(ii) Use the graph of Fig. 3.2 to calculate the peak value of the e.m.f. across the ends of the coil.

peak e.m.f. = ... V [2]

20

This question is about the electron beam inside a television tube.

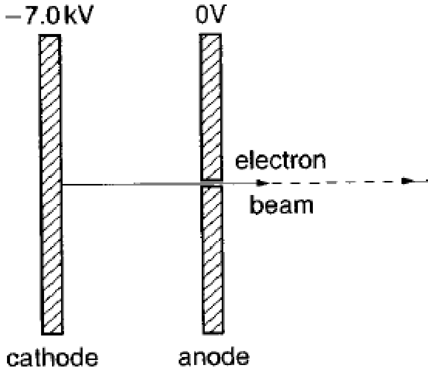

Fig. 5.1

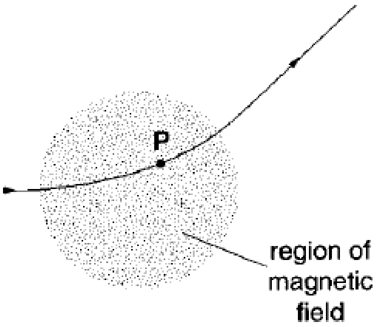

Fig. 5.2

(a) Fig. 5.1 shows a section through a simplified model of an electron gun in an evacuated TV tube.

(i) On Fig. 5.1 draw electric field lines to represent the field between the cathode and the anode. [2]

(ii) The electrons, emitted at negligible speed from the cathode, are accelerated through a p.d. of 7.0 kV. Show that the speed of the electrons at the anode is about $5.0 \times 10^7\,\mathrm{m\,s^{-1}}$.

[2]

(b) Some electrons pass through a small hole in the anode. They enter a region of uniform magnetic field shown by the shaded area in Fig. 5.2. They follow a circular arc in this region before continuing to the TV screen.

(i) Draw an arrow through the point labelled **P** to show the direction of the force on the electrons at this point. [1]

(ii) State the direction of the magnetic field in the shaded area. Explain how you arrived at your answer.

....

....

....[2]

(iii) Calculate the radius of the arc of the path of the electron beam when the value of the magnetic flux density is 3.0×10^{-3} T.

radius = ...m [4]

(c) The region of uniform magnetic field is created by the electric current in an arrangement of coils. Suggest how the end of the electron beam is swept up and down the TV screen.

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....[2]

[Total: 13]

21

This question is about a simple model of a hydrogen iodide molecule.
Fig. 3.1 shows a simple representation of the hydrogen iodide molecule. It consists of two ions, ${}^{1}_{1}H^{+}$ and ${}^{127}_{53}I^{-}$, held together by electric forces.

Fig. 3.1

(a) **(i)** Draw on Fig. 3.1 lines to represent the resultant electric field between the two ions. [2]

(ii) Calculate the electrical force F of attraction between the ions.
Treat the ions as point charges a distance 5.0×10^{-10} m apart. Each ion has a charge of magnitude 1.6×10^{-19} C.

F = ... N [4]

22

In this question, four marks are available for the quality of written communication.

(a) Faraday invented the concept of a field of force. Starting from the definitions of electric, gravitational and magnetic field strengths, discuss the similarities and differences between the three force fields.

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....[7]

(b) To explain the laws of electromagnetic induction (Faraday's law and Lenz's law) Faraday introduced the concept of magnetic flux. Describe how the flux model is used in these laws. Start by defining *magnetic flux* and *magnetic flux linkage*.

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....[5]

Quality of Written Communication [4]

[Total: 16]

23

A small conducting sphere is attached to the end of an insulating rod. It carries a charge of $+5.0 \times 10^{-9}$ C.

(a) Fig. 4.1 shows the sphere held at the midpoint between two parallel metal plates. The plates are uncharged. When the sphere was inserted, negative charges were induced on the parts of the plates closest to it.

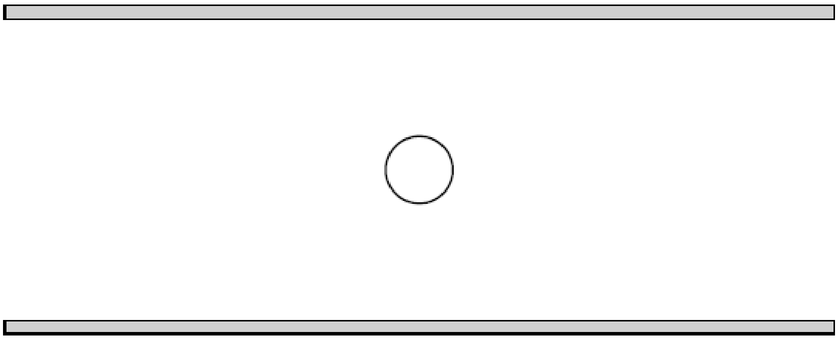

Fig. 4.1

Draw at least **six** electric field lines between the sphere and the plates. [3]

(b) The plates, which are 4.0 cm apart, are now connected to a 50 000 V supply.

Calculate

(i) the magnitude of the electric field strength E between the plates

E = ... N C^{-1} [2]

(ii) the magnitude F of the force on the sphere, treated as a point charge of $+5.0 \times 10^{-9}$ C.

F = ... N [2]

(c) Fig. 4.2 shows a second identically charged sphere attached to a top-pan balance by a vertical insulating rod. The original charged sphere is clamped vertically above the second sphere such that their centres are 4.0 cm apart.

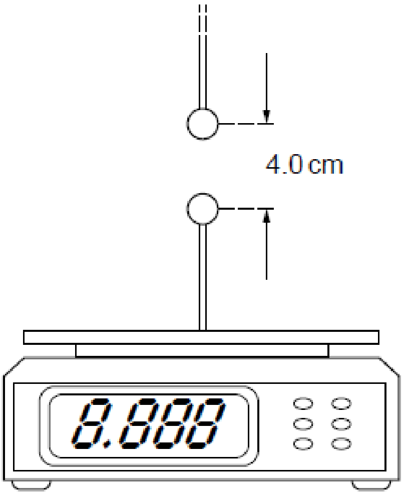

Fig. 4.2

(i) Show that the force between the two spheres acting as point charges is about 0.14 mN.

[3]

(ii) The balance can record masses to the nearest 0.001 g. The initial reading on the balance before the original charged sphere is clamped above the second sphere is 8.205 g. Calculate the final reading on the balance.

final reading = ... g [2]

[Total: 12]

24

Fig. 5.1 shows a horizontal copper wire placed between the opposite poles of a permanent magnet. The wire is in a state of tension and is clamped at each end. The length of the wire in the field of flux density 0.032 T is 6.0 cm.

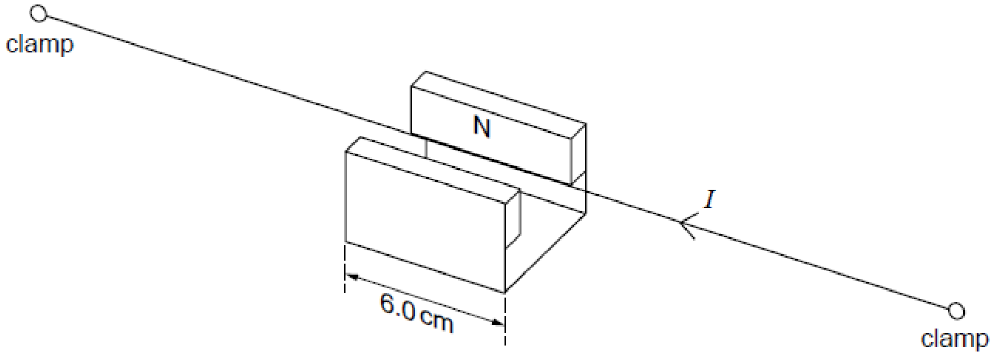

Fig. 5.1

(a) A direct current I is passed through the wire.

(i) On Fig. 5.1 draw and label an arrow **F** to indicate the direction of the force on the wire. [1]

(ii) Calculate the magnitude F of the force when I = 2.5 A.

F = ... N [2]

(b) The direct current is changed to an alternating current of constant amplitude and variable frequency, causing the wire to oscillate. Fig. 5.2 shows how the acceleration of the wire at the centre point between the poles varies with time when the frequency of the current is at the fundamental natural frequency of the wire.

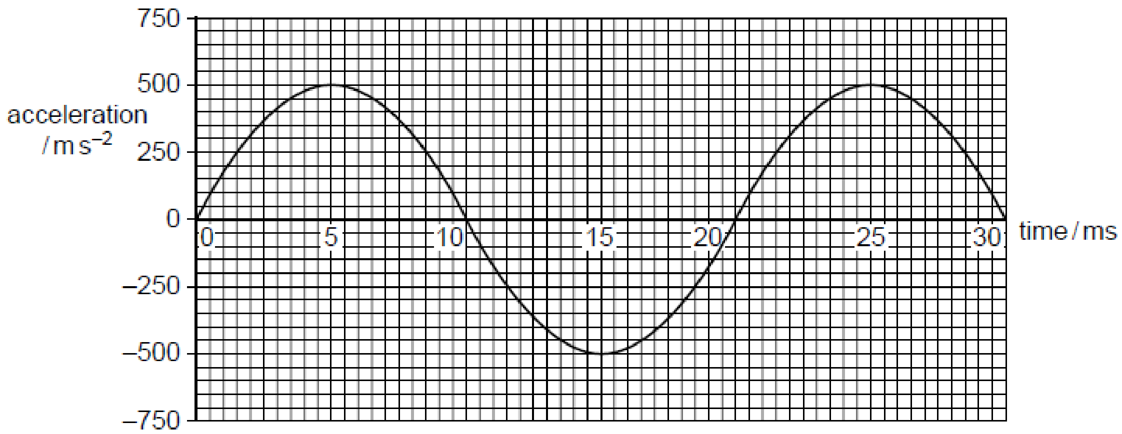

Fig. 5.2

(i) Calculate the frequency of the alternating current.

frequency = ... Hz [2]

(ii) Explain whether the maximum acceleration of all points on the wire between the poles is the same or not. A sketch may help your answer.

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....[3]

25

A spark plug is the device in a petrol engine which ignites the fuel-air mixture, causing an explosion in the cylinder.

(a) A potential difference of 40 kV is needed across a gap of 0.60 mm to produce the spark which ignites the fuel vapour. Calculate the magnitude of the electric field strength in the spark gap just before the spark.

electric field strength = ... unit .... [3]

(b) The electrical supply in a motor car is 12 V. To achieve 40 kV, two coils are wound on the same iron core, shown schematically in Fig. 5.1. The secondary coil is in series with the spark gap. The primary coil is in series with the battery and a switch.

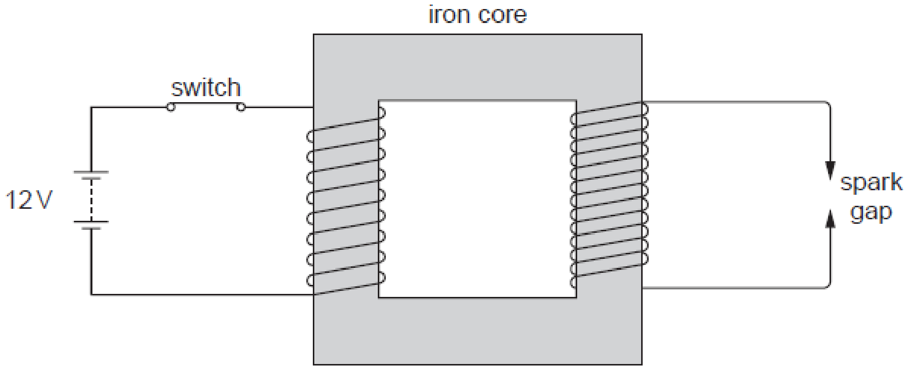

Fig. 5.1

(i) Draw on Fig. 5.1 the complete paths of **two** lines of magnetic flux linked with the current in the primary coil. [2]

(ii) The magnetic flux through both coils is the same but the magnetic flux linkage is not. Explain why.

....

....

....

....[2]

(iii) Explain why a potential difference is produced across the spark gap as the switch is opened.

....

....[1]

(iv) Explain how each of the following factors influences the size of the potential difference across the spark gap:

1 the rate of collapse of the magnetic flux

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....[2]

2 the ratio of the number of turns between the primary and secondary coils.

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....[2]

[Total: 12]

26

This question is about changing the motion of a beam of electrons travelling in a vacuum. Fig. 4.1 shows a simple device for accelerating or decelerating electrons. It consists of two parallel conducting plates, labelled **P** and **Q**, each with a hole at its centre.

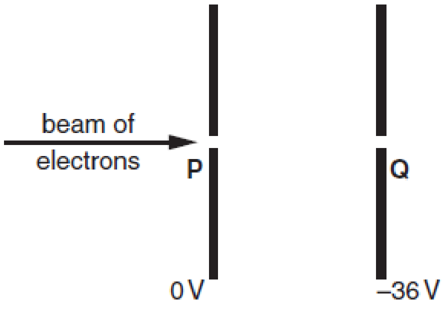

Fig. 4.1

(a) On Fig. 4.1 draw at least **six** arrowed lines to represent the electric field between the plates. **[2]**

(b) The electrons, all travelling at $4.0 \times 10^6\,\text{m s}^{-1}$, pass through the holes in **P** and **Q**. The plates, a distance of 8.0 mm apart, are maintained at 0 V and –36 V as shown in Fig. 4.1.

Calculate

(i) the electric field strength E between the plates

E = ... N C^{-1} **[1]**

(ii) the magnitude F of the force on an electron when between the plates

F = ... N **[1]**

(iii) the loss of kinetic energy $\Delta\varepsilon$ of each electron between **P** and **Q**

$\Delta\varepsilon$ = ... J **[1]**

(iv) the decrease in velocity Δv of each electron between **P** and **Q**.

Δv = ... m s^{-1} **[3]**

(c) The plates are rotated through 90°. Fig. 4.2 shows the same beam of electrons, travelling at $4.0 \times 10^6\,m\,s^{-1}$, entering the region between the plates, but now parallel to the plates. A uniform magnetic field is applied into the paper in the region between the plates.

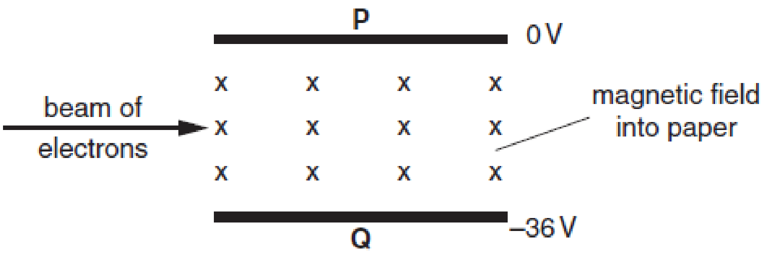

Fig. 4.2

(i) State the direction in which the force due to the magnetic field acts on the electrons as they enter the field.

....

.... **[1]**

(ii) Explain why, by adjusting the strength of the magnetic field, the electrons can pass undeflected between the plates.

....

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....

.... **[2]**

(iii) Calculate the magnitude B of the magnetic field density needed for these electrons to pass undeflected between the plates. Give a unit with your answer.

B = ... unit .... **[4]**

[Total: 15]

27

Fig. 5.1 shows a soft iron ring of variable circular cross-section. It has four coils containing 2, 3, 4 and 5 turns wound around it. The cross-sectional area of the ring is different for each coil.

A d.c. supply is connected across the coil with three turns.

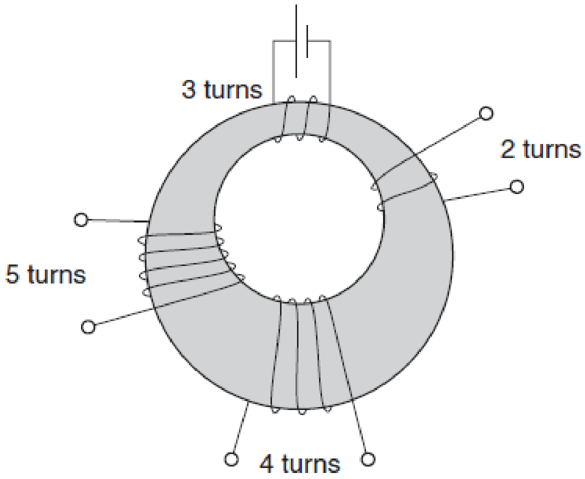

Fig. 5.1

(a) Draw on Fig. 5.1 the complete paths of **two** lines of magnetic flux produced by the three-turn coil when there is a current in it. **[2]**

(b) **(i)** Explain how *magnetic flux density* is related to *magnetic flux*.

....

....

....

.... **[2]**

(ii) State which **one** of the following three quantities,

magnetic flux   magnetic flux density   magnetic flux linkage

is most nearly the same for all four coils in Fig. 5.1. Give a reason for your answer.

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.... **[2]**

(iii) Write down **one** of the **other** two quantities in **(ii)** above. State in which coil this quantity has the largest value. Give a reason for your answer.

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.... **[2]**

(iv) Write down the remaining quantity from **(ii)** above. State in which coil this quantity has the largest value. Give a reason for your answer.

....

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.... **[2]**

(c) Faraday's law applies to situations where the magnetic flux through a circuit is changing. Use this law to explain why the iron core in Fig. 5.1 heats up when an alternating current is supplied to the three-turn coil instead of a direct current.

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.... **[3]**

[Total: 13]

28

This question is about forcing a liquid metal, such as molten sodium, through a tube using a magnetic field.

The liquid metal is in a tube of square cross-section, side of length *w*, made of electrically insulating material. Two electrodes, shaded on Fig. 5.1, are mounted on opposite sides of the tube and a magnetic field of flux density *B* fills the region between the electrodes. An electric current *I* passes across the tube between the electrodes, perpendicular to the magnetic field. The interaction between the current and the field provides the force to move the liquid.

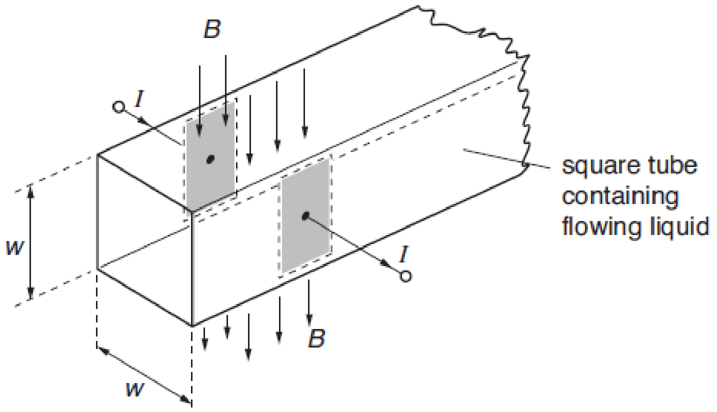

Fig. 5.1

(a) **(i)** Draw on Fig. 5.1 an arrow labelled **F** to indicate the direction of the force on the liquid metal. State the rule that enables you to determine the direction.

....

.... **[2]**

(ii) State a relationship for the force *F* in terms of the current *I*, the magnetic field *B* and the width *w* of the tube.

.... **[1]**

(iii) Data for this device are shown below.

$B = 0.15\,\text{T}$
$I = 800\,\text{A}$
$w = 25\,\text{mm}$

Calculate the force on the metal in the tube.

force = ... N **[2]**