Electric Fields

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Concept of an Electric Field

- Electric fields are regions which exist around particles and objects which have an electric charge.
- Another electric charge place in this region will experiences a force.
- Consider 2 particles which have electrical charges Q1 and Q2.
- The presence of Q1 in space modifies the property of the region of space around it by setting up an electric field.
- The region of the electric field is a region where an electric charge experiences a force.
- Particle Q2 which is in this electric field region will therefore experience a force. (electrostatic force)
- Likewise, Q2 can also be considered as setting up an electric field and Q1 being in contact with it will also experience the electrostatic force.
- Electric field is a vector quantity.

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2 kinds of electric charges

- Basically there are 2 types of charges – **POSITIVE & NEGATIVE CHARGE.**
- Unit for charge is Coulomb (C).

- Putting 2 like charged bodies close to each other causes repulsion, whereas 2 unlike charged objects attract each other.
  a.) + charge & + charge = repulsion
  b.) - charge & - charge = repulsion
  c.) + charge & - charge = attraction

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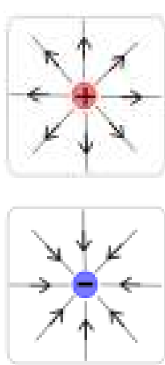
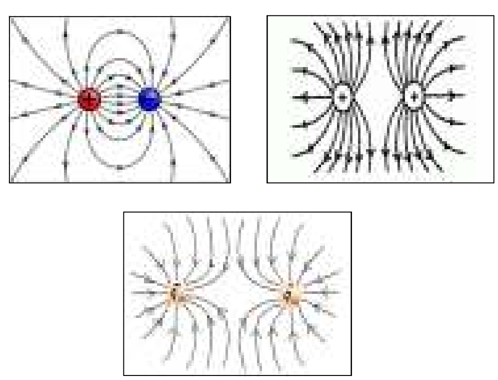
Representing an Electric Field

- An electric field is represented by imaginary electric lines of force which is also known as flux lines.
- The electric field direction is always directed away (radially) from the positive source charges and towards negative source charges.

a.) Isolated point charge



b.) Two point charges



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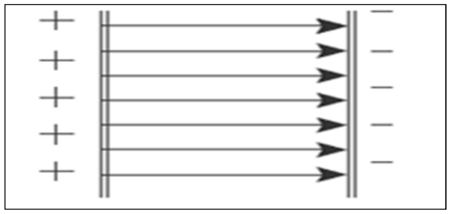
Representing an Electric Field

c.) Charged parallel metal plates



Every point within the charged parallel metal plates has the same field strength since the flux lines are of equal distance to each other.

The electric field direction is always directed away (uniformly) from the positive source charges and towards negative source charges.

Take note that for any electric field:
1.) Line of force / flux line start on a positive charge and end on a negative charge.
2.) The closer the line of force / flux lines, the stronger the field.

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Electric Field & Its Strength

- Electric field is a region where an electric charge experiences a force.
- Electric field strength at a point is defined as the force per unit positive charge place at that point.

$$E = \frac{F}{q}$$

F = Force (N)
q = + test charge (C)
E = Electric field strength (NC^{-1})

- Since there are 2 types of charge, thus the direction of force on these 2 charges in a given field would differs.
- To define the field and its direction, the direction of force on a positive charge has been chosen as the standard.
- Hence, the field direction is parallel to the force acting on a positive test charge, q and opposite to the force acting on a negative test charge, q.

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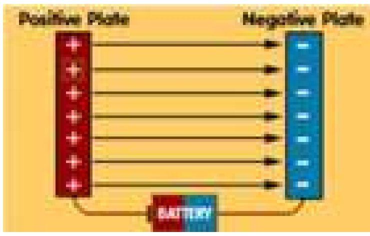
Field Strength of a Uniform Field between Charged Parallel Plates



- A uniform field between 2 parallel metal plates can be set up by connecting them to the terminals of a high voltage power supply.
- The strength of the field between them depends on 2 factors:
  - i.) The higher the voltage between them, the stronger the field.
  - ii.) The greater their separation, d, the weaker the field.
- These factors combined to give an equation **E = V/d**. (unit = Vm^{-1})
- Where 1 Vm^{-1} = 1 NC^{-1}

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Field Strength of a Uniform Field between Charged Parallel Plates

- To calculate the force F on charge Q in the uniform field between 2 parallel plates, we have to combine the 2 equations of electric field strength.

- $E = F / Q$
- $E = V / d$
- $F / Q = V / d$
- $F = VQ / d$

E = V/d (uniform field equation)
E = F/Q (universal equation)

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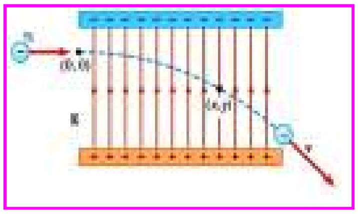
Motion of Charged Particles in a Uniform Electric Field



- A charge is projected perpendicularly into a uniform field.
- Consider the force acting on the electron. Upper plate is negative, lower plate is positive, thus the electron will be pushed downwards.
- If electron was stationary, it would accelerate directly downwards. However, this case the electron is moving to the right.
- As it moves, the horizontal velocity will not be affected by the force. However as it moves sideways, it will also accelerate downwards.
- Therefore it will follow a curved path as shown. A parabolic path.
- The force acting on the electron is the same at all points between the plates, and always in the same direction. (downwards for this case)
- Force due to gravity is negligible because it is small compared to electric force on the electron.
- The motion of this electron is actually similar to the motion of projectile under the influence of gravity.

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Example 1

- Two metal plates 5.0 cm apart have a potential difference of 1000 V between them. Calculate:
  (a) The strength of the electric field between the plates
  (b) The force on a charge of 5.0 nC between the plates

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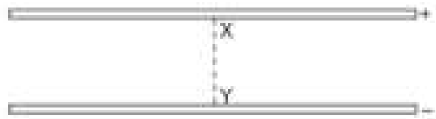
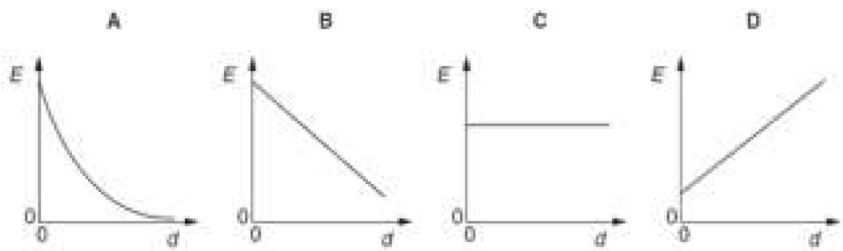
Example 2

An electric field exists in the space between two charged metal plates.



Which of the following graphs shows the variation of electric field strength *E* with distance *d* from X along the line XY?



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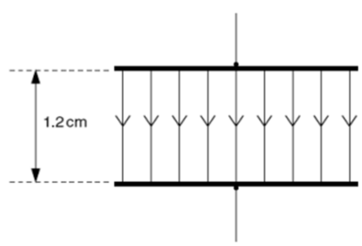
Example 3

- Two horizontal metal plates are situated 1.2 cm apart, as below. The electric field between the plates is found to be 3.0×10^4 N in the downward direction.



a.) On figure above, mark with a + the plate which is at the more positive potential.

b.) Calculate the potential difference between the plates.

c.) Determine the acceleration of an electron between the plates, assuming there is a vacuum between them.

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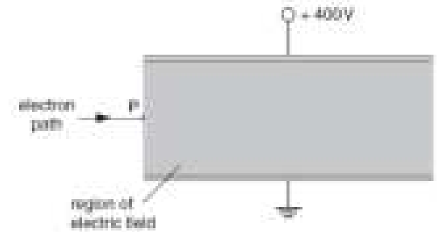
Example 4

- An electron travelling horizontally in a vacuum enters the region between two horizontal metal plates. The lower plate is earthed and the upper plate is at a potential of +400 V. The separation of plates is 0.80 cm. The electric field between the plates may assumed to be uniform and outside the plates to be zero.



a.) On figure above, draw an arrow at P to show the direction of the force on the electron due to the electric field between the plates.

b.) Sketch the path of the electron as it passes between the plates and beyond them.

c.) Determine the electric field strength E between the plates.

d.) Calculate the magnitude of the electric force on the electron and its acceleration.

e.) State and explain the effect, if any, of this electric field on the horizontal component of the motion of the electron.

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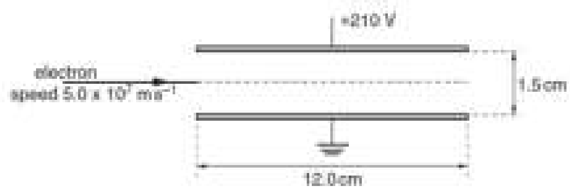
Example 5

- Two flat parallel metal plates, each of length 12.0 cm, are separated by a distance of 1.5 cm, as shown below. The space between the plates is a vacuum. The potential difference between the plates is 210 V. The electric field may be assume to be uniform in the region between the plates and zero outside this region.



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

b.)An electron initially travels parallel to the plates along the midway with speed 5.0 x 10^7 ms^{-1}. Determine the magnitude and direction of its acceleration.

c.) Calculate the time for the electron to travel a horizontal distance equal to the length of the plates.

d.) Use your answer in c.) to determine whether the electron will hit one of the plates or emerge from between the plates.

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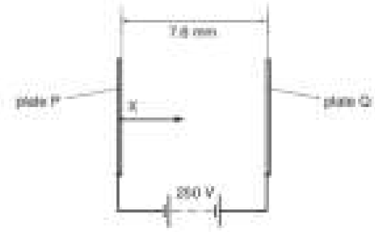
Example 6

- Two parallel plates P and Q are separated by a distance of 7.6 mm in a vacuum. There is a potential difference of 250 V between the plates as shown. Electrons are produced at X on plate P. These electrons accelerate from rest and travel to plate Q. The electric field between the plates may be assumed to be uniform.



a.) Determine the force on an electron due to the electric field.

b.) Show that the change in kinetic energy of an electron as it moves from plate P to Q is 4.0×10^{-17} J.

c.) Determine the speed on an electron as it reaches plate Q.

d.) The positions of the plates are adjusted so that the electric field between them is not uniform. The potential difference remains unchanged. State and explain the effect, if any, of this adjustment on the speed of an electron as it reaches plate Q.

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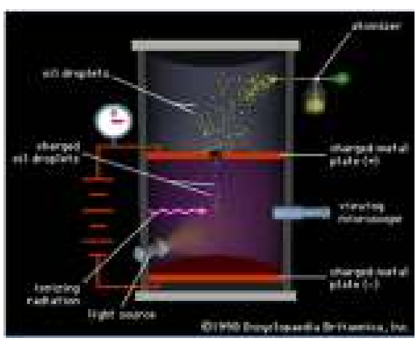
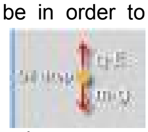
Milikan's Oil Drop Experiment



- What Millikan did was to put charge on a tiny drop of oil, and measure how strong an applied electric field had to be in order to stop the oil drop from falling.



- Millikan first determined the charge on a drop. Then he redid the experiment numerous times, each time varying the strength of the x-rays ionizing the air, so that differing numbers of electrons would jump onto the oil molecules each time.

He obtained various values for q. The charge q on a drop was always a multiple of -1.6 x 10 -19 C, the charge on a single electron.

$$qE = mg$$
$$q = \frac{mg}{E}$$

This number was the one Millikan was looking for, and it also showed that the value was quantized; the smallest unit of charge was this amount, and it was the charge on a single electron.

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Example 7

- A particle has a charge of 4.8×10^{-19} C. The particle remains at rest between a pair of horizontal, parallel plates having a separation of 15 mm. The potential difference between the plates is 660V.

  What is the weight of the particle?

  A 2.1×10^{-14} N

  B 2.1×10^{-15} N

  C 2.1×10^{-17} N

  D 1.1×10^{-23} N

- The diagram shows an oil droplet that has become charged by gaining five electrons. The droplet remains stationary between charged plates.

  

  What is the magnitude and direction of the electrostatic force on the oil droplet?

  A 5.0×10^{-15} N upwards

  B 5.0×10^{-15} N downwards

  C 5.0×10^{-13} N upwards

  D 5.0×10^{-13} N downwards

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