An ohmic conductor is connected to an ideal ammeter and to a power supply of output voltage $V$. 

The following data are available for the conductor:
- density of free electrons = $8.5 \times 10^{22}$ cm$^{-3}$
- resistivity $\rho = 1.7 \times 10^{-8}$ Ωm
- dimensions $w \times h \times l = 0.020$ cm $\times 0.020$ cm $\times 10$ cm.

The ammeter reading is 2.0 A.

1a. Calculate the resistance of the conductor. [2 marks]
1b. Calculate the drift speed $v$ of the electrons in the conductor in cm s$^{-1}$. State your answer to an appropriate number of significant figures. [3 marks]

An electron moves in circular motion in a uniform magnetic field.

The velocity of the electron at point P is $6.8 \times 10^5$ m s$^{-1}$ in the direction shown.
The magnitude of the magnetic field is 8.5 T.

2a. State the direction of the magnetic field. [1 mark]

2b. Calculate, in N, the magnitude of the magnetic force acting on the electron. [1 mark]

2c. Explain why the electron moves at constant speed. [1 mark]
2d. Explain why the electron moves on a circular path. 

The diagram shows a potential divider circuit used to measure the emf $E$ of a cell X. Both cells have negligible internal resistance.

3a. State what is meant by the emf of a cell.
AB is a wire of uniform cross-section and length 1.0 m. The resistance of wire AB is 80 Ω. When the length of AC is 0.35 m the current in cell X is zero.

3b. Show that the resistance of the wire AC is 28 Ω. [2 marks]

3c. Determine $E$. [2 marks]

Electrical resistors can be made by forming a thin film of carbon on a layer of an insulating material.

A carbon film resistor is made from a film of width 8.0 mm and of thickness 2.0 µm. The diagram shows the direction of charge flow through the resistor.

4a. The resistance of the carbon film is 82 Ω. The resistivity of carbon is $4.1 \times 10^{-5}$ Ω m. [1 mark]
Calculate the length $l$ of the film.
4b. The film must dissipate a power less than 1500 W from each square metre of its surface to avoid damage. Calculate the maximum allowable current for the resistor. [2 marks]

4c. State why knowledge of quantities such as resistivity is useful to scientists. [1 mark]
4d. The current direction is now changed so that charge flows vertically through the film.  

\[ \text{charge flow} \]

\[ \text{not to scale} \]

Deduce, without calculation, the change in the resistance.

4e. Draw a circuit diagram to show how you could measure the resistance of the carbon-film resistor using a potential divider arrangement to limit the potential difference across the resistor.
A heater in an electric shower has a power of 8.5 kW when connected to a 240 V electrical supply. It is connected to the electrical supply by a copper cable.

The following data are available:
Length of cable = 10 m
Cross-sectional area of cable = 6.0 mm$^2$
Resistivity of copper = $1.7 \times 10^{-8} \Omega \text{ m}$

5a. Calculate the current in the copper cable. [1 mark]

5b. Calculate the resistance of the cable. [2 marks]

5c. Explain, in terms of electrons, what happens to the resistance of the cable as the temperature of the cable increases. [3 marks]
5d. The heater changes the temperature of the water by 35 K. The specific heat capacity of water is 4200 J kg\(^{-1}\) K\(^{-1}\).

Determine the rate at which water flows through the shower. State an appropriate unit for your answer.

\[ \text{[4 marks]} \]

6a. A cable consisting of many copper wires is used to transfer electrical energy from a generator to an electrical load. The copper wires are protected by an insulator.

\[ \text{[3 marks]} \]

6a. The copper wires and insulator are both exposed to an electric field. Discuss, with reference to charge carriers, why there is a significant electric current only in the copper wires.

\[ \text{[3 marks]} \]
The cable consists of 32 copper wires each of length 35 km. Each wire has a resistance of 64 \( \Omega \). The resistivity of copper is \( 1.7 \times 10^{-8} \Omega \text{ m} \).

6b. Calculate the radius of each wire. [2 marks]

6c. There is a current of 730 A in the cable. Show that the power loss in 1 m of the cable is about 30 W. [2 marks]

6d. When the current is switched on in the cable the initial rate of rise of temperature of the cable is 35 mK s\(^{-1}\). The specific heat capacity of copper is 390 J kg\(^{-1}\) K\(^{-1}\). Determine the mass of a length of one metre of the cable. [2 marks]
7a. (i) State how the resistance of T varies with the current going through T. [3 marks]

(ii) Deduce, without a numerical calculation, whether R or T has the greater resistance at \( I = 0.40 \) A.
Components R and T are placed in a circuit. Both meters are ideal.

Slider Z of the potentiometer is moved from Y to X.

(i) State what happens to the magnitude of the current in the ammeter.

(ii) Estimate, with an explanation, the voltmeter reading when the ammeter reads 0.20 A.
In an experiment a student constructs the circuit shown in the diagram. The ammeter and the voltmeter are assumed to be ideal.

8a. State what is meant by an ideal voltmeter. [1 mark]
8b. The student adjusts the variable resistor and takes readings from the ammeter and voltmeter. The graph shows the variation of the voltmeter reading $V$ with the ammeter reading $I$.

Use the graph to determine
(i) the electromotive force (emf) of the cell.
(ii) the internal resistance of the cell.
8c. A connecting wire in the circuit has a radius of 1.2mm and the current in it is 3.5A. The number of electrons per unit volume of the wire is \(2.4 \times 10^{28} \text{m}^{-3}\). Show that the drift speed of the electrons in the wire is \(2.0 \times 10^{-4} \text{ms}^{-1}\).

8d. The diagram shows a cross-sectional view of the connecting wire in (c).

\[ I = 3.5 \text{ A into page} \]

The wire which carries a current of 3.5A into the page, is placed in a region of uniform magnetic field of flux density 0.25T. The field is directed at right angles to the wire.

Determine the magnitude and direction of the magnetic force on one of the charge carriers in the wire.