Magnetic Fields 2

Exercise A

1.

Show that the units of magnetic flux density, usually T (tesla), can be written as N s C^{-1} m^{-1}.

2.

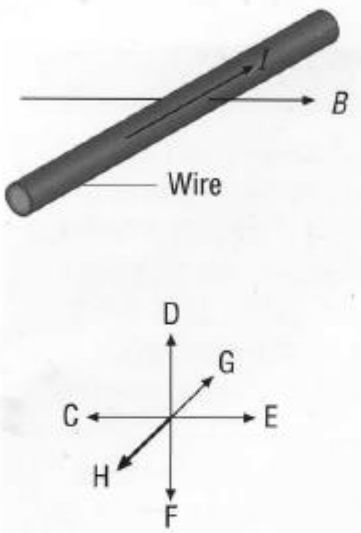


Figure 4

Figure 4 shows the directions of the current I in a short section of wire and the magnetic flux density B at the wire.

(a) The current is in the direction H–G. In which direction is the force on the wire?

(b) The free electrons are drifting in the direction G–H. In which direction is the average force on them?

(c) The wire carries a current of 0.24 A. The length of wire in the magnetic field is 60 mm. The magnetic flux density B is 30 mT. Calculate the force on the wire.

(d) Through what angle must the wire be rotated and in which plane to reduce the force on the wire to **(i)** half the value in (c) and **(ii)** zero?

3.

In a particle accelerator, protons are accelerated from rest in a vacuum by a potential difference (p.d.) V and then directed at right angles into a magnetic field of flux density 0.039 T. They travel in a semicircle that must have a radius less than 0.63 m if they are to remain within the magnetic field.

(a) What is the maximum value of V that can be used to satisfy this condition?

(b) How long does a proton take to complete a semicircle of the maximum allowed radius?

Exercise B

1 Here are three possible paths of an electron in a vacuum: A straight line, B circular path, C parabolic path. Which path best describes the motion of an electron initially moving:

(a) at right angles to a magnetic field, **(b)** at right angles to an electric field and **(c)** parallel to a magnetic field?

2 (a) Calculate the magnitude of the force on an electron moving at 2.0×10^7 m s^{-1} as it enters a region of uniform magnetic field of flux density 5.0×10^{-3} T perpendicular to its path.

(b) Calculate the acceleration of the electron and hence the radius of its orbit in the field.

3 Figure 5 shows a beam of protons passing through a hole into a region where there is a uniform electric field of strength E.

(a) Copy the diagram and sketch on it a possible path for the protons.

(b) A uniform magnetic field of flux density B is now applied at right angles (into the plane of the diagram), and the electric field is switched off. Sketch a possible path for the protons.

(c) The electric field is switched on again. Explain why it is now possible for some of the protons to pass undeflected to the detector.

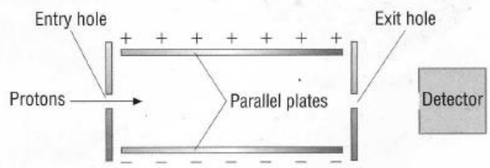


Figure 5

4 The fuel in nuclear fission reactors to generate electricity is $^{235}_{92}U$. In natural uranium over 99% is $^{238}_{92}U$ and only 0.7% is $^{235}_{92}U$. In one 'separation process', each atom of natural uranium is combined with six atoms of fluorine to make the molecule UF_6. The molecules are ionised and, using a velocity selector, made into a beam of particles each with the same velocity.

(a) Explain why the UF_6 ions of $^{238}_{92}U$ have more momentum than those of $^{235}_{92}U$.

(b) The ion beam passes through a region of uniform magnetic field directed at right angles to their velocity as shown in Figure 6 before being collected in a trap.
The figure shows the path of the UF_6 ions of $^{235}_{92}U$. Copy the diagram and add the path of the UF_6 ions of $^{238}_{92}U$.

(c) Hence explain how this device works as a separator. Why would UF_6 ions of $^{238}_{92}U$ reach the collector if the apparatus was not kept under a good vacuum?

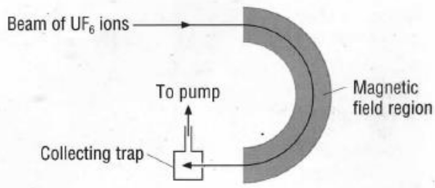


Figure 6

Exercise C

1 A large ion of mass 5.8×10^9 u and charge $+18e$ is accelerated constantly towards a detector by a potential difference of 870 V. Assuming the ion starts from rest, calculate the time taken for the ion to travel 47 cm to the detector.

2 Figure 2 shows a Bainbridge mass spectrometer.
The beam consists of singly ionised neon-20 atoms all travelling at the same speed, 3.0×10^5 m s^{-1}, through a vacuum. As the beam passes through the magnetic field it follows a circular path of radius 0.125 m.

(a) Explain why the path is a semicircle.

(b) Show that the force on each ion of mass 3.32×10^{-26} kg is 2.4×10^{-14} N. In which direction is this force?

(c) Calculate the magnetic field strength or flux density in teslas.

(d) Suggest where the detector should be positioned to detect ions of neon-22 travelling with the same speed. Explain your decision.

(Figure 2 is on the next page.)

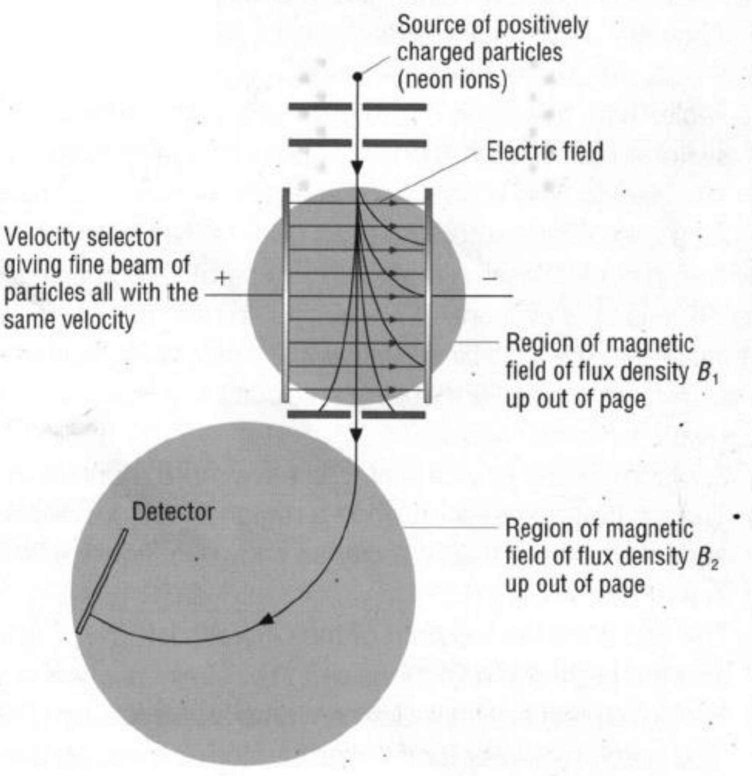


Figure 2 A Bainbridge mass spectrometer

3.

The spectrometer of Figure 4 is used to collect the nuclides $^{238}_{92}U$ and $^{206}_{82}Pb$ from a small sample of rock to date it.

(a) Singly ionised nuclei of the two nuclides from the sample of rock pass through the hole in the 200 V electrode with negligible velocity. They are accelerated towards the electrode at 0 V. Show that the momentum gained by an ion of $^{206}_{82}Pb$, mass 3.5×10^{-25} kg, is about 5×10^{-21} N s.

(b) Calculate the radius of the circular path of the lead ion when within the uniform region of magnetic field of flux density 0.12 T.

(c) The lead and uranium ions have the same charge and kinetic energy when they enter the magnetic field, yet the uranium ions follow a path of greater radius. Explain why this is.

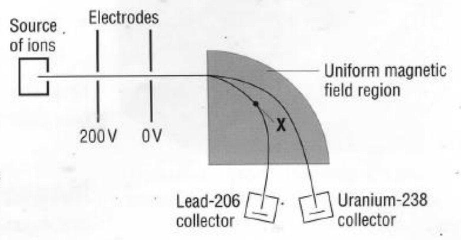
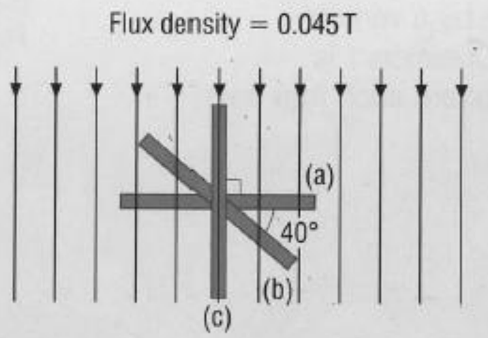


Figure 4

4.

A rectangular coil of 400 turns of wire has length 8.9 cm and width 6.4 cm. It rotates in a magnetic field of flux density 0.045 T. Calculate the flux through the coil and the flux linkage when the plane of the coil is **(a)** at right angles to the field, **(b)** has moved through an angle of 40° and **(c)** has moved through 90° so that it is parallel to the field, as shown in Figure 4.



Coil shown in three positions, (a), (b) and (c)

Figure 4 Rectangular coil

5.

A long coil or solenoid wound on an iron rod has 300 turns of cross-sectional area 4.0×10^{-5} m^2. When it carries a certain current the flux linkage of the coil is 6.0×10^{-4} Wb turns.

(a) Calculate **(i)** the flux linking one turn of the coil and **(ii)** the flux density in the iron rod.

(b) Why is it not possible to answer this question when the coil is wound on a wooden dowel?