For Examiner's Use

2 A student makes a solenoid with insulated copper wire.
The solenoid has length 12.0 cm and the average length of one turn of wire on the solenoid is 8.8 cm, as shown in Fig. 2.1.

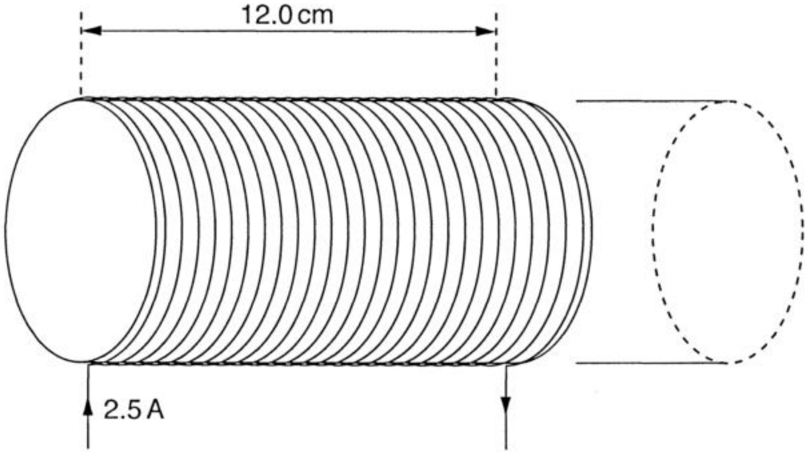

Fig. 2.1

The copper wire has a circular cross-section of diameter 0.60 mm. The resistivity of copper is $1.6 \times 10^{-8}\,\Omega\,m$.
It is found that the current in the solenoid is 2.5 A when the potential difference across its terminals is 4.5 V.

(a) **(i)** Calculate, for the solenoid, the resistance of the wire.

resistance = ... Ω [1]

(ii) Use your answer in **(i)** in order to calculate the total number of turns of wire on the solenoid.

number = ... [3]

(iii) Use your answer in **(ii)** to show that the number of turns per metre length of the solenoid is 3000.

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[1]

(b) The magnetic flux density B (in tesla) inside the solenoid and parallel to its axis is given by the expression

$$B = \mu_0 nI,$$

where n is the number of turns per metre length of the solenoid, I is the current in the solenoid expressed in amperes and μ_0 is the permeability of free space.

(i) Define the tesla.

....

....

....

.... [3]

(ii) Calculate the magnetic flux density in the solenoid.

flux density = ... T [1]

(c) The solenoid in **(b)** is in a vacuum.
An electron is injected into the magnetic field of the solenoid with a speed of $4.0 \times 10^7\,\mathrm{m\,s^{-1}}$ at an angle of 30° to its axis, as shown in Fig. 2.2.

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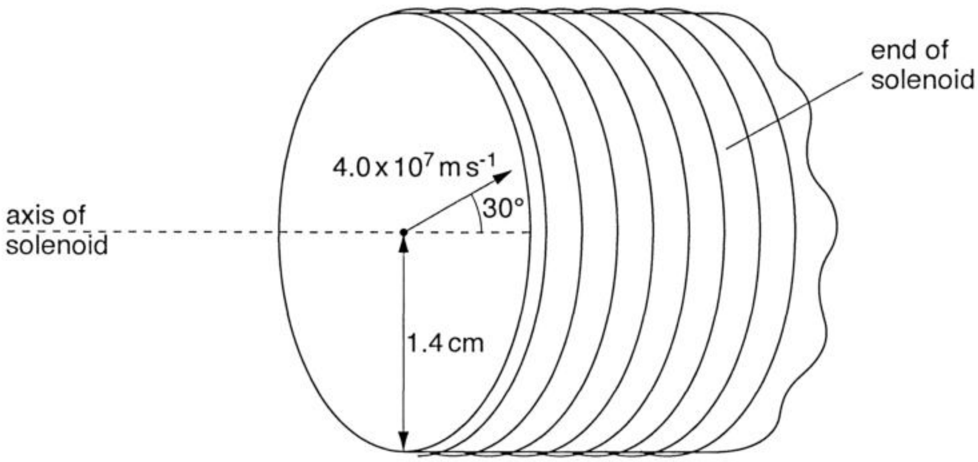

Fig. 2.2

Calculate the magnitude of the component of the electron's velocity

(i) along the axis of the solenoid,

magnitude = ... $\mathrm{m\,s^{-1}}$ [1]

(ii) normal to the axis of the solenoid.

magnitude = ... $\mathrm{m\,s^{-1}}$ [1]

(d) A particle of mass m and charge q is moving with speed v normal to a magnetic field of flux density B.
Show that the particle will move in a circular path of radius r given by the expression

$$r = \frac{mv}{Bq}.$$

Explain your working.

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[3]

(e) The radius of the cross-section of the solenoid in **(c)** is 1.4 cm.
Use data from **(c)** and **(d)** to determine quantitatively whether the electron will travel down the length of the solenoid or will collide with its wall.

[3]