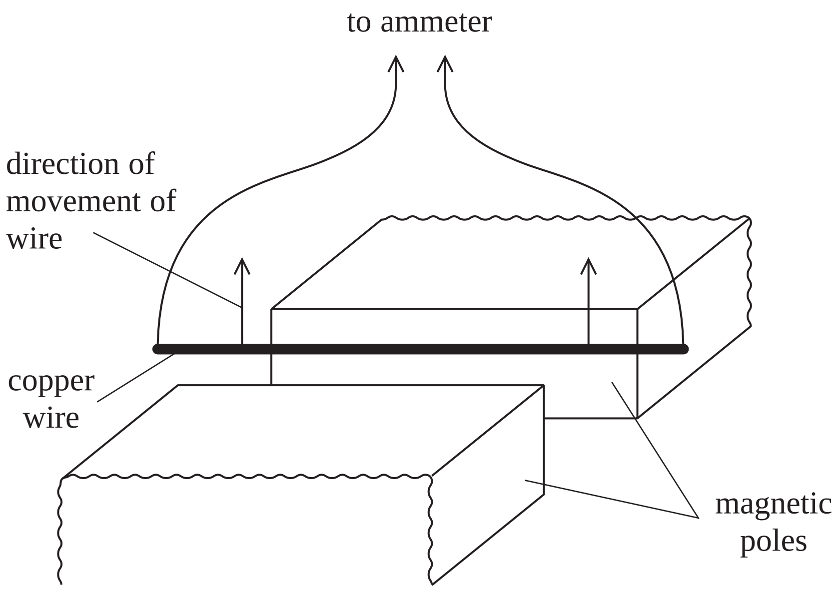
1 A student is investigating electromagnetic induction using a U-shaped magnet. The magnetic flux density between the poles of the magnet is 74 mT. The magnetic field outside the region of the poles is negligible.
She places a stiff copper wire between the poles of the magnet as shown in the diagram.
The wire is connected to an ammeter of resistance 0.25 Ω.



(a) The rectangular poles measure 6.0 cm × 2.4 cm.

Show that the magnetic flux between the poles of the magnet is about 1×10^{-4} Wb.

(3)

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(b) The student holds the wire as shown in the diagram and moves it vertically upwards at a constant speed of 1.2 m s^{-1}.
Calculate the e.m.f. induced in the wire when it is moving.

(3)

Induced e.m.f. =

(c) According to Lenz's law, a force will act on the wire to oppose the motion of the wire.

Calculate the magnitude of the force that opposes the motion and comment on this value.

(4)

Magnitude of force =

Comment

(Total for Question = 10 marks)

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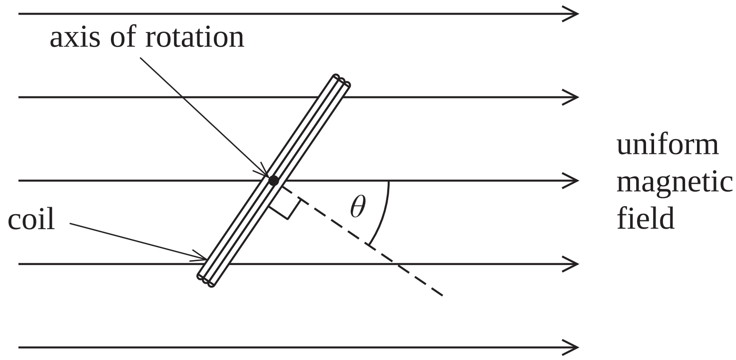
2 The diagram shows an end view of a simple electrical generator. A rectangular coil of wire is rotated in a uniform magnetic field of magnetic flux density 3.0×10^{-2} T. The axis of rotation is at right angles to the field direction.



(a) The coil has 200 turns and an area of 2.0×10^{-4} m².

Calculate the magnetic flux linkage for the coil when $\theta = 0°$.

(2)

Flux linkage =

(b) The coil is rotated at a constant rate of 2 revolutions per second.

(i) Calculate the average e.m.f. induced in the time taken for the coil to rotate from $\theta = 0°$ to $\theta = 90°$.

(3)

Average e.m.f. =

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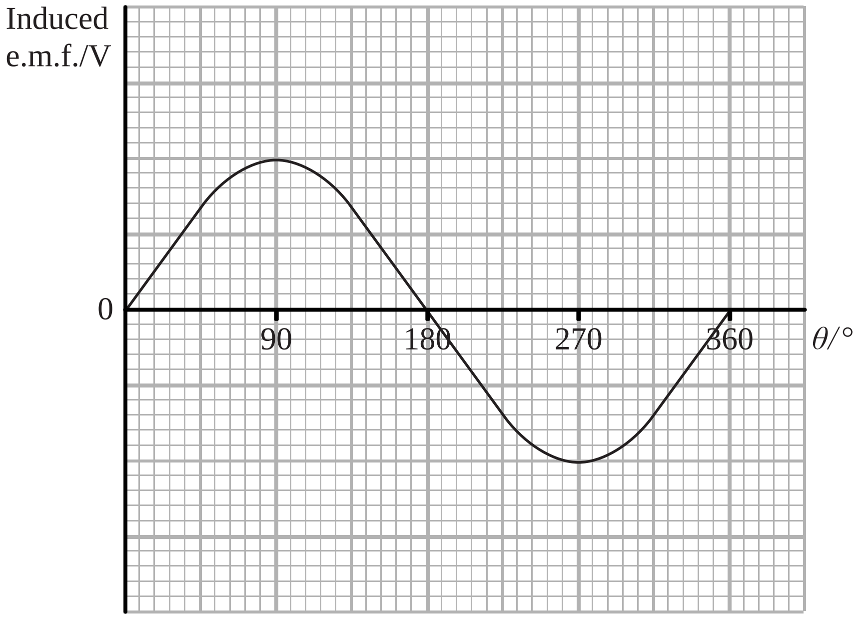
(ii) The graph shows how the induced e.m.f. varies over one cycle of rotation of the coil.



Explain why the magnitude of the e.m.f. is smallest and greatest at the values of θ shown in the graph.

(3)

(iii) State and explain how the graph would differ if the coil rotated at a slower rate.

(2)

(c) Vehicles such as electric cars are driven by electric motors. These vehicles use regenerative braking to reduce the speed of the vehicle. The motor is operated as a generator during braking and the output from the generator is used to recharge the batteries of the car.

(i) Explain how using the motor as a generator slows the car down.

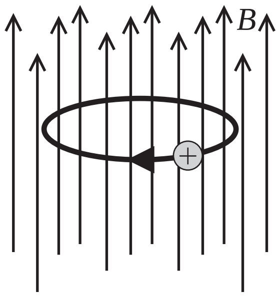
(2)

(ii) In practice, these vehicles also use friction braking as well as regenerative braking. This is because regenerative braking on its own will not fully stop a car. Suggest why.

(2)

(Total for Question = 14 marks)

3 A strong magnetic field of flux density B can be used to trap a positive ion by making it follow a circular orbit as shown.



(a) Explain how the magnetic field maintains the ion in a circular orbit. You may add to the diagram above if you wish.

(2)

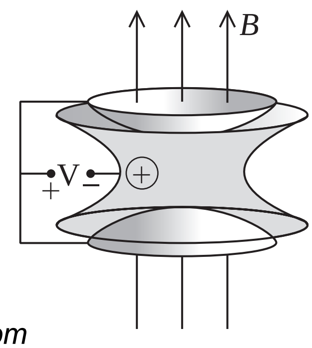
(b) Show that the mass m of the ion will be given by

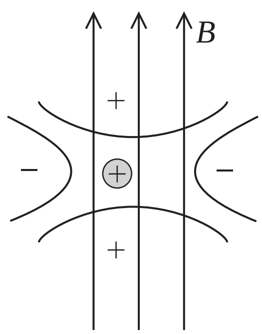
$$m \quad \frac{Bq}{2\pi f}$$

where q is the charge on the ion and f is the number of revolutions per second.

(3)

(c) The above arrangement will not prevent a positive ion from moving vertically. To do this, a weak electric field is applied using the arrangement shown below.





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(i) Explain how the electric field prevents the ion moving vertically.

(2)

(ii) This device is known as a Penning Trap. It can be used to determine the mass of an ion to an accuracy of 3 parts in 10 million.

Confirm that the mass of a sulphur ion can be measured to the nearest 0.00001u.

mass of sulphur ion = 32.0645u

(2)

(iii) Under certain conditions nuclei of sulphur emit a gamma ray with a known energy of 2.2 MeV.

Calculate the resulting loss in mass of a sulphur ion in u and confirm that this value could be determined by the Penning Trap technique.

(4)

(Total for Question = 13 marks)