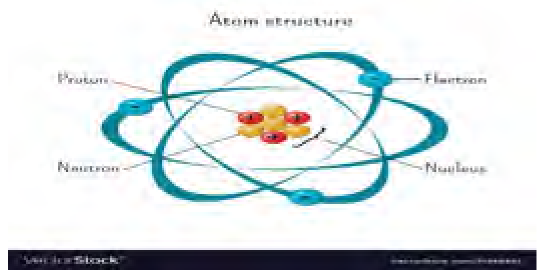
Textbook Chapter	Student Learning Outcomes (SLOs)
Ch. 11: Static Electricity	Sect 1: Electric Charge Students are expected to: - Explain why like charges repel each other and unlike charges attract each other. - Describe how the transfer of electrons can create a net positive or negative charge - Compare the properties of insulators and conductors. Sect 2: Electrostatic Force Students are expected to: - Explain the relationship between electrostatic force and charge. - Describe charging by induction and charging by conduction. - Understand that Coulomb's Law relates the amount of charge on objects and the distance between them to the electrostatic force.

Static electricity

Define static electricity: An object can store electric charges that cannot flow. These charges are called STATIC CHARGES.

A Microscopic View of Charge: All the materials made up of tiny particles called ATOM.



An atom contains electrons, protons and neutrons

Electrons orbit the nucleus

Protons and neutrons are collectively known as nucleons

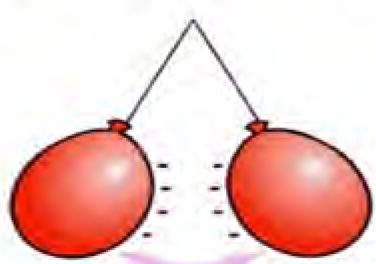
Neutrons have no charge, electrons are negatively charged and protons are positively charged.

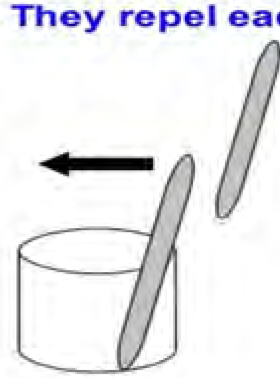
Since an atom is neutral the number of protons is equal to the number of electrons.

a) Like charges repel each other :-

Activity :- Inflate two balloons and hang them in such a way that they do not touch each other. Rub both the balloons with a piece of woollen cloth and release them. They repel each other.

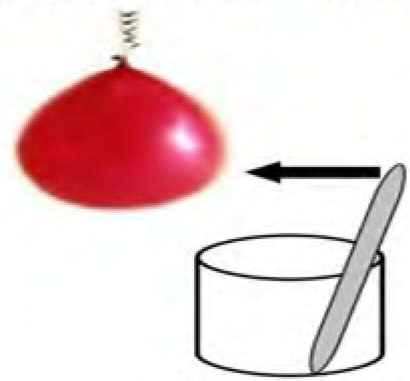
Activity :- Rub a plastic refill with polythene and place it in a glass tumbler. Rub another plastic refill with polythene and bring it near the charged refill. They repel each other.





b) Unlike charges attract each other :-

Activity :- Charge a plastic refill by rubbing with polythene and keep it in a glass tumbler. Charge an inflated balloon by rubbing with a piece of woolen cloth and bring it near the charged plastic refill. They attract each other.



Transfer of electrons

With the addition of energy, the outer electrons of an atom can be removed from the atom. An atom that is missing electrons has a net positive charge, and, consequently, any matter that has electron-deficient atoms is positively charged. The freed electrons can remain unattached, or they can become attached to other atoms, resulting in atoms with net negative charge.

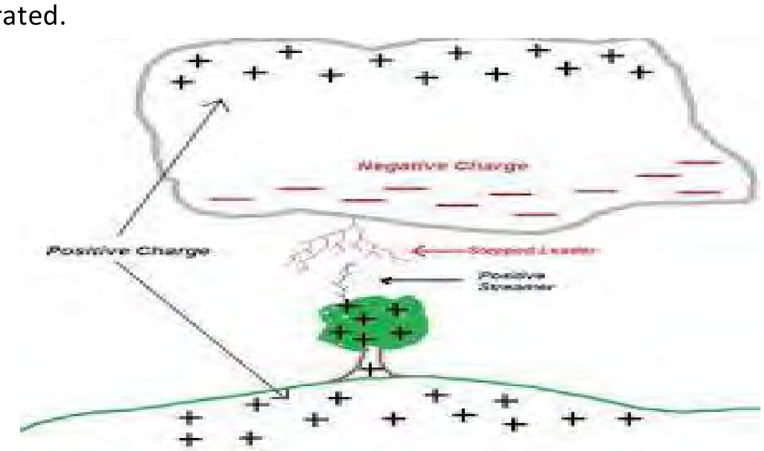
Separation of charge

Rubbing two neutral objects together, each object can become charged. For instance, when you rub rubber shoes on a wool rug, the energy from the rubbing removes outer electrons from

atoms in the wool, and they transfer to the rubber shoe, The extra electrons on the shoe result in a net negative charge on the shoe. The electrons missing from the wool rug result in a net positive

charge on the rug. The combined total charge of the two objects remains the same. Charge is conserved, which is one way of saying that individual charges never are created or destroyed. A net positive or negative charge means that electrons have been transferred.

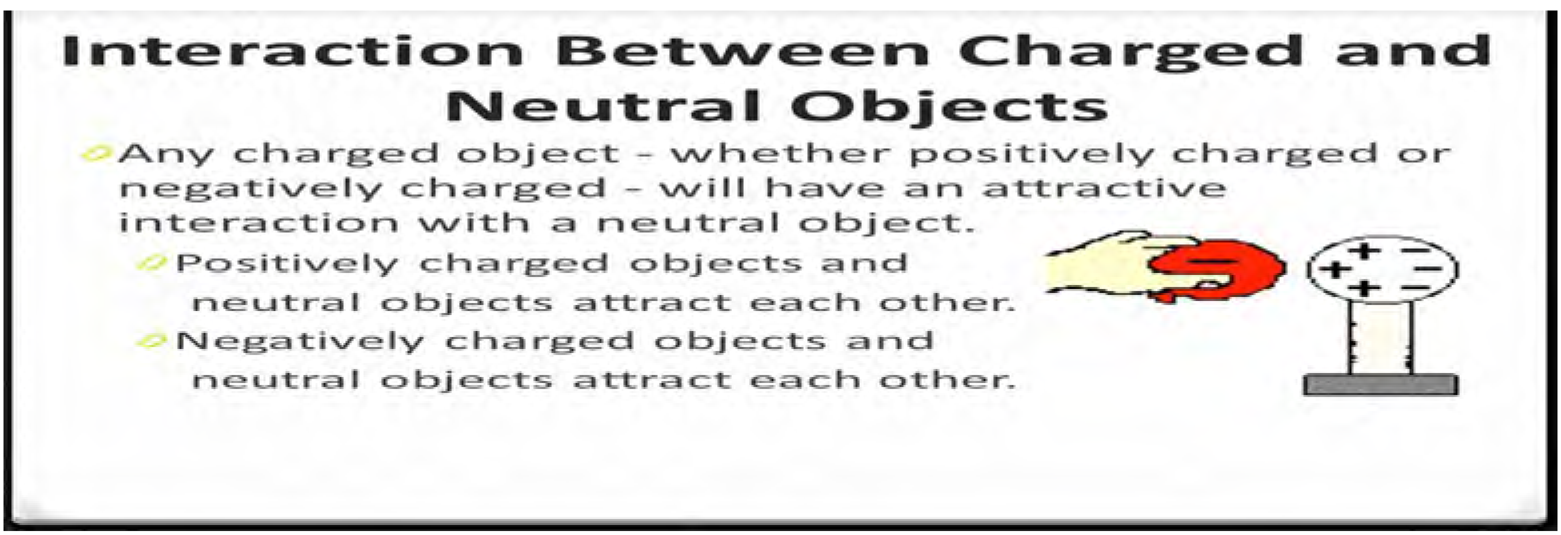
Processes inside a thundercloud can cause the cloud bottom to become negatively charged and the cloud top to become positively charged. Electric charge can be transferred from a road to the car traveling on it. are not created, but separated.



Conductors and Insulators

Conductors	***Insulators***
Conductors are materials that allow electric charges to flow through them easily. *They have large number of free electrons that can move easily from atom to atom* *e.g. metals (e.g. copper, aluminum, steel, iron) etc..*	*Insulators are materials that do not allow electric charges to flow through them easily.* *The electrons are tightly bound to the atoms and they are not free to move.* *e.g. plastic, rubber, wood, glass etc..*

Metals most metals are good conductors. This is because at least one electron of each atom of a metal can be removed easily. These electrons no longer remain with any particular atom, but move through the metal as a whole.



SECTION 1 REVIEW

1. Mandarin the investigations with tape described in this section, how could you find out which strip of tape, B or T, is positively charged?

Answer: Bring a positively charged glass rod near the two strips of tape. The one that is repelled by the rod is positive.

2. Charged Objects After you rub a comb on a wool sweater, you can use the comb to pick up small pieces of paper. Why does the comb lose this ability after a few minutes?

Answer: The comb loses its negative charge to its surroundings and becomes neutral once again.

3.Types of Charge A pith ball is a small sphere made of a light material, such as plastic foam, that is often coated with a layer of graphite or aluminum paint. How could you determine whether a pith ball suspended from an insulating thread is neutral, charged positively, or charged negatively?

Answer: Bring an object of known charge, such as a negatively

charged hard rubber rod, near the pith ball. If the pith ball is repelled, it has the same charge as the rod. If it is attracted, it may have the opposite charge or be neutral. To find out which, bring a positively charged glass rod near the pith ball. If they repel, the pith ball is positive; if they attract, the pith ball must be neutral.

4. Charge Separation You can give a rubber rod a negative charge by rubbing the rod with wool. What happens to the charge of the wool? Why? Answer: The wool becomes positively charged because it gives up electrons to the rubber rod.

5. Net Charge An apple contains approximately 10^{26} charged particles. Why don't two apples repel each other when they are brought together?

Answer: An apple contains equal numbers of positive and negative charges, so it is neutral.

6. Charging a Conductor Suppose you hang a long metal rod from silk threads so that the rod is electrically isolated. You then touch a charged glass rod to one end of the metal rod. Describe the charges on the metal rod.

Answer: The glass rod attracts electrons the metal rod, so the metal becomes positively charged. The charge is distributed uniformly along the rod.

7. Charging by Friction You can charge a rubber rod negatively by rubbing it with wool. What happens when you rub a copper rod with wool?

Answer: Because the copper is a conductor, it remains neutral

as long as it is in contact with your hand.

8. Critical Thinking Some scientists once proposed that electric charge is a type of fluid that flows from objects with an excess of the fluid to objects with a deficit. How is the current two-charge model more accurate than the single-fluid model?

Answer: The two-charge model can better explain the phenomena of attraction and repulsion. It also explains how objects can become charged when they

are rubbed together.

Electrostatic Force

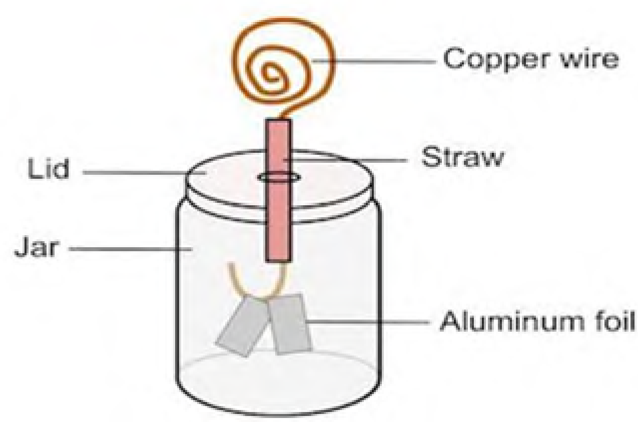
Demonstrating forces

- • There are two kinds of electric charge: positive and negative.
- • Like charges repel; unlike charges attract.
- • Charges exert forces on other charges at a distance.
- • The force is stronger when the charges are closer together

Electroscope

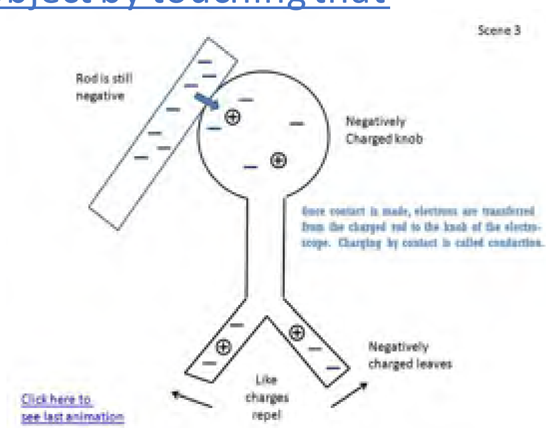
Electroscope

Is advice which is used to determine a charge of an object consists of a metal knob connected by a metal stem to two thin, lightweight pieces of metal foil, called leaves, that are enclosed to eliminate air currents.



charging by conduction

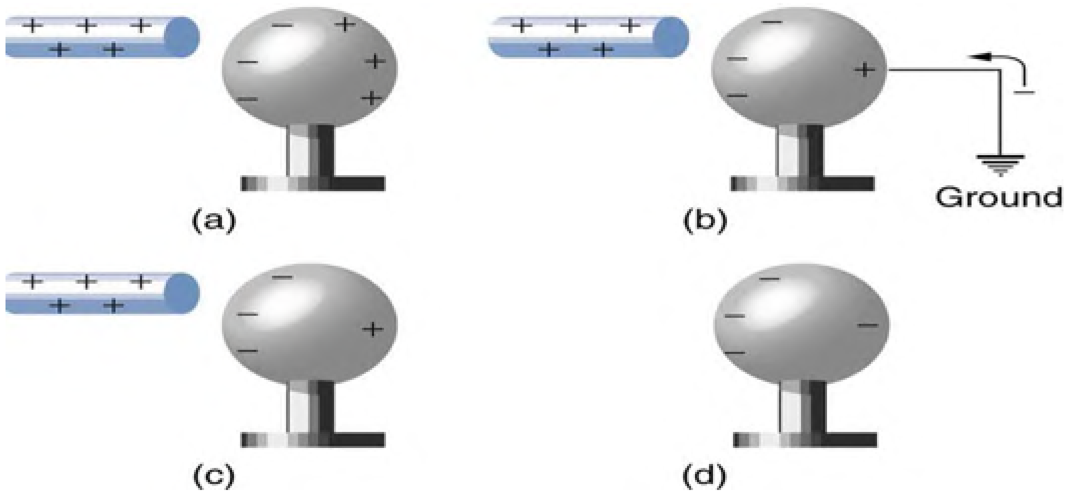
charging by conduction :charging a neutral object by touching that object with a charged object.

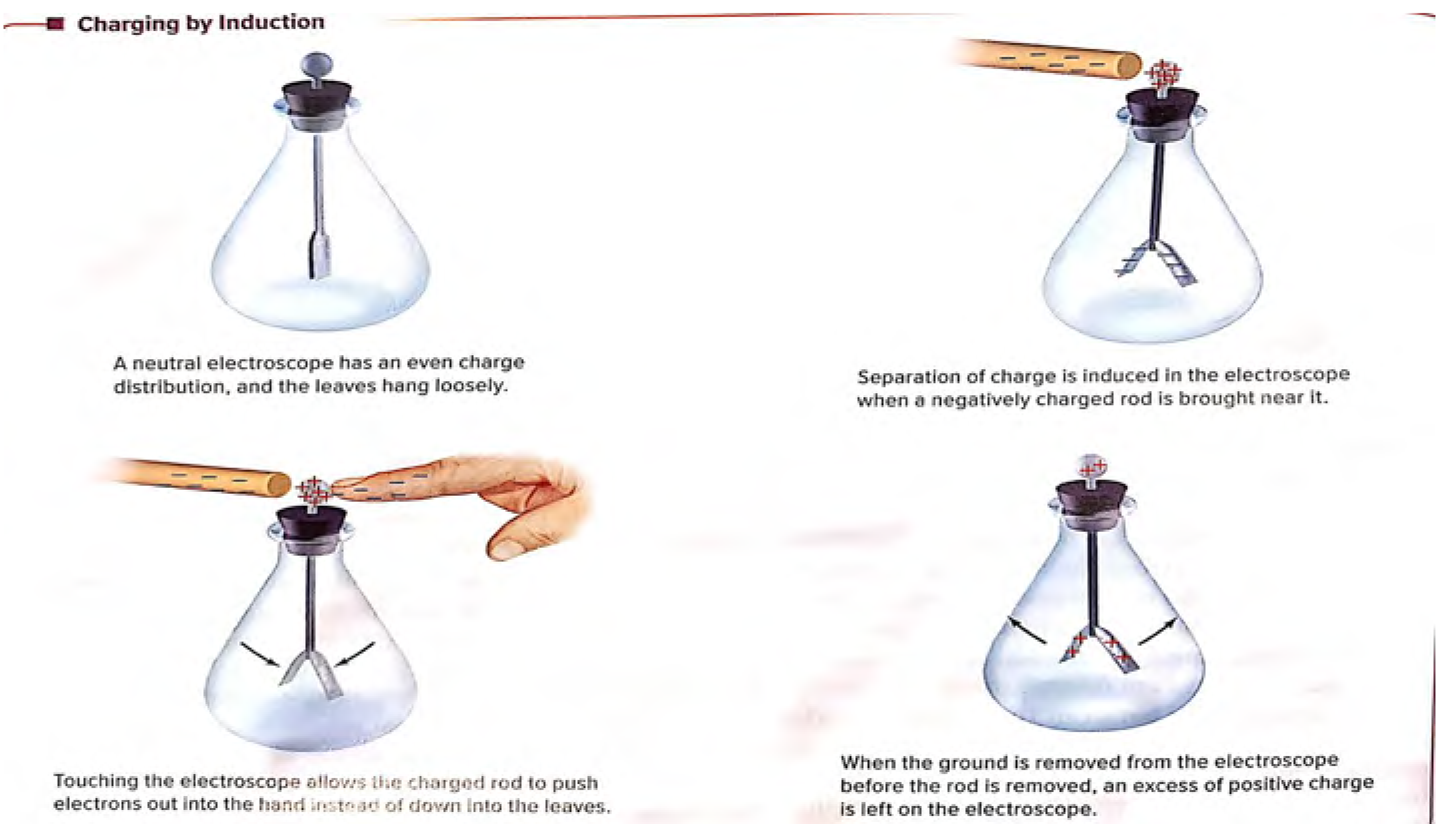


Charging by induction

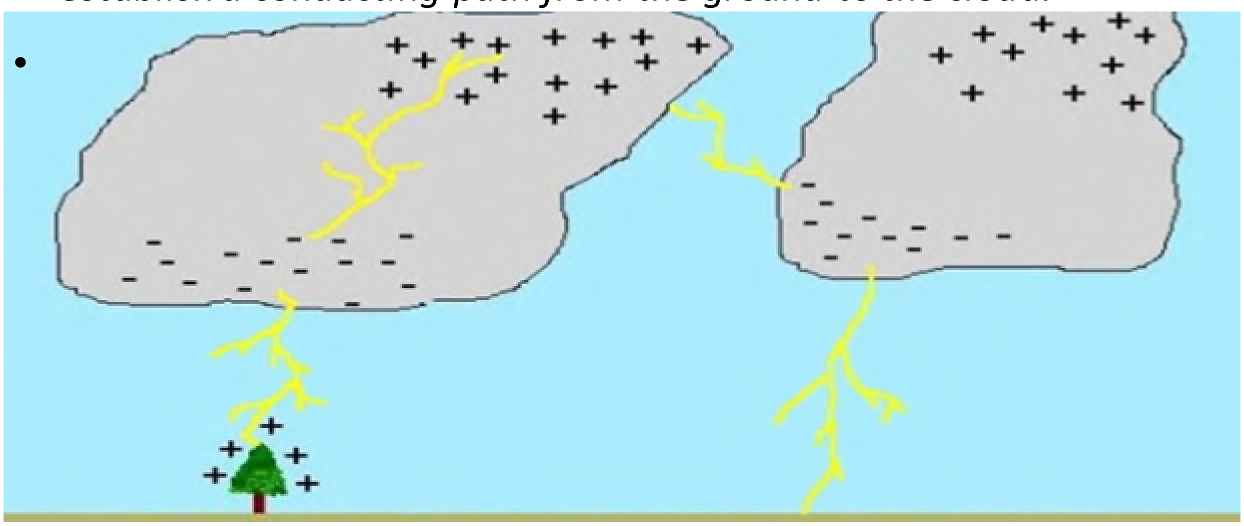
charging by induction :process of charging a neutral object by bringing a charged object near it.

The result of charging by induction is spheres with charges that are equal in magnitude but opposite in sign. No charges were added to the spheres from the rod





Lightning

- *_The negative charges at the bottoms of thunderclouds can cause the separation of charges on Earth. Negative charges in the ground below a cloud are repelled from Earth's surface. The forces between the charges in the cloud and those on Earth's surface can break molecules in the air into positively and negatively charged particles. These charged particles are free to move, and they establish a conducting path from the ground to the cloud.*
- 

Coulomb's Law

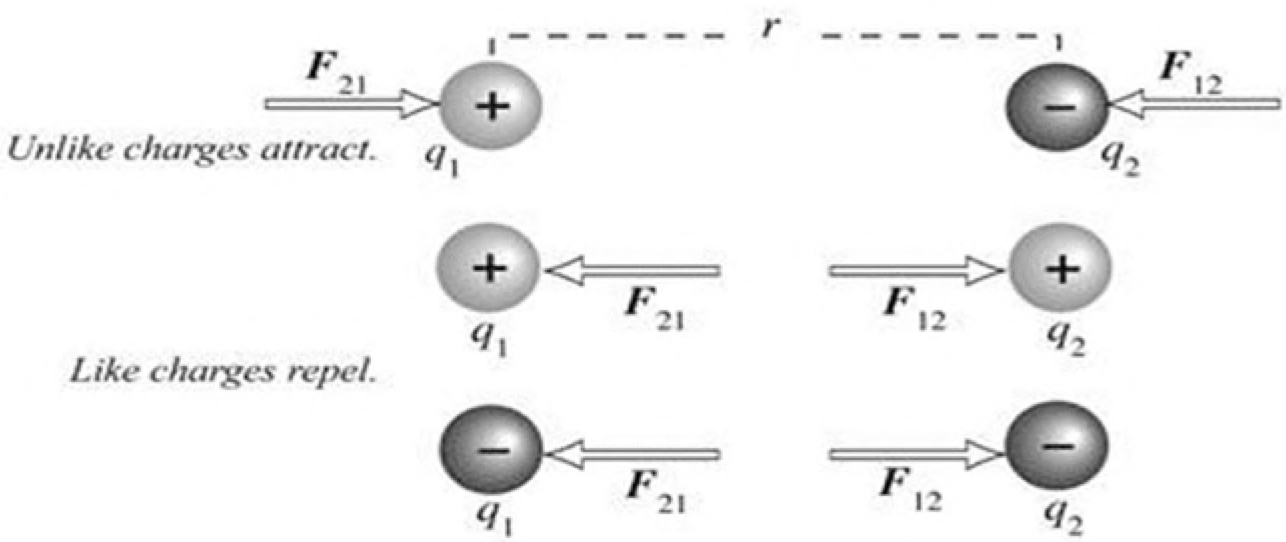
COULOMB'S LAW

The force between two charges is equal to a constant times the product of the two charges, divided by the square of the distance between them

Electrostatic Force - Coulomb's Law

$$F = k\frac{q_1 q_2}{r^2}$$

- F = electrostatic force
- q = electric charge
- r = distance between charge centers
- k = Coulomb constant $9.0 \times 10^9\ N \cdot m^2/C^2$



The electron and proton of a hydrogen atom are separated, on average, by a distance of about 5.3×10^{-11} m. Find the magnitudes of the electric force and the gravitational force that each particle exerts on the other.

Given:

$r = 5.3 \times 10^{-11}$ m

$k_C = 8.99 \times 10^9\ N \cdot m^2/C^2$

$m_e = 9.109 \times 10^{-31}$ kg

$m_p = 1.673 \times 10^{-27}$ kg

$q_e = -1.60 \times 10^{-19}$ C

$q_p = +1.60 \times 10^{-19}$ C

$G = 6.67 \times 10^{-11}\ N \cdot m^2/kg^2$

Choose an equation(s) or situation:

Find the magnitude of the electric force using Coulomb's law and the magnitude of the gravitational force using Newton's law of gravitation (introduced in Chapter 7).

$$F_{electric} = k_C \frac{q_1 q_2}{r^2} \qquad F_g = G \frac{m_e m_p}{r^2}$$

Applications of Electrostatic Forces

example, tiny paint droplets can be charged by induction. When sprayed on automobiles and other objects, the droplets repel each other and paint spreads uniformly. Photocopy machines take advantage of static electricity to place black toner on a page so that a precise reproduction of the original document is achieved. Laser printers use static electricity in a similar way. Toner particles are attracted to charged characters on a drum.

Electrostatic forces also are used to collect emissions in smokestacks.

Emissions are charged when they are released from combustion processes.

They are then attracted to collectors that have been given an opposite charge. A liquid spray removes the collected emissions safely. Electrostatic precipitators make a huge difference in the amount of pollution released into the air.

SECTION 2 REVIEW

ADDITIONAL IN-CLASS EXAMPLE

Use with Example 1.

Problem Use the configuration of charges shown in Example Problem 1 but move sphere C to a position that is 5.0 cm directly below sphere B and let the charge on C be +2.0 μC. Ask students to find the net force on sphere B.

Response Determine the force from sphere C on sphere B.

$$F_{C \text{ on } B} = \frac{Kq_Bq_C}{r_{BC}^2}$$

$$= \frac{\left(9.0\times10^9 \frac{N\cdot m^2}{C^2}\right)(3.0\times10^{-6}\ C)(2.0\times10^{-6}\ C)}{(5.0\times10^{-2}\ m)^2}$$

$$= 2.2\times10^1\ N$$

Spheres C and B have opposite charges so they experience an attractive force. Therefore, the force of C on B is downward. The net force F_{net} on sphere B is the vector sum of $F_{A \text{ on } B}$ and $F_{C \text{ on } B}$, so the magnitude of F_{net} is

$$F_{net} = \sqrt{F_{A \text{ on } B}^2 + F_{C \text{ on } B}^2}$$

$$= \sqrt{(1.0\times10^2\ N)^2 + (2.2\times10^1\ N)^2}$$

$$= 1.0\times10^2\ N.$$

Determine the angle of the force:

$$\tan\theta = \frac{F_{C \text{ on } B}}{F_{A \text{ on } B}}$$

$$= \tan^{-1}\left(\frac{2.2\times10^1\ N}{1.0\times10^2\ N}\right)$$

$$= 12°$$

$F_{net} = 1.0\times10^2$ N, 12° below the *x*-axis.

PHYSICS CHALLENGE ACTIVITY

Calculate Charge You can have students suspend two balloons from strings and charge those balloons. Then have students make careful measurements of the balloons' separation distance *r* and separation angle *θ*. Ask students to calculate the charge *q* on each balloon. The force components F_T of the tension in each string are $F_T \cos\left(\frac{\theta}{2}\right) = mg$ and $F_T \sin\left(\frac{\theta}{2}\right) = \frac{Kq^2}{r^2}$, so $q = \sqrt{\frac{mgr^2}{K}\tan\left(\frac{\theta}{2}\right)}$. Use $K = 9.0\times10^9\ N\cdot m^2/C^2$. The result may be order-of-magnitude accurate.

AL **Kinesthetic**

1- MAINIDEA:Describe the relationship between the magnitude of the electrostatic force, the charge on two objects, and the distance between the objects. What is the equation for this relationship?

Answer: The electrostatic force is proportional to the product of the two charges and inversely proportional to the square of the distance between them.

2- Force and Charge How are electrostatic force and charge related? Describe the force when the charges are like charges and the force when the charges are opposite.

Answer: Electrostatic force is directly related to each charge. It is repulsive between like charges and attractive between opposite charges

3- Force and Distance How are electrostatic force and distance related? How would the force change if the distance between two charges were tripled?

Answer: Electrostatic force is inversely related to the square of the distance between charges. If the distance is tripled, the force will be one-ninth as great.

4- Charging by Induction In an electroscope being charged by induction, what happens when the charging rod is moved away before the ground is removed from the knob?

Answer: The electroscope remains neutral

5- Electroscopes Why do the leaves of a charged electroscope rise to a certain angle and no farther?

Answer:

As the leaves move farther apart, the electrostatic force between them decreases until it is balanced by the gravitational force pulling down on the leaves.

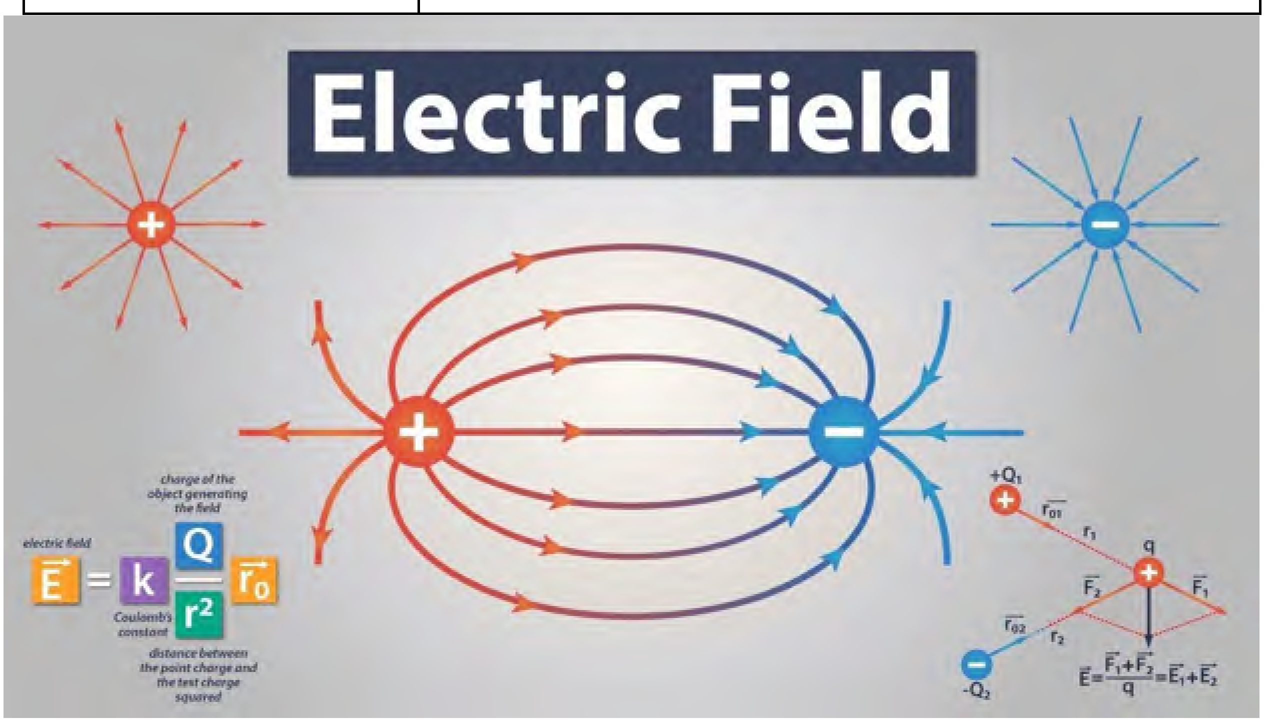
6- Attraction of Neutral Objects What properties explain how both positively charged objects and negatively charged objects can attract neutral objects?

Answer: Charge separation, caused by the attraction of opposite charges and the repulsion of like charges, moves the opposite charges in the neutral body closer to the charged object and the like charges farther away. The inverse relation between force and distance means that the nearer, opposite charges will attract more than the more distant, like charges will repel. The overall is attraction.

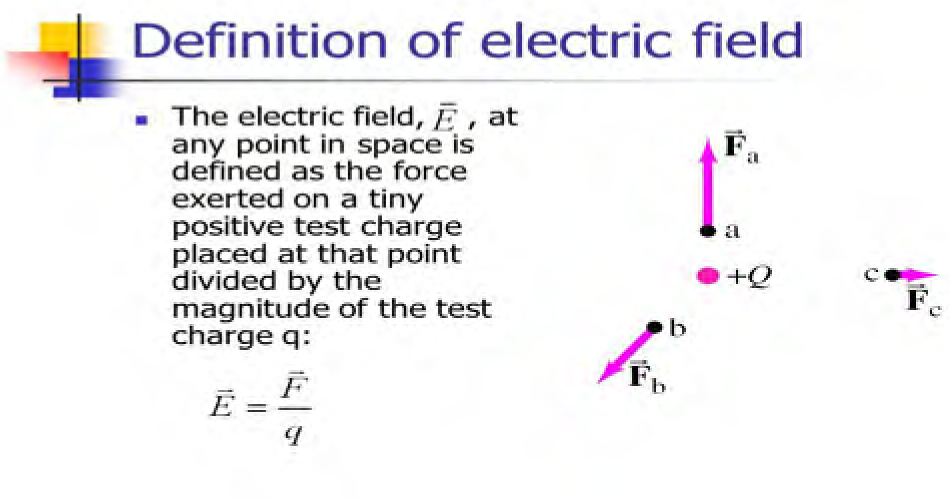
7-Charging an Electroscope. How can you charge an electroscope positively using a positively charged rod? Using a negatively charged rod?

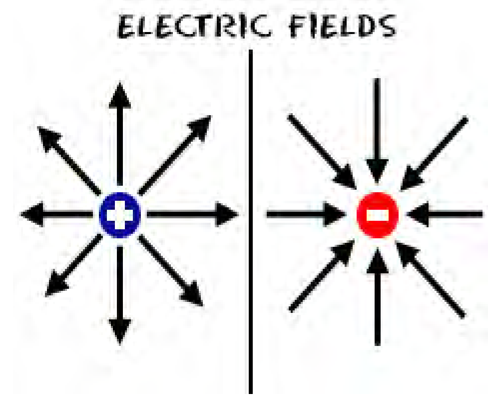
Answer: To charge positively, touch the rod to the electroscope. To charge negatively, bring the rod near the electroscope. Ground the electroscope; remove the ground and then remove the rod.

Text book chapter	Learning outcomes
Ch. 12: Electric Fields	Sect 1: Measuring Electric Fields Students are expected to: - Define electric field - Solve problems involving electric field strength. - Model electric fields using electric field lines. Sect 2: Applications of Electric Fields Students are expected to: - Calculate the electric potential difference between two-point charges and in a uniform electric field - Explain Millikan's oil drop experiment and how it allowed him to determine the charge of an electron. - Explain what happens when an electric field is near a conductor. - Describe the properties of capacitors and solve problems involving capacitance.



Electric Fields and Forces

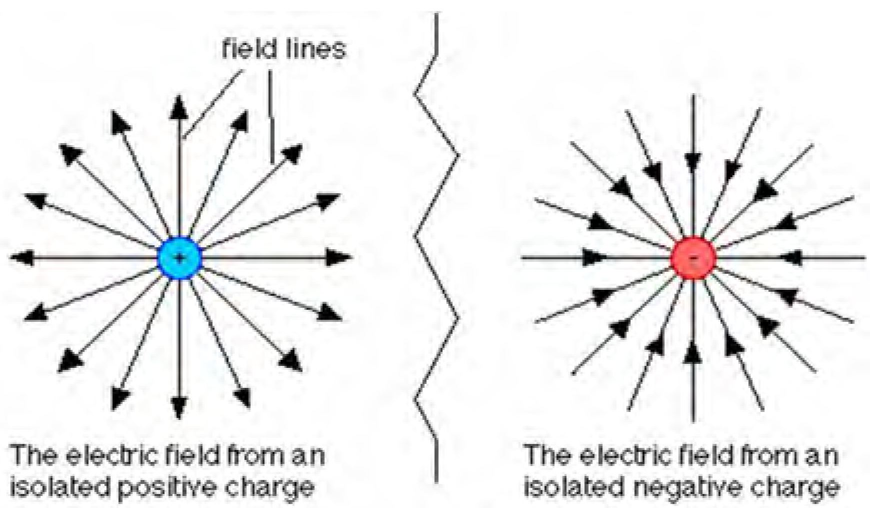




The strength of an electric field:

By definition, the are "LINES OF FORCE" Some important facts: An electric field is a vectoral ways is in the direction that a POSITIVE "test" charge would move The amount of force PER "test" charge.

If you placed a 2nd positive charge (test charge), near the positive charge shown above, it would move AWAY. If you placed that same charge near the negative charge shown above it would move TOWARDS.



ELECTRIC FIELD STRENGTH

The strength of an electric field is equal to the force on a positive test charge divided by the strength of the test charge.

$$E = \frac{F_{\text{on } q'}}{q'}$$

to solve electric field strength problems.

Refer to example problems 1 and 2 on pages 314/315 of textbook.

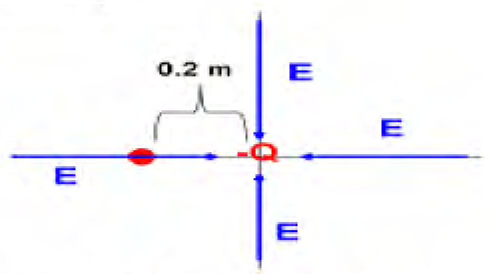
Example

A -4x10^{-12}C charge Q is placed at the origin. What is the magnitude and direction of the electric field produced by Q if a test charge were placed at x = -0.2 m ?

$$E = \frac{kQ}{r^2} = 8.99x10^9 \frac{(4x10^{-12})}{.2^2}$$

$E_{mag} =$ **0.899 N/C**

$E_{dir} =$ **Towards Q to the right**



Remember, our equations will only give us MAGNITUDE. And the electric field LEAVES POSITIVE and ENTERS NEGATIVE.

Example

An electron and proton are each placed at rest in an external field of 520 N/C. Calculate the speed of each particle after 48 ns

What do we know
m_e=9.11 x 10^{-31} kg
m_p= 1.67 x10^{-27} kg
q_{both}=1.6 x10^{-19} C
v_o = 0 m/s
E = 520 N/C
t = 48 x 10^{-9} s

$$\vec{E} = \frac{\vec{F}_E}{q} \qquad 520 = \frac{\vec{F}_E}{1.6x10^{-19}}$$

$F_E =$ **8.32 x10^{-19} N**

$$F_{Net} = ma \qquad F_E = F_{Net}$$

$F_E = m_e a \rightarrow (9.11x10^{-31})a =$ **9.13x10^{13} m/s/s**

$F_E = m_p a \rightarrow (1.67x10^{-27})a =$ **4.98 x10^{10} m/s/s**

$$v = v_o + at$$

$v_e = a_e(48x10^{-9}) =$ **4.38 x10^6 m/s**

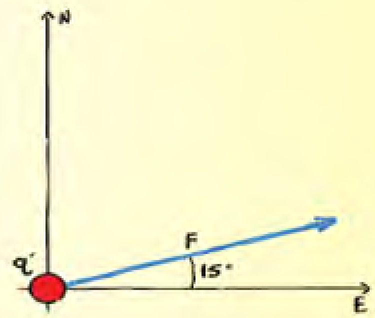
$v_p = a_p(48x10^{-9}) =$ **2.39 x10^3 m/s**

EXAMPLE 1

ELECTRIC FIELD STRENGTH Suppose that you are measuring an electric field using a positive test charge of 3.0×10^{-6} C. This test charge experiences a force of 0.12 N at an angle of 15° north of east. What are the magnitude and direction of the electric field strength at the location of the test charge?

1 ANALYZE AND SKETCH THE PROBLEM

- Draw and label the test charge, q'.
- Show and label the coordinate system centered on the test charge.
- Diagram and label the force vector at 15° north of east.



KNOWN

$q' = 3.0\times10^{-6}$ C

$\boldsymbol{F} = 0.12$ N at 15° N of E

UNKNOWN

$\boldsymbol{E} = ?$

2 SOLVE FOR THE UNKNOWN

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

$$= \frac{0.12\text{ N}}{3.0\times10^{-6}\text{ C}}$$ ◄ Substitute $F = 0.12$ N, $q' = 3.0\times10^{-6}$ C.

$$= 4.0\times10^{4}\text{ N/C}$$

The force on the test charge and the electric field are in the same direction.

$\boldsymbol{E} = 4.0\times10^{4}$ N/C at 15° N of E

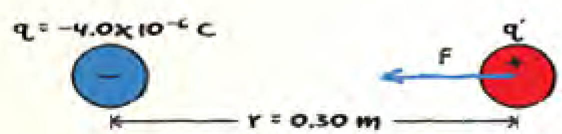
EXAMPLE 2

ELECTRIC FIELD STRENGTH AND COULOMB'S LAW What is the magnitude of the electric field at a point that is 0.30 m to the right of a small sphere with a net charge of -4.0×10^{-6} C?

1 ANALYZE AND SKETCH THE PROBLEM

- Draw and label the sphere with its net charge (q) as well as the test charge (q'), 0.30 m away.
- Show and label the distance between the charges.
- Diagram and label the force vector acting on q'.

Recall that a test charge is usually positive.



KNOWN

$q = -4.0\times10^{-6}$ C

$r = 0.30$ m

UNKNOWN

$\boldsymbol{E} = ?$

2 SOLVE FOR THE UNKNOWN

The force and the magnitude of the test charge are unknown, so use Coulomb's law in combination with the electric field strength equation.

$$E = \frac{Kq}{r^2}$$

$$= \frac{(9.0\times10^{9}\text{ N·m}^2/\text{C}^2)(-4.0\times10^{-6}\text{ C})}{(0.30\text{ m})^2}$$ ◄ Substitute $K = 9.0\times10^{9}$ N·m²/C², $q = -4.0\times10^{-6}$ C, $r = 0.30$ m.

$$= -4.0\times10^{5}\text{ N/C}$$

$\boldsymbol{E} = 4.0\times10^{5}$ N/C toward the sphere, or to the left

Electric field strength depends on charge and distance

To reformulate our equation for electric field strength from a point charge, consider a charge, q, located a distance, r, from a small test charge, q_0. According to Coulomb's law, the magnitude of the force on the test charge is given by the following equation:

$$F_{electric} = k_C \frac{q q_0}{r^2}$$

We can find the magnitude of the electric field due to the point charge q at the position of q_0 by substituting this value into our previous equation for electric field strength.

$$E = \frac{F_{electric}}{q_0} = k_C \frac{q q_0}{r^2 q_0}$$

Notice that q_0 cancels, and we have a new equation for electric field strength from a point charge.

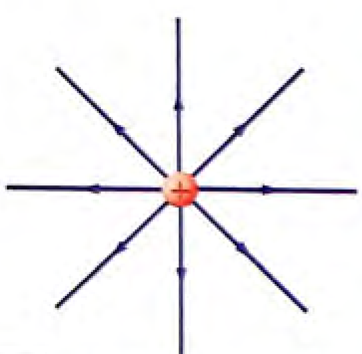
ELECTRIC FIELD STRENGTH FROM A POINT CHARGE

$$E = k_C \frac{q}{r^2}$$

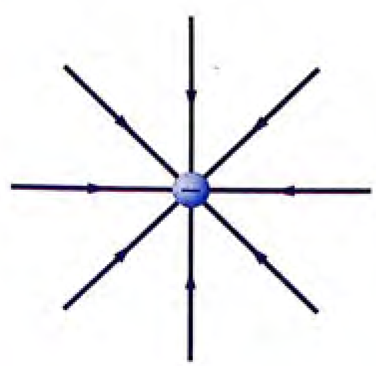
$$\textbf{electric field strength} = \textbf{Coulomb constant} \times \frac{\textbf{charge producing the field}}{\textbf{(distance)}^2}$$

Modeling of electric field

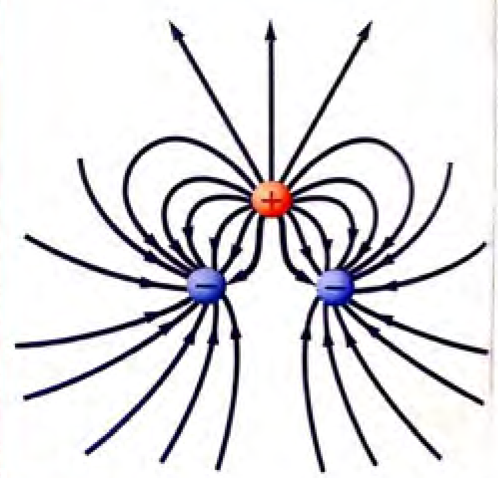
Electric Field Lines—Positive Charge

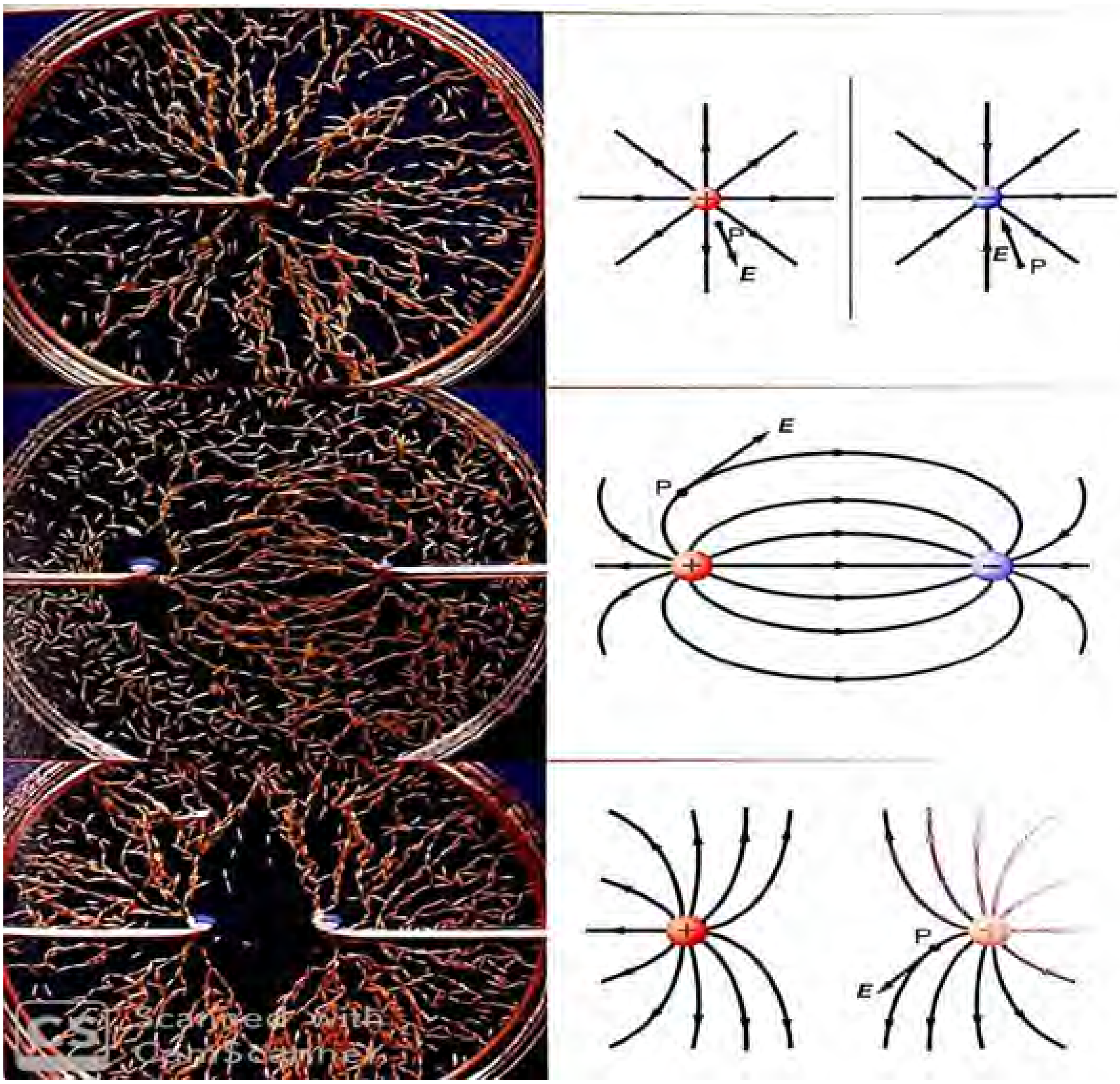


Electric Field Lines—Negative Charge



Electric Field Lines—Mixed Charges





Single Charge For a single charge, the electric field lines radiate from that charge. The field lines radiate out from a positive charge and they radiate inward toward a negative charge. The direction of the electric field (*E*) at any point is the tangent to the field line.

Two Equal and Unlike Charges The electric field lines of two equal and unlike charges form continuous lines from the positive charge to the negative charge. The vector at point P shows the direction of the electric field (*E*) at point P. Where the lines are closest, a charged particle would experience the most force.

Two Like Charges

Electrical Potential Difference

Electrical potential difference **is defined as the work done per unit of charge (Joules per Coulomb) while moving the charge between two points in an electric field. It can also be thought of as the change in PE per unit of charge between two points in an electric field.**

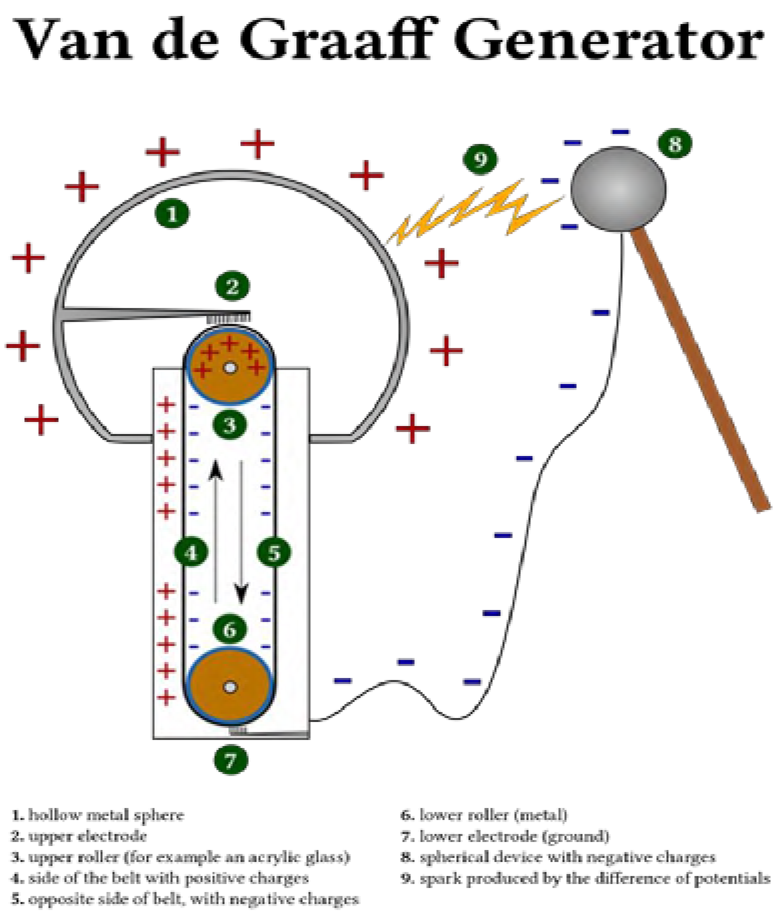
$$\Delta V = \frac{Work}{q} = \frac{-Eq\Delta x}{q} = -E\Delta x$$

in data booklet it is written as $E = -\frac{\Delta V}{\Delta x}$

The negative sign indicates that the direction of decreasing potential is the same as the field direction.

van de Graaff generator

Charges separation to two different zone (area)



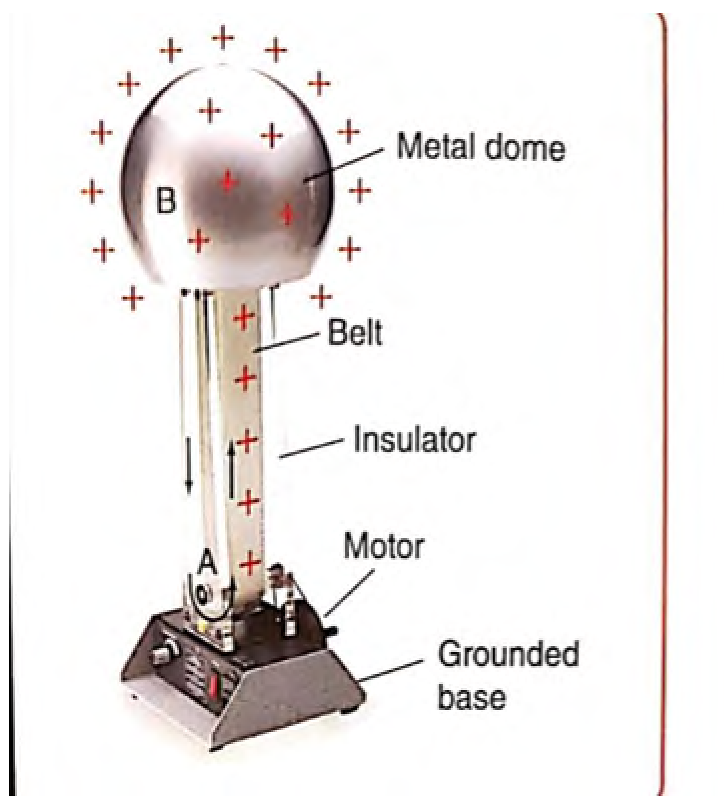
How does it work?

1- by turning on the machine, the bottom roller rotates and moves the belt.

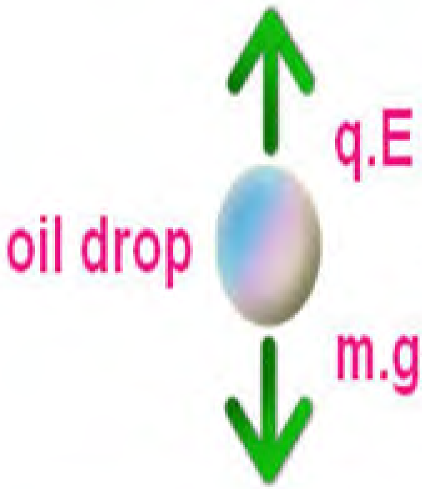
2- The roller builds up a strong negative net charge, and the belt builds a weaker positive net charge.

3- The strong negative electric field on the roller repels electrons in the tips of a brush assembly near position A

4-The positive ions collect on the belt and are transported to the metal dome

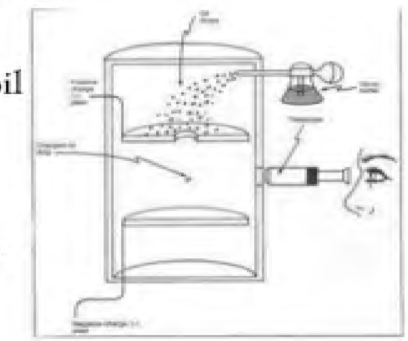


Millikan's Oil-Drop Experiment



Design of the Experiment

- Plates can be charged. Charge can be varied. Oil drops fall through hole in top plate.
- Electrons are present in these oil drops
- Microscope used for observing drops.



Electric Fields Near Conductors

1- Closed metal containers

The field is always perpendicular to the surface of the conductor. This makes the surface an equipotential; the potential difference between any two locations on the surface is zero

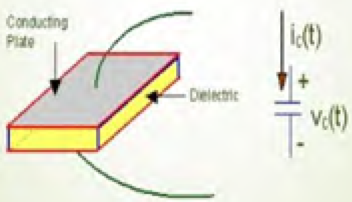
2- Irregular surfaces

This field can become so strong that when electrons are knocked off of atoms, the electrons and resulting ions are accelerated by the field, causing them to strike other atoms, resulting in more ionization of atoms. This chain reaction produces the pink glow seen inside a gas-discharge sphere

Capacitors

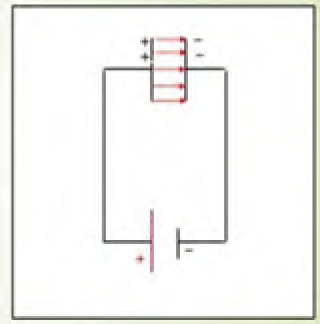
What Is A Capacitor?

Capacitors are two-terminal electrical elements. It is an electrical device consisting of two conductors by an insulating or dielectric medium which carrying equal and opposite charges.



Storing a charge between the plates

- Electrons on the left plate are attracted toward the positive terminal of the voltage source
- This leaves an excess of positively charged holes
- The electrons are pushed toward the right plate
- Excess electrons leave a negative charge
- A capacitor obeys coulombs law



Capacitance, Capacitors and Circuits. Start with a review

The **capacitance C** is defined as

$$C = \frac{Q}{\Delta V}$$

To calculate the capacitance, one starts by introduce Q to the object, and use the Laws we have so far to calculate for the ΔV.

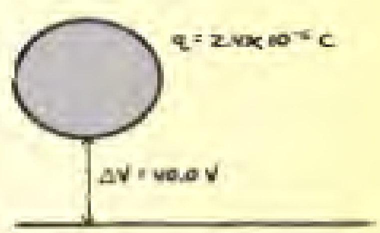
EXAMPLE 5

FINDING CAPACITANCE A sphere was connected to the + pole of a 40 V battery while the − pole was connected to Earth. After a period of time, the sphere was charged to 2.4×10^{-6} C. What is the capacitance of the sphere-Earth system?

1 ANALYZE AND SKETCH THE PROBLEM

Draw a sphere above Earth, and label the net charge and potential difference.

KNOWN	UNKNOWN
$\Delta V = 40.0$ V	$C = ?$
$q = 2.4 \times 10^{-6}$ C	



2 SOLVE FOR THE UNKNOWN

$$C = \frac{q}{\Delta V}$$

$$= \frac{2.4 \times 10^{-6}\ \text{C}}{40.0\ \text{V}}$$ ◄ Substitute $\Delta V = 40.0$ V, $q = 2.4 \times 10^{-6}$ C

$$= 6.0 \times 10^{-8}\ \text{F}$$

$$= 0.060\ \mu\text{F}$$

3 EVALUATE THE ANSWER

- **Are the units correct?** C/V = F. The units are farads.
- **Is the magnitude realistic?** The amount of net charge stored on the sphere equals the capacitance multiplied by 40.0 V.

Section review

1- *explain how electric potential relates to potential energy. Write a brief explanation that you could use to explain this concept to a friend who does not understand the relationship between the two concepts.*

Answer: Electric potential is potential energy per unit charge, and it equals the work required to move a test charge to a given location in an electric field.

2-*What is the difference between electric potential energy and electric potential difference.*

Answer: Electric potential energy changes when work is done to move a charge in an electric field. Electric potential deference is the work done per unit charge to move a charge in an electric field.

3-*Show that a volt per meter is the same as a newton per coulomb.*

Answer: $V/m = J/C \cdot m = N \cdot m/C \cdot m = N/C$

4-*When the net charge on an oil drop suspended in a Millikan apparatus is changed, the drop begins to fall. How should you adjust the potential difference between the conducting plates to bring the drop back into balance?*

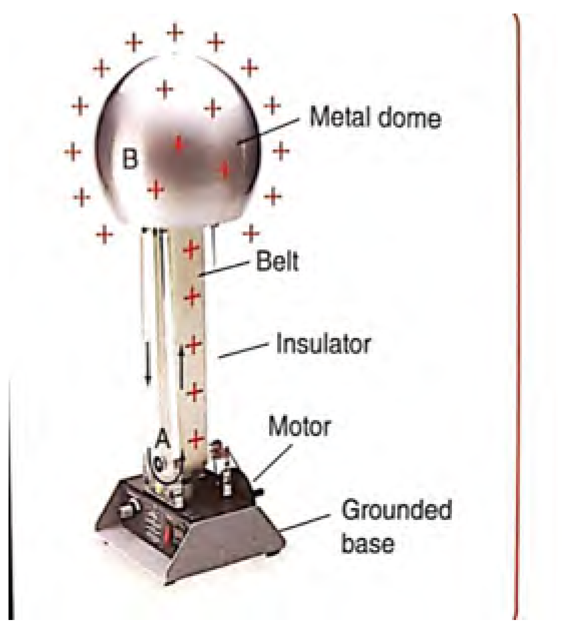
Answer: he potential deference should be increased.

5-*In the previous problem, if changing the potential difference between the conducting plates has no effect on the falling drop, what does this tell you about the new net charge on the drop?*
Answer: The drop is electrically neutral.

6-*f you touch a large, positively charged, conducting sphere with a small, negatively charged, conducting sphere, what can be said about the*
a. potentials of the two spheres;
b. charges on the two spheres?

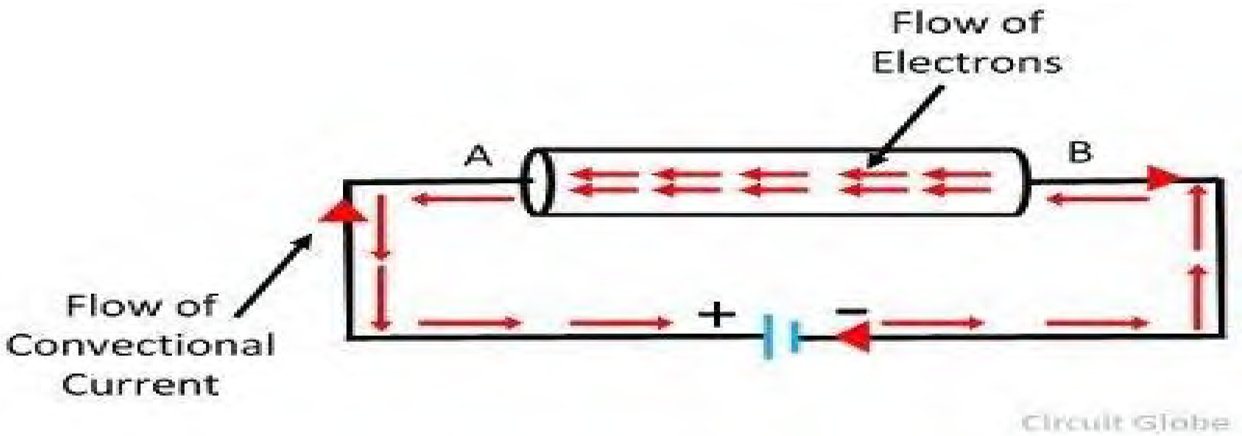
Answer: a. The potential deference between the spheres is zero.
b. The charge per unit area on each sphere would be the same.

7-*Explain how the charge in Figure continues to build up on the metal dome of a Van de Graaff generator. In particular, why isn't charge repelled back onto the belt at point B?*
Answer: The charges on the metal dome produce no field inside the dome. The charges from the belt are transferred immediately to the outside of the dome.



Ch. 13: Electric Current

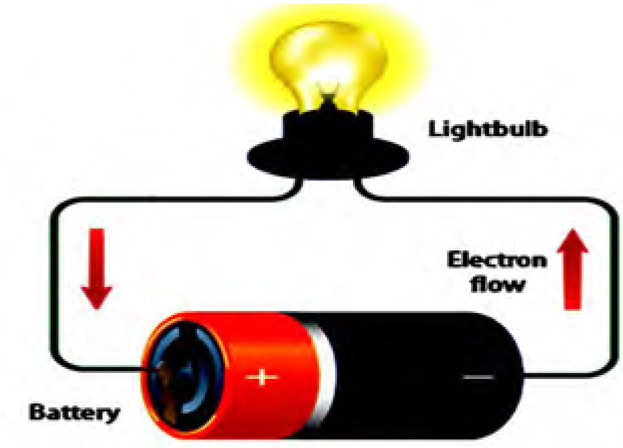
Textbook Chapter	Student Learning Outcomes
Ch. 13: Electric Current	**Sect 1: Current and Circuits** Students are expected to: - **Recognize** current as the rate at which charge flows past a point, identify the units for electric current, and perform simple computations regarding electric current - **Solve** problems which relate the current to the power and the voltage **Describe** a circuit and its components - **Draw** circuit diagrams - **Solve** for each variable in Ohm's law - **Describe** what happens to the current of a circuit when either the voltage or resistance is increased or decreased - **Identify** the difference between parallel and series connections. **Sect 2: Using Electrical Energy** Students are expected to: - **Explain** How electrical energy is transformed into thermal energy - **Solve** problems related to how resistance effects power. - **Describe** how electrical energy is provided to homes and industries.

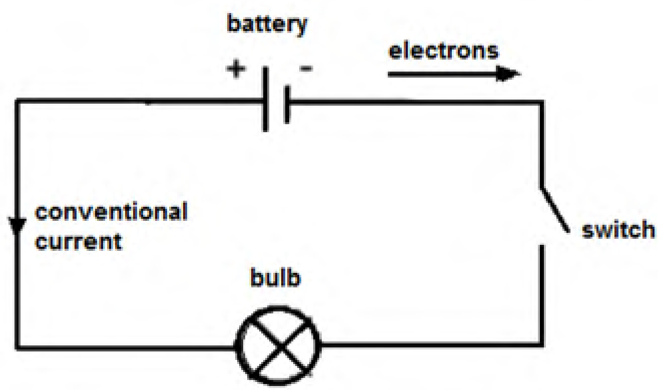


Sect 1: Current and Circuits

CURRENT ELECTRICITY

The flow of charges in a circuit is called current. Current (I) is measured in Amperes (A) and milli ampere (mA). Conventional current direction is from positive to negative. Electrons flow from negative to positive.



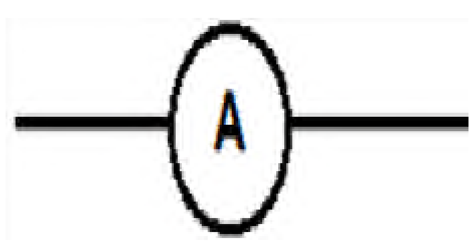


The more the charges passing through the wire in one second, the bigger the current is. Then we can say that current (I) is the rate of charge flowing

$$Q = I \times t$$

$$I = \frac{Q}{t}$$

The electric current flowing in a circuit can be measured by an AMMETER



Example:

A current of 150 mA flows around a circuit for 3 minute. How much electric charge flows around the circuit in this time?

Answer: First convert time into second = 3 × 60 = 180 sec

Then convert current into ampere = 150 / 100o= 0.15 A

Q = I × t   Q = 0.15 × 180 = 27 C

Electromotive force (e.m.f)

Electromotive force (e.m.f.) is measured by the energy dissipated by a source (battery) in driving a unit charge around a complete circuit.

Or:

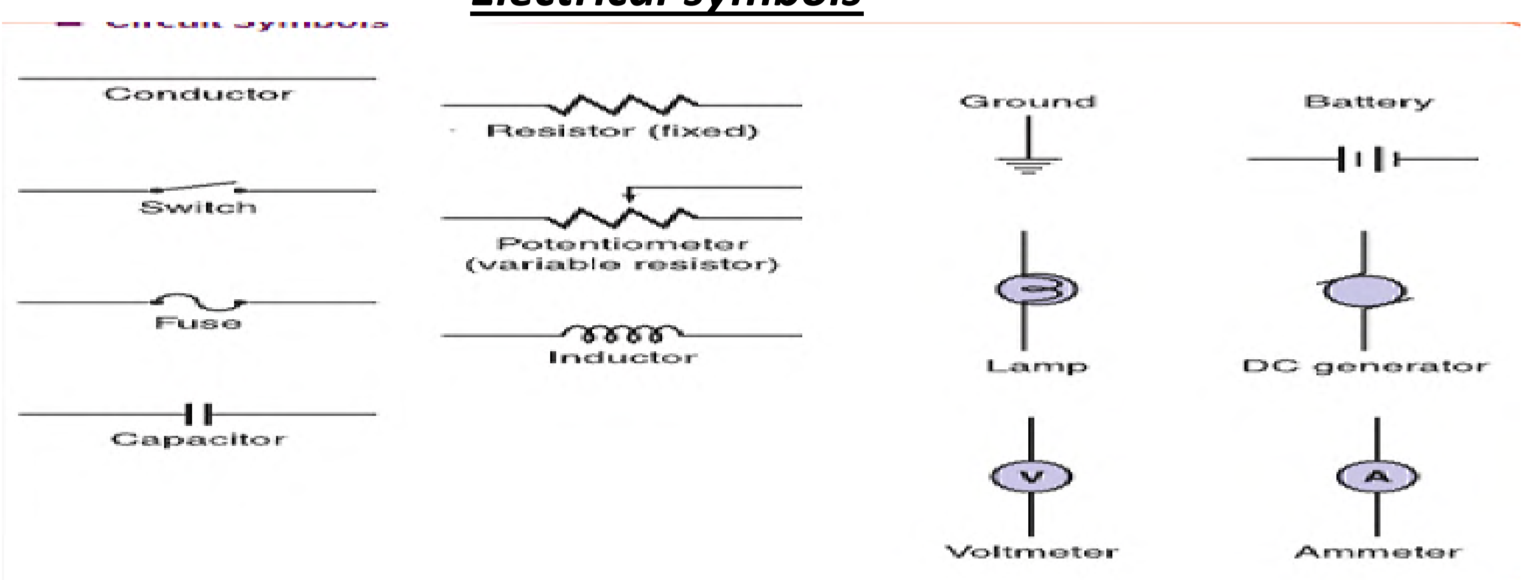
The electromotive force (e.m.f.) of a cell can be defined as the energy supplied to each coulomb of charge within it.

$$e.m.f = \frac{energy\ supplied\ by\ the\ cell}{charges\ flow\ through\ the\ cell}$$

$$e.m.f = \frac{workdone}{charge} \qquad \text{In symbol } \varepsilon = \frac{E}{Q}$$

The unit of e.m.f is J/C or Volt (V)

Electrical symbols



POWER:

Power is equal to the current times the potential difference

$P = I\Delta V$

Unit of power is watt or kilowatt

To Calculate power :

$P = I\,V$

$P = I^2\,R$

$P = V^2 / R$

Resistance and Ohm's Law

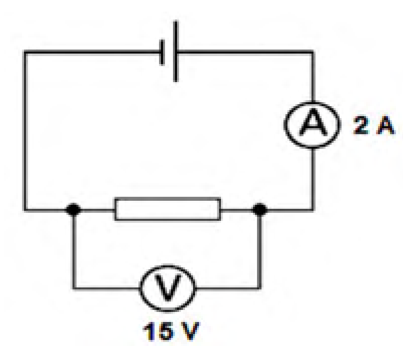
Resistance (R): ***How much current can a cell push through a resistor?***

This depends on the resistance of the resistor. The greater its resistance, the smaller the current that will flow through it. The resistance of a component is measured in Ohm (Ω) and is defined by this equation:

$$resistance = \frac{Potential\ difference}{current} \qquad R = \frac{V}{I}$$

example:

Diagram shows a resistor connected in a circuit. The current in the circuit shown in the ammeter is 2 A and voltage across the resistor is 15 V. Calculate the resistance of the resistor.

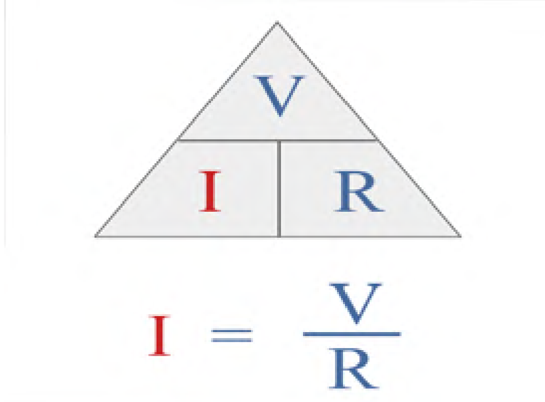


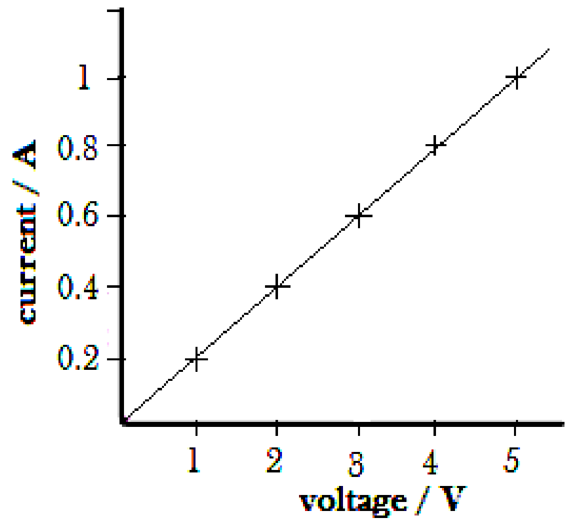
Answer:

$R = \frac{V}{I} \qquad R = \frac{15}{2} \qquad 7.5\ \Omega$

Ohm's law:

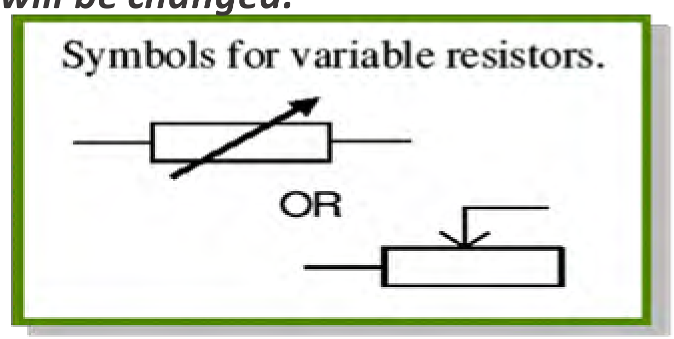
under constant temperature voltage is directly proportional to the current



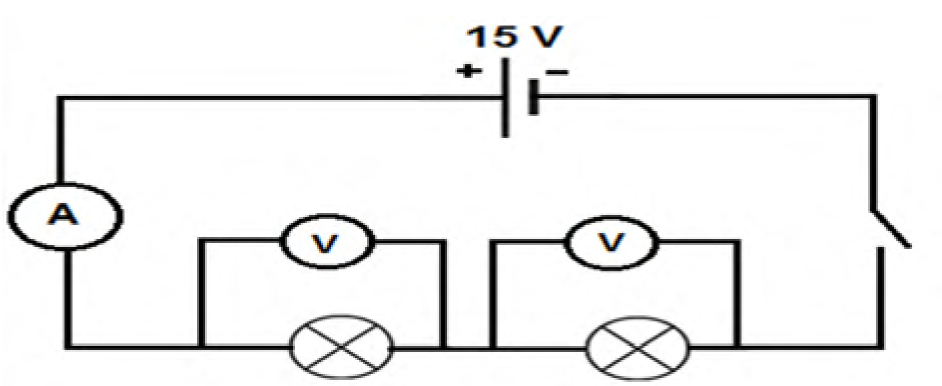


Rheostat:

A variable resistor or rheostat is used to vary the current in a circuit. A sliding contact moves, it varies the length of the wire in the circuit and hence the resistance will be changed.



Drawing a circuit diagram:



Factors affecting resistance:

1- Length of wire

For a wire of uniform cross sectional area, the resistance is proportional to the length of wire. The longer the wire, the further electrons have to travel, the more likely they are to collide with metal ions and so the greater the resistance. So if the length of wire increases resistance also increases.

2- Cross-sectional area

For a wire fixed length, its resistance is inversely proportional to the cross sectional area. The greater the cross sectional area of the wire, the more electrons there are available to carry charge along the wire length and so the lower resistance. So if cross-sectional area of a wire increases resistance of the wire decreases.

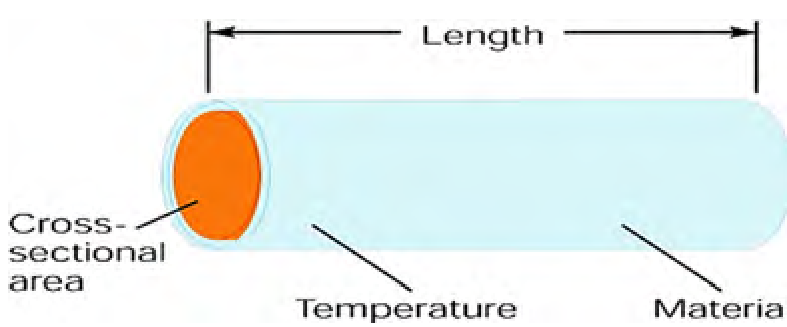
3- temperature

For metallic wires, as temperature increases, the resistance of it also increases. But for some materials like silicon and germanium (semiconductors), as temperature increases resistance decreases

4- Material

Resistance depends on the kind of substance.

Copper is a good conductor and is used for connecting wires. But Nichrome has more resistance and is used in the heating elements of electric heater



Electrical Energy, Resistance, and Power

Remember:

P= W / t
(Power=Work/time)

- **Remember: W= Vq and I = q/t**

So: P= I V

Derive the following using P=IV and Ohm's Law:

$P=V^2/R$

$P=I^2R$

Electric Power, P= I V: P: is the power consumed by a resistor, R. Unit: Joule/s= Watt

Power and thermal energy If you know ΔV and R, but not I, you can substitute $I = \frac{\Delta V}{R}$ into $P = I\Delta V$ to obtain the following equation.

POWER

Power is equal to the potential difference squared divided by the resistance.

$$P = \frac{(\Delta V)^2}{R}$$

Power is the rate at which energy is transformed from one form to another. Energy is changed from electrical to thermal energy, and the temperature of the resistor rises. The resistors in an immersion heater, for example, convert electrical energy to thermal energy fast enough to bring water to a boil in a few minutes.

If power continues to be transformed at a uniform rate, then after time t, the energy transformed to thermal energy will be $E = Pt$. Because $P = I^2R$ and $P = \frac{(\Delta V)^2}{R}$, the total energy to be converted to thermal energy can be written in the following ways.

$$E = Pt \qquad E = I^2Rt \qquad E = \left(\frac{(\Delta V)^2}{R}\right)t$$

Superconductors

A superconductor is a material with zero resistance. There is no restriction of current in superconductors, so there is no potential difference (ΔV) across a superconducting wire. Because the rate of energy transformation in a conductor is given by the product IΔV, a

superconductor can conduct electricity without thermal energy transformations. At present, almost all superconductors must be kept at tempera-tures below 100 K. The practical uses of superconductors today include MRI magnets. Someday superconducting cables may efficiently carry electrical power to cities from distant power plants.

<u>Electric transmission lines</u>

All this electrical energy is transformed to thermal energy and, therefore, is wasted. This waste could be minimized by reducing the

resistance. Cables of high conductivity and large diameter (and therefore low resistance) are available, but such cables are expensive and heavy. Because the thermal energy transformation is also proportional to the square of the current in the conductors, it is even more important to minimize the current in the transmission lines.

<u>The kilowatt-hour(</u>A kilowatt-hour is equal to 1000 watts delivered continuously for 3600 s (1 h) While electric companies are called power companies, they actually provide energy rather than power. Power is the rate at which energy is delivered. When consumers pay their home electric bills, , they pay for electrical energy, not power. The amount of electrical energy used by a device is its rate of energy consumption, in joules per second or watts (W), multiplied by the number of seconds the device is operated. Joules per second times seconds