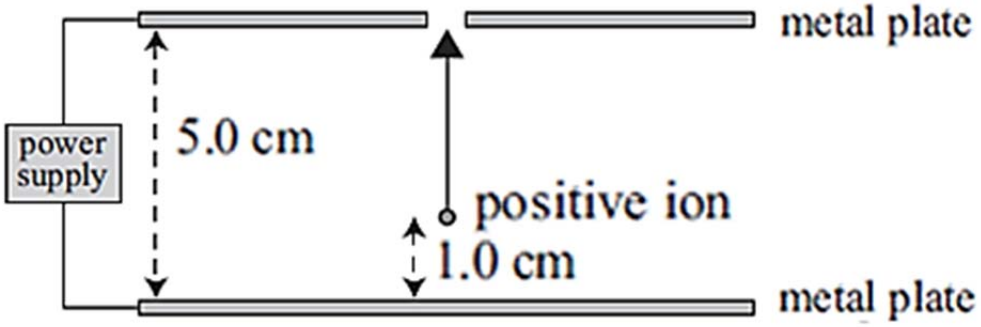
ELECTRICITY: STATICS QUESTIONS

THE MASS SPECTROMETER (2009;1)

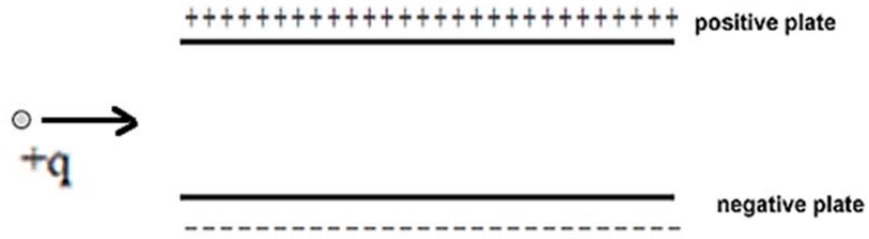
Sean is in the physics lab using a mass spectrometer to measure the mass of an unknown atom. In the mass spectrometer, an electron is removed from an atom, producing a positive ion. The positive ion is then accelerated by a constant electric field between two metal plates. A positive ion is created 1.0 cm above the bottom plate, as shown in the diagram below. The positive ion then accelerates towards the top plate. The ion has a charge of $+1.6 \times 10^{-19}$ C.



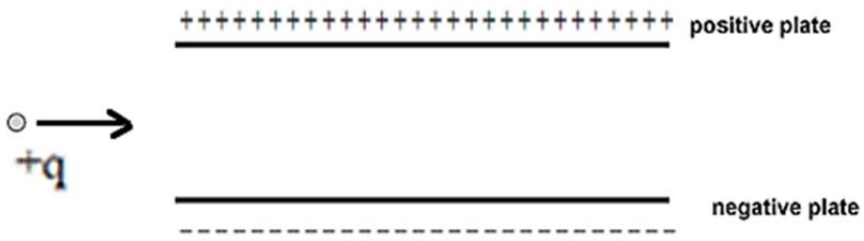
(a) On the diagram above, draw an arrow showing the direction of the electric field between the plates.
(b) The current between the plates is 3.5×10^{-6} A. How many positive ions reach the top plate in one minute?
(c) Explain what happens to the size of the electric force on the positive ion as it moves towards the top plate.
(d) Explain what happens to the maximum velocity of the positive ion if the power supply voltage is increased.
(e) The electric force on the ion is 3.20×10^{-15} N. Calculate the strength of the electric field between the plates.
(f) Show that the maximum velocity of the positive ion if it moves from the position shown to the top plate is 6.9×10^{4} ms^{-1}. The mass of the ion is 5.31×10^{-26} kg.

CHARGED PARTICLES (2008;1)

A velocity sorter is an apparatus that can be used to obtain a stream of charged particles, all travelling with the same velocity. The diagram below shows a simplified velocity sorter. A stream of protons is made to pass between two parallel charged plates – the top plate is positive and the bottom plate is negative.

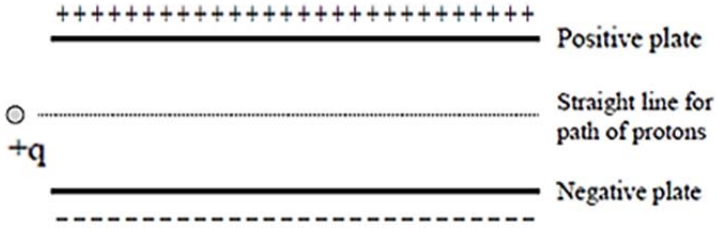


(a) On the diagram above, use arrows to draw the electric field between the plates.
(b) On the diagram below, draw the path of the proton in the field.



(c) Explain why the proton follows this path.

In order for the protons to travel in a **straight line**, a velocity sorter also has a magnetic field.



(d) The proton is travelling through a magnetic and electric field. State the direction of the magnetic field that would allow the protons to go in a straight line. Choose your answer from:

towards the top of the page/towards the bottom of the page/left/right/into the page/out of the page

(e) Explain the effect (if any) of the speed of the proton on the size of the electric force, and on the size of the magnetic force acting on the proton.

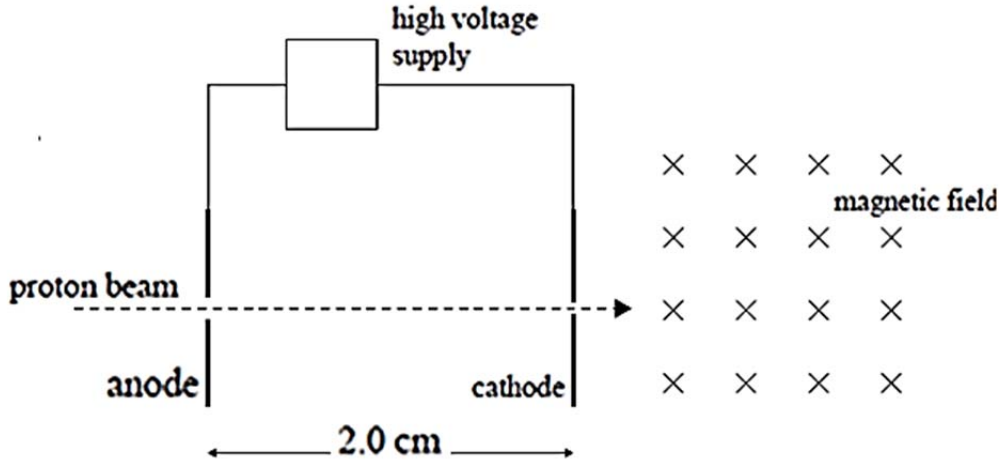
(f) The voltage between the plates is 220 V. The plates are 5.0 cm apart. Calculate the size of the electric force on the proton. Charge on proton = 1.60×10^{-19} C. Give your answer to the correct number of significant figures.

(g) 3.5×10^{15} protons enter the field in 10 s. Calculate the size of the current.

THE PARTICLE ACCELERATOR (2007;1)

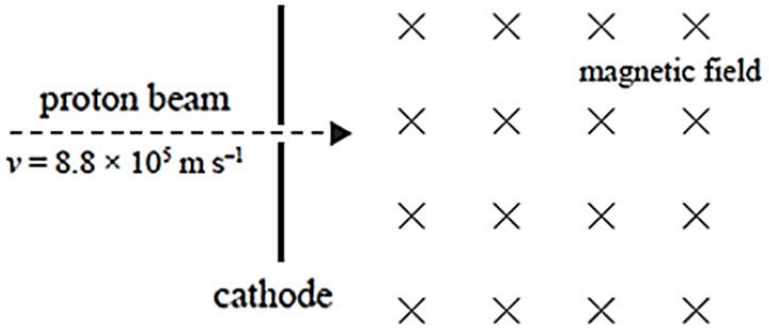
A particle accelerator is a machine designed to accelerate charged particles to very high speeds. In one type of accelerator, protons are accelerated by an electric field and then deflected by a magnetic field. The diagram below shows part of the particle accelerator. Protons pass through the hole in the anode, and are accelerated towards the cathode. The protons pass through the hole in the cathode and travel to the right.

The distance between the anode and cathode is	2.0 cm.
The charge on a proton is	$+1.6 \times 10^{-19}$ C.
The mass of a proton is	1.67×10^{-27} kg.



(a) Draw an arrow on the above diagram to show the direction of the electric field between the anode and the cathode.
(b) Describe the change in the type of energy of the proton as it moves from the anode to the cathode.
(c) A proton passes through the anode at 6.2 x 10^5 ms^{-1} and passes through the cathode at 8.8 x 10^5 ms^{-1}. Show that the strength of the electric field is 100 000 Vm^{-1}.
(d) State a unit for electric field strength other than V m^{-1}
(e) Calculate the voltage between the anode and the cathode.

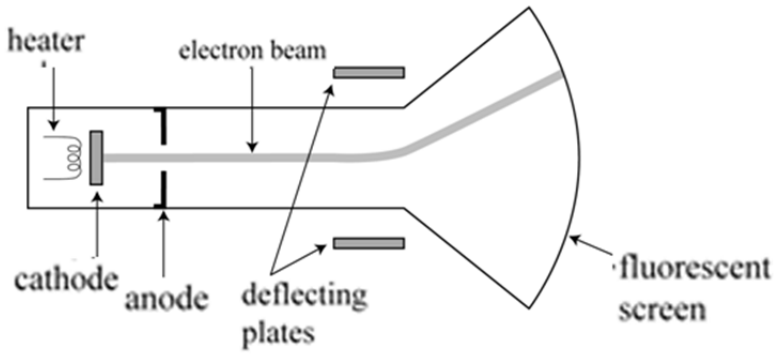
When the protons pass through the hole in the cathode, they enter a magnetic field as shown in the diagram below. The direction of the magnetic field is into the page. Magnetic field strength = 3.5 mT.



(f) State the direction of the force acting on the proton as it enters the magnetic field.
(g) Calculate the size of the magnetic force acting on the proton in the magnetic field. Write your answer to the correct number of significant figures.

CATHODE RAY TUBE (2006;2)

The diagram below shows the path of an electron moving through a cathode ray tube.

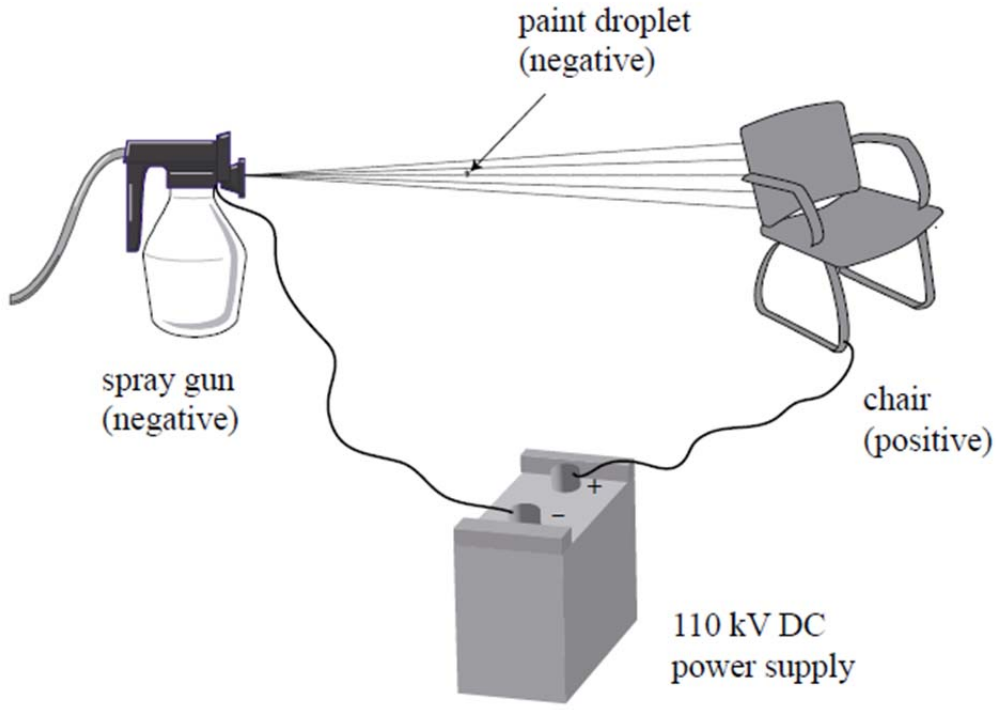


(a) On the diagram, label the positive deflecting plate "+".
(b) On the diagram draw arrows to represent the electric field formed between the deflecting plates.
(c) The deflecting plates are maintained at a voltage of 45 V, and are 8.0 mm apart. Show that the electric field strength between the plates is 5625 V m^{-1}.
(d) Derive TWO different units for electric field strength, E.
(e) The charge on an electron is 1.6×10^{-19} C. Calculate the electric force on an electron between the plates.
(f) Explain why the electron is losing electric potential energy while it is moving from the cathode (negative electrode) to the anode.

SPRAY PAINTING (2005;1)

Spray painting involves firing fine droplets of liquid paint at the object to be sprayed. One problem is that many of the droplets miss the object. A solution to this problem is to use electrostatics.
The electrostatic spray painter in the diagram below shows how a metal chair can be painted. The negative terminal of the power supply is connected to the spray gun so the paint droplets become charged.
The positive terminal of the power supply is connected to the chair. This creates an electric field between the spray gun and the chair, and the charged paint droplets are repelled from the gun and attracted to the chair.
(You should assume the electric field is uniform.)

The charge on one electron is: -1.60×10^{-19} C.



(a) Draw an arrow on the diagram above to show the direction of the electric field between the spray gun and the chair.
(b) One particular paint droplet has 3.0×10^{6} electrons added to it. Show that it has a total charge of -4.8×10^{-13} C.
(c) The spray gun and chair are 0.65 m apart. The voltage between the spray gun and the chair is 110 kV. Calculate the size of the force acting on the paint droplet
(d) Explain clearly what will happen to the force acting on the paint droplets if the spray gun is moved closer to the chair.
(e) Calculate the change in electrical potential energy of this paint droplet as it travels from the spray gun to the chair.
(f) State what is meant by the term electric current.
(g) The spray gun fires out 6.5×10^{5} paint droplets every minute. The average charge on each paint droplet is -8.0×10^{-13} C. Calculate the size of the electric current from the spray gun.

At one time in its journey to the chair, one paint droplet with a charge of - 4.8 x 10^{-13} C is moving at 12.1 ms^{-1} through the earth's magnetic field as shown in the diagram below. The earth's magnetic field is perpendicular to the paint droplet's velocity and has a strength of 0.071 mT.

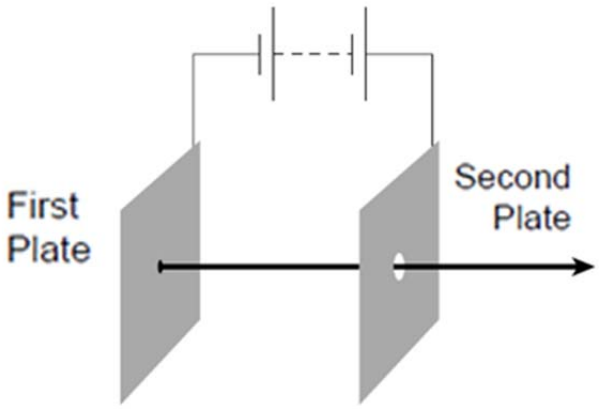
(h) Calculate the size of the magnetic force on this paint droplet. Write your answer to the correct number of significant figures.

(i) The electric field is switched off while the paint droplet is moving. On the diagram above, carefully draw the path of the paint droplet as it moves through the magnetic field. Assume that the magnetic force is the only force acting.

MEASURING ELECTRONS' SPEED (2004;2)

Electron guns are used inside television sets to fire electrons at high speed. Part of the electron gun consists of two parallel metal plates connected to a high voltage power supply. The electrons start near one plate, accelerate towards the second plate and pass through a hole in it.

Voltage between plates = 1100V
Plate separation = 3.5 x10^{-3} m
Charge on electron = 1.60 x10^{-19} C



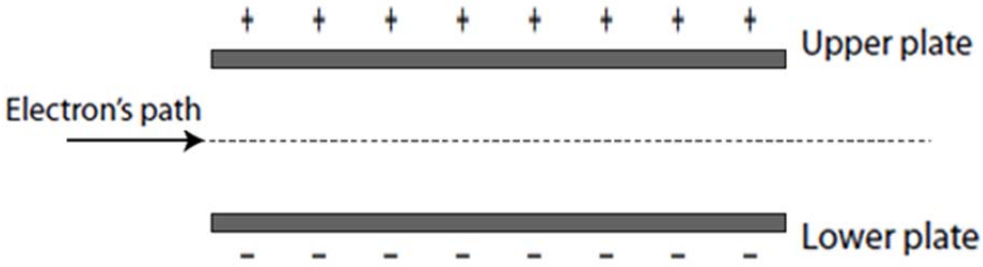
(a) State the name of the type of energy the electron is losing as it moves between the plates.

(b) On the diagram, draw a labelled arrow to show the direction of the electric field between the plates.

(c) Calculate the strength of the electric field between the plates. Give a unit with your answer.

(d) Calculate the size of the force on the electron due to the electric field. Give your answer to the correct number of significant figures.

The velocity of the electrons fired from an electron gun can be measured by passing them through an electric field and a magnetic field that are at right angles to each other. The electric field is produced by two charged metal plates as shown in the diagram.



(e) Describe the effect the charged metal plates have on the electron.

(f) There is also a magnetic field which is perpendicular to the page.

(a) The strength of the magnetic field is adjusted so that the electron's path does not bend upwards, but keeps going in a straight line.

(b) Describe the relationship between the two forces that act on the electron.

(g) Describe the direction of the magnetic field required to keep the electron going in a straight line.

(h) After adjustment, the electric field was measured to be 3.5×10^{3} NC^{-1} and the magnetic field was measured to be 1.3×10^{-3} T. Derive an equation for the velocity of the electron in terms of the electric and magnetic fields. Use it to calculate the electron's velocity.

(i) The electric field is then switched off. An electron is fired into the magnetic field so that the electron's velocity is again at right angles to the magnetic field.

(i) Describe the shape of the electron's path as the electron moves through the field.

(ii) Explain why the path of the electron in the magnetic field has this shape.