

Teaching ideas for Topic 5: *Electricity and magnetism*, Core

Questions

A number of worksheets are provided for this Topic:

- support questions examine the very basic concepts of the syllabus
- extended questions delve deeper and are equivalent to exam level questions.

Teaching ideas

Current

- Examine current in a variety of slightly unusual situations. Examples are: calculate the current from a metallic plate of area 5.0 cm^2 when the number of electrons leaving the surface is $3.8 \times 10^{16} \text{ m}^{-2} \text{ s}^{-1}$.
Answer: number of electrons leaving per second is $5.0 \times 10^{-4} \times 3.8 \times 10^{16} = 1.9 \times 10^{13} \text{ s}^{-1}$ and so the current is $1.9 \times 10^{13} \times 1.6 \times 10^{-19} = 3.0 \text{ } \mu\text{A}$.
- It is good practice to drive the formula $I = neAv$ for the current in a wire of cross sectional area A , with n electrons per unit volume and v being the electron drift speed. Then use this to get an estimate for the drift speed of the electrons for a typical current in a typical wire ($n \approx 10^{28} \text{ m}^{-3}$). Students are usually very surprised by the answer.
- Stress that the definition of resistance includes the terms voltage ‘across’ and current ‘through’!
- Students often think of resistance as the ‘difficulty’ with which electrons go past atoms in a conductor. In other words, it is as if the conductor atoms block off the flow of electrons. It is instructive to ask students how this idea might be tested. Some would say that if this proposition is true, then the greater the density of the conductor the greater the blockage and hence resistance. Ask them to check if this is true by comparing resistivities to densities.
- It is important to stress the fact that the sum of the potential differences across the resistors of a circuit is equal to the e.m.f. in the circuit.

Fields

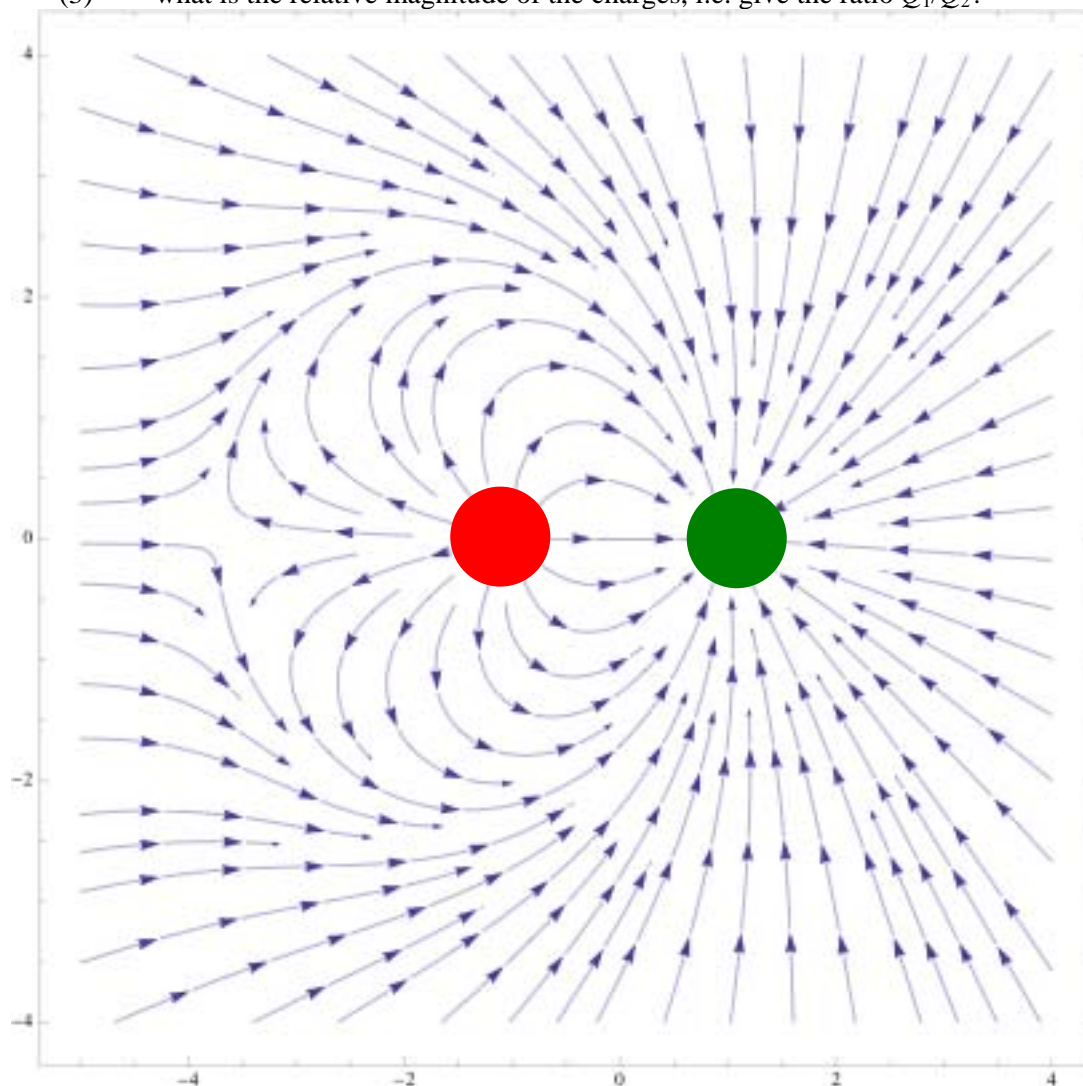
The idea of a field is somewhat abstract for students, so it is worthwhile to make teaching here as concrete as possible. Practical activities (see later) with field patterns and plotting magnets are useful activities.

- Stress to students that the formula $g = \frac{GM}{R^2}$ for the magnitude of the gravitational field strength at the surface of the Earth allows one to calculate the mass of the earth, an amazing achievement! Ask students calculate the mass of the Earth after first asking them to make an estimate of this mass.
- To calculate the mass of the earth you need the radius of the Earth (about 6400 km). It is an extremely interesting (and sometimes amusing) exercise to now ask about the century in which the radius of the Earth was first measured. It is interesting that the time just after the middle ages is a popular answer. Most students are astonished to hear about Eratosthenes’ truly ingenious measurement in 240 BCE. It is worthwhile for students to find out more about this.

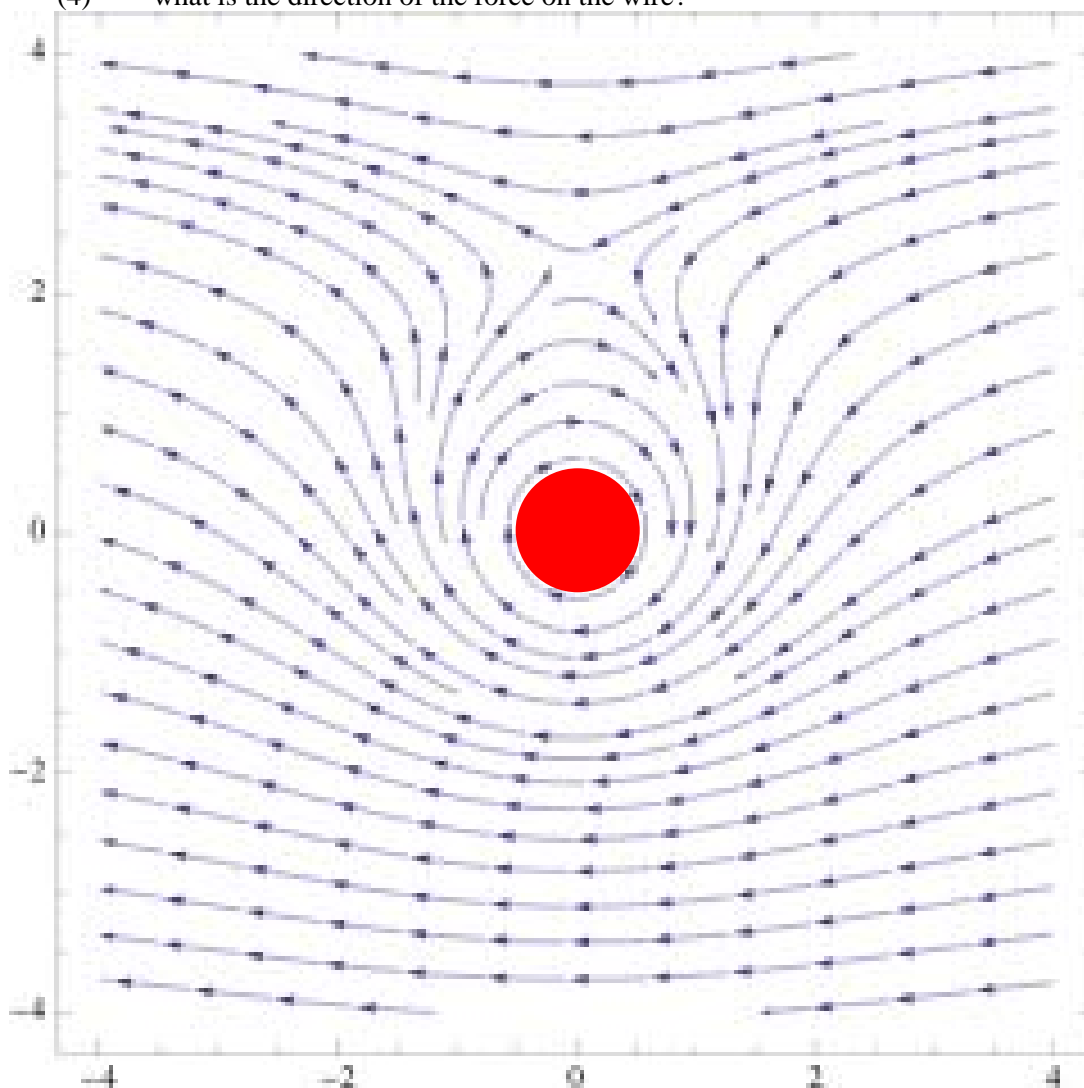
Practical activities/ICT

- See <http://phet.colorado.edu/en/simulation/battery-resistor-circuit> for a simple battery/resistance circuit and electron flow.
- A virtual circuits lab can be found at: <http://phet.colorado.edu/en/simulation/circuit-construction-kit-dc-virtual-lab>

- Using plotting magnets (small compasses) to plot the direction of the magnetic field of a bar magnet or a long straight wire is a very useful exercise that takes the mystery out of the concept of a field.
- A reasonable practical activity in the classroom is to give students a diagram such as the one that follows (or you can make your own). It shows the combined electric field of two point charges. The diagram may be used to ask questions such as:
 - (1) what is the location of the charges?
 - (2) what are the signs of the charges?
 - (3) what is the relative magnitude of the charges, i.e. give the ratio Q_1/Q_2 ?



- Another classroom activity is to give students the following diagram of magnetic field lines due to the combination of a long straight wire normal to the plane of the page and a uniform magnetic field along the plane of the page. Questions that may be asked include:
 - (1) what is the position of the wire?
 - (2) what is the direction of the current?
 - (3) where is the magnetic field zero?
 - (4) what is the direction of the force on the wire?



Common problems

- Perhaps the most common mistake made by students when they first start working with circuits is to assume that the potential difference across a resistor is the e.m.f. of the battery.
- Another mistake is to assume that when a resistor is removed from a circuit the current stays the same as before and is now shared by the remaining resistors.
- Students often confuse the various right-hand (or left-hand rules) for directions of magnetic fields and magnetic forces. It is interesting how different national systems favour different rules, but it is important to give students clear rules – whatever their national origin!

Theory of knowledge (TOK)

- There are some interesting connections between thermal physics and electricity: one is that materials that are good conductors of electricity are also good conductors of heat. This has to do with the fact that both processes involve electrons. It is interesting that both heat and electricity were originally considered to be fluids. It was later shown that in fact heat is a form of energy and that the ‘flow of electricity’ was in fact the motion of electrons.
- The concept of a field has played an important role in the development of physics. Anthropomorphic questions such as ‘How does a charge know that an electric force will act upon it?’ have led to the concept of a field. A charge creates an electric field in space. Another charge placed somewhere near the first charge, ‘feels’ the presence of the field created by the first charge. The charge ‘reacts’ to this by having a force act upon it. Are fields real or are they just convenient ways of thinking about forces?