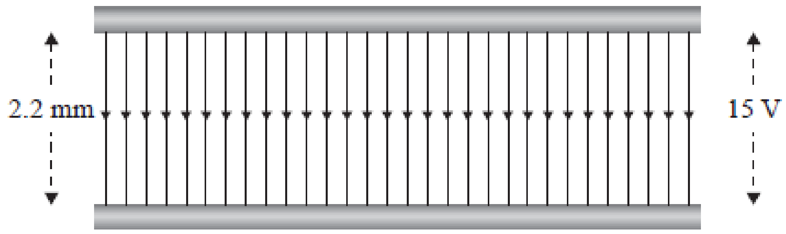
ELECTRICITY: STATICS QUESTIONS

ELECTRIC FIELDS (2022;1)

Two parallel plates are set up 2.2 mm apart with 15 V between them.



(a) Show that the electric field strength between the plates is 6.8×10^3 V m^{-1}.

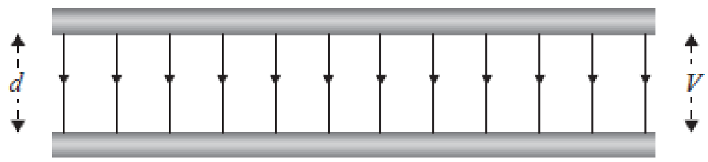
(b) An electron at rest is released from the negative plate and accelerates towards the positive plate. Calculate the maximum speed of the electron when it reaches the positive plate.

(c) A student states that increasing the distance between the plates while keeping the voltage the same, will mean that an electron released from rest at the negative plate is accelerating over a longer distance, and will therefore reach a higher speed than in part (b) when it reaches the positive plate.

(i) Use physics principles to explain why this is incorrect.

(ii) State one thing that could be done to increase the maximum speed of the electron.

(d) The diagram below shows the electric field between a set of parallel plates d metres apart with V volts between them.

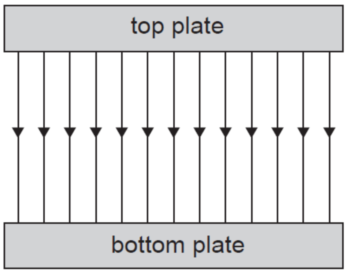


The distance between the plates is now doubled, and the voltage between them is halved.

(i) State what happens to the strength of the electric field. Your answer should include a number.

(ii) Using the same scale, draw in the field lines on the diagram below to show the new electric field between the plates.

ELECTRIC FIELDS (2021;2)

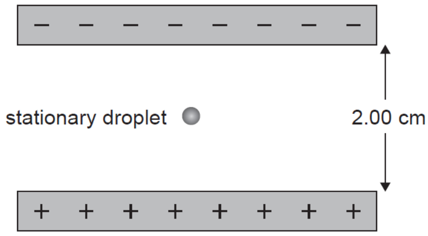


The electric field lines between two parallel plates are shown:

(a) Clearly label the positive plate on the diagram.

(b) Describe the field between the plates and explain how the diagram shows this.

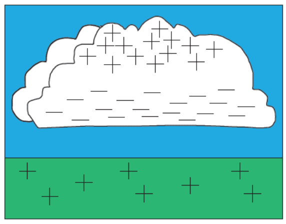
(c) An experiment is carried out on the surface of the Earth ($g = 9.8$ m s^{-2}) where a charged droplet of mass 5.87×10^{-10} kg is held stationary between a different set of parallel plates. The voltage across the plates is 240 V. The distance between the plates is 2.00 cm.



(i) Add labelled arrows to show the TWO forces acting on the stationary droplet.

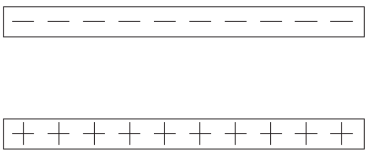
(ii) Calculate the number of elementary charges on the stationary droplet. You should start by calculating the weight of the droplet by using $F_W = mg$. Elementary charge: $+1.61 \times 10^{-19}$ C

LIGHTNING (2020;2)



Mass of electron = 9.11×10^{-31} kg
Charge on electron = -1.60×10^{-19} C

Lightning is typically caused by a build-up of electrons in clouds being released to Earth. The bottom of the cloud is negatively charged, and the ground under the cloud becomes positively charged. The cloud and the ground can be modelled by a pair of parallel plates.



base of cloud

ground

The voltage difference between a particular cloud and the ground is 1.75×10^{8} V, and the electric field strength is 8.57×10^{4} V m^{-1}.

(a) Find the height of the cloud above the ground.

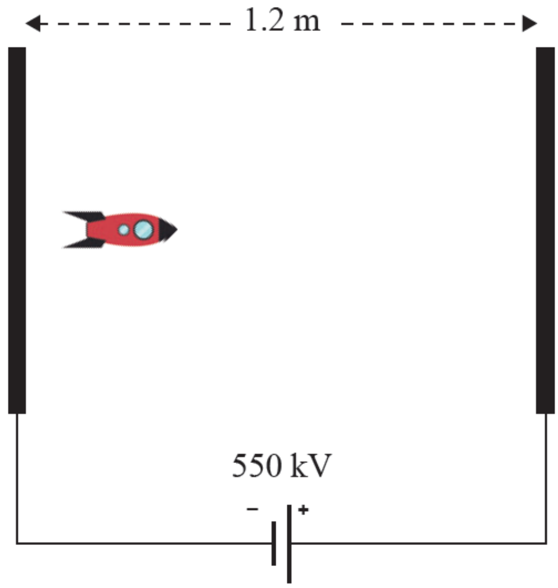
(b) A weather balloon is released from the ground. The balloon has a charge of 3.70 μC (3.70×10^{-6} C). Calculate the size and direction of the electrostatic force exerted on the balloon when it is halfway between the cloud and the ground.

(c) How does the electrostatic force on an electron change as it travels from the cloud to the ground? Use physics principles to explain your answer.

(d) An electron is discharged downwards from the base of the cloud with a speed of 1.20×10^{5} m s^{-1}. It reaches a speed of 4.20×10^{5} m s^{-1}. Calculate the distance it could have travelled from the cloud to have reached this speed.

A MODEL SPACE ROCKET (2019;1)

Manu thinks that he could use an electric field in space to slow down a rocket ship. He models his idea by setting up a pair of parallel plates 1.2 m apart. He connects them to a 550 kV supply and uses a small toy rocket as a trial.

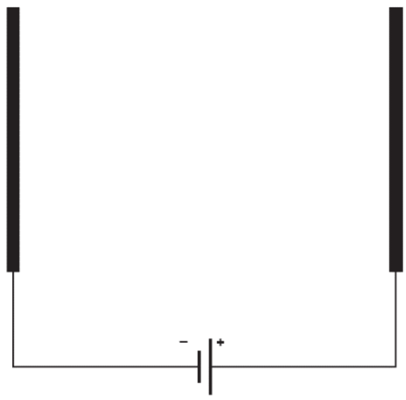


The mass of the toy rocket is 130 g.
The rocket moves from left to right.
The charge on the rocket is 3.5×10^{-6} C.

(a) Calculate the strength of the electric field between the plates.

(b) During one test, the rocket was initially moving at speed v, and was stopped in a distance d. Explain in depth what would happen to the stopping distance if the rocket was tested again at double the initial speed (2v) and the same charge.

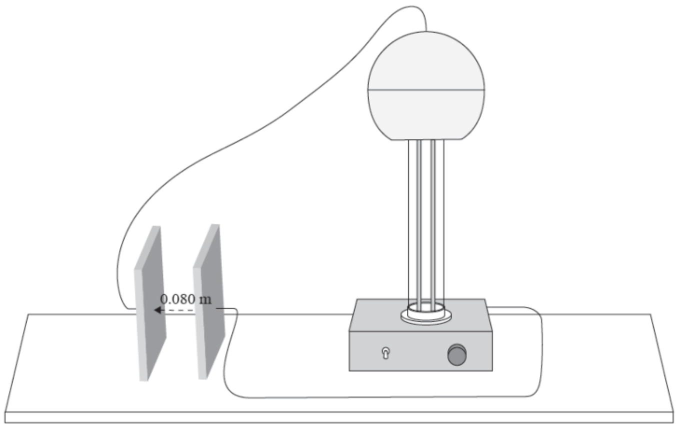
(c) Draw the field lines between the two plates.



(d) The maximum stopping distance for the given setup is 1.2 m. What is the maximum speed that a rocket can initially be moving and still be stopped by this apparatus?

THE CANDLE AND THE VAN DE GRAAFF GENERATOR (2018;1)

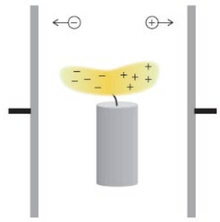
Sam has connected his school's Van de Graaff generator (high voltage DC power source) to two parallel metal plates that are 0.080 m apart.



(a) An electric field strength of 2.50×10^6 V m^{-1} is established between the plates when the Van de Graaff generator is turned on. Calculate the voltage between the plates.

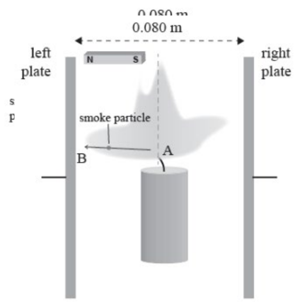
The flame of a candle contains both positively and negatively charged particles.

When Sam places a burning candle between the two parallel metal plates connected to the Van de Graaff generator, the flame spreads out as shown in the diagram. The negatively charged particles within the flame move to the left and the positively charged particles move to the right.



(b) Draw the electric field formed between these two parallel metal plates, clearly indicating which plate is positive.

(c) Sam then extinguishes the candle, causing a moving trail of smoke to appear. The negatively charged smoke particles travel to the left and the positively charged smoke particles travel to the right. An initially stationary negatively charged smoke particle with a charge of 6.52×10^{-13} C is positioned centrally at point A. The smoke particle is accelerated to the left, due to the 2.50×10^6 V m^{-1} electric field. Using conservation of energy, calculate the speed of the 4.5×10^{-6} kg smoke particle the instant before it collides with the left-hand plate (point B) that is 0.040 m away from point A.



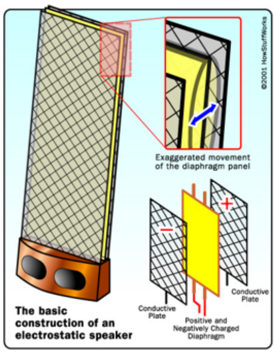
(d) A strong permanent bar magnet is then placed high above the smoke trail, so the north pole is pointing towards the left. The negatively charged smoke particles are travelling from the candle to the left-hand plate (point A to point B).

(i) State two changes, not involving the magnet, that could be made to increase the velocity of the negatively charged smoke particle.

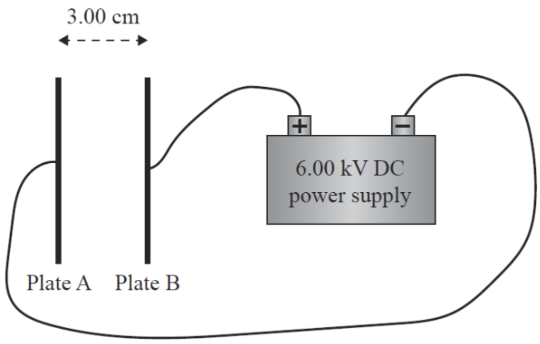
(ii) For one of the changes, clearly explain the relevant physics of how the change increases the velocity of the negatively charged smoke particle.

(iii) Discuss what could be done with the magnet to affect the motion of the negatively charged smoke particle.

Electrostatic speakers (2017;1)



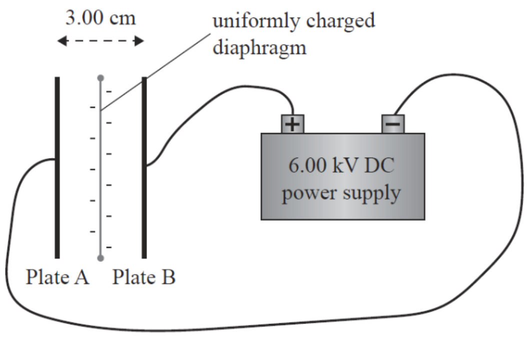
Sam has recently purchased an electrostatic speaker that produces sound by moving a diaphragm (thin sheet of polyester film) between two conducting plates that are 3.00 cm apart.



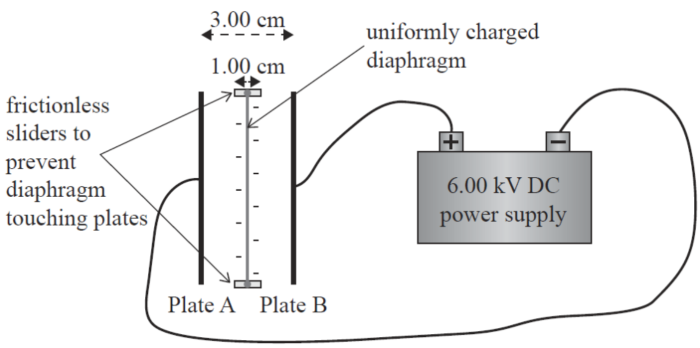
A simplified diagram of an electrostatic speaker is shown below. The plates are connected to a 6.00 kV high-voltage DC power supply.

(a) Show the strength of the electric field between plates A and B is 2.00×10^{5} Vm^{-1}.

(b) The initially neutral diaphragm, centrally placed between the plates, is charged by adding 3.70×10^{12} electrons onto it. Calculate the total charge and the size of the total force (including direction) experienced by the charged diaphragm.



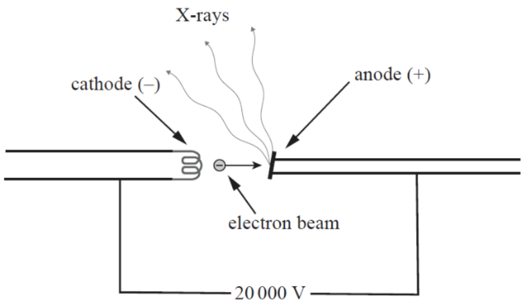
(c) The uniformly charged diaphragm is fixed at the top and bottom to smooth (frictionless) sliders, which allows it to move to the left or right by a total distance of 1.00 cm. Explain why the size of the force on the diaphragm remains constant, and no bending occurs, as the diaphragm moves within the sliders.



(d) At one point the stationary diaphragm has a uniform negative charge of - 4.20×10^{-5} C and is initially located in the middle of the slider. The mass of the diaphragm is 5.80×10^{-5} kg, and the width of the slider is 1.00 cm. The conducting plates are 3.00 cm apart. Find the maximum speed the diaphragm will have before it is stopped by the edge of the slider. State any assumptions you make.

Static Electricity (2016;1)

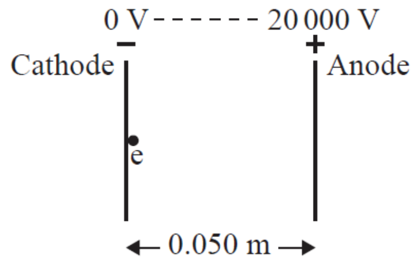
In an X-ray machine, a heating element releases electrons from a negatively charged plate called the cathode. The electrons are then accelerated by an electric field that exists between the cathode and a positively charged tungsten plate called the anode. The cathode and the anode are connected to a high voltage source of 20 000 V. The distance between the cathode and anode plates is 0.050 m. The beam of electrons causes X-rays to be released from the anode.



Charge on an electron = 1.60×10^{-19} C

Mass of an electron = 9.11×10^{-31} kg

The diagram on the right shows the arrangement to accelerate the electrons as they leave the cathode.

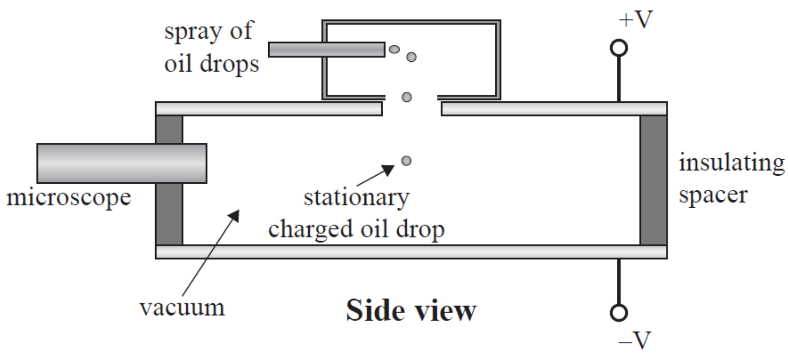


(a) Calculate the electric field strength between the plates and state its direction.

(b) State what type of energy an electron would have at the cathode (negative plate), and what would happen to that energy as the electron moved towards the anode (positive plate).

(c) Calculate the speed of the electron as it reaches the anode (positive plate).

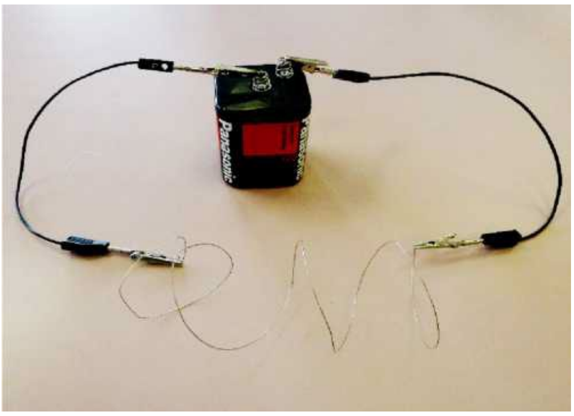
(d) In 1909 Millikan used two oppositely charged metal plates to keep a charged oil drop falling at terminal velocity when he was experimenting to find the charge of an electron. A modified form of his experiment keeps an oil drop stationary. The diagram below shows part of the equipment.



Discuss how it was possible to make the oil drop stationary between the plates. In your comprehensive answer, you should

- identify the forces acting on the oil drop
- describe how the forces can combine to cause the oil drop to be stationary
- explain what type of charge the oil drop must have in order to remain stationary.

Electric Field in a wire (2015;1)



Charge on an electron = - 1.6×10^{-19} C

Hamish connects a circuit as shown in the picture below. The circuit comprises a 6.0 V battery, 1.0 m of Nichrome resistance wire and two connecting wires. The battery produces a uniform electric field in the Nichrome resistance wire.

Assume that the connecting wires have no resistance.

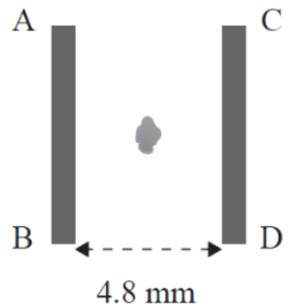
(a) Calculate the strength of the electric field in the Nichrome resistance wire.

(b) Explain what happens to the size of the electric force on an electron as it travels through the Nichrome resistance wire.

(c) Calculate the distance moved by an electron as it loses 9.6×10^{-20} J of electrical potential energy.

(d) Hamish then adds another 6.0 V battery in series AND shortens the wire to 0.50 m. Write a comprehensive explanation on what will happen to the size of the force on the electron. Calculations are not needed.

The Smoke Detector (2015;3)



Charge on an electron = -1.6×10^{-19} C

One type of smoke detector comprises a pair of metal plates 4.8 mm apart, connected to a battery. Alpha particles from a radioactive source ionise particles of smoke between the plates. This causes the smoke particles to lose one or more electrons and become charged.

The diagram shows a positively charged smoke particle. The force on the particle is towards AB.

(a) Draw lines showing the electric field between the plates. Include the direction of the field lines. The mass of the smoke particle is 1.7×10^{7} kg

(b) A particular smoke particle loses two electrons. It experiences a force of 5.88×10^{-16} N due to the electric field. Calculate the strength of the electric field.

(c) Maria brings a magnet close to the smoke detector. The magnet produces a magnetic field of strength 3.0×10^{-2} T, which, with reference to the diagram, is directed into the page. State the size of the force due to the magnet on the stationary smoke particle. Explain your answer.

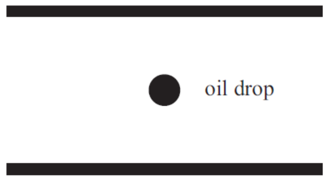
(d) The smoke particle becomes ionised by losing two electrons when it is 2.4 mm from plate AB. Calculate the speed of the smoke particle when it reaches the plate AB. Assume that only the electric force acts on the smoke particle.

Millikan's oil drop experiment (2014;1)

Charge on electron: -1.6×10^{-19} C, Mass of electron: 9.11×10^{-31} kg,
Charge on proton: $+1.6 \times 10^{-19}$ C, Mass of proton: 1.67×10^{-27} kg

In 1909 Robert Millikan performed an experiment to determine the size of the charge on an electron. He put a charge on a tiny drop of oil and measured how strong an applied electric field had to be in order to stop the oil drop from falling. Janet is doing a similar experiment. She has an electrically charged oil drop held stationary in an electric field, so that it floats.

The oil drop has a net negative charge of 24×10^{-10} C and is placed in a uniform electric field of strength 610 N C^{-1} directed vertically. The oil drop "floats" (is held suspended) between the plates. (Assume any buoyancy effect of air to be negligible.)

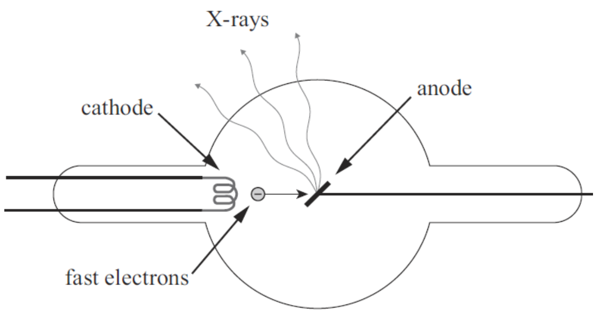


(a) Name the forces (including directions) acting on the oil drop while it is suspended between the plates.
(b) Calculate the mass of the oil drop. (Use g = 9.8 N kg^{-1} and F = mg.)
(c) Explain what the same charged oil drop would do if the plates were brought closer together. Assume the charge on the oil drop remains the same, and the voltage across the plates remains unchanged.
(d) A free electron and a free proton are placed in identical electrical fields (same electric field strength). Compare:
- the strength of the electric force on each particle
- the acceleration of each particle (you may neglect gravity and use a = F/m).

Give reasons to justify your comparisons.

The x-ray tube (2013;1)

Tavita is working on the design of an X-ray tube for hospitals. The diagram shows the main parts of the X-ray tube. Electrons are emitted by a filament in the cathode. A high voltage between the cathode (negative electrode) and anode (positive electrode) causes them to accelerate until they crash into the anode.

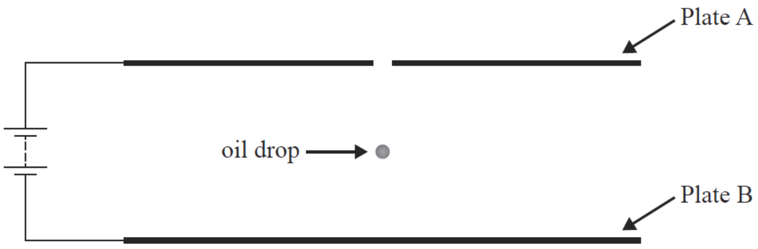


Mass of an electron = 9.1×10^{-31} kg
Charge on an electron = -1.6×10^{-19} C

(a) Approximately 1×10^{15} electrons leave the cathode every second. Calculate the size of the current.
(b) The X-ray tube is in the Earth's magnetic field. The direction of the magnetic field is from the cathode to the anode. State the size of the magnetic force on the moving electrons. Explain your answer.
(c) The electrons start from rest and reach a speed of 3.0×10^{7} m s^{-1}. By considering the energies involved, calculate the size of the voltage between the cathode and the anode.
(d) Tavita decides to reduce the distance from the cathode to the anode by half. Explain fully what will happen to:
  (i) the size of the force acting on an electron
  (ii) the kinetic energy gained by an electron

STATIC ELECTRICITY (2012;3)

An experiment performed by Robert Millikan in 1909 determined the size of the charge on an electron. Millikan put a charge on a tiny drop of oil and measured how strong an applied electric field had to be in order to stop the oil drop from falling. The diagram below shows a simplified version of the apparatus he used.



Millikan used x-rays to produce a negative charge on the oil drops.

(a) Explain why the battery is connected as shown in the diagram.

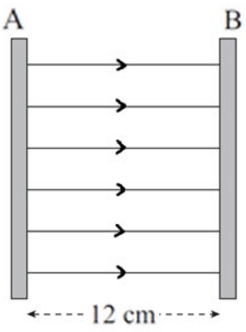
(b) In terms of forces, state the conditions necessary for the oil drop to be held stationary between the horizontal plates.

(c) On one occasion, Millikan used an oil drop of mass 2.54×10^{-5} kg with a charge of 3.6×10^{-9} C. The plates were 4.8×10^{-4} m apart. Calculate the voltage needed to hold the oil drop stationary between the two plates. Start by working out the weight force of the oil drop using $F_g = mg$ and $g = 9.8$ N kg^{-1}.

(d) Express your answer to part (c) to the correct number of significant figures. Give a reason for your choice of significant figures.

ELECTROSTATIC SWING (2011;1)

Sean is helping his physics teacher at the school open day. He connects two vertical metal plates to a Van de Graaff generator. The metal plates are shown in the picture below. They are 12 cm apart. The diagram on the right represents the electric field between the plates when the high voltage supply is turned on.



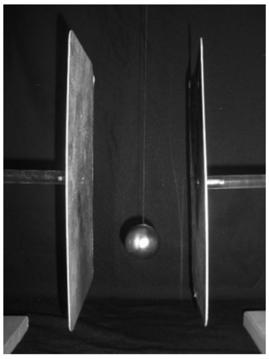
(a) State which plate (A or B) is **positive**. Give a reason for your answer.

(b) State how the diagram shows that the electric field between the plates is uniform.

(c) The strength of the **electric field** between the plates is 3.33×10^{6} V m^{-1}. Show that the **voltage** produced by the Van de Graaff generator is 400 kV.

(d) Sean has a metal ball with a mass of 2.5×10^{-2} kg suspended from a long thread. He puts the metal ball between the plates. It touches the **positive** plate and gains a charge of $+1.5 \times 10^{-10}$ C. Calculate the **speed** of the ball just before it hits the **negative** plate.

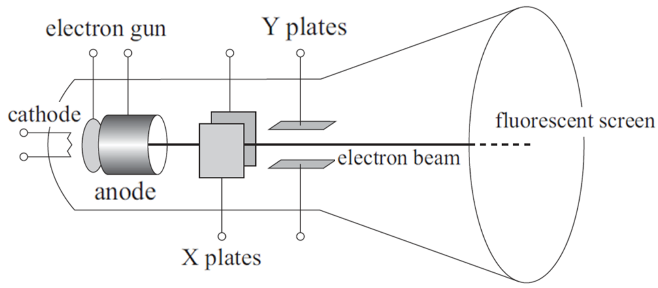
(e) Describe the motion of the ball after it touches the negative plate. Explain your answer.



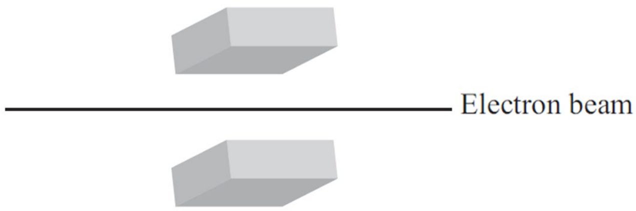
STATIC ELECTRICITY (2010;1)

Charge on electron = -1.6×10^{-19} C
Mass of an electron = 9.0×10^{-31} kg

The oscilloscope is an electronic instrument widely used in making electrical measurements. Its main component is the cathode ray tube. The cathode ray tube is a vacuum tube in which electrons are accelerated and deflected by electric fields. The electrons are deflected in various directions by two sets of plates placed at right angles to each other in the neck of the tube.

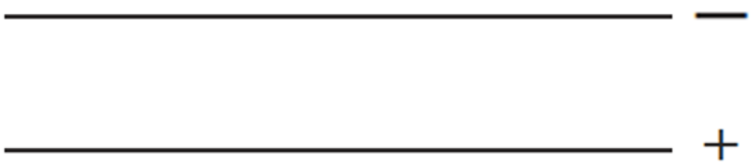


This diagram is a simplified diagram of the Y-plates in the cathode ray tube. These are two parallel metal plates.



The two parallel metal plates are separated by a distance of 3.0 mm. The plates are maintained at a potential difference of 20 V.

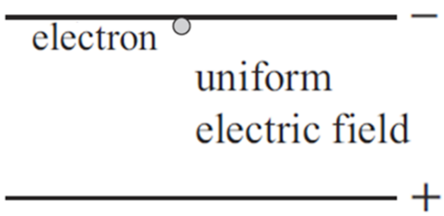
(a) On the diagram below, draw arrows to represent the **shape and direction** of the electric field between the plates.



(b) (i) Show that the electric field strength in the region between the plates is 6.7×10^{3} V m^{-1}.
(ii) State another unit for electric field strength.

(c) An electron is released with **zero velocity** from the **negative** plate as shown in the diagram.

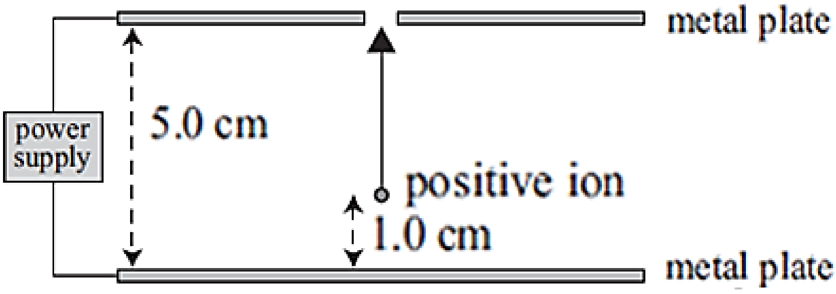
(i) Describe what happens to the electron once it is released, in terms of the energy changes
(ii) Describe what happens to the electron once it is released in terms of the motion of the electron.



(d) Calculate the velocity with which the electron reaches the positive plate after travelling a distance of 3.0 mm.

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. 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.

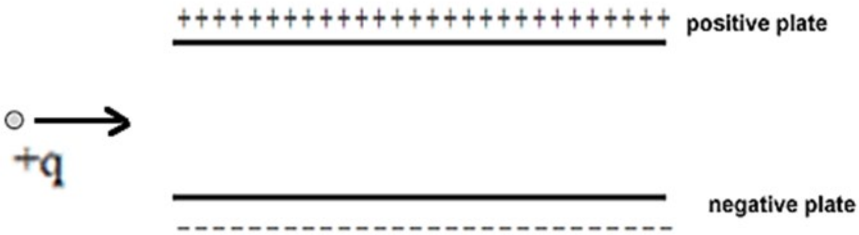
(d) Explain what happens to the maximum velocity of the positive ion if the power supply voltage is increased.

(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.

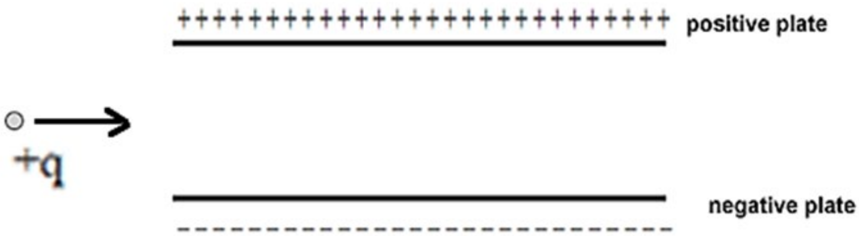
CHARGED PARTICLES (2008;1)

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.



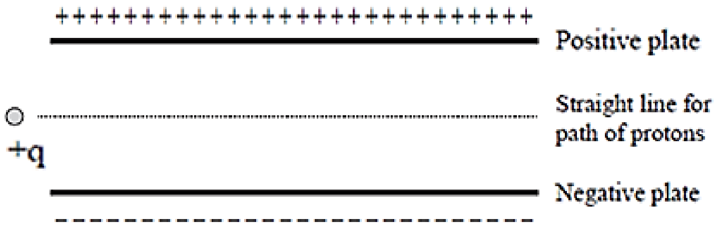
(a) On the diagram above, use arrows to draw the electric field between the plates.

(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.

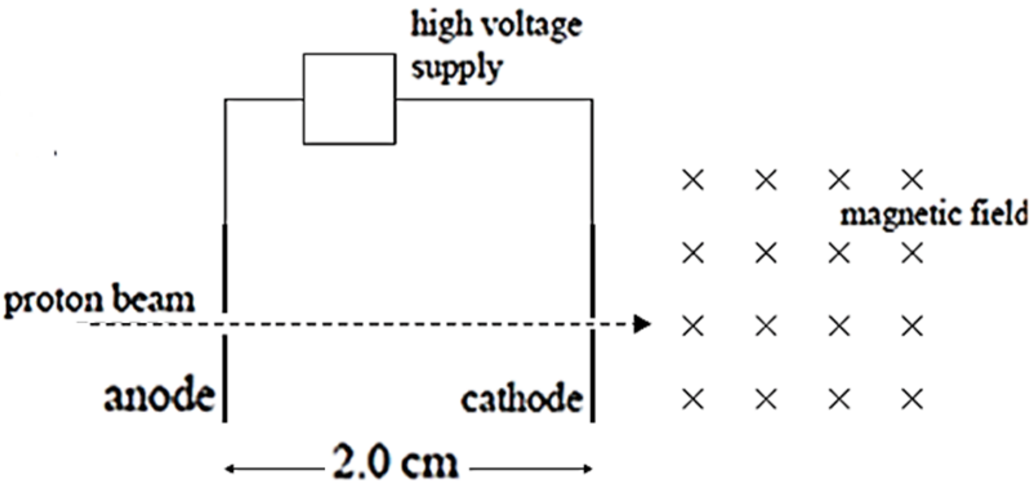
(f) The voltage between the plates is 220 V. The plates are 5.0 cm apart. Calculate the size of the electric force on the proton. Charge on proton = 1.60×10^{-19} C. Give your answer to the correct number of significant figures.

(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.

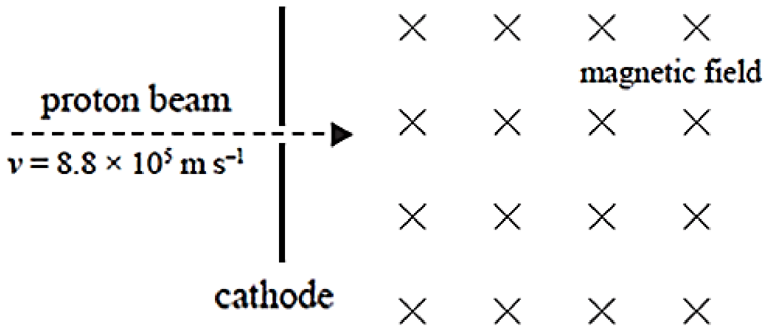
(b) Describe the change in the type of energy of the proton as it moves from the anode to the cathode.

(c) A proton passes through the anode at 6.2×10^5 ms^{-1} and passes through the cathode at 8.8×10^5 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 Vm^{-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.

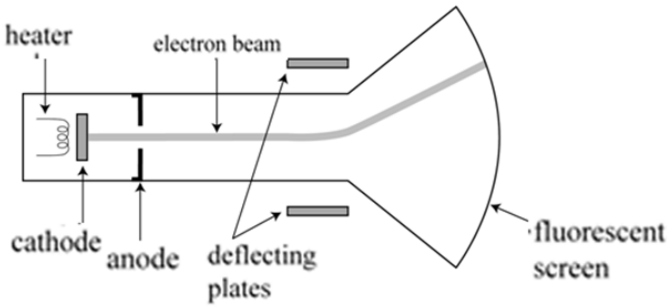
Magnetic field strength = 3.5 mT



(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)

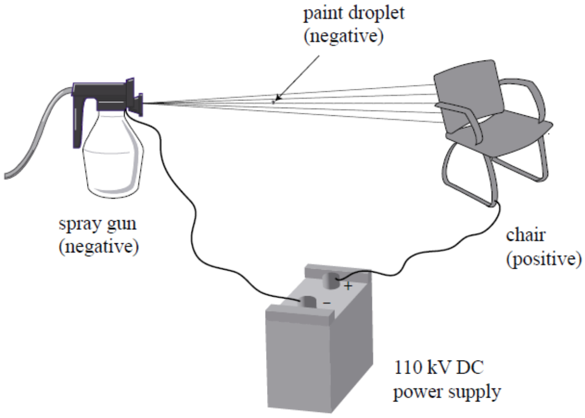
The diagram below shows the path of an electron moving through a cathode ray tube.



(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 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.

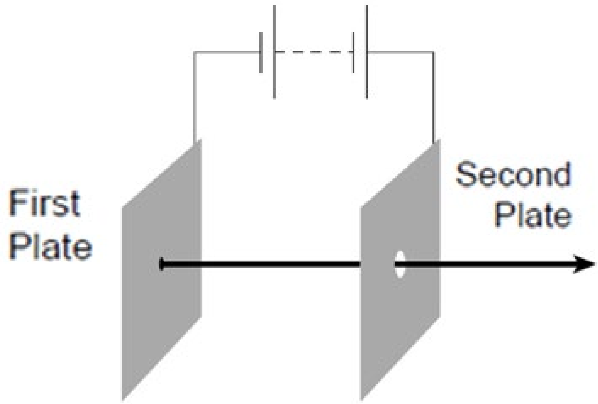
At one time in its journey to the chair, one paint droplet with a charge of -4.8×10^{-13} C is moving at 12.1 ms^{-1} through the earth's magnetic field as shown in the diagram below. The earth's magnetic field is perpendicular to the paint droplet's velocity and has a strength of 0.071 mT.

(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)

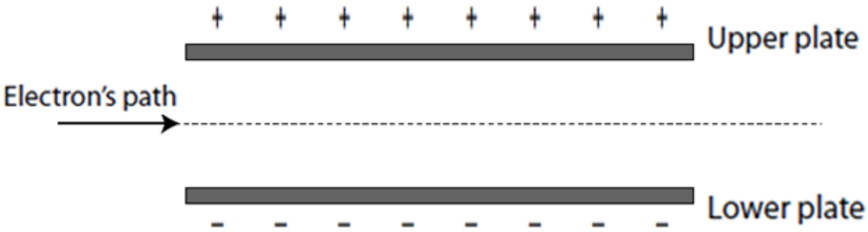
Electron guns are used inside television sets to fire electrons at high speed. Part of the electron gun consists of two parallel metal plates connected to a high voltage power supply. The electrons start near one plate, accelerate towards the second plate and pass through a hole in it.

Voltage between plates	= 1100 V
Plate separation	= 3.5×10^{-3} m
Charge on electron	= 1.60×10^{-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.
(g) 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.
(h) Describe the relationship between the two forces that act on the electron.
(i) Describe the direction of the magnetic field required to keep the electron going in a straight line.
(j) 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.
(k) 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.