Questions on Electromagnetism

1. The dynamo torch, Figure 1, is operated by successive squeezes of the handle. These cause a permanent magnet to rotate within a fixed coil of wires, see Figure 2. Harder squeezes rotate the magnet faster.

Figure 1

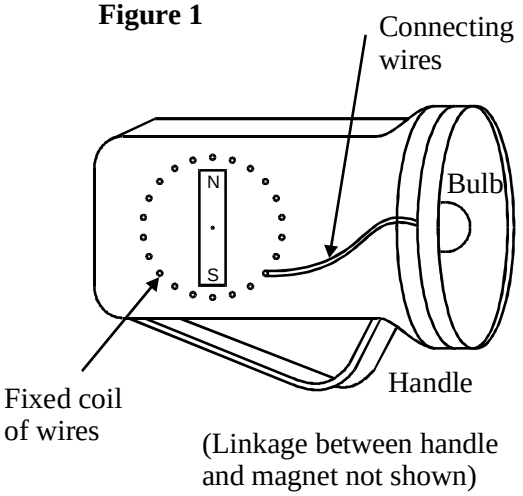
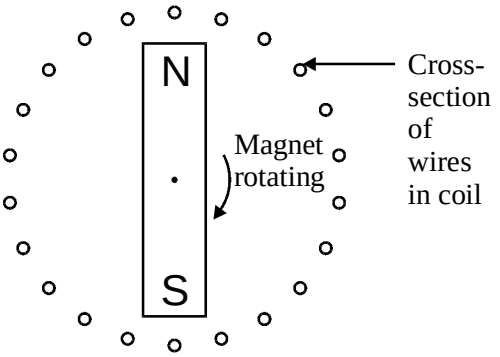


Figure 2



On Figure 2 sketch the field of the permanent magnet.

Discuss the physics of how the torch works and the factors which affect the brightness of the bulb.

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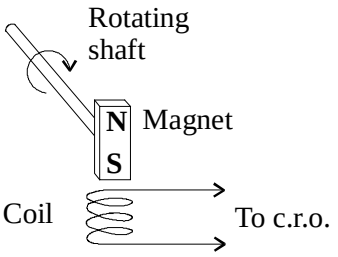
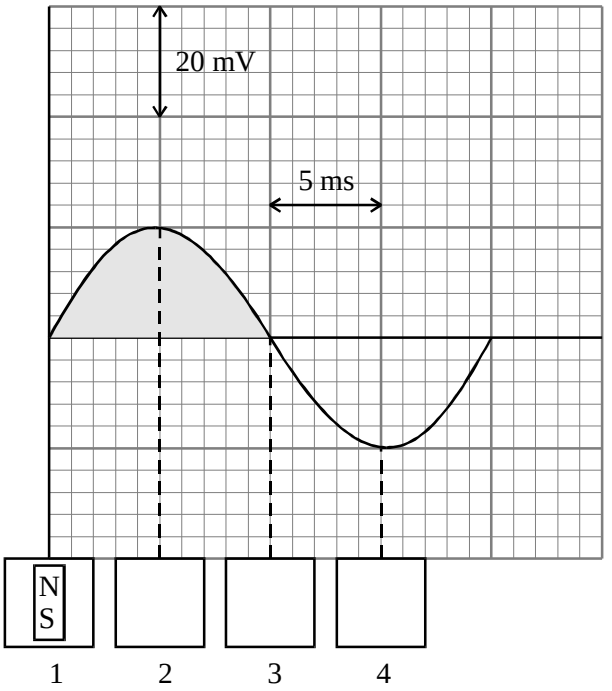
(Total 6 marks)

2. In order to monitor the performance of a motor, it is necessary to measure its rate of rotation. A simple sensor consists of a small bar magnet attached to the output shaft of the motor. A coil of wire is placed so that the magnet rotates close to it as shown below.



The voltage induced across the coil is displayed on a c.r.o. (cathode ray oscilloscope). The c.r.o. screen is shown below.

Figure i



Explain how the movement of the magnet produces the voltage shown. As part of your explanation, fill in the three empty boxes (2, 3 and 4) below figure (i) to show the corresponding positions of the magnet.

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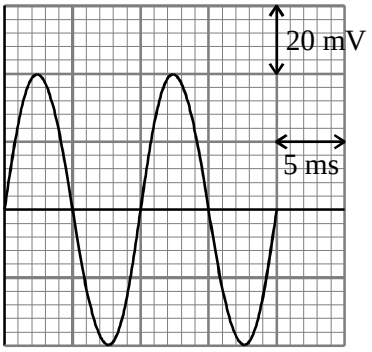
(4)

The rotation rate of the shaft is now doubled. The c.r.o. settings are not changed. This produces the c.r.o screen shown below.

Figure ii



Explain the differences between figure (i) and figure (ii).

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(3)

The shaded area in figure (i) is equal to

2 × (number of turns on coil) × (flux at one end of magnet)

The coil has 240 turns. Show that the flux at each end of the magnet is about 3×10^{-7} Wb.

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(3)

The dimensions of the end of the bar magnet are 1.0 cm × 0.5 cm. Calculate an approximate value for the magnetic flux density at the end of the bar magnet.

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Magnetic flux density = ...

(2)

(Total 12 marks)

3. The formulae list states:

In a magnetic field $F = Bq\upsilon \sin \theta$

Describe the situation to which this equation refers, stating the meaning of each symbol.

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(4)

The formulae list also gives an equation $r = p/BQ$.

Describe the situation modelled by this equation, stating the meaning of the symbol p.

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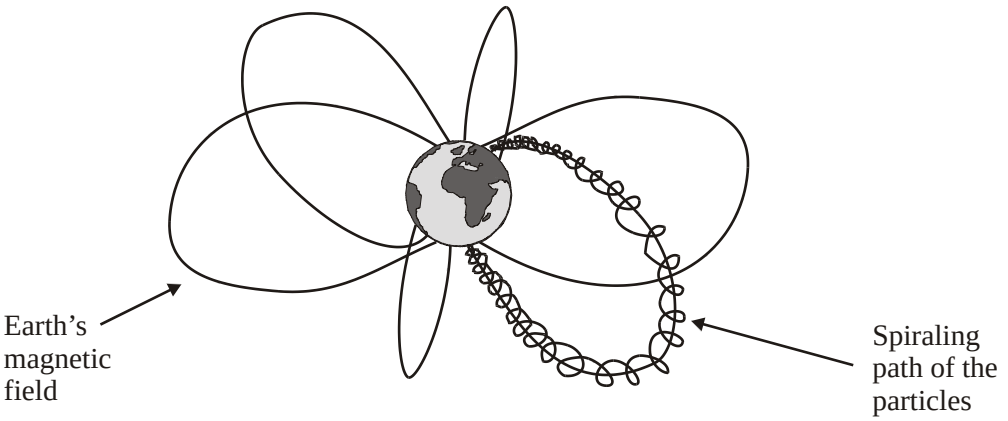
(2)

Particles arriving from the Sun can enter the Earth's magnetic field in such a way that they spiral along towards the North pole as shown in the diagram below. As they near the North pole they give rise to the beautiful Aurora Borealis, or Northern Lights.



Explain why the path of a particle is curved.

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(2)

Explain why the spiralling circular path of a particle decreases in radius as it nears the North Pole.

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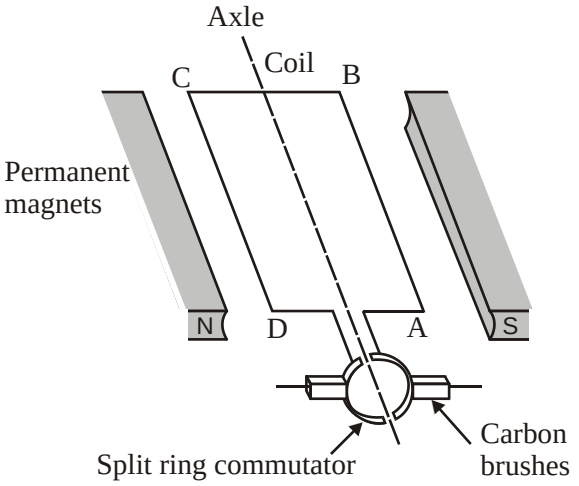
(2)
(Total 10 marks)

4. The diagram shows a device which may be used as either an electric generator or an electric motor.

Explain how the same device may be used for these two separate functions, and suggest one change which would improve its operation in either case.



Motor: .....

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Generator: .....

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Change: .....

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(Total 7 marks)

5. There have been several space missions experimenting with tethered satellites. In a 1992 mission, the tethered satellite was connected to the shuttle Atlantis by a long, conducting cable, the satellite being in the higher orbit. As the shuttle orbited through the Earth's magnetic field, an e.m.f. was induced in the conducting cable.

The shuttle, cable and satellite were all moving through the ionosphere, which contains many charmed particles. The charged particles were able to complete a circuit, allowing a current to flow through the cable. One result of this current was that the orbit height of the shuttle, cable and satellite gradually became less.

Explain

(a) the origin of the induced e.m.f.,

(b) the reduction in the orbit height due to the flow of current.

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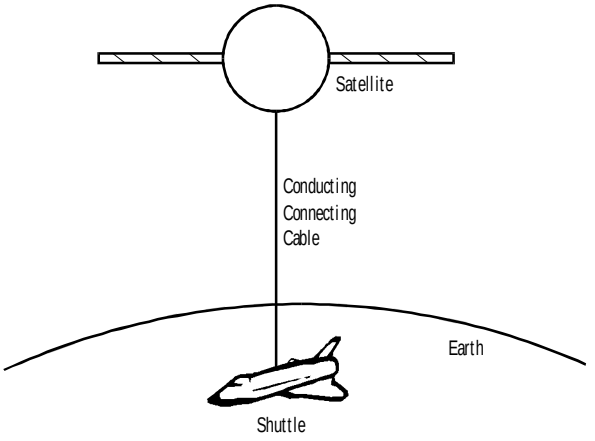
(Total 5 marks)

6. It should in principle be possible to generate useful electric power by moving a conductor through the Earth's magnetic field. In 1996 and 1992 there were (unsuccessful) attempts to do this using a satellite tethered to a space shuttle. The system consists of the satellite connected to the shuttle by a conducting cable which is insulated from the ionised gas through which it moves. (The attempts failed because the cable tangled and broke.)



Suppose a cable of length l moves with a speed v perpendicular to a magnetic field B. By considering the area swept out by the wire in a time Δt, write down an expression in terms of B, l and v, for the magnetic flux $\Delta\Phi$ cut by the cable in time Δt.

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(2)

Hence write an expression for the emf E induced across the ends of this cable.

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(1)

It was expected that the tethered cable would generate a maximum of 5000 V across its ends.

If the length of the cable was 20.7 km, and the component of the Earth's magnetic fluxdensity perpendicular to it was 3.2×10^{-5} T, calculate how fast the tether must have been moving.

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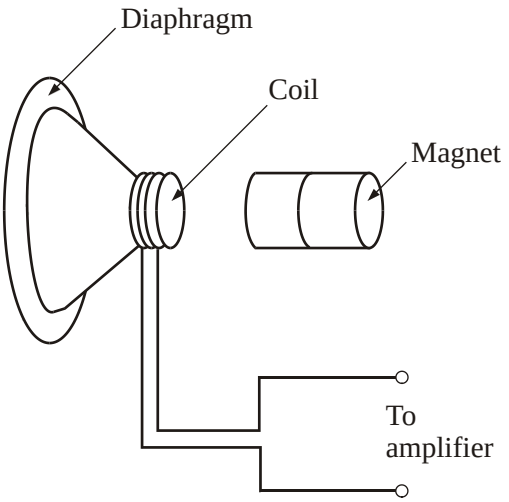
(2)
(Total 5 marks)

7. An induction microphone converts sound waves into electrical signals which can be amplified.



Describe the stages by which the sound waves are converted into electrical signals.
State whether the signals are a.c. or d.c.

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(6)

If the alternating output from a signal generator were fed into the microphone, describe and explain what would happen to the diaphragm.

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(3)
(Total 9 marks)

8. Explain the action of a step-down transformer. Your explanation should include reference to the parts played by the primary and secondary coils and the core of the transformer. You may be awarded a mark for the clarity of your answer.

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(Total 6 marks)

9. State Lenz's law of electromagnetic induction.

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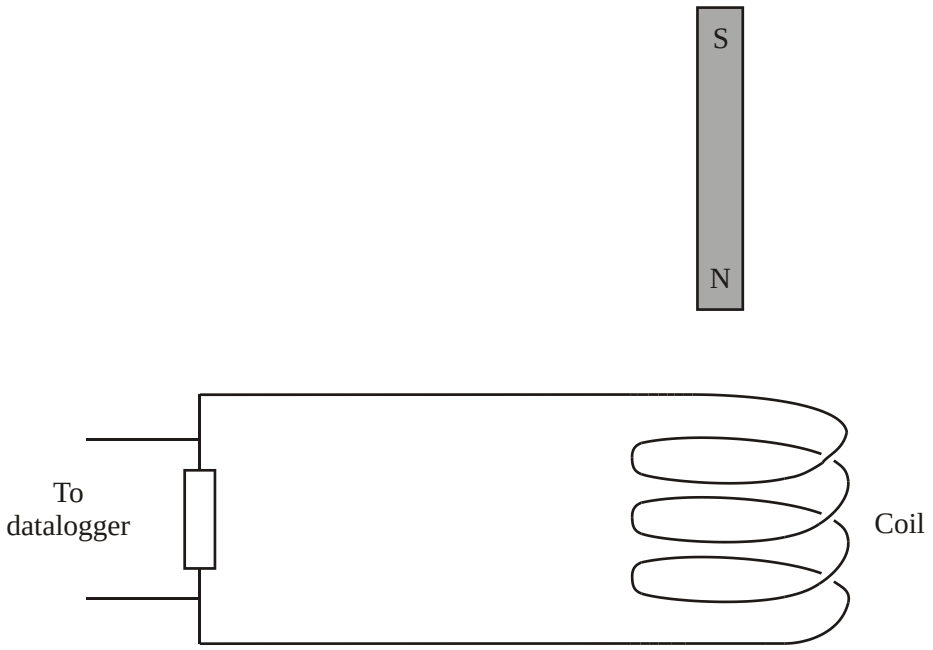
(2)

A bar magnet is dropped from rest through the centre of a coil of wire which is connected to a resistor and datalogger.



State the induced magnetic polarity on the top side of the coil as the magnet falls towards it.

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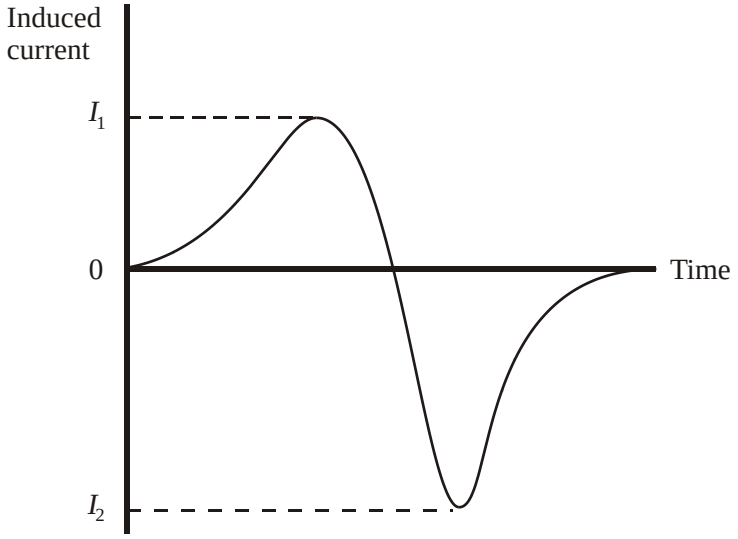
Add an arrow to the wire to show the direction of the induced current as the magnet falls towards the coil.

(2)

The graph shows the variation of induced current in the resistor with time as the magnet falls.



Explain why the magnitude of I_2 is greater than I_1.

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(2)

(Total 6 marks)

10. Explain the action of the transformer shown below. You may be awarded a mark for the clarity of your answer.

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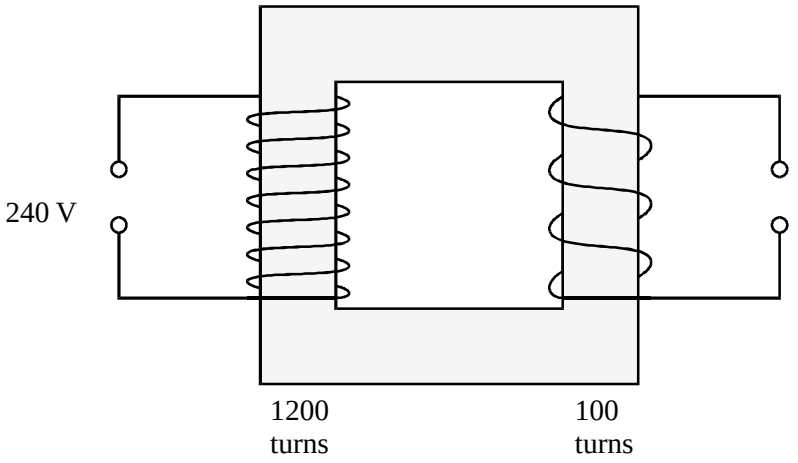
(5)

The following diagram shows an ideal step-down transformer.



The input voltage is 240 V. Calculate the output voltage of the transformer.

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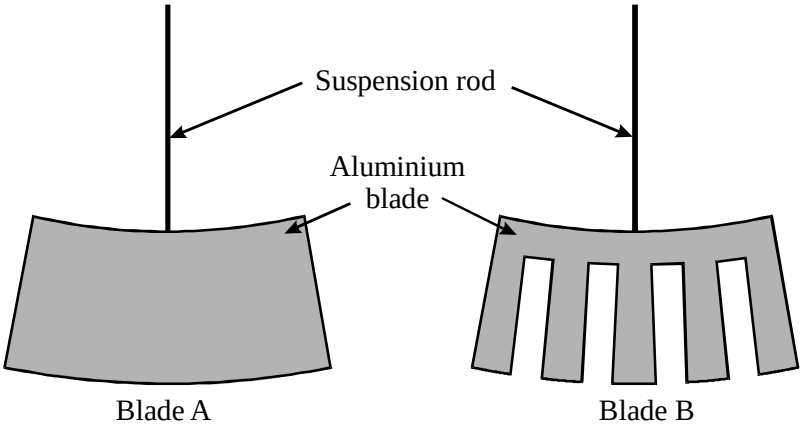
Output voltage = ...

(2)

(Total 7 marks)

11. The diagram shows two blades of aluminium. Blade A is complete. Blade B has been cut to form a comb.



Which electrical property of the blade is increased by cutting away the aluminium?

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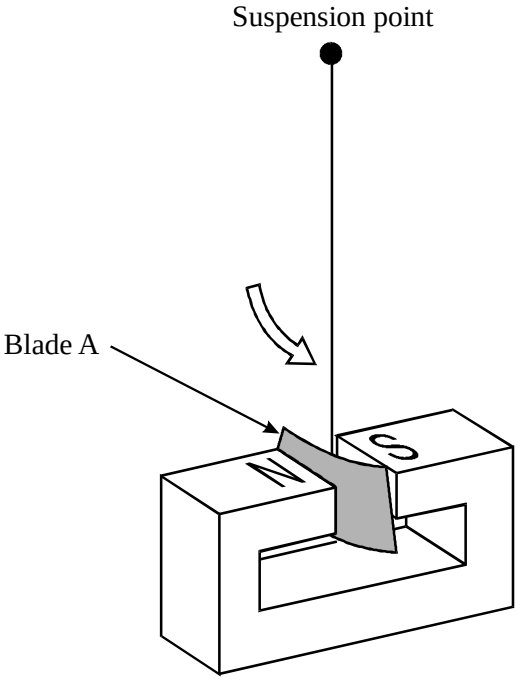
(1)

Each blade is suspended in turn between the poles of a strong permanent magnet.
Electromagnetic induction produces current loops in blade A as it swings between the poles.



Express Faraday's law of electromagnetic induction in words.

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(2)

The oscillations of blade A are rapidly damped. Explain why. You may be awarded a mark for the clarity of your answer.

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(4)

Suggest why the oscillations of blade B are only very lightly damped when it replaces blade A as the blade swinging between the poles.

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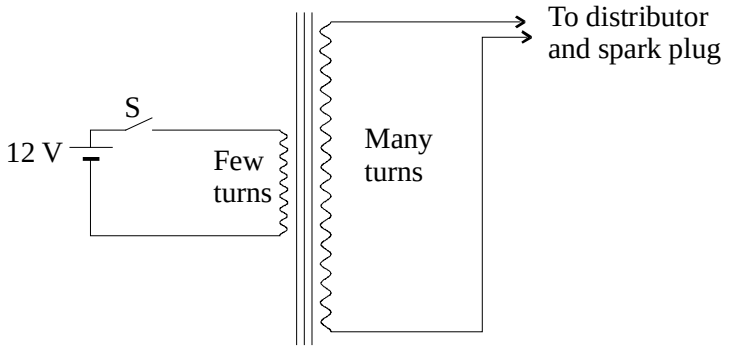
(1)
(Total 8 marks)

12. The ignition system in a car requires 25000 V to be applied to the spark plug to produce a spark in the combustion chamber. This voltage is produced from the car's 12 V d.c. electric supply by using a type of transformer usually called the "ignition coil". A circuit diagram of such a coil is shown below.



In order to generate a pulse of high voltage at the spark plug, the switch S must be closed for a short period and then opened quickly.

Use Faraday's law to explain why a large voltage is generated in the secondary circuit when the switch is opened.

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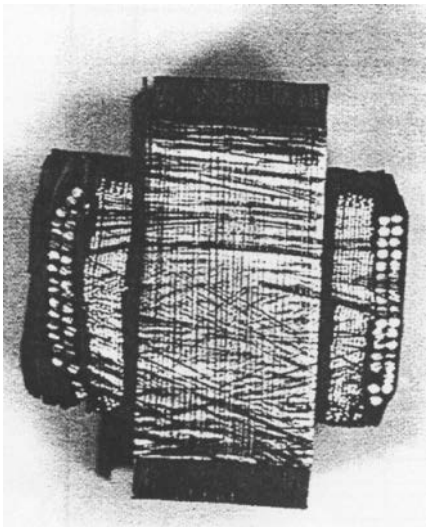
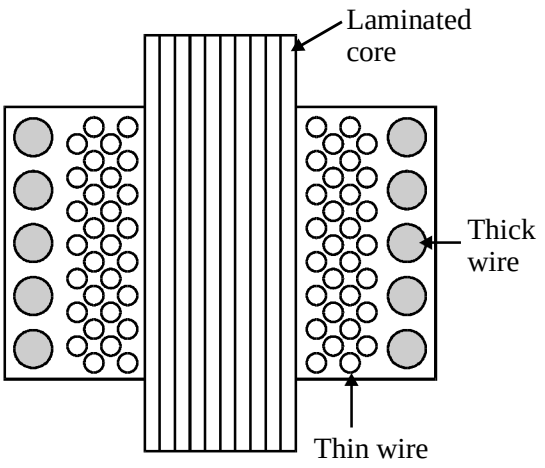
(Total 6 marks)

13. The photograph shows a transformer which has been cut in half. The transformer consists of primary and secondary coils wound around the same laminated iron core. The diagram shows a cross-section of the iron core and the two coils. One coil consists of a few turns of thick wire. The other coil has many turns of thinner wire.





Explain how an e.m.f. is induced in the secondary coil.

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(3)

The transformer in the photograph has one coil with 32 turns of thick wire. and the other with 512 turns of thin wire. Either coil can be the primary. with the other being the secondary. Describe the function of the transformer when the 512-turn coil is the primary.

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(2)

When in use, the 32-turn coil always carries the greater current. Explain why this is so.

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(2)

Explain why this coil is made with much thicker wire.

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(2)

Suggest a reason why the core is made of thin laminated sheets of soft iron.

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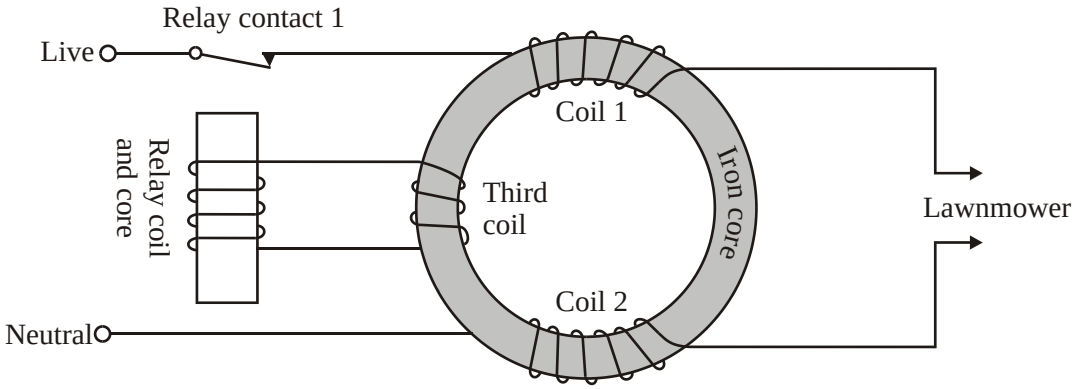
(3)

(Total 12 marks)

14. The diagram shows a device called a Residual Current Circuit Breaker (RCCB). It is designed to protect users of appliances connected to the mains a.c. power supply, e.g. an electric lawnmower.



Explain why, in normal operation, the resultant flux in the iron core due to coils 1 and 2 is zero.

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(2)

If there is a difference in the currents flowing in the live and neutral wires, for example caused by a person coming into contact with a bare wire, the RCCB breaks the circuit. Explain how.

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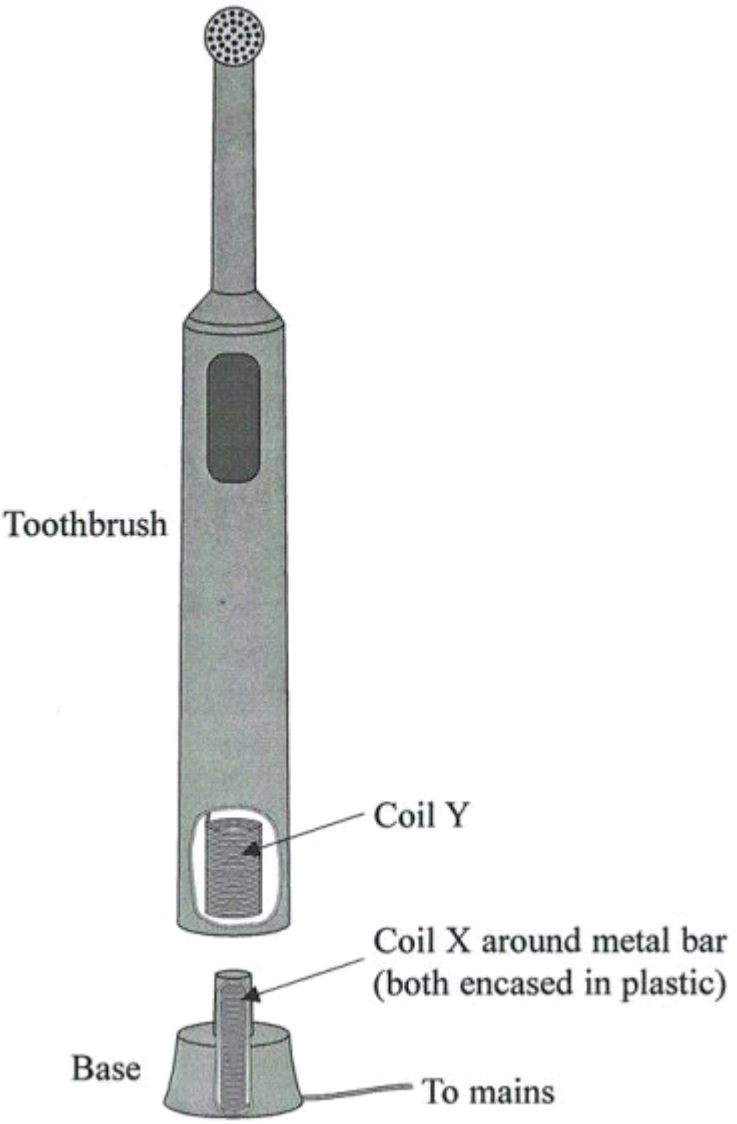
(5)
(Total 7 marks)

15. The diagram shows an electric toothbrush. An electric toothbrush recharges its batteries despite there being no metal contacts between the toothbrush and the base.



State a reason for avoiding metal contacts between the toothbrush and the base.

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(1)

The base, which is connected to an a.c. supply, contains a coil around a metal bar (coil X). The toothbrush contains a second coil (coil Y). When you put the toothbrush on to the base, coil Y goes around the bar and coil X without the two coils making contact.

Explain how this arrangement is able to charge the battery in the toothbrush.

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(6)
(Total 7 marks)