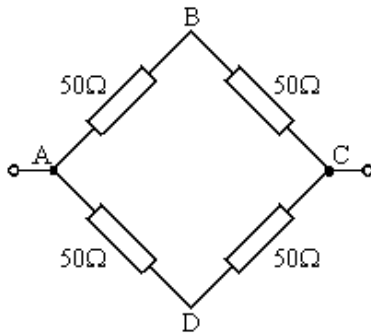


**Q1.** Four resistors, each having resistance of  $50\ \Omega$ , are connected to form a square. A resistance meter measured the resistance between different corners of the square. Determine the resistance the meter records when connected between the following corners.

(a) Between A and C, as in **Figure 1**.



**Figure 1**

.....

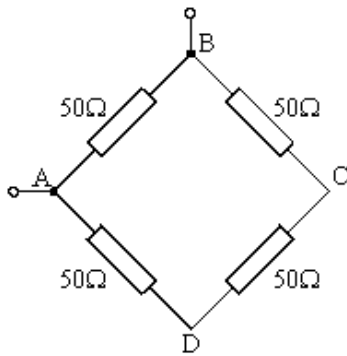
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(2)

(b) Between A and B, as in **Figure 2**.



**Figure 2**

.....

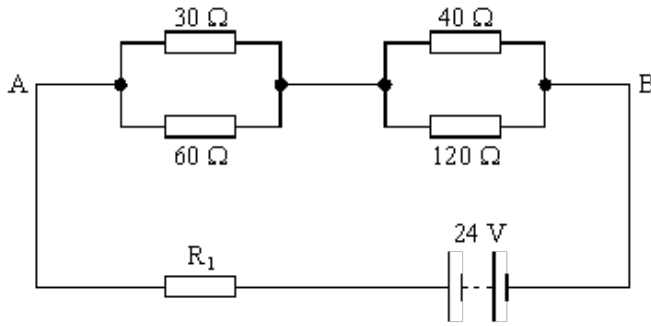
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(3)  
(Total 5 marks)

**Q2.** A battery of emf 24 V and negligible internal resistance is connected to a resistor network as shown in the circuit diagram in the diagram below.



(a) Show that the resistance of the single equivalent resistor that could replace the four resistors between the points A and B is 50 Ω.

.....

.....

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.....

(4)

(b) If  $R_1$  is 50 Ω, calculate

(i) the current in  $R_1$ ,

.....

.....

(ii) the current in the 60 Ω resistor.

.....

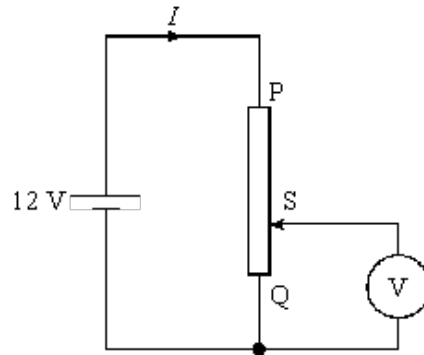
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(4)  
(Total 8 marks)

- Q3.** (a) In the circuit shown in **Figure 1**, the battery has an emf of 12 V and negligible internal resistance.

PQ is a potential divider, S being the position of the sliding contact. In the position shown, the resistance between P and S is  $180\ \Omega$  and the resistance between S and Q is  $60\ \Omega$ .



**Figure 1**

- (i) Calculate the current,  $I$ , in the circuit, assuming that there is no current through the voltmeter V.

.....

.....

.....

- (ii) What property of the voltmeter allows us to assume that no current flows through it?

.....

.....

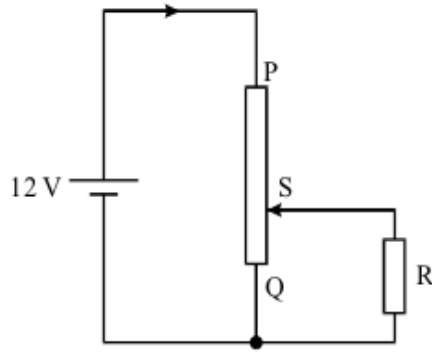
- (iii) What is the reading on the voltmeter?

.....

.....

**(4)**

- (b) The circuit in **Figure 1** is modified as shown in **Figure 2**, by exchanging the voltmeter for a load R, whose resistance is about the same as the resistance of section SQ of the potential divider.



**Figure 2**

Explain, without calculation, why the current through the battery increases in value from that in part (a).

You may be awarded marks for the quality of written communication in your answer.

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(2)  
(Total 6 marks)

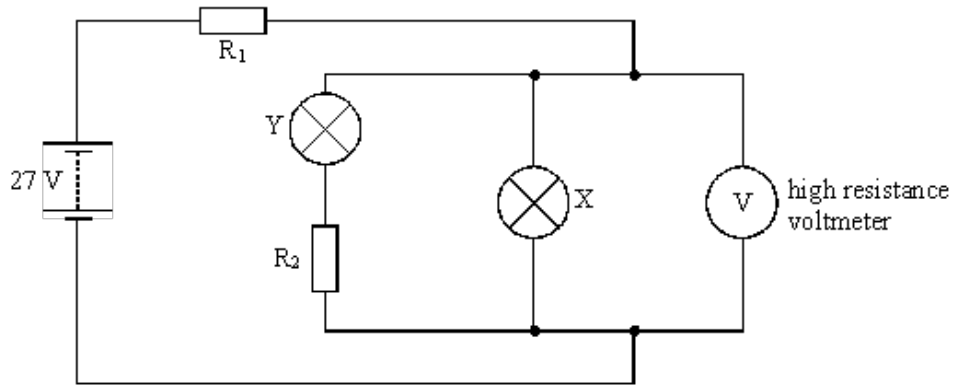
- Q4.** (a) X and Y are two lamps. X is rated at 12 V, 24 W and Y at 6.0 V, 18 W. Calculate the current through each lamp when it operates at its rated voltage.

X: .....

Y: .....

(2)

- (b) The two lamps are connected in the circuit shown. The battery has an emf of 27 V and negligible internal resistance. The resistors  $R_1$  and  $R_2$  are chosen so that the lamps are operating at their rated voltage.



- (i) What is the reading on the voltmeter?

.....

- (ii) Calculate the resistance of  $R_2$ .

.....

.....

.....

- (iii) Calculate the current through  $R_1$ .

.....

- (iv) Calculate the voltage across  $R_1$ .

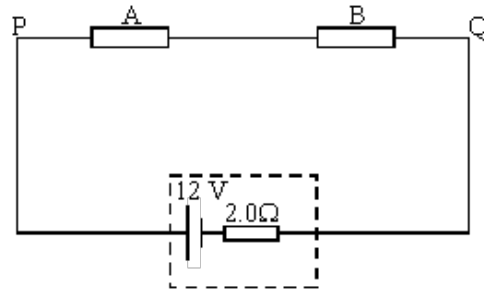
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- (v) Calculate the resistance of  $R_1$ .

.....

(7)  
(Total 9 marks)

**Q5.** In the circuit shown, the battery has an emf of 12 V and an internal resistance of 2.0  $\Omega$ . The resistors A and B each have resistance of 30  $\Omega$ .



Calculate

(i) the total current in the circuit,

.....  
.....

(ii) the voltage between the points P and Q,

.....  
.....

(iii) the power dissipated in resistor A,

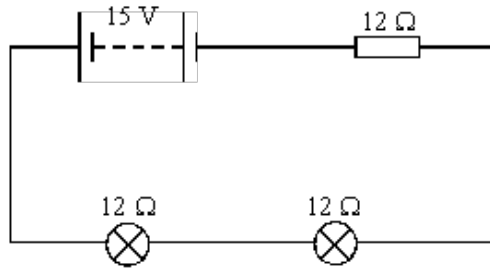
.....  
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(iv) the energy dissipated by resistor A in 20 s.

.....  
.....  
.....

**(Total 8 marks)**

- Q6.** (a) In the circuit in **Figure 1**, the battery, of emf 15 V and the negligible internal resistance, is connected in series with two lamps and a resistor. The three components each have a resistance of  $12\ \Omega$ .



**Figure 1**

- (i) What is the voltage across each lamp?

.....

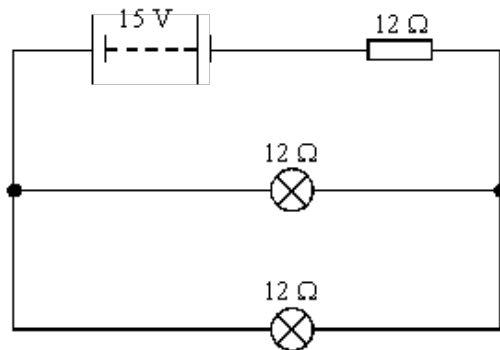
- (ii) Calculate the current through the lamps.

.....

.....

(3)

- (b) The two lamps are now disconnected and reconnected in parallel as shown in **Figure 2**.



**Figure 2**

- (i) Show that the current supplied by the battery is 0.83 A.

.....

.....

.....

.....

- (ii) Hence show that the current in each lamp is the same as the current in the lamps in the circuit in **Figure 1**.

.....

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.....

.....

(3)

- (c) How does the brightness of the lamps in the circuit in **Figure 1** compare with the brightness of the lamps in the circuit in **Figure 2**?

Explain your answer.

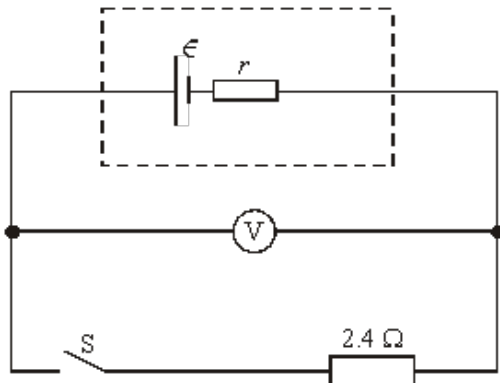
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(2)  
(Total 8 marks)

**Q7.** In the circuit shown the battery has emf  $\epsilon$  and internal resistance  $r$ .



- (a) (i) State what is meant by the emf of a battery.

.....

.....

- (ii) When the switch S is open, the voltmeter, which has infinite resistance, reads 8.0 V. When the switch is closed, the voltmeter reads 6.0 V. Determine the current in the circuit when the switch is closed.

.....

.....

.....



(iii) Show that  $r = 0.80 \Omega$ .

.....  
.....

(4)

(b) The switch S remains closed. Calculate

(i) the power dissipated in the  $2.4 \Omega$  resistor,

.....

(ii) the total power dissipated in the circuit,

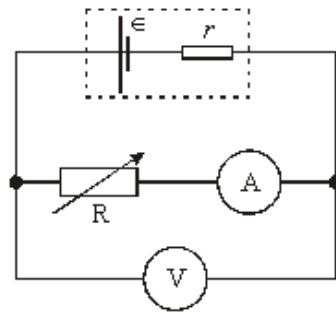
.....  
.....

(iii) the energy wasted in the battery in 2 minutes.

.....

(4)  
(Total 8 marks)

**Q8.** In the circuit shown, a battery of emf  $\epsilon$  and internal resistance  $r$  is connected to a variable resistor  $R$ . The current  $I$  and the voltage  $V$  are read by the ammeter and voltmeter respectively.



(a) The emf is related to  $V$ ,  $I$  and  $r$  by the equation

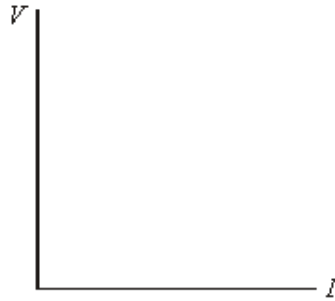
$$\epsilon = V + Ir$$

Rearrange the equation to give  $V$  in terms of  $\epsilon$ ,  $I$  and  $r$ .

.....

(1)

- (b) In an experiment, the value of  $R$  is altered so that a series of values of  $V$  and the corresponding values of  $I$  are obtained. Using the axes, sketch the graph you would expect to obtain as  $R$  is changed.



(2)

- (c) State how the values of  $\epsilon$  and  $r$  may be obtained from the graph.

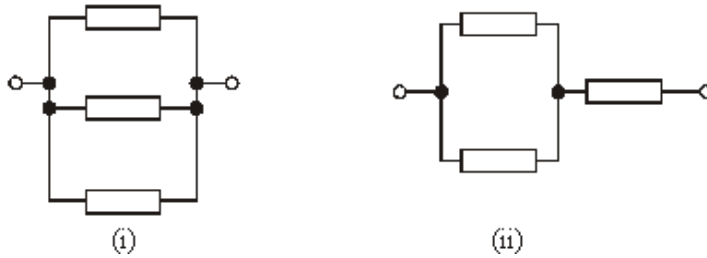
$\epsilon$  .....

$r$  .....

(2)

(Total 5 marks)

- Q9.** (a) **Figure 1** shows two possible arrangements of connecting three resistors, each resistor having a resistance of  $40 \Omega$ .



**Figure 1**

Calculate the equivalent resistance in each case.

(i) .....

.....

.....

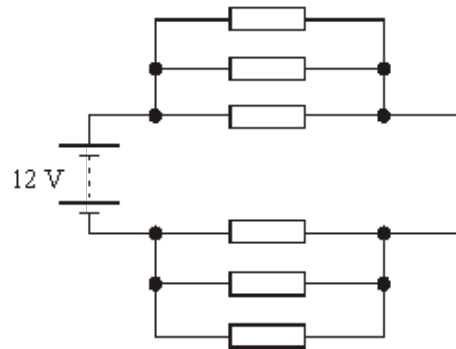
(ii) .....

.....

.....

(3)

- (b) The designer of a heating element for the rear window of a car decides to connect six separate heating elements together as shown in **Figure 2**. Each element has a resistance of  $6.0 \Omega$  and the unit is connected to a 12 V dc supply having zero internal resistance.



**Figure 2**

- (i) Calculate the current in each single element.

.....

.....

.....

.....

.....

- (ii) With the aid of a similar calculation give a reason why the heater would not be as effective if all six were connected in series.

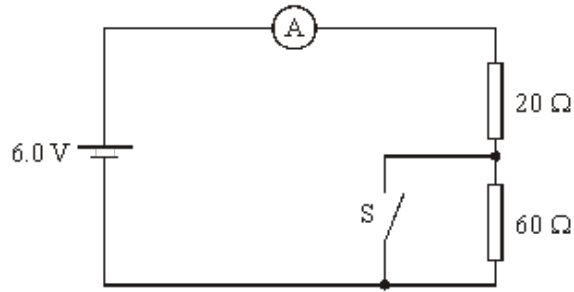
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(5)  
(Total 8 marks)

**Q10.** In the circuit shown in **Figure 1**, the battery, of emf 6.0V, has negligible internal resistance.



**Figure 1**

(a) Calculate the current through the ammeter when the switch S is

(i) open,

.....  
.....  
.....

(ii) closed.

.....  
.....  
.....

(3)

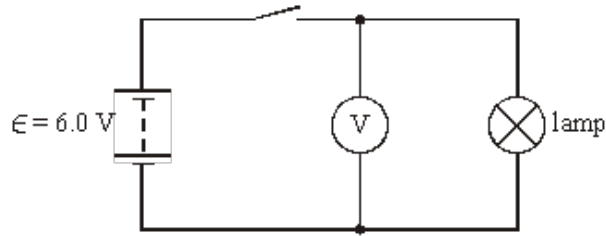
(b) The switch S is now replaced with a voltmeter of infinite resistance. Determine the reading on the voltmeter.

.....  
.....  
.....

(2)

(Total 5 marks)

- Q11.** (a) In the circuit shown in **Figure 1**, the battery has an emf of 6.0 V. With the switch closed and the lamp lit, the reading on the voltmeter is 5.4 V.



**Figure 1**

Explain without calculation, why the voltmeter reading is less than the emf of the battery.

You may be awarded marks for the quality of written communication in your answer.

.....

.....

.....

.....

**(3)**

- (b) A torch is powered by two identical cells each having an emf of 1.5 V and an internal resistance  $r$ . The cells are connected in series. The torch bulb is rated at 1.6 W and the voltage across it is 2.5 V.

(i) Draw the circuit described.

(ii) Calculate the internal resistance of each cell.

.....

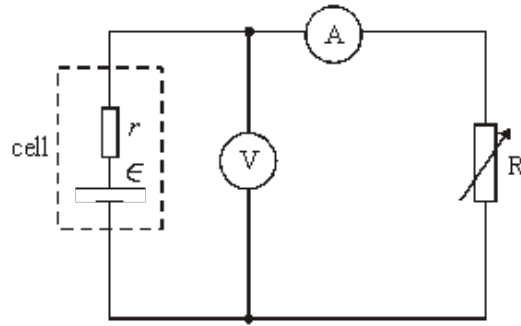
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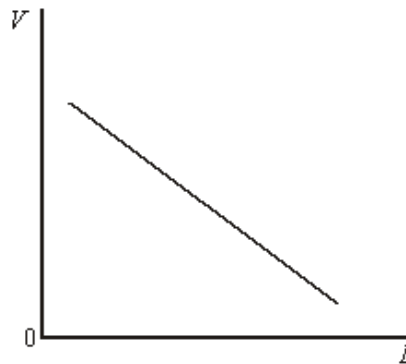
**(5)**

- (c) In the circuit in **Figure 2** the cell has emf  $\epsilon$  and internal resistance  $r$ . The voltage  $V$  across the cell is read on the voltmeter which has infinite resistance, and the current  $I$  through the variable resistor  $R$  is read on the ammeter.



**Figure 2**

By altering the value of the variable resistor  $R$ , a set of values of  $V$  and  $I$  is obtained. These values, when plotted, give the graph shown in **Figure 3**.



**Figure 3**

Show how the values of  $\epsilon$  and  $r$  may be obtained from this graph. Explain your method.

.....

.....

.....

.....

.....

(3)  
(Total 11 marks)

**Q12.** (a) A set of decorative lights consists of a string of lamps. Each lamp is rated at 5.0 V, 0.40 W and is connected in series to a 230 V supply.

Calculate

(i) the number of lamps in the set, so that each lamp operates at the correct rating,

.....  
.....

(ii) the current in the circuit,

.....  
.....

(iii) the resistance of each lamp,

.....  
.....

(iv) the total electrical energy transferred by the set of lights in 2 hours.

.....  
.....  
.....

(5)

(b) When assembled at the factory, one set of lights inadvertently contains 10 lamps too many. All are connected in series. Assume that the resistance of each lamp is the same as that calculated in part (a) (iii).

(i) Calculate the current in this set of lights when connected to a 230 V supply.

.....  
.....  
.....

(ii) How would the brightness of each lamp in this set compare with the brightness of each lamp in the correct set?

.....

(3)

(Total 8 marks)

**Q13.** (a) A student is given three resistors of resistance  $3.0\ \Omega$ ,  $4.0\ \Omega$  and  $6.0\ \Omega$  respectively.

(i) Draw the arrangement, using all three resistors, which will give the largest resistance.

(ii) Calculate the resistance of the arrangement you have drawn.

.....  
.....

(iii) Draw the arrangement, using all three resistors, which will give the smallest resistance.

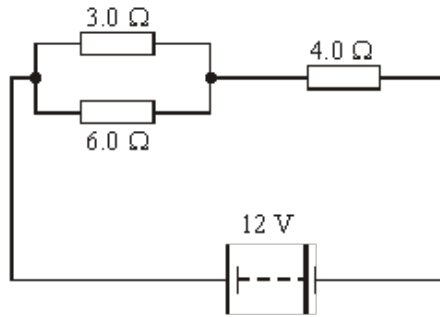
(iv) Calculate the resistance of the arrangement you have drawn.

.....  
.....  
.....

(5)



- (b) The three resistors are now connected to a battery of emf 12 V and negligible internal resistance, as shown in **Figure 1**.



**Figure 1**

- (i) Calculate the total resistance in the circuit.

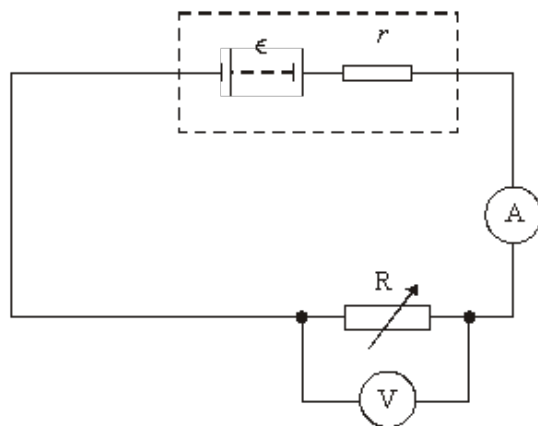
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 .....

- (ii) Calculate the voltage across the 6.0 Ω resistor.

.....  
 .....

(4)  
 (Total 9 marks)

- Q14.** A battery of emf  $\epsilon$  and internal resistance  $r$  is connected in series to a variable resistor  $R$  and an ammeter of negligible resistance. A voltmeter is connected across  $R$ , as shown in the figure below.



- (a) (i) State what is meant by the emf of the battery.

.....  
 .....

(ii) The reading on the voltmeter is less than the emf. Explain why this is so.

.....  
.....

(2)

(b) A student wishes to measure  $\epsilon$  and  $r$ . Using the circuit shown in the figure above the value of  $R$  is decreased in steps and at each step the readings  $V$  and  $I$  on the voltmeter and ammeter respectively are recorded. These are shown in the table.

reading on voltmeter/V	reading on ammeter/A
8.3	0.07
6.8	0.17
4.6	0.33
2.9	0.44
0.3	0.63

(i) Give an expression relating  $V$ ,  $I$ ,  $\epsilon$  and  $r$ .

.....

(ii) Draw a graph of  $V$  (on the  $y$ -axis) against  $I$  (on the  $x$ -axis) on graph paper.

*(Allow one sheet of graph paper)*

(iii) Determine the values of  $\epsilon$  and  $r$  from the graph, explaining your method.

$\epsilon$ : .....

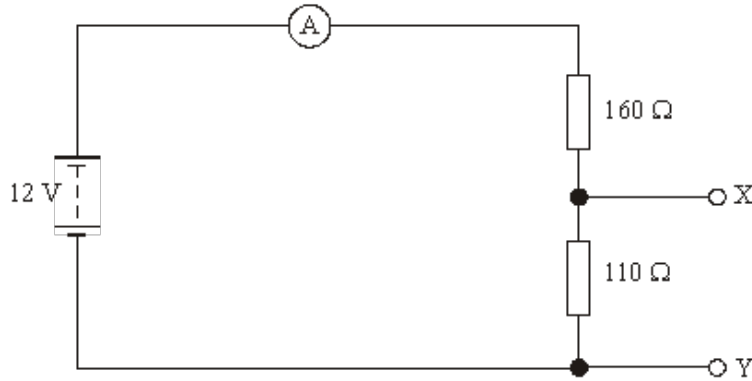
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$r$ : .....

.....

(8)  
(Total 10 marks)

**Q15.** In the circuit shown in the figure below, the battery, of negligible internal resistance, is connected to two resistors which form a potential divider.



(a) (i) Calculate the current through the ammeter.

.....

(ii) A  $20\ \Omega$  resistor is now connected between X and Y. State and explain, without further calculation, whether the current through the ammeter will increase or decrease. You may be awarded marks for the quality of written communication in your answer.

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 .....  
 .....  
 .....  
 .....  
 .....  
 .....

(4)

(b) The  $20\ \Omega$  resistor is now removed and replaced with a voltmeter. Stating the assumption made, show that the reading on the voltmeter is 4.9 V.

.....  
 .....  
 .....

(2)

- (c) The voltmeter is now removed and the terminals X and Y joined together with a wire. Calculate the reading on the ammeter.

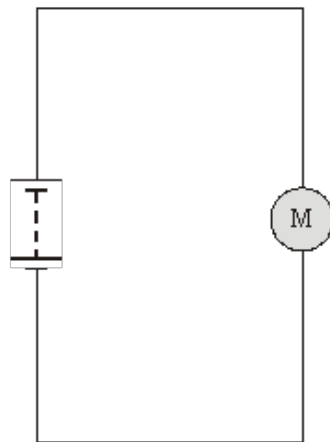
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(2)  
(Total 8 marks)

- Q16.** The battery of an electric car consists of 30 cells, connected in series, to supply current to the motor, as shown in the figure below.



- (a) Assume that the internal resistance of each cell is negligible and that the pd across each cell is 6.0 V.

- (i) State the pd across the motor.

.....

- (ii) The battery provides 7.2 kW to the motor when the car is running. Calculate the current in the circuit.

.....

.....

.....

- (iii) The battery can deliver this current for two hours. Calculate how much charge the battery delivers in this time.

.....

.....

.....

(iv) Calculate the energy delivered to the motor in the two hour period.

.....  
.....  
.....

(7)

(b) In practice, each cell has a small but finite internal resistance. Explain, without calculation, the effect of this resistance on

- the current in the circuit, and
- the time for which the battery can deliver the current in part (a)(ii).

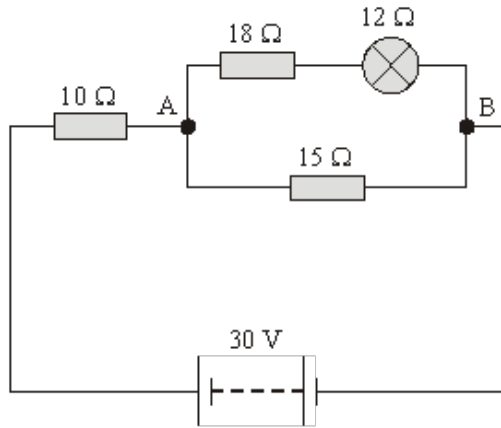
You may assume that the motor behaves as a constant resistance.

You may be awarded additional marks to those shown in brackets for the quality of written communication in your answer.

.....  
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(3)  
(Total 10 marks)

**Q17.** In the circuit shown in the figure below, the battery, of negligible internal resistance, has an emf of 30 V. The pd across the lamp is 6.0 V and its resistance is 12  $\Omega$ .



(a) Show that the total resistance of the circuit is 20  $\Omega$ .

.....  
 .....  
 .....  
 .....

(3)

(b) Calculate

(i) the current supplied by the battery,

.....  
 .....

(ii) the pd between the points A and B,

.....  
 .....

(iii) the current in the lamp.

.....  
 .....

(4)

(c) (i) What is the power of the lamp, in W?

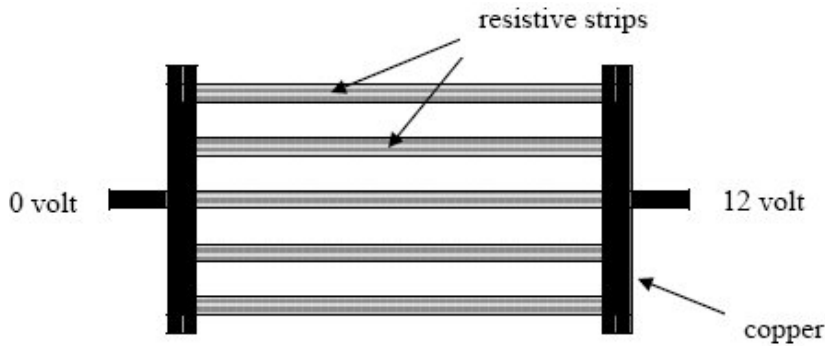
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(ii) What percentage of the power supplied by the battery is dissipated in the lamp?

.....  
.....

(3)  
(Total 10 marks)

**Q18.** A heating unit as used on the rear window of a car consists of five strips of resistive material joined at either end by strips of copper of negligible resistance, shown in the diagram below. Heat is generated at a rate of 45 W when the unit is connected to a 12 V car battery.



(a) (i) Calculate the total resistance of the unit.

total resistance = .....

(ii) Show that the resistance of each strip is about 16  $\Omega$ .

(4)

- (b) If each resistive strip is 2.5 mm wide and of length 0.80 m, determine the thickness of each strip.

Resistivity of the resistive material =  $5.0 \times 10^{-5} \Omega\text{m}$ .

thickness = .....

(3)

- (c) The rear window heater on a car is sometimes set to be switched off automatically after a period of time to prevent draining the battery.

If the charge stored in a fully charged battery is  $1.44 \times 10^5 \text{ C}$ , how long, in hours, would it take to fully drain the battery with the heater?

time = .....hours

(3)

(Total 10 marks)

**Q19.** A car battery has an *emf* of 12 V and an *internal resistance* of  $5.0 \times 10^{-3} \Omega$ .

- (a) (i) Explain what is meant by the *emf* of the battery.

.....  
.....

(1)

- (ii) Explain what is meant by the *internal resistance* of the battery.

.....  
.....

(1)



(b) The battery is used to provide the starting motor of a car with a current of 800 A.

(i) Calculate the potential difference across the terminals of the battery.

answer = ..... V

(2)

(ii) Calculate the rate of dissipation of energy due to its internal resistance stating an appropriate unit.

answer = .....

(3)

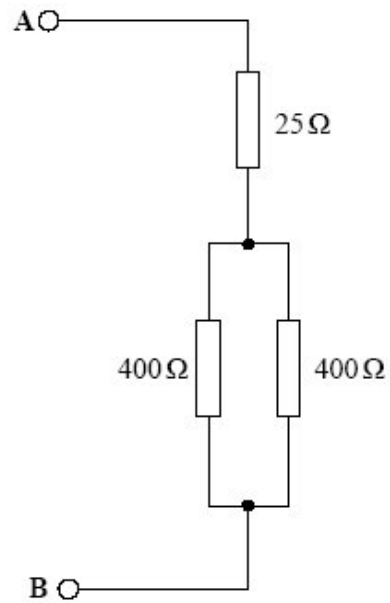
(c) State and explain the effect of attempting to use a battery with a much higher internal resistance to start the car.

.....  
.....  
.....  
.....

(2)

(Total 9 marks)

**Q20.** The diagram below shows an arrangement of resistors.



(a) Calculate the total resistance between terminals **A** and **B**.

answer = .....  $\Omega$

(2)

(b) A potential difference is applied between the two terminals, **A** and **B**, and the power dissipated in each of the  $400\ \Omega$  resistors is  $1.0\ \text{W}$ .

(i) Calculate the potential difference across the  $400\ \Omega$  resistors.

answer = ..... V

(ii) Calculate the current through the  $25\ \Omega$  resistor.

answer = ..... A

(iii) Calculate the potential difference applied to terminals **A** and **B**.

answer = ..... V

(6)  
(Total 8 marks)

**Q21.** A car battery has an emf of 12 V and an internal resistance of  $9.5 \times 10^{-3} \Omega$ . When the battery is used to start a car the current through the battery is 420 A.

(a) Calculate the voltage across the terminals of the battery, when the current through the battery is 420 A.

.....  
.....  
.....  
.....

answer ..... V

(2)

(b) The copper cable connecting the starter motor to the battery has a length of 0.75 m and cross-sectional area of  $7.9 \times 10^{-5} \text{ m}^2$ . The resistance of the cable is  $1.6 \times 10^{-3} \Omega$ .

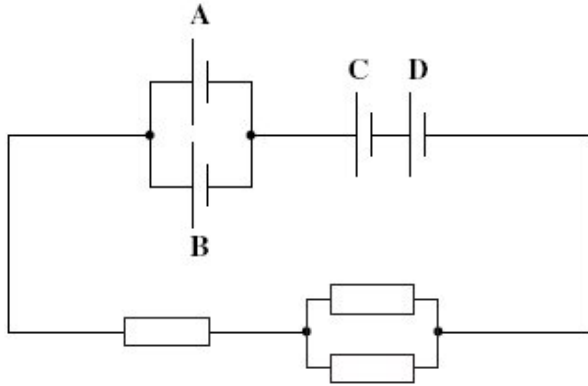
Calculate the resistivity of the copper giving an appropriate unit.

.....  
.....  
.....  
.....  
.....  
.....

answer .....

(3)  
(Total 5 marks)

**Q22.** The circuit in the diagram below contains four identical new cells, **A**, **B**, **C** and **D**, each of emf 1.5V and negligible internal resistance.



(a) The resistance of each resistor is  $4.0 \Omega$ .

(i) Calculate the total resistance of the circuit.

answer = .....  $\Omega$

(1)

(ii) Calculate the total emf of the combination of cells.

answer = ..... V

(1)

(iii) Calculate the current passing through cell **A**.

answer = ..... A

(2)

- (iv) Calculate the charge passing through cell A in five minutes, stating an appropriate unit.

answer = .....

(2)

- (b) Each of the cells can provide the same amount of electrical energy before going flat. State and explain which two cells in this circuit you would expect to go flat first.

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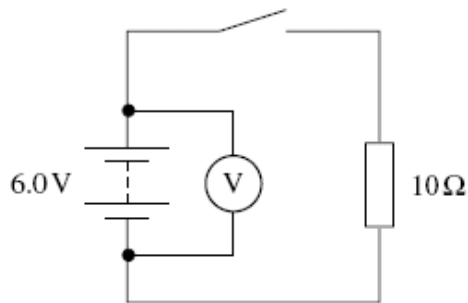
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(3)

(Total 9 marks)

- Q23.** A battery is connected to a  $10\ \Omega$  resistor as shown in the diagram below. The emf (electromotive force) of the battery is  $6.0\ \text{V}$ .



- (a) (i) Define the emf of a battery.

.....

.....

(1)

- (ii) When the switch is open the voltmeter reads 6.0 V and when it is closed it reads 5.8 V.  
Explain why the readings are different.

.....  
.....  
.....  
.....  
.....

(2)

- (b) Calculate the internal resistance of the battery.

answer = .....  $\Omega$

(3)

- (c) State and explain why it is important for car batteries to have a very low internal resistance.

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.....  
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(2)

(Total 8 marks)

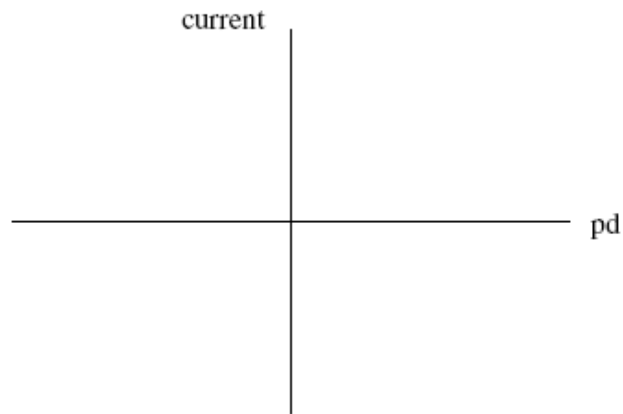
- Q24.** (a) A semiconducting diode is an example of a *non-ohmic* component. State what is meant by a non-ohmic component.

.....  
.....

(1)

(b) A filament lamp is also an example of a non-ohmic component.

(i) Sketch on the axes below the current-voltage characteristic for a filament lamp.



(2)

(ii) State, with reference to the current-voltage characteristic you have drawn, how the resistance of the lamp changes as the pd across its terminals changes.

.....  
.....

(1)

(c) A filament lamp has a power rating of 36 W when there is a pd across its terminals of 12V.

(i) Calculate the resistance of the filament when the pd across its terminals is 12V.

answer = .....  $\Omega$

(2)

- (ii) A student predicts that if the pd across the bulb is reduced to 6.0 V the power rating of the bulb would be 9.0 W. State and explain how in practice the power rating will be slightly different from this value.

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(3)  
(Total 9 marks)

**Q25.**

- (a) A student wishes to investigate how the resistance of a thermistor changes with temperature.
- (i) Draw a labelled diagram of a suitable circuit that would enable the student to measure the resistance of the thermistor.

(2)



- (ii) Describe the procedure the student would follow in order to obtain accurate and reliable measurements of the resistance of the thermistor at different temperatures.

The quality of your written communication will be assessed in this question.

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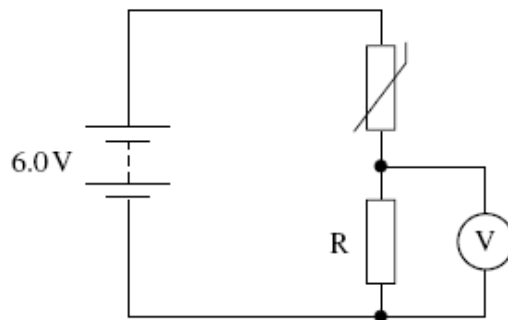
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(6)

- (b) The diagram below shows a thermistor connected in series with a resistor,  $R$ , and battery of emf  $6.0\text{ V}$  and negligible internal resistance.



When the temperature is  $50\text{ }^{\circ}\text{C}$  the resistance of the thermistor is  $1.2\text{ k}\Omega$ . The voltmeter connected across  $R$  reads  $1.6\text{ V}$ .

- (i) Calculate the pd across the thermistor.

answer = ..... V

(1)

(ii) Calculate the current in the circuit.

answer = ..... A

(1)

(iii) Calculate the resistance of R quoting your answer to an appropriate number of significant figures.

answer = .....  $\Omega$

(2)

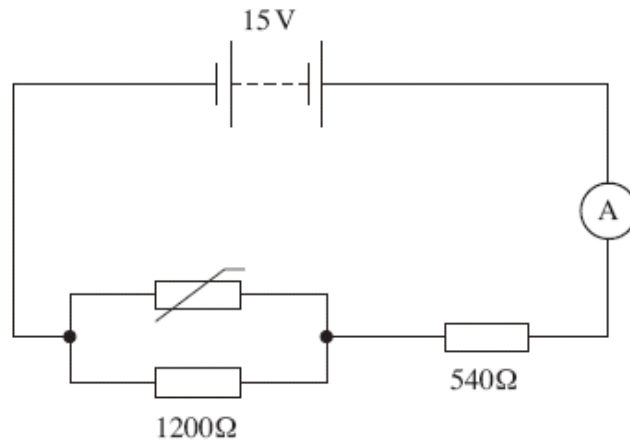
(c) State and explain the effect on the voltmeter reading if the internal resistance of the battery in the circuit in part (b) was not negligible.

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(2)

**(Total 14 marks)**

**Q26.** The circuit shown below shows a thermistor connected in a circuit with two resistors, an ammeter and a battery of emf 15V and negligible internal resistance.



(a) When the thermistor is at a certain temperature the current through the ammeter is 10.0 mA.

(i) Calculate the pd across the 540 Ω resistor.

answer = ..... V

(1)

(ii) Calculate the pd across the 1200 Ω resistor.

answer = ..... V

(1)

(iii) Calculate the resistance of the parallel combination of the resistor and the thermistor.

answer = ..... Ω

(2)

(iv) Calculate the resistance of the thermistor.

answer = .....  $\Omega$

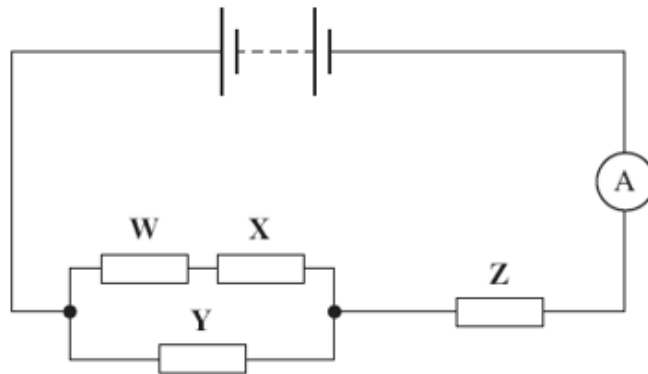
(2)

(b) The temperature of the thermistor is increased so that its resistance decreases. State and explain what happens to the pd across the  $1200 \Omega$  resistor.

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(3)  
(Total 9 marks)

**Q27.** The circuit shown in the figure below shows an arrangement of resistors, W, X, Y, Z, connected to a battery of negligible internal resistance.



The emf of the battery is 10V and the reading on the ammeter is 2.0 A.

(a) (i) Calculate the total resistance of the circuit.

answer = .....  $\Omega$

(1)

- (ii) The resistors **W**, **X**, **Y**, and **Z** all have the same resistance. Show that your answer to part (a) (i) is consistent with the resistance of each resistor being  $3.0 \Omega$ .

answer = .....  $\Omega$

(3)

- (b) (i) Calculate the current through resistor **Y**.

answer = ..... A

(2)

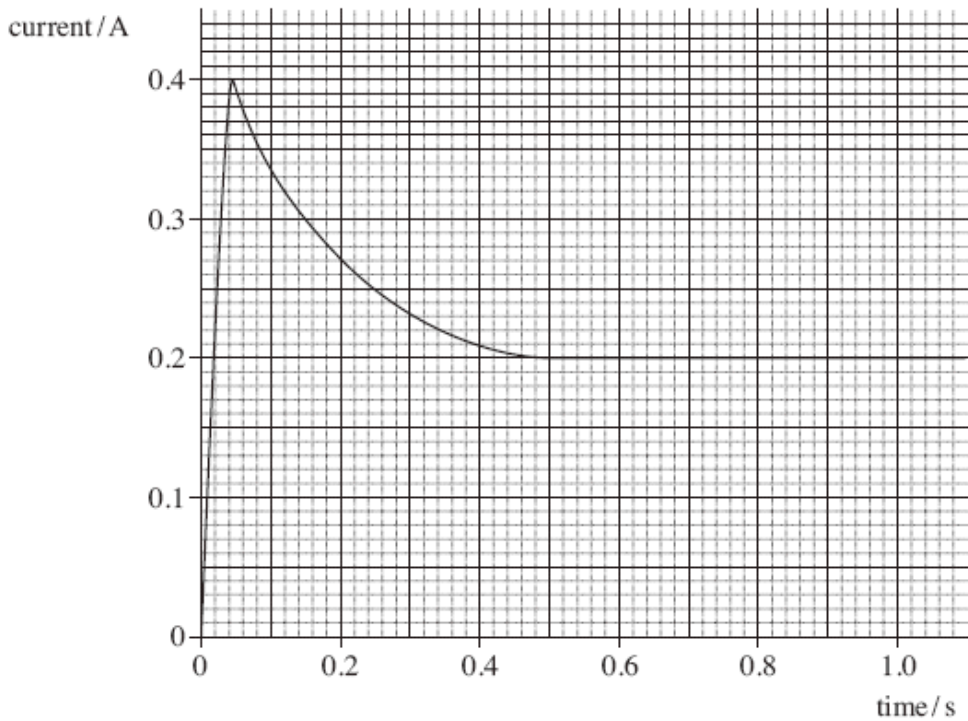
- (ii) Calculate the pd across resistor **W**.

answer = ..... V

(2)

(Total 8 marks)

**Q28.** When a filament lamp is switched on it takes 0.50 seconds for the filament to reach its normal operating temperature. The way in which the current changes during the first second after switching on is shown on the graph below.



(a) Use the graph to determine the maximum current through the lamp.

answer = ..... A

(1)

(b) Assuming that the lamp is connected to a 12V dc supply of a negligible internal resistance,

(i) Calculate the resistance of the lamp when it has reached its normal operating temperature,

answer = .....  $\Omega$

(1)

- (ii) Calculate the power of the lamp when it has reached its normal operating temperature.

answer = ..... W

(1)

- (c) Explain why the current through the lamp decreases between 0.05 s and 0.50 s.

.....  
.....  
.....  
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(2)

- (d) State and explain the change, if any, to the final current through the lamp if it is connected to the same supply with another similar lamp

- (i) in series,

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(2)

- (ii) in parallel.

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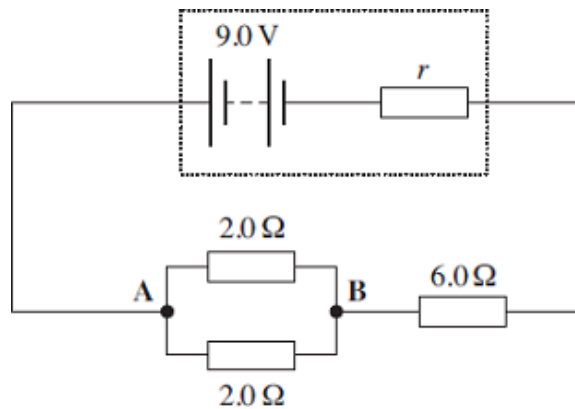
(2)

(e) State and explain why a filament lamp is most likely to fail as it is switched on.

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(2)  
(Total 11 marks)

**Q29.** A battery of emf 9.0 V and internal resistance,  $r$ , is connected in the circuit shown in the figure below.



(a) The current in the battery is 1.0 A.

(i) Calculate the pd between points **A** and **B** in the circuit.

answer = ..... V

(2)

(ii) Calculate the internal resistance,  $r$ .

answer = .....  $\Omega$

(2)



(iii) Calculate the **total** energy transformed by the battery in 5.0 minutes.

answer = .....

(2)

(iv) Calculate the percentage of the energy calculated in part (iii) that is dissipated in the battery in 5.0 minutes.

answer = .....

(2)

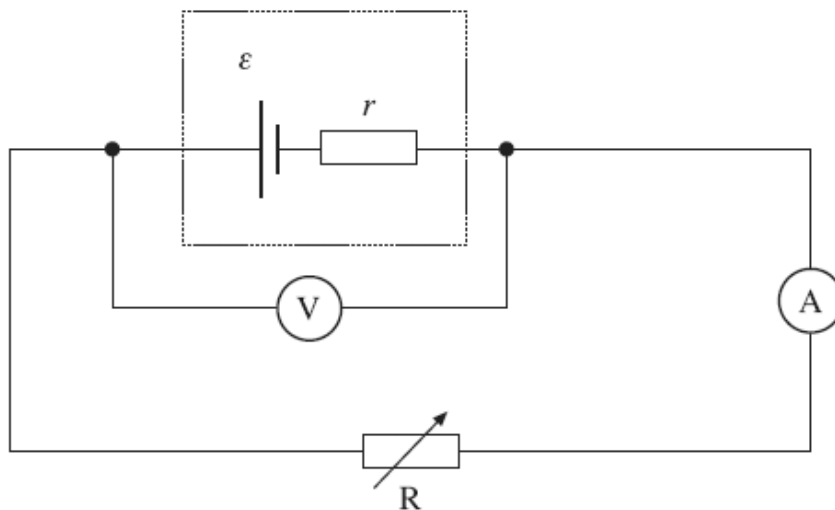
(b) State and explain **one** reason why it is an advantage for a rechargeable battery to have a low internal resistance.

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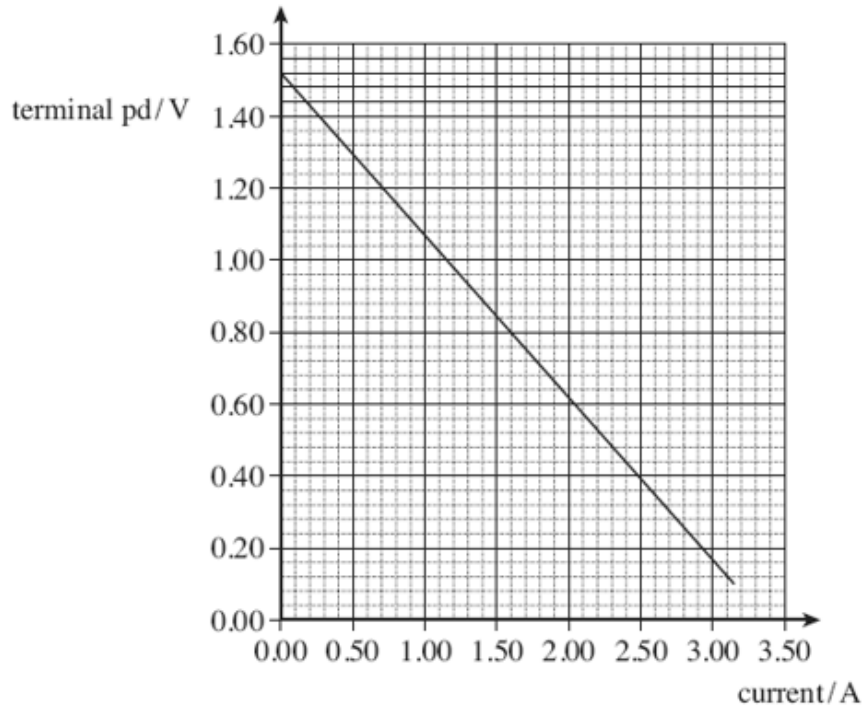
(2)

(Total 10 marks)

**Q30.** A cell of emf,  $\epsilon$ , and internal resistance,  $r$ , is connected to a variable resistor  $R$ . The current through the cell and the terminal pd of the cell are measured as  $R$  is decreased. The circuit is shown in the figure below.



The graph below shows the results from the experiment.



(a) Explain why the terminal pd decreases as the current increases.

.....  
.....  
.....  
.....

(2)

(b) (i) Use the graph to find the emf,  $\epsilon$ , of the cell.

answer = ..... V

(1)

- (ii) Use the graph above to find the internal resistance,  $r$ , of the cell.

answer = .....  $\Omega$  (3)

- (c) Draw a line on the graph above that shows the results obtained from a cell with

(i) the same emf but double the internal resistance of the first cell labelling your graph **A**. (2)

(ii) the same emf but negligible internal resistance labelling your graph **B**. (1)

- (d) In the original circuit shown in part (a), the variable resistor is set at a value such that the current through the cell is 0.89 A.

(i) Calculate the charge flowing through the cell in 15 s, stating an appropriate unit.

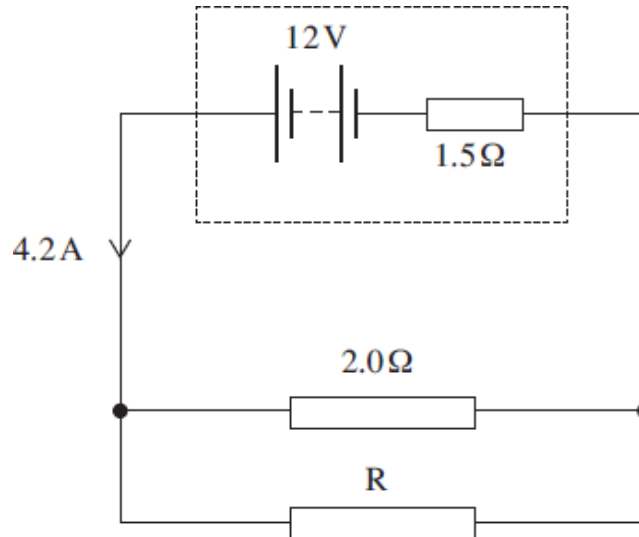
answer = ..... (2)

- (ii) Calculate the energy dissipated in the internal resistance of the cell per second.

answer = ..... W

(2)  
(Total 13 marks)

- Q31.** The circuit diagram below shows a battery of electromotive force (emf) 12 V and internal resistance 1.5 Ω connected to a 2.0 Ω resistor in parallel with an unknown resistor, R. The battery supplies a current of 4.2 A.



- (a) (i) Show that the potential difference (pd) across the internal resistance is 6.3 V.

(1)

- (ii) Calculate the pd across the 2.0 Ω resistor.

pd .....V

(1)

(iii) Calculate the current in the  $2.0 \Omega$  resistor.

current .....A (1)

(iv) Determine the current in R.

current ..... A (1)

(v) Calculate the resistance of R.

R .....  $\Omega$  (1)

(vi) Calculate the total resistance of the circuit.

circuit resistance .....  $\Omega$  (2)

(b) The battery converts chemical energy into electrical energy that is then dissipated in the internal resistance and the two external resistors.

(i) Using appropriate data values that you have calculated, complete the following table by calculating the rate of energy dissipation in each resistor.

resistor	rate of energy dissipation / W
internal resistance	
$2.0 \Omega$	
R	

(3)

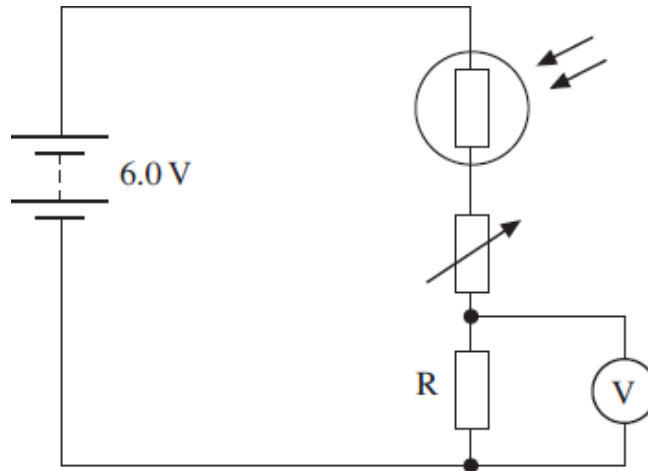
(ii) Hence show that energy is conserved in the circuit.

.....  
.....

(2)

(Total 12 marks)

**Q32.** The circuit diagram below shows a 6.0 V battery of negligible internal resistance connected in series to a light dependent resistor (LDR), a variable resistor and a fixed resistor, R.



(a) For a particular light intensity the resistance of the LDR is 50 kΩ. The resistance of R is 5.0 kΩ and the variable resistor is set to a value of 35 kΩ.

(i) Calculate the current in the circuit.

current.....A

(2)

(ii) Calculate the reading on the voltmeter.

voltmeter reading .....V

(2)

(b) State and explain what happens to the reading on the voltmeter if the intensity of the light incident on the LDR increases.

.....  
 .....  
 .....

(2)

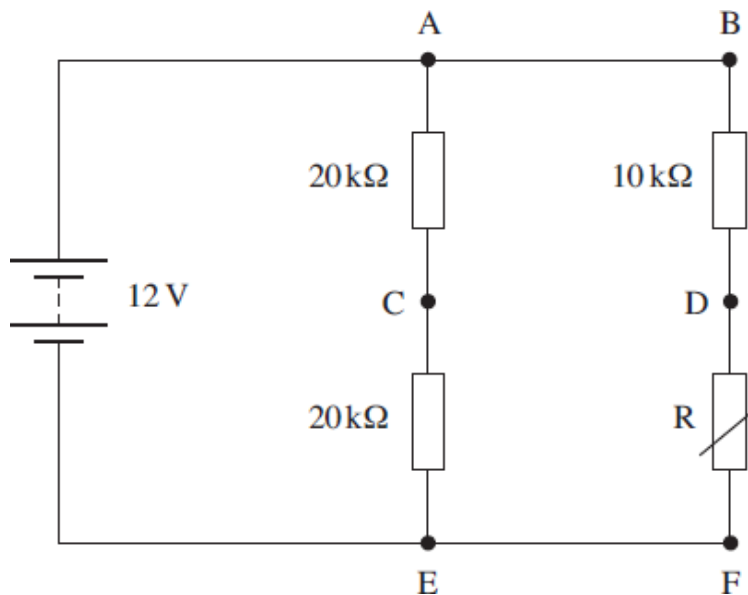
- (c) For a certain application at a particular light intensity the pd across R needs to be 0.75 V. The resistance of the LDR at this intensity is 5.0 k $\Omega$ .

Calculate the required resistance of the variable resistor in this situation.

resistance .....  $\Omega$

(3)  
(Total 9 marks)

- Q33.** The circuit diagram below shows a 12 V battery of negligible internal resistance connected to a combination of three resistors and a thermistor.



- (a) When the resistance of the thermistor is 5.0 k $\Omega$
- (i) calculate the total resistance of the circuit,

total resistance = ..... k $\Omega$

(3)

- (ii) calculate the current in the battery.

current = ..... mA

(1)

- (b) A high-resistance voltmeter is used to measure the potential difference (pd) between points A-C, D-F and C-D in turn. Complete the following table indicating the reading of the voltmeter at each of the three positions.

voltmeter position	pd / V
A-C	
D-F	
C-D	

(3)

- (c) The thermistor is heated so that its resistance decreases. State and explain the effect this has on the voltmeter reading in the following positions.

- (i) A-C.....  
 .....  
 .....  
 .....

(2)

- (ii) D-F.....  
 .....  
 .....  
 .....

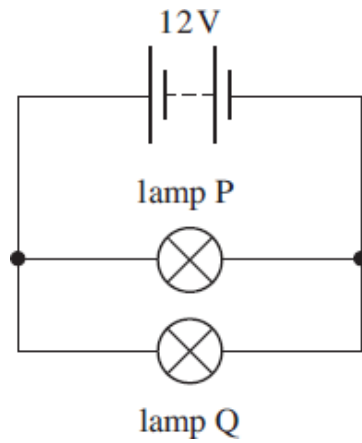
(2)

(Total 11 marks)



**Q34.** A battery of negligible internal resistance is connected to lamp P in parallel with lamp Q as shown in **Figure 1**. The emf of the battery is 12 V.

**Figure 1**



(a) Lamp P is rated at 12 V 36 W and lamp Q is rated at 12 V 6 W.

(i) Calculate the current in the battery.

answer = ..... A

(2)

(ii) Calculate the resistance of P.

answer = .....  $\Omega$

(1)

(iii) Calculate the resistance of Q.

answer = .....  $\Omega$

(1)

- (b) State and explain the effect on the brightness of the lamps in the circuit shown in **Figure 1** if the battery has a significant internal resistance.

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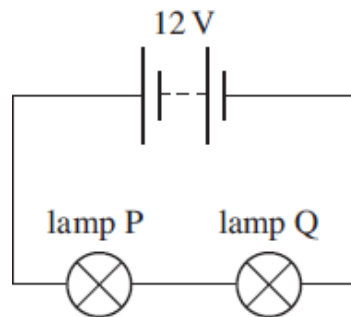
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(3)

- (c) The lamps are now reconnected to the 12 V battery in series as shown in **Figure 2**.

**Figure 2**



- (i) Explain why the lamps will not be at their normal brightness in this circuit.

.....

.....

.....

.....

.....

(2)

- (ii) State and explain which of the lamps will be brighter assuming that the resistance of the lamps does not change significantly with temperature.

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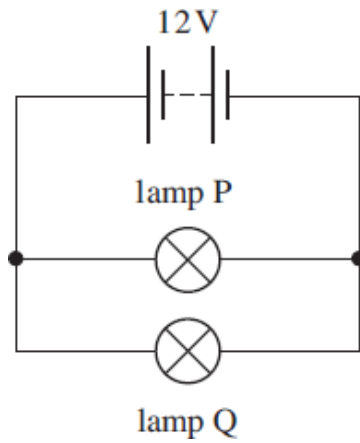
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(3)

**(Total 12 marks)**

**Q35.** A battery of negligible internal resistance is connected to lamp P in parallel with lamp Q as shown in **Figure 1**. The emf of the battery is 12 V.

**Figure 1**



(a) Lamp P is rated at 12 V 36 W and lamp Q is rated at 12 V 6 W.

(i) Calculate the current in the battery.

answer = ..... A

(2)

(ii) Calculate the resistance of P.

answer = .....  $\Omega$

(1)

(iii) Calculate the resistance of Q.

answer = .....  $\Omega$

(1)

- (b) State and explain the effect on the brightness of the lamps in the circuit shown in **Figure 1** if the battery has a significant internal resistance.

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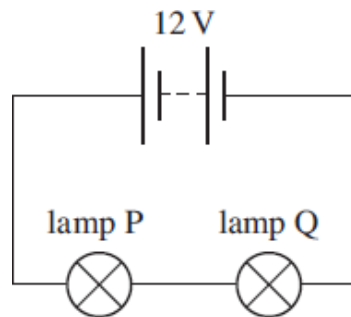
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(3)

- (c) The lamps are now reconnected to the 12 V battery in series as shown in **Figure 2**.

**Figure 2**



- (i) Explain why the lamps will not be at their normal brightness in this circuit.

.....

.....

.....

.....

.....

(2)

- (ii) State and explain which of the lamps will be brighter assuming that the resistance of the lamps does not change significantly with temperature.

.....

.....

.....

.....

(3)

**(Total 12 marks)**

**M1.** (a) between A and C: (each) series resistance =  $100\Omega$  **(1)**

(parallel resistors give)  $\frac{1}{100} + \frac{1}{100} = \frac{1}{50}$  + = gives  $R_{AC} = 50\Omega$  **(1)**

2

(allow C.E. for incorrect series resistance)

(b) between A and B: series resistance =  $150\Omega$  **(1)**

parallel =  $\frac{1}{50} + \frac{1}{150}$  **(1)**

(allow C.E. for series resistance)

$R_{AB} = 37.5\Omega$  **(1)** (38 $\Omega$ )

3

[5]

**M2.** (a) first pair in parallel  $\frac{1}{R'} = \frac{1}{30} + \frac{1}{60}$  **(1)**

=  $\frac{3}{60}$  = gives  $R' = 20 (\Omega)$  **(1)**

second pair in parallel  $\frac{1}{R''} = \frac{1}{40} + \frac{1}{120}$  gives  $R'' = 30(\Omega)$  **(1)**

resistance between A and B =  $20 + 30$  **(1)** (=  $50 \Omega$ )

(allow C.E. for values of  $R'$  and  $R''$ )

4

(b) (i) total resistance =  $50 + 50 = 100 \Omega$  **(1)**  
( $V = IR$  gives)  $24 = I 100$  and  $I = 0.24 \text{ A}$  **(1)**

(ii) current in  $60 \Omega = \frac{1}{3} I$  **(1)**  
=  $0.080 \text{ (A)}$  **(1)**

[or alternative method]

(allow C.E. for value of  $I$  from (b)(i))

4

[8]

**M3.** (a) (i) total resistance =  $180 + 60 = 240 (\Omega)$  **(1)**  
( $V = IR$  gives)  $12 = I 240$  and  $I = 0.05 \text{ A}$  **(1)**

(ii) very large or infinite resistance **(1)**

(iii)  $V = 0.05 \times 60 = 3.0\text{V}$  **(1)**

[or statement that  $V = \frac{1}{4}$  of 12 V]

[or use of potentiometer equation

$$V_{\text{out}} = V_{\text{in}} \left[ \frac{R_2}{R_1 + R_2} \right] = 12 \times \left[ \frac{60}{240} \right] = 3.0 \text{ V}$$

(allow C.E. for value of  $I$  from (a)(i))

4

- (b) parallel resistance gives lower equivalent resistance  
[or resistance of lower section of potentiometer reduced] **(1)**  
total resistance in circuit reduced **(1)**  
current through battery increases since  $V$  constant **(1)**

max 2  
QWC 2

[6]

- M4.** (a) (i) for X: ( $P = VI$  gives)  $24 = 12I$  and  $I = 2 \text{ A}$  **(1)**  
for Y  $18 = 6I$  and  $I = 3 \text{ A}$  **(1)**

2

- (b) (i) 12 V **(1)**
- (ii) voltage across  $R_2$  ( $= 12 - 6$ ) = 6 (V) **(1)**  
 $I = 3$  (A) **(1)**  
( $V = IR$  gives)  $6 = 3R_2$  and  $R_2 = 2\Omega$  **(1)**  
(allow C.E. for  $I$  and  $V$  from (a) and (b)(i))
- [or  $V = I(R_1 + R_2)$  **(1)**  $12 = 3(2 + R_2)$  **(1)**  $R_2 = 2\Omega$  **(1)**]
- (iii) current = 2 (A) + 3 (A) = 5 A **(1)**  
(allow C.E. for values of the currents)
- (iv) 27 (V) – 12 (V) = 15 V across  $R_1$  **(1)**
- (v) for  $R_1$ ,  $15 = 5 R_1$  and  $R_1 = 3\Omega$  **(1)**  
(allow C.E. for values of  $I$  and  $V$  from (iii) and (iv))

7

[9]

**M5.** (i) ( $V = IR$  gives)  $12 = (30 + 30 + 2)I$  (1)

$$I = \left( \frac{12}{62} \right) = 0.19 \text{ A (1)} \quad (0.194 \text{ A})$$

(ii)  $V_{PQ} = 12 - (0.19 \times 2)$  (1)  
 $= 11.6 \text{ V (1)}$

(allow C.E. for incorrect  $I$  in (i))

[or  $V_{PQ} = 0.19 \times 60 = 11.6 \text{ V}$ ] ( $I = 0.194 \text{ A}$  gives  $11.6 \text{ V}$ )

[or  $V_{PQ} = 12 \times \frac{60}{62} = 11.6 \text{ V}$ ]

(iii) ( $P_A = I^2 R$  gives)  $P_A = (0.19)^2 \times 30 = 1.08$  (1) W (1)

[or  $P_A = \frac{V^2}{R}$ ]

(allow C.E. for incorrect  $I$  in (i) or incorrect  $V$  in (ii))

(iv) ( $E = P_A t$  gives)  $E = 1.08 \times 20$  (1)

$= 21.6 \text{ J (1)}$

(allow C.E. for incorrect  $P_A$  in (iii))

[8]

**M6.** (a) (i)  $5 \text{ V (1)}$

(ii)  $R_T = 36 \text{ } (\Omega)$

(use of  $V = IR$  gives)  $15 = I \times 36$  and  $I = 0.42 \text{ A (1)}$

3

(b) (i) equivalent resistance of the two lamps  $\frac{1}{R} = \frac{1}{12} + \frac{1}{12} = \frac{1}{6}$  (1)

$R_T = 6 + 12 = 18 \text{ } (\Omega)$  and  $15 = I \times 18$  (1) (to give  $I = 0.83 \text{ A}$ )

(ii) current divides equally between lamps (to give  $I = 0.42 \text{ A}$ )  
 (or equivalent statement) (1)

3

- (c) same brightness **(1)**  
(because) same current **(1)**

2

[8]

- M7.** (a) (i) energy changed to electrical energy per unit charge/coulomb  
passing through  
[or electrical energy produced per coulomb or unit charge]  
[or pd when no current passes through/or open circuit] **(1)**

(ii)  $I = \frac{6}{2.4} = 2.5 \text{ A}$  **(1)**

- (iii) (use of  $\epsilon = I(R + r)$  gives)  $\epsilon = V + Ir$  and  $8 = 6 + Ir$  **(1)**

substitution gives  $8 - 6 = 2.5r$  **(1)** (and  $r = 0.8 \Omega$ )

4

- (b) (i) (use of  $P = I^2R$  gives)  $P_R = 2.5^2 \times 2.4 = 15 \text{ W}$

[or  $P = VI$  gives  $P = 6 \times 2.5 = 15 \text{ W}$ ] **(1)**

(allow C.E. for value of  $I$  from (a))

(ii)  $P_T = 15 + (2.5^2 \times 0.8)$  **(1)**

$= 20 \text{ (W)}$  **(1)**

(allow C.E. for values of  $P_R$  and  $I$ )

(iii)  $E = 5 \times 2 \times 60 = 600 \text{ J}$  **(1)**

(allow C.E. for value of  $P$  from (i) and  $P_T$  from (ii))

4

[8]



- M8.** (a)  $V = -Ir + \epsilon$  (1) 1
- (b) straight line (within 1st quadrant) (1)  
negative gradient (1) 2
- (c)  $\epsilon$  : intercept on voltage axis (1)  
 $r$ : gradient (1) 2

[5]

- M9.** (a) (i)  $\frac{1}{R} = \frac{1}{40} + \frac{1}{40} + \frac{1}{40}$  (1)
- $R = \frac{40}{3} = 13 \Omega$  (1) (13.3)
- (ii) two resistors in parallel give 20 ( $\Omega$ ) (1)  
 $R = 20 + 40 = 60 \Omega$  (1) max 3

- (b) (i) three resistors in parallel give  $\frac{1}{6} + \frac{1}{6} + \frac{1}{6}$  (= 2 ( $\Omega$ ))  
and total resistance = 4 ( $\Omega$ ) (1)

total current =  $\frac{12}{4} = 3$  (A) (1)

(allow C.E. for value of total resistance)

current in each element 1.0 A (1)

(allow C.E. for value of total current)

[or 6 V across each set

resistance of each set = 2  $\Omega$ , gives current through  
each set = 3 (A)

current in each element = 1.0 A]

[or 6 V across each set/resistor,

resistance of one resistor = 6  $\Omega$ ,

gives current in each element = 1.0 A]

- (ii) six resistors in series gives  $R = 36 \Omega$  and  $I = \frac{12}{36} = 0.3$  (A) (1)

**heating effect** ( $I^2R$ ) much reduced [or less power] (1)

5

[8]

**M10.** (a) (i) (total) resistance = (20 + 60) ( $\Omega$ ) **(1)**

$$(V = IR \text{ gives}) \quad I = \frac{6.0}{80} = 0.075 \text{ A } \mathbf{(1)}$$

(ii) with S closed, (effective) resistance = 20 ( $\Omega$ ) **(1)**

$$I = \frac{6.0}{20} = 0.3 \text{ A } \mathbf{(1)}$$

max 3

(b) use of same current as in part (i) **(1)**  
voltmeter reading =  $0.075 \times 60 = 4.5 \text{ V}$  **(1)**

$$\text{[or use potentiometer equation } 6 \times \frac{60}{80} = 4.5 \text{ V]} \\ \text{(allow C.E. for value of } I \text{ from (a)(i))}$$

2

[5]

**M11.** (a) **battery** has internal resistance **(1)**  
**current** passes through (this resistance) **(1)**  
work done/voltage lost, which reduces the value of the emf **(1)**

3  
QWC 1

(b) (i) circuit diagram to show:  
two **cells** in series **(1)**  
two resistors, each labelled  $r$  **(1)**

(ii) (use of  $P = IV$  gives)  $1.6 = 2.5 I$  **(1)** ( $I = 0.64 \text{ A}$ )  
(use of  $\epsilon = V + Ir$  gives)  $3.0 = 2.5 + 0.64 \times 2r$  **(1)** **(1)**  
 $0.5 = 1.28r$  and  $r = 0.39 \Omega$  **(1)**

[or  $R_{\text{bulb}} = 2.5^2 / 1.6 = 3.9 \text{ } (\Omega)$  and  $2.5 = 3.9 \times I$  gives  $I = 0.64 \text{ A}$   
'lost volts' =  $(3 - 2.5) = 0.5 \text{ V}$  i.e.  $0.25 \text{ V}$  per cell  
 $0.25 = 0.64r$  and  $r = 0.39 \Omega$ ]

5

(c)  $\epsilon = V + Ir$  gives  $V = -Ir + \epsilon$  (equation of straight line) **(1)**  
intercept on  $y$ -axis gives  $\epsilon$  **(1)**  
gradient gives  $(-r)$  **(1)**

3

[11]

- M12.** (a) (i) no of bulbs =  $\left(\frac{230}{5}\right) = 46$  **(1)**
- (ii) (use of  $P = VI$  gives)  $I = \left(\frac{0.4}{5}\right) = 0.080$  A **(1)**
- (iii) resistance of each bulb =  $\frac{230}{0.080 \times 46} = 63 \Omega$  (62.5  $\Omega$ )  
(allow C.E. for number of bulbs and value of  $I$ )

$$\text{[or } R \left( = \frac{V}{I} \right) = \frac{5}{0.08} = 62.5 \Omega$$

$$\text{or } \left( P = \frac{V^2}{R} \text{ gives } \right) R = \frac{25}{0.40} = 62.5 \Omega]$$

5

- (iv) energy consumed by the set =  $0.4 \times 46 \times (2 \times 60 \times 60)$  **(1)**  
= 132 kJ **(1)**  
(allow C.E. for number of bulbs from (i))

- (b) (i) no of bulbs = 56, gives total resistance =  $62.5 \times 56$  ( $\Omega$ ) (= 3500) **(1)**

$$I = \frac{230}{3500} = 0.066$$
 A **(1)** (0.0657 A)

(use of 63  $\Omega$  gives 0.065 A)

(allow C.E. for no. of bulbs in (a) (i) and  $R$  in (a) (iii))

- (ii) bulbs would shine less bright **(1)**

3

[8]

- M13.** (a) (i) three resistors in series **(1)**
- (ii)  $R = 3.0 + 4.0 + 6.0 = 13 \Omega$  **(1)**
- (iii) three resistors in parallel **(1)**

$$(iv) \frac{1}{R} = \frac{1}{3} + \frac{1}{4} + \frac{1}{6} = \frac{9}{12} \text{ (1)}$$

$$R = 1.3 \Omega \text{ (1)}$$

5

- (b) (i) two resistors in parallel give  $\frac{1}{R'} = \frac{1}{3} + \frac{1}{6}$  and  $R' = 2.0 \text{ } (\Omega)$  **(1)**  
 total resistance =  $(2 + 4) = 6.0 \text{ } \Omega$  **(1)**

4

- (ii) divide the emf in the ratio of 2 : 4 **(1)**  
 to give 4.0 V **(1)**  
 [or any suitable method]

[9]

- M14.** (a) (i) electrical energy produced (in the battery) per unit charge **(1)**  
 [or potential/voltage across terminals when there is no current]  
 (ii) there is a current (through the battery) **(1)**  
 voltage 'lost' across the internal resistance **(1)**

Max 2

- (b) (i)  $\epsilon = V + Ir$  **(1)**  
 (ii) labelled scales **(1)**  
 correct plotting **(1)**  
 best straight line **(1)**  
 $\epsilon$ : intercept on y axis **(1)** = 9.2 ( $\pm 0.1$ ) V **(1)**

$$r: (-) \text{ gradient} = \frac{9.2}{0.65} = 14.2 \text{ } \Omega \text{ } \mathbf{(1)} \text{ (range 14.0 to 14.3)}$$

8

[10]

- M15.** (a) (i) (use of  $V = IR$  gives)  $12 = I \times 270$  and  $I = 44.4 \text{ mA}$  **(1)**  
 (ii) two resistors in parallel give resistance less than 110  $\Omega$  **(1)**  
 ( $\therefore$ ) total resistance decreases **(1)**  
 current increases **(1)**

4

- (b)  $V = 44.4 \times 10^{-3} \times 110$  **(1)** (= 4.9 V)

$$\text{[or } V = 12 \times \left( \frac{110}{110 + 160} \right)]$$

(assumption) no current flows through voltmeter **(1)**

[or voltmeter has very large or infinite resistance]

2

(c) total resistance (in circuit) = 160 ( $\Omega$ ) (1)

$$12 = I \times 160 \text{ and } I = 75 \text{ mA (1)}$$

2

[8]

**M16.** (a) (i) 180V (1)

(ii) (use of  $P = VI$  gives)  $I = \frac{7.2 \times 10^3}{180}$  (1)  
= 40A (1)

(allow C.E. for value of  $v$  from (i))

(iii) (use of  $Q = It$  gives)  $Q = 40 \times 2 \times 60 \times 60$  (1)  
=  $2.9 \times 10^5 \text{C}$  (1)

$$(2.88 \times 10^5 \text{C})$$

(allow C.E. for value of  $I$  from (ii))

(iv)  $E = QV$  (1)

(or  $Pt$  or  $VIt$ )

$$= 2.9 \times 10^5 \times 180 = 52 (.2) \times 10^6 \text{J (1)}$$

(use of  $Q = 2.88 \times 10^5$  gives  $5.18 \times 10^6 \text{ J}$ )

(allow C.E. for values of  $Q$  and  $V$ )

7

(b) (i) pd across each cell/battery is reduced (1)  
[or because of resistance in each cell]  
current in circuit is reduced (1)

(total) charge circulated by battery remains the same (1)

[or valid energy reasons]

time for which (reduced) current flows is increased (1)

3

[10]

**M17.** (a) (for lamp and resistor)  $18(\Omega) + 12(\Omega) = 30(\Omega)$  (1)

(in parallel)  $\frac{1}{30} + \frac{1}{15} = \frac{3}{30}$  (1) (gives  $R = 10(\Omega)$ )

(allow C.E. for wrong value in first step)

$$\text{total resistance} = \frac{30}{3} + 10 \text{ (1)}$$

(= 20  $\Omega$ )

3

(b) (i) (use of  $V = IR$  gives)  $I = \left(\frac{30}{20}\right) = 1.5 \text{ A (1)}$

(ii)  $\text{pd}_{AB} = 30 - (10 \times 1.5) \text{ (1)}$   
 $= 15\text{V (1)}$

[or alternative method]

(allow C.E. for value of  $I$  from (i))

(iii)  $I_{\text{lamp}} = \frac{6}{12} = 0.5 \text{ A (1)}$

[or alternative method] (allow C.E. for value of  $\text{pd}_{AB}$  from (ii))

4

(c) (i) (lamp power)  $(= I^2R) = 0.5^2 \times 12 = 3.0 \text{ (W) (1)}$   
(allow C.E. for value of  $I_{\text{lamp}}$  from (b) (iii))

(ii) power from battery  $= 30 \times 1.5 = 45 \text{ (W) (1)}$   
(allow C.E. for value of  $I$  from (b) (i))

$$\% = \frac{3 \times 100}{45} = 6.7(\%) \text{ (1)}$$

(allow C.E. for power in lamp and/or battery in (i))

3

[10]

**M18.** (a) (i)  $R (= V^2/P) = 12^2/45 \text{ (1)}$

$$R = 3.2\Omega \text{ (1)}$$

(ii) (resistive strips are in parallel)

$$1/R_T = 1/R_1 + 1/R_2 \dots = 5/R \text{ (1)}$$

$$R_T (= 5 \times 3.2) = 16\Omega \text{ (1)}$$

4

(b) (using  $R = \rho l/A$  and  $A = wt$ )

$$\text{thickness} = \rho/wR \text{ (1)}$$

$$= 3 \times 10^{-5} \times 0.80/2.5 \times 10^{-3} \times 16 \text{ (1)}$$

$$= 0.60 \text{ mm (1)}$$

3

(c)  $I (= P/V) = 45/12 = 3.75 \text{ A}$  (1)

$t (Q/I) = 1.44 \times 10^{-5}/3.75 = 3.84 \times 10^4 \text{ s}$  (1)

$3.84 \times 10^4/60 \times 60 = 10.7 \text{ hr}$  (1)

3

[10]

**M19.** (a) (i) work done (by the battery) per unit charge (1)  
or (electrical) energy per unit charge  
or pd/voltage when open circuit/no current

(ii) the resistance of the materials within the battery (1)  
or hindrance to flow of charge **in** battery  
or loss of pd/voltage per unit current

2

(b) (i) (use of  $E = V + Ir$ )

$12 = V + 800 \times 0.005$  (1) (working/equation needs to be shown)

$V = 12 - 4 = 8.0 \text{ V}$  (1)

(ii) (use of  $P = I^2 r$ )

$P = 800^2 \times 0.005$  (1) (working/equation needs to be shown)

$P = 3200$  (1) W (1) or  $\text{J s}^{-1}$

5

(c) car will probably **not** start (1)

battery will not be able to provide enough current (1)  
or less current  
or lower terminal pd/voltage

2

[9]

**M20.** (a) (use of  $1/R_{\text{total}} = 1/R_1 + 1/R_2$ )

$1/R_{\text{total}} = 1/400 + 1/400 = 2/400$

$R_{\text{total}} = 200 \Omega$  (1) (working does not need to be shown)

hence total resistance =  $25 + 200 = 225 \Omega$  (1)

2

(b) (i) (use of  $P = V^2/R$ )

$$1 = V^2/400 \text{ (1)}$$

$$V^2 = 400 \text{ (working does not need to be shown)}$$

$$V = 20V \text{ (1)}$$

(ii) (use of  $I = V/R$ )

$$I = 20/400 = 0.05A \text{ (1) (working does not need to be shown)}$$

$$\text{hence current} = 2 \times 0.05 = 0.10A \text{ (1)}$$

(iii) (use of  $V = IR$ )

$$\text{pd across } 25\Omega \text{ resistor} = 25 \times 0.10 = 2.5V \text{ (1)}$$

(working does not need to be shown)

$$\text{hence maximum applied pd} = 20 + 2.5 = 22.5V \text{ (1)}$$

6

[8]

**M21.** (a) (use of  $E = V + Ir$ )

$$12 = V + 420 \times 0.0095 \text{ (1)}$$

$$V = 8.0(1)V \text{ (1)}$$

2

(b)  $\rho = RA/I = 1.6 \times 10^{-3} \times 7.9 \times 10^{-5}/0.75 \text{ (1)}$

$$R = 1.7 \times 10^{-7} \text{ (1) } \Omega\text{m (1)}$$

3

[5]

**M22.** (a) (i) 6.0 ( $\Omega$ ) (1)

1

(ii) 4.5 (V) (1)

1



(iii) (use of  $I = V/R$ )

$$I = 4.5/6.0 = 0.75 \text{ (A) (1)}$$

$$\text{current through cell A} = 0.75/2 = 0.375 \text{ (A) (1)}$$

2

(iv) charge =  $0.375 \times 300 = 112$  (1) C (1)

2

(b) cells C and D will go flat first or A and B last longer (1)

current/charge passing through cells C and D (per second) is double/more than that passing through A or B (1)

energy given to charge passing through cells **per second** is double or more than in cells C and D (1) or in terms of power

3

[9]

**M23.** (a) (i) work (done)/energy (supplied) per unit charge (by battery) (1)

(or pd across terminals when no current passing through cell or open circuit)

1

(ii) when switch is closed a **current flows** (through the battery) (1)

hence a pd/lost volts develops across the internal resistance (1)

2

(b) (use of  $\epsilon = V + Ir$ )

$$I = 5.8/10 = 0.58 \text{ (A) (1)}$$

$$6.0 = 5.8 + 0.58r \text{ (1)}$$

$$r = 0.2/0.58 = 0.34 \text{ (}\Omega\text{) (1)}$$

3

(c) need large current/power to start the car (1) (or current too low)

internal resistance limits the current/wastes power(or energy)/reduces terminal pd/increases lost volts (1)

2

[8]

- M24.** (a) a non-ohmic conductor does not have a constant resistance **(1)** 1
- (b) (i) curve of decreasing gradient with increasing V **(1)**  
 attempt to make graph symmetric in two opposite quadrants **(1)** 2
- (ii) resistance **increases** as pd increases/current increases **(1)** 1
- (c) (i) (use of  $P = V^2/R$ )  
 $36 = 144/R$  **(1)**  
 $R = 4.0$  ( $\Omega$ ) **(1)** 2
- (ii) reference to temperature change **(1)**  
 (resulting in) a lower resistance **(1)**  
 (hence) power rating would be greater **(1)** 3

[9]

- M25.** (a) (i) **working** circuit including power supply and thermistor  
 (correct symbol) **(1)**  
 voltmeter and ammeter or ohm meter **(1)** 2

- (ii) **The candidate's writing should be legible and the spelling, punctuation and grammar should be sufficiently accurate for the meaning to be clear.**

The candidate's answer will be assessed holistically. The answer will be assigned to one of three levels according to the following criteria.

**High Level (Good to excellent): 5 or 6 marks**

The information conveyed by the answer is clearly organised, logical and coherent, using appropriate specialist vocabulary correctly. The form and style of writing is appropriate to answer the question.

The candidate states that the thermistor is connected in a suitable circuit with voltmeter and ammeter or ohmmeter.

The candidate gives details of how the thermistor is heated in a beaker of water **or** a water bath and a thermometer is used to measure the temperature at small regular intervals.

The candidate states that the resistance is found at various temperatures either directly with an ohmmeter or by dividing voltage by current. The candidate may mention that the water must be stirred to ensure that the thermistor is at the temperature measured by the thermometer.

The candidate may give some indication of the range of temperatures to be used.

The candidate may refer to repetition of whole experiment.

The candidate may plot a graph of resistance against temperature.

The candidate may use a digital thermometer.

**Intermediate Level (Modest to adequate): 3 or 4 marks**

The information conveyed by the answer may be less well organised and not fully coherent. There is less use of specialist vocabulary, or specialist vocabulary may be used incorrectly. The form and style of writing is less appropriate.

The candidate states that the thermistor is connected in a suitable circuit with voltmeter and ammeter or ohmmeter.

The candidate gives details of how the thermistor is heated in a beaker of water and a thermometer is used to measure the temperature.

The candidate states that the resistance is found at various temperatures either directly with an ohmmeter or by dividing voltage by current.

**Low Level (Poor to limited): 1 or 2 marks**

The information conveyed by the answer is poorly organised and may not be relevant or coherent. There is little correct use of specialist vocabulary.  
The form and style of writing may be only partly appropriate.

The candidate changes temperature at least once and measures V and I or R.

**The explanation expected in a competent answer should include a coherent selection of the following points concerning the physical principles involved and their consequences in this case.**

Max 6

- (b) (i)  $pd = 6.0 - 1.6 = 4.4$  (V) **(1)** 1
- (ii)  $current = 4.4/1200 = 3.7 \times 10^{-3}$  (A) **(1)** (not 3.6) 1
- (iii)  $resistance = 1.6/3.7 \times 10^{-3} = 440$  **or** 430 ( $\Omega$ ) **(1)**  
2 sfs **(1)** 2
- (c) less current now flows **or terminal pd/voltage** lower **(1)**  
(or voltage across cell/external circuit is lower)  
(hence) pd/voltage across resistor will decrease **(1)** 2

[14]

- M26.** (a) (i)  $voltage = 0.01 \times 540 = 5.4$  V **(1)** 1
- (ii)  $voltage = 15 - 5.4 = 9.6$  V **(1)** 1
- (iii) (use of  $resistance = voltage/current$ )  
 $resistance = 9.6/0.01$  **(1)** = 960  $\Omega$  **(1)**  
**or**  $R_T = 15/0.01 = 1500$   $\Omega$  **(1)**  
 $R = 150 - 590 = 960$   $\Omega$  **(1)**  
**or potential divider ratio** **(1)(1)** 2

(iv) (use of  $1/R = 1/R_1 + 1/R_2$ )

$$1/960 = 1/200 + 1/R_2 \text{ (1)}$$

$$1/R_2 = 1/960 - 1/1200$$

$$R_2 = 4800 \Omega \text{ (1)}$$

2

(b) (voltage of supply constant)

(circuit resistance decreases)

(supply) current increases or potential divider argument **(1)**

hence pd across 540  $\Omega$  resistor increases **(1)**

hence pd across 1200  $\Omega$  decreases **(1)**

**or** resistance in parallel combination decreases **(1)**

pd across parallel resistors decreases **(1)**

pd across 1200  $\Omega$  decreases **(1)**

3

[9]

**M27.** (a) (i) (use of  $R = V/I$ )

$$R = 10/2.0 = 5.0 \Omega \checkmark$$

1

(ii)  $\frac{1}{R} = \frac{1}{3} + \frac{1}{3+3} = \frac{3}{6} \checkmark$

$$R = 2 (\Omega) \checkmark$$

$$R_{\text{total}} = 2 + 3 \checkmark (= 5 \Omega)$$

3

- (b) (i) voltage across Y =  $10.0 - 2.0 \times 3.0 = 4.0 \text{ V}$  ✓  
 current in Y =  $4.0/3.0 = 1.3 \text{ A}$  ✓ 2
- (ii) current through W =  $0.67 \text{ A}$  ✓  
 voltage =  $0.67 \times 3 = 2.0 \text{ V}$  ✓  
 (or  $4.0/2 = 2.0 \text{ V}$  ✓) 2

[8]

- M28.** (a) current =  $0.40 \text{ A}$  **(1)** 1
- (b) (i) resistance =  $12/0.2 = 60 \Omega$  **(1)** 1
- (ii) power =  $12 \times 0.2 = 2.4 \text{ W}$  **(1)** 1
- (c) resistance of filament increases **or** more collisions/scattering **(1)**  
 as temperature of filament increase **or** filament gets hot/heats  
 (until reaches thermal equilibrium) **(1)** 2
- (d) (i) voltage of supply now shared by lamps  
**or** resistance increased **(1)**  
 hence current reduced **(1)** 2
- (ii) current through the **lamps** unchanged/stays the same **(1)**  
 as both connected directly to the supply  
**or** correct resistance argument **(1)** 2
- (e) resistance of lamps will be lower when first switched on **(1)**  
 hence initial current will be larger **(1)**  
 sudden rapid change in temperature **(1)** max 2

[11]

**M29.** (a) (i) (use of  $V = IR$ )

$$R_{\text{total}} = 1 \text{ (ohm)} \checkmark$$

$$V = 1 \times 1 = 1.0 \text{ V} \checkmark$$

2

(ii) (use of  $V = IR$ )

$$R = 9.0/1.0 = 9.0 \ \Omega \checkmark$$

$$r = 9.0 - 1.0 - 6.0 = 2.0 \ \Omega \checkmark$$

**or** use of ( $E = I(R + r)$ )

$$9.0 = 1(7 + r) \checkmark$$

$$r = 9.0 - 7.0 = 2.0 \ \Omega \checkmark$$

2

(iii) (use of  $W = VIt$ )

$$W = 9.0 \times 1.0 \times 5 \times 60 \checkmark$$

$$W = 2700 \text{ J} \checkmark$$

2

(iv) energy dissipated in internal resistance =  $1^2 \times 2.0 \times 5 \times 60 = 600 \text{ (J)}$   $\checkmark$

$$\text{percentage} = 100 \times 600/2700 = 22\% \checkmark \text{ CE from part aii}$$

2

(b) internal resistance limits current  $\checkmark$

hence can provide higher current  $\checkmark$

**or** energy wasted in internal resistance/battery  $\checkmark$

less energy wasted (with lower internal resistance)  $\checkmark$

**or** charges quicker  $\checkmark$

as current higher or less energy wasted  $\checkmark$

**or** (lower internal resistance) means higher terminal pd/voltage  $\checkmark$

as less pd across internal resistance or mention of lost volts  $\checkmark$

2

[10]

**M30.** (a) mention of pd across internal resistance **or** energy loss in internal resistance **or**  $\text{emf} > V$   $\checkmark$

pd across internal resistance/lost volts increases with current **or** correct use of equation to demonstrate  $\checkmark$

2

- (b) (i)  $y$  – intercept 1.52 V ( $\pm 0.01$  V) ✓ 1
- (ii) identifies gradient as  $r$  **or** use of equation ✓  
substitution to find gradient **or** substitution in equation ✓  
 $r = 0.45 \pm 0.02 \Omega$  ✓ 3
- (c) (i) same intercept ✓  
double gradient (must go through 1.25,  $0.40 \pm 1.5$  squares) ✓ 2
- (ii) same intercept horizontal line ✓ 1
- (d) (i) (use of  $Q = It$ )  
 $Q = 0.89 \times 15 = 13$  ✓ C ✓ 2
- (ii) use of  $P = I^2 r$  ✓  
 $P = 0.89^2 \times 0.45$   
 $P = 0.36$  W ✓ 2

[13]

- M31.** (a) (i) (use of  $V=Ir$ )  
 $V = 4.2 \times 1.5$  ✓ = 6.3 (V) 1
- (ii)  $pd = 12 - 6.3 = 5.7$  V ✓  
NO CE from (i) 1
- (iii) (use of  $I = V/R$ )  
 $I = 5.7 / 2.0 = 2.8(5)$  A ✓  
CE from (ii)  
(a(ii)/2.0)  
accept 2.8 or 2.9 1
- (iv)  $I = 4.2 - 2.85 = 1.3(5)$  A ✓  
CE from (iii)  
(4.2 – (a)(iii))  
accept 1.3 or 1.4 1



- (v)  $R = 5.7 / 1.35 = 4.2 \Omega$  ✓  
 CE from (iv)  
 (a(ii) / (a)(iv))  
 Accept range 4.4 to 4.1

1

(vi)  $\frac{1}{R_{\text{parallel}}} = \frac{1}{4.2} + \frac{1}{2.0} = 0.737$  ✓

CE from (a)(v)

$R_{\text{parallel}} = 1.35 \Omega$

second mark for adding internal resistance

$R_{\text{total}} = 1.35 + 1.5$  ✓ = 2.85  $\Omega$

OR

$R = 12 / 4.2$  ✓

$R = 2.85 \Omega$  ✓

2

(b) (i)

resistor	Rate of energy dissipation (W)	CE from answers in (a) but not for first value
1.5 $\Omega$ internal resistance	$4.2^2 \times 1.5 = 26.5$ ✓	
2.0 $\Omega$	$2.85^2 \times 2.0 = 16.2$ (15.68 – 16.82) ✓	
R	$1.35^2 \times 4.2 = 7.7$ (7.1 – 8.2) ✓	

2.0:  $a(\text{iii})^2 \times 2$

R:  $a(\text{iv})^2 \times a(\text{v})$

3

- (ii) energy provided by cell per second =  $12 \times 4.2 = 50.4$  (W) ✓  
 energy dissipated in resistors per second =  $26.5 + 16.2 + 7.7 = 50.4$  ✓  
 (hence energy input per second equals energy output)  
 if not equal can score second mark if an appropriate comment

2

[12]

**M32.**

- (a) (i) (use of  $I = V / R$ )  
 first mark for adding resistance values 90 k  $\Omega$

$I = 6.0 / (50\,000 + 35\,000 + 5000)$  ✓ =  $6.7 \times 10^{-5}$  A ✓

accept  $7 \times 10^{-5}$  or dotted  $6 \times 10^{-5}$

but not  $7.0 \times 10^{-5}$  and not  $6.6 \times 10^{-5}$

2

(ii)  $V = 6.7 \times 10^{-5} \times 5000 \checkmark = 0.33 (0.33 - 0.35) V \checkmark$   
 OR  
 $V = 5 / 90 \times 6 \checkmark = 0.33(V) \checkmark$   
*CE from (i)*  
*BALD answer full credit*  
*0.3 OK and dotted 0.3*

2

- (b) resistance of LDR decreases  $\checkmark$   
*need first mark before can qualify for second*

reading increase because greater proportion / share of the voltage across R OR higher current  $\checkmark$

2

(c)  $I = 0.75 / 5000 = 1.5 \times 10^{-4} (A) \checkmark$   
 (pd across LDR = 0.75 (V))  
 pd across variable resistor =  $6.0 - 0.75 - 0.75 = 4.5 (V) \checkmark$   
 $R = 4.5 / 1.5 \times 10^{-4} = 30\,000 \Omega \checkmark$   
 or  
 $I = 0.75 / 5000 = 1.5 \times 10^{-4} (A) \checkmark$   
 $R_{total} I = 6.0 / 1.5 \times 10^{-4} = 40\,000 \Omega \checkmark$   
 $R = 40\,000 - 5000 - 5000 = 30\,000 \Omega \checkmark$

3

[9]

**M33.** (a) (i)  $1/R_{total} = 1/(40) \checkmark + 1/(10+5) \checkmark = 0.09167$   
 $R_{total} = 10.9 \text{ k}\Omega \checkmark$

3

(ii)  $I = 12 / 10.9 \text{ k} = 1.1 \text{ mA} \checkmark$

1

(b)

position	pd / V
AC	6.0 $\checkmark$
DF	4.0 $\checkmark$
CD	2.0 $\checkmark$

*C.E. for CD*

3

- (c) (i) AC: no change  $\checkmark$   
 constant pd across resistors / parallel branches(AE)  $\checkmark$   
*no CE from first mark*

2

- (ii) DF: decreases  $\checkmark$   
 as greater proportion of voltage across fixed / 10 k  $\Omega$  resistor  $\checkmark$   
*no CE from first mark*

2

[11]

- M34.** (a) (i) (use of  $P=VI$ )  
 $I = 36/12 + 6/12 \checkmark = 3.5 \text{ (A)} \checkmark$  2
- (ii) (use of  $V=IR$ )  
 $R = 12/3 = 4 \text{ (}\Omega\text{)} \checkmark$  1
- (iii)  $R = 12/0.50 = 24 \checkmark \text{ (}\Omega\text{)}$  1
- (b) terminal pd/voltage across lamp is now less OR current is less  $\checkmark$   
 due to lost volts across internal resistance OR due to higher resistance  $\checkmark$   
 lamps less bright  $\checkmark$  3
- (c) (i) current through lamps is reduced as resistance is increased **or**  
 pd across lamps is reduced as voltage is shared  $\checkmark$   
 hence power is less OR lamps dimmer  $\checkmark$  2
- (ii) lamp Q is brighter  $\checkmark$   
 lamp Q has the higher resistance hence pd/voltage across is greater  $\checkmark$   
 current is the same for both  $\checkmark$   
 hence power of Q greater  $\checkmark$  3

[12]

- M35.** (a) (i) (use of  $P=VI$ )  
 $I = 36/12 + 6/12 \checkmark = 3.5 \text{ (A)} \checkmark$  2
- (ii) (use of  $V=IR$ )  
 $R = 12/3 = 4 \text{ (}\Omega\text{)} \checkmark$  1
- (iii)  $R = 12/0.50 = 24 \checkmark \text{ (}\Omega\text{)}$  1
- (b) terminal pd/voltage across lamp is now less OR current is less  $\checkmark$   
 due to lost volts across internal resistance OR due to higher resistance  $\checkmark$   
 lamps less bright  $\checkmark$  3

- (c) (i) current through lamps is reduced as resistance is increased **or**  
pd across lamps is reduced as voltage is shared ✓

hence power is less OR lamps dimmer ✓

2

- (ii) lamp Q is brighter ✓

lamp Q has the higher resistance hence pd/voltage across is greater ✓

current is the same for both ✓

hence power of Q greater ✓

3

[12]

**E1.** In this example of calculating equivalent resistance, the same resistor network was used twice, the equivalent resistance being calculated between different terminals. The majority of candidates had no difficulty with the calculations, but it was worrying to find many answers where the candidates had attempted a solution, not by calculation, but with phrases such as “electricity takes the path of least resistance and therefore the effective resistance (in part (b)) is  $50 \Omega$ .”

It was surprising to find that a significant number of candidates obtained the correct result in part (b) but failed on part (a), since part (b) was deemed to be the most difficult of the two. Considerable arithmetical difficulty was encountered by many candidates with the reciprocal of the resistance when calculating the resistance of parallel resistors.

**E2.** Part (a) was the calculation of the equivalent resistance of a network of resistors consisting of resistors connected in series and in parallel. The majority of candidates gained full marks on this section and were not troubled by the calculation. However, it is worth pointing out that since the final answer of  $50 \Omega$  was given in the question, then in order to gain full marks it was necessary to show that the two equivalent series resistors were being added together.

Part (b) did not prove to be as easy; the problem in (i) was that many candidates gave the total resistance as  $50 \Omega$  rather than  $100 \Omega$ . No consequential error for calculating the current was allowed and frequently no marks were awarded for this section. It was possible in part (b)(ii) to gain the two marks even if the answer to (i) was incorrect, but very few candidates managed to gain these marks. The usual error was giving the current in the circuit as  $24/20$ , i.e. ignoring the second batch of parallel resistors. Again, many candidates, having calculated the total current correctly, assumed that  $2/3$  would pass through the  $60 \Omega$  resistor, not realising that the greater the resistor, the lower the current for a given voltage.

**E3.** The calculation in part (a)(i) was reasonably well done, although a significant number of candidates used only the resistance of the upper part of the potential divider to calculate the current and ignored the lower section. The property of the voltmeter was generally well known, although a significant number of candidates assumed that the resistance was zero or very low. Part (iii) usually realised correct results, even by those candidates who had the first part incorrect; they achieved this by using the potentiometer equation.

Although there was only a maximum of two marks for part (b) it was disappointing to find that many candidates gained only one or were not awarded any marks. Explaining what happens in a circuit in terms of Ohm's law, without the accompanying calculation is a technique that needs to be developed. No doubt, many of the candidates who failed on the explanation would have gained full marks if a calculation had been required. Many candidates who argued correctly that the total resistance in the circuit decreased, then made the simple statement that the current would therefore increase, without justifying this in terms of a constant voltage.

**E4.** This question involved the analysis of a relatively difficult circuit, which included two lamps and two resistors. The question however, was so structured that the majority of candidates were able to work through and gain full marks. Others, unfortunately, although making a reasonable attempt, failed to gain many marks. In part (a), the majority of candidates calculated the correct value of the currents passing through each lamp.

In part (b), obtaining the correct answers to parts (i) and (ii) depended to a large extent on realising that the reading on the voltmeter equalled the voltage across lamp X. Many candidates missed this point, but were still able to gain some marks. In part (ii) the error that was committed regularly was determining the resistance of lamp Y instead of the resistance of resistor  $R_2$ . But at least, more candidates realised that the same current passed through lamp Y and  $R_2$ .

Answers to parts (iii) and (iv) used the answer to part (a) as a starting point, but many candidates failed to realise that the current through  $R_1$  was the sum of the current through the two lamps. Considerable guesswork took over at this stage and although most of it was wrong, candidates could still get a mark for part (v) by using the answers obtained to parts (iii) and (iv).

**E5.** This question worked well and many candidates gained full marks. The majority of the other candidates only failed to gain maximum marks because of a unit error or significant figure error. Disappointingly, many answers were expressed as a fraction. It should be noted that this practice is not acceptable and the first answer expressed as a fraction was treated as a significant figure error.

In part (i) the error which occurred most frequently was ignoring the internal resistance of the battery. The correct answer was 0.19 A, to two significant figures, but many candidates rounded this down to 0.2 A, which apart from incurring a penalty, also, when carried forward to part (ii), gave a voltage across the resistors of 12 V. This implied that there was no voltage developed across the internal resistance of the battery. Although many candidates produced such an answer no one noted that such a situation was not possible. Many answers to part (ii), when carrying forward an incorrect value of the current from part (i), gave an answer well in excess of 12 V. Again this did not seem to worry the candidates.

In part (iii) many candidates made the error of calculating the power dissipated in the total external resistance instead of in resistor A alone. The unit of power was usually correct as was the unit of energy in part (iv). Many candidates arrived at the correct answer in part (iv). Consequential errors were carried forward throughout the whole question. This gave many candidates the chance to gain some marks even if their initial calculation and subsequent answer was incorrect.

**E6.** The question involved straightforward calculations on voltage, resistance and current. In part (a)(i) it was hoped that candidates would have spotted the correct voltage across each lamp by inspection. Surprisingly, even those who managed to get the wrong answer in part (i) nevertheless ignored their answer and proceeded from first principles to obtain the correct answer to part (ii).

Part (b) involved the same circuit components as in part (a) but connected differently. The majority of candidates showed that the current from the battery was the value given in the question. Using this value they then proceeded to argue or calculate the current in each lamp. Those candidates who merely halved the current value obtained in part (i) without any reasoning did not gain the mark.

Although the question told the candidates that the current through each lamp was the same in both circuits it was disappointing to find in part (c) how many candidates tried to argue that the brightness of the bulbs in the 2nd circuit would be different to that in the first, the main thrust of their argument being that the voltage across each bulb was different and therefore that the brightness would be different.

**E7.** Candidates found this question very accessible and many gained full marks. In part (a) the meaning of emf seems to be reasonably well understood with most candidates opting for the voltage when no current passed through the circuit. Others defined it correctly in terms of energy per unit coulomb. There were, unfortunately, many candidates who, apparently, had not encountered the definition of emf and merely quoted electromagnetic force, or even tried to define it in terms of a force in the circuit. The calculation of the current in part (ii) was well done and in part (iii) correct substitution of values into the equation  $\epsilon = V + Ir$  gave  $r = 0.80 \Omega$ .

Part (b) was involved with calculation of power and energy and although the majority of candidates obtained the correct answer for the power dissipated in the  $2.4 \Omega$  resistor, fewer had the correct answer for the total power dissipated in the circuit and a disappointing number had the correct value for the energy wasted the battery. The usual answer to the last part was to give the energy in the complete circuit. Whether this was due to inaccurate reading of the question or due to lack of understanding could not be decided.

**E8.** The response to this question was very disappointing, especially in view of the fact that this topic has been examined several times previously, including questions on the graphical nature of the quantities involved. Rearranging the equation in part (a) was intended as a guide to drawing the graph in part (b). The majority of candidates did rearrange the equation correctly, but some candidates failed to do this and ended up with a quotient.

Sketching the  $I$ - $V$  graph in part (b) was, quite literally, a disaster area. The large majority of candidates drew a straight line of positive gradient passing through the origin. Obviously this was the easiest line to draw without applying any thought to the question. No marks were awarded for such attempts. If a line of positive gradient was drawn, and did not pass through the origin, then 1 mark was awarded. A large number of curved lines, some starting at zero, others at a positive value of  $V$  and decreasing to zero, were also presented. Of the candidates who drew a straight line with a negative gradient, many lost marks by either extending the line into negative values of  $V$ , or negative values of  $I$ . It must be pointed out that when carrying out an experiment to obtain this graph, it is not possible to obtain zero values of  $V$  or  $I$ . However, since some textbooks do show the graph extending to the  $V$  axis, this was accepted, but graphs extending to the  $I$  axis were not.

Most candidates gained at least one mark in part (c), but the impression gained was that candidates had learned the answers parrot fashion with no reference to the graph. The gradient of a curved graph was often given as the answer.

**E9.** Candidates are by now well used to questions on resistors in series and in parallel and part (a) contained no hidden terrors. Invariably, correct answers were gained for both circuits. Examiners are concerned however at the trend of using an unusual nomenclature for a combination of resistors in series and in parallel, e.g. the combination of resistors in the second circuit would be given by candidates in some

centres as  $R_T = \frac{1}{40} + \frac{1}{40} + 40$ . The fact that they subsequently gave the correct

answer of  $60 \Omega$  showed that the candidates had worked out the parallel section first and then added the series section. Such a system is not to be encouraged since it serves to confuse and if a wrong answer is given, it does not help the examiner to find out where the error occurred and then perhaps award a consequential error mark. The other point concerning this section, was that answers to part (i) were given in many instances as  $13\frac{1}{3} \Omega$  or  $13.3 \Omega$  (i.e. recurring). These were treated as significant figure errors. Answers given as fractions are not accepted.

Part (b) was more difficult and many candidates failed to understand the physics of the circuit. Comparatively few candidates gained full marks. An error which cropped up continually in part (i) was correctly calculating the resistance of three resistors in parallel ( $2\Omega$ ) but then using 12 V to calculate the current, not realising that the effect of the other three resistors halved the pd. There were also many candidates who calculated the correct current from the supply, but split this equally between the six resistors and not three. In part (ii), although most candidates calculated the current as 0.33 A and thus correctly concluded that the current was less than that in the part (i), they failed to capitalise on this and merely said that 'therefore the heater was less effective'. In order to gain the final mark it was necessary to mention the heat/power generated by the current.



**E10.** The majority of candidates found this question straightforward and gained the maximum number of marks. Others, however, were not sure of the effect on the circuit of having the switch open or closed. A considerable number of candidates reversed the calculations for parts (a) (i) and (ii). Several candidates, in the situation when the switch was closed, i.e. effectively shorting out the  $60\Omega$ , resorted to adding up the two resistances using the expression for parallel resistors.

In part (b) the majority of candidates realized that a voltmeter of infinite resistance had the same effect on the circuit as an open switch and proceeded accordingly.

**E11.** This question proved to be more difficult than the previous two questions and few candidates gained full marks. However, all candidates scored. In part (a), the large majority of candidates were aware that the internal resistance of the battery played an important role in the emf being greater than the voltmeter reading. Unfortunately, that is as far as most candidates went in the argument. To gain the remaining two marks it was essential to state that a current flowed through the circuit. Most candidates failed to mention this. Once the presence of a current had been established it was quite easy then to gain the third mark.

The circuits drawn in part (b) were, generally speaking, disappointing. Many candidates, rather than drawing two separate cells, drew a battery, which was not acceptable. In most cases the symbol for the internal resistance was not included. Many candidates lost marks by drawing the resistance symbol, but marking it as  $r$  instead of  $2r$ . Quite a large number of the calculations in part (ii) were correct, except that candidates who had marked the resistance as being  $r$  instead of  $2r$  ended up with twice the required value, thereby losing a mark.

A question along the lines of that set in part (c) has been asked many times and yet many answers were poor. Very few candidates took the trouble to give the standard equation in the form of  $V = -Ir + \epsilon$ , thereby helping themselves to realise that that the  $y$  intercept was equal to  $\epsilon$  and the gradient was  $r$ , and not the other way round. Many candidates gave the intercept as  $R$ . The other common feature, which was not acceptable, was to take values off the graph and calculate the required data from the equation.

**E12.** All candidates were able to gain a reasonable number of marks for this question, and many were awarded full marks. The answer to part (a) (i) was usually correct, but there were some problems with part (a) (ii). The most common error was obtaining the correct value of the current in the circuit, as required, but then dividing this value by the number of lamps. The resistance of each lamp, in part (iii), was usually calculated correctly, although some candidates made heavy weather of the calculation when using the expression  $VIR$  for power. Several recurring errors in part (iv) resulted in this part not being answered as well as the others. These errors would be calculating the energy used by one lamp instead of by the set, or omitting the factor of 2 (hours) when calculating the number of seconds, or omitting the conversion from minutes into seconds.

Incorrect answers in part (a) were allowed to be carried forward into part (b), which resulted in part (b) performing quite well. The usual error in part (i) was carrying out the calculations for 10 lamps, instead of 56. Answers to part (ii) were usually correct, candidates realising that the greater the current, the greater the brightness.

**E13.** This is the first time in these series of examinations that candidates have been required to draw their own arrangement of resistors. The majority of candidates gave the correct answers in part (a), although some did try an arrangement of resistors similar to that in part (b). There were a few incorrect calculations in part (a) (ii) even though the three resistors were in series. The usual error in part (iv) was calculating correctly the value of  $V/R$  but then forgetting to invert to obtain  $R$ .

In part (b) the calculation for the total resistance was usually correct although there was some concern amongst the examiners to see the expression  $R_T = \frac{1}{3} + \frac{1}{6} + 4$  occurring quite frequently.

Invariably this resulted in the wrong answer, because candidates would not invert the value for the parallel resistors. The occurrence of this 'system' of calculating resistance was brought to the attention of teachers in the last report, but it seems to be more common than before. Part (ii) was not answered well, with candidates just writing numbers down without any reasoning and in the end confusing themselves. Candidates who just gave an answer of 4 V with no working shown were not credited, because it was possible to obtain that answer by incorrect physics. Candidates should be trained to give some explanation of what they are attempting in such calculations. It was also sad to see candidates obtaining the (correct) answer of 4.0 V across the parallel resistors, but then shooting themselves in the foot by assuming that the voltage across the  $6.0 \Omega$  was different to that across the  $3.0 \Omega$ .

**E14.** Explaining what is meant by emf in part (a) is still beyond the capabilities of a very large number of candidates. The most popular acceptable definition was that of the voltage across the terminals when no current flowed. Many candidates attempted to define emf in terms of the energy produced in the battery, but either forgot, or did not know, that it was the energy per unit charge. In part (a)(ii), the majority of candidates were aware that the reason involved the internal resistance, but merely quoting internal resistance on its own was not sufficient to gain a mark. There must be some reference to the voltage or pd across this resistance when a current flows.

The graph section in part (b) was answered well by the large majority of candidates, who drew excellent graphs. Some candidates missed out by using almost impossible scales in their bid to use the full page of the exam paper. Again, most candidates, having produced the correct equation in (i), knew how to obtain  $\mathcal{E}$  and  $r$  from the graph. Some candidates, having produced an acceptable value for  $\mathcal{E}$ , proceeded to insert values in their equation. This was not acceptable. Another incorrect method was to obtain  $\mathcal{E}$  from the area under the graph.

**E15.** Although the type of question set in part (a) has appeared in previous examinations, many candidates lost marks unnecessarily due to the use of incorrect significant figures in part (i), the usual answer being given as 0.04 A or as a fraction or as a repetitive number. None of these are acceptable. The type of answer required in part (a) (ii) should, by now, be familiar to candidates. The question requires a candidate to reason through the problem without the aid of a calculation. It was pleasing to see how many candidates realised that not only did the resistance in the parallel resistance section decrease, but that this also produced a decrease in the total resistance of the circuit. This step in the answer enabled many candidates to gain full marks. A surprising number of candidates did carry out a calculation and were duly penalised.

The calculation in part (b) was usually correct, but the majority of candidates either ignored the request in the question to state the assumption made or were not aware that a voltmeter has a very large, or infinite resistance. The ideas of short circuiting a section in part (c), is now well understood and the large majority of candidates obtained the correct answer.

**E16.** Part (a) effectively tested the use and understanding of basic relationships such as  $Q = It$  and, to a very large extent, most candidates coped well with this section and scored high marks. In fact the maximum mark of seven was a common occurrence. Very few candidates failed to recognise that 7.2 kW was the same as  $7.2 \times 10^3$  W, but conversely comparatively few candidates gave the answers to parts (iii) and (iv) in scientific notation, preferring to give the answer to part (iii), for example, as 288000 C. There was very little difficulty with realising that two hours had to be expressed in seconds, and the only real problem with the whole section was using the expression  $\frac{1}{2} QV$  for the energy. This was considered to be a basic error in physics and both marks for part (iv) were withheld.

Part (b) proved to be more difficult and comparatively few candidates gained the maximum marks. The effect of the internal resistance on the current, i.e. reducing it, was usually deduced correctly, but the effect on the time took a little more thought. Candidates who deduced correctly that the time increased usually approached the problem from energy or charge considerations.

**E17.** This question proved to be very accessible and full marks were gained frequently. It is worth, however, pointing out a few recurring errors. In part (a), because the answer was given, it was expected that candidates would show full working. Very often the final expression would contain  $10Q$ , being added in series to the product of the parallel

arrangement, the parallel resistance still being in the mathematical form  $\frac{1}{R_1} + \frac{1}{R_2}$  etc.

Because it was so easy to deduce that the parallel section was equivalent to  $10 \Omega$ , examiners did expect to see the value being worked out from the basic expression, otherwise a mark would be deducted.

In part (b) the first two calculations were usually correct, but the third part often produced wrong answers, 1.25 A appearing quite frequently. Part (c) produced many correct answers, with candidates being quite familiar with calculations for power and being able to calculate the percentage.

**E19.** Most candidates were able to explain what is meant by internal resistance but were less clear about the meaning of the emf of a battery. Most appreciated that it was connected to energy but their answers were far from convincing.

Part (b) (i) produced some good responses although a number calculated the potential difference across the internal resistance as opposed to the terminal potential difference which meant that the answer 4.0 V was commonly seen.

Part (b) (ii) was generally answered well and the unit  $\text{J s}^{-1}$  or W did not seem to present too many problems.

Part (c) is an application mentioned in the specification and there was good evidence that this is something that has been considered by most centres. The most common answer was that the current would be reduced. The effect of a reduced current was sometimes not clearly expressed and candidates tended to say things like it would take longer to start or that it would be more difficult to start rather than making a definite statement about the car not starting.

**E20.** Part (a) was answered well, with many candidates obtaining full marks.

Part (b) caused more problems and the use of the power formula that involves potential difference and resistance was quite rare. In part (b) (ii) there was some confusion over potential difference and candidates frequently used their answer from part (b) (i). Part (b) (iii) was answered much better, with candidates frequently benefiting from consequential error.

**E21.** Part (a) caused similar problems to the question on emf and internal resistance in the January examination. A common, incorrect approach was to calculate the potential difference across the internal resistance and quote this as the value of terminal pd.

Part (b) proved to be much more accessible and the calculation only caused a few candidates problems. The unit for resistivity does confuse a significant proportion of candidates and this is often quoted as  $\Omega \text{ m}^{-1}$  or  $\Omega/\text{m}$ .

**E22.** The majority of candidates seemed to approach this question with confidence and set out their working well. Many did not appreciate the effect of connecting the two identical cells in parallel and it was quite common to see them using the combination of parallel resistors formula to combine the emfs of the two cells. This was something that was not confined to the less able candidates but was seen across the full ability range. This was not a heavy penalty as subsequent answers received full credit whatever value candidates had deduced for the total emf.

Part (a) (iv) assessed the unit for charge and the majority of candidates had no problems with this.

The deduction required for part (b) proved quite discriminating and only the very best candidates obtained all three marks. The first mark for identifying cells C and D proved quite straightforward but the explanation less so. Many candidates appreciated that the greater current in the cells in series was significant but were unable to take this to the next step and link this with the rate of energy dissipation.

**E23.** Candidates' performance in this question was generally poor and it appears that the effect of internal resistance on terminal pd is not well understood. While many came up with an acceptable definition of emf few were able to explain convincingly the effect on the voltmeter if the switch is closed. A significant proportion of candidates assumed a current was flowing when the switch was open and it was quite common to see statements such as '*when the switch is closed voltage stops flowing through the voltmeter and so its reading decreases*', which supports the view that potential difference in circuits is a concept that many candidates struggle with. Further evidence of this was provided by the explanations given in part (c).

Many candidates did not seem to appreciate the reason why a car battery needs to have a low internal resistance.

**E24.** This question was answered well although a minority stated that non-ohmic conductors did not follow Ohm's Law without explaining the consequence of this. The  $I-V$  characteristics of the filament lamp seemed to be quite familiar but some answers were spoiled by carelessly drawn graphs that were either horizontal at the end or were not noticeably symmetric in the two quadrants.

The calculation in part (c) was well done but the deduction required for part (c) (ii) proved quite discriminating and only the most able candidates obtained all three marks. Many identified why the power might be 9.0 W, but were unable to explain why, in practice, the power rating is slightly different.

**E25.** A significant proportion of candidates found part (a) difficult. It seems that many candidates were not familiar with an appropriate experiment that enables the variation of a thermistor's resistance with temperature to be investigated. While many drew a correct circuit diagram, few were able to explain suitable techniques for varying the temperature of the thermistor. It was common to see answers that confused this experiment with one that investigated the  $I-V$  characteristics of a filament lamp. This led candidates to suggest that it was appropriate to investigate resistance change by using increasing current to change the thermistor resistance. There was also much confusion as to how resistance was to be determined and the use of a graph of current against voltage was a regular response. Candidates incorrectly stated that they would determine the resistance of the thermistor by measuring the gradient of the graph. This would not be an appropriate method as the graph would be a curve and the gradient of the curve is not the resistance. It was extremely rare for water baths to be used for heating the thermistor and also many did not explain how they would measure the temperature of the thermistor. Many candidates did not address the issue of precision in a convincing way and failed to describe how they would make all the measurements needed. It is clear from this paper and from previous papers that candidates find describing experiments difficult and would benefit from some practice of this skill.

In contrast parts (b) and (c) were generally answered well and full marks were frequently seen. Less able candidates found it difficult to explain clearly the effect on the voltmeter reading if the battery did have an appreciable internal resistance. There is some evidence that candidates did not understand the meaning of the term negligible.

**E26.** This question proved to be very discriminating with only the more able candidates able to score high marks. The calculations involved in part (a) proved too challenging for many candidates. Part (a) (i) and (ii) generated the most correct responses, but the remainder of the analysis was only accessible to the more able candidates.

Part (b) required analysis without calculation and the majority of explanations seen were confused and not self consistent. Many candidates stated that more current goes through the thermistor and therefore the pd across it falls, resulting in the pd across the parallel  $1200\ \Omega$  resistor increasing. Another common misunderstanding was the effect that the decreasing thermistor resistance had on the current through the battery. Many thought that the current remained constant and, although this still led them to deduce that the pd fell, their arguments frequently contained contradictions.

**E27.** This question proved to be very discriminating with only the high performing candidates able to score high marks. The calculations involved in part (a) proved to be straightforward and the majority of candidates realised that this was  $5.0\ \Omega$ . Part (a)(ii) caused more problems and there were many answers in which the calculation of the resistance of the parallel component was spoiled by poor setting out – equating  $\frac{1}{2}$  to  $2\ \Omega$  was a common occurrence.

Part (b) required candidates to calculate currents in the parallel branches of the circuit. Many tried to do this by ratio and got the currents the wrong way round, ie quoting a value of  $0.67\ \text{A}$  instead of the correct  $1.3\ \text{A}$ . A more successful approach, used by more able candidates, involved the calculation the pd across the series resistor and hence the deduction of the pd across Y. Once this was known the current in Y could be correctly calculated. This approach also enabled candidates to give the correct pd across W because they realised it was half the value of the pd they had already calculated for Y.

**E28.** The majority of candidates were able to provide correct answers to parts (a) and (b) although a minority did use the maximum current of  $0.40\ \text{A}$  rather than the normal working current of  $0.20\ \text{A}$ .

Parts (c), (d) and (e) required more qualitative answers and proved to be much more challenging.

Part (c) was well answered, although some candidates were let down by a looseness in their technical language. An example of this occurred when a significant minority referred to the 'filament increasing in heat' rather than temperature.

Part (d) was not answered well and many candidates were confused by the context of the question and gave answers that generally related to series and parallel circuits. This meant that in (i) they stated the current was the same everywhere and therefore did not change, and in (ii) they stated that the current split and therefore decreased. In both these cases, they did not consider the effect the second bulb had on the resistance of the circuit.

Part (e) was more successfully answered by a significant proportion of the candidates, with many realising the significance of the rapid increase in temperature.

**E29.** Students fared better in the circuit analysis involved in this question than they did in question 6. Parts (a) (i), (ii) and (iii) were answered well with a significant proportion of students able to correctly find the total circuit resistance. The calculation of the parallel network was done correctly by the majority of students, although the working shown by many was sometimes not set out properly with the reciprocal of total resistance being equated to the total resistance. This was in part due to the combined resistance being equal to  $1 \Omega$ .

Part (a) (iv), in which students had to calculate the energy transformed by the battery in 5.0 minutes, was not answered as well. A significant proportion of students did not appreciate that this was found by multiplying the emf of the battery by the appropriate time. Part (a) (v) caused students even more problems and only a minority of the more able students were able to correctly calculate the energy dissipated in the internal resistance of the battery.

The final part of this question was well answered with most students giving sensible suggestions. However, one out of two marks was quite common due to students mixing up an explanation with a reason; an example being 'has a higher terminal pd' and 'provides large current'.

**E30.** Part (a) of this question generated some of the poorest responses in the paper with over three quarters of the candidates obtaining no marks. The evidence suggests that candidates find the concept of internal resistance and its relationship with terminal pd quite challenging and were unable to convincingly explain what was happening in this circuit as the current increased. A significant number of candidates assumed that the terminal pd decreased because the internal resistance was increasing due to an increase in temperature of the cell. There was also a lack of precision in answers making it hard to determine which resistance was being referred to in many explanations.

In part (b), the majority were able to find the emf of the cell correctly but the determination of internal resistance,  $r$ , proved to be much more discriminating. The more able candidates appreciated that the gradient of the graph was equal in magnitude to  $r$  and those who did, for the most part, produced acceptable answers. Alternative solutions using the equation,  $\varepsilon = IR + Ir$ , were less successful as there were often careless mistakes made when this approach was used – an example being the calculation of  $R$  using terminal pd and current and then using this value with a different value of current to find  $r$ .

Part (c) required candidates to add lines to the existing graph. Most appreciated that these two lines had the same intercept as the original line and a significant number realised that the line for the cell with double the internal resistance would have a gradient double in magnitude. The line for the cell with zero internal resistance caused more problems and less than half the candidates drew horizontal lines.

Part (d) produced some mixed responses. The calculation of charge was successfully answered by the majority and the unit for charge is clearly well known. However, the calculation of energy dissipated in the internal resistance per second caused far more problems and over half the candidates did not score any marks in this section – many applied the wrong equation and this resulted in them either multiplying the terminal pd or the emf of the cell by the given current.

**E31.** Part (a) was highly structured and led candidates through a full circuit calculation in stages. This approach appeared to have helped them and more successful solutions were seen than has been the case in the past with this type of circuit.

The part that caused the most problems was (a) (ii) with a significant proportion of candidates not appreciating that the pd across the  $2.0 \Omega$  resistor was the same as that across resistor R. Candidates were however, not penalized when they carried their incorrect answer to subsequent parts and consequently the remaining calculations were often carried out successfully.

Part (b) proved to be much more demanding and only about half the candidates managed to complete the table for the rate of energy dissipation successfully.

The demonstration of energy conservation in part (b) (ii) provided an even greater challenge and only about a third of candidates provided a convincing analysis of energy conservation in the circuit. A fifth of candidates made no attempt at this part of the question.

**E32.** This question on a potential divider circuit was a mixture of qualitative and quantitative. As is often the case with questions involving electric circuits, candidates coped better with quantitative parts. This was particularly true in part (a) where the calculation involved more than one stage.

Part (b) was not well done and only the strongest candidates manage to relate the changing light intensity to the voltmeter reading. A significant proportion of candidates were under the impression that increasing the light intensity increases the ldr resistance.

Part (c) did involve a calculation but this was much more challenging than part (a) because there were no intermediate stages. Only a third of candidates were able to calculate a correct value for the resistance of the variable resistor. The majority of those who were successful calculated the value using a ratio method rather than calculating the current and then using this value with the correct pd to find the resistance.

**E33.** In this question candidates were required to analyse a bridge network of resistors. The calculation of the circuit resistance in part (a) proved to be reasonably straightforward with over two thirds of candidates scoring full marks. The only common error in weaker scripts was the combining of all the resistors as parallel resistors instead of combining the series branches first. The calculation of current in part (a) (ii) was done well and with consequential error applied, the majority of candidates were able to do this successfully.

Part (b) was not well answered and very few candidates were able to give correct answers for the voltmeter reading in the three positions. The position that proved the most challenging was the pd between C and D and it is clear that many candidates did not appreciate that this was found by subtracting the pd across D and F from the pd across C and E.

Part (c) was a qualitative question and previous papers suggest that candidates find these difficult. Only the very best candidates managed to get full marks in this section and it was the explanations of the effect on the voltmeter that proved to be the most challenging. For example over 60% of candidates appreciated that the pd across the thermistor decreased but only about 14% managed to explain why. A common mistake was to try and use current in explanations and this led them to conclude incorrectly that if current goes up then so does pd or that the increase in current cancels out the decrease in resistance. Very few used the constant  $12 \text{ V}$  across the parallel branches to justify their conclusions.



**E34.** The quantitative parts of this question were well answered but as is often case, students found the qualitative aspect the much more challenging. The calculations of current and resistance caused few problems and the majority of students were able to explain the effect of an appreciable internal resistance. Part (c) caused far more problems and a significant proportion could not convincingly explain why the lamps were not at normal brightness when connected in series. They seemed not to appreciate that the voltage of the 12 V battery was divided between the lamps or that the circuit resistance is higher when the lamps are in series. They also found it very difficult to explain which lamp was brighter – many incorrectly assuming that it was lamp P as it had a higher power rating.

**E35.** The quantitative parts of this question were well answered but as is often case, students found the qualitative aspect the much more challenging. The calculations of current and resistance caused few problems and the majority of students were able to explain the effect of an appreciable internal resistance. Part (c) caused far more problems and a significant proportion could not convincingly explain why the lamps were not at normal brightness when connected in series. They seemed not to appreciate that the voltage of the 12 V battery was divided between the lamps or that the circuit resistance is higher when the lamps are in series. They also found it very difficult to explain which lamp was brighter – many incorrectly assuming that it was lamp P as it had a higher power rating.

