5.2 Heating Effect of Electric Currents

Question Paper

Course	DP IB Physics
Section	5. Electricity & Magnetism
Topic	5.2 Heating Effect of Electric Currents
Difficulty	Medium

Time allowed: 80

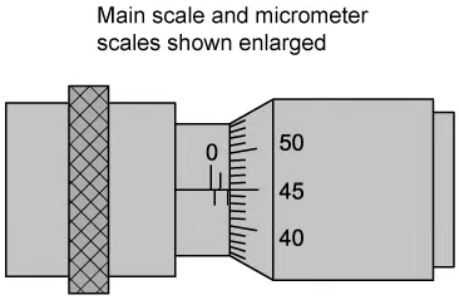
Score: /60

Percentage: /100

Question 1a

Deborah is an aspiring electrical engineer who sets out to investigate the resistivity of a metal wire. The material of the wire is unknown.

She measures the diameter of the wire using a micrometer screw gauge and takes a reading from the main scale and micrometer scale.



(a)
Determine the cross-sectional area of Deborah's wire.

[3 marks]

Question 1b

Deborah then uses an ohmmeter to measure the resistance R for different lengths L of the wire.

Length L / cm	Resistance R / Ω	
80.0	7.94	
70.0	6.99	
60.0	5.89	
50.0	4.93	
40.0	4.27	

(b)
Use Deborah's measurements to complete the final column in the table and then determine the resistivity of the wire.

[4 marks]

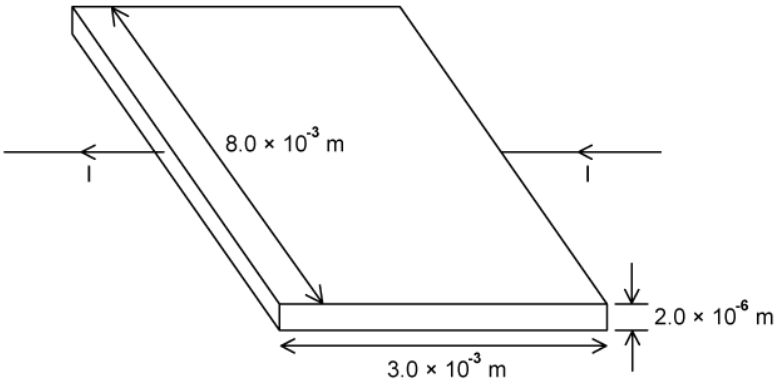
Question 1c

(c)
Suggest and explain two improvements to Deborah's experimental method that would reduce the uncertainty in the final value of resistivity.

[4 marks]

Question 1d

Deborah swaps the sample of wire used in her experiment for a thin film of carbon.



(d)

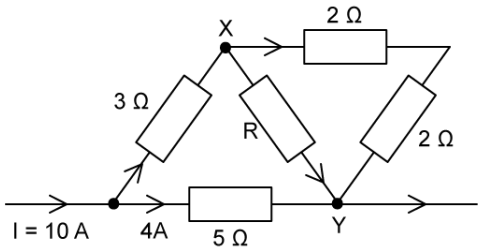
Calculate the current which passes through the carbon film in the diagram for an applied voltage of 2.5 mV.

The resistivity of carbon is $4.0 \times 10^{-5}\ \Omega\,m$.

[3 marks]

Question 2a

A current $I = 10$ A flows through a network of six resistors as shown.



The potential difference across the line XY is 8 V.

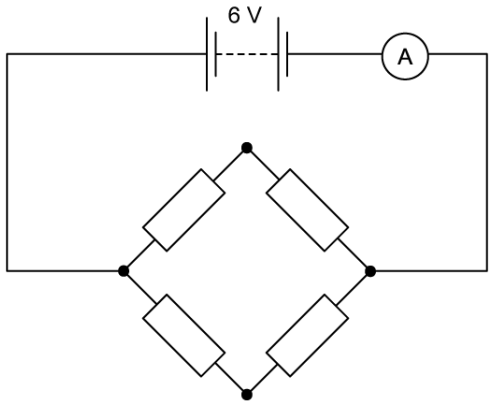
(a)

Calculate the value of the unknown resistance R.

[4 marks]

Question 2b

Another network, comprised of four identical resistors each of resistance 2 Ω, is connected to a 6 V battery with negligible internal resistance.

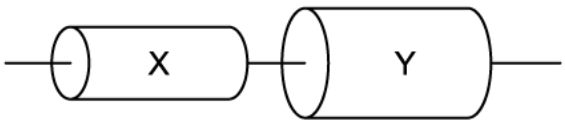


(b)
Determine the reading on the ammeter.

[3 marks]

Question 2c

A resistor is made by connecting two uniform cylinders X and Y of the same material and equal in length, in series.



Cylinder Y has a resistance of 5 Ω and is twice the diameter of cylinder X.

(c)
Calculate the total resistance of this series combination.

[1 mark]

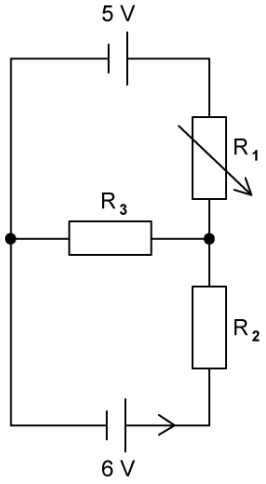
Question 2d

(d)
State and explain why knowledge of quantities like resistivity is useful to scientists.

[2 marks]

Question 3a

A variable resistor R_1 has a resistance that varies between 0 and 10 Ω is connected to two resistors R_2 and R_3 and two cells of e.m.f. 5 V and 6 V.



(a)
Use Kirchhoff's junction law to deduce an equation for three currents I_1, I_2 and I_3 at the junction between the resistors R_1, R_2 and R_3.

[2 marks]

Question 3b

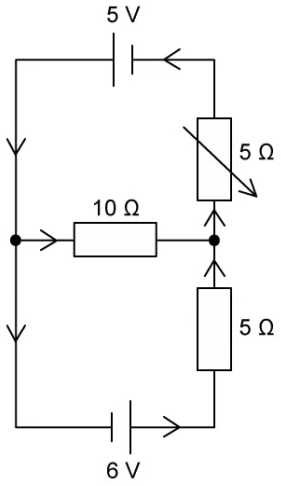
Initially, the variable resistor R_1 is set to 0 Ω.

(b)
If R_2 is 5 Ω and R_3 is 10 Ω, determine the current through resistor R_2.

[4 marks]

Question 3c

The terminals of the 5 V cell are reversed, and the variable resistor is set to a resistance of 5 Ω.



(c)

Using the current directions indicated, write:

(i)

Two unique equations using Kirchhoff's circuit law for loops.

(ii)

One equation using Kirchhoff's circuit law for junctions.

[3 marks]

Question 3d

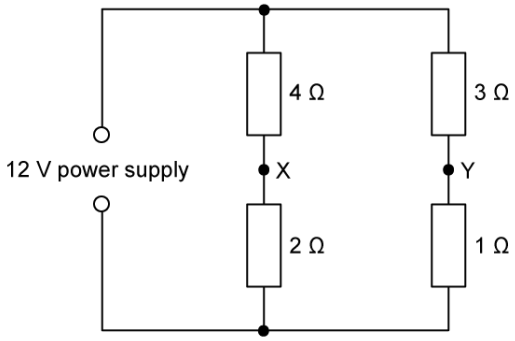
(d)

Hence, calculate the power dissipated in R_3.

[4 marks]

Question 4a

A circuit containing four resistors is connected to a 12 V power supply.

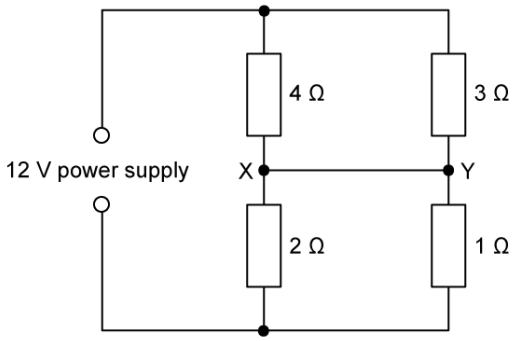


(a)
Show that the potential difference between X and Y is 1 V.

[2 marks]

Question 4b

A wire joins X and Y in the circuit.



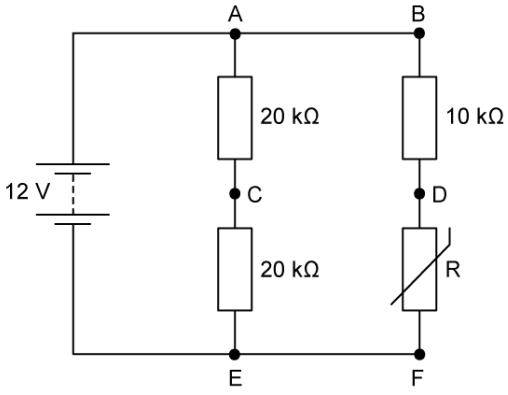
(b)

Assuming current flows anticlockwise from the power supply, state and explain the direction of current along the line XY.

[3 marks]

Question 4c

Another potential divider circuit includes a thermistor with resistance *R*.



The battery has an e.m.f. of 12 V, with negligible internal resistance. At room temperature, the resistance of the thermistor is 4.0 kΩ.

(c)

Calculate the current in the battery at room temperature, giving your answer to an appropriate number of significant figures.

[4 marks]

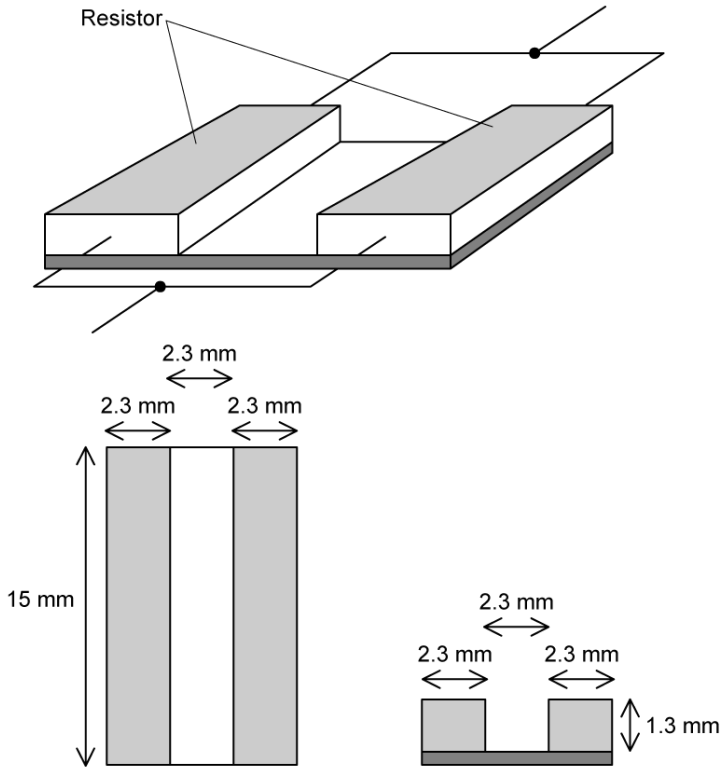
Question 4d

(d)
For temperatures higher than room temperature, describe and explain how the power dissipated varies across:
(i)
AE
(ii))
BD

[4 marks]

Question 5a

An electronic circuit contains two resistors connected as shown.



The material from which each resistor is made has a resistivity of $2.0 \times 10^{5}\ \Omega\,\text{m}$ and both resistors have dimensions of 15 mm by 2.3 mm by 1.3 mm.

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

[2 marks]

Question 5b

The circuit is designed such that changes to the dimensions of each resistor by a common factor x are easily accomplished.

(b)
Show that if the dimensions of each resistor are increased by a factor of x then the resistance decreases by the same factor.

[2 marks]

Question 5c

An electrical heating element is made of nichrome wire of resistivity $1.1 \times 10^{-6}\,\Omega\,m$. It is required to dissipate 800 W when connected to the 230 V mains supply. The radius of the wire is 0.17 mm.

(c)
Calculate the length of wire required for the heating element.

[4 marks]

Question 5d

(d)
Suggest **two** properties that the nichrome wire must have to make it suitable as an electrical heating element.

[2 marks]