Chap 17 Electric Field

LimWH 2012

What is a field?

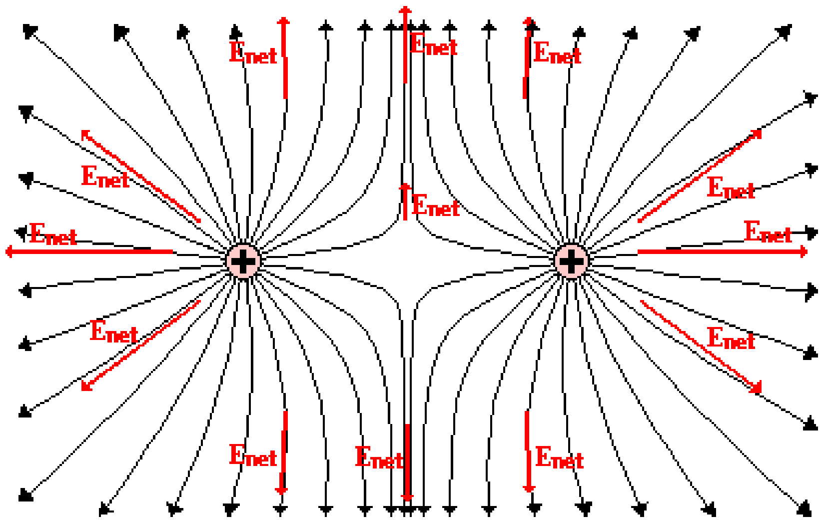
A field is a region or an area.

What is an Electric Field?

It is a region where an electrical charge is exerted by electric force.

The electric field around a positive charge is represented by lines radially outwards from the centre of the charge and radially inwards for a negative charge.

The tangential line at any point in the field indicates the direction of force and field strength at that point.



AS and A2 syllabuses

AS

Electric Field

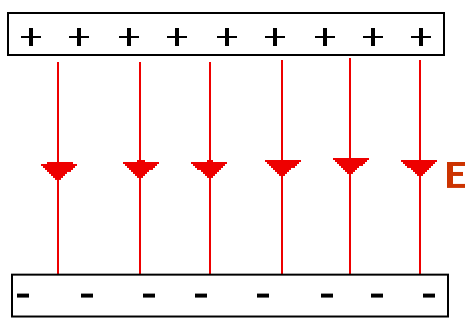
A2

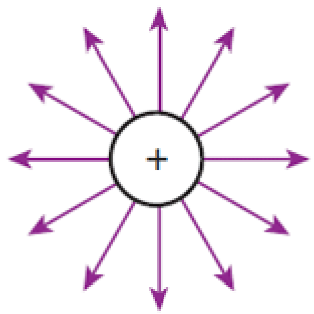
Uniform

Non - uniform

Between two parallel metal plates

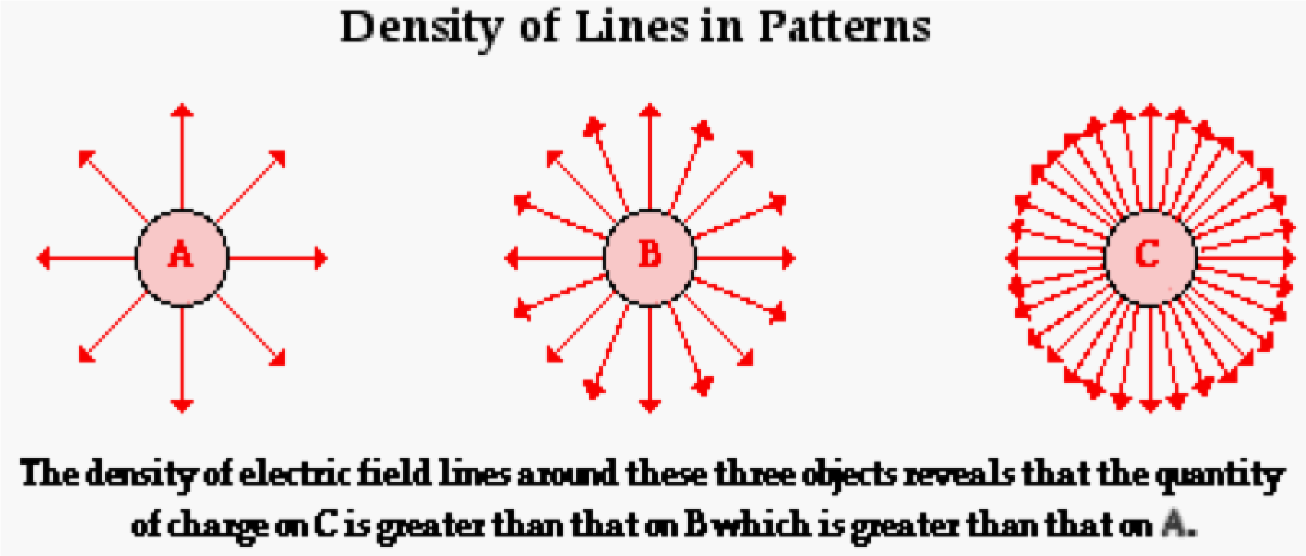
Around a point charge





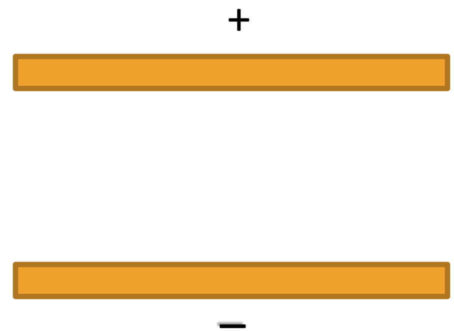
Field lines or flux

- A field can be represented by lines of force, known as field lines or flux. The field lines never cross.
- Arrows on the lines show the direction of force acting on an object located at any point in the field.
- The closer the field lines are to each other (i.e. the higher the density of lines), the greater the **field strength** (i.e. the stronger the field is).



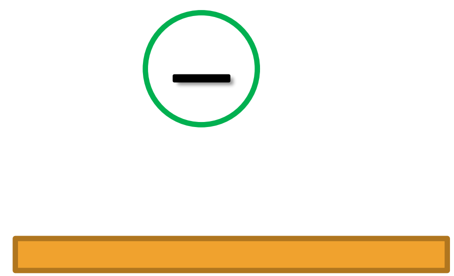
Sketch the field lines around these charges/plates

Unlike charges



Uniform field between two parallel metal plates

like charges



Between a plate and a point charge

Electric Field Strength E

- Different charges located in the same field are exerted by electric forces of different magnitudes. The larger the magnitude of a charge is, the larger the force acting on it.
- When a charge is located in two different fields, the stronger a field is, the larger the force acting on the charge.
- Thus, when one describes the strength of an electric field at one point, one must divide the electric force acting by the magnitude of the charge.
- Electric field strength E is defined as force F per unit positive charge Q. Thus, $E = F/Q$ and $F = EQ$ –(1)
- It is a vector. Units: NC^{-1} or Vm^{-1}.

- But why positive charge?
- Show that the units of NC^{-1} and Vm^{-1} are equivalent.

Example 1

A charge of $+3.2\times10^{-19}$ C has a force of 5.7×10^{-7} N exerted on it when it is placed at point in an electric field. Determine the electric field strength at the point.

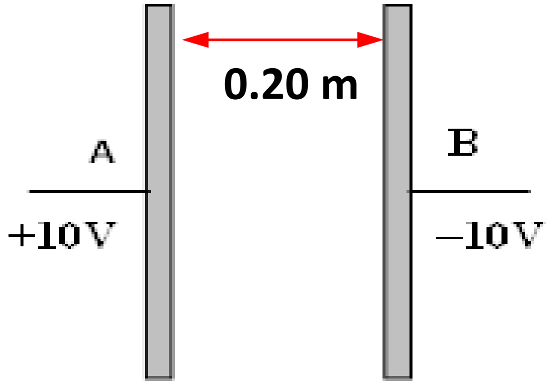
[$1.78\times10^{12} NC^{-1}$]

Uniform Electric Field Strength E

Between two parallel metal plates, the uniform electric field strength, E is given by $E = V/d$ –(2)

where V is the potential difference between two plates and d is the separation between two plates.

Example 2: Determine the electric field strength for the set up as shown below:



Answer:

$E = V/d =$

$20/0.2=100\ NC^{-1}$

Example 3

Two large horizontal metal plates are separated by 4 mm. The lower plate is at a potential of – 6 V.

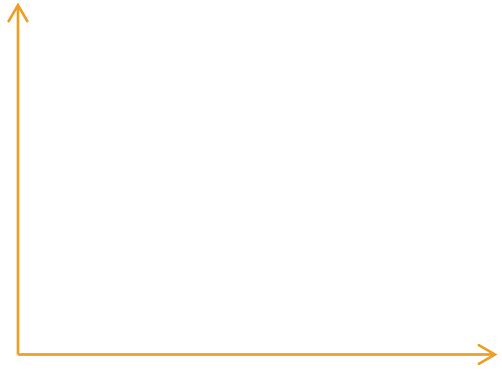
What potential should be applied to the upper plate to create an electric field of strength 5000 V m^{-1} upwards in the space between the plates?

A. +14V B. – 20 V C. + 26 V D. – 26 V

Graphical Representation

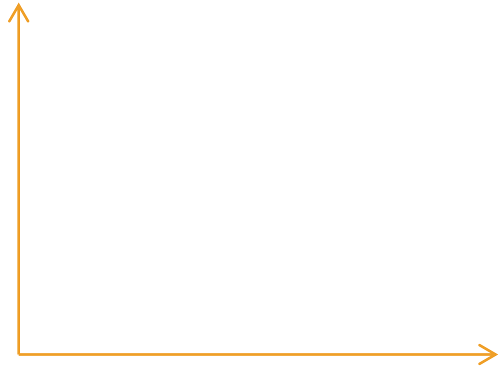
(1) Two plates are connected to a fixed p.d.

Sketch a graph to show the variation of Electric field strength with the separation between the plates.



(2) Two plates, separated by a fixed distance, are connected to a fixed p.d.

Sketch a graph to show the variation of Electric field strength with the distance from the positive plate.



Two types of motions in a uniform electric field

1) Linear motion with constant acceleration *a* …

when a charged particle is released in the field.

$a = F/m = Eq/m = Vq/(dm)$

since E and other quantities are constant, *a* is constant, the four kinematics equations can be used.

$v = u+at$

$v^2 = u^2 + 2as$

$s = ut + \frac{1}{2} a t^2$

$s = (v+u)/2 \times t$ –(3) to (6)

2) Projectile motion …

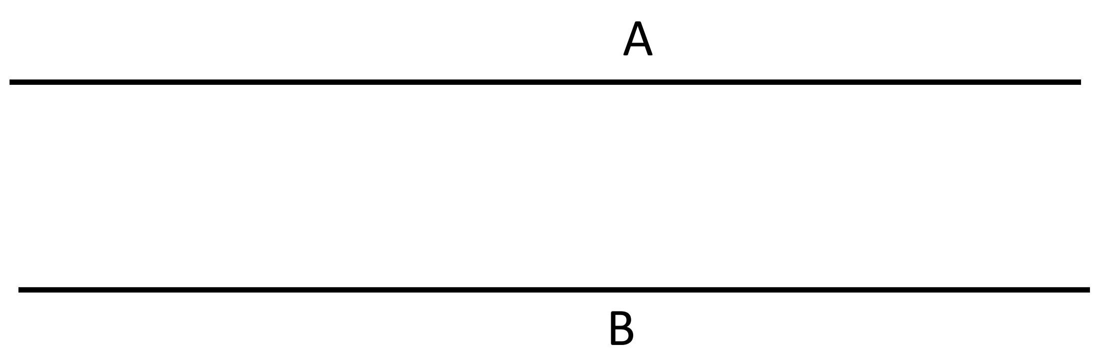
when a charged particle enters at right angle to the field with a horizontal velocity *u*. vertical velocity increases uniformly from zero due to the electric force. Thus, the four kinematics equations can be used for vertical motion. Horizontal velocity *u* remains unchanged as there is no resultant force along the horizontal direction.

Weight vs Electric force

In most cases, the weight of a charged particle is negligible compared to the electric force acting on it. Thus, unless it is stated that a charged particle remains stationary in the field, only electric force is taken into account when calculating the force acting on a charge.

Example 4: Two plates are arranged vertically, one on top of the another, as shown below. A negatively charged particle is held motionless within the plates.

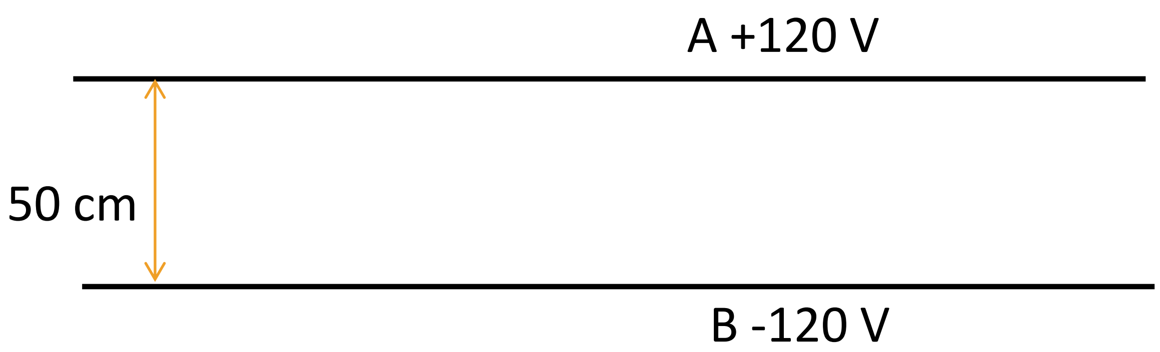
State, with a reason, if plate A or plate B is positively charged.



Example 5 – Linear motion

Two parallel plates, A and B, are connected to a potential of +120V and –120V, respectively. The plates are 50 cm apart.

($e = -1.60 \times 10^{-19}$ C ; $m_e = 9.11 \times 10^{-31}$ kg)



Determine:

(a) The electric field strength E

(b) Electric force F exerted on an electron placed in the field at a point 10 cm from plate B

(c) Acceleration of the electron at that point.

(d) Assuming an electron is released with a negligible initial speed at plate B, calculate its speed and kinetic energy when reaching plate A.

Solutions:

(a) The electric field strength E

$$E = V/d = 480\ Vm^{-1}$$

(b) Electric force F exerted on an electron placed in the field at a point 10 cm from plate B

$$F = Eq = 480 \times 1.6 \times 10^{-19}\ C = \ldots\ldots\ldots\ldots\ldots\ldots\ldots$$

* the strength is uniform regardless the distance

* the negative sign is omitted as it just represents the polarity of charge, not direction.

(c) Acceleration of the electron at that point.

$$a = F/m = 480 \times 1.6 \times 10^{-19}\ C / 9.11 \times 10^{-31}\ kg$$

$$= 8.43 \times 10^{13}$$

Solutions:

(d) Assuming an electron is released with a negligible initial speed at plate B, calculate its speed and kinetic energy when reaching plate A.

u=0, a = ……. from (c), s = 0.5 m

$v^2 = u^2 + 2as$

$v = 9.18 \times 10^6$

$\frac{1}{2} m v^2 = 3.84 \times 10^{-17}$ J

OR

Work done by electric force *F* to move charge *q* over *d* distance

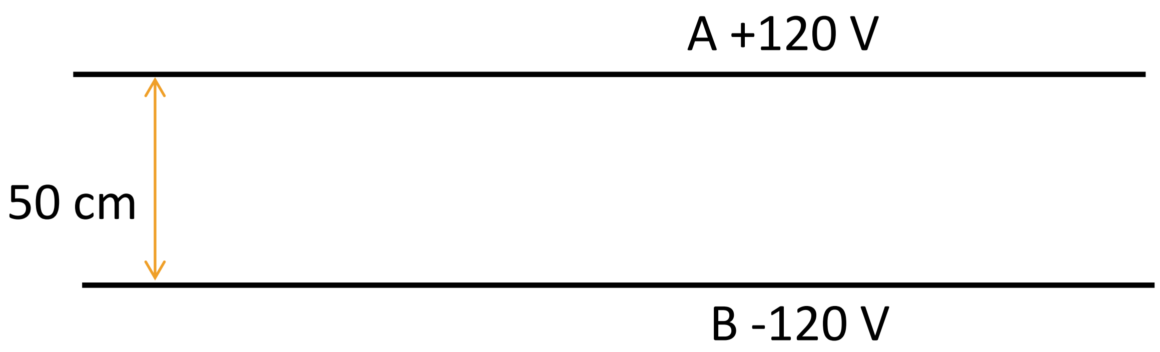
$= F d = (Eq)d = Vq =$ increase in KE $= \frac{1}{2} m (v^2 - u^2)$ –(7)

where E = V/d; potential difference, *V* = Ed

Example 6 – Projectile motion

Two parallel plates, A and B, are connected to a potential of +120V and –120V, respectively. The plates are 50 cm apart. An electron enters the field at right angles and at a point mid-way between the plates with an initial velocity of 3×10^{6} ms^{-1}. The length of each plate is 15 cm.

($e = -1.60 \times 10^{-19}$ C ; $m_e = 9.11 \times 10^{-31}$ kg)



Questions

(a) Show on the diagram above:

i. the path of the electron moving in the field

ii. the direction of the electric field strength

iii. the direction of the force acting on the electron

(b) Calculate

i. the acceleration of the electron when moving in the field

ii. the magnitude of velocity when it leaves the field [$5.17x10^6$]

iii. the vertical distance of the electron from the positively charged plate when it leaves the field. [0.395m]