)	power supplied = 30 x 120/1000 = 3.6 kW cost = 3.6 x 7 x 26 = 655 (p)	A1	**ecf c(i) accept** any consistent answer **do not allow** 2.88 kW giving 524 p **unless** repeated error from **b(iv)**
			Total	**17**	

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Question			Answer	Marks	Guidance
3	(a)	(i)	sum of/total current into a junction equals the sum of/total current out conservation of charge	B1 B1	total vector sum of currents is zero **allow** 'point in a circuit' for 'junction'
		(ii)	(sum of) e.m.f.s = sum /total of p.d.s/sum of voltages in/around a (closed) loop (in a circuit) energy is conserved	B1 B1	**allow** 'in a (closed) circuit' in place of 'loop'
	(b)	(i)	current in 750 Ω = 0.020 A	A1	**allow** 20 mA **or** 0.02 A
		(ii)	V across 750 Ω = 0.02 x 750 = 15 V	A1	**ecf b(i)**
		(iii)	R_1 = (45 – 15)/0.03 = 1000 Ω R_2 = 15/0.01 = 1500 Ω	A1 A1	**ecf b(ii)**
	(c)	(i)	correct symbol connected in circuit	B1	2 arrows pointing towards the resistor at about 45^0 with or without a circle; arrows outside circle if drawn
A A A		(ii)	total R falls so I in circuit/in R_1 increases so V across R_1 increases and V across 750 Ω falls	B1 M1 A1	**accept** sum of R's in parallel falls R_1 is fixed so V across R_1 increases so V across R's in parallel falls (so V across 750 Ω falls) **or** correct potential divider argument
		(iii)	in series with LDR: ammeter (A); 50 mA in parallel with LDR: voltmeter (V); 20 V	M1 A1 B1	**allow** voltmeter in parallel with R_1 (30 – 50 V) **allow** multimeter connected as A (series) or V (parallel) and a correct unit for range given **allow** 20 to 100 mA; or 15 to 50 V
			Total	**15**	

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Question			Answer	Marks	Guidance
4	(a)	(i)	is a transfer of energy as a result of oscillations (of the source/medium/particles through which energy is travelling)	M1 A1	**accept** carries/AW **accept** without the transfer of the medium/particles/matter
		(ii)	a *progressive* wave transfers energy a *progressive* wave transfers shape/information **either** every point on a *progressive* wave has the same amplitude **or** every point on a *progressive* wave oscillates all points on *a progressive* wave have different phase (in one λ)	B1 B1 B1 B1	**or** a *stationary* wave traps energy in pockets/AW **or** a *stationary* wave does not transfer shape/information **or** a *stationary* wave has nodes and antinodes **or** in a *stationary* wave some points do not move (nodes) **or** all points in a *stationary* wave between nodes are in phase **or** in adjacent loops are in antiphase **max** 2 marks
A **A** **A**	(b)	(i)	shape: sinusoidal and only 2 cycles amplitude constant at 0.03 m (y-axis labelled) period 0.2 s (x-axis labelled to 0.4 s) phase: cosine curve	B1 B1 B1 B1	 one correct label of 0.03 m on y-axis is enough to score mark
		(ii) **1** **2** **3**	X W W and X	B1 B1 B1	
		(iii)	Y vertically up Z vertically down	B1 B1	**award** 1 mark if directions of both reversed
	(c)		v has increased by 2 so (λ has increased by same factor) new λ = 0.60 x 2 = 1.2 (m)	M1 A1	correct reasoning correct answer
A **A** **A**	(d)		f has increased by 2 so point W has to move same distance in half the time/double the distance in the same time therefore speed is doubled to 1.9 (m s^{-1})	M1 A1	**N.B.** zero marks for using v = f λ as this is the wave velocity not the particle velocity **allow** v = 2πfA **or** v proportional to f(mark BOD) **accept** 1.88 (m s^{-1})
			Total	**17**	

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Question			Answer	Marks	Guidance
5	(a)	(i)	when 2 or more waves <u>meet</u> (at a point) the (resultant) <u>displacement</u> is equal to the (vector) <u>sum</u> of the <u>displacements</u> of each wave	B1 B1	**accept** alternative words which mean *meet* **not** *collide, interfere* or *superpose* **not** amplitude
		(ii)	travel through a vacuum/ at c (in a vacuum)	B1	**allow** caused by oscillating charges; consist of electric and magnetic fields/oscillations
		(iii)	only transverse waves can be polarised	B1	**accept** sound waves are longitudinal/not transverse
A **A** **A**	(b)	(i)	the waves interfere/superpose producing a stationary wave (with nodes and antinodes) **the resultant signal is zero at a node** distance from max (antinode) to zero (node) is <u>λ/4 = 0.75 cm</u>	B1 B1 B1 B1	constructive interference produces maximum (at R) **or** signals in phase/zero path diff. of waves (at R) **destructive interference produces minimum/zero signal or out of phase/ ½λ** **or** phase difference of <u>π/2</u> is caused by 0.75 cm shift maximum of 3/4 if nodes and antinodes interchanged QWC mark in bold
A **A** **A**		(ii)	emitted waves are polarised (in vertical plane) detected signal from T_2 falls to zero (when T_2 is rotated by 90°) aerial only receives signal from one transmitter (T_1 , signal is halved) (no change in detected signal as) no interference/signals at right angles to each other/AW	B1 B1 B1 B1	plane of oscillation of waves from T_2 changes/AW **max** 3 marks from 4 marking points
			Total	**11**	

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Question			Answer	Marks	Guidance
6	(a)	(i)	emission of electron(s) from a <u>metal</u> (surface) when photon(s)/ light/uv/em radiation are incident (on surface)	B1	**allow** singular electron and absorption of photon
		(ii)	energy to accelerate/move an electron through a p.d. of 1 V/AW	B1	**not** 1.6 x 10^{-19} J
		(iii)	5.0 x 1.6 x 10^{-19} = 8.0 x 10^{-19} J	B1	**allow** 8 for 8.0; no mark if unit incorrect
	(b)	(i)1	the <u>minimum</u> energy required to release an electron from the <u>surface</u> of the metal	B1	
		(i)2	φ = 8.0 x 10^{-19} – 1.1 x 10^{-19} = 6.9 x 10^{-19} J	B1	no mark if unit incorrect unless unit in **a(iii)** incorrect
		(ii)1	½mv^2 = 1.1x 10^{-19} v^2 = 2.2 x 10^{-19}/9.11 x 10^{-31} (= 2.4 x 10^{11}) v = 4.9 x 10^5 (m s^{-1})	C1 M1 A0	**accept ora** substitute 5 x 10^5 to find E = 1.1 x 10^{-19}
		(ii)2	λ = h/mv = 6.63 x 10^{-34} / 9.11 x 10^{-31} x 4.9 x 10^5 = 1.5 x 10^{-9} (m)	C1 C1 A1	**accept** 1.46 x 10^{-9} if using v = 5 x 10^5
A A A	(c)	(i)	Electrons behave as waves/diffract (observable because) gaps/atoms are of similar wavelength to electrons <u>regular/ordered</u> pattern of atoms/atoms act as a grating/AW allowing interference to produce pattern on screen/AW rings occur because atomic 'crystals' at all possible orientations to beam/AW	B1 B1 B1 B1 B1	**allow** graphite for atoms **max** 3 from 5 marking points
		(ii)	wavelength is too large to produce a diffraction pattern/electrons not travelling fast enough/AW	B1	**ecf (b)(ii)2**; e.g. for AW: wavelength is about 10 times atomic spacing **or** wavelength is different to spacing
			Total	**14**	

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Question			Answer	Marks	Guidance
7	(a)		light from the two sources must be/slits is coherent only possible to produce constant phase difference using a single source	B1 B1	**allow** 'has a constant phase difference' for 'is coherent' **allow** separate light sources are not coherent/do not have a constant phase difference
	(b)		at D: 180° **or** π rad at B: 0 or 360° **or** 2π rad	B1 B1	**max** 1 out of 2 if unit omitted except on zero **allow** ^{c} as symbol for rad
	(c)	(i)	2.0×10^{-3} (m)	B1	**allow** 1 SF and 2 mm; **allow** 1.8 or 1.9 mm, **only** 2 SF
		(ii)	λ = ax/D $= 0.4 \times 10^{-3} \times 2.0 \times 10^{-3} / 1.5$ $= 5.3(3) \times 10^{-7}$ (m)	C1 C1 A1	select formula **ecf c(i)**; substitute answer
	(d)		2 λ 1060 (nm)	C1 A1	**ecf c(ii); allow** 1000 for 5×10^{-7} **allow** 1066, 1067, 1070,1100
A A A	(e)	(i)	$E = (8.7 \times 10^{-19} - 5.0 \times 10^{-19}) = 3.7 \times 10^{-19}$ (J) select E = hc/ λ $E = 6.63 \times 10^{-34} \times 3.0 \times 10^{8} / 5.3 \times 10^{-7}$ $= 3.73 \times 10^{-19}$ (J) [or 3.98×10^{-19} if using 5.0×10^{-7}]	B1 C1 M1 A1	readings from diagram must see substitution **ora** substitute for E and find λ calculation **ora** 5.4×10^{-7} (m) **N.B**. the B mark can be awarded inside the calculation **only** for the **ora** method
		(ii)	**X** in infra-red/ir **Z** in ultra-violet/uv	B1 B1	**allow** 1 mark for answers reversed
			Total	**16**	

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Friday 18 January 2013 – Morning

AS GCE PHYSICS A

G482/01 Electrons, Waves and Photons

G411580113

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

G 4 8 2 0 1

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 pages 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 Fig. 1.1 shows the $I-V$ characteristic of a filament lamp.

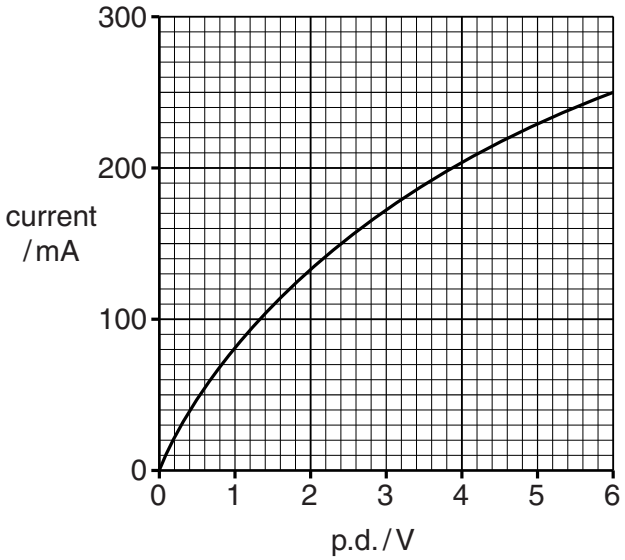


Fig. 1.1

(a) Explain how the graph of Fig. 1.1 shows that the filament lamp does not obey Ohm's law.

.....

.....

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

(b) You are to carry out an experiment to obtain the $I-V$ characteristic shown in Fig. 1.1.

(i) Draw a suitable circuit diagram for your experiment in the space below. **[2]**

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(ii) Describe how you would carry out the experiment.

In your answer you should make clear how you make the measurements to obtain the data for the characteristic.

.....

.....

.....

.....

.....

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

(c) The lamp is connected in **parallel** with a resistor of resistance 20 Ω to a 6.0 V d.c. supply of negligible internal resistance. Use Fig. 1.1 to calculate the current I_P drawn from the supply.

I_P = ... A **[3]**

(d) The circuit is rearranged with the lamp connected in **series** with the 20 Ω resistor to the same 6.0 V supply.

(i) On Fig. 1.1 draw the $I-V$ characteristic of the resistor. **[1]**

(ii) Use your answer to **(i)** and Fig. 1.1 to determine the current I_S drawn from the supply. Explain your method.

I_S = ... A **[3]**

[Total: 14]

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2 An electric heater has a constant resistance of 42.5 Ω. It is connected to the 230 V mains supply by wires of total resistance 2.50 Ω. See Fig. 2.1.

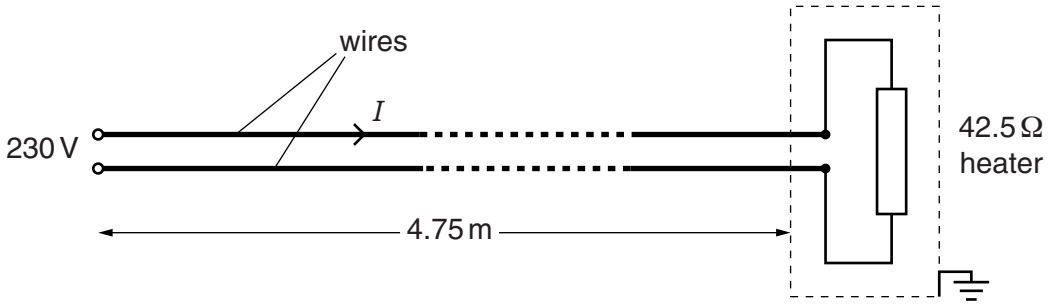


Fig. 2.1

(a) (i) Show that the current I in the wires is about 5 A.

[2]

(ii) Calculate the total power P dissipated in the heater and wires. Give your answer to three significant figures.

P = ... W **[3]**

(iii) Suggest a suitable value for the fuse in the plug connecting the cable to the mains supply.

fuse value = ... A **[1]**

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(b) Calculate the cost, to the nearest penny, of using this heater for 4.0 hours, when 1 kW h costs 21p.

cost = ... p **[2]**

(c) The wires used to connect the heater to the supply have a total length of 9.50 m. The wires are made of copper. The resistivity of copper is $1.70 \times 10^{-8}\,\Omega\,m$.

Calculate the cross-sectional area A of the wire.

A = ... m^2 **[3]**

(d) Suggest and explain **one** disadvantage of connecting the heater to the mains supply using thinner copper wires.

.....

.....

.....

.....

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

[Total: 14]

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3 Fig. 3.1 shows a circuit consisting of a battery of electromotive force 16.0 V and negligible internal resistance, two resistors and a thermistor.

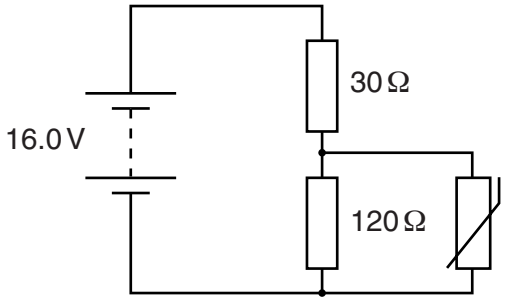


Fig. 3.1

(a) (i) Define the term *electromotive force* (*e.m.f.*).

.....

.....

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

(ii) Explain the meaning of the term *internal resistance*.

.....

.....

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

(b) The thermistor has a resistance of 360 Ω at 20 °C. Calculate

(i) the total resistance R of the thermistor and the resistor of resistance 120 Ω at 20 °C

R = ... Ω **[2]**

(ii) the potential difference V across the thermistor.

V = ... V **[3]**

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(iii) It is suggested that the thermistor in the circuit of Fig. 3.1 is used to monitor temperatures between 20 °C and 200 °C. Describe how the potential difference across the thermistor and the current in it will vary as the temperature increases above 20 °C.



In your answer you should explain why the potential difference and current vary as the temperature increases.

.....

.....

.....

.....

.....

.....

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

(c) The battery in Fig. 3.1 is rechargeable.

(i) Calculate the charge stored in the battery when it is charged for 8.0 hours at a constant current of 1.2 A.

charge = …… unit …….. **[3]**

(ii) After charging, the battery loses energy at a constant rate of 1.4 J s^{-1}. The e.m.f. of the battery remains constant at 16.0 V. Calculate how many hours it takes for the battery to discharge.

discharge time = ... h **[3]**

[Total: 18]

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4 Fig. 4.1 shows the variation with time t of the displacement y of the air at a point **P** in front of a loudspeaker emitting a sound wave of a single frequency.

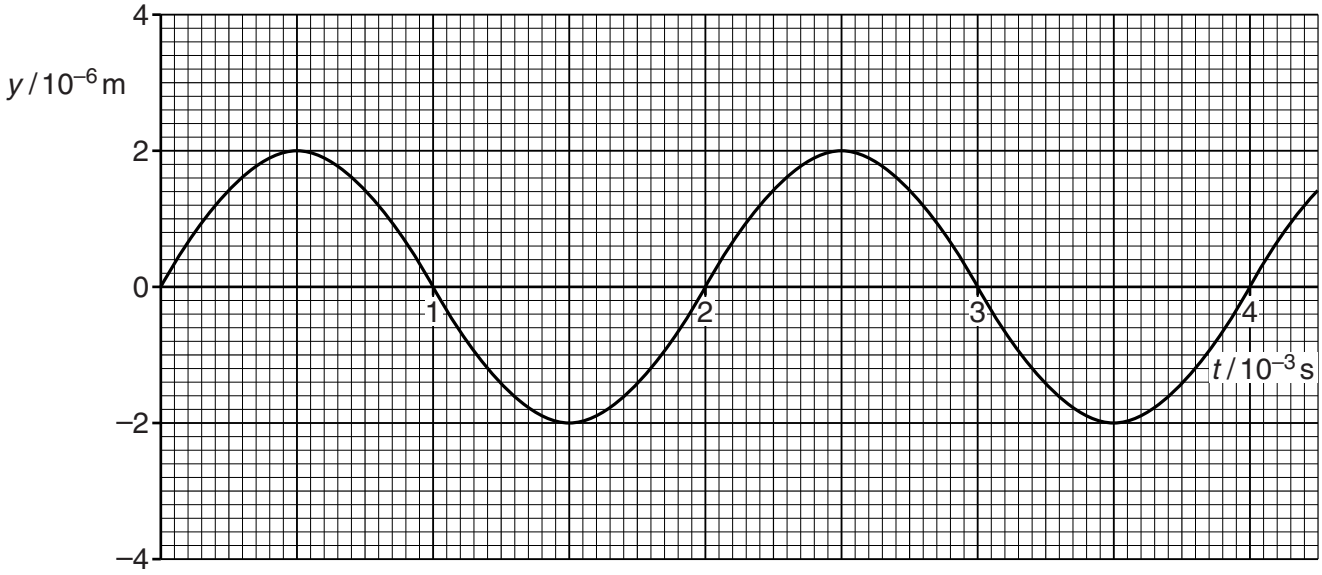


Fig. 4.1

(a) Calculate

(i) the frequency f of oscillation of the air at **P**

f = ... Hz **[2]**

(ii) the wavelength λ of the wave which is travelling at 340 m s^{-1}.

λ = ... m **[2]**

(b) Draw on Fig. 4.1 the variation with time of the displacement of the air at a point **Q** a distance of one quarter of a wavelength $\lambda/4$ beyond **P**. Label this curve **Q.** **[2]**

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(c) Explain the meaning of the term *phase difference*. Illustrate your answer by stating the phase difference between the displacements of the air at the points **P** and **Q**.

.....

.....

.....

.....

.....

.....

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

(d) The amplitude of vibration of the loudspeaker is increased to produce a wave at the original frequency, but of twice the **intensity**. Sketch on Fig. 4.1 the new displacement against time graph, for $t = 0$ to $t = 2 \times 10^{-3}$ s, at point **P**. Label this curve **P**. Explain your reasoning.

.....

.....

.....

.....

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

TURN OVER FOR PART (e) OF QUESTION 4

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(e) An open tube is placed in front of the loudspeaker such that its far end is at point **Q**. See Fig. 4.2.

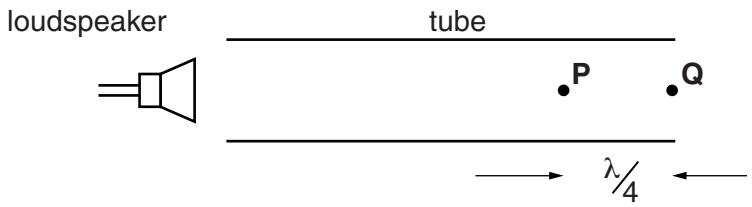


Fig. 4.2

(i) Explain how and under what conditions a stationary sound wave is formed in the tube.

.....

.....

.....

.....

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.....

.....

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

(ii) Assume that the conditions are met for a stationary wave to be set up in the tube. The distance between the points **P** and **Q** is $\lambda/4$.

Describe the motion of the air molecules

1 at point **Q**

.....

.....

.....

2 at point **P**.

.....

.....

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

[Total: 18]

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Question 5 begins on page 12

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5 (a) State the principle of superposition of waves.

.....

.....

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

(b) Coherent red light of wavelength 6.00×10^{-7} m is incident normally on a pair of narrow slits $\mathbf{S_1}$ and $\mathbf{S_2}$. A pattern of bright and dark lines, called fringes, appears close to point **P** on a distant viewing screen.

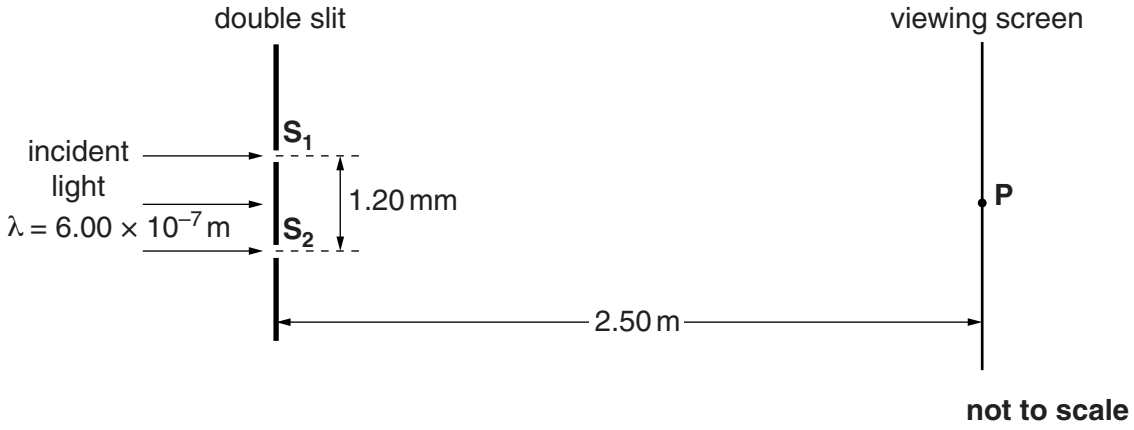


Fig. 5.1

(i) Explain the term *coherent*.

.....

.....

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

(ii) State a value of the path difference between the light waves from slits $\mathbf{S_1}$ and $\mathbf{S_2}$ to the screen to produce a **dark** fringe on the screen.

path difference = ... m **[1]**

(iii) Calculate the separation of adjacent dark fringes on the screen near to point **P**.

Use the following data: slit separation $\mathbf{S_1S_2}$ = 1.20 mm
distance between slits and screen = 2.50 m

separation = ... m **[3]**

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(iv) State and explain the effect, if any, on the **position** of the bright fringes on the screen when each of the following changes is made, separately, to the apparatus.

1 The light source is changed from a red to a yellow light source.

.....

.....

.....

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

2 Slit $\mathbf{S_1}$ is made wider than slit $\mathbf{S_2}$ but their centres remain the same distance apart.

.....

.....

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

3 The viewing screen is moved closer to the slits.

.....

.....

.....

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

[Total: 13]

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6 This question is about the light from low energy compact fluorescent lamps which are replacing filament lamps in the home.

(a) The light from a compact fluorescent lamp is analysed by passing it through a diffraction grating. Fig. 6.1 shows the angular positions of the three major lines in the first order spectrum and the bright central beam.

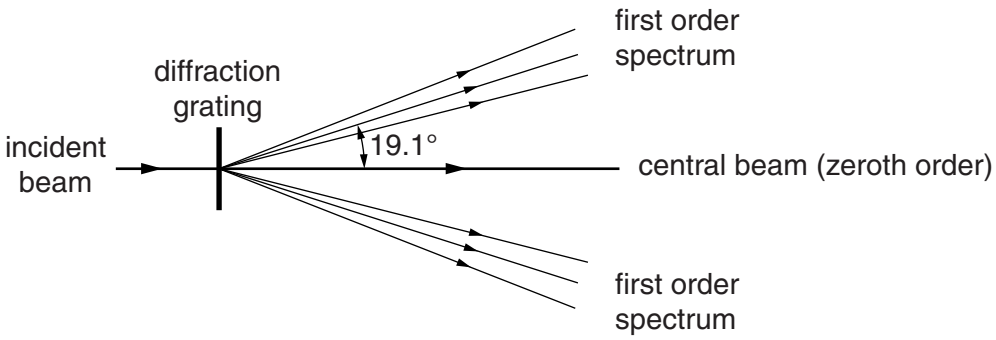


Fig. 6.1

(i) On Fig. 6.1 label one set of the lines in the first order spectrum **R**, **G** and **V** to indicate which is red, green and violet. **[1]**

(ii) Explain why the bright central beam appears white.

.....

.....

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

(iii) The line separation d on the grating is 1.67×10^{-6} m.

Calculate the wavelength λ of the light producing the first order line at an angle of 19.1° to the central bright beam.

λ = ... m **[3]**

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(b) The wavelength of the violet light is 436 nm. Calculate the energy of a photon of this wavelength.

energy = ... J **[3]**

(c) The energy level diagram of Fig. 6.2 is for the atoms emitting light in the lamp. The three electron transitions between the four levels **A**, **B**, **C** and **D** shown produce the photons of red, green and violet light. The energy *E* of an electron bound to an atom is negative. The ionisation level, not shown on the diagram, defines the zero of the vertical energy scale.

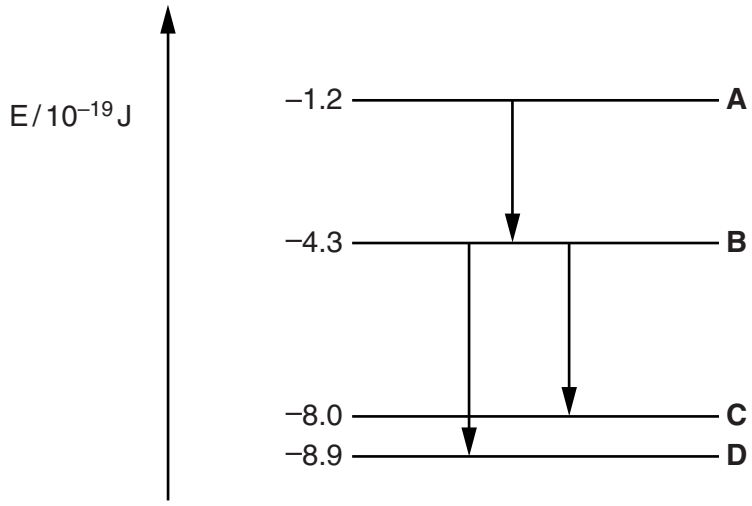


Fig. 6.2

Label the arrows on Fig. 6.2 **R**, **G** and **V** to indicate which results in the red, green and violet photons. **[2]**

[Total: 10]

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7 This question is about an experiment to measure the Planck constant h using light-emitting diodes (LEDs).

(a) Each LED used in the experiment emits monochromatic light. The wavelength λ of the emitted photons is determined during the manufacturing process.

When the p.d. across the LED reaches a specific minimum value V_{min} the LED suddenly switches on emitting photons of light of wavelength λ. V_{min} and λ are related by the equation $eV_{min} = hc/\lambda$.

Explain the meaning of this equation in words.

.....

.....

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

(b) Describe the experiment that uses the circuit of Fig. 7.1 to generate the data shown in the table. The wavelength value for each LED is provided by the manufacturer.

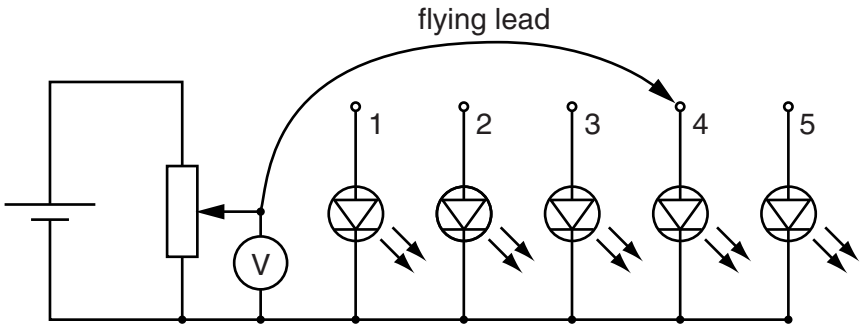


Fig. 7.1

LED	λ/nm	$1/\lambda$ /10^6 m^{-1}	average V_{min}/ V
1 red	627	1.59	1.98
2 yellow	590	1.69	2.10
3 green	546	1.83	2.27
4 blue	468		2.66
5 violet	411		3.02

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

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(c) (i) Complete the table and use the data to complete the graph of Fig. 7.2. Three of the points have been plotted for you.

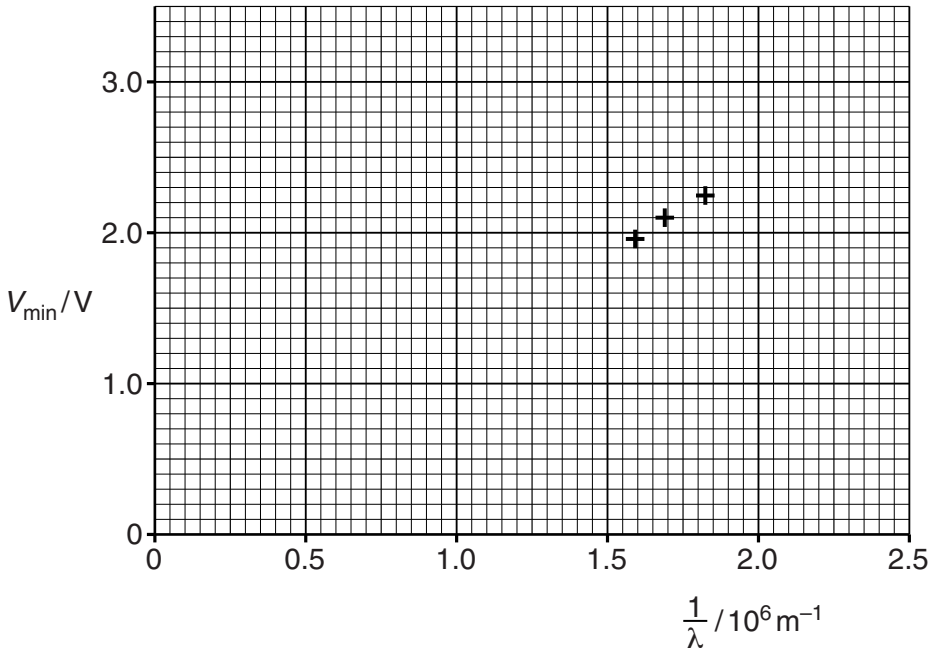


Fig. 7.2

Draw the line of best fit. Show that the gradient is about 1.2×10^{-6} V m.
Show your working clearly.

gradient = ... V m **[4]**

(ii) Use the equation given in **(a)** to show that the gradient of the line in Fig. 7.2 is equal to *hc/e*.

[2]

(iii) Calculate a value for the Planck constant using your value in **(i)** for the gradient of the graph. Show your working.

h = ... J s **[2]**

[Total: 13]

END OF QUESTION PAPER

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ADDITIONAL ANSWER SPACE

If additional space is required, you should use the lined pages below. The question number(s) must be clearly shown.

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ADDITIONAL ANSWER SPACE

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RECOGNISING ACHIEVEMENT

GCE

Physics A

Advanced Subsidiary GCE

Unit **G482:** Electrons, Waves and Photons

Mark Scheme for January 2013

Oxford Cambridge and RSA Examinations

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This mark scheme is published as an aid to teachers and students, to indicate the requirements of the examination. It shows the basis on which marks were awarded by examiners. It does not indicate the details of the discussions which took place at an examiners' meeting before marking commenced.

All examiners are instructed that alternative correct answers and unexpected approaches in candidates' scripts must be given marks that fairly reflect the relevant knowledge and skills demonstrated.

Mark schemes should be read in conjunction with the published question papers and the report on the examination.

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Annotations

Available in Scoris

Annotation	Meaning
	Benefit of doubt given
	Contradiction
	Incorrect response
	Error carried forward
	Follow through
	Not answered question
	Benefit of doubt not given
	Power of 10 error
	Omission mark
	Rounding error or repeat error
	Error in number of significant figures
	Correct response
	Arithmetic error
	Wrong physics or equation

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The abbreviations, annotations and conventions used in the detailed Mark Scheme are:

Annotation	Meaning
/	Alternative and acceptable answers for the same marking point
(1)	Separates marking points
reject	Answers which are not worthy of credit
not	Answers which are not worthy of credit
IGNORE	Statements which are irrelevant
ALLOW	Answers that can be accepted
( )	Words which are not essential to gain credit
__	Underlined words must be present in answer to score a mark
ecf	Error carried forward
AW	Alternative wording
ORA	Or reverse argument

Subject-specific Marking Instructions

CATEGORISATION OF MARKS

The marking scheme categorises marks on the MABC scheme

B marks: These are awarded as independent marks, which do not depend on other marks. For a **B**-mark to be scored, the point to which it refers must be seen specifically in the candidate's answer.

M marks: These are method marks upon which **A**-marks (accuracy marks) later depend. For an **M**-mark to be scored, the point to which it refers must be seen in the candidate's answer. If a candidate fails to score a particular **M**-mark, then none of the dependent **A**-marks can be scored.

C marks: These are compensatory method marks which can be scored even if the points to which they refer are not written down by the candidate, providing subsequent working gives evidence that they must have known it. For example, if an equation carries a **C**-mark and the candidate does not write down the actual equation but does correct working which shows that the candidate knew the equation, then the **C**-mark is given.

A marks: These are accuracy or answer marks, which either depend on an **M**-mark, or allow a **C**-mark to be scored.

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Note about significant figures:
If the data given in a question is to 2 SF, then allow answers to 2 or more SF.
If an answer is given to fewer than 2 SF, then penalise once only in the entire paper. **N.B.** Also penalise RE only once per paper.
Any exception to this rule will be mentioned in the Guidance.

Please put ticks and crosses against all sub-sections marked AAA (7 in total)

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Question			Answer	Marks	Guidance
1	(a)		V is not proportional to I the characteristic/line is a curve/not a straight line	B1 B1	**accept** statement of Ohm's law for 1 mark **not** resistance is not constant/AW
	(b)	(i)	variable power supply **or** fixed supply + potential divider ammeter in series with and voltmeter in parallel with lamp	B1 B1	value of power supply **not** required **accept** cross or Ω in circle for lamp symbol **penalise** each extra component connected (up to two)
A A A		(ii)	vary p.d. (across lamp)/current (in circuit) by changing voltage supply/moving contact on the potential divider take/record set of values of V and I	B1 B1 B1	 **accept** increase voltage in steps of 1 V/AW **accept as ecf** changing variable resistor in series in circuit QWC mark
	(c)		From Fig. 1.1 lamp I_L = 0.25 A for R I_R = 6/20 = 0.30 A so I_P = 0.55 (A)	C1 C1 A1	1 mark for each current; 1 mark for $I_R + I_L$ **or** R_L = 6/0.25 = 24 Ω; Rs in // gives R_{tot} = 10.9; so I_P = 6.0/10.9 = 0.55 A
	(d)	(i)	straight line through origin and 300,6	B1	
		(ii)	appreciation that p.d.s across both components add to 6 V attempt to find where current is the same in both components I_S = 0.16 to 0.17 (A) **or** 165 ± 5 x 10^{-3} A **or** 165 ± 5 mA	B1 B1 B1	**accept** answers in terms of lines drawn on fig.1.1 **or** description of using ruler horizontally on graph and adding squares across graph,etc. **ecf (d)(i)**
			Total	**14**	

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Question			Answer	Marks	Guidance
2	(a)	(i)	I = 230/(42.5 + 2.5) I = 5.11 (A)	C1 A1	 **accept** 5.1 A
		(ii)	$P = I^2R = 5.11^2 \times 45$ $= 1175.0$ W **or** use $P = VI$ or $P = V^2/R$ answer given to 3 SF i.e. 1180 (W)	C1 A1 B1	**ecf(a)(i)** and **allow** $5.00^2 \times 45 = 1125$ W $5.1^2 \times 45 = 1170$ W **give** 1 mark for 65.3 W (wires only) or 1110 W (heater only) **any** follow through answer given to 3 SF gains third mark
		(iii)	6 to 10 A (integer values only)	B1	**ecf(a)(i)** ; **allow** 13 A
	(b)		1180 x 21 x 4/1000 = 99 p	C1 A1	**ecf(a)(ii)** **allow** 99.1(2) **or** 100 p
	(c)		R = ρl/A $A = 1.70 \times 10^{-8} \times 9.50/2.50$ $A = 6.46 \times 10^{-8}$ (m^2)	C1 C1 A1	select formula mark correct substitution **allow** correct answer to 2 SF, i.e. 6.5×10^{-8} (m^2) **special case** 2/3 marks for: I = 4.75 m; $A = 3.23 \times 10^{-8}$ (m^2)
A **A** **A**	(d)		resistance of wires increases so smaller current (in heater) power dissipation in <u>heater</u> less	B1 B1 B1	**N.B.** wires can be implied by e.g. A reduces so R increases **or** lower voltage across heater/greater voltage across wires **or** power dissipation in wires greater/wires get hotter/melt **N.B.** any statement implying constant or increased current invalidates second and third marking points
		•	**Total**	**14**	

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Question			Answer	Marks	Guidance
3	(a)	(i)	energy transferred from source/changed from some form to electrical energy; per unit charge (to drive charge round a complete circuit)	M1 A1	**allow** chemical
		(ii)	(some) energy is transferred into thermal energy /lost as heat in (driving charge through) the battery. It behaves as if it has an (internal) resistance/AW **or** there is a voltage drop across/decrease in voltage from the battery when a current is drawn from it/AW	B1	**allow** any description which uses E = V + Ir with symbols defined but **not** just the formula alone **or** e.g. statement about 'lost volts'/current
	(b)	(i)	correct substitution into resistors in parallel formula R = 90 Ω	C1 A1	1/R = 1/90 or 0.011 correct answer
		(ii)	using $V_{out} = R_2/(R_1 + R_2)\ V_{in}$: **alt:** 16 = I x 120 V_{out} = 90/(30 + 90) 16 so I = 0.133 A V_{out} = 12 V V_{out} = 0.13 x 90 = 12 V	C1 C1 A1	**ecf (b)(i)** **accept** V_{out} = (90/120) x 16 = 12 V for full marks **N.B.** beware of false ratios, e.g. 360/(120 + 360) giving correct answer; give first marking point only
A A A		(iii)	resistance (of thermistor) decreases (with temperature increase) current <u>in circuit</u> increases **or** as <u>total</u> resistance is less so current in thermistor increases voltage ratio between 30 Ω and combination changes so voltage across thermistor falls	B1 M1 A1 M1 A1	**max** 4 marks QWC mark is either of the M marks
	(c)	(i)	Q = It = 1.2 x 8 x 60 x 60 Q = 34560 (C) correct unit,	C1 A1 B1	**accept** 3.5 or 3.46 x 10^4 **allow** 1 mark for answer of 9.6 or 576 **allow** C, kC, A s; **N.B.** 9.6 A h or 576 A min score 3/3
		(ii)	energy = 34560 x 16 = 552960 J **or** I = 1.4/16 = 00875 A time = 552960/1.4 = 394970 s **then** t = 34560/I time = 394970/3600 = (109.7 h) = 110 h	C1 C1 A1	**ecf (c)(i)** **allow** full marks for 1.2 x 8 x 16/1.4 = 110 h **allow** 111 h when using 3.5 x 10^4 C
			Total	**18**	

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Question			Answer	Marks	Guidance
4	(a)	(i)	f = 1000/2 f = 500 (Hz)	C1 A1	**give** 1 mark for ½ (POT error)
		(ii)	v = fλ giving 340 = 500 x λ λ = 0.68 (m)	C1 A1	**ecf(a)(i)**
	(b)		sinusoidal curve of same frequency and amplitude ± cosine curve	B1 B1	**must** be drawn for 2 full cycles to score this mark **allow** drawn as sine curve from t = 0.5 ms
A A A	(c)		relates to the oscillation of two points on the (same) wave how far 'out of step' one oscillation is from the other/AW λ/4 means a phase difference of 90° or π/2 (rad)	B1 B1 B1	**accept** vibration **N.B.** statements about oscillations of two waves can only score the third marking point
	(d)		sine wave of same frequency with increased amplitude realisation that intensity is proportional to (amplitude)^2 giving amplitude increase by √2, i.e.2.8 mm	B1 B1 B1	
A A A	(e)	(i)	the wave reflected at the end of the pipe interferes/superposes with the incident wave to produce a resultant wave with nodes and antinodes both ends must be antinodes the pipe must be nλ/2 in length for this to happen	 B1 B1 B1 B1	**max** 3 marks
		(ii) 1	air molecules oscillate along the axis of the tube with maximum amplitude	B1 B1 B1	**max** 2 marks; **allow** vibrate; if transverse wave is clearly implied then can only score third marking point
		(ii) 2	no motion/nodal point	B1	**allow** zero displacement/amplitude
			Total	**18**	
			SCAN DOWN TO CHECK NO ANSWERS ON PAGE 11		

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Question			Answer	Marks	Guidance
5	(a)		when two(or more) waves meet/cross/interact (at a point) the (resultant) <u>displacement</u> is the (vector) sum of the (individual) <u>displacements</u>	B1 B1	**do not allow** for two waves travelling in opposite directions **allow** as a special case: the <u>resultant wave</u> is…..
	(b)	**(i)**	<u>constant</u> phase difference/relationship (between the waves)	B1	**allow** fixed
		(ii)	6 x (2n + 1)/2 x10^{-7} (m) where n = 0, 1,2, etc.	B1	**expect** 3 x 10^{-7}; next values: 9 x 10^{-7}, 15 x 10^{-7} allow 300 nm, etc
		(iii)	select λ = ax/D 6.00 x 10^{-7} = 1.20 x 10^{-3} x/2.50 x = 1.25 x 10^{-3} (m)	C1 C1 A1	
		(iv) 1	fringes move closer together a smaller distance is required between the rays from the slits to produce λ/2 /π phase change	B1 B1	**allow** (use of formula) x α λ as (a and D fixed) and λ decreases
		(iv) 2	fringes same distance apart paths of rays unchanged/slit centres same distance apart	B1 B1	**allow** (use of formula) x unchanged as a (λ and D) fixed
		(iv) 3	fringes move closer together the angle at which the dark fringes appear from the slits is the same, but the distance to the screen is much less	B1 B1	**allow** (use of formula) x α D (as λ and a fixed)
			Total	**13**	

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Question			Answer	Marks	Guidance
6	(a)	(i)	3 correct labels	B1	
		(ii)	the (three) colours add up/superpose to give white light **or** no dispersion/diffraction of incident white light/AW	B1	**allow** use of formula d sin θ = nλ so constructive interference at θ = 0 for all λ
		(iii)	select λ = d sin θ λ = 1.67 x 10^{-6} sin 19.1 λ = 546 x 10^{-9} (m)	C1 C1 A1	**allow** 547 x 10^{-9} as answer is 546.46 x 10^{-9} **do not allow** 550 x 10^{-9} unless SF mark already deducted
	(b)		select E = hc/ λ E = 6.63 x 10^{-34} x 3.0 x 10^{8}/436 x 10^{-9} E = 4.56 x 10^{-19} (J)	C1 C1 A1	**do not allow** 4.6 x 10^{-19} unless SF mark already deducted
	(c)	(i)	1 arrow correctly labelled 2 more arrows correctly labelled	B1 B1	
			Total	**10**	

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Question			Answer	Marks	Guidance
7	(a)		the energy of an electron✓ equals the energy of the (emitted) photon✓	B1 B1	**alt:** the electron energy✓ is converted into the energy of the emitted photon✓ **or** the minimum energy✓ of an electron required to produce a photon✓/AW
A A A	(b)		Adjust the potential divider to low/zero voltage connect flying lead to one LED increase voltage until LED just lights/strikes repeat several times and average to find V_{min} repeat for each LED shield LED inside opaque tube to judge strike more accurately	B1 B1 B1 B1 B1 B1	**max** 3 marks
A A A	(c)	(i)	values of 1/λ calculated correctly: 2.14 and 2.43 2 points plotted correctly line of best fit drawn through origin gradient = 1.24×10^{-6} (V m)	B1 B1 B1 B1	**not** 2.13 unless this is second rounding error in paper **ecf** calculated values in table working **must be shown** to score the mark **allow ecf** for correct gradient from line drawn
		(ii)	gradient of line = V λ from eV = hc/ λ Vλ = hc/e	B1 B1	**must have** clear indication that V λ is gradient of graph
		(iii)	1.24×10^{-6} = hc/e h = $1.24 \times 10^{-6} \times 1.6 \times 10^{-19} / 3.0 \times 10^{8}$ h = 6.6(1) $\times 10^{-34}$ (J s)	 M1 A1	**ecf (c)(i)** correct substitution into equation mark ans = 5.3 x grad (ignoring all powers of 10)
			Total	**13**	
			SCAN DOWN TO CHECK NO ANSWERS ON PAGE 18		

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RECOGNISING ACHIEVEMENT

Friday 25 May 2012 – Afternoon

AS GCE PHYSICS A

G482 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

G411720612

G 4 8 2

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 pages 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.
- Where you see this icon you will be awarded marks for the quality of written communication in your answer.
  This means for example your 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 The power of a 230 V mains filament lamp is 40 W.

(a) Define *power*.

.....

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

(b) The lamp is connected to the 230 V supply. Calculate

(i) the current I in the filament

I = ... A **[2]**

(ii) the resistance R of the filament.

R = ... Ω **[1]**

(c) The cross-sectional area of the wire of the filament is $3.0 \times 10^{-8}\,m^2$. The resistivity of the filament when the lamp is lit is $7.0 \times 10^{-5}\,\Omega m$. Use your answer to **(b)(ii)** to calculate the length L of the filament wire.

L = ... m **[3]**

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(d) Explain whether the filament of a 60 W, 230 V lamp is thicker or thinner than that of the 40 W, 230 V lamp. The length and material of the filament are the same in both lamps.

.....

.....

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.....

.....

.....

.....

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

(e) The 40 W filament lamp is left on for 8 hours.

(i) Calculate the charge *Q* passing through the lamp in this time.

Q = ... C **[2]**

(ii) **1** Define the *kilowatt-hour*.

.....

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

2 Calculate the cost of leaving the lamp switched on. The cost of 1 kWh is 22 p.

cost = ... p **[2]**

[Total: 15]

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2 Fig. 2.1 shows the I–V characteristic of a light-emitting diode (LED).

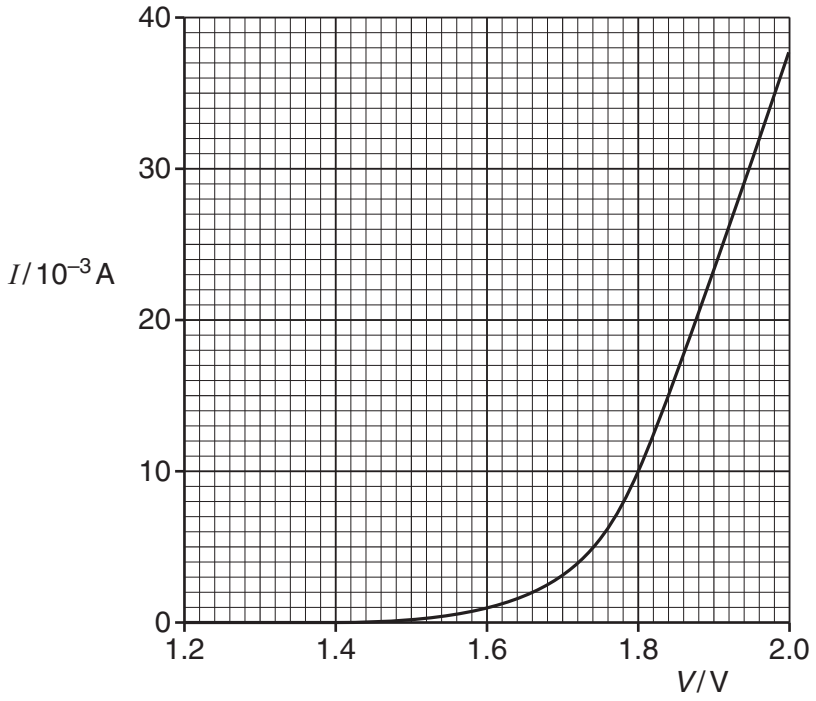


Fig. 2.1

(a) (i) Use Fig. 2.1 to

1 state the value of the resistance R below 1.4V.

R = ... Ω **[1]**

2 determine the resistance R of the LED at V = 1.8V.

R = ... Ω **[2]**

(ii) At voltages V above 1.8V, state whether the resistance of the LED increases, remains the same or decreases as V increases. Justify your answer.

In your answer you should link features of the graph into your justification.

.....

.....

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.....

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

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(b) A circuit is set up to obtain the I–V characteristic shown in Fig. 2.1. It consists of a variable 0 – 6.0 V d.c. power supply connected in **series** to a 100 Ω resistor and the LED. Fig. 2.2 shows the variable supply. Draw the resistor, LED and suitable meters on the diagram between terminals **X** and **Y** to complete the circuit required for the experiment. **[4]**

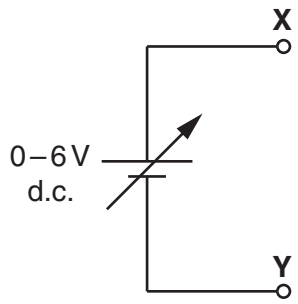


Fig. 2.2

(c) One or more LEDs are often used in places where, in the past, a filament lamp would have been used.
Give **one** example of such a situation.
Explain **one** advantage of using LEDs in place of a filament lamp in the situation you have chosen.

.....

.....

.....

.....

.....

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

[Total: 12]

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3 Fig. 3.1 shows how the resistance of a thermistor varies with temperature.

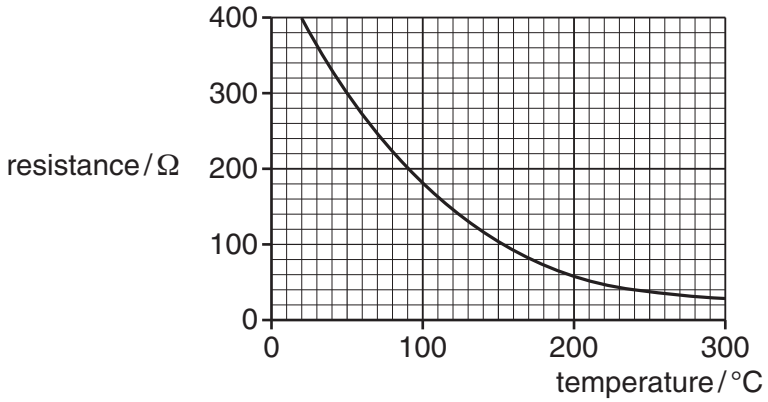


Fig. 3.1

The thermistor is used in the potential divider circuit of Fig. 3.2 to monitor the temperature of an oven. The 6.0 V d.c. supply has zero internal resistance and the voltmeter has infinite resistance.

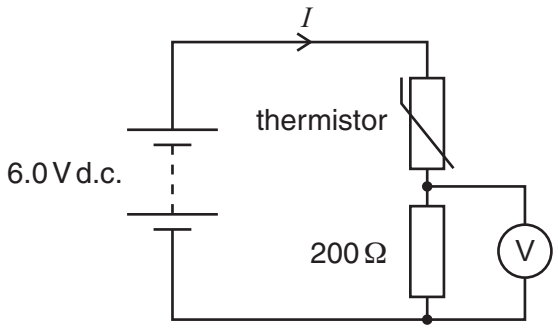


Fig. 3.2

(a) State and explain how the current I in the circuit changes as the thermistor is heated.

.....

.....

.....

.....

.....

.....

.....

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

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(b) Use Fig. 3.1 to calculate the voltmeter reading when the temperature of the oven is 240 °C.

voltmeter reading = ... V **[4]**

(c) A light-dependent resistor (LDR) is another component used in sensing circuits.

(i) Complete Fig. 3.3 with an LDR between **X** and **Y**.

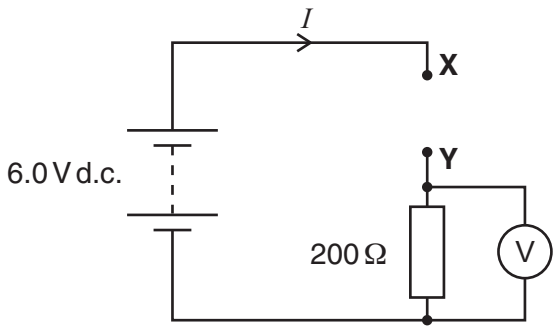


Fig. 3.3

[1]

(ii) State with a reason how the voltmeter reading varies as the intensity of the light incident on the LDR increases.

.....

.....

.....

.....

.....

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

[Total: 10]

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4 Fig. 4.1 shows part of a circuit where three resistors are connected together.

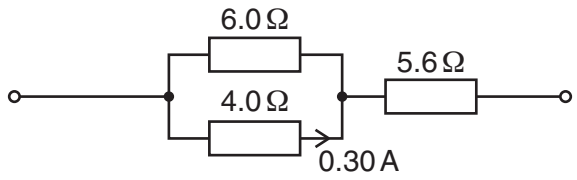


Fig. 4.1

The current in the 4.0 Ω resistor is 0.30 A.

(a) Explain why the current in the 6.0 Ω resistor is 0.20 A.

.....

.....

.....

.....

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

(b) **(i)** State the law which enables you to calculate the current in the 5.6 Ω resistor.

.....

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

(ii) Calculate the current in the 5.6 Ω resistor.

current = ... A **[1]**

(c) Calculate the total resistance *R* of the combination of resistors.

R = ... Ω **[3]**

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(d) To cause the current of 0.30 A in the 4.0 Ω resistor, the resistor combination is connected to a d.c. supply of electromotive force (e.m.f.) 5.0 V.

(i) Explain the term *e.m.f.*

.....

.....

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

(ii) Show that the terminal potential difference across the supply is 4.0 V.

[1]

(iii) Calculate the internal resistance of the supply.

internal resistance = ... Ω **[2]**

[Total: 12]

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5 This question is about electrons and photons.

(a) Both electrons and photons can be considered as particles. State **two** differences between their properties.

.....

.....

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

(b) An electron is accelerated from rest through a p.d. of 5000 V.

(i) Show that the energy gained by the electron is 8.0×10^{-16} J.

[2]

(ii) Show that the speed of the electron is about $4 \times 10^{7}\,m\,s^{-1}$.

[3]

(c) **(i)** Explain what is meant by the de Broglie wavelength of an electron.

.....

.....

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

(ii) Calculate the de Broglie wavelength of the electron in **(b)**.

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

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(d) Calculate the wavelength of a photon of energy 8.0×10^{-16} J.

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

(e) Photons of energy 9.0×10^{-19} J are incident on a clean tungsten surface causing electrons to be emitted.

(i) State the name of this process.

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

(ii) Calculate the maximum kinetic energy of the emitted electrons. Tungsten has a work function of 7.2×10^{-19} J.

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

(iii) Explain why your answer to **(ii)** is a maximum value.

.....

.....

.....

.....

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

[Total: 19]

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6 **(a)** Define the following terms as applied to wave motion

(i) *displacement* and *amplitude*

.....

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.....

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.....

.....

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

(ii) *frequency* and *phase difference*.

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

(b) Fig. 6.1 shows a transverse pulse on a *slinky*, an open wound spring, at time $t = 0$. The pulse is travelling at a speed of $0.50\,m\,s^{-1}$ from left to right. The front of the pulse is at point **X**, 0.25 m from the point **P**.

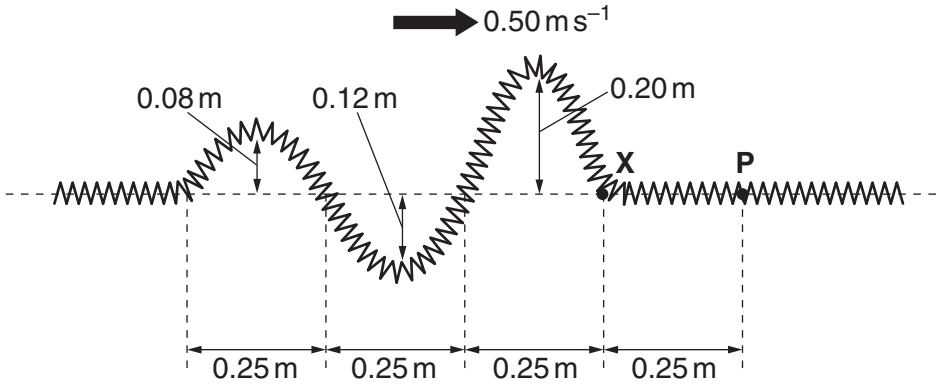


Fig. 6.1

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On Fig. 6.2 draw a displacement y against time t graph of the motion of point **P** on the slinky from $t = 0$ to $t = 2.5$ s.

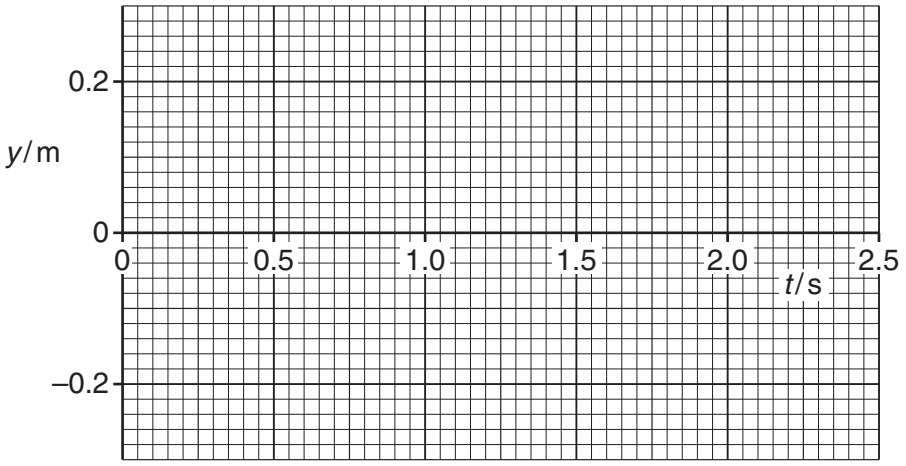


Fig. 6.2

[4]

[Total: 8]

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7 Fig. 7.1 shows the three lowest energy levels of the hydrogen atom, labelled $n = 1$, 2 and 3.

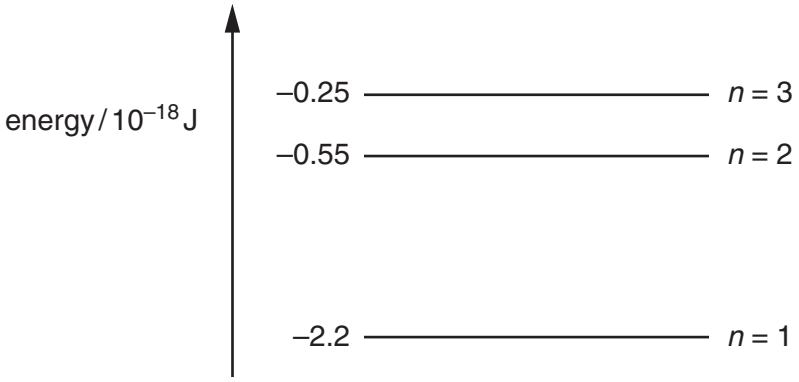


Fig. 7.1

(a) (i) Explain why electron transitions between the energy levels can produce three different wavelengths of radiation. You may draw lines on Fig. 7.1 to illustrate your explanation.

.....

.....

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.....

.....

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

(ii) The strong red line in the hydrogen spectrum has a wavelength of 6.56×10^{-7} m.

1 Calculate the energy of the photon at this wavelength.

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

2 Use Fig. 7.1 to identify the electron transition responsible for the spectral line of this wavelength.

.....

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

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(b) A parallel beam of light from a hydrogen lamp is incident on a diffraction grating. The first order red spectral line at 6.56×10^{-7} m is seen at an angle of 11.4° as shown in Fig. 7.2.

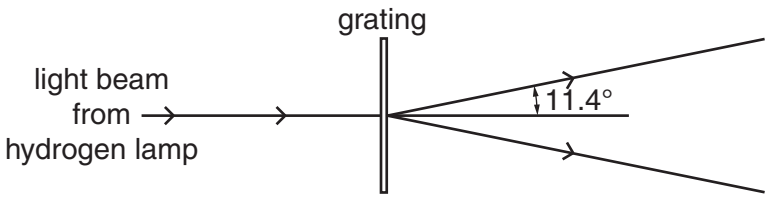


Fig. 7.2

(i) Calculate

1 the separation *d* of the lines on the grating

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

2 the number of lines per millimetre on the grating.

number = ... lines mm^{-1} **[1]**

(ii) The hydrogen lamp also emits blue light at a wavelength of 4.86×10^{-7} m.

Draw rays on Fig. 7.2 to indicate roughly, that is without calculation, the direction of the **first** order blue spectral line as the rays leave the grating. **[1]**

[Total: 11]

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8 **(a)** State **two** properties shared by all electromagnetic waves which distinguish them from all other waves.

.....

.....

.....

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

(b) The two columns below list four regions of the electromagnetic spectrum and four orders of magnitude of wavelength in m.

region	wavelength/m
microwaves	10^{-12}
ultra violet light	10^{-8}
gamma rays	10^{-6}
infra red light	10^{-4}

Draw a straight line from each **region** box to the corresponding **wavelength** box. **[2]**

(c) Fig. 8.1 shows a microwave receiver **R** placed between a microwave transmitter **T** and a flat metal sheet.

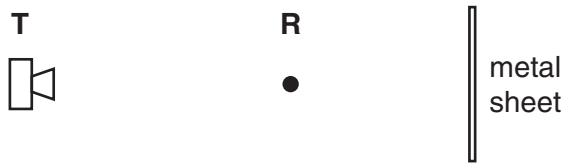


Fig. 8.1

(i) Explain why **R** receives two signals of different amplitude but of the same frequency.

.....

.....

.....

.....

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

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(ii) Explain why the strength of the detected signal varies between maximum and minimum values as **R** is moved towards or away from the metal sheet.



In your answer you should make clear how the maxima and minima occur.

.....

.....

.....

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.....

.....

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

(iii) Determine the wavelength of the microwaves given that the distance between adjacent positions of maximum and minimum signal strength is 7.5 mm.

wavelength = ... mm **[1]**

(iv) The amplitude of the signal from the transmitter is a. The amplitude of the two signals detected at **R** are $0.8a$ and $0.6a$. The changes in amplitude of the detected signals are negligible as **R** moves 7.5 mm. Show that the ratio

$$\frac{\text{maximum intensity of detected signal}}{\text{minimum intensity of detected signal}}$$

is about 50.

[3]

[Total: 13]

END OF QUESTION PAPER

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ADDITIONAL PAGE

If additional space is required, you should use the lined pages below. The question number(s) must be clearly shown.

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ADDITIONAL PAGE

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GCE

Physics A

Advanced Subsidiary GCE

Unit **G482:** Electrons, Waves and Photons

Mark Scheme for June 2012

Oxford Cambridge and RSA Examinations

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This mark scheme is published as an aid to teachers and students, to indicate the requirements of the examination. It shows the basis on which marks were awarded by examiners. It does not indicate the details of the discussions which took place at an examiners' meeting before marking commenced.

All examiners are instructed that alternative correct answers and unexpected approaches in candidates' scripts must be given marks that fairly reflect the relevant knowledge and skills demonstrated.

Mark schemes should be read in conjunction with the published question papers and the report on the examination.

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Annotations

Annotation	Meaning
	Benefit of doubt given
	Contradiction
	Incorrect response
	Error carried forward
	Follow through
	Not answered question
	Benefit of doubt not given
	Power of 10 error
	Omission mark
	Rounding error or repeated error
	Error in number of significant figures
	Correct response
	Arithmetic error
	Wrong physics or equation

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Abbreviations, annotations and conventions used in the detailed Mark Scheme (to include abbreviations and subject–specific conventions).

Annotation	Meaning
/	alternative and acceptable answers for the same marking point
(1)	Separates marking points
reject	Answers which are not worthy of credit
not	Answers which are not worthy of credit
IGNORE	Statements which are irrelevant
ALLOW	Answers that can be accepted
( )	Words which are not essential to gain credit
__	Underlined words must be present in answer to score a mark
ecf	Error carried forward
AW	Alternative wording
ORA	Or reverse argument

Subject-specific Marking Instructions

CATEGORISATION OF MARKS

The marking scheme categorises marks on the MABC scheme

B marks: These are awarded as independent marks, which do not depend on other marks. For a **B**-mark to be scored, the point to which it refers must be seen specifically in the candidate's answer.

M marks: These are method marks upon which **A**-marks (accuracy marks) later depend. For an **M**-mark to be scored, the point to which it refers must be seen in the candidate's answer. If a candidate fails to score a particular **M**-mark, then none of the dependent **A**-marks can be scored.

C marks: These are compensatory method marks which can be scored even if the points to which they refer are not written down by the candidate, providing subsequent working gives evidence that they must have known it. For example, if an equation carries a **C**-mark and the candidate does not write down the actual equation but does correct working which shows that the candidate knew the equation, then the **C**-mark is given.

A marks: These are accuracy or answer marks, which either depend on an **M**-mark, or allow a **C**-mark to be scored.

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Note about significant figures:

If the data given in a question is to 2 sf, then allow answers to 2 or more sf.
If an answer is given to fewer than 2 sf, then penalise once only in the entire paper.
Any exception to this rule will be mentioned in the Guidance.

Please put ticks and crosses against all sub-sections marked AAA (7 in total)

Question			Answer	Marks	Guidance
1	(a)		Work done/energy transfer(red) per unit time	B1	**accept** per second **or** rate of energy transfer / rate of doing work **or** energy transfer / time taken
	(b)	(i)	using P = VI I = 40/230 = 0.17(4) (A)	C1 A1	 accept 4/23
	(b)	(ii)	R = 230/0.17 = 1400 (Ω)	B1	**possible ecf b(i);** expect and **accept** 1322 or 1353 Ω **accept** 40 = 230^2/R giving R = 52900/40 = 1322 Ω
	(c)		l = RA/ρ l = 1.3 x 10^3 x 3.0 x 10^{-8} /7.0 x 10^{-5} l = 0.56 (m)	C1 C1 A1	Choosing R = ρl/A substitution; **ecf b(ii)** evaluation; **allow** 0.57 m (using R = 1322 Ω) and 0.58 m (using 1353 Ω) and 0.6 m (using 1400 Ω)
A A A	(d)		larger power needs larger I so smaller R (for same V) smaller R (but same length) so larger A / thicker	B1 B1 B1	**accept** P = V^2/R **or** calculation I = 0.26 A giving R **=** 880 or 890 Ω NB if R calculated correctly here, give first 2 marks hence smaller R (but same length) so larger A / thicker
	(e)	(i)	Q = It = 0.17 x 8 x 60 x 60 Q = 4900 (C)	C1 A1	**ecf b(i)** **allow** 4896; or 5000 or 5011 if using I = 0.174 A give 1 mark for 1.36 or 81.6
		(ii)1	(a unit of) energy equal to 3.6 MJ **or** 1 kW for 1 h/AW	B1	**eg** 1000 W for 3600 s or similar
		(ii)2	40 x 8 = 320 Wh / 0.32 kWh 0.32 x 22 = 7.0(4) p	C1 A1	 **accept** 7 p (no SF error); allow 7000p (7040) for 1 mark
			Total	15	

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Question			Answer	Marks	Guidance
2	(a)	(i)1	infinity	B1	accept symbol
	(a)	(i)2	R = 1.8/10 x 10^{-3} R =180 Ω	C1 A1	0.18 Ω scores 1 mark
A A A	(a)	(ii)	resistance decreases because I increases more than V therefore since R = V/I value decreases/AW	B1 B1 B1	**accept** calculation at second value, e.g. at 2.0 R = 53 Ω, with comparison **OR** at two other values **QWC mark** for second marking point
A A A	(b)		correct symbol and direction for LED R in series with LED across XY ammeter in series voltmeter in parallel with LED only	B1 B1 B1 B1	circle not essential, internal line optional no variable resistor
	(c)		torch; car brake/rear light/ traffic light, etc. torch: draws a lower current / light lasts longer before battery discharged/AW **or** LEDs (much) more efficient (at converting electrical energy into light)/AW **or** if one LED fails remainder still lit/AW	M1 A1	suitable example **accept** any **one** sensible statement, include longer life, more durable contradictory statements score zero
			Total	12	

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Question			Answer	Marks	Guidance
3 A A A	(a)		R <u>of thermistor</u> decreases as temperature increases supply V is constant/ <u>total</u> R is smaller current increases <u>as V = IR</u>/AW	B1 B1 B1	**accept** more free e's as temperature rises using I = nAev current increases as v decrease very small/AW
	(b)		R_{th} = 40 Ω at 240 ^{o}C (stated or used in calculation) total R in circuit = 240 Ω I = 6/240 = 0.025 A V = 200 x 0.025 = 5.0 V	B1 C1 C1 A1	**apply ecf** if wrong value of R read from graph **allow** V = (200/240)6 so V = 5.0 V **accept** 5 V (no SF error)
	(c)	(i)	correct symbol for LDR	B1	no circle required
		(ii)	R <u>of LDR</u> decreases/current in circuit increases so V increases <u>across fixed</u>/<u>200 Ω resistor</u>/AW	M1 A1	 **accept** simple potential divider argument **accept** voltmeter reading increases
			Total	10	

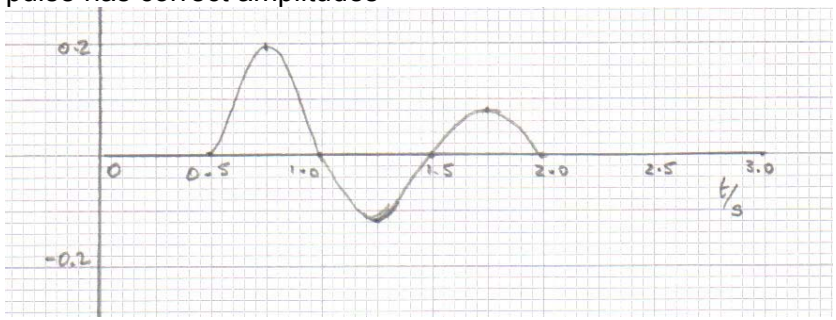
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Question			Answer	Marks	Guidance
4	(a)		R's in parallel have same V/AW so 4.0 x 0.30 = 6.0 x 0.20	**M1** **A1**	**allow** I splits in inverse ratio to R **or** AW; hence I in 6 ohm = 4 / 6 x 0.3 = 0.2 A
	(b)	(i)	sum of/total current into a junction equals the sum of/total current out **or** total algebraic sum of currents is zero	**B1**	**allow** Kirchhoff's first law
		(ii)	0.50 (A)	**A1**	**accept** 0.5 (A) (no SF error)
	(c)		correct formula for R_p and substitution R_p = 2.4 Ω R_s = 8.0 (Ω)	**C1** **C1** **A1**	 **apply ecf** to R_p for second mark **accept** 8 (Ω) (no SF error)
	(d)	(i)	energy transferred from source/changed from some form to electrical energy; per unit charge (to drive charge round a complete circuit)	**M1** **A1**	**allow** form as e.g. light/chemical/heat **allow** energy divided by charge
		(ii)	V = IR = 0.50 x 8.0 =4.0 (V)	**A1**	**ecf b(ii),c** i.e. answer = b(ii) x c **accept** 4 (V) (no SF error)
		(iii)	E – V = Ir giving 5.0 – 4.0 = 0.50 r r = 2.0 (Ω)	**C1** **A1**	**ecf b(ii)** **accept** 2 (Ω) (no SF error); give max of 1 mark for r = 3.3 Ω , i.e. using I = 0.3 A
			Total	**12**	

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Question			Answer	Marks	Guidance
5	(a)		electrons have mass, photons have zero mass electrons have charge, photons are uncharged photons travel at <u>speed of light</u>	**B1** **B1**	**max** 2 marks from 3 marking points lower speed of electrons **not** required for mark
	(b)	(i)	energy = eV = $1.6 \times 10^{-19} \times 5000 = 8.0 \times 10^{-16}$ (J)	**C1** **A1**	**accept** 8×10^{-16} (J) (no SF error)
		(ii)	$\frac{1}{2}mv^2 = 8.0 \times 10^{-16}$ $v^2 = 1.76 \times 10^{+15}$ $v = 4.2 \times 10^{7}$ (m s^{-1})	**C1** **C1** **A1**	 evidence of calculation required
	(c)	(i)	electron wavelength depends on its speed/momentum	**B1**	**accept** de Broglie equation with labels defined
		(ii)	$\lambda = h/mv$ $\lambda = 6.63 \times 10^{-34}/(9.1 \times 10^{-31} \times 4.2 \times 10^{7})$ $= 1.7 \times 10^{-11}$ (m)	**C1** **C1** **A1**	select formula substitution; **allow** 4×10^{7} **allow** 1.8×10^{-11} (m)
	(d)		$E = hc/\lambda$ $\lambda = 6.63 \times 10^{-34} \times 3.0 \times 10^{8}/8.0 \times 10^{-16}$ $= 2.5 \times 10^{-10}$ (m)	**C1** **C1** **A1**	select equation substitute and manipulate answer 2.49×10^{-10} (m)
	(e)	(i)	photoelectric effect / emission	**B1**	
		(ii)	$KE_{max} = hf - \varphi$ or $hf = \varphi + KE_{max}$ $9.0 \times 10^{-19} - 7.2 \times 10^{-19} = 1.8 \times 10^{-19}$ (J)	**C1** **A1**	can be copied from data sheet
		(iii)	Electrons in the metal have a range of energies most require more than the w.f. energy to escape from the surface/AW	**B1** **B1**	w.f. is <u>minimum</u> energy to escape from surface /AW <u>max</u> k.e. given when w.f. subtracted from photon energy **or** photon gives all of its energy to one electron
			Total	**19**	

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Question			Answer	Marks	Guidance
6	(a)	(i)	*displacement :* (any) distance moved from equilibrium of a point/particle on a wave *amplitude* maximum displacement (caused by wave motion)	B1 B1	**allow** rest, zero, mean position
	(a)	(ii)	*frequency* number of wavelengths passing a point /vibrations at a point per unit time/second or produced by the wave source /AW *phase difference* between two points on the same wave/waves of the same frequency, how far through the cycle one point is compared to the other	B1 B1	**allow** number of oscillations / cycles per second **accept** in one second **allow** suitable descriptions of in phase and out of phase; **or** an angular measurement of how much a wave leads or lags/AW
A **A** **A**	(b)		pulse starts at 0.5 s ends at 2.0 s pulse shape is reversed from Fig 6.1 pulse has correct amplitudes  	B1 B1 B1 B1	ie amplitude decreasing from L to R over 1.5s accept inversion in time axis NB if extra loops, probably only first marking point available if diagram looks like a coiled spring rather than a smooth curve, 1st, 2nd and 4th marking points are possible
			Total	**8**	

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Question			Answer	Marks	Guidance
7 A A A	(a)	(i)	(atom releases energy when) electron moves from high to low level energy released is in form of a photon possible transitions are between n = 3 and n = 1, n = 3 and n = 2, n = 2 and n= 1	B1 B1 B1	can be illustrated on diagram by downward arrow connecting levels can be illustrated on diagram
	(a)	(ii)1	$\varepsilon = hc/\lambda$ $= 6.63 \times 10^{-34} \times 3.0 \times 10^{8} / 6.56 \times 10^{-7}$ $= 3.0(3) \times 10^{-19}$ (J)	 C1 A1	choosing formula and substitution answer accept 3×10^{-19} (J) (no SF error)
	(a)	(ii)2	from n = 3 to n = 2	B1	**allow** between n = 3 and n = 2 **allow** n = 2 to n = 3 or between n = 2 and n = 3 **if** there is no contradiction with answer given in 7ai
	(b)	(i)1	$d \sin\theta = \lambda$ $\quad d \sin 11.4^{o} = 6.56 \times 10^{-7}$ $d = 6.56 \times 10^{-7}/0.198$ $d = 3.3 \times 10^{-6}$ (m)	C1 C1 A1	choosing formula and substitution manipulation and $\sin 11.4^{o} = 0.198$
	(b)	(i)2	$1/d = 3 \times 10^{5}$ m^{-1} = 300 mm^{-1}	A1	**ecf b(i)1**; allow 301 or 302 as data given to 3 sig figs
	(b)	(ii)	**2** rays, one either side of normal to grating at about 8°, say	B1	**accept** any sensible angle
			Total	**11**	

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Question			Answer	Marks	Guidance
8	(a)		travel in a vacuum same speed (in vacuum)/at c caused by accelerating charges are (oscillating) electric and magnetic fields	B1 B1	**max** 2 marks from 4 marking points for any one incorrect property, max of 1/2 if 2 incorrect properties, score 0
	(b)		10^{-4} microwaves; 10^{-6} ir; 10^{-8} uv; 10^{-12} gamma	B1 B1	4 correct 2 marks 2 correct 1 mark
	(c)	(i)	the incident wave is reflected at the sheet to produce return wave <u>of same frequency</u>/AW reflected wave is weaker **OR** the reflected wave has travelled a greater distance	 B1 B1	**accept** incident and reflected waves are from same source/of same wavelength/AW **allow** wave amplitude decreases with distance
A A A	(c)	(ii)	reflected wave interferes/superposes with the incident wave constructive interference occurs (**or** waves add) to give maxima/AW **and** destructive interference occurs (**or** waves add) to give minima/AW detail given, e.g. waves add in phase for max/out of phase for min **or** path difference nλ for max (2n +1)/2 λ for min	B1 M1 A1	if <u>incident</u> and <u>reflected</u> waves identified in (c)(i) **accept** "the waves interfere / superpose" **QWC mark** for second marking point **accept** antinodes for maxima and nodes for minima
	(c)	(iii)	λ/4 = 7.5 mm; λ = 30 mm	B1	
	(c)	(iv)	appreciation that I is proportional to a^2 ratio = $(0.8 +0.6)^2/(0.8-0.6)^2$ = $(1.4/0.2)^2 = 7^2 = 49$	C1 C1 A1	
			NOW SCROLL DOWN TO CHECK PAGE 18 IS BLANK		
			Total	**13**	

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RECOGNISING ACHIEVEMENT

Friday 20 January 2012 – Morning

AS GCE PHYSICS A

G482 Electrons, Waves and Photons

G411580112

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

G 4 8 2

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. Additional paper may be used if necessary but you must clearly show your candidate number, centre number and question number(s).
- 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 This question is about the rigid copper bars which carry the very large currents generated in a power station to the transformers. Fig. 1.1 shows such a copper bar.

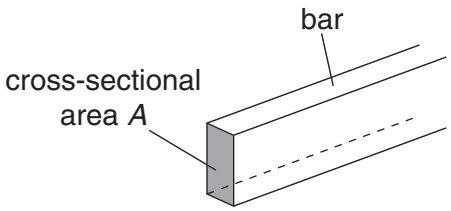


Fig. 1.1

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

.....

.....

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

(b) **(i)** The cross-sectional area A of the bar is $6.4 \times 10^{-3}\,m^2$. Calculate the resistance of a 1.0 m length of the bar. The resistivity of copper is $1.7 \times 10^{-8}\,\Omega\,m$.

resistance = ... Ω **[2]**

(ii) The bar carries a constant current of 8000 A. Calculate the power dissipated as heat along a 1.0 m length of it.

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

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(iii) The bar is 9.0 m long. Estimate the total energy in kW h lost from the bar in one day.

energy = ... kW h **[2]**

(iv) Calculate the cost per day of operating the copper bar. The cost of 1kW h is 15p.

cost = ... p **[1]**

(c) Calculate the mean drift velocity v of the free electrons in the copper bar. The number of free electrons per unit volume in copper is $8.4 \times 10^{28}\,m^{-3}$.

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

[Total: 12]

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2 **(a)** Fig. 2.1 shows combinations of resistors connected to a power supply of e.m.f. *E*.

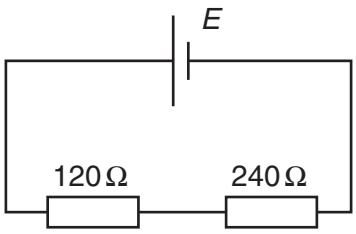


Fig. 2.1a

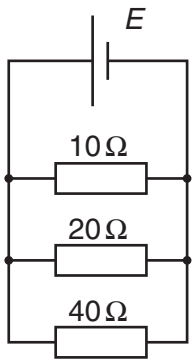


Fig. 2.1b

(i) For the circuit of Fig. 2.1a

1 calculate the total resistance R_s

R_s = ... Ω **[1]**

2 state one electrical quantity which is the same for both resistors.

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

(ii) For the circuit of Fig. 2.1b

1 calculate the total resistance R_p

R_p = ... Ω **[2]**

2 state one electrical quantity which is the same for all the resistors.

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

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(b) Fig. 2.2 shows the I–V characteristics of two electrical components, a resistor, line **R** and a thermistor, line **T**.

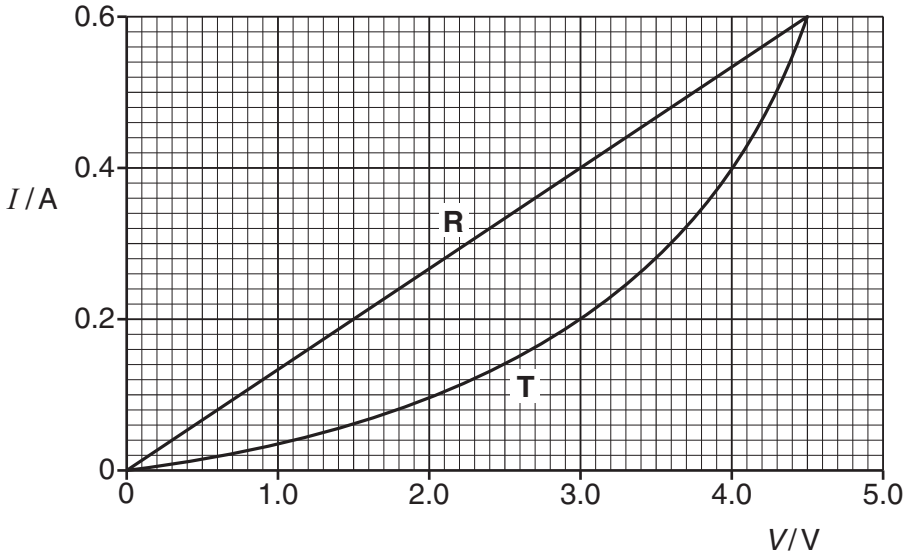


Fig. 2.2

(i) State Ohm's law. Use Fig. 2.2 to explain why component **R** obeys Ohm's law.

.....

.....

.....

.....

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

(ii) The resistor and the thermistor can be connected to a variable voltage supply of negligible internal resistance in two ways as shown in Fig. 2.3a and Fig. 2.3b.

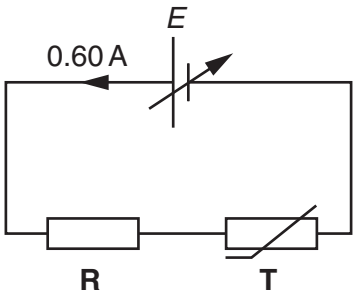


Fig. 2.3a

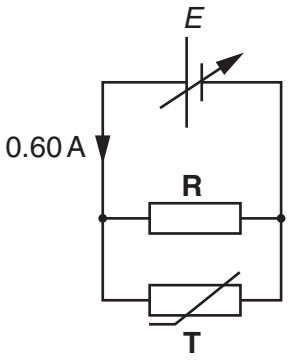


Fig. 2.3b

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The voltage of the supply is varied in each circuit until the current drawn from it is 0.60 A. Use data from Fig. 2.2 to explain why the e.m.f. *E* of the supply is

1 9.0 V in Fig. 2.3a

.....

.....

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

2 3.0 V in Fig. 2.3b.

.....

.....

.....

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

(iii) The thermistor is now connected on its own across the terminals of the supply set at 4.5 V. Fig. 2.4 shows the variation of current I with time t from the moment the thermistor is connected to the supply.

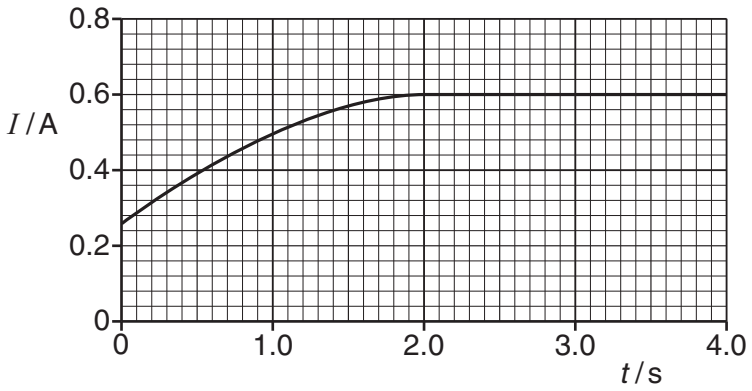


Fig. 2.4

Explain the shape of the graph in Fig. 2.4.

.....

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

[Total: 15]

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3 A cell is a source of e.m.f. When the cell is connected into a circuit the potential difference measured between its terminals, called the *terminal p.d.*, is less than its e.m.f.

(a) **(i)** Define the term *e.m.f.*

.....

.....

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

(ii) Explain why the terminal p.d. is less than the e.m.f.

.....

.....

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

(b) In the circuit of Fig. 3.1 the cell of e.m.f. 1.6 V and internal resistance *r* is delivering a current of 0.20 A to a resistor of resistance *R*. The voltmeter reads the terminal p.d. It is 1.2 V.

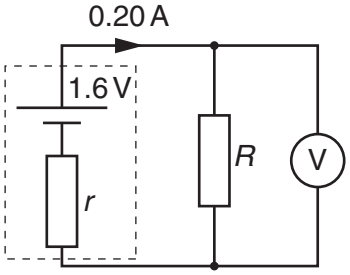


Fig. 3.1

Calculate the values of

(i) the resistance *R*

R = ... Ω **[2]**

(ii) the internal resistance *r*.

r = ... Ω **[2]**

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(c) (i) The current in the resistor of Fig. 3.1 remains constant at 0.20 A for several hours. Calculate

1 the charge which passes through the resistor in 1.5 hours

charge = ... unit ..... **[3]**

2 the energy dissipated by the resistor in 1.5 hours.

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

(ii) The cell is left connected to the resistor for 12 hours. The graph of Fig. 3.2 shows the variation of current I with time t.

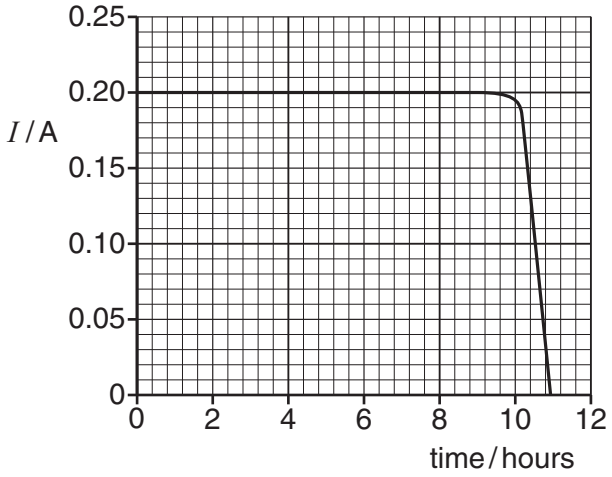


Fig. 3.2

Describe how the current varies with time. Suggest reasons why it varies in this way.

In your answer you should link each feature of the graph to the reason for it.

.....

.....

.....

.....

.....

.....

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

[Total: 17]

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4 **(a)** Explain what is meant by a *progressive wave*.

.....

.....

.....

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

(b) Describe how a *transverse* wave differs from a *longitudinal* wave.

.....

.....

.....

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

(c) **(i)** Explain what is meant by *diffraction* of a wave.

.....

.....

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

(ii) Describe how you would demonstrate that a sound wave of wavelength 0.10 m emitted from a loudspeaker can be diffracted.

In your answer you should make clear how your observations show that diffraction is occurring.

.....

.....

.....

.....

.....

.....

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

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(d) Fig. 4.1 shows two loudspeakers connected to a signal generator, set to a frequency of 1.2 kHz. A person walks in the direction **P** to **Q** at a distance of 3.0 m from the loudspeakers.

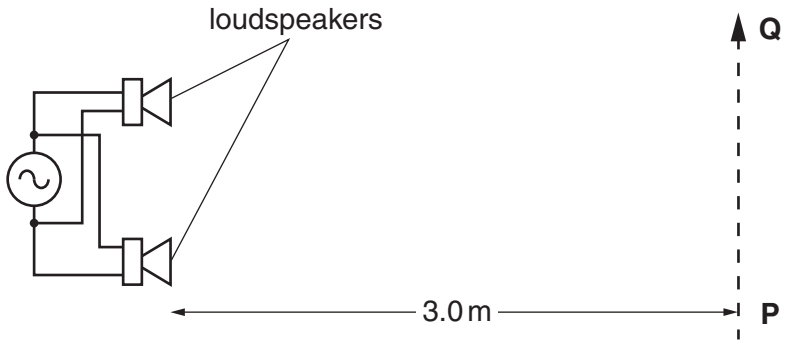


Fig. 4.1

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

speed of sound in air = 340 m s^{-1}

λ = ... m **[2]**

(ii) Explain, either in terms of path difference or phase difference, why the intensity of the sound heard varies as the person moves along **PQ**.

.....

.....

.....

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.....

.....

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.....

.....

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

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(iii) The distance x between adjacent positions of maximum sound is 0.50 m. Calculate the separation a between the loudspeakers. Assume that the equation used for the interference of light also applies to sound.

a = ... m **[2]**

(iv) The connections to one of the loudspeakers are reversed. Describe the similarities and differences in what the person hears.

.....

.....

.....

.....

.....

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

[Total: 18]

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5 Fig. 5.1 shows a uniform string which is kept under tension between a clamp and a pulley. The frequency of the mechanical oscillator close to one end is varied so that a stationary wave is set up on the string.

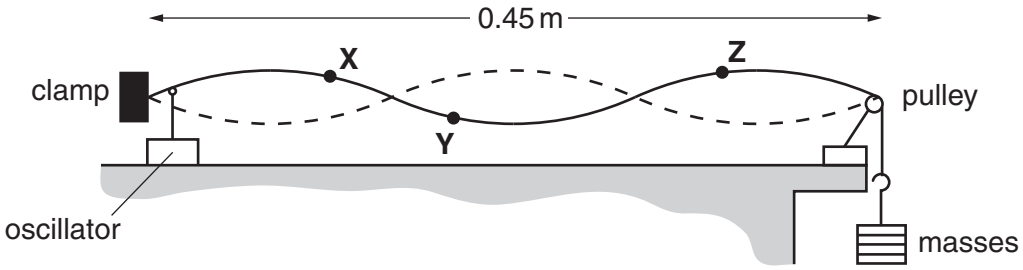


Fig. 5.1

(a) State two features of a stationary wave.

.....

.....

.....

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

(b) Explain how the stationary wave is formed on the string.

.....

.....

.....

.....

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

(c) The distance between the clamp and the pulley is 0.45 m. **X**, **Y** and **Z** are three points on the string. **X** and **Y** are each 0.040 m from the nearest node and **Z** is 0.090 m from the pulley. State, giving a reason for your choice, which of the points **Y** or **Z** or both oscillate

(i) with the same amplitude as **X**

.....

.....

.....

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

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(ii) with the same frequency as **X**

.....

.....

.....

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

(iii) in phase with **X**.

.....

.....

.....

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

[Total: 10]

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6 **(a)** X-rays and radio waves are two examples of electromagnetic waves.

(i) Name **two** other examples of electromagnetic waves.

.....

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

(ii) State **one** similarity and **one** difference between X-rays and radio waves.

similarity .....

.....

.....

difference .....

.....

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

(iii) Explain why X-rays are easily diffracted by layers of atoms, about 2×10^{-10} m apart, but radio waves are not.

.....

.....

.....

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

(b) On the Earth, we are all exposed to ultraviolet radiation coming from the Sun.
State **one** advantage and **one** disadvantage of UV-B radiation.

.....

.....

.....

.....

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

(c) **(i)** Circle a typical value for the wavelength of an X-ray from the list below.

2×10^{-4} m 2×10^{-7} m 2×10^{-10} m 2×10^{-13} m **[1]**

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(ii) Use your answer to **(i)** to determine how many X-ray photons must be collected to produce an energy of 1.0×10^{-6} J.

number of photons = ... **[4]**

(d) A plane polarised radio wave is transmitted from a vertical aerial to a nearby receiving aerial as shown in Fig. 6.1.

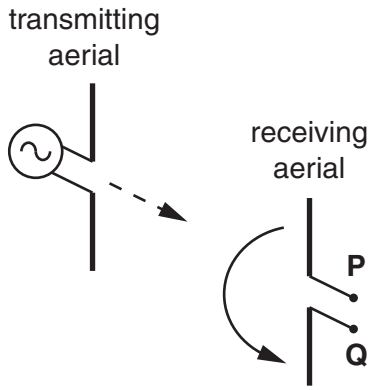


Fig. 6.1

A diode, resistor and ammeter are connected in series across the terminals **P** and **Q**.

(i) Draw the circuit between terminals **P** and **Q** on Fig. 6.1 in the space to the right of **PQ**. **[2]**

(ii) The entire receiving aerial is rotated slowly through 180° in the direction shown by the arrow. Explain clearly what will be observed on the ammeter and how the detected signal varies.

.....

.....

.....

.....

.....

.....

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

[Total: 17]

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7 **(a)** State **one** experiment for each case which provides evidence that electromagnetic radiation can behave like

(i) a stream of particles, called *photons*

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

(ii) waves.

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

(b) A beam of ultraviolet light is incident on a clean metal surface. The graph of Fig. 7.1 shows how the maximum kinetic energy KE_{max} of the electrons ejected from the surface varies with the frequency f of the incident light.

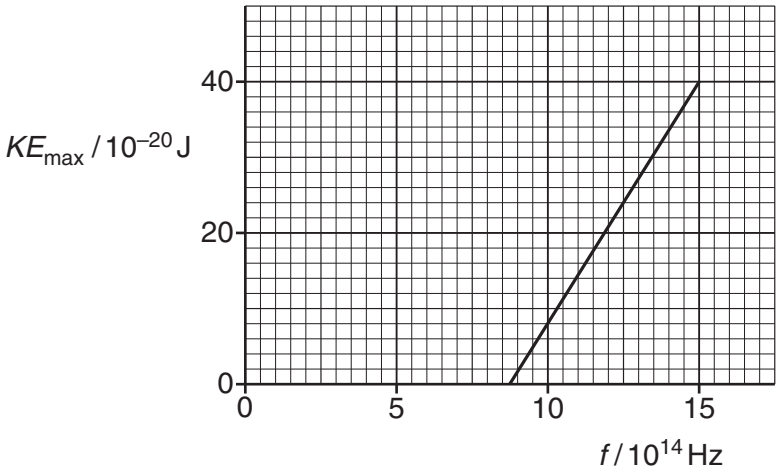


Fig. 7.1

(i) Define the work function ϕ of the metal.

.....

.....

.....

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

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(ii) Write down the relationship between KE_{max} and f. Use it to explain why the y-intercept of the graph in Fig. 7.1 is equal to the work function of the metal and the gradient of the line is equal to the Planck constant.

.....

.....

.....

.....

.....

.....

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

(iii) Use data from Fig. 7.1 to find a value of

1 the Planck constant

Planck constant = ... J s **[2]**

2 the threshold frequency of the metal

threshold frequency = ... Hz **[1]**

3 the work function of the metal.

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

[Total: 11]

END OF QUESTION PAPER

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RECOGNISING ACHIEVEMENT

GCE

Physics A

Advanced Subsidiary GCE

Unit **G482:** Electrons, Waves and Photons

Mark Scheme for January 2012

Oxford Cambridge and RSA Examinations

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Annotations available in SCORIS

Annotation	Meaning
	Benefit of doubt given
	Contradiction
	Incorrect response
	Error carried forward
	Follow through
	Not answered question
	Benefit of doubt not given
	Power of 10 error
	Omission mark
	Rounding error ONLY APPLIED ONCE IN THE PAPER; also use as Repeated error
	Error in number of significant figures ONLY APPLIED ONCE IN THE PAPER
	Correct response
	Arithmetic error
	Wrong physics or equation
/	alternative and acceptable answers for the same marking point
(1)	Separates marking points
reject	Answers which are not worthy of credit

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Annotations in detailed mark schemes

Annotation	Meaning
not	Answers which are not worthy of credit
IGNORE	Statements which are irrelevant
ALLOW	Answers that can be accepted
( )	Words which are not essential to gain credit
__	Underlined words must be present in answer to score a mark
ecf	Error carried forward
AW	Alternative wording
ORA	Or reverse argument

Subject-specific Marking Instructions

CATEGORISATION OF MARKS

The marking scheme categorises marks on the MABC scheme

B marks: These are awarded as independent marks, which do not depend on other marks. For a **B**-mark to be scored, the point to which it refers must be seen specifically in the candidate's answer.

M marks: These are method marks upon which **A**-marks (accuracy marks) later depend. For an **M**-mark to be scored, the point to which it refers must be seen in the candidate's answer. If a candidate fails to score a particular **M**-mark, then none of the dependent **A**-marks can be scored.

C marks: These are compensatory method marks which can be scored even if the points to which they refer are not written down by the candidate, providing subsequent working gives evidence that they must have known it. For example, if an equation carries a **C**-mark and the candidate does not write down the actual equation but does correct working which shows that the candidate knew the equation, then the **C**-mark is given.

A marks: These are accuracy or answer marks, which either depend on an **M**-mark, or allow a **C**-mark to be scored.

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Question			Answer	Marks	Guidance
1	(a)		resistivity = resistance x area (of cross-section)/length	B1	**accept** equation with *resistance* as subject **allow** *over* for divide by; do **NOT** allow formula with a word for each symbol
	(b)	(i)	$R = \rho l/A = 1.7 \times 10^{-8} / 6.4 \times 10^{-3}$ $= 2.7 \times 10^{-6}$ (Ω)	C1 A1	**accept** 2.66×10^{-6} (Ω)
		(ii)	$P = I^2R$ $= 8000^2 \times 2.7 \times 10^{-6}$ = 170 W	C1 C1 A1	select formula**;** can use P = VI & V = IR **ecf b(i)** 173 (2.7), 170 (2.66)
		(iii)	170 x 9.0 = 1530 W **or** 170 x 24 = 4080 W 1.5 x 24 = 36 (kW h) 4.08 x 9 = 36.7 (kWh)	B1 B1	**ecf b(ii)**; 1 mark for X 9 **or** 1 mark for X 24
		(iv)	36 x 15 = 540 p	B1	**ecf b(iii)** 551(36.7), 555 (37)
	(c)		I = nAev $8000 = 8.4 \times 10^{28} \times 6.4 \times 10^{-3} \times 1.6 \times 10^{-19} v$ $v = 9.3 \times 10^{-5}$ (m s^{-1})	C1 C1 A1	select formula correct substitution
			Total	**12**	

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			Answer	Marks	Guidance
2	(a)	(i)1	360 (Ω)	B1	
		(i)2	Current	B1	**not** symbol only; **not** unit only
		(ii)1	1/10 + 1/20 + 1/40 = 1/R R = 5.7 (Ω)	C1 A1	1/R = 0.175 **accept** 40/7
		(ii)2	potential difference	B1	**accept** p.d. or voltage **not** e.m.f.; **not** symbol only; **not** unit only
	(b)	(i)	**p.d./voltage must be proportional to current** as long as temperature and/or (other) physical conditions remain constant **R** line is straight and <u>through the origin</u>	**M1** A1 B1	symbols may be used but must be defined
		(ii)1	(same current so) at 0.6 A have 4.5 V + 4.5 V (=9.0 V)	B1 B1	**accept** resistors in series (so V's add); i.e recognise that at 0.6 A each component has 4.5 V across it.
		(ii)2	add currents so at 3.0 V have 0.2 A + 0.4 A = 0.6 A	B1 B1	**accept** attempt to add currents for 1 mark (i.e. method mark)
		(iii)	thermistor heats up/temperature increases resistance (of thermistor/circuit) decreases (so current rises) temperature/resistance becomes constant (after 2 s) because thermal equilibrium reached	B1 B1 B1 B1	**max** 3 marks **accept** thermal energy frees more charge carriers/AW **accept** energy/power/heat in/generated = energy/power/heat out/lost
			Total	**15**	

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Question			Answer	Marks	Guidance
3	(a)	(i)	**energy transferred from source/changed from some form to electrical energy**; per unit charge (to drive charge round a complete circuit)	**M1** A1	 allow energy divided by charge
		(ii)	any source has an internal resistance where energy is transferred into thermal energy /lost as heat	B1 B1	 there will be 'lost' volts (across the cell when a current is drawn) **or** V = E – Ir explained
	(b)	(i)	V = IR 1.2 = 0.2 R R = 6.0 Ω	C1 A1	substitution needed to score mark **allow** 6 Ω
		(ii)	1.6 – 1.2 = 0.4 = 0.2 r r = 2.0 Ω	C1 A1	 **allow** 2 Ω
	(c)	(i)1	Q = It = 0.20 x 3600 x 1.5 =1100 correct unit,	C1 A1 B1	substitution needed to score mark 1080 **allow** 1 mark max for 0.3 or 18 **allow** C, kC, A s **exception** 0.3 A h or 18 A min scores 3 marks
		(i)2	energy = QV = 1100 x 1.2 **or** $I^2Rt = 0.2^2$ x 6 x5400 = 1320 (J)	C1 A1	**ecf (c)(i)1** substitution needed to score mark 1296(1080) **allow** 1 mark for 1728 (using 1.6)
		(ii)	I is constant for about 9 to 10 hours because internal resistance remains constant/cell operates at constant emf I falls rapidly/towards zero over last hour or so because cell's/chemical energy is used up (so E falls)	B1 B1 B1 B1	QWC must have link between observation and reason to score full marks **accept** r of cell increases causing fall in V or I
			Total	**17**	

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Question			Answer	Marks	Guidance
4	(a)		**is a transfer of energy** as a result of oscillations (of the source/medium/particles through which energy is travelling)	**M1** A1	**allow** carries **allow** information **accept** without the transfer of the medium/particles/matter
	(b)		displacement/oscillation (of particles) is normal/perpendicular to direction of energy transfer in transverse wave displacement/oscillation (of particles) is parallel to direction of energy transfer in longitudinal wave	B1 B1	**allow** vibrations **allow** to direction of <u>wave</u> motion/propagation/velocity/travel **NOT** transverse wave can travel through a vacuum give max 1 mark for 2 similar poor definitions, e.g. direction of travel, waves oscillate, etc. (two such errors scores zero)
	(c)	(i)	wavefronts/paths spread out after passing through a gap or around an obstacle/AW	B1	**NOT** wave changes direction
		(ii)	use a slit/hole/ barrier width of gap/position beyond barrier comparable to wavelength microphone/observer's ear suitably placed sound detected/heard outside 'geometrical shadow' region (showing diffraction)	B1 B1 B1 B1	**accept** doorway/end of wall **accept** position of detector beyond doorway **N.B.** good diagram can illustrate first 3 marking points **allow** 'hears sound' in suitable context only observation mark which is QWC mark must be in words 2 marks max for double slit experiment(1st and 3rd m.p.)
	(d)	(i)	$v = f\lambda$ giving $340 = 1200 \times \lambda$ $\lambda = 0.28$ (m)	C1 A1	substitution needed to score mark POT error for using 1.2 kHz giving 280 m **N.B.** $\lambda = 0.3$ SF error (remember apply only once)
		(ii)	waves superpose/interfere at points along **PQ** (constructively and destructively) path difference from sources of $n\lambda$ for maximum/loud sound/intensity path difference of $(2n + 1)\lambda/2$ for minimum/quiet sound/intensity	B1 B1 B1	**max** 2/3 for writing phase difference is $n\lambda$ or path difference is 2π i.e. mixing path and phase consistently through answer **allow** waves arrive in phase (0, 2π, 360°, etc) **allow** waves arrive in anti-phase (π, 180°, etc) **do not allow** waves arrive out of phase **or** answers in terms of peaks and troughs for 2nd and 3rd marks
		(iii)	$a = \lambda D/x$ giving $a = 0.28 \times 3.0/0.50$ $a = 1.7$ m	C1 A1	**ecf (d)(i)** substitution needed to score mark
		(iv)	intensity of sound (at maxima) unchanged/AW <u>positions</u> of maxima and minima <u>reversed</u>/AW	B1 B1	**allow** volume or amplitude
			Total	**18**	

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Question			Answer	Marks	Guidance
5	(a)		energy is trapped in pockets/ where the shape or energy does not move along/energy is stored/AW there are nodes/positions of zero amplitude/motion there are positions where there is max. amplitude/antinodes different/adjacent points have different amplitudes/AW all points between nodes in phase/all points in adjacent λ/2's in anti-phase/AW	B1 B1 B1 B1 B1	**accept** any **two** sensible but different features **allow** there are nodes and antinodes as 1 marking point **penalise** displacement for amplitude once only
	(b)		incident wave is reflected (at the fixed end of the string) and the reflected wave (or it) interferes/superposes with the incident wave (to produce the stationary wave)	B1 B1	
	(c)	(i)	**points which are the same distance from the nodes will have the same amplitude** so **Y** (has the same amplitude as **X**)	**M1** A1	**N.B**. some will add **Z** stating it is the same distance from the node – these candidates can score the first mark
		(ii)	**all points on the string oscillate with the same frequency** so **Y** and **Z** (have the same f as **X**)	**M1** A1	
		(iii)	**all points in alternate segments of the string oscillate in phase/AW** so **Z** (is in phase with **X**)	**M1** A1	**accept** e.g. have positive displacement at the same time
			Total	**10**	

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Question			Answer	Marks	Guidance
6	(a)	(i)	gamma rays, u.v., visible/light, i.r., microwaves	B1	**two** out of five needed for mark
		(ii)	*similarity*: travel in a vacuum/same speed (in vacuum)/at c/transverse (wave)/can be polarised/caused by accelerating charges/are oscillating electric and magnetic fields *difference:* different λ, f, (photon) energy	B1 B1	any **one** for mark **NOT** can be reflected/refracted/diffracted/interfere,etc. any **one** for mark
		(iii)	wavelength of X-rays is close to atomic spacing/AW **or** wavelength of radio waves many/million times the atomic separation maximum/significant diffraction occurs when radiation wavelength ~ spacing (between diffracting planes) within material	B1 B1	
	(b)		**advantage** produces vitamin D (in skin cells) **disadvantage** damage DNA/cause cancer/sunburn, etc.	B1 B1	**allow** any sensible use, e.g. sterilise equipment, forensic science, disco lighting, etc. **NOT** tanning, photosynthesis
	(c)	(i)	2×10^{-10} m	B1	
		(ii)	$E = hc/\lambda$ $= 6.63 \times 10^{-34} \times 3.0 \times 10^{8}/2 \times 10^{-10}$ $= 9.9(5) \times 10^{-16}$ number = 1×10^{9}	C1 C1 A1 B1	Select equation and attempt to apply it **ecf (c)(i)** accept 1×10^{-15}, i.e 1 SF mark scored for 1×10^{-6}/value of E
	(d)	(i)	diode symbol all three components in series	B1 B1	**allow** LED symbol; basic requirement is triangle along wire direction with bar, with or without circle and line through **ecf** for diode symbol
		(ii)	maximum ammeter reading when aerials in line/parallel zero signal/current when aerials at 90° to each other at 180° same signal/ammeter reading as at 0° quoting $I = I_o\cos^2\theta$ to indicate variation through 180^0	B1 B1 B1 B1	**accept** ammeter reading falls as aerial is rotated **accept** minimum **allow** full marks for answers in terms of only ammeter reading or signal strength max 3 out of 4 marking points
			Total	**17**	

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Question			Answer	Marks	Guidance
7	(a)	(i)	photoelectric effect (experiment) **or** (discrete) counting of gamma rays **or** Compton effect	B1	**NOT** the gold leaf/ the zinc plate experiment, etc.
		(ii)	Young's slits (experiment)	B1	**accept** any interference/diffraction experiment, e.g. using a diffraction grating, a double slit experiment, etc.
	(b)	(i)	φ is the minimum energy required to release an electron from the metal/surface	B1	**allow** escape from
		(ii)	$KE_{max} = hf - \varphi$ or $hf = \varphi + KE_{max}$ **the straight line equation is y = mx + c (where m is the gradient and c the y-intercept)** hence giving c = (-) φ and m = h	B1 **M1** A1	can be copied from the data sheet
		(iii)1	**h = 32 x 10^{-20}/5 x 10^{14} or 40 x 10^{-20}/6.25 x 10^{14} or 20 x 10^{-20}/3 x 10^{14} etc** = 6.4 x 10^{-34} (J s)	**M1** A1	any sensible attempt at gradient gains 1 mark check that answer is consistent with figures and not just quoted, e.g. 6.7 for third set of data above
		(iii)2	8.75 ± 0.25 x 10^{14} (Hz)	B1	tolerance is to within the grid square **N.B**. SF applies i.e answer must be 9.0 NOT 9
		(iii)3	φ = 6.4 x 10^{-34} x 8.75 x 10^{14} = 5.6 x 10^{-19} (J)	C1 A1	**ecf (b)(iii)1,2 or ecf b(iii) 2** x 6.6(3) x 10^{-34} ans = **1** x **2**; 5.8 x 10^{-19} (J) if use h = 6.6 x 10^{-34} **allow** use of $\varphi = hf - KE_{max}$ at (15,40) for example
			Total	**11**	

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ADVANCED SUBSIDIARY GCE

PHYSICS A

Electrons, Waves and Photons

G482

Candidates answer on the question paper.

OCR Supplied Materials:
- Data, Formulae and Relationships Booklet

Other Materials Required:
- Electronic calculator

Monday 6 June 2011
Afternoon

Duration: 1 hour 45 minutes

OCE/23932

G 4 8 2

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. Pencil may be used for graphs and diagrams only.
- 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 pages at the end of this booklet. The question number(s) must be clearly shown.
- Answer **all** the questions.
- 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 Two 6.0 V torches produce similar light intensities. The light source of one is a single filament lamp and of the other is a combination of four light-emitting diodes (LEDs). Fig. 1.1 shows the I-V characteristics of the filament lamp and **one** LED.

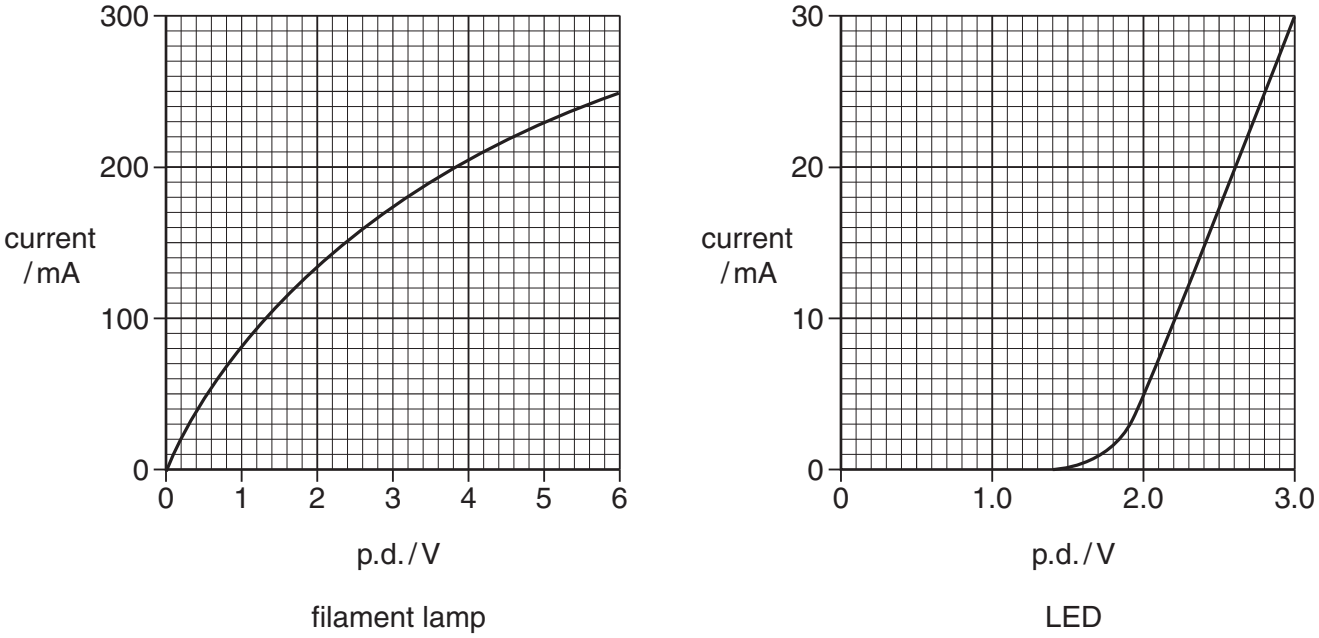


Fig. 1.1

(a) (i) Describe how the resistance of the filament lamp at 6.0 V can be determined from its I-V characteristic.

.....

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

(ii) State how the I-V characteristics show that the filament lamp and the LED do not obey Ohm's law.

.....

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

(b) When at normal brightness the current in the filament lamp is 0.25 A at a p.d. of 6.0 V.

(i) Calculate the charge Q passing through the filament each second.

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

(ii) Calculate the energy drawn from the battery each second.

energy = ... J **[1]**

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(iii) The battery is able to keep the lamp lit for 4 hours. Estimate the energy stored in the battery.

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

(c) The LEDs in the LED torch are connected in pairs across the 6.0 V battery and switch so that the potential difference across each of the four LEDs is 3.0 V.

(i) Define the term *potential difference*.

.....

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

(ii) Use Fig. 1.1 to determine the current through each LED.

current = ... mA **[1]**

(iii) Show that the power drawn from the battery in the LED torch is 0.36 W.

[2]

(iv) Sketch a circuit diagram showing how the battery, the four LEDs and the switch are connected in the torch.

[3]

(d) Suggest one advantage of using LEDs rather than a filament lamp in a torch.

.....

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

[Total: 16]

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2 This question is about possible heating circuits used to demist the rear window of a car. The heater is made of 8 thin strips of a metal conductor fused onto the glass surface. Fig. 2.1 shows the 8 strips connected in parallel to the car battery of e.m.f. E and internal resistance r.

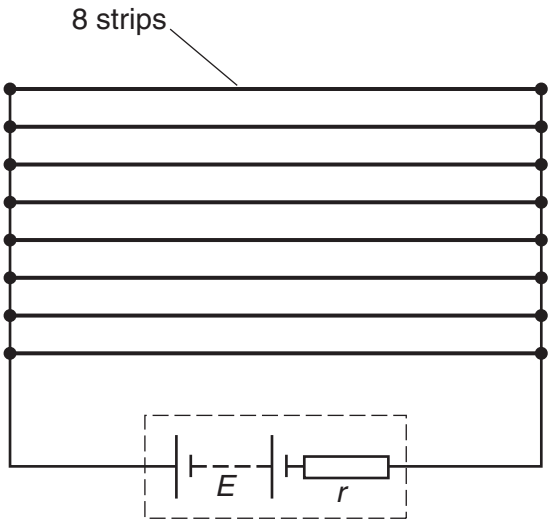


Fig. 2.1

(a) The potential difference across each strip is 12 V when a current of 2.0 A passes through it.

(i) Calculate the resistance r_p of one strip of the heater.

r_p = ... Ω **[1]**

(ii) Calculate the total resistance R_p of the heater.

R_p = ... Ω **[3]**

(iii) Show that the power P dissipated by the heater is about 200 W.

[2]

(b) Each strip is 0.90 m long, 2.4×10^{-4} m thick and 2.0×10^{-3} m wide.

Calculate the resistivity ρ of the metal of the strip. Give the unit with your answer.

ρ = ...unit ..... **[4]**

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(c) An alternative way of making the heater is to connect eight metal strips in **series**. The heater is to dissipate the same power as the parallel combination of **(a)** when the p.d. across it is 12V.

(i) Explain why the total resistance of the series heater must equal R_p calculated in **(a)(ii)**.

.....

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

(ii) Calculate the resistance r_s of one strip of this series heater.

r_s = ... Ω **[1]**

(iii) Suggest, with a reason, whether you would choose the series or parallel circuit arrangement of the strips for a demister heater.

.....

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

(d) Fig. 2.2 is a graph showing how the potential difference across the terminals of the battery varies with the current drawn from it.

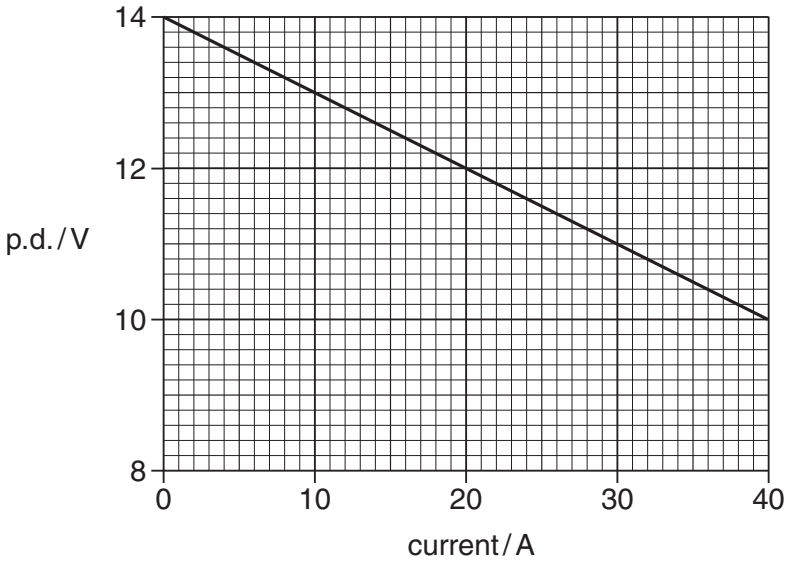


Fig. 2.2

(i) From the graph find the e.m.f. E of the battery.

E = ... V **[1]**

(ii) Use data from the graph to calculate the internal resistance r of the battery.

r = ... Ω **[3]**

[Total: 17]

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3 This question is about the use of a light-dependent resistor (LDR) as a light sensor in a potential divider circuit. Fig. 3.1 shows how the resistance of a particular LDR varies with light intensity.

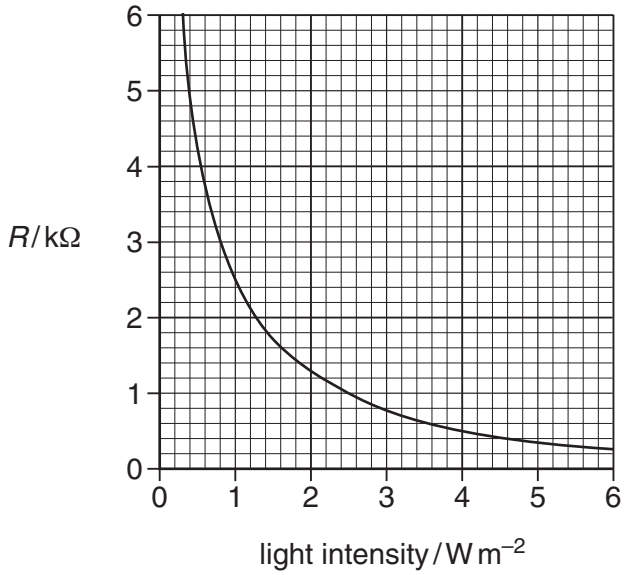


Fig. 3.1

(a) Explain the term *intensity*.

.....

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

(b) The intensity of daylight is about $10\,W\,m^{-2}$ and at night time is about $0.1\,W\,m^{-2}$. Describe how the resistance of the LDR changes during the day compared with how it changes at night.

.....

.....

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

(c) Fig. 3.2 shows a light-sensing potential divider circuit where the LDR is connected in parallel to the input of an electronic circuit that operates a 230 V mains lamp.

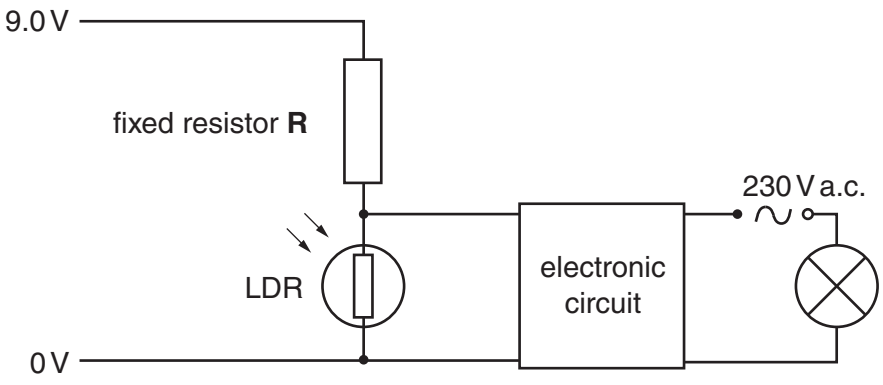


Fig. 3.2

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The electronic circuit draws a negligible current. The potential difference across the LDR must be at least 5.0 V to activate the circuit and switch on the lamp. The lamp is switched on when the light intensity falls to 1.0 W m^{-2}.

(i) Use Fig. 3.1 to determine the resistance of the LDR at a light intensity of 1.0 W m^{-2}.

resistance = ... kΩ **[1]**

(ii) Calculate the current in the LDR in Fig. 3.2 for the p.d. across it to be 5.0 V.

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

(iii) Show that the resistance of the fixed resistor **R** in Fig. 3.2 is 2.0 kΩ.

[1]

(d) The lamp switches off when the light intensity reaches 2.5 W m^{-2}. Calculate the p.d. across the LDR when this happens.

potential difference = ... V **[3]**

(e) Explain why the LDR must be shielded or be at some distance from the lamp when it switches on.

.....

.....

.....

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

[Total: 12]

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4 A photoelectric cell is an electronic device that can detect photons.

(a) Fig. 4.1 shows a cross-section through a simple photocell.

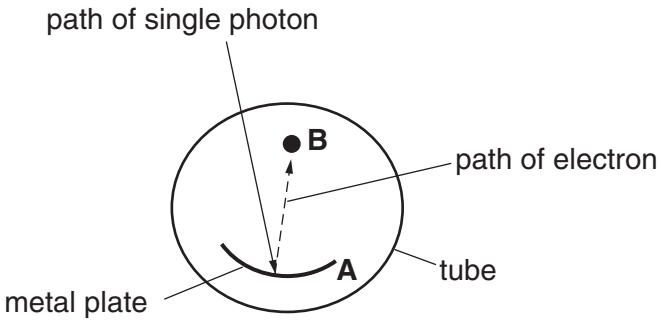


Fig. 4.1

A metal plate **A** is coated with potassium in an evacuated transparent tube. A photon entering the tube is absorbed by the plate, causing one electron to be released from the surface towards the collector rod **B**.

(i) State the name of this process.

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

(ii) Potassium has a work function of 3.5×10^{-19} J.

1 Define the term *work function*.

.....

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

2 Calculate the threshold frequency of potassium.

threshold frequency = ... Hz **[2]**

(iii) The photon incident on plate **A** has a wavelength of 4.2×10^{-7} m. Show that its energy is about 5×10^{-19} J.

[2]

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(iv) Calculate the maximum kinetic energy of the electron emitted from the potassium surface of plate **A**.

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

(b) An electron is released with zero speed from plate **A**. It is accelerated from plate **A** through a potential difference of 12V to the metal rod **B** in Fig. 4.1.

(i) **1** State the increase in kinetic energy of the electron in electronvolts (eV).

increase in k.e. = ... eV **[1]**

2 Show that this increase is about 2×10^{-18}J.

[1]

(ii) Calculate the speed of the electron as it hits rod **B**.

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

(c) The photocell is connected to a 12V d.c. supply through a very sensitive ammeter. Light of wavelength 4.2×10^{-7}m shines on plate **A**. The plate absorbs 1.2×10^{-6}J of light energy every second. One per cent of the absorbed photons cause electrons to be emitted from the plate. Estimate the current in the circuit.

current = ... A **[3]**

[Total: 16]

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5 In Fig. 5.1 the solid line on the graph represents the displacement y against position x of a **progressive** transverse wave on a stretched wire at time $t = 0$. The dotted line shows the displacement at a later time $t = 0.75\,\text{ms}$, where the wave has moved to the right.

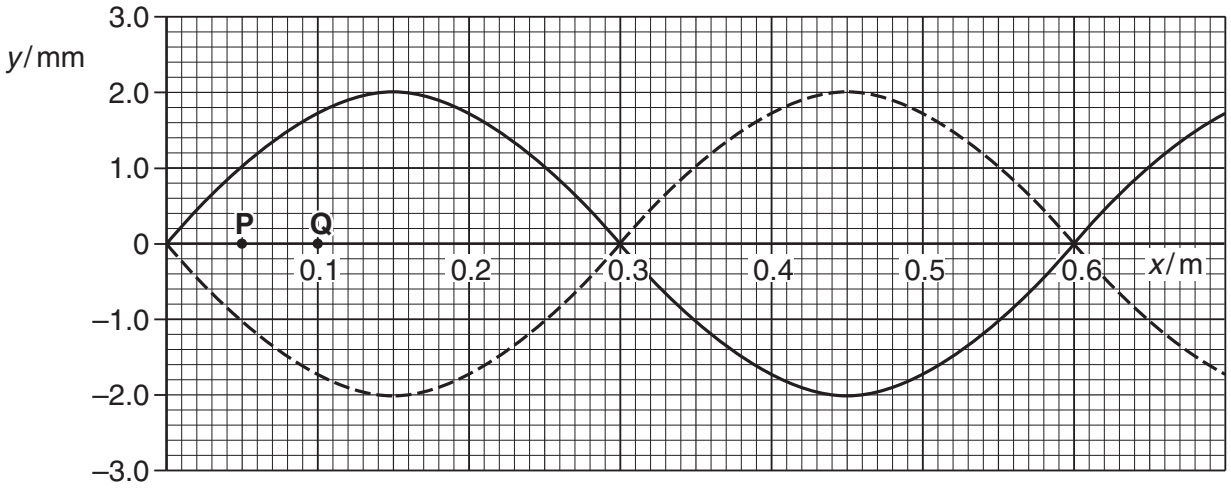


Fig. 5.1

(a) (i) Determine the wavelength of the wave.

wavelength = ... m **[1]**

(ii) 1 Explain how Fig. 5.1 shows that the period of the wave is 1.5 ms.

.....

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

2 Calculate the speed of the wave along the wire.

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

(b) Consider the oscillations of the wire at positions **P** ($x = 0.05\,\text{m}$) and **Q** ($x = 0.10\,\text{m}$). See Fig. 5.1. For the **progressive** wave on the wire state the difference, if any, in **amplitude** of the oscillations of the wave at **P** and **Q**.

difference = ... mm **[1]**

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(c) (i) Describe the diference between the *displacement* and the *amplitude* of a wave.

.....

.....

.....

.....

.....

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

(ii) Describe how a *stationary* wave is different from a *progressive* wave.

.....

.....

.....

.....

.....

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

Question 5 is continued on page 12

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(d) Fig. 5.2 shows the wire of Fig. 5.1 under tension fixed at points $x = 0$ and 0.60 m. The frequency of the mechanical oscillator close to one end is varied so that a **stationary** wave is set up on the wire.

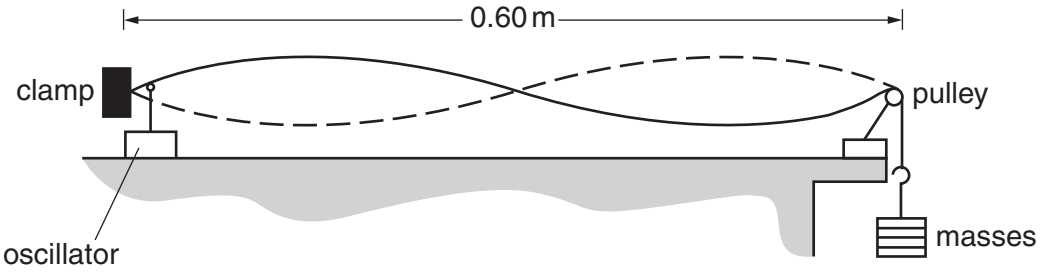


Fig. 5.2

(i) By considering the motion of progressive waves on the wire, explain how the stationary wave is produced.

In your answer you should make clear how the stationary wave arises.

.....

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

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(ii) In Fig. 5.3 the solid line on the graph represents the displacement y against position x of the **stationary** wave on the stretched wire at time $t = 0$. The dotted line shows the displacement at a later time $t = 0.75$ ms.

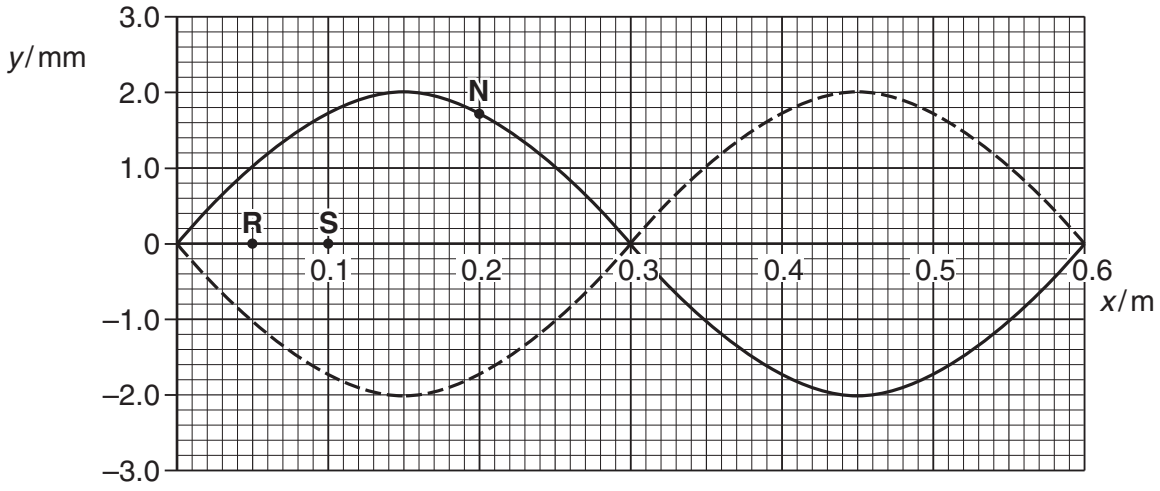


Fig. 5.3

For the **stationary** wave on the wire

1 state the difference, if any, in **amplitude** of the oscillations at **R** and **S**

difference = ... mm **[1]**

2 mark with an **X** the position of one antinode **[1]**

3 mark with a **Y** on the dotted line on Fig. 5.3 where the point **N** on the wave is at $t = 0.75$ ms. **[1]**

[Total: 15]

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6 This question is about measuring the wavelength of the yellow light from a sodium lamp.

(a) A beam of light from a sodium lamp passes through a pair of narrow slits S_1 and S_2 producing a pattern on a screen. See Fig. 6.1. The pattern on the screen consists of regularly spaced bright and dark lines, called fringes. See Fig. 6.2.

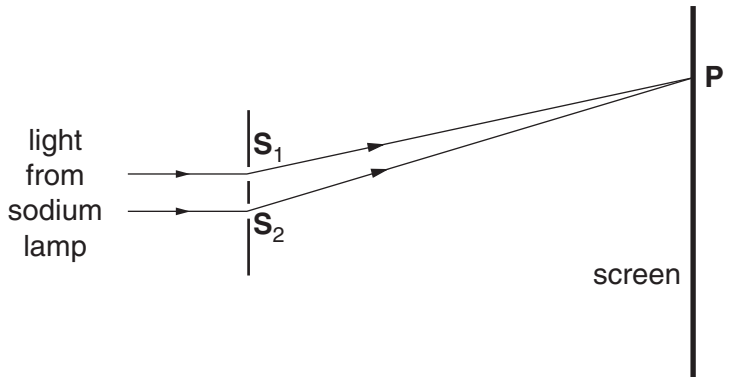


Fig. 6.1

(i) State and explain the conditions necessary for the light from the two slits S_1 and S_2 to produce a visible pattern on the screen.

.....

.....

.....

.....

.....

.....

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

(ii) Using the ideas of wave superposition, explain the existence of the bright and the dark fringes. In your answer state the condition for a bright fringe to appear on the screen at **P** in Fig. 6.1 and the condition for a dark fringe to appear at **P**.

.....

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.....

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

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(b) Fig. 6.2 shows the central part of the fringe pattern on the screen at 1.5 m from the slits S_1 and S_2 which are 0.60 mm apart.

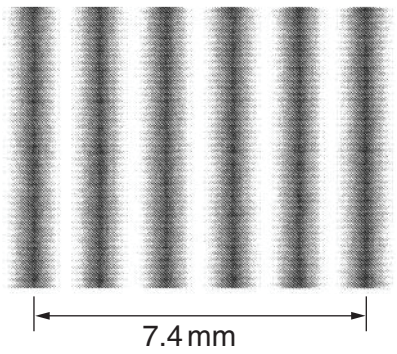


Fig. 6.2

Calculate

(i) the fringe separation, that is, the separation x between adjacent dark lines

x = ... m **[1]**

(ii) the wavelength λ of the yellow light.

λ = ... m **[3]**

(c) One of the two slits is covered up. Describe and explain how the pattern of light on the screen is different from that of Fig. 6.2.

.....

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.....

.....

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

[Total: 14]

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7 **(a)** Describe a *plane polarised wave*.

.....

.....

.....

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

(b) Light reflected from the surface of water is partially plane polarised in the horizontal direction. The reflected light is totally plane polarised when the angle of reflection is about 53°.

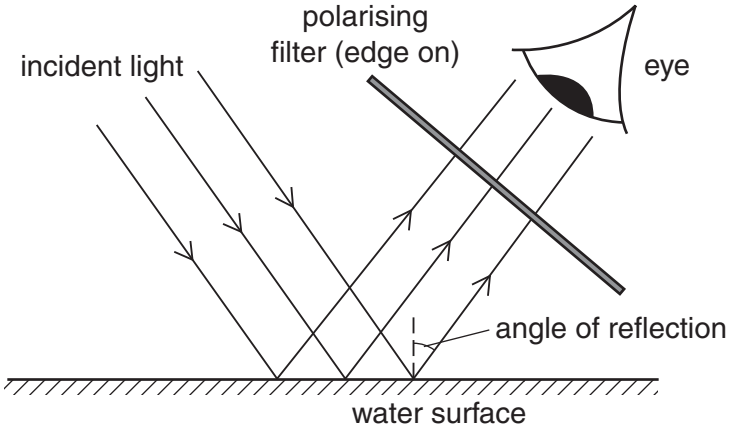


Fig. 7.1

Describe, referring to Fig. 7.1, the experiment that you would perform using a polarising filter (a sheet of Polaroid) to determine whether this statement is correct. Describe what you expect to observe.

In your answer you should make clear how you would use any apparatus to make observations or take suitable measurements.

.....

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.....

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.....

.....

.....

.....

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

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(c) State Malus' law for the intensity I of a beam of plane polarised light transmitted through a polarising sheet with its transmission axis at an angle θ to the plane of polarisation. Explain the meaning of any other symbols that you use.
Use Malus' law to explain the observations in the experiment of part **(b)**.

.....

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.....

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.....

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.....

.....

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

[Total: 10]

END OF QUESTION PAPER

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ADDITIONAL PAGE

If additional space if required, you should use the lined pages below. The question number(s) must be clearly shown.

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ADDITIONAL PAGE

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ADDITIONAL PAGE

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GCE

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Advanced Subsidiary GCE

Unit **G482:** Electrons, Waves and Photons

Mark Scheme for June 2011

Oxford Cambridge and RSA Examinations

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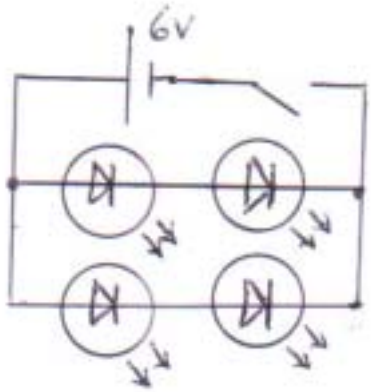
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Question			Expected Answers	M	Additional Guidance
1					
	a	i	read off value of current (at V = 6.0 V) calculate R using V/I	B1 B1	any reference to using gradient scores 0/2 **accept** I = 0.25 (A) or 250 (mA) **accept** R = 24 Ω
		ii	V is not proportional to I	B1	**accept** not a straight line; R is not constant
	b	i ii iii	Q = It = 0.25 x 1 = 0.25 C E = VIt or QV = 6 x 0.25 = 1.5 J E = VIt = 1.5 x 4 x 60 x 60 = 2.16 x10^4 J	B1 B1 C1 A1	 **ecf(b)(i)** **ecf b(ii)** **accept** 2.2 x 10^4 J; **allow** 360 J for 1 mark only
	c	i ii iii	energy transfer per unit charge from electrical to other forms 30 mA Use of P = VI suitable method (may be expressed purely in numerical form) = 0.36 W	B1 B1 A1 M1 A1 A0	**or** energy transfer/charge; work done /charge **or** across LED 3 x 0.030 = 0.090 W per LED so 0.090 x 4 **or** 30 mA in two branches at 6 V **or** total current is 60 mA from 6 V battery
		iv		B1 B1 B1	symbol for LED correct orientation of LED correct circuit
	d		draws a lower current/ light lasts longer (before battery discharged/)AW **or** LEDs more efficient (at converting electrical energy into light) **or** if one LED fails there are still two lit **or** more robust/longer working life	B1	 **allow** lower power consumption/AW
			Total question 1	**16**	

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Question			Expected Answers	M	Additional Guidance
2					
	a	i	12/2.0 = 6.0 (Ω)	B1	**allow** 6; do not apply the SF penalty (N.B. applied only once per paper) for any answer where the second SF is 0
		ii	attempt to use resistors in parallel formula 1/R = 8/6 R = 0.75 (Ω)	C1 C1 A1	no mark for just quoting formula **ecf (a)(i)** **allow** ¾ (Ω)
		iii	$P = V^2/R = 12^2/0.75$ **or** $8VI = 8 \times 12 \times 2$ **or** $I^2R = 16^2 \times 0.75$ = 192 W	C1 A1	**ecf (a)(ii)**
	b		ρ = RA/l $= 6.0 \times 0.24 \times 2.0 \times 10^{-6}/0.9$ $= 3.2 \times 10^{-6}$ Ω m	C1 C1 A1 B1	correct rearrangement of formula **ecf (a)(i);** substitution into a correct formula 2/3 marks for one or more POT errors **accept** 3.2 Ω μm; 4×10^{-7} scores 2/3
	c	i	(As V is the same) then R must be the same to give same P	B1	**accept** alternative wording producing same argument, e.g. same I, same V so same R
		ii	0.75/8 = 0.094 (Ω)	B1	**ecf (a)(ii)**/8; **accept** 3/32 but NOT 0.09
		iii	for parallel circuit with break in one wire rest still work **or** series strips very wide (if use material of same resistivity as such low resistance/ giving poor visibility))	B1	any sensible statement
	d	i	14 V	B1	
		ii	e.g. V = 12 V; I = 20 A substitution into E = V + Ir, e.g. 14 = 12 + 20 r r = 0.1 Ω	C1 C1 A1	**or** any suitable pair of readings from graph **ecf(d)(i); accept** r = gradient; = (14 – 10)/40 or similar ; = 0.1 Ω
			Total question 2	**17**	

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Question			Expected Answers	M	Additional Guidance
3					
	a		energy per unit area per unit time	B1	**accept** power per unit area; **allow** second for unit time
	b		Small changes in R for high light intensities/daylight conditions Large changes in R for low light intensities/dim light/night time conditions to change circuit state need a significant change in R to be useful/reliable	B1 B1 B1	**accept** low R by day, high R by night for 1 mark **NOT** comparison e.g. R by day smaller than R at night **max 2 marks** from 3 marking points
	c	i ii iii	2.5 (kΩ) 5.0 = I x 2.5 kΩ giving I = 2.0 x 10^{-3} A 4.0 = 2.0 x 10^{-3} x R **or** potential divider argument giving R = 2.0 x 10^{3} Ω	A1 C1 A1 M1 A0	**allow** 2.4 to 2.6 **ecf (c)(i)** **accept** 2.0 mA **ecf (c)(ii) or ecf (c)(i)** **accept** 2.0 kΩ
	d		R (of LDR) = 1(.0 kΩ) potential divider of 1.0 kΩ and 2.0 kΩ giving 3.0 V across LDR	B1 C1 A1	 **accept** I = 3.0 (mA) so V = 3.0 (mA) x 1.0 (kΩ) = 3.0 V
	e		light shining on the LDR will cause it to switch the illumination off causing an ON/OFF oscillation/AW	B1 B1	two suitable qualifying statements for the 2 marks
			Total question 3	**12**	

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Question			Expected Answers	M	Additional Guidance
4					
	a	i	photoelectric effect/emission	B1	
		ii1	the minimum energy (required) to release an electron (from the surface of the metal)	B1	
		ii2	$3.5 \times 10^{-19} = 6.6 \times 10^{-34}$ f $f = 5.3 \times 10^{14}$ (Hz)	C1 A1	
		iii	$\varepsilon = hc/\lambda = 6.6 \times 10^{-34} \times 3.0 \times 10^{8} / 4.2 \times 10^{-7}$ $= 4.7 \times 10^{-19}$ (J)	C1 A1	no second mark unless there is evidence of the calculation being done
		iv	$½mv^2 = 4.7 \times 10^{-19} - 3.5 \times 10^{-19}$ $= 1.2 \times 10^{-19}$ (J)	C1 A1	mark for using the p.e. equation **accept** 1.5×10^{-19} from those using 5×10^{-19} J
	b	i1	12 (eV)	B1	
		ii2	$\varepsilon = eV = 12 \times 1.6 \times 10^{-19} = 1.92 \times 10^{-18}$ (J)	A1	**ecf(b)(i)1**
		ii	$½mv^2 = 2.0 \times 10^{-18}$ $v^2 = 2 \times 2.0 \times 10^{-18} / 9.1 \times 10^{-31} = 4.4 \times 10^{12}$ $v = 2.1 \times 10^{6}$ (m s^{-1})	C1 C1 A1	$½mv^2 = 12$ scores 0/3 **accept** 1.9×10^{-18} from **(b)(i)2** giving $v = 2.0(5) \times 10^{6}$
	c		e's emitted/s = $1.2 \times 10^{-8} / 5 \times 10^{-19} = 2.4 \times 10^{10}$ current = $2.4 \times 10^{10} \times 1.6 \times 10^{-19}$ $= 3.8 \times 10^{-9}$ (A) to 4.1×10^{-9} (A)	C1 C1 A1	using 4.7×10^{-19} gives 2.55×10^{10} omitting 1% scores as a POT error allow 4 nA as the question states 'estimate'
			Total question 4	**16**	

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Question			Expected Answers	M	Additional Guidance
5					
	a	**i**	0.60 m	B1	**allow** 0.6 another example of SF comment Q2
		ii1 **ii2**	the wave has moved along 0.5 wavelengths in 0.75 ms so will move one wavelength in 1.5 ms which is the period/AW f = 670 Hz so v = fλ = 670 x 0.60 = 400 (m s^{-1})	 B1 C1 A1	can be answered in terms of phase **ecf(a)(i)** **accept** v = λ/T = 0.60/1.5 x 10^{-3}
	b		0	B1	
	c	**i**	*displacement* any distance moved from equilibrium of a point/particle (on a wave) *amplitude* <u>maximum</u> possible <u>displacement</u> (caused by wave motion)	 B1 B1	**allow** alternatives for equilibrium, e.g. mean/rest/undisturbed position
		ii	*progressive* a wave which transfers energy *stationary* a wave which <u>traps/stores</u> energy (in pockets) **OR** *progressive* : transfers shape/information from one place to another *stationary* where the shape does not move along/which has nodes and antinodes/AW	B1 B1 B1 B1	**accept** phase relationship descriptions between different points on wave; must be a comparison for same property to score both marks
	d	**i**	the incident wave is <u>reflected</u> at the fixed ends of the wire reflected wave <u>interferes/superposes</u> with the incident wave to produce a resultant wave with nodes and antinodes/no energy transfer	B1 B1 B1	must have reference to an end of the wire QWC mark
		ii1 **ii2** **ii3**	0.70 (mm) 0.15 (m)/0.45 (m) x = 0.2, y = -1.7	B1 B1 B1	**allow** 0.60 to 0.80 mm anywhere on vertical line x = 0.15 or 0.45
			Total question 5	**15**	

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Question			Expected Answers	M	Additional Guidance
6					
	a	i	method of producing coherent sources at S_1 and S_2 light (waves) from the two slits/sources must be coherent; that is, they must have a constant phase relationship/difference slits must be narrow/close together (so that diffraction patterns overlap) light (waves) from two slits must have similar amplitudes/intensities	B1 B1 B1 B1 B1	e.g. initial single slit **max 3 marks** from 5 marking points
		ii	*bright*: constructive interference occurs/waves add to give a maximum amplitude at the screen path difference between slits and screen is a whole/integer number of wavelengths/waves arrive in phase at screen *dark*: destructive interference occurs/waves add to give a minimum amplitude/zero at the screen path difference between slits and screen is an odd half number of wavelengths/waves arrive out of/in antiphase at screen	B1 B1 B1 B1	 **accept** explanation in terms of distance or phase **accept** explanation in terms of distance or phase
	b	i	$7.4/5 = 1.48 \times 10^{-3}$ (m)	B1	**accept** 1.5 mm
		ii	$\lambda = xd/L$ $= 1.48 \times 10^{-3} \times 0.6 \times 10^{-3}/1.5$ $= 5.9(2) \times 10^{-7}$ (m)	C1 C1 A1	using 1.5 mm gives 600 nm **ecf(b)(i)** e.g. 4 92 x 10^{-7} for 1.23 mm **accept** 590 nm
	c		pattern/fringes vanish because there is now no interference from light from the two slits/AW light spreads out over whole/similar region light intensity (at screen) is less diffraction spreads light simple description of single slit pattern further features of single slit pattern	B1 B1 B1 B1 B1 B1 B2	 e.g. bright in middle and dim at edges/sketch of bell shape **max 3 marks** from 8 marking points
			Total question 6	**14**	

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Question			Expected Answers	M	Additional Guidance
7					
	a		reference to a transverse wave or to vibrations in plane normal to the direction of (energy) propagation oscillations/vibrations in one direction only/confined to single plane (containing the direction of propagation)	B1 B1	can be answered with suitable diagram(s) NOT the wave oscillating in one plane
	b		set up apparatus, e.g. tray of water on table with lamp/light from window rotate the filter rotation of filter changes the image intensity/brightness/AW correct orientation for maximum and minimum intensities of image move head up or down to change angle of reflected light observed use of protractor to measure angles image/reflection becomes partially plane polarised/ image changes from bright to dim but does not disappear	B1 B1 B1 B1 B1 B1 B1	QWC mark essential for full marks **allow** from bright to zero or vice versa transmission axis parallel to water surface for maximum and perpendicular for minimum can hold head still and move lamp **max 3** from 6 marking points **+ QWC mark**
	c		$I = I_0 \cos^2\theta$ where I_0 is the maximum intensity (of the polarised beam) when θ is zero maximum intensity transmitted/ image bright when θ is 90° minimum/zero intensity transmitted/image dim/vanished	B1 B1 B1 B1	**allow** incident/original/initial for maximum
			Total question 7	**10**	

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ADVANCED SUBSIDIARY GCE

PHYSICS A

Electrons, Waves and Photons

G482

Candidates answer on the Question Paper

OCR Supplied Materials:
- Data, Formulae and Relationships Booklet

Other Materials Required:
- Electronic calculator

Monday 17 January 2011
Afternoon

Duration: 1 hour 45 minutes

G4822

OCE/17468

Candidate Forename		Candidate Surname	

Centre Number						Candidate Number				

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- Use black ink. Pencil may be used for graphs and diagrams only.
- Read each question carefully and make sure that you know what you have to do before starting your answer.
- Answer **all** the questions.
- Do **not** write in the bar codes.
- Write your answer to each question in the space provided. If additional space is required, you should use the lined pages at the end of this booklet. The question number(s) must be clearly shown.

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- 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.

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Answer **all** the questions.

1 A resistor **X** is constructed from a rod of cross-sectional area $9.0 \times 10^{-6}\,m^2$ and length 0.012 m as shown in Fig. 1.1. The resistivity of the material of the rod is $2.4\,\Omega m$.

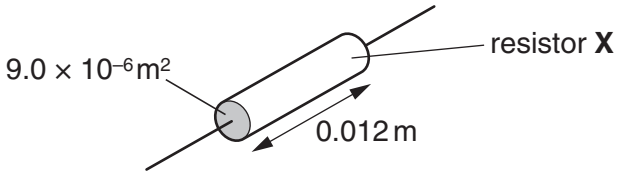


Fig. 1.1

(a) Show that the resistance of the resistor **X** is $3.2\,k\Omega$.

[2]

(b) The power rating of resistor **X** is 0.125 W. Show that the maximum potential difference which should be applied safely across the resistor is 20 V.

[2]

(c) A student needs a resistor of the same resistance as **X** but with a power rating of 0.50 W. The only resistors available are identical to **X**. It is suggested that four of these resistors could be connected as shown in Fig. 1.2 to solve the problem. The potential difference across the combination of resistors is 40 V.

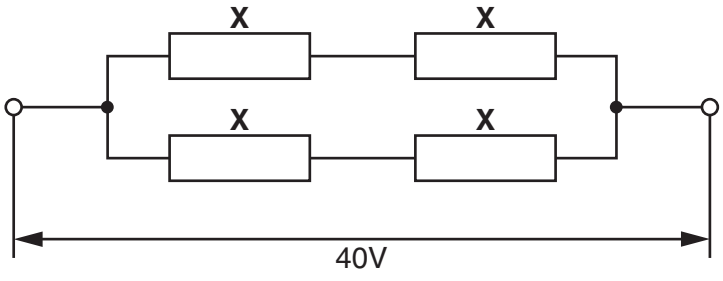


Fig. 1.2

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(i) Show that the total resistance of the combination in Fig. 1.2 is 3.2 kΩ.

[2]

(ii) Show that the power dissipation in each resistor is 0.125 W.

.....

.....

.....

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

(d) Another resistor **Y** is constructed from the same material but has twice the length and twice the diameter of resistor **X**.

(i) Show that the resistance R_Y of **Y** is half the resistance R_X of resistor **X**.

[2]

(ii) The two resistors **X** and **Y**, where $R_Y = R_X/2$, are connected in series to a d.c. power supply as shown in Fig. 1.3.

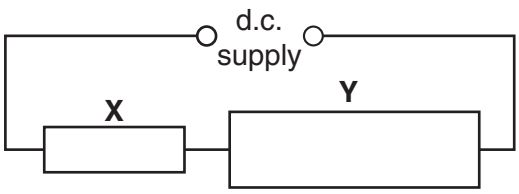


Fig. 1.3

State and explain which resistor dissipates greater power.

.....

.....

.....

.....

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

[Total: 13]

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2 **(a)** A 12V car battery contains an electrolyte. The battery is connected to an electric motor **M**. There is a current in the motor and the battery. See Fig. 2.1.

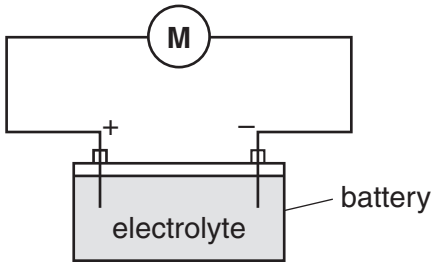


Fig. 2.1

State

(i) the charge carriers in the electrolyte

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

(ii) the charge carriers moving through the electrolyte to the positive terminal of the battery

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

(iii) the charge carriers moving through the wires to the positive terminal of the battery.

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

(b) When used to start the engine of the car, the electric motor draws 40A from the battery of e.m.f. 12V. The potential difference across the motor at this time is only 8.0V.

(i) Explain why the potential difference across the motor at this time is not the same as the e.m.f. of the car battery.

.....

.....

.....

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

(ii) Show that the internal resistance of the battery is 0.10Ω.

[3]

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(iii) It takes 1.2 s for the electric motor to start the engine. Calculate the charge Q which passes through the electric motor in this time.

$Q =$ ..... C **[2]**

(c) The car has two 12 V headlamps each rated at 54 W, connected in parallel to the battery. In normal working conditions the current in each lamp is 4.5 A.

(i) Explain how and why the resistance of the headlamp filament varies with the current passing through it.

.....

.....

.....

.....

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

(ii) Suggest a value for the current rating of a fuse for the headlamp circuit. Justify your choice.

.....

.....

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

(iii) A car contains a number of different fuses for its various electrical circuits. Suggest why this is necessary.

.....

.....

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

[Total: 15]

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3 **(a)** The following electrical quantities are often used when analysing circuits. Draw a straight line from each quantity on the left-hand side to its correct units on the right-hand side.

potential difference	$C\,s^{-1}$
resistance	$J\,C^{-1}$
power	$V\,A^{-1}$
current	$J\,s^{-1}$

[3]

(b) Fig. 3.1 shows a battery of e.m.f. 6.0 V and negligible internal resistance connected in series with a thermistor and a 560 Ω resistor.

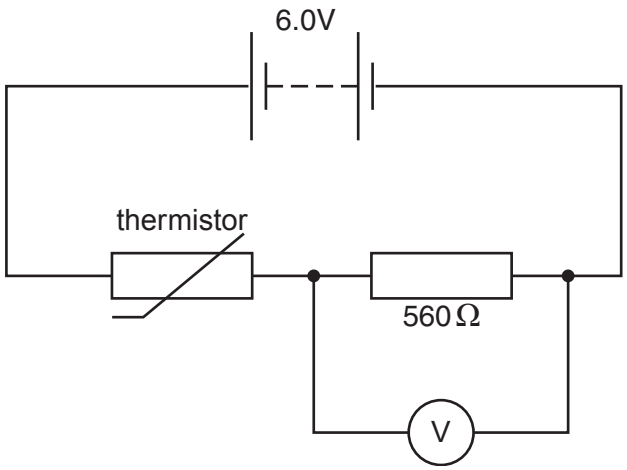


Fig. 3.1

The voltmeter across the resistor has infinite resistance.

(i) The reading on the voltmeter is 2.4 V. Calculate the resistance R_T of the thermistor.

R_T = ... Ω **[3]**

(ii) Calculate the current in the circuit.

current = ... A **[1]**

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(c) The variation of resistance with temperature for this thermistor is shown in the graph of Fig. 3.2.

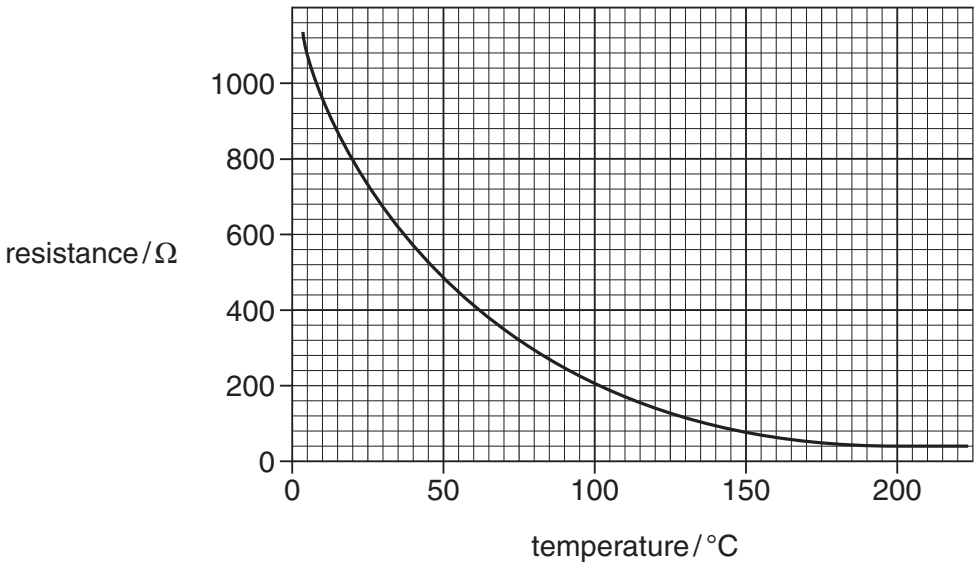


Fig. 3.2

(i) Use the graph to determine the temperature of the thermistor when its resistance is 800 Ω.

temperature = ... °C **[1]**

(ii) State and explain, without calculation, how the reading of the voltmeter in Fig. 3.1 will change as the temperature of the thermistor increases to 80 °C.

.....

.....

.....

.....

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

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(iii) The circuit of Fig. 3.1 can be used as a temperature sensor. Temperature sensors are used in the kitchen to control the internal temperatures of ovens (typically 200 °C) and refrigerators (typically 4 °C). Use the graph of Fig. 3.2 to suggest in which device this sensor would be more suitable.



In your answer you should link the information from the graph to the working of the sensor.

.....

.....

.....

.....

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

[Total: 14]

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4 Fig. 4.1 shows the variation with time t of the displacements x_S and x_T at a point **P** of two sound waves **S** and **T**.

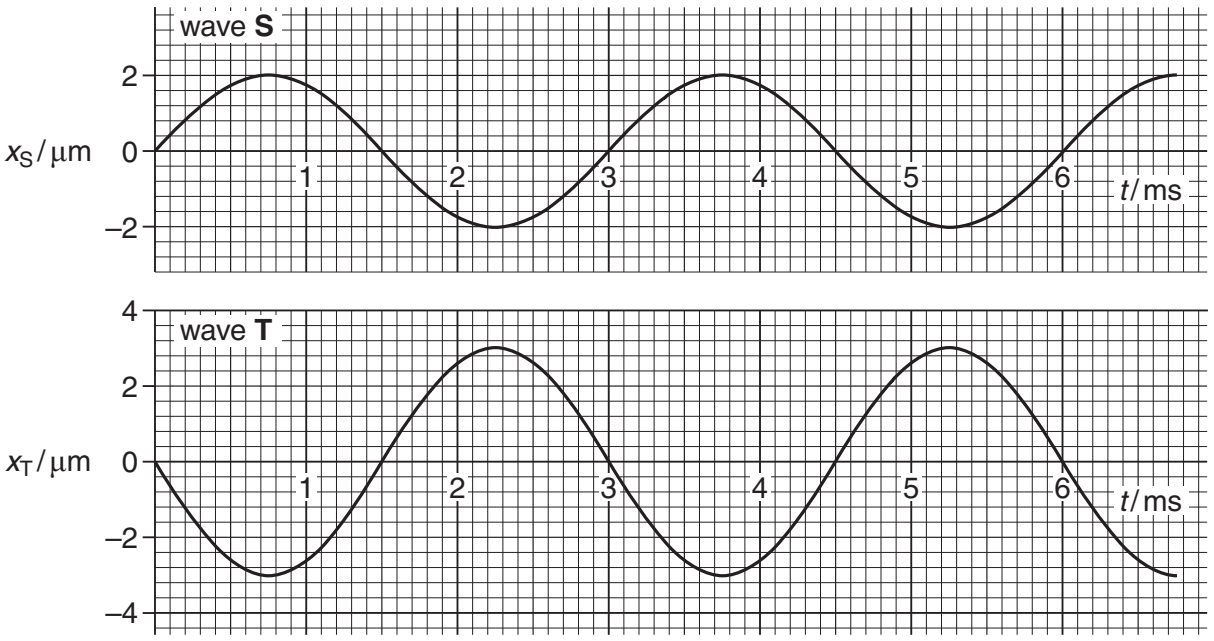


Fig. 4.1

(a) By reference to Fig. 4.1, state one similarity and one difference between these two waves.

similarity .....

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

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

.....

.....

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

(c) The speed of the sound waves is 340 m s^{-1}. Determine the frequency of wave **S** and hence its wavelength.

frequency = ... Hz

wavelength = ... m **[4]**

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(d) At point **P** the two sound waves superpose (combine). By reference to Fig. 4.1 determine the resultant displacement x of the two waves at time

(i) $t_1 = 1.5\,\text{ms}$

x_1 = ... μm **[1]**

(ii) $t_2 = 2.25\,\text{ms}$.

x_2 = ... μm **[1]**

(e) The intensity of wave **S** alone at point **P** is I.

(i) Show that the intensity of wave **T** alone at point **P** is $2.25I$.

[2]

(ii) Calculate the intensity of the resultant wave at point **P** in terms of I.

intensity = ... I **[2]**

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(f) The sound waves shown in Fig. 4.1 are emitted from the loudspeakers labelled **S** and **T** in Fig. 4.2 and detected by the microphone at point **P**.



Fig. 4.2

(i) Calculate the distance that loudspeaker **S** must be moved towards **P** to bring the two waves into phase at **P**. State your reasoning clearly.

distance = ... m **[2]**

(ii) Describe how the intensity of the sound wave detected at **P** varies as loudspeaker **S** is moved as in **(i)**.

.....

.....

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

[Total: 18]

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5 **(a)** Kirchhoff's first and second laws can be used to analyse any electrical circuit. They are a consequence of the conservation of physical quantities in the circuit.

(i) State Kirchhoff's **first** law and the physical quantity conserved.

.....

.....

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

(ii) State Kirchhoff's **second** law and the physical quantity conserved.

.....

.....

.....

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

(b) A physical quantity is also conserved in the photoelectric effect. Describe and explain the photoelectric effect.



In your answer you should link the description to the conservation of this quantity.

.....

.....

.....

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.....

..... **[6]**

[Total: 10]

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6 **(a)** In atomic physics electron energies are often stated in *electronvolts* (eV).

Define the *electronvolt*. State its value in joule.

.....

.....

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

(b) An electron is accelerated from rest through a potential difference of 300 V.

(i) Calculate the final kinetic energy of the electron

1 in eV

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

2 in J.

kinetic energy = ... J **[1]**

(ii) Show that the final speed of the electron is about $1 \times 10^7\,m\,s^{-1}$.

[2]

(c) **(i)** Explain what is meant by the *de Broglie wavelength* of an electron.

.....

.....

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

(ii) Calculate the de Broglie wavelength of the electron in **(b)**.

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

[Total: 10]

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7 The tungsten filament of a 12V 24W lamp glows white hot emitting photons across a continuous spectrum of energies. The intensity variation with wavelength of the electromagnetic radiation from the filament is shown in Fig. 7.1.

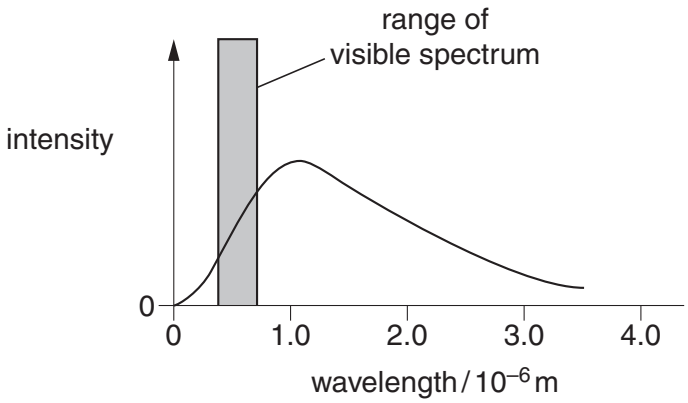


Fig. 7.1

(a) Explain what is meant by

(i) a *photon*

.....

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

(ii) a *continuous spectrum*.

.....

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

(b) **(i)** Fig. 7.1 shows that only a small percentage of the energy radiated from the filament lamp is emitted in the visible region. The majority of the energy is emitted in other regions of the electromagnetic spectrum.

1 State the region of the spectrum in which most of the radiation from the lamp is emitted.

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

2 State a simple observation which is evidence for your answer to **1**.

.....

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

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(ii) The 12V filament lamp emits 24W of power as electromagnetic waves. Only 5.0% of this power is converted into photons of visible light of average energy 4.0×10^{-19} J.

Estimate the number of these visible photons emitted from the filament per second.

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

(c) The light from the filament is viewed through a diffraction grating, having 300 lines per millimetre. The continuous first order spectrum appears between angles θ of 7° and 12° to the direction of the incident light. See Fig. 7.2.

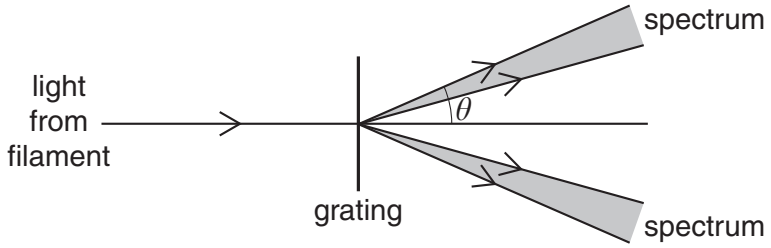


Fig. 7.2

(i) State the colour of the light that is seen at the angle of

7° .....

12° ..... **[2]**

(ii) Calculate the angle at which green light of wavelength 5.4×10^{-7} m is observed in this first order spectrum.

angle = ... ° **[3]**

[Total: 12]

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8 Fig. 8.1 shows some energy levels of the hydrogen atom. The diagram is not to scale.

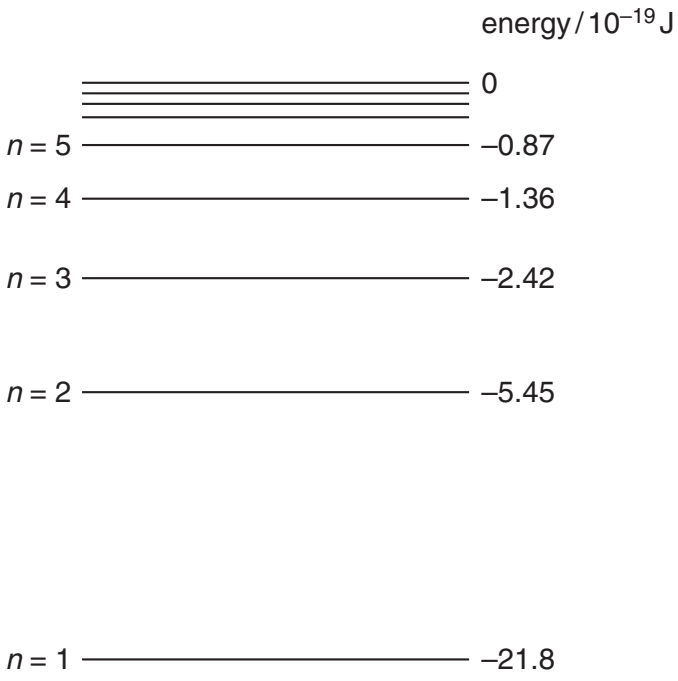


Fig. 8.1

The energy level corresponding to the lowest energy (ground) state of the atom is $n = 1$.

The hydrogen atom is ionised when it absorbs sufficient energy for the electron to escape from the proton; that is, for the energy labelled on Fig. 8.1 to become zero or positive.

(a) (i) Draw an arrowed line on Fig. 8.1 to indicate the process of ionisation of an atom initially in its ground state. **[1]**

(ii) Write down the value of the minimum energy required to ionise an atom in its ground state.

minimum energy = ... J **[1]**

(b) (i) Show that the energy change between levels required for the emission of a photon of wavelength 490 nm is about 4×10^{-19} J.

[2]

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(ii) Draw an arrowed line on Fig. 8.1 to indicate the transition which results in the emission of a photon of wavelength 490 nm. **[1]**

(c) In space, a beam of photons of different energies passes through a cloud of atomic hydrogen gas. Explain, with a reason, what is likely to happen to photons of energy 19.38×10^{-19} J and to some of the hydrogen atoms.

.....

.....

.....

.....

.....

.....

.....

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

[Total: 8]

END OF QUESTION PAPER

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ADDITIONAL PAGE

If additional space is required, you should use the lined pages below. The question number(s) must be clearly shown.

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GCE

Physics A

Advanced Subsidiary GCE

Unit **G482:** Electrons, Waves and Photons

Mark Scheme for January 2011

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Question			Expected Answers	M	Additional Guidance
1	a		use of $R = \rho l/A$ $= 2.4 \times 12 \times 10^{-3}/9.0 \times 10^{-6}$ $= 3.2 \times 10^{3}$ (Ω)	C1 M1 A0	
	b		$V^2 = PR$ $= 0.125 \times 3.2 \times 10^{3}$ V = 20(V)	C1 M1 A0	**allow** $V = \sqrt{(0.125 \times 3.2 \times 10^{3})}$ **allow** substituting V = 20 to prove P = 0.125 W
	c	i	adding resistors in series and then in parallel to show that total resistance is 3.2 kΩ	B1 B1	**do not allow** any reference to values of V or P, etc in answer
		ii	p.d across each resistor is 20 V so power dissipated is 0.125 W	B1 B1	**accept** $P = 40^2/3.2\text{ k} = 0.50$ W so P per resistor = 0.50/4 = 0.125 W **do not accept** P_{total} = 0.50 W without proof – scores zero
	d	i	using $R_X = \rho l/A$; $A \rightarrow 4A$ and $l \rightarrow 2l$ $R_Y = \rho 2l/4A = \rho l/2A = R_X/2$	M1 A1	**accept** figures 24×10^{-3} m and 36×10^{-6} m^2 to give 1.6×10^{3} Ω
		ii	same current in X and Y (as in series) power dissipated is I^2R **or** IV where $V_X = 2V_Y$ so X has larger P (dissipation)	B1 M1 A1	**allow** $P = V^2/R$; $V_X = 2V_Y$ etc. **allow** 1 mark only for using $P = V^2/R$ or IV and V is larger across X (i.e. not quantitative) so X has larger P
			Total question 1	**13**	

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Question			Expected Answers	M	Additional Guidance
2	a	i	ions	B1	
		ii	positive ions	B1	**allow** positive charges / cations
		iii	electrons	B1	
	b	i	the battery has an internal resistance/AW some of the emf is across the (internal) resistance (leaving a smaller p.d. across motor)	B1 B1	**accept** connecting leads have resistance **accept** V = E - Ir or 'lost volts'/p.d. across r
		ii	use E = V + Ir giving 12 = 8 + 40r r = (12 – 8)/40 **or** 4/40 = 0.10 Ω	C1 M1 M1 A0	**accept** reverse solution, 0.10 Ω → 8 V→ 12 V substitution and or solution showing working
		iii	Q = It = 40 x 1.2 I= 48 (C)	C1 A1	
	c	i	The current heats the filament The resistance/resistivity (of the metal filament) increases (with temperature). .	B1 B1	no mention of temperature increase or heating scores zero
		ii	4.5 to 8 A in each (parallel) arm **or** 9 to 16 A for both together needs to be great enough to cover initial surge/current **or** use antisurge fuses	B1 B1	no mark if fuse value outside range
		iii	e.g. the starter motor draws 40 A so would need a bigger fuse than headlamp circuit so need different fuses for different situations **or** if battery used for starter motor with lights on will need too large a fuse – damage occurs before fuse blows/AW	B1	**accept** headlamp circuit damaged before fuse blows if 40 A fuse only used **or** fuse blows in starter circuit if 10 A used, etc.
			Total question 2	**15**	

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Question			Expected Answers	M	Additional Guidance
3					
	a	i	V J C^{-1} R V A^{-1} P J s^{-1} I C s^{-1}.	B1 B1 B1	4 correct 3 marks; 2 correct 2 marks 1 correct 1 mark
	b	i	using $V_{out} = R_2/(R_1 + R_2)\ V_{in}$: **alt:** 2.4 = I x 560 V_{out} = 3.6 V so I = 4.3 mA 3.6 = R_2/(560 + R_2) 6 3.6 = I R_2 R_2 = 840 (Ω)	C1 C1 A1	 **accept** R_2 = (3.6/2.4) x 560 or .2.4 = 560/(560 + R_2) 6
		ii	I = 4.3 x 10^{-3} (A)	B1	**accept** 4.3 m(A) or 3/700 (A) **ecf (b)(i)** i.e. I = 6/(560 + R_2)
	c	i	20 ± 2 (^{o}C)	B1	
		ii	R_{Th} will fall/ resistance will fall giving greater share of supply V across fixed R/AW causing the voltage across (fixed) R/voltmeter reading to rise	B1 B1 B1	 **accept** explanation in terms of potential divider equation **or** current increases **or** current same in both resistors/resistors in series
		iii	ΔR is large for small ΔT at low temperatures/AW in terms of gradient so thermistor is better in circuit to control low temp, refrigerator	M2 A1	**accept** sensitivity greater at low temperature **or** vice versa **or** ΔR is small for small ΔT at high temperatures scores 1 out of 2
			Total question 3	**14**	

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Question			Expected Answers	M	Additional Guidance
4					
	a		same frequency / period different amplitude / phase	B1 B1	**accept** wavelength / sinusoidal /AW **accept** + sine and – sine for 2 marks
	b		because the waves have a <u>constant</u> phase relationship **or** are <u>continuous</u> and have the <u>same</u> f/period/λ they are coherent	M1 A1	**accept** same phase relationship for 1 mark only
	c		use of 3 ms as period $f = 1/3.0 \times 10^{-3} = 330$ (Hz) using $v = f\lambda$ $340 = 330\ \lambda$ $\lambda = 1.0(2)$ (m)	C1 A1 C1 A1	 **ecf** for f possible e.g. λ = 1020 (m) **accept** 1.03 (m) **no** SF error here
	d	i	0	B1	
		ii	1.0 (μm)	B1	**look for** SF error i.e. zero for 1 (μm)
	e	i	Intensity α (amplitude)^2 so ratio is $(3/2)^2 = 9/4$ (giving 2.25 I)	C1 A1	**allow** I α A^2
		ii	resultant $A = A_S + A_T = (\pm)\ 1$ so ratio is $(1/2)^2$ giving 0.25 I	C1 A1	**ecf** from **(d)(ii)**
	f	i	phase shift of π or 180° required **or** movement of λ/2 1.02/2 = 0.51 (m)	B1 B1	**ecf** from **(c)**; **accept** (2n + 1)/2 λ **accept** 0.50 m
		ii	intensity increases to the maximum value	B1 B1	**accept** quantitative answers, i.e. from 0.25 I to 6.25 I
			Total question 4	**18**	

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Question			Expected Answers	M	Additional Guidance
5					
	a	i	(sum of/total) current into a junction equals the (sum of/total) current out conservation of charge	B1 B1	total vector sum of currents is zero
		ii	(sum of) e.m.f.s = (sum /total of) p.d.s/sum of voltages in/around a (closed) loop (in a circuit) energy is conserved	B1 B1	
	b		a photon is absorbed by an electron (in a metal surface); causing electron to be emitted (from surface). Energy is conserved (in the interaction).	B1 B1 B1	**not** hits QWC mark
			Only photons with energy/frequency above the work function energy/threshold frequency will cause emission Reference to Einstein's photoelectric energy equation (energy of photon) = (work function of metal) + (maximum possible kinetic energy of emitted electron) work function energy is the <u>minimum</u> energy to release an electron from the surface Number of electrons emitted also depends on light intensity Emission is instantaneous	B1 B2 B1 B1 B1	3 marks from 6 marking points in symbols only scores 1 mark out of 2, i.e. selects from formula sheet
			Total question 5	**10**	

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Question			Expected Answers	M	Additional Guidance
6					
	a		an eV is the <u>energy</u> acquired by an electron accelerated/moves through a p.d. of 1 V 1 eV = 1.6×10^{-19} J	B1 B1	
	b	i	300 (eV) 4.8×10^{-17} (J)	B1 B1	1 mark if write correct answers on wrong lines **ecf** for (first answer) x 1.6×10^{-19} e.g. 7.68×10^{-36} using 4.8×10^{-17}
		ii	$½mv^2 = 4.8 \times 10^{-17} \Rightarrow v^2 = 9.6 \times 10^{-17} / 9.1 \times 10^{-31}$ (= 1.06×10^{14}) $v = 1.03 \times 10^7$ (m s^{-1})	M1 A1	**allow** 1 mark only for $v^2 = 2 \times$ **b(i)**/ 9.1×10^{-31} if **b(i)** incorrect **allow** 1.0×10^7, 1×10^7 is not acceptable
	c	i	Electrons are observed to behave as waves/show wavelike properties where the electron wavelength depends on its speed/momentum	B1 B1	**accept** by being diffracted (by a crystal lattice)/AW **accept** de Broglie eqn with m,v or p defined
		ii	$\lambda = h/mv = 6.63 \times 10^{-34} / (9.1 \times 10^{-31} \times 1.03 \times 10^7)$ $= 7.1 \times 10^{-11}$ (m)	C1 A1	**allow** 1 mark for 3.9 or 4.0×10^{-14} (m) caused by subs m_p for m **allow** 7.3×10^{-11} (m)
			Total question 6	**10**	

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Question			Expected Answers	M	Additional Guidance
7					
	a	i	a quantum/lump/unit/packet/particle of (e-m) energy/light	B1	
		ii	all wavelengths/frequencies are present (in the radiation)/AW	B1	**accept** colours
	b	i	**1** infra red **2** the bulb of the lamp is **hot**	B1 B1	
		ii	5/100 x 24 = 1.2 W n = 1.2/4 x 10^{-19} = 3.0 x 10^{18}	C1 C1 A1	**allow** 2 marks if forgotten 5% and obtain 6 x 10^{19} allow 3 x 10^{18} – no SF as estimate
	c	i	7° violet/blue 12° red	B1 B1	**not** purple
		ii	d = 1/3 x 10^{5} = 3.3 x 10^{-6} m sin θ = λ/d = 5.4 x 10^{-7}/3.3 x 10^{-6} (= 0.162) θ = 9.3^{o} or 9.4^{o} do not accept 9°	B1 M1 A1	with d = 3 x 10^{-6} m θ = 10.4^{o} give 2 out of 3 **ecf** incorrect value of d substituted correctly, scores 1 out of 3
			Total question 7	**12**	

Question			Expected Answers	M	Additional Guidance
8					
	a	i	vertical arrow upwards from ground state to zero level or above	B1	
		ii	21.8 x 10^{-19} (J)	B1	**no ecf** from (i); ignore sign
	b	i	E = hc/ λ = 6.63 x 10^{-34} x 3.0 x 10^{8}/4.9 x 10^{-7} = 4.06 x 10^{-19} (J) **or** 4.1 x 10^{-19} (J)	M1 A1	**accept** use of 6.6 instead of 6.63 which can round down answer to 4.0(4)
		ii	vertical arrow downwards between n = 4 to n = 2 levels	B1	
	c		some photons will be absorbed hydrogen atoms become excited (excited) hydrogen atoms re-emit photons the photon energy is equal to the transition n = 1 to n = 3	B1 B1 B1 B2	**not** hits **allow** electron moves up energy levels **NB** full marks = lines 1 + 4 or 1 + 2 + 3
			Total question 8	**8**	

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ADVANCED SUBSIDIARY GCE
PHYSICS A
Electrons, Waves and Photons

G482

Candidates answer on the Question Paper

OCR Supplied Materials:
- Data, Formulae and Relationships Booklet

Other Materials Required:
- Electronic calculator

Wednesday 9 June 2010
Morning

Duration: 1 hour 45 minutes

OCE/23017

G4832

Candidate Forename		Candidate Surname	

Centre Number						Candidate Number				

INSTRUCTIONS TO CANDIDATES

- Write your name clearly in capital letters, your Centre Number and Candidate Number in the boxes above.
- Use black ink. Pencil may be used for graphs and diagrams only.
- Read each question carefully and make sure that you know what you have to do before starting your answer.
- Answer **all** the questions.
- Do **not** write in the bar codes.
- Write your answer to each question in the space provided. If additional space is required, you should use the lined pages at the end of this booklet. The question number(s) must be clearly shown.

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)** State the difference between the directions of conventional current and electron flow.

.....

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

(b) Circle one or more of the combinations of units which could act as a unit for current.

J s C s^{-1} $\text{V}\Omega^{-1}$ J C^{-1}

[2]

(c) Fig. 1.1 shows a current I in a thick metal wire **X** connected to a longer thinner wire **Y** of the same metal as shown in Fig. 1.1.

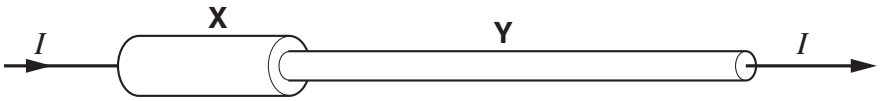


Fig. 1.1

(i) State why the current in **Y** must also be I.

.....

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

(ii) Wire **Y** has half the cross-sectional area of the thicker wire **X** and is three times as long.

The resistance R_X of **X** is $12.0\,\Omega$.

1 Show that the resistance R_Y of **Y** is $72\,\Omega$.

2 Calculate the total resistance R of both wires.

$R =$ ..... Ω **[4]**

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(iii) The mean drift velocity v_X of electrons in **X** is $2.0 \times 10^{-5}\,m\,s^{-1}$.

Use the fact that **X** has twice the cross-sectional area of the thinner wire **Y** to calculate the mean drift velocity v_Y of electrons in **Y**. Show your working.

v_Y = ... $m\,s^{-1}$ **[2]**

[Total: 10]

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2 **(a)** Two filament lamps are described as being 230 V, 25 W and 230 V, 60 W.

(i) Describe what is meant by '230 V, 25 W' for a lamp.

.....

.....

.....

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

(ii) Calculate the resistance of the 25 W lamp when connected to a 230 V supply.

resistance = ... Ω **[2]**

(iii) Each of the two lamps is connected across a 230 V supply. Explain which lamp has the greater current.

.....

.....

.....

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

(iv) Both lamps are connected in parallel across the 230 V supply. The resistance of the 60 W lamp in the circuit is 880 Ω. Calculate

1 the total resistance R across the supply

R = ... Ω

2 the current I drawn from the supply.

I = ... A **[4]**

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(b) The 60W filament lamp is connected to a 6.0V battery. The resistance of the lamp in this circuit is 70Ω. Explain why this value differs from the value given in **(a)(iv)** when the lamp is connected to the 230V supply.



In your answer, you should make clear how your explanation links with the observations.

.....

.....

.....

.....

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

(c) By mistake a householder leaves a 60W filament lamp switched on overnight for a period of 8.0 hours.

The cost of 1.0 kilowatt-hour of electricity is 21 pence.

(i) Define the *kilowatt-hour* (kWh).

.....

.....

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

(ii) Calculate the cost of this mistake to the householder.

cost = ... pence **[2]**

[Total: 15]

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3 **(a)** A student wishes to determine the power dissipated in a variable resistor connected to a cell.

(i) Part of the circuit for this experiment is shown in Fig. 3.1. Complete the circuit of Fig. 3.1 showing how the variable resistor is connected and how the potential difference across it is measured. **[3]**

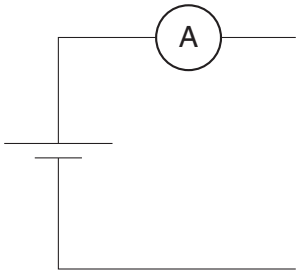


Fig. 3.1

(ii) Fig. 3.2 shows the variation of the potential difference V across the variable resistor with the current I in it.

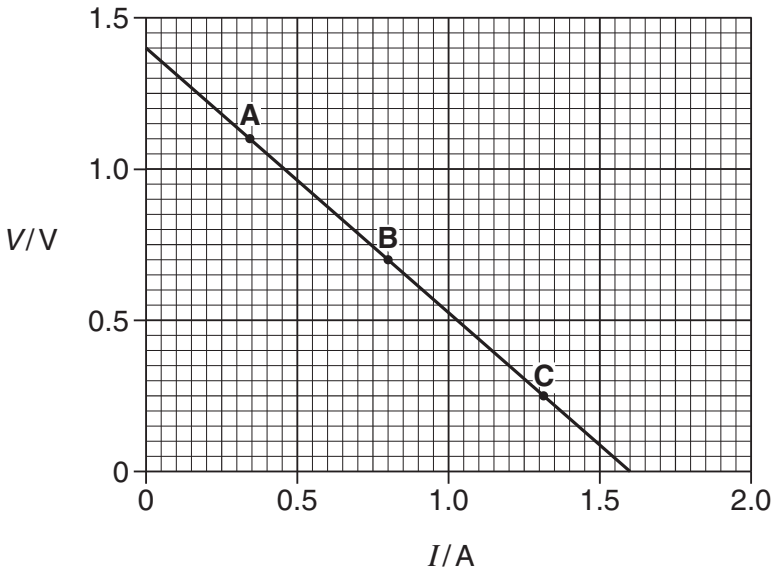


Fig. 3.2

1 The potential difference V across the variable resistor is also the terminal p.d. across the cell. Describe how the potential difference across the cell varies with the **resistance** R of the variable resistor. Suggest why the terminal p.d. varies in this way.

.....

.....

.....

.....

.....

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

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2 By referring to the points **A** and **C**, justify that the power dissipated in the variable resistor is a maximum at or near point **B**.

.....

.....

.....

.....

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

3 Determine the e.m.f. E of the cell.

E = ... V **[1]**

4 Calculate the internal resistance r of the cell.

r = ... Ω **[2]**

(b) In Fig. 3.1, the cell is replaced by a solar cell as the source of e.m.f.
A solar cell transforms light energy into electrical energy. The maximum intensity of sunlight on the solar cell is $800\,W\,m^{-2}$. The surface area of the cell is $2.5 \times 10^{-3}\,m^2$.

(i) Define the term *intensity*.

.....

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

(ii) The maximum power delivered by the solar cell to the variable resistor is 0.25 W. Determine the maximum efficiency of the solar cell.

maximum efficiency = ... **[3]**

[Total: 16]

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4 Fig. 4.1 shows how the resistance of a light-dependent resistor (LDR) varies with the intensity of the light incident on it.

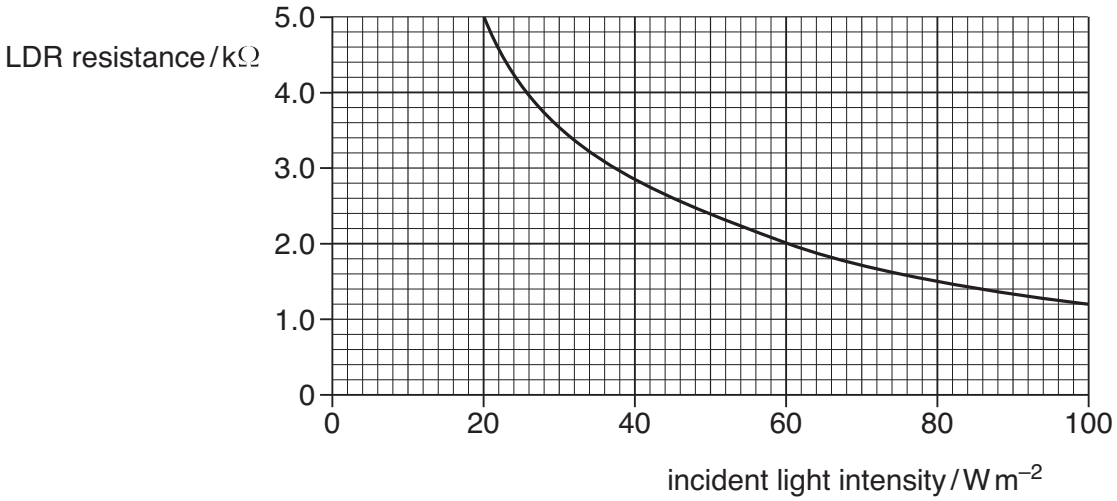


Fig. 4.1

(a) State how the resistance of the LDR changes with light intensity.

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

(b) Fig. 4.2 shows a light-sensing potential divider circuit where the LDR is connected in parallel to a voltmeter and data-logger.

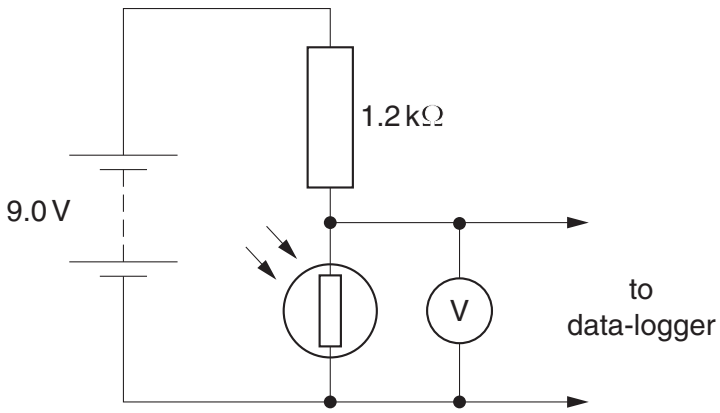


Fig. 4.2

The battery has an e.m.f. of 9.0 V and negligible internal resistance. The 1.2 kΩ resistor is made of carbon. The potential difference across the LDR is 6.0 V.

(i) State the potential difference across the 1.2 kΩ resistor.

potential difference = ... V **[1]**

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(ii) Calculate the resistance R of the LDR.

R = ... kΩ **[3]**

(iii) Use Fig. 4.1 to determine the light intensity when the p.d. across the LDR is 6.0 V.

light intensity = ... $W\,m^{-2}$ **[1]**

(c) (i) Fig. 4.1 shows that the change in resistance when the light intensity rises from $60\,W\,m^{-2}$ to $80\,W\,m^{-2}$ is 0.5 kΩ. State the change in resistance when the light intensity rises from $20\,W\,m^{-2}$ to $40\,W\,m^{-2}$.

change in resistance = ... kΩ **[1]**

(ii) Larger changes in data-logger voltage are observed for changes at low light intensity rather than at high light intensity. Explain this.

.....

.....

.....

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

(d) When the circuit of Fig. 4.2 is operated for a long time, the carbon resistor becomes hot. The resistivity of carbon falls as the temperature rises. State and explain the effect on the potential difference across the LDR.

.....

.....

.....

.....

.....

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

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(e) Describe briefly **two** advantages of using a data-logger to monitor the variation of light intensity falling on the LDR.

.....

.....

.....

.....

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

[Total: 14]

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5 **(a)** Name one common property of electromagnetic waves not shared by other waves.

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

(b) Fig. 5.1 shows a block diagram of the seven regions of the electromagnetic spectrum, labelled **A** to **G**.

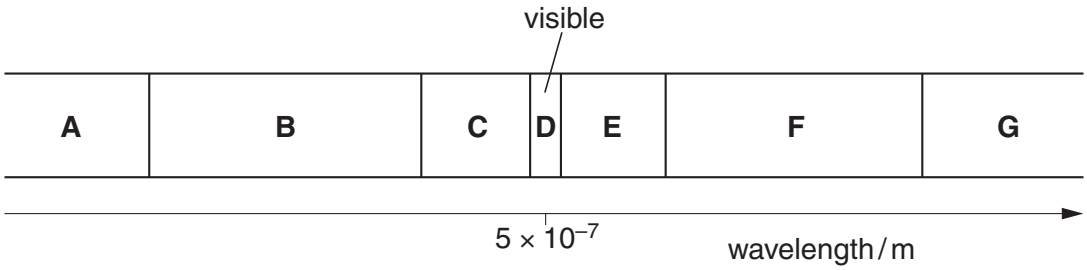


Fig. 5.1

Name the principal radiation in each of the regions **A**, **C** and **F**.

A ..... **C** .....

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

(c) An aerial mounted vertically transmits vertically polarised radio waves of frequency 1.0×10^9 Hz. The waves are detected by a receiving aerial some distance away. Initially the receiving aerial is also mounted vertically as shown in Fig. 5.2.

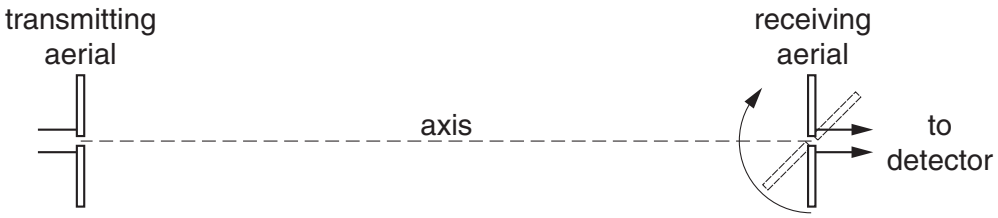


Fig. 5.2

The length of each aerial is half the wavelength of the radio waves.

(i) Calculate the wavelength of the waves.

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

(ii) Calculate the length of an aerial.

length = ... m **[1]**

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(iii) The receiving aerial is rotated through 180° about the axis joining the centres of the two aerials. See Fig. 5.2. Describe and explain how the output signal from the receiving aerial changes with the angle of rotation.

.....

.....

.....

.....

.....

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

(d) Ultra-violet radiation from the Sun is often divided into three regions UV-A, UV-B and UV-C.

(i) Describe the characteristics and dangers of UV-A, UV-B and UV-C radiations.

.....

.....

.....

.....

.....

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

(ii) Explain how sunscreen protects the human skin.

.....

.....

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

(e) Explain why electrons can be emitted from a clean metal surface illuminated with bright ultra-violet light but never when infra-red light is used, however intense.

.....

.....

.....

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

[Total: 16]

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6 **(a)** Describe, in terms of vibrations, the difference between a longitudinal and a transverse wave. Give one example of each wave.

.....

.....

.....

.....

.....

.....

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

(b) Fig. 6.1 shows a loudspeaker fixed near the end of a tube of length 0.6 m.

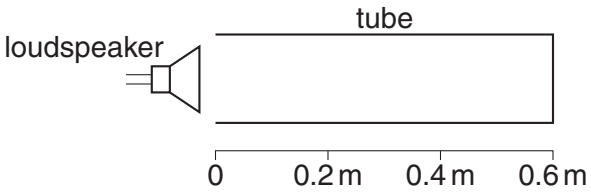


Fig. 6.1

The far end of the tube is closed. The frequency of the sound emitted from the loudspeaker is increased from zero. At a particular frequency a stationary wave is set up in the tube and the sound heard is much louder.

Explain how a stationary wave is formed in the tube.

In your answer, you should make clear how the stationary wave arises.

.....

.....

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.....

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.....

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

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(c) Figs. 6.2 and 6.3 show stationary wave patterns of amplitude against position along the tube at the fundamental frequency f_0 and the next possible harmonic at frequency $3f_0$.

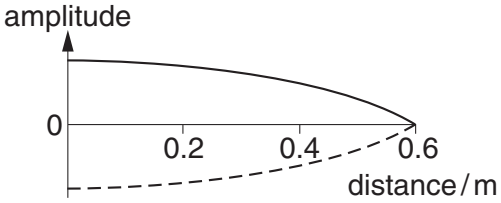


Fig. 6.2

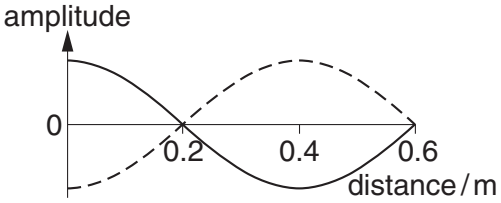


Fig. 6.3

Describe the motion of the air in the tube containing the stationary wave

(i) at points 0 m, 0.2 m and 0.6 m in Fig. 6.2

.....

.....

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

(ii) at points 0 m, 0.2 m and 0.4 m in Fig. 6.3.

.....

.....

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

(d) The end of the tube at 0.6 m from the loudspeaker is now opened.

(i) On Fig. 6.4 sketch the stationary wave pattern of amplitude against position along the tube at the new fundamental frequency. **[2]**

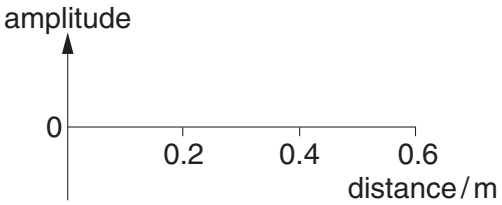


Fig. 6.4

(ii) State how the frequency of this stationary wave is related to the frequency f_0 of Fig. 6.2.

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

[Total: 14]

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7 **(a)** When a glowing gas discharge tube is viewed through a diffraction grating an emission line spectrum is observed.

(i) Explain what is meant by a *line spectrum*.

.....

.....

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

(ii) Describe how an absorption line spectrum differs from an emission line spectrum.

.....

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

(b) A fluorescent tube used for commercial lighting contains excited mercury atoms. Two bright lines in the visible spectrum of mercury are at wavelengths 436 nm and 546 nm.

$1\,\text{nm} = 10^{-9}\,\text{m}$

Calculate

(i) the energy of a photon of violet light of wavelength 436 nm

energy = ... J **[3]**

(ii) the energy of a photon of green light of wavelength 546 nm.

energy = ... J **[1]**

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(c) Electron transitions between the three levels **A**, **B** and **C** in the energy level diagram for a mercury atom (Fig. 7.1) produce photons at 436 nm and 546 nm. The energy E of an electron bound to an atom is negative. The ionisation level, not shown on the diagram, defines the zero of the vertical energy scale.

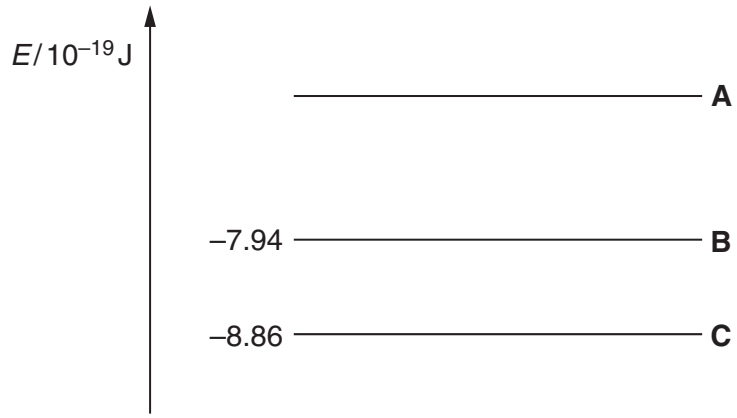


Fig. 7.1

(i) Draw two arrows on Fig. 7.1 to represent the transitions which give rise to these photons. Label each arrow with its emitted photon wavelength. **[3]**

(ii) Use your values for the energy of the photons from **(b)** to calculate the value of the energy level **A**.

E = ... J **[2]**

(d) The light from a distant fluorescent tube is viewed through a diffraction grating aligned so that the tube and the lines on the grating are parallel. The light from the tube is incident as a parallel beam at right angles to the diffraction grating.

The line separation on the grating is 3.3×10^{-6} m.

Calculate the angle to the straight through direction of the first order green (546 nm) image of the tube seen through the grating.

angle = ... ° **[3]**

[Total: 15]

END OF QUESTION PAPER

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ADDITIONAL PAGE

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ADDITIONAL PAGE

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GCE

Physics A

Advanced Subsidiary GCE **G482/01**

Electrons, Waves and Photons

Mark Scheme for June 2010

Oxford Cambridge and RSA Examinations

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Question			Expected Answers	M	Additional Guidance
1					
	a		current moves from + to – (of battery in circuit) **and** electrons move from – to +	B1	
	b		$C\ s^{-1}$ $V\ \Omega^{-1}$	B1 B1	2 correct 2 marks; 1 correct 1 mark, withhold a mark for each additional answer given
	c	i	statement of Kirchhoff's first law or conservation of charge	B1	**accept** wires are in series or current is the same (at every point) in a series circuit/AW **not** current in = current out
		ii1	R = ρl/A calculation to justify R = 72 Ω	B1 A1	accept R α l and R α 1/A **or** similar method/argument must be convincing **accept** 3/½ x12 but **not** 3 x 2 x 12
		ii2	R = sum of Rs R = 84 Ω	C1 A1	**accept** Rs in series **ecf (c)(ii)1**
		iii	select I = nAev $v = 4.0 \times 10^{-5}$ (m s^{-1})	B1 B1	**allow** v α 1/A **accept** 4×10^{-5} (m s^{-1}) **no** SF error
			Total question 1	**10**	

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Question			Expected Answers	M	Additional Guidance
2					
	a	i	When connected/using/AW to the 230 V supply the power/energy per second from supply/output/dissipated/AW is 25 W	B1 B1	**accept** when working normally/AW **not** 230 V (going) through/into lamp/AW **accept** transferred from electrical (into other) form(s) is 25 W
		ii	$25 = 230^2/R$ R = 2100 Ω **or** 2.1 kΩ	C1 A1	**accept** I = 25/230 = 0.11 A R = 230/0.11 = 2100 Ω (2116 Ω)
		iii	Using the equation in the form P = VI, for larger P need larger I so 60 W	M1 A1	accept $P = V^2/R$, for larger P need smaller R so larger I; do **not** allow any argument using 880 Ω unless this value is calculated here
		iv1	1/R = 1/2100 + 1/880 R = 620 Ω	C1 A1	substitution into formula for Rs in parallel **ecf (a)(ii)**
		iv2	I = 230/620 I = 0.37 (A)	C1 A1	**ecf (a)(iv)1** using 1/R gives 143 kA accept total P = 85 W so I = 85/230 ;= 0.37 (A)
	b		the resistivity/resistance (of a metal) increases with temperature **or** R is greater when hot(ter) at 6V/low I little heating effect **or** at 230 V/high I large heating effect	B1 A1	**ora** less when colder **QWC mark**: explanation linked to observations
	c	i	(a unit of) energy equal to 3.6 MJ **or** 1 kW for 1 h/AW	B1	**eg** 1000 W for 3600 s or similar
		ii	0.06 x 8 = 0.48 (kWh) or 60 x 8 = 480 (Wh) 0.48 x 21 = 10(.1) p	C1 A1	no marks for using s instead of h POT error e.g. 100 or 10000 p
			Total question 2	**15**	

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Question			Expected Answers	M	Additional Guidance
3					
	a	i	correct symbols (variable) R in series with ammeter and cell voltmeter correctly in parallel with variable R	B1 B1 B1	variable R and voltmeter needed **ecf** variable resistor symbol **accept** voltmeter in parallel with cell
		ii1	V decreases as I increases caused by R decreasing V is large when R is large **or** V is small when R is small V = e.m.f. when R is infinite/open circuit **or** V = 0 when R = 0 3.14 Ω at A; 0.88 Ω at B and 0.19 Ω at C any correct reference to internal resistance of cell	B1 B1 B1	**max 3 marks** with 2 marks for first two or second two marking points or three numbers and 1 mark for reference to r **allow** as R increases (decreases) V increases (decreases) for 1 mark but **not** as V increases R increases; **award 0/2** if reason given as V α R or I is constant
		ii2	at A I is small or V is much bigger than I/AW at C V is small or I is much bigger than V/AW product of V. and I is largest when the values of both quantities are about equal/half of the maximum value	B1 B1 B1	**accept** numerical answers, e.g. 0.39 W at A, 0.33 W at C 0.56 W at B for 2 marks comment on values for third mark
		ii3	1.4 (V)	B1	
		ii4	appreciating V against I is a straight line graph with gradient –r; giving r = 0.88 ± 0.02 Ω	C1 A1	**accept** using V = E – Ir **not** just quoting formula **allow** 0.8 ± 0.02 for calculation using any point on line N.B. can also have **ecf(ii)3**
	b	i	intensity is the (incident) energy <u>per</u> unit area <u>per</u> second	B1	**accept** power per unit area or power per m^2 or (total) power/(surface) area
		ii	efficiency = power out/power in = 0.25/(800 x 2.5 x 10^{-3}) = 0.125 or 12.5%	C1 C1 A1	**not** energy out/energy in **accept** 13%
			Total question 3	**16**	

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Question			Expected Answers	M	Additional Guidance
4					
	a		resistance decreases with increase in light intensity	B1	**ora**
	b	i	3.0 (V)	B1	**accept** 3 V, no SF error
		ii	3.0 = I.1.2 x 10^{3} giving I = 2.5 x 10^{-3} A 6.0 /2.5 10^{-3} = R = 2400 Ω 2.4 kΩ	C1 C1 A1	**accept** 6 = (R/ R + 1.2 k).9 2R + 2.4 k = 3R or similar R = 2.4 k ;**give** 2 with POT error **accept** ratio of resistors 6/3 x 1.2 good candidates can do this by inspection with no working – full marks **allow** 2400 written on answer line rather than 2.4 if 2400 Ω within body of text
		iii	49 **or** 50 (W m^{-2})	B1	**ecf (b)(ii)** if on R within graph range
	c	i	2.2 (kΩ)	B1	**allow** any value from 2.1 to 2.2
		ii	large(r) changes in R at low light intensities relating change in R to change in V	B1 B1	**allow** greater sensitivity of LDR at low light **or** steeper gradient/AW **e.g.** bigger change in I so in V **or** use of V = R/(R + 1200) V_s **or** bigger change in V ratio across Rs
	d		V across 1.2 kΩ falls so V across LDR rises because ratio of Rs changes in favour of LDR/ potential divider argument **or** total V is constant	B1 B1 B1	**alternative** I increases because total R is less so V across LDR rises do **not** award B marks where there is CON e.g. V across 1.2 k rises so V across LDR rises
	e		continuous record for very long time scale of observation can record very short time scale signals (at intervals) automatic recording/remote sensing data can be fed directly to computer (for analysis)	B1 B1	**allow** any two sensible suggestions which fall within the 4 categories listed for 2 marks
			Total question 4	**14**	

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Question			Expected Answers	M	Additional Guidance
5					
	a	i	travel through a vacuum	B1	**allow** travel at c (in a vacuum)
	b	ii	A gamma; C uv; F microwave	B3	**allow** 1 mark for A radio; C ir; F X-ray
	c	i	$3.0 \times 10^8 = 1.0 \times 10^9 \lambda$ $\lambda = 0.30$ m	C1 A1	 **allow** 0.3 no SF error
		ii	aerial length = $\lambda/2 = 0.15$ m	A1	**ecf (c)(i)**
		iii	emitted wave is (plane) polarised detecting aerial will receive weaker signal/cos θ component when it is rotated (through angle θ)/AW signal falls to zero at 90° and then rises to max again at 180°	B1 B1 B1 	**allow** max signal initially/at 0° **max 3 marks** from 4 marking points
	d	i	UV-A causes tanning or skin ageing ; most of (99%) uv light; 400-315 nm UV-B causes damage or sunburn or skin cancer; 315-260 nm UV-C is filtered out by atmosphere/ozone layer; 260-100 nm	B1 B1 B1	accept values within ranges with tolerance of 20 nm **allow** $\lambda_A > \lambda_B > \lambda_C$ for 1 mark **max 3 marks** from 7 marking points
		ii	filters out/blocks/reflects/absorbs UV(-B)	B1	**allow** chemicals prevent sunburn/skin cancer **not** stops UV penetrating skin
	e		energy of the infra-red photon is less than the work function of the metal surface	B1 B1	**accept** frequency and threshold frequency **or** wavelength and threshold wavelength used correctly in place of energy and work function **1 mark** only: energy of the uv photon greater than work function with no mention of ir
			Total question 5	**16**	

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Question			Expected Answers	M	Additional Guidance
6					
	a		oscillation/vibration of <u>particles/medium</u> in direction of travel of the wave example: sound wave, etc. oscillation/vibration of <u>particles/medium</u> (in the plane) at right angles to direction of travel of the wave example: surface water waves, string, electromagnetic, etc	B1 B1 B1 B1	**allow** direction of energy transfer of the wave **not** direction of wave motion **allow** direction of energy transfer of the wave **allow** RE mark for weaker descriptions with same omissions as in longitudinal wave
	b		the incident wave is reflected at the end of the pipe <u>reflected</u> wave <u>interferes/superposes</u> with the incident wave to produce (a resultant wave with) nodes and/or antinodes	B1 B1 B1	 **QWC mark** **accept** resultant wave with no energy transfer
	c	i	at 0 oscillation with max amplitude along tube at 0.2 m (oscillation along tube with) smaller amplitude at 0.6 m no motion/node	B1 B1 	**not** displacement (penalise only once) all 4 correct for 2 marks; 2 correct for 1 mark
		ii	oscillation at 3 times the frequency of c(i) at 0 (oscillation with) max amplitude (along tube)/antinode at 0.2 m no motion/node at 0.4 m motion as at 0 (but in antiphase/opposite direction)	B1 B1 	 3 correct for 2 marks; 2 correct for 1 mark
	d	i	λ/2 sketch with zero at 0.3 m	M1 A1	**accept** 1 or 2 lines, solid or dotted
		ii	$2f_0$	B1	**no ecf from d(i)**
			Total question 6	**14**	

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Question			Expected Answers	M	Additional Guidance
7					
	a	i	light emitted from (excited isolated) atoms produces a line spectrum a series of (sharp/bright/coloured) lines against a dark background	B1 B1	**max 2 marks** from 3 marking points
		ii	in an absorption spectrum a series of dark lines (appears against a bright background/within a continuous spectrum)	B1	**accept** black
	b	i	$\varepsilon = hc/\lambda$ $= 6.63 \times 10^{-34} \times 3.00 \times 10^{8} / 436 \times 10^{-9}$ $= 4.56 \times 10^{-19}$ (J)	C1 C1 A1	**apply** SF error if all numbers not to 3+ figures 4.54 if use 6.6
		ii	3.64×10^{-19} (J)	A1	**allow** mark if repeated error from **b(i)**
	c	i	correct vertical lines; correct labels arrow(s) downwards	B1 B1 B1	**1 mark** for 1 vertical line + correct label
		ii	$-8.86 + 4.56 = -4.3 \times 10^{-19}$ (J) $-7.94 + 3.64 = -4.3 \times 10^{-19}$ (J)	B1 B1	**ecf b(i)** **do** calculation for one line only correctly scores 2 marks; give answer as 4.3×10^{-19} **or** -4.3 scores 1 mark **do** calculation for both lines and give answer as 4.3×10^{-19} **or** -4.3 scores both marks
N.B. Before marking 7d check pages 18, 19 and 20 for additional answers by scrolling down. Extra answers MUST be annotated to show that they have been seen and credited back in the relevant question when appropriate. **✓ = 1 extra mark** **x = incorrect; scores 0** **NBOD = no added value or no further action needed; scores 0** **CON = if reference is made to the additional answer in the main text and this answer contradicts the other then deduct the original mark; = if NO reference is made to the additional answer in the main text and this answer contradicts the other then do NOT change the original mark**					
	d		$(d \sin\theta = \lambda)$ $3.3 \times 10^{-6} \sin\theta = 546 \times 10^{-9}$ $\sin\theta = 0.165$ $\theta = 9.5^{o}$	C1 C1 A1	
			Total question 7	**15**	

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THIS IS A NEW SPECIFICATION

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RECOGNISING ACHIEVEMENT

ADVANCED SUBSIDIARY GCE
PHYSICS A
Electrons, Waves and Photons

G482

Candidates answer on the Question Paper

OCR Supplied Materials:
- Data, Formulae and Relationships Booklet

Other Materials Required:
- Electronic calculator

Wednesday 13 January 2010
Morning

Duration: 1 hour 45 minutes

OCE/19082

Candidate Forename		Candidate Surname	

Centre Number						Candidate Number				

INSTRUCTIONS TO CANDIDATES

- Write your name clearly in capital letters, your Centre Number and Candidate Number in the boxes above.
- Use black ink. Pencil may be used for graphs and diagrams only.
- Read each question carefully and make sure that you know what you have to do before starting your answer.
- Answer **all** the questions.
- Do **not** write in the bar codes.
- Write your answer to each question in the space provided, however additional paper may be used if necessary.

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**.
- 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.
- You may use an electronic calculator.
- You are advised to show all the steps in any calculations.
- This document consists of **20** pages. Any blank pages are indicated.

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Answer **all** the questions.

1 **(a)** A 12V 36W lamp is lit to normal brightness using a 12V car battery of negligible internal resistance. The lamp is switched on for one hour (3600 s). For the time of 1 hour, calculate

(i) the energy supplied by the battery

energy = ……..J **[2]**

(ii) the charge passing through the lamp

charge = ……unit…….**[3]**

(iii) the total number of electrons passing through the lamp.

number of electrons = …… **[2]**

(b) The wires connecting the 36W lamp to the 12V battery are made of copper. They have a cross-sectional area of 1.1×10^{-7} m^2. The current in the wire is 3.0 A. The number n of free electrons per m^3 for copper is 8.0×10^{28} m^{-3}.

(i) Describe what is meant by the term *mean drift velocity* of the electrons in the wire.

.....

.....

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

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(ii) Calculate the mean drift velocity v of the electrons in this wire.

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

[Total: 12]

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2 **(a)** Define the *resistivity* ρ of a metal wire.

.....

.....

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

(b) In the UK the National Grid is used to transmit electric power. Each pylon supports 24 cables. See Fig. 2.1. Each cable consists of 38 strands of aluminium. See Fig. 2.2.

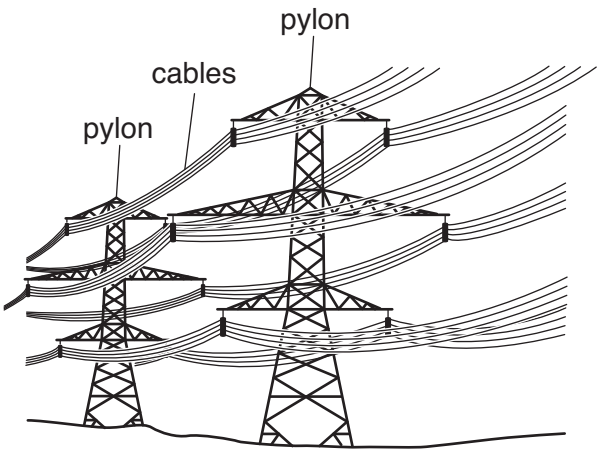


Fig. 2.1

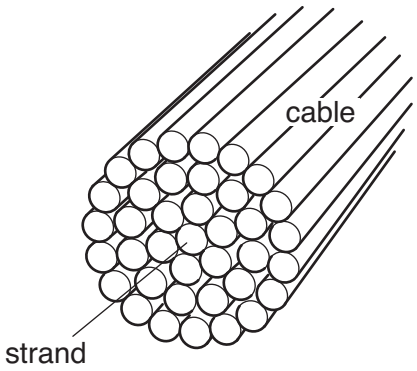


Fig. 2.2

(i) The resistance per km of a cable is 0.052 Ω km^{-1}. Explain why the resistance per km of a single strand is approximately 2.0 Ω km^{-1}.

.....

.....

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

(ii) The resistivity of aluminium is 2.6 x 10^{-8} Ω m. Calculate the cross-sectional area A of a single strand of the cable.

A = ...m^2 **[2]**

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(c) The input voltage to each cable in Fig. 2.1 is 400 kV. The cable carries a current of 440 A. Calculate

(i) the input power to one cable

input power = ...W **[2]**

(ii) the number of cables required to transmit the power from a 2000 MW power station

number of cables = ...**[1]**

(iii) the power lost as heat per km of cable

lost power = ...**[3]**

(iv) the percentage of the input power that is available at a distance of 100 km from the power station.

percentage of power =.....% **[2]**

[Total: 14]

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3 Fig. 3.1 shows a circuit containing a battery of e.m.f. 12V, two resistors, a light-dependent resistor (LDR), an ammeter and a switch **S**. The battery has negligible internal resistance.

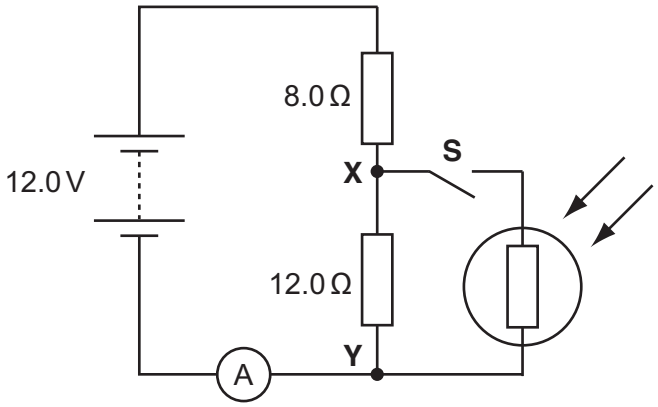


Fig. 3.1

(a) When the switch **S** is open, show that the potential difference between the points **X** and **Y** is 7.2V.

[2]

(b) The switch **S** is now closed. Describe and explain the change to each of the following when the intensity of light falling on the LDR is increased:

(i) the ammeter reading

.....

.....

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

(ii) the potential difference across **XY**.

.....

.....

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

[Total: 6]

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

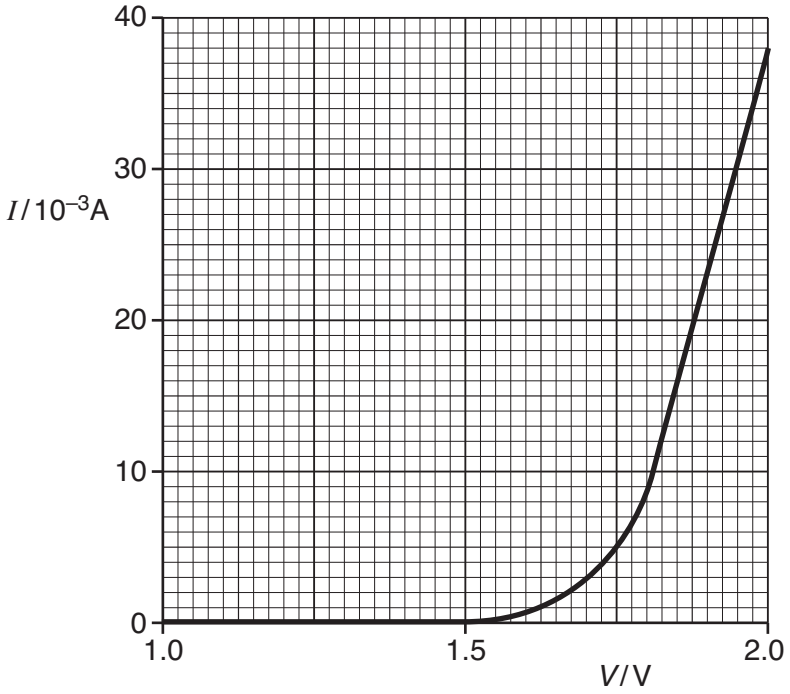


Fig. 4.1

(i) Describe the significant features of the graph in terms of current, voltage and resistance.

In your answer you should make clear how the features of the graph are related to the action of an LED.

.....

.....

.....

.....

.....

.....

.....

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

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(ii) Calculate the resistance of the LED

1 at 1.2V

resistance = ... Ω **[1]**

2 at 1.9V.

resistance = ... Ω **[2]**

(b) In order to carry out an investigation to determine the *I*-*V* characteristic of an LED a student connects the circuit shown in Fig. 4.2.

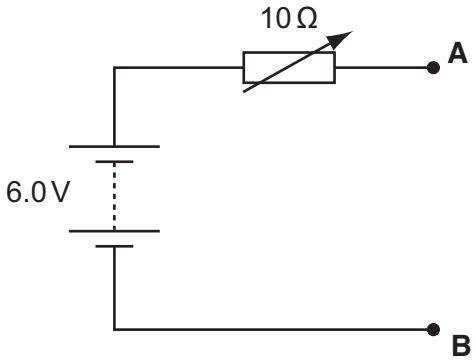


Fig. 4.2

On Fig. 4.2 add an LED with a 100 Ω resistor in series, an ammeter and a voltmeter to complete the circuit between terminals **A** and **B**. **[3]**

(c) When designing a circuit which includes an LED, it is normal practice to connect a resistor in series with the LED, in this case 100 Ω. Suggest and explain the purpose of this resistor.

.....

.....

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

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(d) Another student uses the 10 Ω variable resistor as a potentiometer (potential divider) as shown in Fig. 4.3. The rest of the circuit is then completed between terminals **A** and **B** as for Fig. 4.2 in **(b)**.

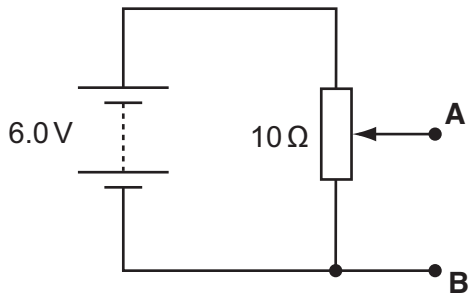


Fig. 4.3

Explain why the circuit of Fig. 4.3 is more suitable for obtaining the I-V characteristic of the LED than the circuit of Fig. 4.2.

.....

.....

.....

.....

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

[Total: 16]

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

wavelength, λ .....

.....

frequency, f.....

.....

speed, v.....

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

(ii) Hence derive the wave equation $v = f\lambda$ which relates these terms together.

[2]

(b) **(i)** Explain what is meant by *infra-red radiation*.

.....

.....

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

(ii) For infra-red radiation emitted at a frequency of 6.7×10^{13} Hz, calculate

1 its wavelength

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

2 its period of oscillation.

period = ... s **[2]**

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(iii) Infra-red radiation is absorbed by molecular ions in a crystal causing them to vibrate at a frequency of 6.7×10^{13} Hz. The amplitude of oscillation of the ions is 8.0×10^{-12} m.

On the grid of Fig. 5.1 sketch a graph showing the variation with time of the displacement of an ion.

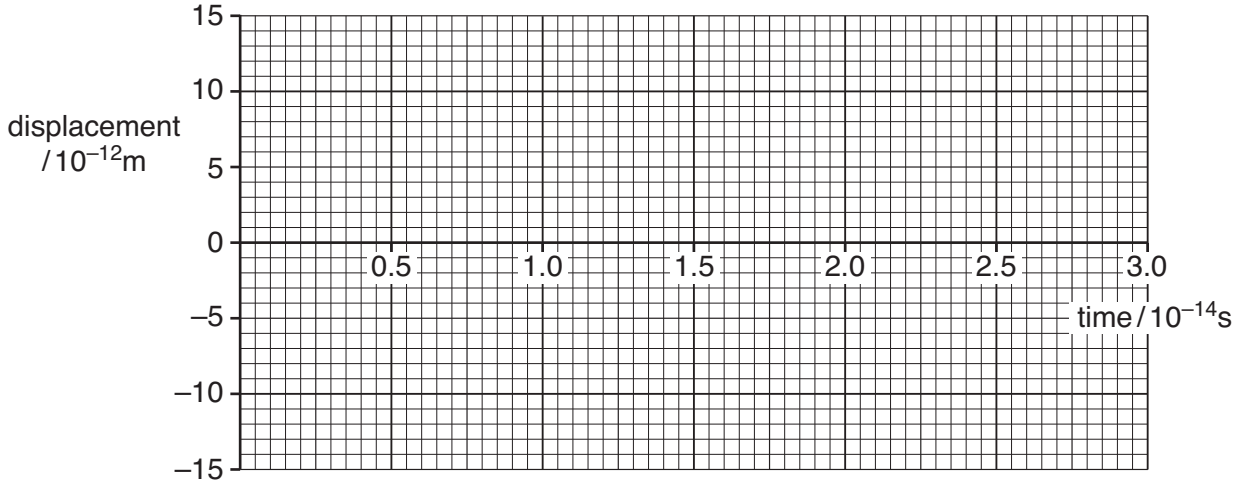


Fig. 5.1

[3]

[Total: 14]

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6 **(a)** Interference of waves from two sources can only be observed when the waves are coherent.

Explain the meaning of

(i) *interference*

.....

.....

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

(ii) *coherence*.

.....

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

(b) Fig. 6.1 shows two microwave transmitters **A** and **B** 0.20 m apart. The transmitters emit microwaves of equal amplitude in phase and of wavelength 30 mm. A detector, moved along the line **PQ** at a distance of 5.0 m from **AB**, detects regions of high and low intensity forming an interference pattern.

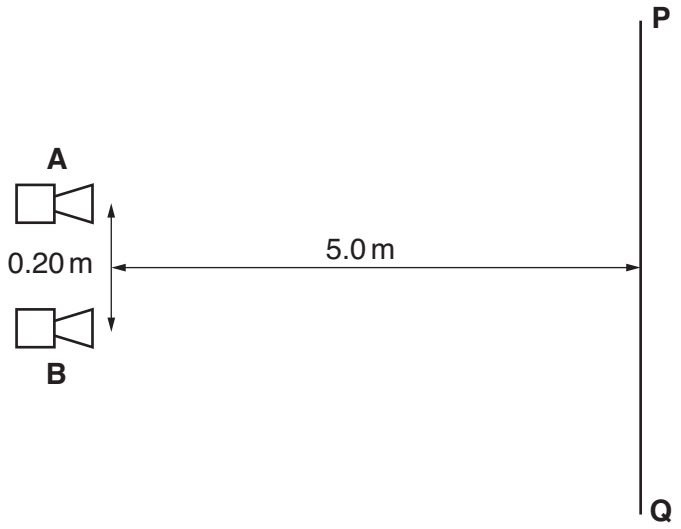


Fig. 6.1

(i) Use the ideas of path difference or phase difference to explain how the interference pattern is formed.

.....

.....

.....

.....

.....

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

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(ii) Calculate the separation between one region of high intensity and the next along the line **PQ**.

separation = ... m **[2]**

(iii) State the effect, if any, on the position and intensity of the maxima when each of the following changes is made, separately, to the experiment.

1 The amplitude of the transmitted waves is doubled.

.....

.....

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

2 The separation between the transmitters is halved.

.....

.....

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

3 The phase of transmitter **A** is reversed so that there is now a phase difference of 180° between the waves from **A** and **B**.

.....

.....

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

[Total: 14]

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7 **(a)** A helium-neon laser emits red light of wavelength 6.3×10^{-7} m.

(i) Show that the energy of a single photon is about 3×10^{-19} J.

[2]

(ii) The power of the laser beam is 1.0 mW. Show that about 3×10^{15} photons are emitted by the laser each second.

[1]

(iii) The photons of red light are emitted by the neon atoms in the gas inside the laser.

Explain what *energy levels* are and how they can be used to explain the emission of photons from atoms.

In your answer take care to make your explanation clear.

.....

.....

.....

.....

.....

.....

.....

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

(iv) Another laser emits blue light. The power in its beam is also 1.0 mW.

Explain why the laser emitting blue light emits fewer photons per second compared with a laser of the same power emitting red light.

.....

.....

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

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(b) A photodiode is a circuit component which can be used to convert a light signal into an electrical one. Fig. 7.1 shows an enlarged cross-section through a photodiode to illustrate how it is constructed. Light incident on the thin transparent conducting surface layer of the diode passes through it to be absorbed in the insulating layer. The energy of each photon is sufficient to release one electron in the insulating layer. The potential difference *V* applied across the insulating layer causes these electrons to move to one of the conducting layers.

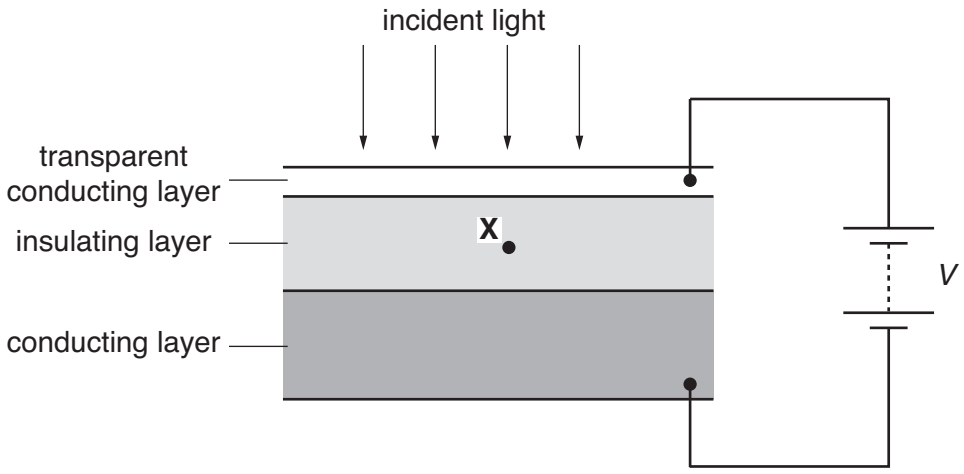


Fig. 7.1

(i) Draw an arrow on Fig. 7.1 to show the direction of motion of an electron released at point **X** in the centre of the insulating layer. **[1]**

(ii) The red light from the laser in **(a)** is incident on the photodiode. Experiments show that only 20% of the red light photons release electrons in the insulating layer and hence in the circuit of Fig. 7.1. Calculate the current through the photodiode.

current = ... A **[3]**

(iii) Suggest one reason why the efficiency of the photodiode is less than 100%.

.....

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

[Total: 14]

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8 In 1927 it was shown by experiment that electrons can produce a diffraction pattern.

(a) (i) Explain the meaning of the term *diffraction*.

.....

.....

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

(ii) State the condition necessary for electrons to produce observable diffraction when passing through matter, e.g. a thin sheet of graphite in an evacuated chamber.

.....

.....

.....

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

(b) Show that the speed of an electron with a de Broglie wavelength of 1.2×10^{-10} m is $6.0 \times 10^{6}\ \text{m s}^{-1}$.

[3]

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(c) The electrons in **(b)** are accelerated to a speed of 6.0×10^6 m s^{-1} using an electron gun shown diagrammatically in Fig. 8.1.

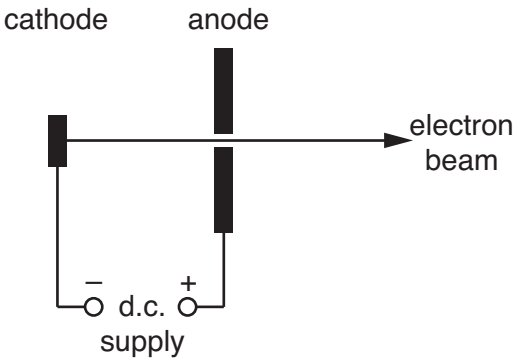


Fig. 8.1

(i) Calculate the potential difference V across the d.c. supply between the cathode and the anode.

V = ... V **[3]**

(ii) Suggest why, in an electron gun, the cathode is connected to the negative terminal of the supply rather than the positive terminal.

.....

.....

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

[Total: 10]

END OF QUESTION PAPER

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G482 Electrons, Waves and Photons

Question			Expected Answers	Marks	Additional Guidance
1					
	a	i	E = (Pt =) 36 x 3600 = 1.3 x 10^5 (J)	C1 A1	**allow** I = 3 A and E = VIt, etc. **accept** 129600 (J)
		ii	Q = E/V = 1.3 x 10^5/12 **or** Q =It =3 x 3600 = 1.1 x 10^4 unit: C	C1 A1 B1	**ecf (a)(i)** **accept** 1.08 x 10^4 **allow** A s **not** J V^{-1}
		iii	Q/e = 1.1 x 10^4/1.6 x 10^{-19} = 6.9 x 10^{22}	C1 A1	**ecf (a)(ii)** **accept** 6.75 or 6.8 x 10^{22} using 10800
	b	i	the average displacement/distance travelled of the electrons along the wire per second; (over time/on average) they move slowly in one direction through the metal/Cu lattice (when there is a p.d. across the wire); (because) they collide constantly/in a short distance with the lattice/AW	B1 B1 B1	no mark for quoting formula **allow** in one second **max 2 marks** from 3 marking points
		ii	select I = nAev (= 3.0 A) v = 3.0/8.0 x 10^{28} x 1.1 x 10^{-7} x 1.6 x 10^{-19} = 2.1 x 10^{-3} (m s^{-1})	C1 C1 A1	1 mark for correct formula 1 mark for correct substitutions into formula 1 mark for correct answer to 2 or more SF
			Total question 1	**12**	

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Question			Expected Answers	Marks	Additional Guidance
2					
	a		ρ = RA/l with terms defined	M1 A1	full word definition gains both marks **allow** *A is area* as adequate; no unit cubes
	b	i	**either** the cable consists of (38) strands <u>in parallel;</u> **or** the area of the cable is 38 times the area of a strand or vice versa; so the resistance of 1 strand is 38 times bigger, (i.e. 1.98 Ω km^{-1}) **or** the resistance is inversely proportional to the area	B1 B1	max 1 mark for 38 x 0.052 = 1.98 with no further explanation **allow** with **either** and **or** **allow only** with **or**
		ii	A = ρ l/R = 2.6 x 10^{-8} x 1000/2.0 = 1.3 x 10^{-5} (m^2)	C1 A1	**allow** 1 mark max. for R = 0.052 giving A = 5.0 x 10^{-4} (m^2) **give** 1 mark max. for 1.3 x 10^{-8} (m^2)
	c	i	P = VI = 400x 10^3 x 440 = 1.8 x 10^8 (W) or 180 M(W)	C1 A1	P = VI **not** adequate for first mark **expect** 176
		ii	2000/176 = 11.4 so 12 required	B1	**ecf(c)(i);** using 180 gives 11.1
		iii	P = I^2R = 440^2 x 0.052 = 1.0 x 10^4 W (km^{-1}) or 10 kW (km^{-1})	C1 C1 A1	**accept** power/cable = 2000/12 = 167 MW I = 167M/400k = 417 A P = 417^2 x 0.052 = 9.0(3) kW (km^{-1}) **N.B.** answer mark includes consistent unit
		iv	power lost per cable = 10 k x 100 x 12 = 12.0 MW fraction remaining = (2000 – 12)/2000 = 0.994 x 100 = 0.994 so 99.4% or power lost per strand = 10 k x100 = 1.0 MW fraction remaining = (176 – 1)/176 = 0.994 so 99.4%	C1 A1	**ecf(c)(ii)(iii)** **allow** second mark for 'correct' answer as fraction not percentage with BOD sign **allow** 1 mark max. if give correct % lost given rather than % remaining **allow** 1 mark max. for 100 x (2000 – 1)/2000 = 99.95%
			Total question 2	**14**	

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Question			Expected Answers	Marks	Additional Guidance
3					
	a		resistors in series add to 20 Ω and current is 0.60 A so p.d. across XY is 0.60 x 12 (= 7.2 V)	B1 B1	**accept** potential divider stated **or** formula gives (12 /20) x 12 V (= 7.2)V
	b	i	the resistance <u>of the LDR</u> decreases (so total resistance in circuit decreases) and current increases	M1 A1	
		ii	resistance of <u>LDR and 12 Ω</u> (in parallel)/<u>across **XY**</u> decreases so has smaller share of supply p.d. (and p.d. across XY falls)	B1 B1	**alternative** I increases so p.d. across 8.0 Ω increases; so p.d. across **XY** falls
			Total question 3	**6**	

Question			Expected Answers	Marks	Additional Guidance
4					
	a	i	no current/no light/does not conduct until V is greater than 1.5 V brightness/intensity of LED increases with current/voltage above 1.5 V above 1.8 V current rises almost linearly with increase in p.d./AW the LED does not obey Ohm's law as I is not proportional to V/AW below 1.5 V, LED acts as an infinite R/ very high R/acts as open switch above 1.5 V, LED resistance decreases (with increasing current/voltage)	B1 B1 B1 M1 A1 B1 B1	**allow** 1.4 to 1.6 V (QWC mark) (alternative QWC mark) **max 5 marks** which must include at least one of the first 2 marking points
		ii 1 2	infinite resistance I = 23.0 ± 1.0 (mA) R = 1.9 x 10^3/(23 ± 1) = 83 ± 4 Ω	B1 C1 A1	 **apply** POT error for 0.083 Ω
	b		LED symbol with correct orientation resistor (need not be labelled) and ammeter in series with it voltmeter in parallel across LED only	B1 B1 B1	diode symbol + circle + at least one arrow pointing away
	c		the resistor limits the <u>current</u> in the circuit (when the LED conducts) otherwise it could overheat/burn out/be damaged/AW	B1 B1	
	d		in fig 4.3 the <u>voltage</u> range is from zero to maximum possible in fig. 4.2 the resistance variation is small/AW (so) in fig. 4.2 voltage variation across LED is small	B1 B1 B1	**allow** 6.0 V **accept** the LED is part of a potential divider **accept** only at the top end of the range/AW
			Total question 4	**16**	

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Question			Expected Answers	Marks	Additional Guidance
5					
	a	i	λ distance between (neighbouring) identical points/points with same phase (on the wave) f number of waves passing a point /cycles/vibrations (at a point) per unit time/second v distance travelled by the wave (energy) per unit time/second	B1 B1 B1	**accept** peak/crest to peak/crest, etc. **accept** number of waves produced by the wave source per unit time/second **not** v = f λ and not 'in one second'
		ii	in 1 second f waves are produced each of one wavelength λ distance travelled by first wave in one second is f λ = v	M1 A1	**accept** time for one λ to pass is 1/f so v = λ/(1/f) =f λ **give** max 1 mark for plausible derivations purely in terms of algebra (no words)
	b	i	infra red is part of the e-m spectrum lower f **or** longer λ than the visible region/light **or** suitable value or range of λ	B1 B1	**accept** any single λ in range 10^{-5} m to 7.5 x 10^{-7} m or any reasonable wider range
		ii1	λ = c/f = 3.0 x 10^{8}/ 6.7 x 10^{13} 4.5 x 10^{-6} (m)	C1 A1	**accept** 4.48 x 10^{-6} or more s.f.
		2	T = 1/f = 1/6.7 x 10^{13} T = 1.5 x 10^{-14} (s)	C1 A1	**accept** 1.49 x 10^{-14}
		iii	at least one cycle of a sine or cosine curve as judged by eye amplitude 8.0 x 10^{-12} m period = 1.5 x 10^{-14} s	B1 B1 B1	**ecf (b)(ii)2**
			Total question 5	**14**	

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Question			Expected Answers	Marks	Additional Guidance
6					
	a	i	when (two) waves meet/combine/interact/superpose, etc. (at a point) there is a change in overall intensity/displacement	M1 A1	**allow** for A1 mark: (vector) sum/resultant displacement(s)/AW
		ii	constant phase difference/relationship (between the waves)	B1	just stating same frequency **not** sufficient
	b	i	path difference of nλ for constructive interference producing **either** maximum amplitude/intensity **or** a maximum path difference of (2n + 1)λ/2 for destructive interference producing **either** minimum amplitude/intensity **or** a minimum	M1 A1 M1 A1	**allow** waves arrive in phase **allow** waves arrive in anti-/out of phase **max** 3 marks; max 1 mark for two correct marking points but with n omitted
		ii	x = λD/a = 0.030 x 5.0/0.20 =0.75 (m)	C1 A1	**give** 1 mark max for 0.75 mm but zero for 750 m
		iii 1	intensity increases by factor of 4 position unchanged	B1 B1	
		2	intensity unchanged distance apart of maxima is doubled	B1 B1	
		3	intensity unchanged maxima move to positions of minima (and vice versa)	B1 B1	
			Total question 6	**14**	

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Question			Expected Answers	Marks	Additional Guidance
7					
	a	i	E = hc/λ = 6.63 x 10^{-34} x 3.0 x 10^{8}/ 6.3 x 10^{-7} = 3.16 x 10^{-19} (J)	M1 A1	mark is for correct substitution into formula min of 2 sig figs;**allow** 3.1 for h = 6.6 x 10^{-34}
		ii	1.0 x 10^{-3}/3(.2) x 10^{-19} (= 3.1 x 10^{15})	B1	**accept** 3 x 10^{15}; the mark is for the expression
		iii	energy levels explanation: electrons have discrete energies in atom/AW each photon produced by electron moving between levels photon energy equal to energy difference between levels electron loses energy/making transition in correct direction	B1 B1 B1 B1	QWC mark good diagram can score marks **allow** $E_1 - E_2$ = hf or similar
		iv	blue light has a higher frequency/shorter wavelength than red light energy per photon is higher (so fewer needed to produce one mW)	B1 B1	
	b	i	vertical arrow up approximately through **X**	B1	**allow** tolerance e.g. ± 10°
		ii	I = 0.2 ne ; = 0.2 x 3.2 x 10^{15} x 1.6 x 10^{-19} = 1.0(24) x 10^{-4} (A) or 0.10 mA (9.6 x 10^{-5} if using 3 x 10^{15})	C2 A1	**max** 2 marks if forget 0.2 factor 0.51 mA (0.48) if forget 0.2 factor
		iii	reflection/absorption at top layer; light/some photons reach bottom layer; photons below threshold energy/photons absorbed by electrons without release; recombination of ion pairs in insulating layer; scattering of light/photons out of insulating layer	B1	**award** mark for any sensible comment; see examples given
			Total question 7	**14**	

Question			Expected Answers	Marks	Additional Guidance
8					
	a	i	paths spread out after passing through a gap or around an obstacle/AW	B1	
		ii	wavelength of electrons must be comparable/of the order of magnitude of the atomic spacing	M1 A1	**allow** electrons behave as waves/AW **allow** must be about 10^{-10} m
	b		λ = h/mv v = 6.6(3) x 10^{-34} / 9.1(1) x 10^{-31} x 1.2 x 10^{-10} = 6.0 or 6.1 x 10^{6} (m s^{-1})	C1 M1 A1	mark for selecting formula correct manipulation and subs. shown **give** all 3 marks for answers to 3 figs or more: i.e. 6.04, 6.06 or 6.07
	c	i	eV = ½mv^2 V = mv^2/2e = 9.1 x 10^{-31} x (6.0 x 10^{6})^2/2 x 1.6 x 10^{-19} = 1.0(2) x 10^{2} (V)	C1 C1 A1	mark for algebraic equation mark for correct substitution **give** 1 mark max for k.e. = 1.6(4) x 10^{-17} J using 6.1 gives 104 (V)
		ii	electrons should be repelled by cathode and/or attracted by anode **or** they will be attracted back to the cathode/slowed down if cathode positive	B1	**award** mark if answer indicates this idea
			Total question 8	**10**	

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THIS IS A NEW SPECIFICATION

OCR
RECOGNISING ACHIEVEMENT

ADVANCED SUBSIDIARY GCE
PHYSICS A
Electrons, Waves and Photons

G482

Candidates answer on the question paper

OCR Supplied Materials:
- Data, Formulae & Relationships Booklet

Other Materials Required:
- Electronic Calculator

Thursday 21 May 2009
Afternoon

Duration: 1 hour 45 minutes

OCE/T67602

G 4 8 2

Candidate Forename		Candidate Surname	

Centre Number						Candidate Number				

INSTRUCTIONS TO CANDIDATES

- Write your name clearly in capital letters, your Centre Number and Candidate Number in the boxes above.
- Use black ink. Pencil may be used for graphs and diagrams only.
- Read each question carefully and make sure that you know what you have to do before starting your answer.
- Answer **all** the questions.
- Do **not** write in the bar codes.
- Write your answer to each question in the space provided, however additional paper may be used if necessary.

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.

FOR EXAMINER'S USE		
Qu.	**Max.**	**Mark**
1	16	
2	12	
3	15	
4	15	
5	13	
6	19	
7	10	
TOTAL	**100**	

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Answer **all** the questions.

1 A set of Christmas tree lights consists of 40 identical filament lamps connected in series across a supply of 240 V.

(a) Define *resistance.*

.....

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

(b) Each lamp when lit normally carries a current of 250 mA.

Calculate

(i) the potential difference V across a lamp

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

(ii) the resistance R of a lamp.

R = ... Ω **[2]**

(c) Fig. 1.1 shows the results of an experiment to find how the current in one of the lamps varies with the potential difference across it.

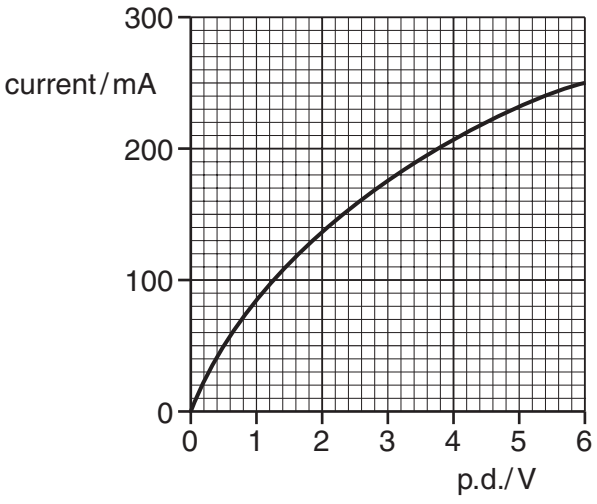


Fig. 1.1

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(i) Draw a diagram of the circuit that you would use to perform this experiment.

[3]

(ii) The resistance of the lamp when at room temperature is 10 Ω. Using Fig. 1.1 sketch a graph on the axes of Fig. 1.2 of the variation of resistance *R* with current for the lamp.

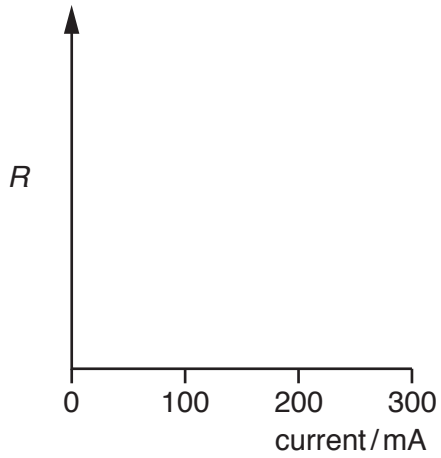


Fig. 1.2

[2]

(iii) Explain why the resistance of the lamp varies as shown by the graph you have drawn on Fig. 1.2.

.....

.....

.....

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

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(d) In an alternative design for the set of Christmas tree lights, a 100 Ω resistor is connected in parallel with each lamp.

(i) Describe what happens to the brightness in each set of lamps when one lamp filament burns out.

1 *original set* .....

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

2 *alternative set* .....

.....

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

(ii) Calculate the current drawn from the supply for the alternative set of lamps with all lamps working.

current = ... A **[3]**

[Total: 16]

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2 **(a)** A battery of e.m.f. E and internal resistance r delivers a current I to a circuit of resistance R.

Write down an equation for E in terms of r, I and R.

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

(b) A 'flat' car battery of internal resistance 0.06 Ω is to be charged using a battery charger having an e.m.f. of 14 V and internal resistance of 0.74 Ω, as shown in Fig. 2.1.

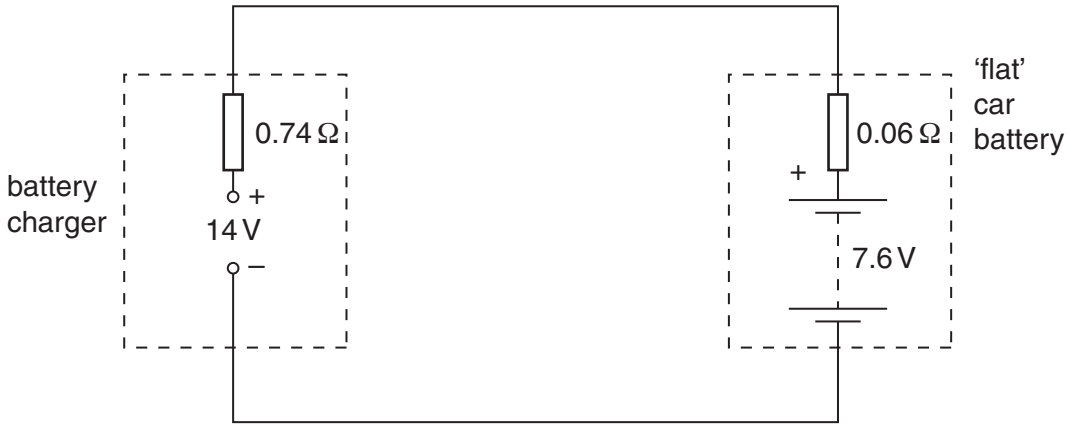


Fig. 2.1

You can see that the battery to be charged has its positive terminal connected to the positive terminal of the battery charger.

At the beginning of the charging process, the e.m.f. of the 'flat' car battery is 7.6 V.

(i) For the circuit of Fig. 2.1, determine

1 the total resistance

resistance = ... Ω **[1]**

2 the sum of the e.m.f.s in the circuit.

e.m.f. = ... V **[1]**

(ii) State Kirchhoff's second law.

.....

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

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(iii) Apply the law to this circuit to calculate the initial charging current.

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

(c) For the majority of the charging time of the car battery in the circuit of Fig. 2.1, the e.m.f. of the car battery is 12 V and the charging current is 2.5 A. The battery is charged at this current for 6.0 hours. Calculate, for this charging time,

(i) the charge that passes through the battery

charge = ... C **[2]**

(ii) the energy supplied by the battery charger of e.m.f. 14 V

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

(iii) the percentage of the energy supplied by the charger which is dissipated in the internal resistances of the battery charger and the car battery.

percentage of energy = ... % **[2]**

[Total: 12]

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3 Fig. 3.1 shows a thermistor and fixed resistor of 200 Ω connected through a switch **S** to a 24 V d.c. supply of negligible internal resistance. The voltmeter across the fixed resistor has a very high resistance.

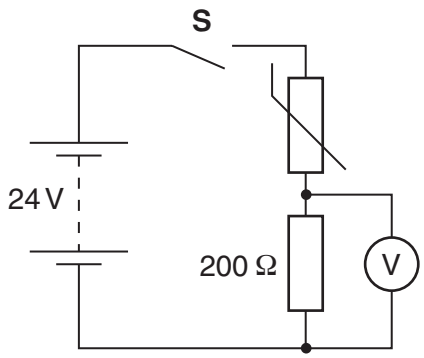


Fig. 3.1

(a) When the switch **S** is closed the voltmeter initially measures 8.0 V.

Calculate

(i) the current I in the circuit

I = ... A **[2]**

(ii) the potential difference V_T across the thermistor

V_T = ... V **[1]**

(iii) the resistance R_T of the thermistor

R_T = ... Ω **[2]**

(iv) the power P_T dissipated in the thermistor.

P_T = ... W **[2]**

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(b) A few minutes after closing the switch **S** the voltmeter reading has risen to a steady value of 12 V. The value of the fixed resistor remains at 200 Ω.

Explain why

(i) the potential difference across the fixed resistor has increased

.....

.....

.....

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

(ii) the resistance of the thermistor must now be 200 Ω.

.....

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

(c) Sketch, on the labelled axes of Fig. 3.2 below, a possible *I*-*V* characteristic for:

(i) the fixed resistor. Label it **R**. **[2]**

(ii) the thermistor. Label it **T**. **[2]**

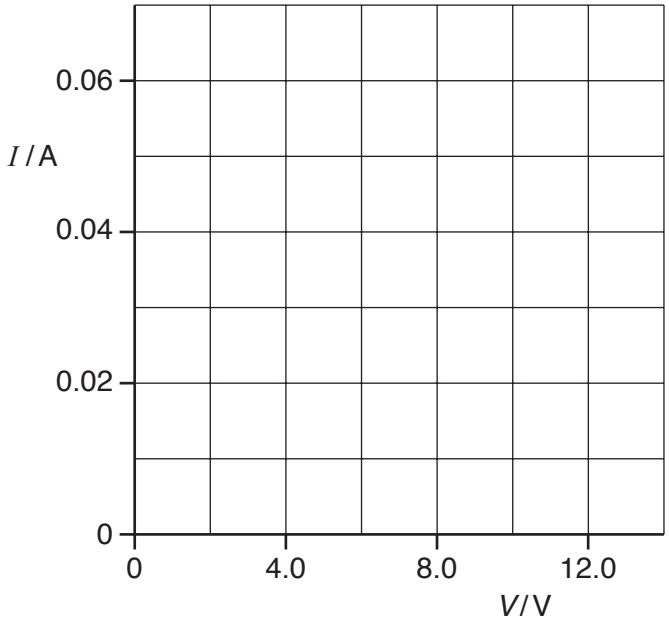


Fig. 3.2

[Total: 15]

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4 **(a)** **(i)** Both electromagnetic waves and sound waves can be **reflected**. State **two** other wave phenomena that apply to both electromagnetic waves and sound waves.

1. .....

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

(ii) Explain why electromagnetic waves can be polarised but sound waves cannot be polarised.

.....

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

(iii) Describe briefly an experiment to demonstrate the polarisation of microwaves in the laboratory.



In your answer you should make clear how your observations demonstrate polarisation.

.....

.....

.....

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

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(b) A sound wave emitted by a loudspeaker consists of a single frequency. Fig. 4.1 shows the displacement against time graph of the air at a point **P** in front of the speaker.

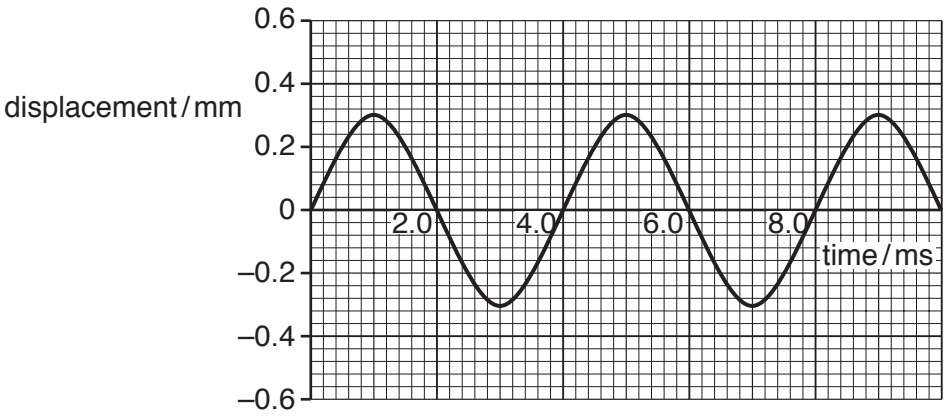


Fig. 4.1

(i) Use Fig. 4.1 to find

1 the amplitude of the air motion

amplitude = ... mm **[1]**

2 the frequency of the sound wave.

frequency = ... Hz **[2]**

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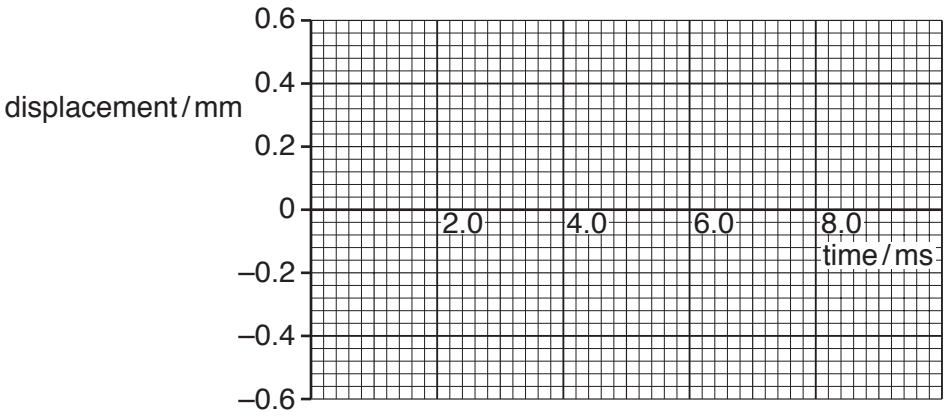
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(ii) The sound generator is adjusted so that the loudspeaker emits a sound at the original frequency and twice the **intensity**. Sketch on Fig. 4.2 the new displacement against time graph at point **P**. Explain your reasoning.

.....

.....

.....



[3]

Fig. 4.2

(iii) Suggest, with reasons, the apparatus that you would choose to detect and measure the frequency of the sound wave at **P**.

.....

.....

.....

.....

.....

.....

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

[Total: 15]

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5 **(a)** When used to describe stationary (standing) waves explain the terms

(i) node .....

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

(ii) antinode. .....

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

(b) Fig. 5.1 shows a string fixed at one end under tension. The frequency of the mechanical oscillator close to the fixed end is varied until a stationary wave is formed on the string.

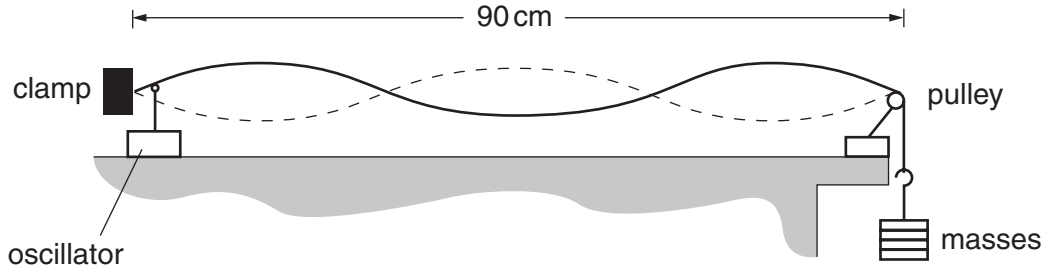


Fig. 5.1

(i) Explain with reference to a progressive wave on the string how the stationary wave is formed.

.....

.....

.....

.....

.....

.....

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

(ii) On Fig. 5.1 label one node with the letter **N** and one antinode with the letter **A**. **[1]**

(iii) State the number of antinodes on the string in Fig. 5.1.

number of antinodes = ... **[1]**

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(iv) The frequency of the oscillator causing the stationary wave shown in Fig. 5.1 is 120 Hz.

The length of the string between the fixed end and the pulley is 90 cm.

Calculate the speed of the progressive wave on the string.

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

(c) The speed v of a progressive wave on a stretched string is given by the formula

$$v = k\sqrt{W}$$

where k is a constant for that string. W is the tension in the string which is equal to the weight of the mass hanging from the end of the string.

In **(b)** the weight of the mass on the end of the string is 4.0 N. The oscillator continues to vibrate the string at 120 Hz. Explain whether or not you would expect to observe a stationary wave on the string when the weight of the suspended mass is changed to 9.0 N.

.....

.....

.....

.....

.....

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

[Total: 13]

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6 **(a)** A parallel beam of red light of wavelength 6.3×10^{-7} m from a laser is incident normally on a diffraction grating as shown in Fig. 6.1.

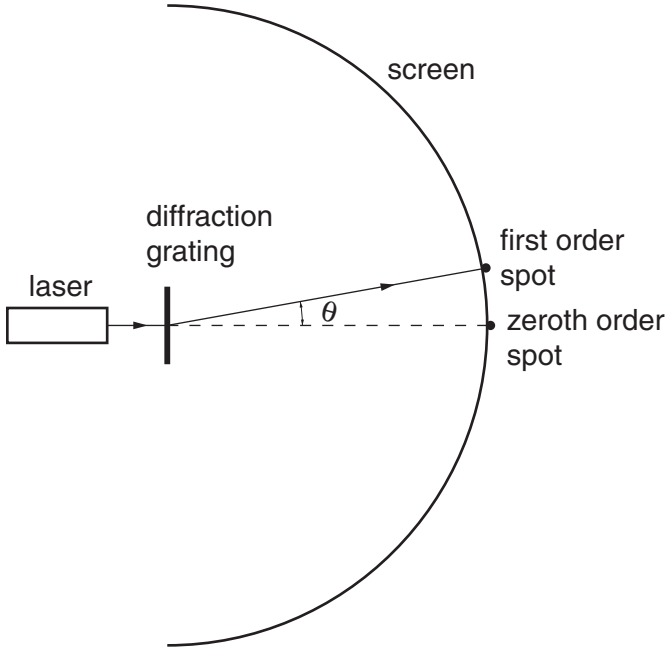


Fig. 6.1

Bright red spots are observed on the curved screen placed beyond the grating.

(i) The diffraction grating has 300 lines per millimetre. Show that the separation d between adjacent lines of the grating is 3.3×10^{-6} m.

[1]

(ii) Calculate the angle θ at which the first order red spot is seen. This is the first spot away from the straight through position.

θ = ... degrees **[3]**

(iii) The screen curves around the full 180° in front of the grating. Explain why there are eleven bright red spots on the screen.

.....

.....

.....

.....

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

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(b) Calculate

(i) the energy of each photon of light emitted by the laser at a wavelength of 6.3×10^{-7} m

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

(ii) the number of photons emitted each second to produce a power of 0.50 mW.

number = ... **[2]**

(c) **(i)** A beam of electrons in a vacuum can travel through a thin sheet of graphite perpendicular to the beam to produce a diffraction pattern of rings on a fluorescent screen beyond the graphite sheet. Explain why this pattern is produced.

.....

.....

.....

.....

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

(ii) Calculate

1 the speed v of electrons with a de Broglie wavelength of 5.0×10^{-11} m

v = ... $m\,s^{-1}$ **[2]**

2 the potential difference V required to accelerate the electrons to this speed.

V = ... V **[3]**

[Total: 19]

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7 In 1905 Einstein presented a theory to explain the photoelectric effect using the concept of quantisation of radiation proposed by Planck in 1900.

(a) Show, with the aid of a suitably labelled diagram, the arrangement of apparatus that could be used to demonstrate the photoelectric effect. Describe how you would use the apparatus and what would be observed.



In your answer you should make clear how your observations provide evidence for the photoelectric effect.

.....

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

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(b) Describe how the photoelectric effect can be explained in terms of the physics of quantum behaviour.

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.....

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

[Total: 10]

END OF QUESTION PAPER

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G482 Electrons, Waves and Photons

CATEGORISATION OF MARKS

The marking schemes categorise marks on the MACB scheme.

B marks: These are awarded as independent marks, which do not depend on other marks. For a **B**-mark to be scored, the point to which it refers must be seen specifically in the candidate's answers.

M marks: These are method marks upon which **A**-marks (accuracy marks) later depend. For an **M**-mark to be scored, the point to which it refers must be seen in the candidate's answers. If a candidate fails to score a particular **M**-mark, then none of the dependent **A**-marks can be scored.

C marks: These are compensatory method marks which can be scored even if the points to which they refer are not written down by the candidate, providing subsequent working gives evidence that they must have known it. For example, if an equation carries a **C**-mark and the candidate does not write down the actual equation but does correct working which shows the candidate knew the equation, then the **C**-mark is given.

A marks: These are accuracy or answer marks, which either depend on an **M**-mark, or allow a **C**-mark to be scored.

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Question			Expected Answers	Marks	Additional Guidance
1	(a)		resistance = p.d./current	B1	**accept** voltage instead of p.d.; ratio of voltage to current; voltage per (unit) current **not** R = V/I or p.d. = current x resistance or p.d. per amp or answer in units or voltage over current
	(b)	(i)	6 V	B1	
		(ii)	R = V/I = 6/0.25 = 24 (Ω)	C1 A1	**ecf (b)(i)** 240 V gives 960 Ω **award** 0.024 Ω 1 mark only (POT error)
	(c)	(i)	6 V supply with potential divider 'input' across it and lamp across p.d. 'output' ammeter in series with lamp voltmeter across lamp	B1 B1 B1	**accept** 0 – 6 V variable supply with lamp across it **not** variable R in series with supply circuit with no battery present can only score voltmeter mark
		(ii)	non-zero intercept line indicating increasing value of R with current	B1 B1	curve must reach y-axis **accept** straight line or upward curve
		(iii)	resistivity/resistance of filament wire increases with temperature the temperature of the lamp increases with current/voltage increase more frequent electron-ion/atom collisions/AW increased ion vibrations	B1 B1	**accept** any two of the four statements **accept** AW, e.g the lamp heats up because of the current
	(d)	(i)	lamps do not light	B1	**ignore** reasons unless too contrary
			remaining lamps are lit with qualification	B1	qualification could be more dimly or sensible explanation
		(ii)	using resistors in parallel formula to obtain a value of R per unit R per unit = 19.4 Ω or R total = 774 Ω I = 6/19.4 or 240/774 = 0.31 A	C1 C1 A1	eg takes R of bulb = 10 Ω giving R per unit = 9.1 Ω gains first mark only **ecf (b)(i)(ii)** **accept** R of resistors = 4000 Ω; current in chain = 0.06 A; total current = 0.06 + 0.25 = 0.31 A 0.3 A is SF error so gains 2 marks only apply **SF error only once** in paper
			Total question 1	**16**	

Question			Expected Answers	Marks	Additional Guidance
2	**(a)**		E = I(R + r)	B1	
	(b)	**(i) 1** **2**	0.80 Ω 6.4 V	B1 B1	
		(ii)	(sum of) e.m.f.s = sum /total of p.d.s/sum of voltages (in a loop)	B1	
		(iii)	6.4 = 0.80I I = 8.0 A	C1 A1	**can be 2 ecf** from **(b)(i),** eg 21.6/0.8 = 27 A (1 ecf) or 21.8/0.68 = 31.8 A (2 ecf)
	(c)	**(i)**	Q = It = 2.5 x 6 x 60 x 60 = 54000 (C)	C1 A1	**allow** 1 mark if forgets one or two 60's giving 900 C or 15 C
		(ii)	energy = QE = 54000 x 14 = 756000 (J)	C1 A1	**allow** (use of 12 V gives) 648000 J for 1 mark
		(iii)	energy loss = I2Rt = VIt = 2 x 2.5 x 6.0 x 60 x 60= 108000 J percentage = (108000/756000) x 100 = 14%	C1 A1	**accept** QΔV = 54000 x 2.0 = 108000 J **accept** QΔV/QE = 2.0/14.0 = 14% **not** 756000/54000 = 14%
			Total question 2	**12**	

Question			Expected Answers	Marks	Additional Guidance
3	(a)	(i)	I = V/R = 8.0/200 I = 0.040 (A)	C1 A1	
		(ii)	V = 24 – 8 = 16 (V)	B1	
		(iii)	R = 16/0.04 giving R = 400 (Ω)	C1 A1	**accept** ratio of p.d.s to ratio of Rs **ecf** from **(i)** & **(ii)** ie **(a)(ii)/(a)(i)**
		(iv)	$P = VI = I^2R = V^2/R$ P = 0.640 (W)	C1 A1	**ecf** from **(i)** & **(ii)** **accept** 640 mW
	(b)	(i)	the thermistor has heated up/ its temperature has increased so its resistance has dropped so the ratio of the voltages across the potential divider changes/AW	B1 M1 A1	 **accept** so the current increases **accept** so IR of fixed resistor increases
		(ii)	voltages are equal so resistances are equal	B1	
	(c)	(ii)	straight line through origin labelled R passing through 0.06,12	B1 B1	**allow** correct lines with no labels
		(ii)	upward curve below straight line through origin labelled T passing through 0.06,12	B1 B1	
			Total question 3	**15**	

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Question			Expected Answers	Marks	Additional Guidance
4	(a)	(i) (ii)	diffraction or refraction or superposition or interference only transverse waves can be polarised	B2 B1	**accept** any two from the four listed **accept** sound is a longitudinal wave or e-m waves are transverse
		(iii)	place transmitter and receiver facing each other rotate either transmitter or receiver through 90° about axis joining aerials **or** use two polarising filters and rotate from parallel to crossed observe signal fall to zero/minimum from initial high value on meter monitoring output of receiver explanation of observations/link between observations and polarisation	B1 B1 B1 B1	**accept** from diagram **allow** (metal) grille/polarising filter to polarise microwaves **accept** place (metal) grille/polarising filter [**not** Polaroid] between transmitter and receiver and rotate through 90° QWC mark
	(b)	(i) 1	0.3 (mm)	B1	tolerance ±0.02 mm ie 0.28 – 0.32 (mm)
		2	T = 4.0 ms F = 1/T = 250 (Hz)	C1 A1	 **allow** 0.25 Hz or any other POT error for 1 mark
		(ii)	realisation that intensity is proportional to (amplitude)^2 giving amplitude increase by $\sqrt{2}$, ie4(.2) mm sine wave of same frequency with any increased amplitude	B1 B1 B1	
		(iii)	microphone (to transfer mechanical motion to electrical signal/voltage) oscilloscope to display oscillation/wave for measurement (of period)/AW	B1 B1	 **accept** computer/datalogger/frequency meter with qualification as for oscilloscope
			Total question 4	**15**	

Question			Expected Answers	Marks	Additional Guidance
5	(a)	(i) (ii)	node occurs where the amplitude/displacement is (always) zero antinode occurs where the amplitude (of the standing wave) takes the maximum (possible) value	B1 B1	**accept** displacement for amplitude for **(i)** only
	(b)	(i)	wave travels to end and is reflected reflected wave <u>interferes/superposes</u> with incident wave always destructively at certain points to produce nodes **or** always constructively at certain points to produce antinodes	B1 B1 B1	 **accept** 2 waves of same f travelling in opposite directions <u>interfere</u> with no reference to reflection
		(ii)	A and N points labelled correctly	B1	
		(iii)	3	B1	
		(iv)	30 cm = $\lambda/2$ or λ = 60 cm v = f λ = 120 x 0.6 v = 72 (m s^{-1})	C1 C1 A1	**allow** 1 mark for correct calculation using v = f λ with wrong wavelength if method/reasoning clear
	(c)		v = 2k becomes v = 3k (k = 36) wavelength increases by 3/2 (as frequency unchanged) 2 half wavelengths fit on the string so standing wave is set up/AW	B1 B1 B1	**accept** v increases by 3/2 or v = 108 m s^{-1} **accept** wavelength becomes 90 cm **allow ecf** correct conclusion with wrong λ
			Total question 5	**13**	

Question			Expected Answers	Marks	Additional Guidance
6	(a)	(i)	line spacing d = 1/(300 x 1000) (= 3.3 x 10^{-6} (m))	B1	look for clear reasoning to award mark
		(ii)	sin θ = λ/d = 6.3 x 10^{-7}/3.3 x 10^{-6} = 0.19 θ = 11 degrees	C1 C1 A1	 rounding error of 0.2 here gives 11.9° 11.9° gets 2 marks
		(iii)	spots can be seen where n = d sin θ/λ maximum n when sin θ = 1 (giving n = 5.3) so n =5 can be seen thus 5 spots on either side of straight through + straight through = 11	B1 B1 B1	**accept** basic idea of orders for first mark N.B. calculation not necessary
	(b)	(i)	ε = hc/λ = 6.6 x 10^{-34} x 3.0 x 10^{8}/6.3 x 10^{-7} = 3.14 x 10^{-19} (J)	C1 A1	 **accept** 3.2 x 10^{-19} (J)
		(ii)	5.0 x 10^{-4}/3.14 x 10^{-19} = 1.6 x 10^{15}	C1 A1	**ecf** from **b(i)1**
	(c)	(i)	Electrons behave as waves/have a wavelength diffraction observable because gaps/atoms are similar to wavelength of electrons regular pattern of atoms acts as a grating allowing constructive interference to produce pattern on screen/AW rings occur because atomic 'crystals' at all possible orientations to beam/AW	B1 B1 B1 B1 B1	max 2 out of next 4 marking points **can** gain first 'waves' mark here as well as second mark if first line not written explicitly
		(ii) **1**	λ = h/mv = 6.63 x 10^{-34}/9.1 x 10^{-31}v v = 6.63 x 10^{-34}/9.1 x 10^{-31} x 5.0 x 10^{-11} v = 1.5 x 10^{7} (m s^{-1})	C1 A1	 using 6.6 instead of 6.63 gives 1.45 x 10^{7}
		2	½mv^2 = eV ½ x 9.1 x 10^{-31} x 2.25 x 10^{14} = 1.6 x 10^{-19}V V = 6.4 x 10^{2} (V)	C1 C1 A1	 using v =1.45 x 10^{7} gives 600 V
			Total question 6	**19**	

Question			Expected Answers	Marks	Additional Guidance
7	a		A (clean) zinc plate mounted on the cap of a gold-leaf electroscope. Plate initially charged negatively A u-v lamp shining on plate The gold leaf collapses as the charge leaks away from the plate (when ultra-violet light is incident on the zinc plate) so experiment indicates the emission of negative charge/electrons	B1 B1 B1 B1 B1	first 3 marks can be awarded from diagram or description QWC mark
		Or	A simple photocell, eg two plates in a vacuum envelope A (12 V) dc supply is connected to the photocell and (nano)ammeter. A suitable frequency/u-v lamp shining on one plate The presence of u-v /blue light causes a current in the circuit. so experiment indicates the emission of negative charge/electrons	B1 B1 B1 B1 B1	**accept** photocell made of clean magnesium ribbon surrounded by fine copper gauze first 3 marks can be awarded from diagram or description **ignore** polarity of supply QWC mark
		Or	A (potassium) photocell connected across a (high impedance) voltmeter. Incident light of different frequencies; produced either by white light source and colour filters of known spectral range or by using a diffraction grating or prism to produce a first order spectrum. Different p.d.s are set up across the electrodes of the photocell (when the photocathode is illuminated with light of different frequencies). so experiment indicates the emission of negative charge	B1 B1 B1 B1 B1	first 3 marks can be awarded from diagram or description QWC mark
	b		Individual photons are absorbed by individual electrons in the metal surface. These electrons must have absorbed sufficient energy to overcome the work function energy of the metal/to reach the minimum energy to release an electron from the surface **or** only photons with energies above the work function energy will cause photoelectron emission Concept of instantaneous emission Number of electrons emitted also depends on light intensity Einstein's photoelectric energy equation in symbols with symbols explained, ie (energy of photon) = (work function of metal) + (maximum possible kinetic energy of emitted electron)	 B1 B1 B1 B1 B1 B1	**stop marking after the first five marking points, ie ticks and crosses** **not** photons are absorbed by electrons; 1 to 1 relationship must be implied **accept** definition of work function energy **accept** shorter λ/higher f photon causes higher (kinetic) energy electron **accept** full word equation without symbols for 2 marks maximum 5 marks
			Total question 7	**10**	