PRESTON MANOR

Physics Exam Pack

I-V Characteristics

Name: Date:

Question / Paper	Mark

(b) Some conducting putty is moulded into different cylindrical shapes. The putty has resistance of 36 Ω when it has length l and diameter d.
Complete the table below for different cylinders made from this putty.

length	diameter	resistance / Ω
l	d	36
$3l$	d	
l	$2d$	
$5l$	$2d$	

[3]

[Total: 8]

3 **(a)** Thermistors and light-dependent resistors are useful components in potential divider circuits.

(i) Draw the symbol for a thermistor and describe how the resistance of a negative temperature coefficient (NTC) thermistor is affected by temperature.

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..... [2]

(ii) Draw the symbol for a light-dependent resistor and describe how its resistance is affected by the intensity of light.

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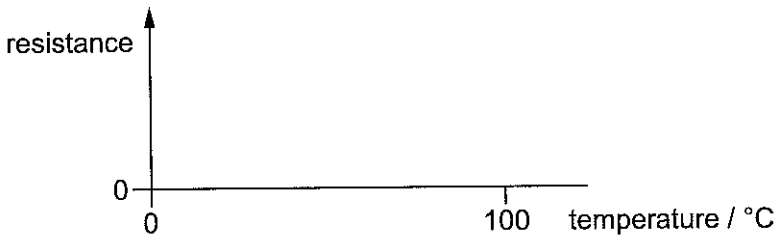
..... [2]

(iii) Draw a potential divider circuit that may be used to monitor the intensity of light in a room. You are not expected to show any values of the components used.

[2]

(b) (i) On the axes below, show how the resistance of a pure metal conductor in the form of a wire depends on its temperature.



[1]

(ii) In this question two marks are available for the quality of written communication.

Describe an experiment to determine how the resistance of a wire varies with its temperature. Assume that no ohmmeter is available.

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.....[5]

Quality of Written Communication [2]

[Total: 14]

[Turn over

Question			Expected Answers	Marks	Additional Guidance
3	a	i	Correct symbol for thermistor	B1	To score the symbol mark, must have an oblong with a 'line + bend at one end' through the oblong in **any** orientation (do not allow arrow)
			The resistance decreases as the temperature (of thermistor) increases (ora)	B1	**Allow** It increases as the temperature decreases (1) **Not** any reference to 'heat' instead of temperature
		ii	Correct symbol for LDR	B1	To score the symbol mark, must have an oblong plus a minimum of one arrow towards the oblong – the circle round the oblong is not necessary.
			The resistance decreases as intensity / light increases (ora)	B1	**Allow** In light the resistance is low / small (1) **Allow** In dark(ness) the resistance is high / large / big (1)
		iii	A diagram with a resistor / variable resistor and an LDR connected in series to a supply / battery / cell	M1	The LDR symbol is ecf from (a)(ii)
			A voltmeter connected is across the resistor or the LDR	A1	**The second mark can only be scored if the first mark is awarded and a correct symbol for a voltmeter (circle with a letter V)**
	b	i	A line / curve of positive gradient	B1	To score this mark, the line or curve must have a finite resistance value at 0 °C - allow resistance intercept at or above the 'top of zero' on the l.h.s. **Not** A line/curve that becomes horizontal

Question	Expected Answers	Marks	Additional Guidance
ii			**Must show ticks on the script to indicate where marks are being awarded**
	Place the wire in a (water) bath / use a hot plate / oven	B1	**Not** 'heat the wire'
	Any remaining <u>four</u> from: 1. Connect conductor / wire in series with a battery / cell / power supply 2. Ammeter placed in series (with wire) / voltmeter placed in parallel (with wire) 3. Record / read / measure current / voltage (across the wire) (AW) 4. (Calculate the resistance using the equation:) $R = \frac{V}{I}$ 5. Thermometer / 'temperature probe' mentioned 6. Measurements (for *V* and *I*) repeated for different temperatures	B1 × 4	Numbered marking points 1 and 2 can be scored on diagram or in the text but **all** others marking points must be written Not '*V* = *IR*' for numbered marking point 4 **Not** '*Plot a graph of R against temperature*' for numbered marking point 6
	QWC		For **QWC** marks, the answer must involve physics, which attempts to answer the question – otherwise the mark for QWC is zero.
	Structure and organisation mark	B1	Award this mark if the whole answer is well structured Bulleted answers are allowed – must have full stops
	Spelling and Grammar mark	B1	More than two spelling mistakes <u>or</u> more than two grammatical errors mean that this mark is lost
	Total	**14**	

2 The force on the wire is the result of each free electron within the wire experiencing a force as it travels in the magnetic field between the poles. The wire has a cross-sectional area $1.2 \times 10^{-7}\ m^2$ and it contains 8.5×10^{28} free electrons per cubic metre (m^3). Calculate the average force experienced by one of these free electrons.

force = ... N **[2]**

[Total: 9]

5 **(a)** A battery delivers a constant current through a circuit when a switch is closed at time $t = 0$.

(i) On Fig. 5.1, sketch a graph to show how the total charge that has been supplied by the battery varies with time t.

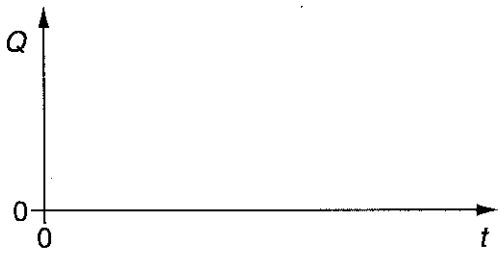

Fig. 5.1

[1]

(ii) The battery delivers a constant current of 5.2 A for a time of 3.5 hours. Calculate the total charge supplied by the battery after a time of 3.5 hours.

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

(b) Fig. 5.2 shows an electrical circuit.

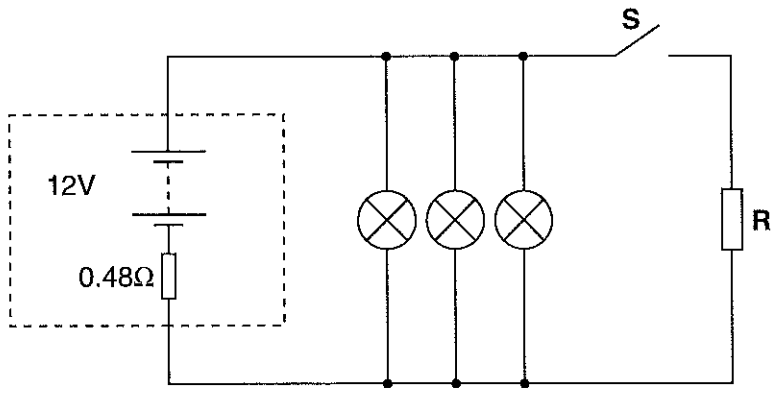

Fig. 5.2

The switch **S** is open. The battery has e.m.f. 12V and an internal resistance 0.48 Ω. The three lamps are identical, each of resistance 3.6 Ω. The filament of each lamp is a coiled wire of cross-sectional area of $2.0 \times 10^{-8}\,m^2$. The material of the filament has resistivity $7.9 \times 10^{-7}\,\Omega m$.

(i) Calculate the length of the filament wire in each lamp.

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

(ii) With the switch **S open**, determine

1 the total resistance of the circuit

total resistance = ... Ω **[2]**

(c) Electromagnetic waves are incident on the surface of a particular metal. Fig. 6.1 shows a graph of the maximum kinetic energy KE_{max} of the electrons released from the surface against the frequency f of the electromagnetic waves.

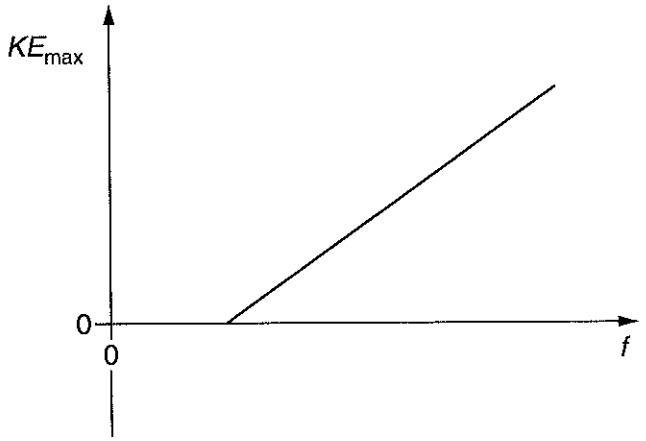

Fig. 6.1

(i) On Fig. 6.1

1 mark with a letter **F** a point corresponding to the threshold frequency of the metal **[1]**

2 mark with a letter **W** on the vertical axis a point corresponding to the work function energy of the metal. **[1]**

(ii) State and explain how the graph of Fig. 6.1 will change when a metal of higher work function energy is illuminated by electromagnetic radiation. You may support your answer by drawing on Fig. 6.1.

.....

.....

.....

.....

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

2 the current from the battery.

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

(iii) With the switch **S closed**, the current in the resistor **R** is 20 A. Explain why the lamps dim when the switch is closed.

.....

.....

.....

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

[Total: 12]

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

.....

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

(b) Explain why electrons are released from a particular metal when it is illuminated by weak blue light, but not when it is illuminated by very intense red light.

.....

.....

.....

.....

.....

.....

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

Question			Expected Answers	Marks	Additional Guidance
5	a	i	Straight line (by eye)	B1	
		ii	$Q = It$ $Q = 5.2 \times (3.5 \times 3600)$ charge = 6.55×10^4 unit: coulomb / C	C1 A1 B1	**Allow** 2 sf answer **Allow** 6.6×10^4 This unit mark is an independent mark
	b	i	$R = \frac{\rho L}{A}$ $L = \frac{3.6 \times 2.0 \times 10^{-8}}{7.9 \times 10^{-7}}$ length = 9.1×10^{-2} (m)	C1 C1 A1	**Allow** any subject **Bald** 9.1×10^{-2} m scores 3/3
		ii 1.	resistance of lamps = $\frac{3.6}{3} (= 1.2)$ total resistance = 1.2 + 0.48 total resistance =1.68 Ω	C1 A1	Possible ecf from above step for resistance of lamps in parallel **Allow** 1.7 Ω
		ii 2.	current = $\frac{12}{1.68}$ current 7.1(4) (A)	B1	Possible ecf **Allow** 2 sf answer
		iii	Appreciation that 'internal resistance' is responsible for dimness (Larger) voltage across internal resistance / less p.d across lamps	B1 B1	
			Total	12	

Answer **all** the questions.

1 **(a)** Define the ohm.

.....

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

(b) Fig. 1.1 shows the *I*/*V* characteristics of a resistor (resistance wire) and a filament lamp.

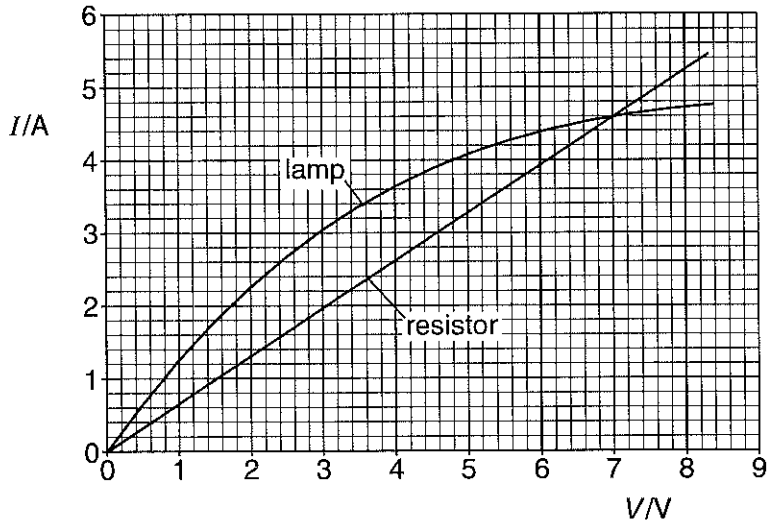


Fig. 1.1

(i) State how the resistance varies with the potential difference *V*

1 across the resistor

.....

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

2 across the filament lamp.

.....

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

(ii) State the value of the potential difference when the resistor and the filament lamp have the same resistance. Explain your answer.

.....

.....

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

(iii) The filament lamp and the resistor are connected in **parallel** to a d.c. supply of e.m.f. 4.0 V. This supply has negligible internal resistance. Use Fig. 1.1 to determine the total resistance of the circuit.

resistance = ... Ω **[3]**

[Total: 8]

2822 Electrons and Photons

Question			Expected Answers	Marks	Additional Guidance
1	a		volt per amp(ere) / (1) V A^{-1}	B1	**Allow** 'It is the resistance when current is 1A and voltage is 1V' (1) **Not** $R = V/I$ or 'volt per current' or 'voltage per amp(ere)'
	b	i	**1.** The resistance remains constant **2.** The resistance increases (as p.d increases) ora	B1 B1	
		ii	At 7.(0)(V) Resistance is *V/I* and both *V* and *I* are the same	M1 A1	*R=V/I allowed in any form.* *No back/forward credit on R=V/I*
		iii	At *V* = 4.0 V, currents are 2.6 (A) and 3.6 (A) total current = 6.2 (A) resistance = $\frac{4.0}{6.2}$ resistance = 0.645 (Ω) ≈ 0.65 (Ω)	C1 C1 A1	**Do not allow** any other voltage. **Allow** first mark for: R_r = 1.5(4) (Ω) / R_b = 1.1(1) (Ω) **Allow** between 3.6 and 3.65A **Allow** 2 marks if candidates has written: $R = \frac{1.54 \times 1.11}{1.54 + 1.11}$ / $\frac{1}{R_T} = \frac{1}{1.54} + \frac{1}{1.11}$ (**Allow** full credit for 2 sf substitution above) **Bald** 0.645 or 0.65 or 0.64 or 0.635 scores 3 marks
			Total	8	

Answer **all** the questions.

1 **(a)** The *I*/*V* characteristic of a particular component is shown in Fig. 1.1.

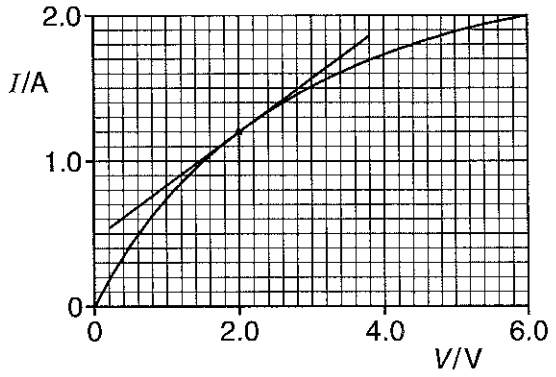


Fig. 1.1

(i) Name the component.

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

(ii) According to one student, the *'gradient of the graph at 2.0V can be used to determine the resistance of the component at 2.0V'.*
Explain why the student is wrong.

.....

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

(iii) Determine the resistance of the component at 2.0V.

resistance = ... Ω **[2]**

(b) Fig. 1.2 shows a sketch graph of the variation of resistance R of a different component with potential difference (voltage) V.

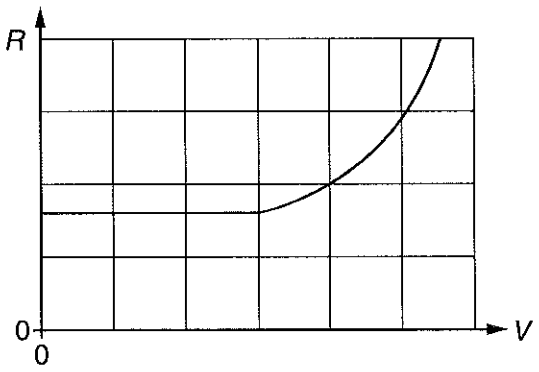


Fig. 1.2

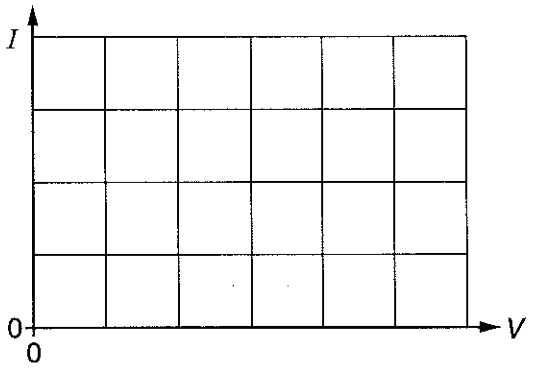


Fig. 1.3

Complete Fig. 1.3 by drawing a sketch graph to show the I/V characteristic of the component. **[2]**

(c) Fig. 1.4 shows an electrical circuit containing a semiconductor diode.

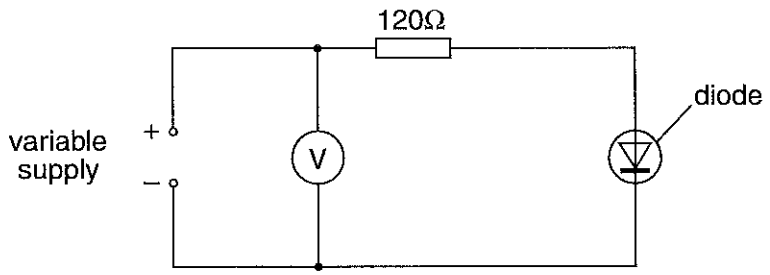


Fig. 1.4

This diode has a very low resistance when it conducts. It has an infinite resistance when the potential difference across it is less than 0.6V. The variable supply is adjusted to give a reading of 0.4V on the voltmeter.

(i) State the current in the 120Ω resistor.

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

(ii) State the potential difference across the diode.

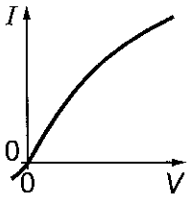
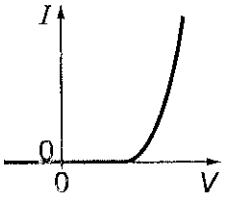
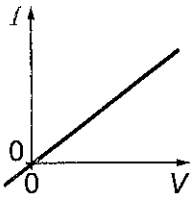
potential difference = ... V **[1]**

[Total: 8]

2822 Electrons and Photons

Question			Expected Answers	Marks	Additional Guidance
1	a	i	(Filament) lamp / bulb	B1	
		ii	Resistance is $\frac{V}{I}$ (and not the gradient) – wtte	B1	**Allow** Resistance is the ratio of *V* and *I*. **Not** units in definition
		iii	current = 1.2 (A) / $R = \frac{2.0}{1.2}$ resistance = 1.7 (Ω)	C1 A1	**Bald** 1.7 (Ω) scores 2/2 marks
	b		Straight line through the origin (for first three squares for *V*) Correct curve (after three squares of *V*)	B1 B1	These are independent marks
	c	i	current = 0 (A)	B1	
		ii	potential difference = 0.4 (V)	B1	
			Total	8	

2 **(a)** Draw a line from each of the named components on the left-hand side to the correct *I*-*V* characteristic on the right-hand side.

metallic wire at constant temperature	
semiconductor diode	
filament lamp	

[1]

(b) In this question, two marks are available for the quality of written communication.

Explain, in terms of resistance, the shape of the *I-V* graph for each component below.

(i) Metallic wire at constant temperature.

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(ii) Semiconductor diode.

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(iii) Filament lamp.

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[6]

Quality of Written Communication [2]

[Total: 9]

1

(a) Correct symbols for the cell (not battery), resistor and thermistor B1
Correctly drawn circuit B1

(b)(i) $V = IR$ / $V = 0.005 \times 120$ C1
potential difference = 0.60 (V) (Allow 1 sf) A1

(b)(ii) V = 1.4 – 0.6 (= 0.8 V) (Possible ecf) C1

$$R = \frac{0.8}{0.005}$$

resistance = 160 (Ω) A1
[Allow 1 mark for total resistance calculation: $R = 1.4 / 0.005 = 280$ (Ω)]

(c) The resistance of the thermistor increases / the current decreases B1
Hence, the p.d across the resistor decreases. B1

[Total: 8]

2

(a) All I-V graphs identified correctly B1

(b)(i) The resistance / R remains constant B1
$I \propto V$ / Graph has a constant slope / gradient / Obeys Ohm's law B1

(b)(ii) R is infinite / large when: I = 0 / no conduction / 'reverse' direction / 'up to a point' / negative V / negatively biased B1
R is small / decreases / low(er) when: I is not zero / there is conduction / 'positive' direction / 'beyond a point' / positive V / positively biased B1
(No credit for 'conducts in one direction only')

(b)(iii) The resistance increases as I (or V) increases B1
The temperature increases (as I increases) / more electrons collisions (with the vibrating atoms / ions) B1

QWC
The answer must involve physics, which attempts to answer the question.

Structure and organisation -
Award this mark if the whole answer is well structured. B1

Spelling and Grammar mark -
More than two spelling mistakes or more than two grammatical errors means the SPAG mark is lost. B1

[Total: 9]

Answer **all** the questions.

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

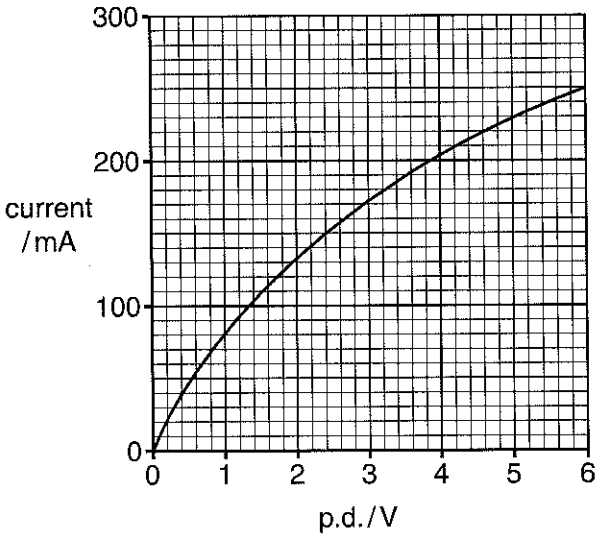

Fig. 1.1

(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]**

(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.

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..... **[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]

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**	

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.

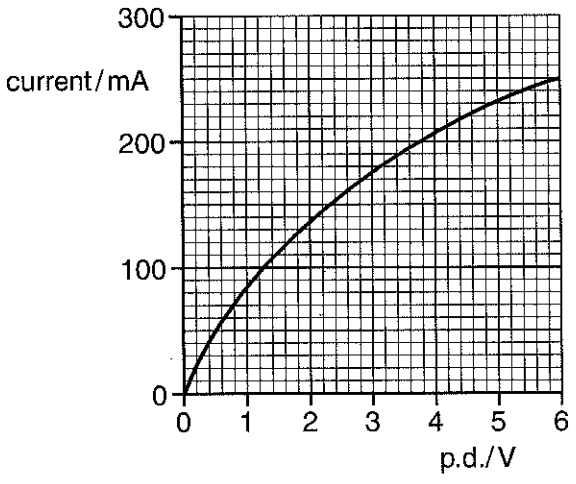

Fig. 1.1

(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 10Ω. 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.

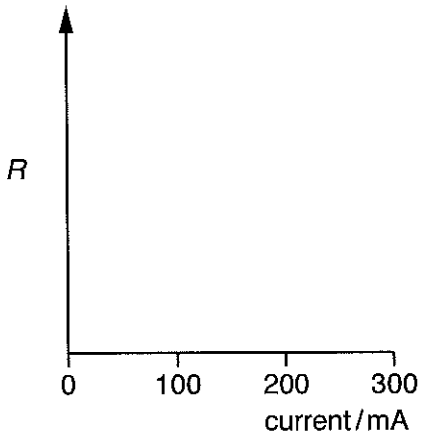

Fig. 1.2

[2]

(iii) Explain why the resistance of the lamp varies as shown by the graph you have drawn on Fig. 1.2.

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.....

.....

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

(d) In an alternative design for the set of Christmas tree lights, a 100Ω 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]

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**	

Answer **all** the questions.

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

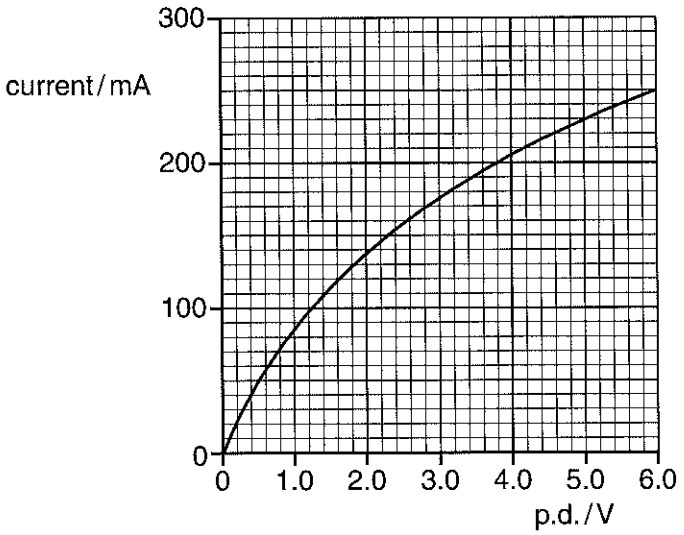

Fig. 1.1

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

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

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

[2]

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

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

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

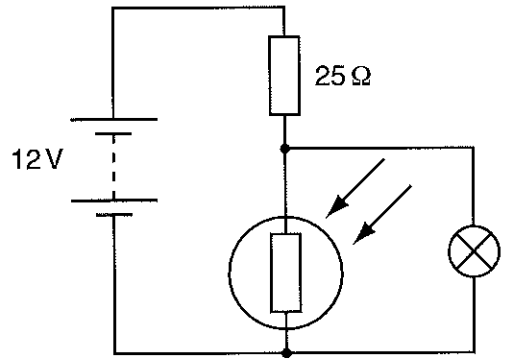

Fig. 1.2

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

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

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

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

[Total: 10]

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**	

26 **(a)** Filament lamps are being replaced by LED lamps in many large organisations. LEDs are low-powered devices.

(i) Apart from cost, state one major advantage this can have on the environment.

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

(ii) A light-emitting diode emits photons of a specific wavelength. The intensity of the light emitted from the LED is doubled.
Explain the effect this has on the energy of a photon.

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

(b) **Fig. 26.1** shows part of the apparatus for an experiment in which electrons pass through a thin slice of graphite (carbon atoms) and emerge to produce concentric rings on a fluorescent screen.

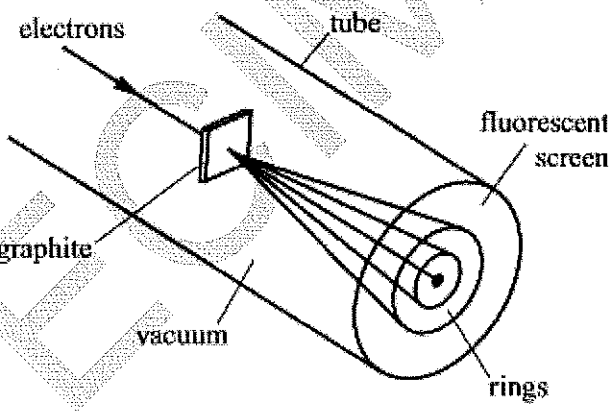

Fig. 26.1

(i) Explain how this experiment demonstrates the wave-nature of electrons.

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

(ii) The beam of electrons in the apparatus shown in **Fig. 26.1** is produced by accelerating electrons through a potential difference of 1200 V.

Show that the de Broglie wavelength of the electrons is 3.5×10^{-11} m.

[2]

(iii) When de Broglie first put forward his idea it was new to the scientific community. Describe one way in which they could validate his ideas.

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[1]

END OF QUESTION PAPER

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Question			Answer	Marks	Guidance
26	(a)	(i)	Less energy used from power stations, which in turn produce less carbon dioxide emissions and hence less environmental damage **or** Infrequent need for disposal of LED lamps has less impact on landfill sites or use of natural resources.	B1	
		(ii)	The energy of a photon depends on the wavelength **or** frequency. Energy does not depend on intensity therefore energy of the photon is the same.	B1 B1	
	(b)	(i)	Electrons behave **or** travel as waves. The rings demonstrate that the electrons are diffracted by individual carbon atoms / spacing between carbon atoms. The (de Broglie) wavelength of the electrons is comparable to the 'size' of the carbon atoms or the spacing between carbon atoms.	B1 B1 B1	
		(ii)	$v^2 = \frac{1.6\times10^{-19}\times1200}{0.5\times9.11\times10^{-31}}$ or $v = 2.053.. \times 10^7$ (m s^{-1}) $\lambda = \frac{6.63\times10^{-34}}{9.11\times10^{-31}\times2.053\times10^7}$ wavelength = 3.5×10^{-11} (m)	C1 C1	Correct use of $½ mv^2 = eV$
		(iii)	Results published to allow peer review Procedure shared with other scientists to allow replication	B1	
			Total	**9**	

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

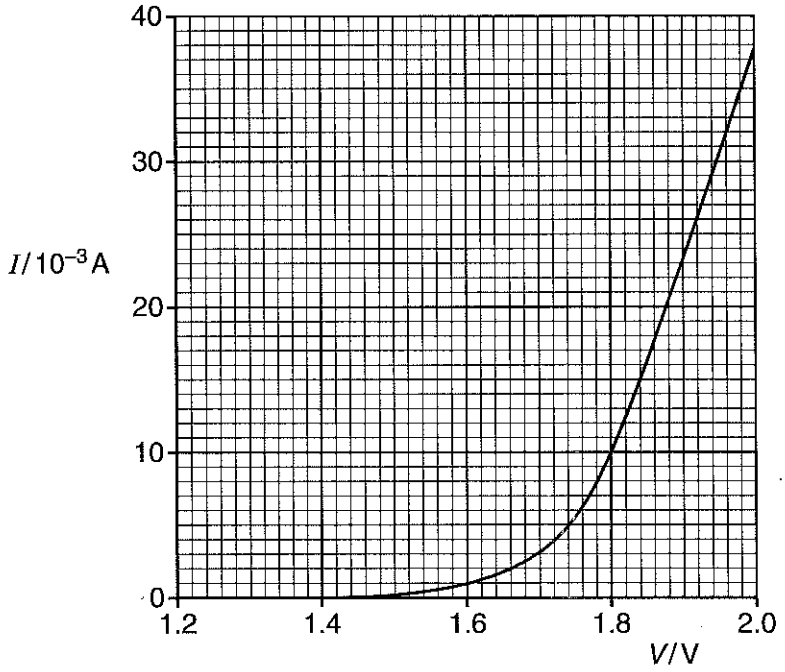

Fig. 2.1

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

(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]**

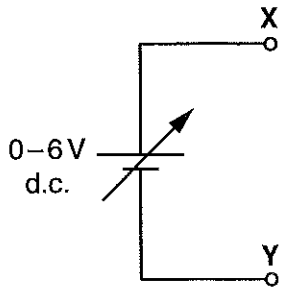

Fig. 2.2

(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.

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

[Total: 12]

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	

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

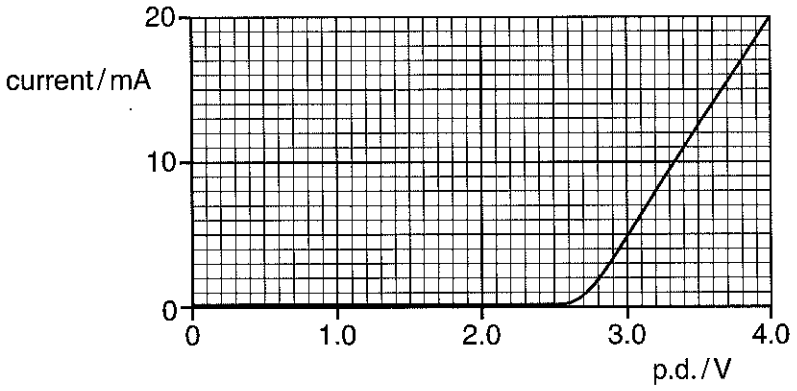

Fig. 4.1

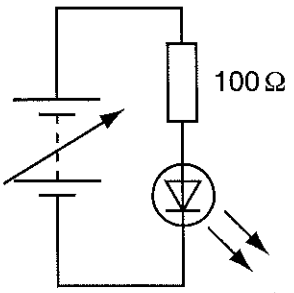

Fig. 4.2

(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.

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

(c) Calculate for a current of 20 mA

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

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

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

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

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

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

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

[Total: 15]

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	

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

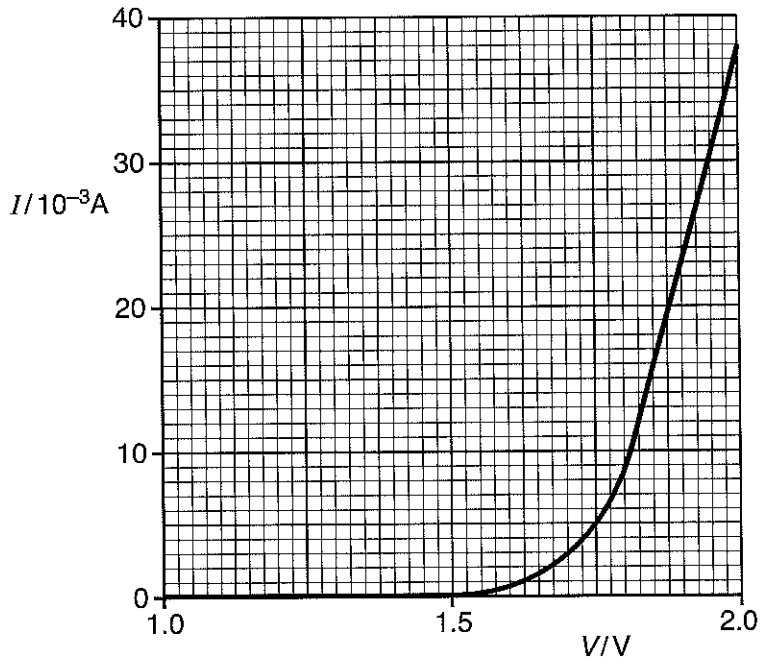

Fig. 4.1

(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.

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

(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.

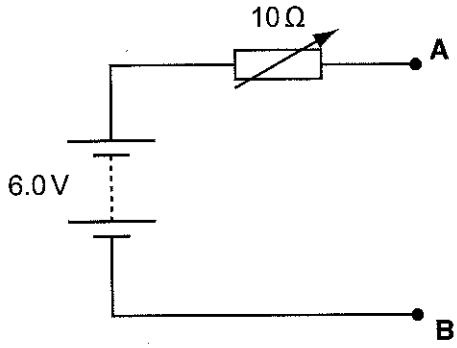

Fig. 4.2

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.

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

(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)**.

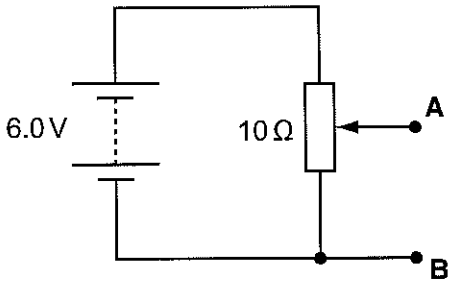

Fig. 4.3

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.

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

[Total: 16]

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 of the LDR decreases (so total resistance in circuit decreases) and current increases	M1 A1	
		ii	resistance of LDR and 12 Ω (in parallel)/across **XY** 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 current in the circuit (when the LED conducts) otherwise it could overheat/burn out/be damaged/AW	B1 B1	
	d		in fig 4.3 the voltage 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**	

Answer **all** the questions.

1 Two 6.0V 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.

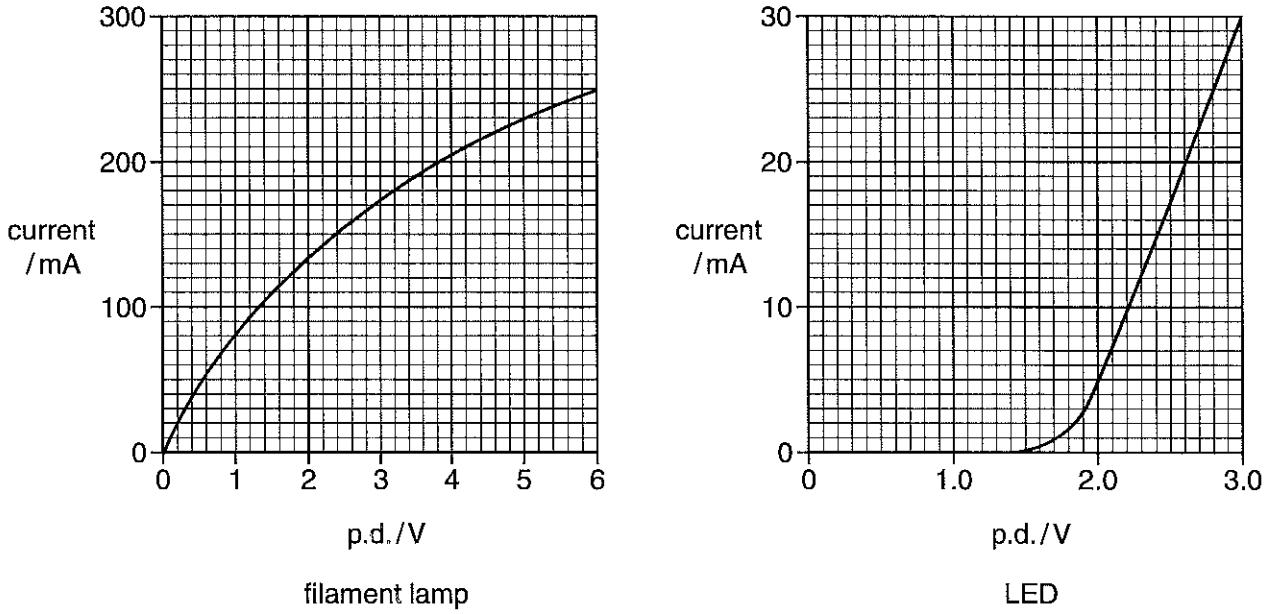

Fig. 1.1

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

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..... **[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 0.25A at a p.d. of 6.0V.

(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]**

(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 6.0V battery and switch so that the potential difference across each of the four LEDs is 3.0V.

(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 0.36W.

[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.

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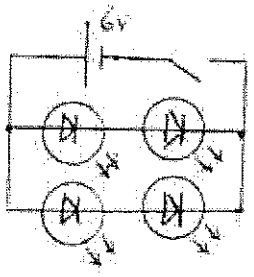
..... **[1]**

[Total: 16]

Question			Expected Answers	M	Additional Guidance
1					
	a	i	read off value of current (at V = 6.0 V)	B1	any reference to using gradient scores 0/2 **accept** I = 0.25 (A) or 250 (mA)
			calculate R using V/I	B1	**accept** R = 24 Ω
		ii	V is not proportional to I	B1	**accept** not a straight line; R is not constant
	b	i	Q = It = 0.25 x 1 = 0.25 C	B1	
		ii	E = VIt or QV = 6 x 0.25 = 1.5 J	B1	**ecf(b)(i)**
		iii	E = VIt = 1.5 x 4 x 60 x 60	C1	**ecf b(ii)**
			= 2.16 x10^4 J	A1	**accept** 2.2 x 10^4 J; **allow** 360 J for 1 mark only
	c	i	energy transfer per unit charge	B1	**or** energy transfer/charge; work done /charge
			from electrical to other forms	B1	**or** across LED
		ii	30 mA	A1	
		iii	Use of P = VI	M1	3 x 0.030 = 0.090 W per LED so 0.090 x 4
			suitable method (may be expressed purely in numerical form)	A1	**or** 30 mA in two branches at 6 V **or** total current is 60
			= 0.36 W	A0	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**	