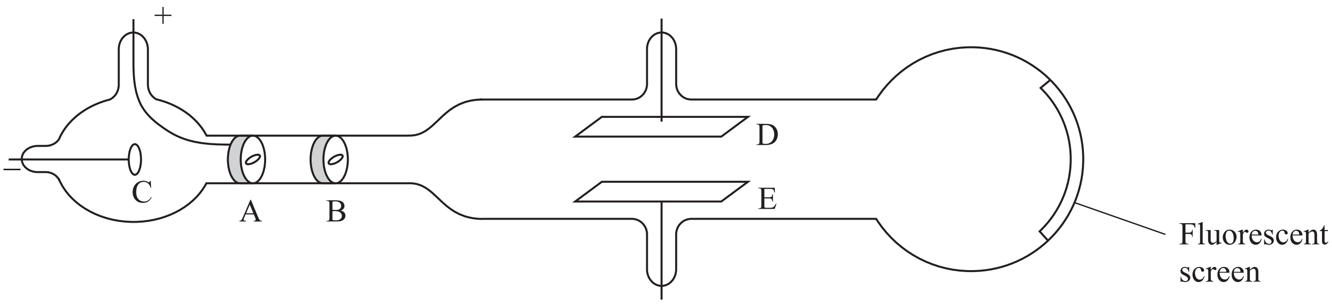
Electromagnetic Effects QP2

1 J J Thomson is credited with the discovery of the electron. He measured the 'charge to mass ratio' *e/m* for the electron, using the apparatus shown.



A metal disc at C emits electrons. A positively-charged disc at A accelerates the electrons along the tube. Slits in A and B produce a narrow horizontal beam of electrons. An electric field is produced between plates D and E, which can be used to deflect the beam vertically. The final position of the beam is shown on a fluorescent screen at the end of the tube.

(a) Describe how a metal disc can be made to emit electrons.

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(b) The length of plates D and E is l. Thomson deduced that the vertical component v_v of velocity gained by the electrons as they leave the plates is given by

$$v_v = \frac{Ee}{m} \times \frac{l}{v}$$

where E is the electric field strength between the plates and v is the velocity with which the electrons entered the field.

Show that this expression is correct.

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(c) Thomson determined the angle θ at which the beam was deflected.

Suggest how this angle could be determined.

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(d) The angle θ is also given by

$$\tan\theta = \frac{Ee}{m} \times \frac{l}{v^2}$$

Show that this equation is correct.

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(e) Thomson replaced the electric field with a uniform magnetic field which acted over the same length as the plates. He adjusted the flux density B to obtain the same deflection on the screen.

For this arrangement he assumed that the vertical component of velocity gained by the electrons as they leave the plates is given by

$$v_{\mathrm{v}} = \frac{Bev}{m} \times \frac{l}{v}$$

(i) Thomson just replaced the term eE in the equation in part (b) with Bev.

Suggest why he did this.

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(ii) Give **two** reasons why the equation $v_{\mathrm{v}} = \frac{Bev}{m} \times \frac{l}{v}$ is **not** correct.

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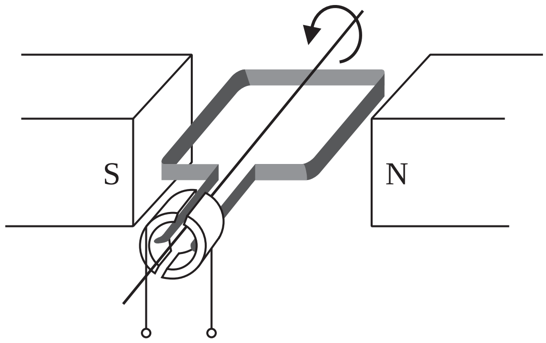
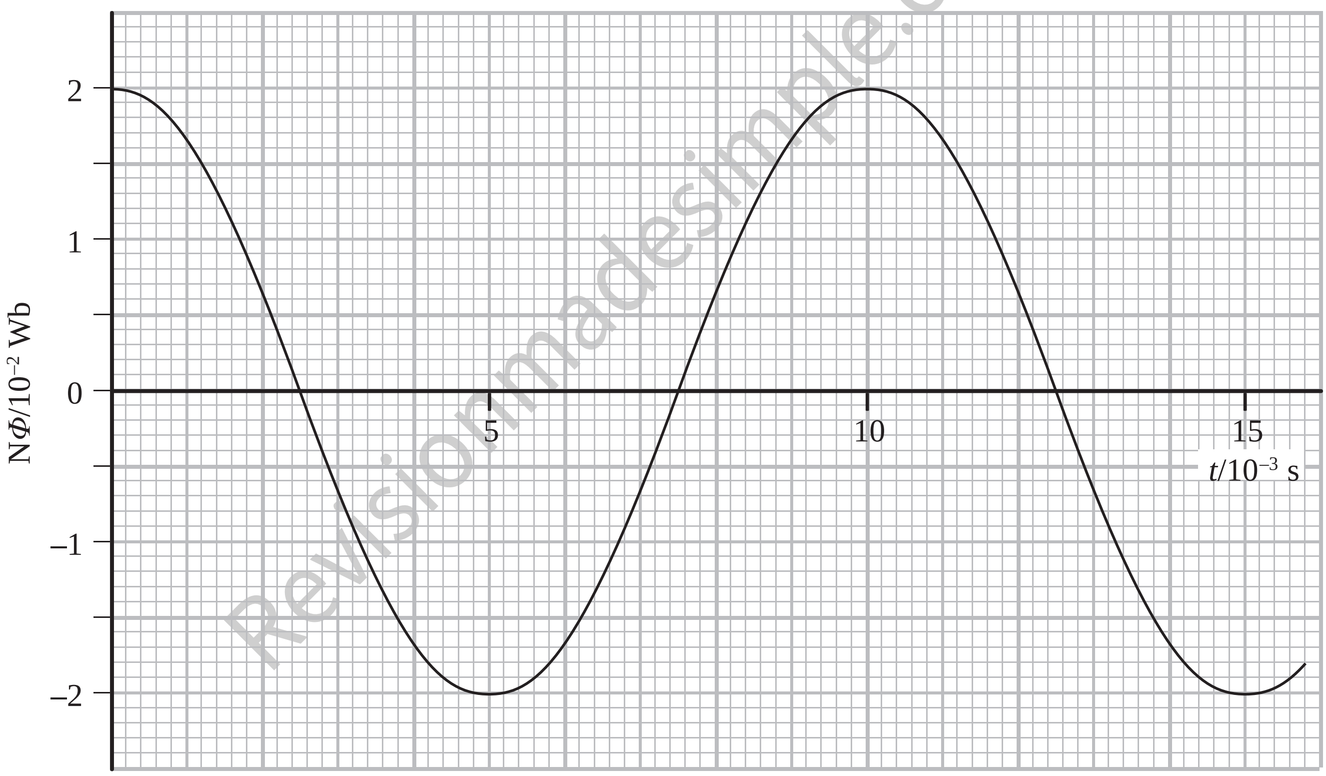
(Total for Question 1 = 13 marks)

2 The diagram shows a simple generator. It has a flat coil of negligible resistance which can be rotated in a magnetic field. The coil has 500 turns and an area of 2.5×10^{-3} m^2.



The graph shows the variation of the magnetic flux linkage $N\Phi$ with time t as the coil is rotated at a steady frequency in a uniform magnetic field.



(a) Determine the frequency of rotation of the coil.

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Frequency = ...

(b) Determine the magnetic flux density of the field.

(2)

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Magnetic flux density = ...

(c) Determine the maximum e.m.f. induced in the coil.

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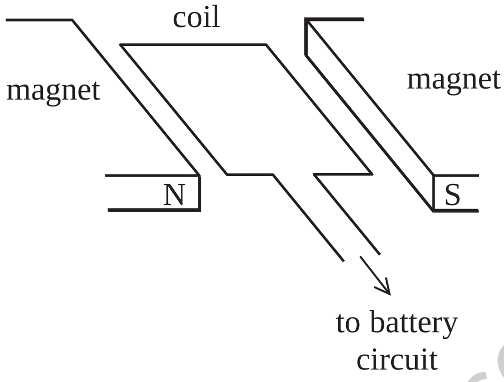
Maximum e.m.f. = ...

(Total for Question 2 = 7 marks)

3 Regenerative braking is used in electric cars. When the driver applies the brakes the motor acts as an electric generator, making use of the rotation of the wheels as they slow down. This enables the battery to be charged whilst the car is braking.

The diagram shows a coil in a magnetic field which when rotating can be used as an electric generator.



*(a) The coil rotates.

Explain how this produces a current in the coil.

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(b) State why the current produced in the coil cannot be used directly to charge a battery.

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(c) When regenerative braking is being used, explain how the magnitude of the generated e.m.f. changes as the driver brakes steadily.

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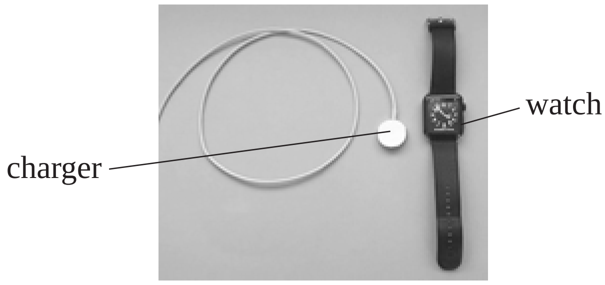
(Total for Question 3 = 7 marks)

4 Many electrical devices may be charged using induction chargers. The photograph shows a watch that is charged in this way and its charger.



Induction charging does not require a metal connection between the charger and the device. The battery in the watch is charged by placing the watch on top of the charger.

The charger contains a coil. When the charger is plugged into the electrical supply, there is a current in this coil.
The watch also contains a coil in a circuit that includes the battery.

*(a) Explain how this arrangement produces a current in the watch circuit.

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(b) To charge the battery, the watch circuit must contain a diode between the coil and the battery.

State why the diode is necessary.

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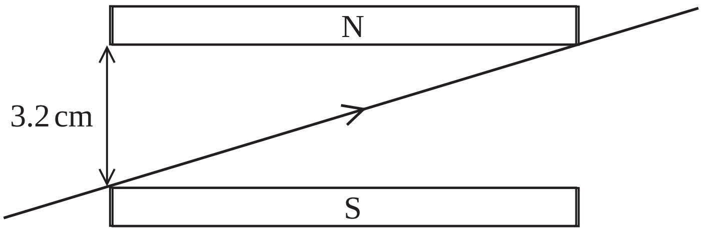
(Total for Question 4 = 5 marks)

5 A current-carrying wire is placed between the poles of a U-shaped magnet as shown in the diagram.



(a) Determine the magnitude of the force on the wire due to the magnetic field. You may assume the field is uniform.

current in wire = 820 mA
length of wire in field = 6.9 cm
magnetic flux density = 0.074 T

(3)

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Magnitude of force = ...

(b) Explain the direction of this force on the wire.

(2)

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(Total for Question 5 = 5 marks)