On magnetic forces

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Warm-up problems

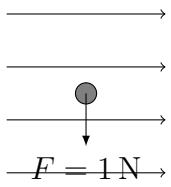
1. Describe in your own words what a field is in physics, and give 3 examples of physical fields.

2. Explain in what circumstances a force is felt by a *particle* in each kind of field from the previous question, and show how the size of the force can be worked out.

3. Draw a diagram to show Fleming's left hand rule to determine the direction of the force on (a) a current carrying wire and (b) an electron, making it clear what each digit (fingers and thumb) represents. What factors might increase the force in each case?

Regular problems

4. In the following diagram, a uniform magnetic field of strength 2.5 T is directed toward the right, and a wire of length 10 cm lies perpendicular to the plane of the paper (shown in cross section) carrying electric current. The force on the wire is also shown, and has magnitude 1 N. What is the size and direction of the current?



5. Show that the overall force on a current carrying wire arises owing to tiny forces on each of the individual charge carriers, drawing a diagram and making clear what assumptions you use.

6. (a) What is the equation that gives the force F on an electron of charge e that enters perpendicularly a uniform magnetic field of magnetic flux density B at a velocity v?
   (b) What is the equation that gives the centripetal force F on a particle of mass m moving in a circle of radius r with a velocity v?
   (c) By equating these two, derive an equation that gives the radius of an electron's orbit in a magnetic field.
   (d) Show that the time taken for one orbit is

$$T = \frac{2\pi m}{Be}$$

(e) If the speed of the electron changed to $2v$, what effect, if any, would this have on

i. the orbital radius,

ii. the orbital period?

7. Describe the paths of

(a) a neutron,

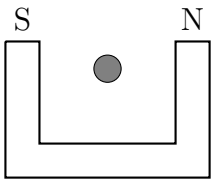
(b) a proton, and

(c) an α particle,

when each is directed at right angles to the same magnetic field and at the same velocity, stating quantitatively, where appropriate, any differences.

Extension problems

8. The diagram shows a horseshoe magnet with its north and south poles marked. Between the poles is the cross section of a wire which is 5 cm long.



When no current flows, the balance reads 272.0 g. When a current of 2 A flows, the reading on the balance is 274.0 g. Calculate the magnetic flux density between the poles of the magnet.

9. A beam of protons is aimed at a speed of $3.7 \times 10^6\,\mathrm{m\,s^{-1}}$ into a metal cylinder of length 10 cm and radius 5 cm via a hole in its flat end face 3.0 cm from its center. Within the cylinder there is a uniform magnetic field of 0.8 T which is directed perpendicular to the flat faces and the protons are aimed such that their path stays at a constant distance of 3.0 cm from the line of symmetry joining the centres of the flat faces.

(a) What is the angle θ between the path of the protons as they enter the cylinder and the flat surface of the cylinder?

(b) Where exactly do the protons hit the side of the can?