

Electrons and Magnets

The fundamental equation governing the movement of charges in a magnetic field is

$$\mathbf{F} = q\mathbf{v} \times \mathbf{B}$$

Where \mathbf{F} is the force experienced by a charge q , travelling at velocity \mathbf{v} through a magnetic field \mathbf{B} . If we ignore the direction, the *magnitude* of the force is

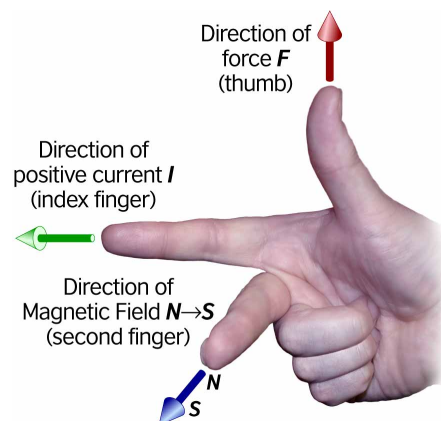
$$F = qvB\sin\theta,$$

where θ is the angle between the direction of charge and the magnetic field.

Question 1: For what angle θ would the force on the charges be zero? (This is important for later.)

For this experiment, you only need to be able to work out the *direction* of the force on a charge, using the *right-hand* rule, shown opposite. Note that your index finger here is pointing in the direction of a positive charge. (For a beam of negative charges you should point in the opposite direction to the beam.) Your middle finger points in the magnetic field direction N→S.

(Actually, you can use the *left-hand* version of this rule, the only difference being that the index finger points in the direction of the *electron* current, which is more intuitive. The thumb and second finger have the same meaning as they do opposite.)



A standard CRT¹ monitor image is generated when a beam of electrons is directed onto a phosphorescent screen, the strength of the beam being directly related to the brightness of the image elements. The beam is guided over the picture area by pairs of deflecting magnets, both in the horizontal and vertical planes.

You can cause additional deflections to the beam (and hence distort the image) by bringing a suitably powerful magnet up to the monitor.

NOTE: *Never* do this with a television (and *especially* not with a colour TV): it will permanently distort the image...

Continued...

¹ It's increasingly the case (2006) that people will not have come across a cathode ray tube TV set! (And this experiment doesn't work for LCD or Plasma screens...)

Experiments

For the rest of this worksheet you'll be carrying out some basic experiments (using the magnets provided and the TV monitor) in two stages. First, you will be *theoreticians*: using your knowledge of the rules above, the nature of the TV tube, and the shape of the magnets, you will *calculate* what you expect to see when you carry out certain actions. Only then will you shift into the mode of *experimenters*, carrying out an experiment, and comparing the results with your theoretical predictions.

Task #1

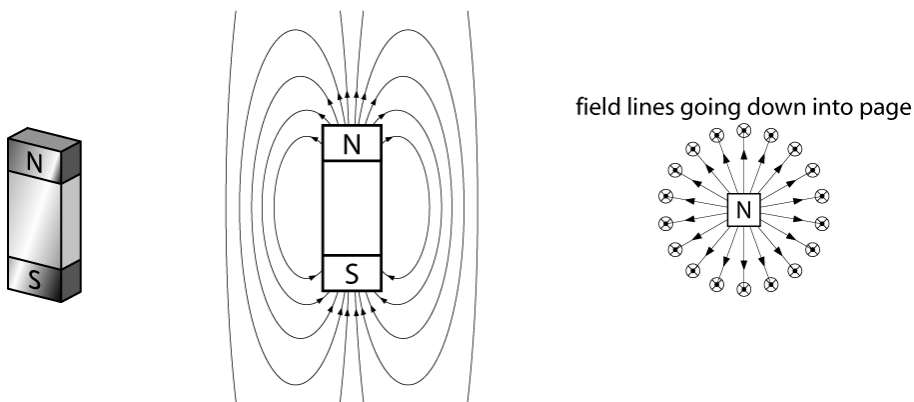
Theoretical analysis:

Knowing how the electron beam moves in the tube, and knowing (or assuming!) that the poles of the bar magnet are at either end of the bar, use the right- (or left-) hand rule to predict what would happen if you brought the North pole up to, say, the left side of the TV (looking from the front).

Prediction:

Experiment:

Take the bar magnet provided, and work out which of its ends is the North pole, using the monitor, and the rule given above. Check with the demonstrator, to see if you are correct. (The diagram below shows the standard magnetic field lines around a bar magnet, going from the North to the South poles.)



Did the result agree with your prediction? If not, why not?

Supplementary question:

If a compass needle's North points North, what does that say about the North magnetic pole at the North pole?

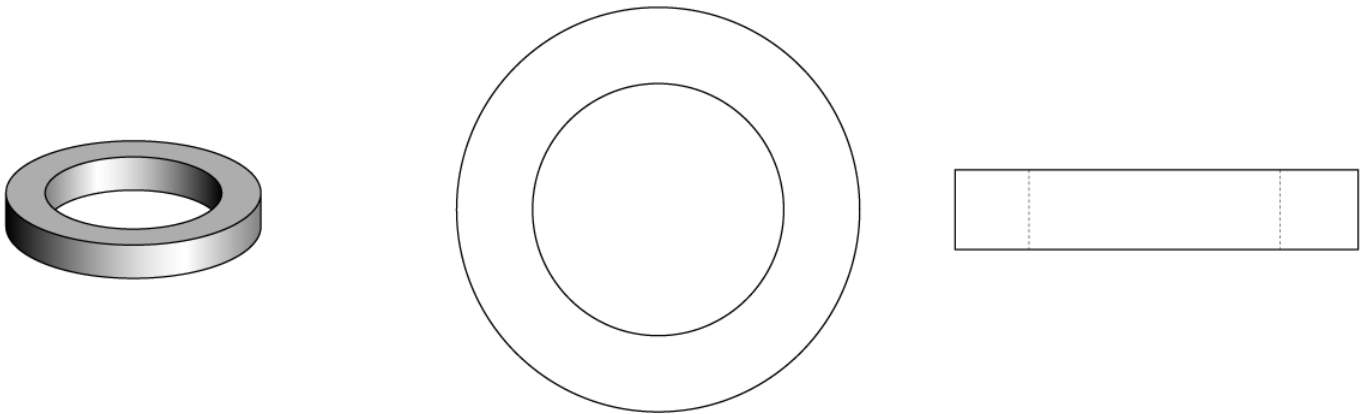
Task #2: the Toroidal Magnet

What do you think will happen if you place the magnet flat onto the front of the monitor screen? *Don't do it yet*; read the section below, and see if you can work out the structure of the magnetic field around the magnet, and then use the rule from the previous page to make your prediction.. Only then should you carry out any experiments on the TV.

The Magnetic Field around the Toroidal Magnet

Theoretical analysis:

What do you think the field around the toroidal magnet would be, if the poles are on the two flat faces? Try sketching the field lines on the diagrams below, in the same way as was done for the bar magnet on the first page. Look at the field lines through the toroid: what might their effect be on the electron beam?



Experiment:

Use the flat tray of small magnetic wires to work out the field around the magnet. If you hold the tray against one face, say, or perpendicular to one side, and then gently tap it, the wires should orient themselves to follow (approximately) the field lines; they should at least give you a clue as to the shape of the field.

Did the field shape from the experiment match your prediction? Check with the demonstrator to see if your ideas are correct: you'll be using the field for the next prediction.

Continued...

Theoretical analysis:

Given the shape of the field around the toroidal magnet, predict what would happen if you placed the magnet with one face flat against the front of the screen. In particular, consider what the field lines are doing around and in the centre of the magnet, and what direction the electron beam is taking.

You should predict how the screen will look in two places: 1) around the magnet, and 2) in the central hole of the magnet.

Confirm with the demonstrator that you've made a prediction, before continuing.

Experiment:

Place the magnet flat onto the front and centre of the screen. What do you observe? Does this match what you predicted, given the shape of the field? Can you explain why the image distorts (or not) in the way it does?

Are there any differences from what you expected? Can you explain them?

Supplementary question:

Use the same technique as you did with the bar magnet to work out which of the two toroidal magnet faces is the North pole.

Final (observation) question:

Was there anything odd on the first page of this worksheet?...