How Do Things Move Without Contact?

Reference: Heinemann Physics 12 4th Edition Chapters 1 – 3 Pages 1 – 106

Some resources

1. Electricity introduction.
https://www.youtube.com/watch?v=ZAFW4zdXpbY

2. How to measure electrical charge by Derek Muller
https://www.youtube.com/watch?v=DvlpAsDwXPY

3. Electricity (Hewitt drewit)
http://www.youtube.com/watch?v=0z9moyl8uZg&index=88&list=PL6Pw5RXSrjGNN6Kp1fq7X_rgoGu6qKM8j

4. Electric Potential (Hewitt drewit)
http://www.youtube.com/watch?v=nnLf090OPNg&index=91&list=PL6Pw5RXSrjGNN6Kp1fq7X_rgoGu6qKM8j

5. Electric Fields (Hewitt drewit)
https://www.youtube.com/watch?v=9nlflkR8tvs&index=89&list=PL6Pw5RXSrjGNN6Kp1fq7X_rgoGu6qKM8j

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Physics with Synno – Move Without Contact – Lesson 4

E.1 Electric Charge

Video: Electric Charge and Electric Fields

Charge, like energy, cannot be created nor destroyed, but it can be transferred from one object to another.

The number of electrons in an electrically neutral body is equal to the number of positive charges. This infers that the size of the charge on the electron is the same as the size of the charge on the proton. The **elementary charge**, e, is the magnitude of the charge on a proton or electron. It is the smallest charge found in nature.

Because it is so small, we have a measure of charge, called COULOMB (C), which is a standard number of elementary charges.

1 Coulomb = 6.25×10^{18} elementary charges, or e = 1.6×10^{-19} Coulomb.

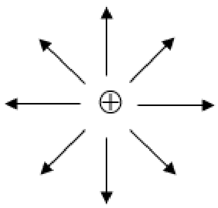
E.2 Electric Fields

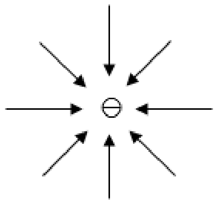
Video: Demonstrating Electric Field Lines
The effect of electric field

An electric field is the space around a charge, or a group of charges. We know if a field is present at a particular space because if we place a point charge there, it will experience a force. (Much the same as a point mass experiences a force in a gravitational field). The stronger the force, the stronger the field.

The magnitude of the field is the size of the force it causes to act on a charge of one coulomb. The direction of the field is defined as the direction of the force it causes to act on a positive charge.
An electric field **E** is the region around a charged body where another charged body would experience electric forces of attraction or repulsion. The direction of the electric field is defined as the direction of the force on a positive charge placed in the field.

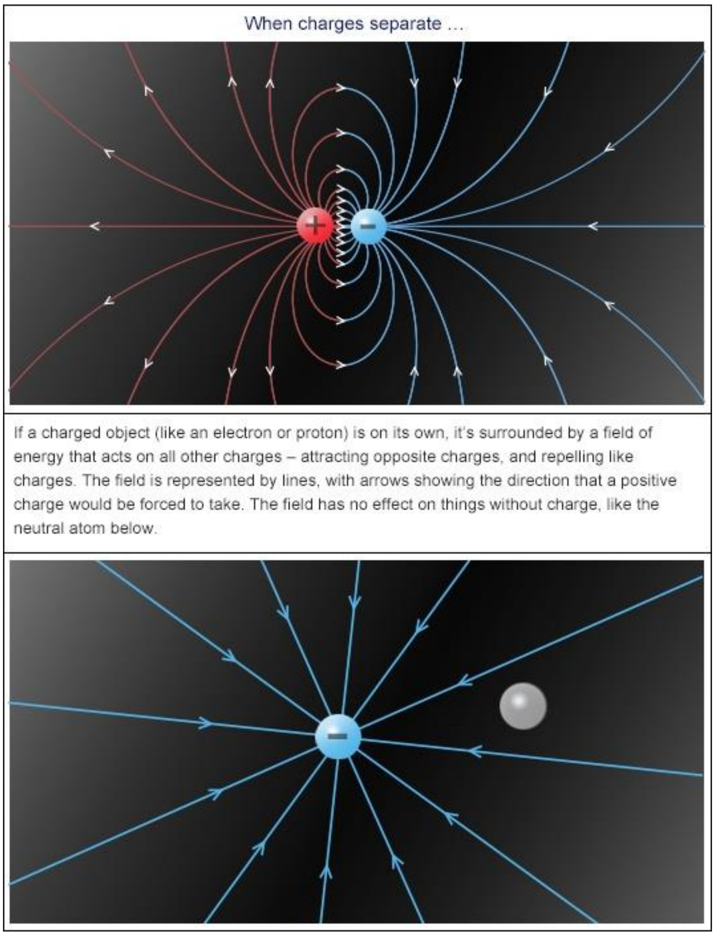
Electric field around positive point charge





Electric field around negative point charge

The strength of the field is indicated by the closeness of the field lines.



The more negative and positive charges you separate, the stronger the electric field that forms between and around them, and the more electrical energy that can be tapped. That separation of charge is what creates voltage, or potential difference.

E.2.1 Electric Forces

Electric forces are given by the product of the electric field and the quantity of charge.

$$F_E = q\,\mathbf{E}$$

Where F_E = electric force (N)
q = charge (C)
E = electric field strength (N / C)

Therefore, the direction and magnitude of the electric forces represent the direction and magnitude of the electric field at that point.

Example

Calculate the magnitude of the uniform electric field that creates a force of 9.00×10^{-23} N on a proton. $(q_p = +1.602 \times 10^{-19}\ C)$

$$E = \frac{F}{q} = \frac{9.00 \times 10^{-23}}{1.602 \times 10^{-19}} = 5.62 \times 10^{-5}\ NC^{-1}$$

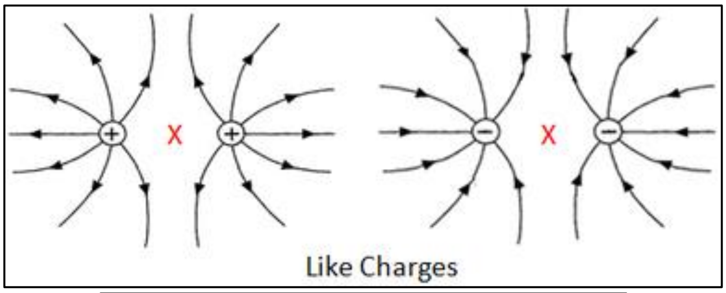
E.2.2 Field lines

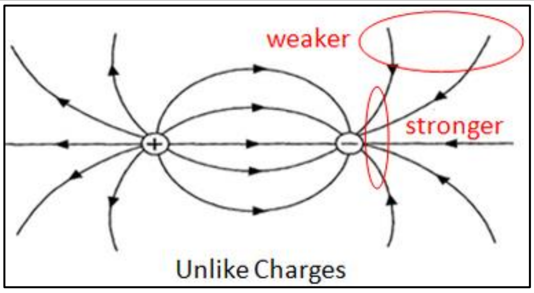
A field has both magnitude (strength) and direction. The magnitude of the field is the force per unit charge or mass. Fields are vectors, and more than one field will combine using vector addition principles.

It is really important to take care when drawing field lines. There are four basic principles that always need to be followed.

1. Field lines do not touch or cross each other
2. The arrow shows the direction of the field
3. The further the field lines are apart, the weaker the field.
4. Field lines start and end perpendicular to the surface.

Field lines are lines of force, they indicate the direction of the force acting on a unit positive charge at that point. For an isolated charge the lines extend to infinity, for two or more opposite charges we represent the lines as emanating from a positive charge and terminating on a negative charge.





Static electric fields are constant **fields**, which do not change in intensity or direction over time. They exert a force on charges or charged particles.

The strength of a static electric field is expressed in volts per meter (V/m). The strength of the natural electric field in the atmosphere varies from about 100 V/m in fair weather to several thousand V/m under thunderclouds.

Note: A single electric point charge, such as an electron or positron, in which all the electric field lines point inward for a net negative electric charge or away for a net positive electric charge can be referred to as an Electric Monopole.

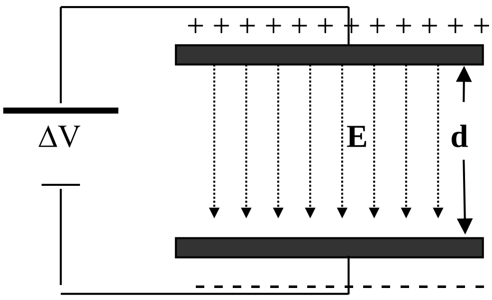
E.2.2.1 Electric Fields Between Charged Plates

In the region between parallel charged plates, the electric field **E** is uniform. The strength of the field depends on the potential difference between the plates and the distance between the plates.

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

Where E = electric field strength (V m^{-1})

V = potential difference (V)
d = distance between plates (m)



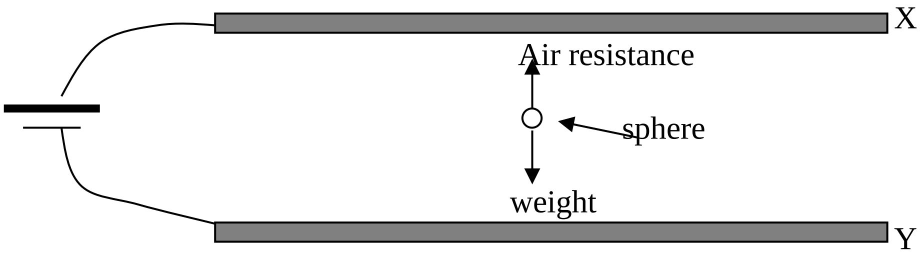
E.2.2.2 Millikan's Experiment

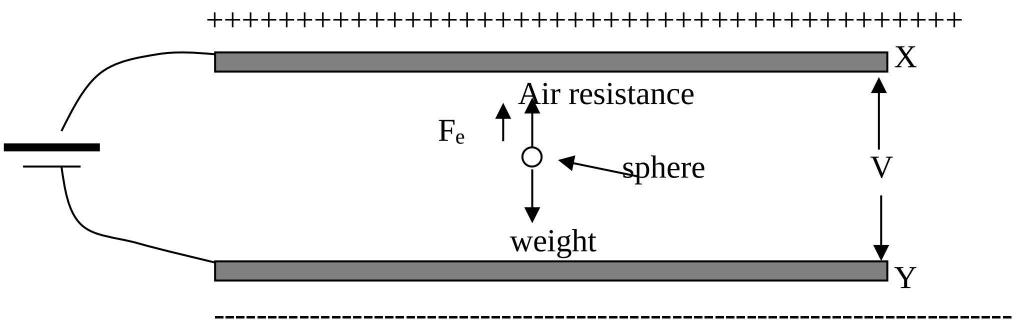
Video: Millikan Oil Drop Experiment
Charge of an Electron - Millikan's Oil Drop Experiment

In 1907 Robert Millikan set out to show that electric charge came in fundamental units (called the elementary unit). He set up two plates X and Y, which were charged by battery (B) to 8000V. He used small identical oil drops and observed their motion under a microscope.

The small spheres fell due to the force of gravity. An opposing upward force due to air resistance increases as the velocity of the spheres increases. In a short time the two forces equalised, this allowed him to calculate the weight from the measurements of their speed.

When the plates were charged by the battery, the speed changed as a result of the added electric force on the drops. Some drops fell even faster, others almost stopped or even rose. As the speed at which the drops fell was directly related to the total force on them, he was able to calculate the strength of the electric force. From this he was able to calculate the electric charge on the drop.





The direction of F_e depends on the charge on the sphere. Millikan found that the charge on the oil drop was always a multiple of a particular value. I.e. the charge on the oil drop is given by: q = ne, where n is a whole number, and e was 1.6×10^{-19}C. Millikan suggested that 'e' is the charge on an electron. Millikan argued that an oil drop got its charge by gaining or losing electrons, hence the 'e' charge on the drop had to be a whole number times the charge on one electron.
In 1909 Millikan determined that

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

E.2.3 Electrical Potential

When a current passes through a resistor, the resistor gets hot. Electrical energy is being converted to thermal energy. Electrical energy can also be converted into mechanical energy.

If q of charge passes through a potential difference of V, the work done by the electrical force is

$$W = q\,V$$

Where W is the work done (J)

Q is the charge (C)

V is the electric potential ($J\,C^{-1}$) or Volts (V)

So if it takes V joules of energy to get one (1) coulomb of charge form one place to another, then it takes V q joules to get q coulomb from one place to another

As the current is the rate at which charge is moving, the total charge q = I t.

$$\Rightarrow \quad W = V\,i\,t.$$

If we combine the equations $E = \frac{V}{d}$ and W = q V

We get $W = q\,E\,d$

Example

A student sets up a parallel plate arrangement so that one plate is at a potential of 12.0 V and the other earthed plate is positioned 0.50 m away. Calculate the work done to move a proton a distance of 10.0 cm towards the negative plate. $(q_p = +1.602 \times 10^{-19}\ C)$

$E = \frac{V}{d} \qquad W = q\,E\,d$

$E = \frac{12}{0.50} = 24 \qquad W = 1.602 \times 10^{-19} \times 24 \times 0.10 = 3.84 \times 10^{-19}\,J$

Text Questions: Page 39 All Questions