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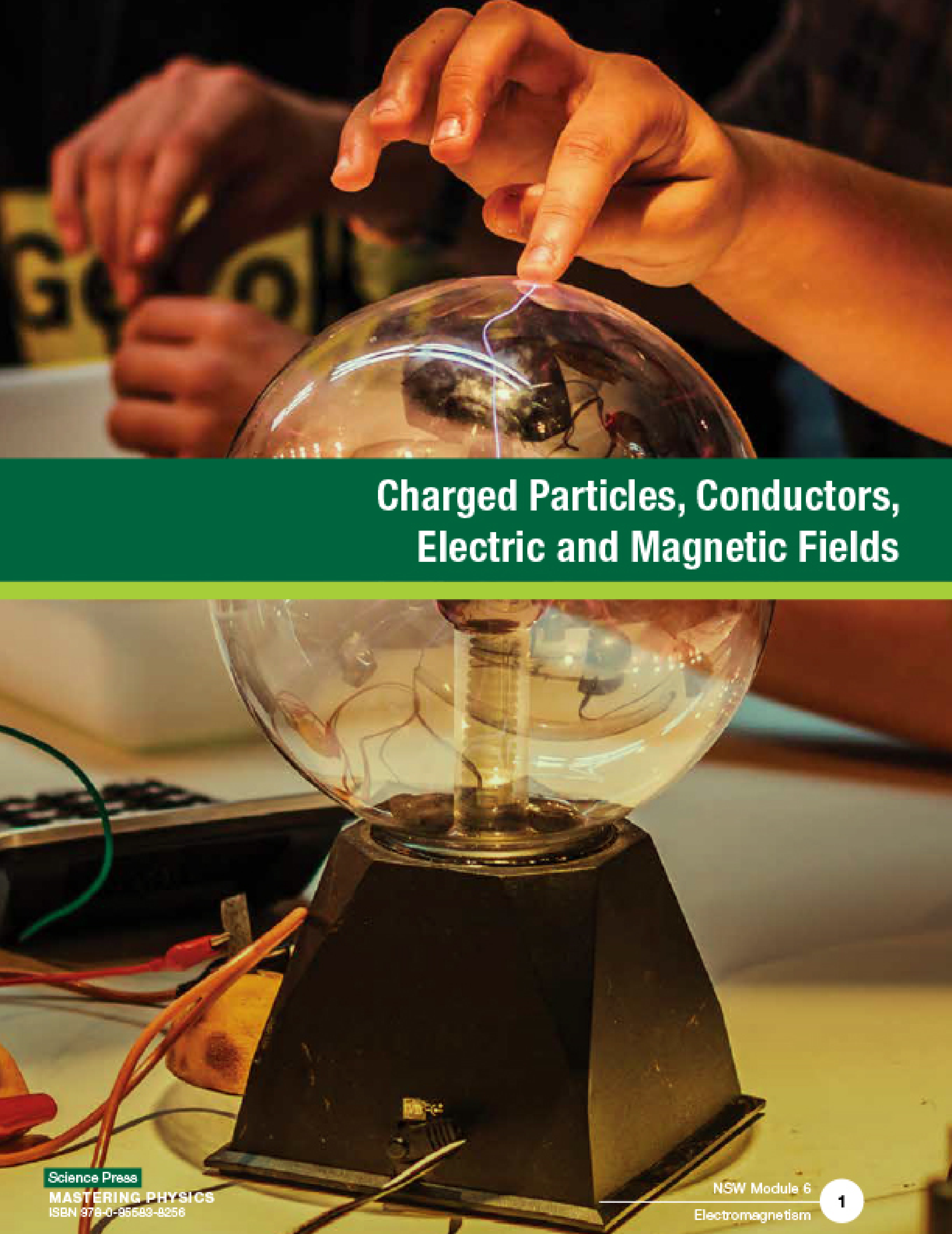


Charged Particles, Conductors, Electric and Magnetic Fields

ISBN 978-0-85583-8256

6.1 Electric Fields and Parallel Plates

Investigate and quantitatively derive and analyse the interaction between charged particles and uniform electric fields, including the electric field between parallel charged plates: $E = \frac{V}{d}$.

Electric fields

A **field** is a region in which something will experience a force.

An **electric field** is a region in which charged particles experience forces.

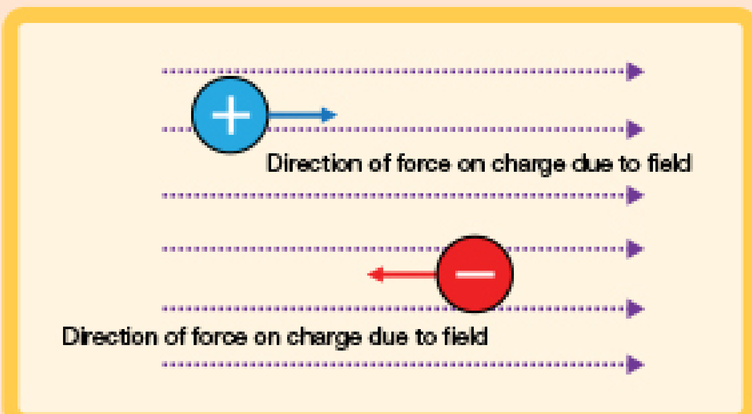
An electric field exists at a point if a charge placed at that point experiences a force.

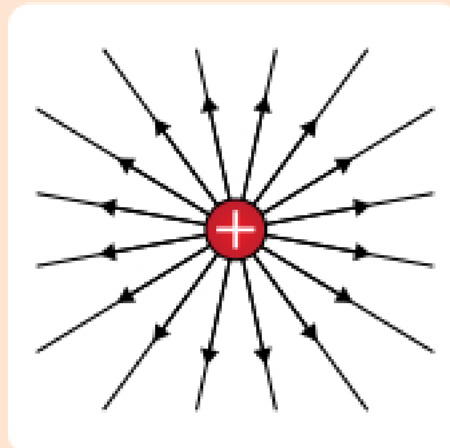
Electric field is directed **away from positive towards negative**, or

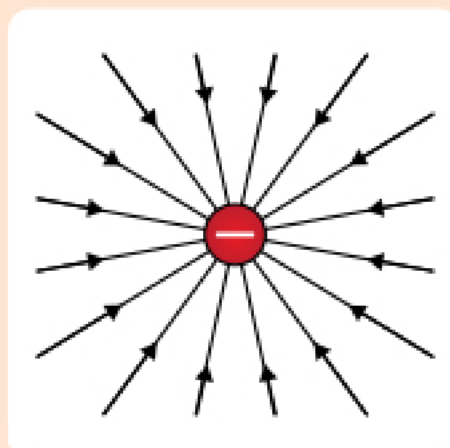
Electric field is directed **from high potential to low potential**.

As a result of these forces, if the charges are free to move they will accelerate in the direction of the force on them (Newton's second law of motion).

The direction of the electric field at a point can also be defined as the direction of the force experienced by a positive charge placed in the field at that point.







A positive charge will experience a force in the direction of the field.

A negative charge will experience a force in the opposite direction to the field.

Electric field is a **vector** quantity and can be represented by vector arrows.

The **direction of the arrow represents the direction of the field** (from positive to negative, or, from high to low potential), and

The **closeness of the arrows indicates** the magnitude of the field at each point in the field.

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Sample *Questions*

1. (a) Define an electric field.

(b) What are the units of electric field?

(c) In what direction relative to a field will a positive charge move when placed in it?

(d) In what direction relative to a field will a negative charge move when placed in it?

(e) Why do we use arrows to represent an electric field?

(f) How do we compare the relative strengths of electric fields by looking at diagrams representing them?

(g) What is the direction of electric field relative to a positive charge?

(h) What is the direction of electric field relative to a negative charge?

(i) What is the direction of electric field relative to a high potential position?

(j) What is the direction of electric field relative to a low potential position?

2. A uniform electric field acts to the left. In which direction will each of these particles accelerate?

(a) An electron.

(b) A positron (an antielectron).

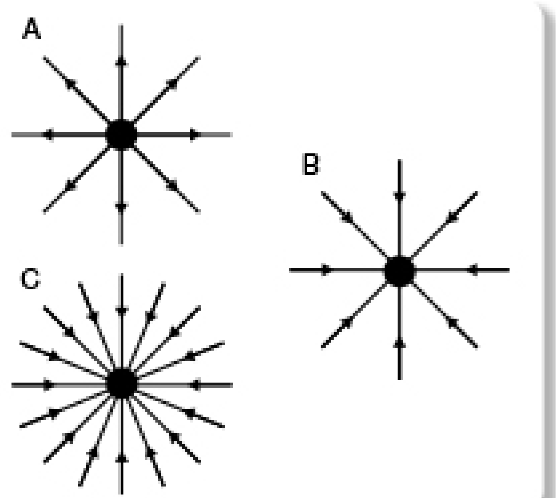
(c) A neutron.

(d) An antiproton.

(e) A helium nucleus (He^{2+}).

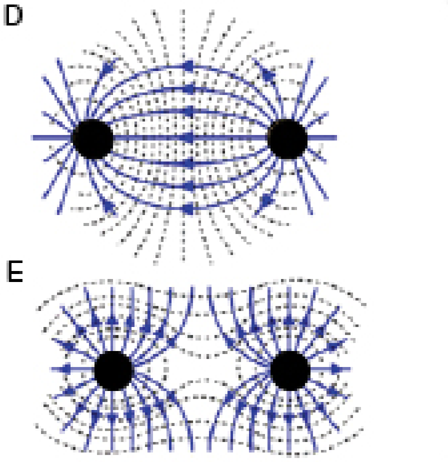
(f) A neutrino.

3. Consider the field lines around the charges shown.

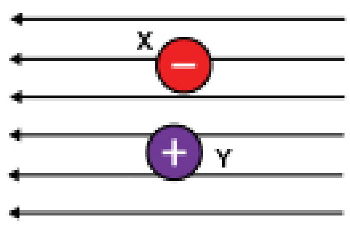


(a) Compare the fields A, B and C and the charges causing them. Justify your answer.

(b) Compare fields D and E and the charges causing them. Justify your answer.



4. Two charged particles X and Y are placed in an electric field as shown. The field is directed towards the left.

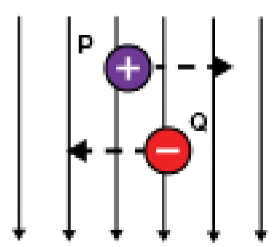


(a) Describe what happens to each particle.

(b) Describe what happens to the kinetic energy of each particle.

(c) Describe what happens to the electrical potential energy of each particle.

5. Consider charged particles P and Q in an electric field directed towards the bottom of the page as shown. P is moved at constant velocity to the right through the field and Q is moved to the left.



(a) How does the electrical potential energy of each charge change? Justify your answer.

(b) Describe the nature and source of the force causing the movement of each charge. Justify your answer.

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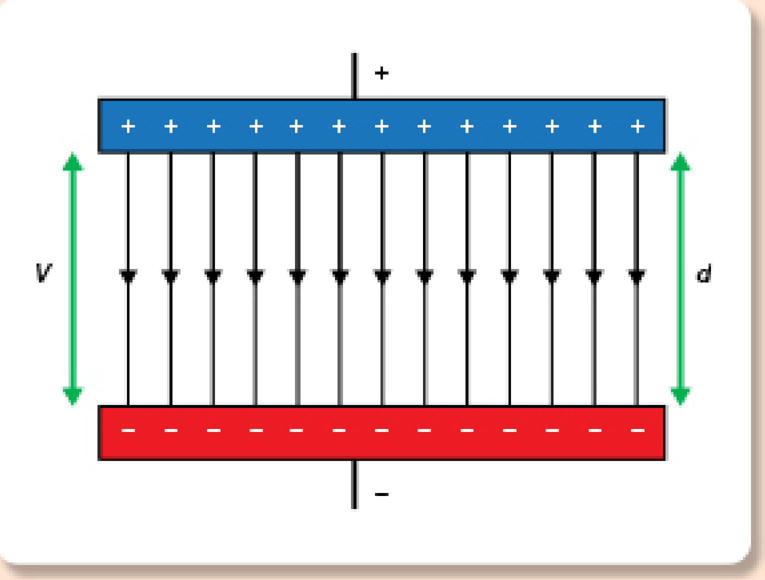
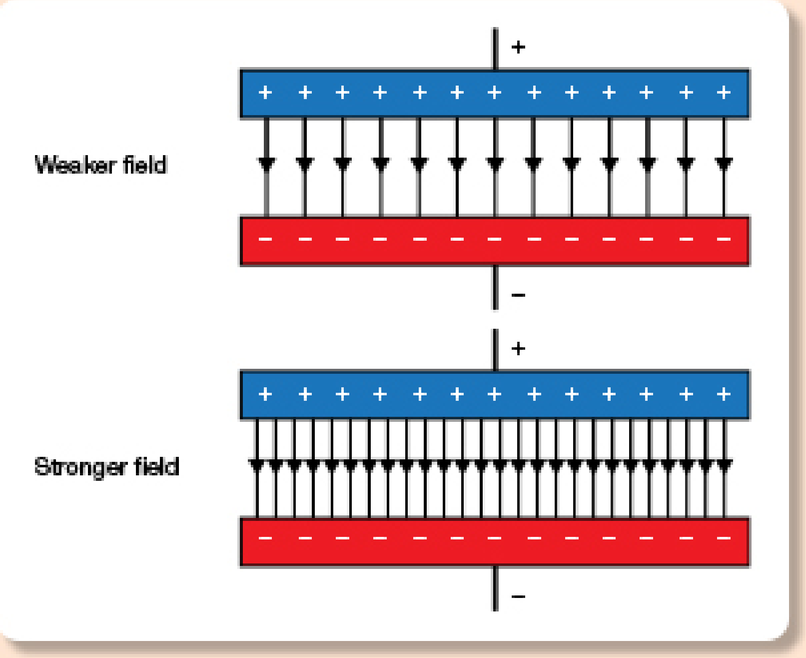
Parallel plates

- The electric field between parallel plates is directed from the high potential (positive) plate to the low potential (negative) plate.
- The field between the plates is **uniform** in intensity.
- This is shown by the field lines being equidistant from each other.



- The **closeness of the arrows indicates** the magnitude of the field at each point in the field.



- The intensity of the field is given by the following.

$$E = \frac{V}{d}$$

Where V = electrical potential difference between plates (V)

d = distance between plates (m)

E = electric field in volts per metre (V m^{-1})

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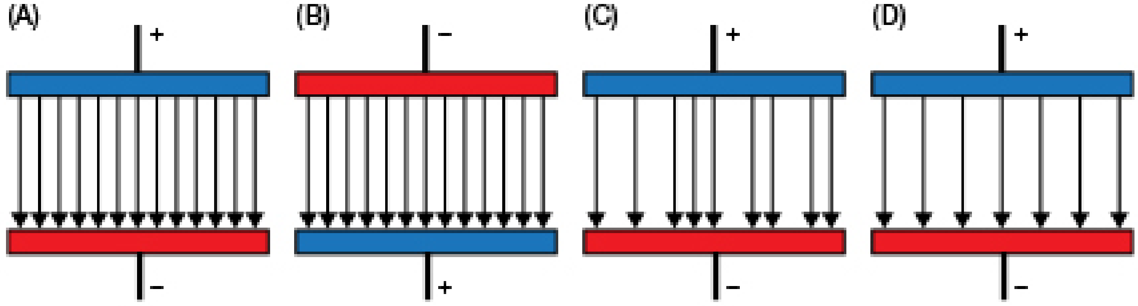
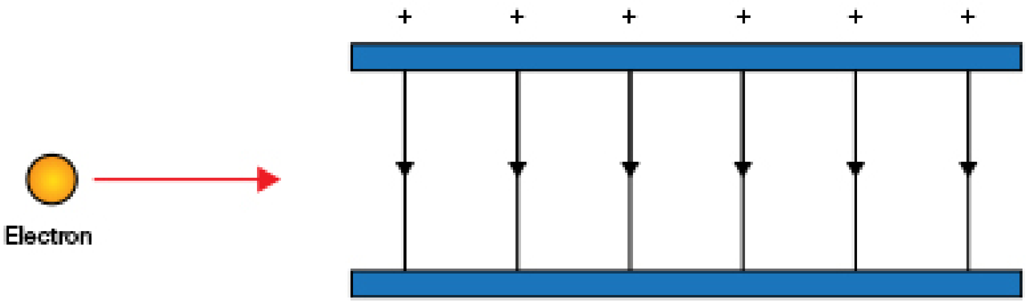
Sample Questions

1. (a) Which of the following fields between the parallel plates is correct and the strongest?

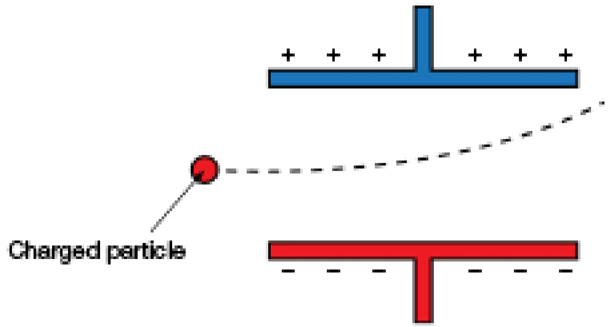


(b) Which of the fields above are represented correctly?

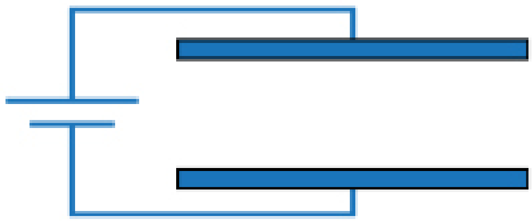
2. An electron is about to enter and pass through the electric field between the parallel plates shown below. Draw in its path through the field and after it leaves the field.



3. What is the charge on the particle in this diagram? Justify your answer.



4. (a) Draw in the field lines between the parallel plates shown. Justify your answer.
   (b) What would these field lines look like if the voltage between the plates was doubled?
   (c) What would these field lines look like if the distance between the plates was doubled?
   (d) Why should you have drawn your field lines equidistant apart?



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6.2 Interaction Between Charges and Electric Fields

Investigate and quantitatively derive and analyse the interaction between charged particles and uniform electric fields, including acceleration of charged particles by the electric field: $F = ma$, $F = qE$:

Interaction between charges and electric fields

- The force on a charge in an electric field can be found using: $F = qE$

And we already have: $E = \frac{V}{d}$

- Where F = force on charge Q_1 due to field produced by charge Q_2 (N)
  E = strength of electric field V m^{-1} or, from the equation above, N C^{-1}
  q = charge (C)
  k = constant = 9×10^9 (N m^2 C^{-2})

- Combining these two equations, we get: $F = \frac{qV}{d}$

- Note that the equation above for electric field will give us another definition for the strength of the field:

The strength of an electric field can be defined as the force per unit charge at that point.

- Note also that the force on a charge in an electric field may also be a net force in which case Newton's second law of motion applies to it. It will therefore **accelerate** within the field according to:

$$F = qE = \frac{qV}{d} = ma$$

- From which we can find the acceleration of the charge in the field:

$$a = \frac{F}{m} = \frac{qE}{m} = \frac{qV}{md}$$

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