ELECTRICITY WORKSHEET
AS-Level Physics 9702

ON24/22/Q5

1 **(a)** Define electric potential difference (p.d.).

....

.... [1]

(b) A power supply, three resistors and a component X are connected in the circuit shown in Fig. 5.1.

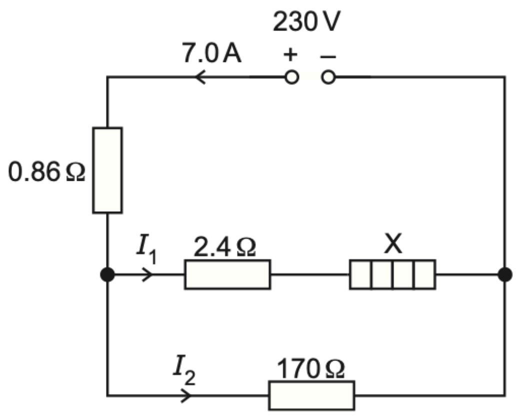

Fig. 5.1

The power supply has an electromotive force (e.m.f.) of 230 V and negligible internal resistance. The current in the power supply is 7.0 A.

(i) Identify component X.

.... [1]

(ii) Show that the p.d. across the resistor of resistance 0.86 Ω is 6.0 V.

[1]

(iii) Determine the current I_1.

I_1 = ... A [2]

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(iv) Calculate the p.d. across component X.

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

(v) Calculate the power dissipated in component X.

power = ... W [2]

(vi) The purpose of the circuit is to provide power to component X.

Determine the percentage efficiency of the circuit.

efficiency = ... % [2]

(vii) The resistor of resistance 170 Ω is removed, leaving an open circuit in the lower branch of the circuit. There is no change to the resistance of component X.

State whether the current in the power supply increases, decreases or remains the same.

.... [1]

[Total: 12]

2 **(a)** Define resistance. **ON24/23/Q6**

....

.... [1]

(b) A cylindrical metal wire of length 2.4 m and cross-sectional area $8.0 \times 10^{-6}\,m^2$ has a resistance of 0.33 Ω. There is a current in the wire of 4.7 A.

(i) Determine the resistivity of the metal from which the wire is made.

resistivity = ... Ωm [2]

(ii) Calculate the charge that passes through the wire in a time of 5.0 minutes.

charge = ... C [2]

(iii) The free electrons (charge carriers) in the wire have an average drift speed of $0.16\,mm\,s^{-1}$.

Determine the number density of charge carriers in the metal.

number density = ... m^{-3} [2]

(c) The wire in **(b)** may be considered to be a fixed resistor. It is connected in series with a thermistor to a battery that has negligible internal resistance.

(i) Use circuit symbols to complete Fig. 6.1 to show the circuit diagram of this arrangement.

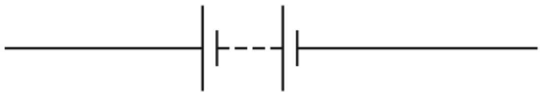

Fig. 6.1

[1]

(ii) Explain, without calculation, how the power dissipated in the wire changes as the temperature of the thermistor is increased.

....

....

....

.... [2]

[Total: 10]

MJ24/22/Q5

3 **(b)** A battery of electromotive force (e.m.f.) 9.0V and negligible internal resistance is connected in series with a variable resistor X and a thermistor Y as shown in Fig. 5.1.

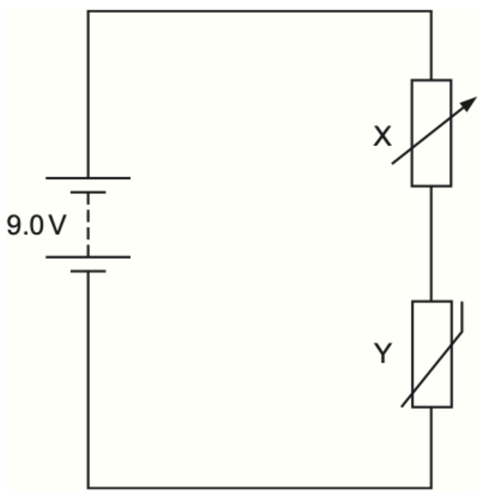

Fig. 5.1

Fig. 5.2 shows the relationship between temperature and resistance for the thermistor.

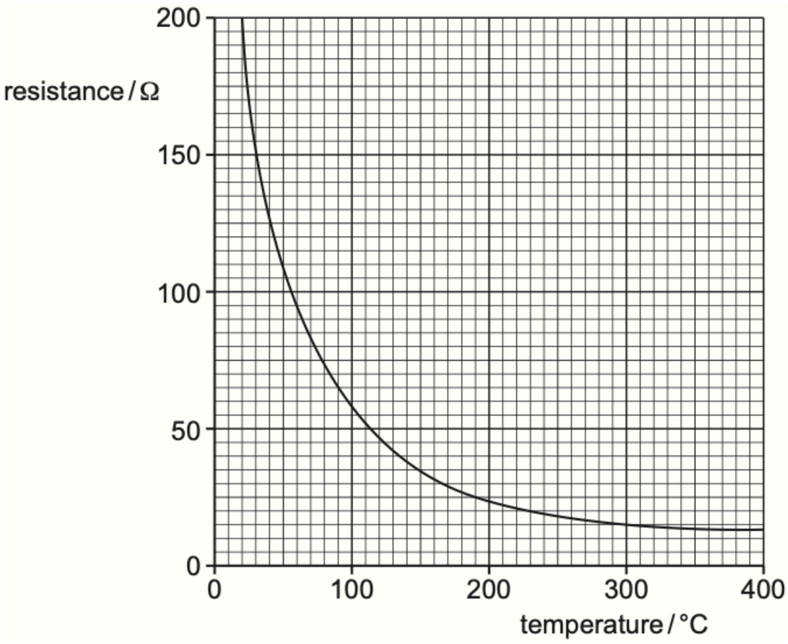

Fig. 5.2

(i) The current in the circuit is 1.1×10^{-2} A. The potential difference across Y is 4.0 V.

Calculate the resistance of X.

resistance = ... Ω [2]

(ii) The temperature of Y is changed to 190 °C. The resistance of X remains unchanged.

Determine the new potential difference across Y.

potential difference = ... V [3]

(iii) The resistance of X is increased. The temperature of Y remains at 190 °C.

By reference to the current in the circuit, state and explain the effect of this change, if any, on the potential difference **across Y**.

....

....

....

....

....

.... [3]

4 A battery is connected in a circuit with a light-dependent resistor (LDR), two fixed resistors and a voltmeter, as shown in Fig. 6.1.

ON23/21/Q6

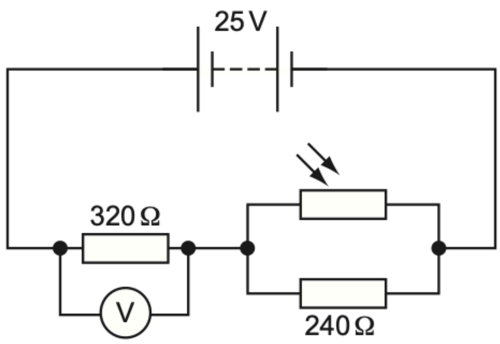

Fig. 6.1

The battery has an electromotive force (e.m.f.) of 25 V and negligible internal resistance. The resistors have resistances of 320 Ω and 240 Ω.

(a) The voltmeter displays a reading of 16 V.

(i) Show that the current in the battery is 0.050 A.

[1]

(ii) Calculate the resistance of the LDR.

resistance = ... Ω [3]

(iii) Determine the ratio

$$\frac{\text{power dissipated in the LDR}}{\text{power dissipated in the } 240\,\Omega \text{ resistor}}.$$

ratio = ... [2]

(b) The intensity of the light incident on the LDR increases.

State and explain what happens to the voltmeter reading.

....

....

....

.... [3]

[Total: 9]

ON23/22/Q6

5 **(a)** A metal wire has a resistance per unit length of $0.92\,\Omega\,m^{-1}$. The wire has a uniform cross-sectional area of $5.3 \times 10^{-7}\,m^2$.

Calculate the resistivity of the metal of the wire.

resistivity = ... Ω m [2]

(b) A battery of electromotive force (e.m.f.) *E* and negligible internal resistance is connected in series with a fixed resistor and a light-dependent resistor (LDR), as shown in Fig. 6.1.

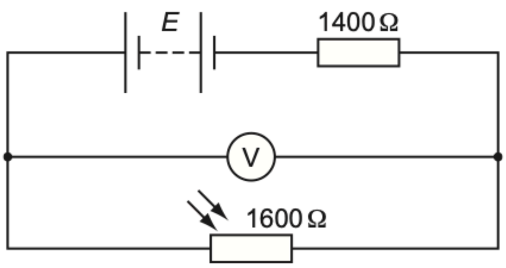

Fig. 6.1

The resistance of the fixed resistor is 1400 Ω. The intensity of the light illuminating the LDR causes it to have a resistance of 1600 Ω. A voltmeter connected across the LDR reads 6.4 V.

(i) Show that the current in the LDR is 4.0×10^{-3} A.

[1]

(ii) Calculate the number of free electrons passing through the LDR in a time of 3.2 minutes.

number of free electrons = ... [2]

(iii) Calculate the e.m.f. *E*.

E = ... V [2]

(iv) Determine the ratio

$$\frac{\text{power dissipated in LDR}}{\text{power dissipated in fixed resistor}}.$$

ratio = ... [2]

(c) The environmental conditions change causing a decrease in the resistance of the LDR in **(b)**. The temperature of the environment does not change.

State whether there is a decrease, increase or no change to:

(i) the intensity of the light illuminating the LDR

.... [1]

(ii) the current in the battery

.... [1]

(iii) the reading of the voltmeter.

.... [1]

[Total: 12]

March19/22/Q6

6 **(a)** Using energy transformations, describe the *electromotive force* (*e.m.f.*) of a battery and the *potential difference* (*p.d.*) across a resistor.

e.m.f.: ....

....

p.d.: ....

.... [2]

(b) A battery of e.m.f. 6.0 V and negligible internal resistance is connected to a network of resistors and a voltmeter, as shown in Fig. 6.1.

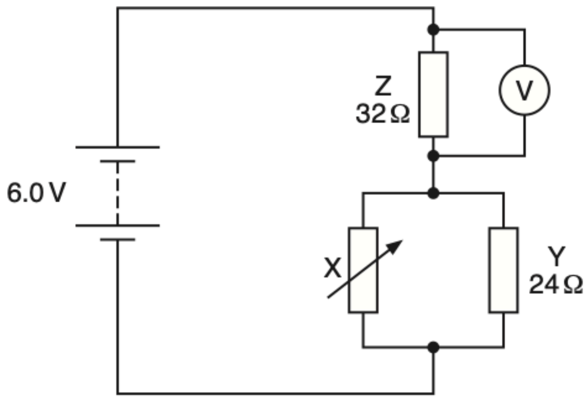

Fig. 6.1

Resistor Y has a resistance of 24 Ω and resistor Z has a resistance of 32 Ω.

(i) The resistance R_X of the variable resistor X is adjusted until the voltmeter reads 4.8 V.

Calculate:

1. the current in resistor Z

current = ... A [1]

2. the total power provided by the battery

power = ... W [2]

3. the number of conduction electrons that move through the battery in a time interval of 25 s

number = ... [2]

4. the total resistance of X and Y connected in parallel

total resistance = ... Ω [2]

5. the resistance R_X.

R_X = ... Ω [2]

(ii) The resistance R_X is now decreased.

State and explain the change, if any, to the reading on the voltmeter.

....

....

....[2]

[Total: 13]

7 A metal wire in a circuit has a length of 1.8 m and a cross-sectional area of $1.5 \times 10^{-6}\,m^2$.
The total number of free electrons (charge carriers) in the wire is 2.3×10^{23}.

There is a current in the wire so that a charge of 172 C moves past a fixed point in the wire in a time of 2.5 minutes.

(a) Show that the number density of the free electrons in the wire is $8.5 \times 10^{28}\,m^{-3}$.

[1]

(b) Calculate the average drift speed of the free electrons.

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

[Total: 4]

MJ23/21/Q7

8 A battery of electromotive force (e.m.f.) 9.6 V and negligible internal resistance is connected in series with two fixed resistors and a thermistor, as shown in Fig. 7.1.

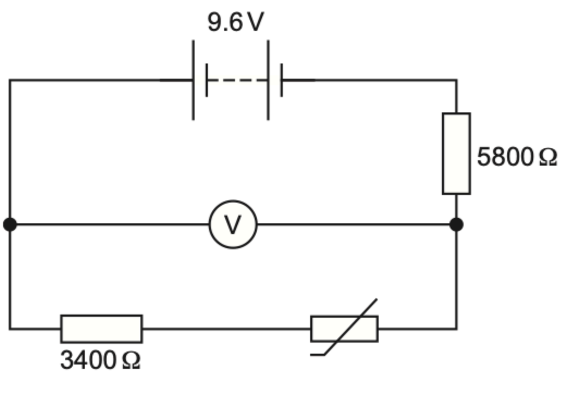

Fig. 7.1

The fixed resistors have resistances of 3400 Ω and 5800 Ω. The reading on the voltmeter in the circuit is 6.0 V.

(a) Calculate the current in the resistor of resistance 5800 Ω.

current = ...A [2]

(b) Calculate the resistance of the thermistor.

resistance = ... Ω [2]

(c) The initial energy stored in the battery is 2.6×10^4 J.

Assume that the e.m.f. of the battery is constant.

Determine the final energy stored in the battery after a charge of 330 C has moved through it.

final stored energy = ... J [2]

(d) The environmental conditions change causing an increase in the resistance of the thermistor.

State whether there is a decrease, increase or no change to:

(i) the temperature of the thermistor

.... [1]

(ii) the current in the thermistor

.... [1]

(iii) the potential difference across the thermistor.

.... [1]

[Total: 9]

9 **(a)** The current in a filament lamp decreases. **MJ23/22/Q6**

State and explain how the resistance of the lamp changes.

....

.... [1]

(b) A cylindrical wire has length L and resistance R. The **total** number of free electrons (charge carriers) contained in the volume of the wire is N. Each free electron has charge e. The potential difference between the ends of the wire is V.

Determine expressions, in terms of some or all of the symbols e, L, N, R and V for:

(i) the current in the wire

current = ... [1]

(ii) the average drift speed of the free electrons

average drift speed = ... [2]

(iii) the average time taken for a free electron to move along the full length of the wire.

time taken = ... [1]

[Total: 5]

10 A student sets up a circuit with a battery, an ammeter, a heater and a light-dependent resistor (LDR) all in series.

The battery has negligible internal resistance.

A voltmeter is connected across (in parallel with) the heater.

(a) On Fig. 5.1, complete the circuit diagram of this arrangement.

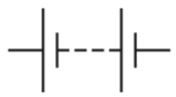

Fig. 5.1

[3]

(b) The heater is a wire made of metal of resistivity $1.1 \times 10^{-6}\,\Omega\,m$. The wire has length 2.0 m and cross-sectional area $3.8 \times 10^{-7}\,m^2$.

The reading on the voltmeter is 4.8 V.

Calculate:

(i) the resistance of the heater

resistance = ... Ω [2]

(ii) the reading on the ammeter.

reading on ammeter = ... A [1]

(c) The heater is replaced by a new wire. The new wire is made of the same metal as the wire in **(b)** and has the same length but a larger diameter.

The resistance of the LDR remains constant.

(i) State and explain whether the new wire has a resistance that is greater than, less than or the same as that of the wire in **(b)**.

....

....

.... [2]

(ii) State and explain whether the new reading on the voltmeter is greater than, less than or equal to 4.8 V.

....

....

.... [2]

[Total: 10]

ON22/21/Q5

11 (a) State Ohm's law.

....

....

.... [2]

(b) The variation of current I with potential difference V for a filament lamp is shown in Fig. 5.1.

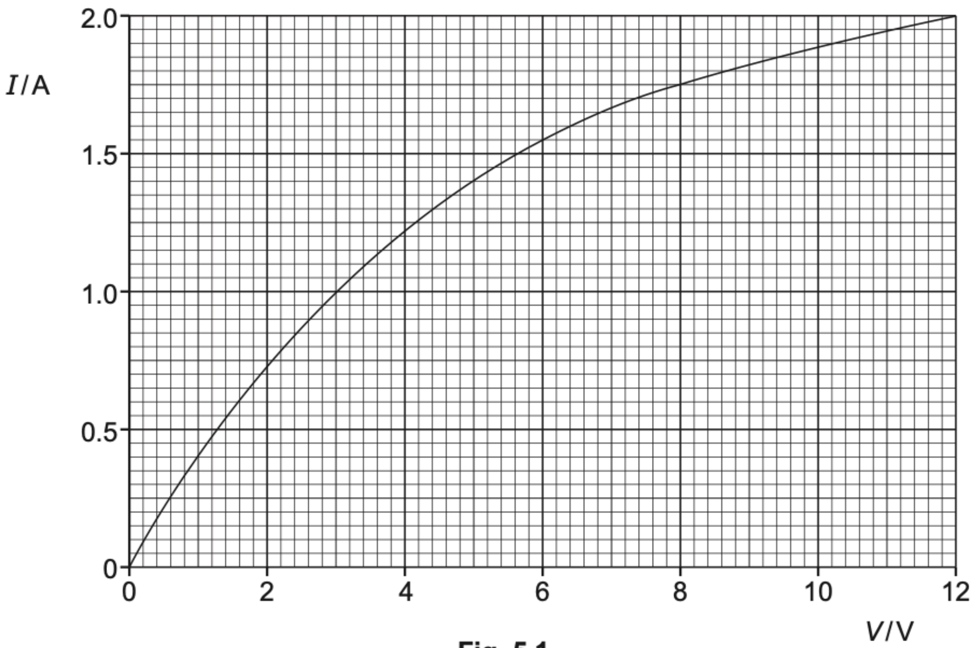

Fig. 5.1

The resistance of the filament lamp increases with potential difference.

(i) State how Fig. 5.1 shows this.

....

.... [1]

(ii) Explain why the resistance varies in this way.

....

.... [1]

(c) Fig. 5.2 shows a circuit with a battery of electromotive force (e.m.f.) 12.0 V connected to a linear potentiometer AB and two identical filament lamps P and Q.

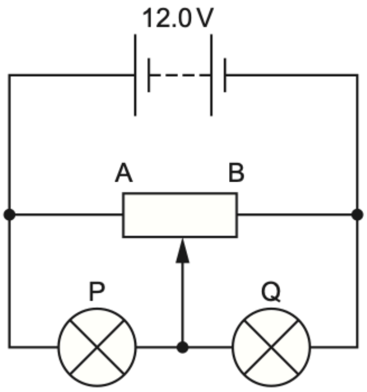

Fig. 5.2

The battery has negligible internal resistance and the lamps each have the same I–V characteristic shown in Fig. 5.1.

When the slider of the potentiometer is at its midpoint, as shown in Fig. 5.2, the current I in the battery is 1.78 A.

Determine:

(i) the current in lamp P

current = ... A [1]

(ii) the total power dissipated in lamps P and Q

total power = ... W [2]

(iii) the resistance of the potentiometer between its ends A and B.

resistance = ... Ω [2]

(d) The slider of the potentiometer in **(c)** is moved to end A.

State and explain the effect on the brightness of lamps P and Q.

lamp P: ....

....

lamp Q: ....

....
[2]

[Total: 11]

12 (b) A battery is connected to two resistors X and Y, as shown in Fig. 6.1. **MJ22/21/Q6**

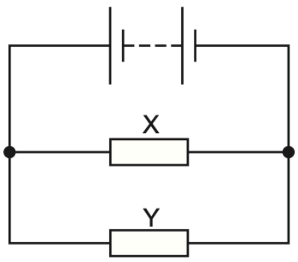

Fig. 6.1

The resistance of resistor X is greater than the resistance of resistor Y.

(i) State and explain which resistor dissipates more power.

....

....

....

....

.... [3]

(ii) The two resistors are made of wires that have the same length. Both wires are made from metal of the same resistivity.

State and explain which resistor is made of wire with the larger cross-sectional area.

....

....

.... [2]

(c) A battery of electromotive force (e.m.f.) 9.0 V and negligible internal resistance is connected in series with a light-dependent resistor (LDR) and a fixed resistor of resistance 1800 Ω, as shown in Fig. 6.2.

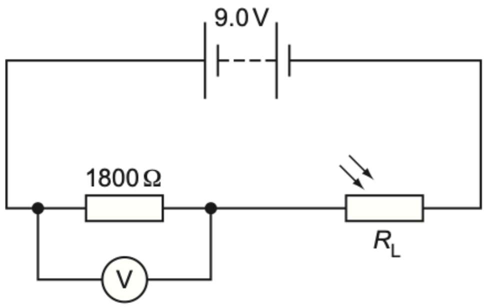

Fig. 6.2

A voltmeter is connected across the fixed resistor. The reading on the voltmeter is 5.4 V.

(i) Calculate the current in the circuit.

current = ... A [1]

(ii) Calculate the resistance R_L of the LDR.

R_L = ... Ω [2]

(iii) The intensity of the light illuminating the LDR increases.

By reference to the current in the circuit, state and explain the change, if any, to the voltmeter reading.

....

....

....

.... [2]

13 **(a)** **(i)** On Fig. 6.1, sketch the I–V characteristic of a filament lamp.

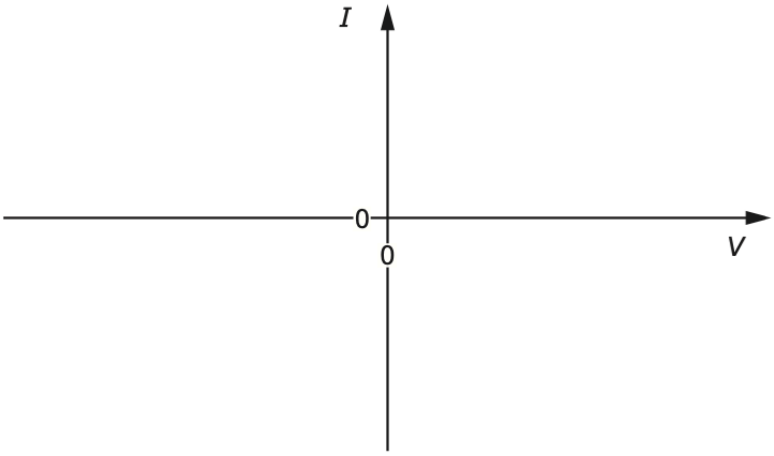

Fig. 6.1

[2]

(ii) Explain the shape of the line in **(a)(i)**.

....

....

....

.... [3]

(b) A conducting wire has length 5.8 m and cross-sectional area $3.4 \times 10^{-8}\,m^2$. The resistivity of the metal of the wire is $5.6 \times 10^{-8}\,\Omega\,m$.

Calculate the resistance of the wire.

resistance = ... Ω [2]

Fig. 6.2

(c) A resistor of resistance R is placed in a circuit with a cell of negligible internal resistance, two switches S_1 and S_2, a second resistor of resistance $2R$ and three ammeters X, Y and Z. The circuit is shown in Fig. 6.2.

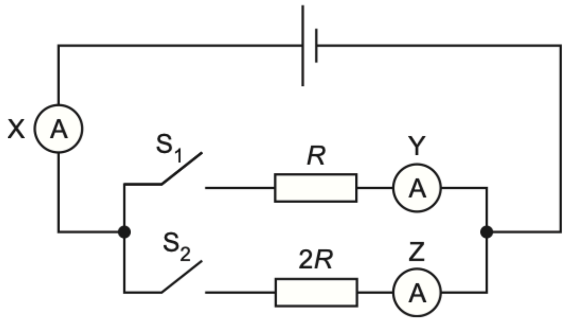

Fig. 6.2

The reading on X is 1.0A when S_1 is open and S_2 is closed.

Complete Table 6.1.

Table 6.1

position of switches		ammeter readings		
S_1	S_2	reading on X/A	reading on Y/A	reading on Z/A
open	open	0	0	0
open	closed	1.0		
closed	open			
closed	closed			

[4]

[Total: 11]

14 The ends of a metal resistance wire are connected to a battery of electromotive force (e.m.f.) 8.0 V and negligible internal resistance, as shown in Fig. 6.1.

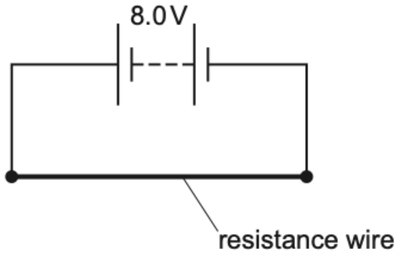

Fig. 6.1

The power dissipated by the resistance wire is 36 W.

(a) Calculate:

(i) the current in the resistance wire

current = ...A [2]

(ii) the number of free electrons that pass through the resistance wire in a time of 50 s

number = ... [2]

(iii) the resistance of the wire.

resistance = ... Ω [2]

(b) The metal of the resistance wire in the circuit has a resistivity of $1.4 \times 10^{-6}\,\Omega$m. The cross-sectional area of the wire is $0.25\,mm^2$.

Determine the length of the wire.

length = ... m [2]

(c) The circuit shown in Fig. 6.1 is modified by replacing the original resistance wire with a second resistance wire. The second wire has a greater diameter than the original wire. There are no other differences between the second wire and the original wire.

By reference to resistance, state and explain whether the power dissipated by the second wire is more than, less than or the same as the power dissipated by the original wire.

....

....

....

.... [2]

(d) The circuit shown in Fig. 6.1 is modified by connecting a second battery, of e.m.f. 8.0 V and negligible internal resistance, in parallel with the original battery and the original resistance wire, as shown in Fig. 6.2.

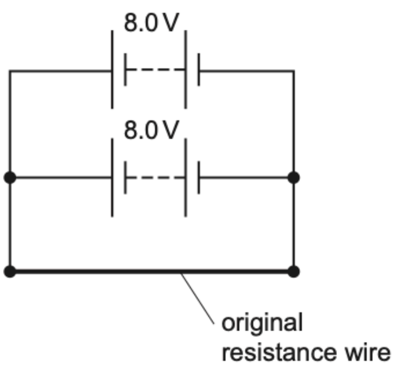

Fig. 6.2

By reference to the current in the resistance wire, state and explain whether the addition of the second battery causes the power in the original resistance wire to decrease, increase or stay the same.

....

....

....

.... [2]

[Total: 12]

15 **(a)** Metal wire is used to connect a power supply to a lamp. The wire has a total resistance of $3.4\,\Omega$ and the metal has a resistivity of $2.6 \times 10^{-8}\,\Omega\text{m}$. The total length of the wire is 59 m.

(i) Show that the wire has a cross-sectional area of $4.5 \times 10^{-7}\,\text{m}^2$.

[2]

(ii) The potential difference across the total length of wire is 1.8 V.

Calculate the current in the wire.

current = ... A [1]

(iii) The number density of the free electrons in the wire is $6.1 \times 10^{28}\,\text{m}^{-3}$.

Calculate the average drift speed of the free electrons in the wire.

average drift speed = ... $\text{m}\,\text{s}^{-1}$ [2]

(b) A different wire carries a current. This wire has a part that is thinner than the rest of the wire, as shown in Fig. 5.1.

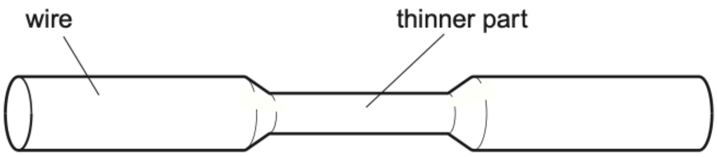

Fig. 5.1

(i) State and explain qualitatively how the average drift speed of the free electrons in the thinner part compares with that in the rest of the wire.

....

....

.... [2]

(ii) State and explain whether the power dissipated in the thinner part is the same, less or more than the power dissipated in an equal length of the rest of the wire.

....

....

.... [2]

(c) Three resistors have resistances of 180 Ω, 90 Ω and 30 Ω.

(i) Sketch a diagram showing how **two** of these three resistors may be connected together to give a combined resistance of 60 Ω between the terminals shown.
Ensure you label the values of the resistances in your diagram.

[1]

(ii) A potential divider circuit is produced by connecting the three resistors to a battery of electromotive force (e.m.f.) 12 V and negligible internal resistance. The potential divider circuit provides an output potential difference V_{OUT} of 8.0 V.
Fig. 5.2 shows the circuit diagram.

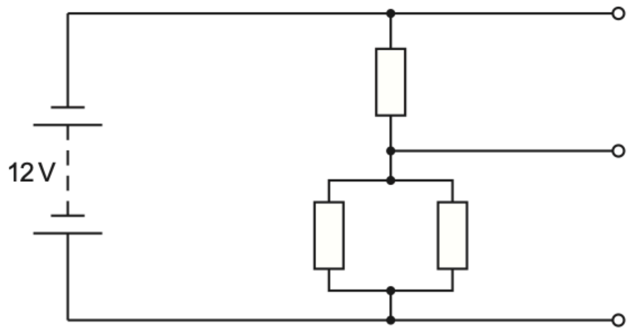

Fig. 5.2

On Fig. 5.2, label the resistances of all three resistors and the potential difference V_{OUT}. [2]

[Total: 12]

16 **(a)** Define the *volt*.

....

.... [1]

(b) Fig. 5.1 shows a network of three resistors.

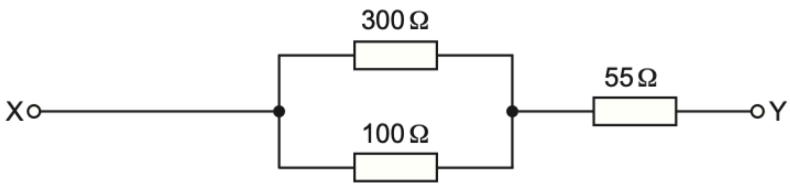

Fig. 5.1

Calculate:

(i) the combined resistance of the two resistors connected in parallel

combined resistance = ... Ω [1]

(ii) the total resistance between terminals X and Y.

total resistance = ... Ω [1]

(c) The network in **(b)** is connected to a power supply so that there is a potential difference between terminals X and Y. The power dissipated in the resistor of resistance 55 Ω is 0.20 W.

(i) Calculate the current in the resistor of resistance:

1. 55 Ω

current = ... A

2. 300 Ω.

current = ... A
[3]

(ii) Calculate the potential difference between X and Y.

potential difference = ... V [1]

[Total: 7]

17 The current I in a metal wire is given by the expression

$$I = Anve$$

where v is the average drift speed of the free electrons in the wire and e is the elementary charge.

(a) State what is meant by the symbols A and n.

A: ....

n: .... [2]

(b) Use the above expression to determine the SI base units of e.
Show your working.

base units .... [2]

(c) Two lamps P and Q are connected in series to a battery, as shown in Fig. 6.1.

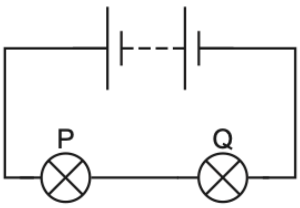

Fig. 6.1

The radius of the filament wire of lamp P is twice the radius of the filament wire of lamp Q. The filament wires are made of metals with the same value of n.

Calculate the ratio

$$\frac{\text{average drift speed of free electrons in filament wire of P}}{\text{average drift speed of free electrons in filament wire of Q}}.$$

ratio = ... [2]

[Total: 6]

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

....

....

.... [1]

(b) A wire has a resistance of 1.8 Ω. The wire has a uniform cross-sectional area of 0.38 mm^2 and is made of metal of resistivity 9.6 × 10^{-7} Ω m.

Calculate the length of the wire.

length = ... m [3]

(c) A resistor X of resistance 1.8 Ω is connected to a resistor Y of resistance 0.60 Ω and a battery P, as shown in Fig. 5.1.

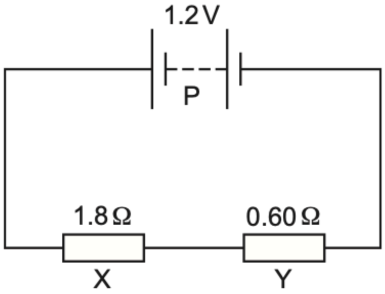

Fig. 5.1

The battery P has an electromotive force (e.m.f.) of 1.2 V and negligible internal resistance.

(i) Explain, in terms of energy, why the potential difference (p.d.) across resistor X is less than the e.m.f. of the battery.

....

....

.... [1]

(ii) Calculate the potential difference across resistor X.

potential difference = ... V [2]

(d) Another battery Q of e.m.f. 1.2 V and negligible internal resistance is now connected into the circuit of Fig. 5.1 to produce the new circuit shown in Fig. 5.2.

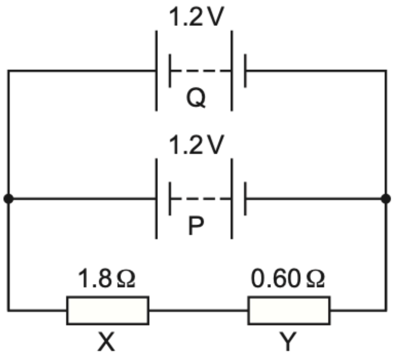

Fig. 5.2

State whether the addition of battery Q causes the current to decrease, increase or remain the same in:

(i) resistor X .... [1]

(ii) battery P. .... [1]

(e) The circuit shown in Fig. 5.2 is modified to produce the new circuit shown in Fig. 5.3.

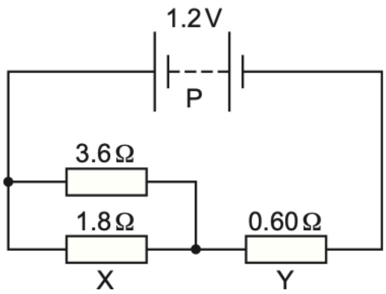

Fig. 5.3

Calculate:

(i) the total resistance of the two resistors connected in parallel

resistance = ... Ω [1]

(ii) the current in resistor Y.

current = ... A [2]

[Total: 12]

19 **(a)** Define *electric potential difference* (*p.d.*).

....

.... [1]

(b) The variation with potential difference *V* of the current *I* in a semiconductor diode is shown in Fig. 6.1.

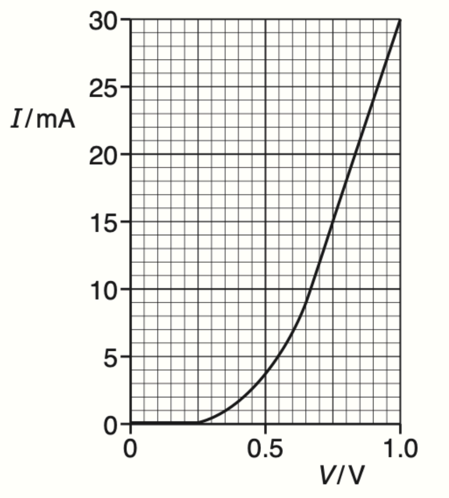

Fig. 6.1

Use Fig. 6.1 to describe qualitatively the variation of the resistance of the diode as *V* increases from 0 to 1.0 V.

....

....

....

.... [2]

(c) The diode in **(b)** is part of the circuit shown in Fig. 6.2.

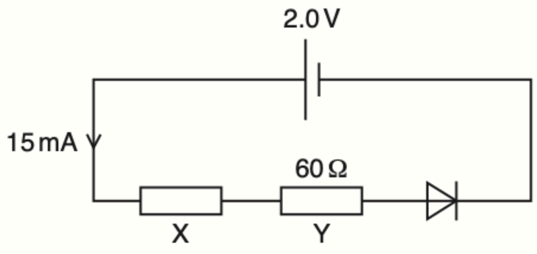

Fig. 6.2

The cell of electromotive force (e.m.f.) 2.0 V and negligible internal resistance is connected in series with the diode and resistors X and Y. The resistance of Y is 60 Ω. The current in the cell is 15 mA.

(i) Use Fig. 6.1 to determine the resistance of the diode.

resistance = ... Ω [3]

(ii) Calculate:

1. the resistance of X

resistance = ... Ω [3]

2. the ratio

$$\frac{\text{power dissipated in resistor Y}}{\text{total power produced by the cell}}.$$

ratio = ... [2]

[Total: 11]

20 A battery of electromotive force (e.m.f.) 12 V and negligible internal resistance is connected to a network of two lamps and two resistors, as shown in Fig. 6.1.

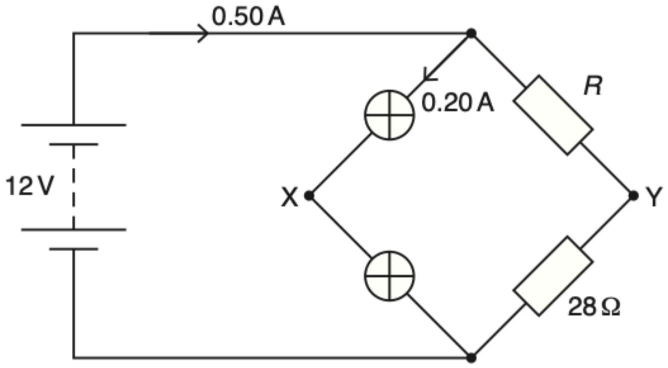

Fig. 6.1

The two lamps in the circuit have equal resistances. The two resistors have resistances *R* and 28 Ω. The lamps are connected at junction X and the resistors are connected at junction Y. The current in the battery is 0.50 A and the current in the lamps is 0.20 A.

(a) Calculate:

(i) the resistance of each lamp

resistance = ... Ω [2]

(ii) resistance *R*.

R = ... Ω [2]

(b) Determine the potential difference V_{XY} between points X and Y.

V_{XY} = ... V [3]

(c) Calculate the ratio

$$\frac{\text{total power dissipated by the lamps}}{\text{total power produced by the battery}}.$$

ratio = ... [2]

(d) The resistor of resistance *R* is now replaced by another resistor of lower resistance.

State and explain the effect, if any, of this change on the ratio in **(c)**.

....

....

....

....

.... [2]

[Total: 11]

1 (a)	energy transferred per unit charge (from electrical to other forms)	**B1**
5(b)(i)	heater	**A1**
5(b)(ii)	(V =) 7.0 × 0.86 = 6.0 (V)	**A1**
5(b)(iii)	I = (230 – 6.0) / 170 (= 1.3 A)	**C1**
	I_1 = 7.0 – 1.3 = 5.7 A	**A1**
5(b)(iv)	V = 230 – 6.0 – (5.7 × 2.4)	**C1**
	= 210 V	**A1**
	or	
	R = ((230 – 6.0) / 5.7) – 2.4 (= 36.9 Ω)	**(C1)**
	V = 5.7 × 36.9 = 210 V	**(A1)**
5(b)(v)	$P = IV$ **or** $P = I^2R$ **or** $P = V^2/R$	**C1**
	P = 5.7 × 210 **or** P = 5.7² × (210 / 5.7) **or** P = 210² / (210 / 5.7) P = 1200 W	**A1**
5(b)(vi)	% efficiency = <u>useful</u> power out / (total) power in (× 100)	**C1**
	= 1200 / (230 × 7.0) (×100) = 0.75 (× 100) = 75% or 74% (using 3 s.f. value from **(v)** gives 74%)	**A1**
5(b)(vii)	(current) decreases	**A1**

2 (a)	potential difference per unit current	**B1**
6(b)(i)	$\rho = RA/L$	**C1**
	= (0.33 × 8.0 × 10⁻⁶) / 2.4 = 1.1 × 10⁻⁶ Ω m	**A1**
6(b)(ii)	$Q = It$	**C1**
	= 4.7 × 5.0 × 60 = 1400 C	**A1**
6(b)(iii)	$I = nAvq$ n = 4.7 / (8.0 × 10⁻⁶ × 0.16 × 10⁻³ × 1.60 × 10⁻¹⁹)	**C1**
	= 2.3 × 10²⁸ m⁻³	**A1**
6(c)(i)	correct symbols for resistor and thermistor, shown correctly connected in series with the battery	**B1**
6(c)(ii)	(as temperature increases) resistance of thermistor decreases	**M1**
	(total resistance decreases so) greater current (in circuit/wire) so power (dissipated in the wire) increases **or** (total resistance decreases so) greater (share of) p.d. across wire so power (dissipated in the wire) increases	**A1**

3 b)(i)	$R = V / I$	C1
	$= (9.0 - 4.0) / 1.1 \times 10^{-2}$ $= 450\ \Omega$	A1
5(b)(ii)	resistance (of thermistor) = 25 (Ω) (from graph)	C1
	$V = E \times R_Y / (R_Y + R_X)$ $= 9 \times 25 / (25 + 450)$ **or** $I = E / R_{Total} = 9 / (25 + 450) = 1.89 \times 10^{-2}$ A $V = IR = 1.89 \times 10^{-2} \times 25$ **or** $V_{(X)} = 9 \times 450 / (25 + 450) = 8.53$ V $V = 9 - 8.53$	C1
	$V = 0.47$ V	A1
5(b)(iii)	(resistance of X increases so) the total resistance increases	B1
	current decreases	B1
	potential difference (across thermistor / Y) decreases	B1

4 (a)(i)	(I =) 16 / 320 = 0.050 (A)	A1
6(a)(ii)	$R = (25 - 16) / 0.050$ **or** $R = (9 / 16) \times 320$ **or** $R = (25 / 0.050) - 320$	C1
	$R = 180$ (Ω)	C1
	$R_{(LDR)} = [(1 / 180) - (1 / 240)]^{-1}$ $= 720\ \Omega$	A1
	or	
	$I = (25 - 16) / 240$ (= 0.0375 A)	(C1)
	$I_{(LDR)} = 0.050 - 0.0375$ (= 0.0125 A)	(C1)
	$R_{(LDR)} = 9.0 / 0.0125$ $= 720\ \Omega$	(A1)
6(a)(iii)	$P = V^2 / R$ **or** $P = VI$ **or** $P = I^2R$	C1
	ratio = $(9^2 / 720) / (9^2 / 240)$ **or** ratio = $(9 \times 0.0125) / (9 \times 0.0375)$ **or** ratio = $(0.0125^2 \times 720) / (0.0375^2 \times 240)$ ratio = 0.1125 / 0.3375 = 0.33	A1
6(b)	resistance of LDR decreases	B1
	resistance of parallel combination decreases **or** total resistance (of circuit) decreases **or** current in resistor of resistance 320 Ω increases **or** potential difference across parallel combination / LDR / 240 Ω resistor decreases	M1
	voltmeter reading increases	A1

5 (a)		$R = \rho L / A$	C1
		$\rho = 0.92 \times 5.3 \times 10^{-7}$ $= 4.9 \times 10^{-7}\ \Omega\,m$	A1
6(b)(i)		(current =) $6.4 / 1600 = 4.0 \times 10^{-3}$ (A)	A1
6(b)(ii)		charge = $4.0 \times 10^{-3} \times 3.2 \times 60$ (= 0.768 C)	C1
		number = $0.768 / 1.6 \times 10^{-19}$ $= 4.8 \times 10^{18}$	A1
6(b)(iii)		$6.4 / E = 1600 / (1400 + 1600)$ **or** $E = 6.4 + (4.0 \times 10^{-3} \times 1400)$ **or** $E = 4.0 \times 10^{-3} (1600 + 1400)$	C1
		$E = 12$ V	A1
6(b)(iv)		$P = I^2R$ **or** $P = VI$ **or** $P = V^2 / R$	C1
		ratio $= (6.4^2 / 1600) / [(4.0 \times 10^{-3})^2 \times 1400]$ $= 1.1$	A1
6(c)(i)		increase	B1
6(c)(ii)		increase	B1
6(c)(iii)		decrease	B1

6 (a)	e.m.f.: energy transferred from chemical to electrical (per unit charge)	B1
	p.d.: energy transferred from electrical to thermal (per unit charge)	B1

6(b)(i)	1 $I = 4.8 / 32$ $= 0.15$ A	A1
	2 $P = EI$ or $P = VI$ or $P = I^2R$ or $P = V^2/R$ $= 6.0 \times 0.15$ or $0.15^2 \times 40$ or $6.0^2 / 40$	C1
	$= 0.90$ W	A1
	3 number $= It / e$ $= [0.15 \times 25] / 1.6 \times 10^{-19}$	C1
	$= 2.3 \times 10^{19}$	A1
	or $Q = 0.15 \times 25$ (= 3.75) number $= 3.75 / 1.6 \times 10^{-19}$	(C1)
	$= 2.3 \times 10^{19}$	(A1)
	4 $4.8 / 6.0 = 32 / (R_{XY} + 32)$ or $1.2 / 6.0 = R_{XY} / (R_{XY} + 32)$ or $4.8 / 1.2 = 32 / R_{XY}$	C1
	$R_{XY} = 8.0\ \Omega$	A1
	Alternative methods:	
	$R_{XY} = (6.0 – 4.8) / 0.15$ or	(C1)
	$= 8.0\ \Omega$	(A1)
	or $6.0 = 0.15 (32 + R_{XY})$	(C1)
	$R_{XY} = 40 – 32$ $= 8.0\ \Omega$	(A1)

6(b)(i)	5 $1/8.0 = 1/R_X + 1/24$	C1
	$R_X = 12\,\Omega$	A1
	Alternative method:	
	$I_Z = 4.8/32 = 0.15$ and $I_Y = 1.2/24 = 0.05$ $I_X = 0.15 - 0.05$ (= 0.10)	(C1)
	$R_X = 1.2/0.10 = 12\,\Omega$	(A1)
6(b)(ii)	total resistance decreases	M1
	(so voltmeter) reading increases	A1

7 (a)	(number density =) $2.3 \times 10^{23} / (1.5 \times 10^{-6} \times 1.8) = 8.5 \times 10^{28}$ (m^{-3})	A1
6(b)	$I = Q/t$ **or** $I = 172/2.5 \times 60$ **or** $I = 1.1(5)$	C1
	$I = nAvq$ $172/(2.5 \times 60) = 1.5 \times 10^{-6} \times 8.5 \times 10^{28} \times v \times 1.6 \times 10^{-19}$	C1
	$v = 5.6 \times 10^{-5}$ m s^{-1}	A1

8 (a)	$9.6 = 6.0 + (I \times 5800)$ **or** $3.6 = I \times 5800$	C1
	$I = 6.2 \times 10^{-4}$ A	A1
7(b)	$9.6 = 6.2 \times 10^{-4} \times (3400 + 5800 + R)$ **or** $6.0 = 6.2 \times 10^{-4} \times (3400 + R)$	C1
	$R = 6.3 \times 10^{3}\,\Omega$	A1
7(c)	(ΔE =) 9.6×330 (= 3170 J)	C1
	final stored energy = $2.6 \times 10^4 - 3170$ = 2.3×10^4 J	A1
7(d)(i)	decrease	B1
7(d)(ii)	decrease	B1
7(d)(iii)	increase	B1

9 (a)	temperature decreases (so) resistance decreases	B1
6(b)(i)	current = V/R	A1
6(b)(ii)	$I = Anvq$ $n = N/V$ **or** $n = N/AL$	C1
	$v = (V/R)/[(V/L)(N/V)e]$ **or** $(V/R)/[A(N/AL)e]$ $= VL/RNe$	A1
	or	
	$v = L/t$ $= L/(Q/I)$	(C1)
	$= LI/Q$ $= L(V/R)/Ne$ $= VL/RNe$	(A1)
6(b)(iii)	time = distance / speed **or** Q/I $= L/(VL/RNe)$ **or** $Ne/(V/R)$ time = RNe/V	A1

10 a)	correct symbol for the heater **or** for the LDR	**M1**
	all correct symbols in series (ignore voltmeter) and no extra symbols	**A1**
	correct symbol for voltmeter and in parallel with the heater	**B1**
5(b)(i)	$R = \rho L / A$	**C1**
	$= (1.1 \times 10^{-6} \times 2.0) / 3.8 \times 10^{-7}$ $= 5.8\,\Omega$	**A1**
5(b)(ii)	$I = 4.8 / 5.8$ $= 0.83$ A	**A1**
5(c)(i)	*A* larger (for new wire) **or** $A \propto d^2$ (and *d* larger for new wire) **or** $R \propto 1 / d^2$ (and *d* larger for new wire)	**M1**
	so *R* is less (than that of first wire)	**A1**
5(c)(ii)	(heater / total resistance decreases so) current (in circuit) increases (so p.d. across LDR increases) **or** heater resistance decreases so it has a smaller share/proportion/fraction of the (total) voltage / e.m.f.	**M1**
	(so voltmeter) reading is less (than 4.8 V)	**A1**

11 (a)	current (through a conductor is directly) proportional to potential difference (across the conductor)	**M1**
	(provided that) temperature (of conductor remains) constant	**A1**
5(b)(i)	(ratio of) V / I increases (as p.d. increases)	**B1**
5(b)(ii)	(as p.d. increases, current increases so) temperature increases	**B1**
5(c)(i)	$I = 1.55$ A	**A1**
5(c)(ii)	$P = VI$ **or** $P = I^2R$ **or** $P = V^2 / R$	**C1**
	$= 6.0 \times 1.55 \times 2$ **or** $1.55^2 \times 3.87 \times 2$ **or** $(6.0^2 / 3.87) \times 2$ $= 19$ W	**A1**
5(c)(iii)	$I = 1.78 - 1.55$ $(= 0.23$ A$)$	**C1**
	$R = 12.0 / 0.23$ $= 52\,\Omega$	**A1**
5(d)	lamp P: p.d. across lamp decreases to zero so goes ‘out’	**B1**
	lamp Q: p.d. across lamp increases to 12 V so gets brighter	**B1**

12 (b)(i)	same potential difference (across X and Y as in parallel)	**B1**
	power $= V^2 / R$ (and $R_X > R_Y$) **or** power $= VI$ **and** $I_X < I_Y$	**M1**
	(so) Y (dissipates more power)	**A1**
6(b)(ii)	$R = \rho L / A$ (and $R_X > R_Y$)	**M1**
	(so) Y (has the larger (cross-sectional) area)	**A1**
6(c)(i)	current $= 5.4 / 1800$ $= 3.0 \times 10^{-3}$ A	**A1**
6(c)(ii)	$5.4 / 9.0 = 1800 / (1800 + R_L)$ **or** $R_L = (9.0 - 5.4) / 3.0 \times 10^{-3}$	**C1**
	$R_L = 1200\,\Omega$	**A1**
6(c)(iii)	resistance of LDR / R_L decreases	**B1**
	current (in the circuit) increases (so) voltmeter reading increases	**B1**

13	(a)(i)	line passes through (0,0) and is in first and third quadrants only	**M1**
		gradient of line becoming less steep in both quadrants and roughly symmetrical	**A1**
	6(a)(ii)	(as I increases) the temperature (of the filament wire/lamp) increases	**B1**
		(as I / temperature / V increases) the resistance (of wire/lamp) increases	**B1**
		(as I / temperature / V increases the graph curves because) ratio V / I increases or ratio I / V decreases	**B1**
	6(b)	$R = \rho L / A$	**C1**
		$= (5.6 \times 10^{-8} \times 5.8) / 3.4 \times 10^{-8}$ $= 9.6\ \Omega$	**A1**

6(c) **B4**

position of switches		ammeter readings		
S_1	S_2	X / A	Y / A	Z / A
open	open	0	0	0
open	closed	1.0	**0**	**1.0**
closed	open	**2.0**	**2.0**	**0**
closed	closed	**3.0**	**2.0**	**1.0**

second row: both values correct (B1)

third row: all three values correct (B1)

fourth row: $X = Y + Z$ (any values) (B1)

all three values correct (B1)

14	(a)(i)	$P = VI$	**C1**
		$I = 36 / 8.0$ $= 4.5$ A	**A1**
	6(a)(ii)	charge $= 4.5 \times 50$ $= 225$	**C1**
		number $= 225 / 1.6 \times 10^{-19}$ $= 1.4 \times 10^{21}$	**A1**
	6(a)(iii)	$R = V^2 / P$ or $R = V / I$ or $R = P / I^2$ $= 8.0^2 / 36$ or $= 8.0 / 4.5$ or $= 36 / 4.5^2$	**C1**
		$= 1.8\ \Omega$	**A1**
	6(b)	$R = \rho L / A$	**C1**
		$L = (1.8 \times 0.25 \times 10^{-6}) / 1.4 \times 10^{-6}$ $= 0.32$ m	**A1**
	6(c)	(larger cross-sectional area, same length, same resistivity and so) less resistance	**M1**
		(same p.d. and more current so) more power (dissipated)	**A1**
	6(d)	current (in wire) is the same	**M1**
		(same p.d. across wire so) power stays the same	**A1**

15 a)(i)	$R = \rho L / A$	**C1**
	$A = (2.6 \times 10^{-8} \times 59) / 3.4 = 4.5 \times 10^{-7}\ m^2$	**A1**
5(a)(ii)	$I = 1.8 / 3.4$ $= 0.53\ A$	**A1**
5(a)(iii)	$I = Anvq$ $v = 0.53 / (4.5 \times 10^{-7} \times 6.1 \times 10^{28} \times 1.60 \times 10^{-19})$	**C1**
	$= 1.2 \times 10^{-4}\ m\ s^{-1}$	**A1**
5(b)(i)	(cross-sectional) area/A is less	**M1**
	(I, n, e the same so) average drift speed is greater	**A1**
5(b)(ii)	(area is less so) more resistance/R	**M1**
	(I is the same, so) more power/P	**A1**
	or	
	($P = I^2\rho L / A$ so) $P \propto 1 / A$	**(M1)**
	(A is less so) more P	**(A1)**
5(c)(i)	180 Ω and 90 Ω resistors shown connected in parallel	**B1**
5(c)(ii)	resistors connected in parallel labelled as 180 Ω and 90 Ω **and** the other resistor labelled as 30 Ω	**M1**
	V_{OUT} or 8.0 V labelled across the two resistors in parallel	**A1**

16 a)	joule per coulomb	**B1**
5(b)(i)	$1 / R = 1 / R_1 + 1 / R_2$ $= 1 / 300 + 1 / 200$ $R = 75\ \Omega$	**A1**
5(b)(ii)	$R = 75 + 55$ $= 130\ \Omega$	**A1**
5(c)(i)	**1.** $P = I^2R$ **or** $P = VI$ **and** $V = IR$	**C1**
	$I = (0.20 / 55)^{0.5}$ $= 0.060\ A$	**A1**
	2. $I = 0.060 / 4$ $= 0.015\ A$	**A1**
5(c)(ii)	potential difference $= 130 \times 0.060$ $= 7.8\ V$	**A1**
	or	
	potential difference $= (300 \times 0.015) + (55 \times 0.060)$ $= 7.8\ V$ (*other valid methods are also possible*)	**(A1)**

17 a)	*A*: cross-sectional area	B1
	n: number density of <u>free</u> electrons	B1
6(b)	units of *I*: A **and** units of *A*: m^2 **and** units of *v*: $m\,s^{-1}$	B1
	units of e: $A / (m^2\,m^{-3}\,m\,s^{-1}) = A\,s$	A1
6(c)	ratio $= A_Q / A_P$	C1
	$= [\pi r^2] / [\pi(2r^2)]$ $= 0.25$	A1

18 a)	volt / ampere	B1
5(b)	$R = \rho L / A$	C1
	$L = (1.8 \times 0.38 \times 10^{-6}) / 9.6 \times 10^{-7}$	C1
	$= 0.71$ m	A1
5(c)(i)	thermal energy is dissipated in resistor Y	B1
5(c)(ii)	$V / 1.2 = 1.8 / (1.8 + 0.6)$	C1
	$V = 0.90$ V	A1
	or	
	$I = 1.2 / (1.8 + 0.6)$ (= 0.50)	(C1)
	$V = 0.50 \times 1.8$ $= 0.90$ V	(A1)
5(d)(i)	remain the same	B1
5(d)(ii)	decrease	B1
5(e)(i)	$1 / R = 1 / 1.8 + 1 / 3.6$ $R = 1.2\,\Omega$	A1
5(e)(ii)	$I = 1.2 / (1.2 + 0.60)$	C1
	$= 0.67$ A	A1
	or	
	$V_Y = 1.2 \times 0.60 / (1.2 + 0.60)$ (= 0.40)	(C1)
	$I = 0.40 / 0.60$ $= 0.67$ A	(A1)

19 `(a)	work done / charge **or** energy (transferred from electrical to other forms) / charge	**B1**
6(b)	for $V < 0.25$ V resistance is infinite/very high (as current is zero)	**B1**
	for $V > 0.25$ V resistance decreases (as V increases)	**B1**
6(c)(i)	$R = V / I$	**C1**
	$= 0.75 / (15 \times 10^{-3})$	**C1**
	$= 50\ \Omega$	**A1**
6(c)(ii)	**1.** $V_Y = 15 \times 10^{-3} \times 60$ (= 0.90 V)	**C1**
	$V_X = 2.0 - 0.90 - 0.75$ (= 0.35 V)	**C1**
	$R_X = 0.35 / (15 \times 10^{-3})$ $= 23\ \Omega$	**A1**
	or	
	total $R = 60 + 50 + R_X$	**(C1)**
	$60 + 50 + R_X = 2.0 / (15 \times 10^{-3})$	**(C1)**
	$R_X = 23\ \Omega$	**(A1)**
	2. $P = VI$ **or** $P = EI$ **or** $P = I^2R$ **or** $P = V^2 / R$	**C1**
	ratio $= \dfrac{(15\times10^{-3})^2\times60}{2.0\times15\times10^{-3}}$ **or** $\dfrac{0.90\times15\times10^{-3}}{2.0\times15\times10^{-3}}$ **or** $\dfrac{(0.90^2/60)}{2.0\times15\times10^{-3}}$ $= 0.45$	**A1**

20 6(a)(i)	$R = V / I$	**C1**
	resistance $= (12 / 0.20) / 2$ **or** $6 / 0.20$ $= 30\ \Omega$	**A1**
6(a)(ii)	$I = 0.50 - 0.20$ (= 0.30 A)	**C1**
	$R + 28 = 12 / 0.30$ (= 40 Ω) $R = 12\ \Omega$	**A1**
6(b)	p.d. across lamp $= 0.20 \times 30$ (= 6.0 V)	**C1**
	p.d. across $R = 0.30 \times 12$ (= 3.6 V)	**C1**
	$V_{XY} = 6.0 - 3.6$ $= 2.4$ V	**A1**
	or	
	p.d. across lamp $= 0.20 \times 30$ (= 6.0 V)	**(C1)**
	p.d. across 28 Ω resistor $= 0.30 \times 28$ (= 8.4 V)	**(C1)**
	$V_{XY} = 8.4 - 6.0$ $= 2.4$ V	**(A1)**
6(c)	$P = VI$ **or** $P = EI$ **or** $P = I^2R$ **or** $P = V^2/R$	**C1**
	ratio $= (6.0 \times 0.20) \times 2 / (12 \times 0.50)$ **or** $0.20 / 0.50$ $= 0.40$	**A1**
6(d)	no change to V across lamps, so power in lamps unchanged **or** current in battery/total current increases (and e.m.f. the same) so power produced by battery increases	**B1**
	both the above statements and so the ratio decreases	**B1**