Module-1 - Module 1

Professional Education 10 (Dr. Emilio B. Espinosa Sr. Memorial State College of Agriculture and Technology)

SHS

AIRs - LM in

General Physics 2
Quarter 3 – Week 1 Module 1
Electrostatic Charging

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General Physics
Grade 12 Quarter 1 –Week 1: Module 1: Electrostatic Charging
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Region I

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Target

The discovery of electricity is generally credited to the Greeks and is thought to have occurred around 2 500 years ago. The Greeks observed electric charges and forces between them in a variety of situations. Many of their observations made use of a material called amber, a plastic-like substance formed by allowing the sap from certain trees to dry and hardened.

Benjamin Franklin performed many experiments on the nature of electricity. In one of these, he flew a kite during a thunderstorm to show that clouds are electrically charged and that he could draw sparks from a key tied to the kite string.

In this lesson, you will be learning the nature of static electricity, the two kinds of electrostatic charge and methods of identifying and transferring them. Some simple experiment will be perform to show how electric charge is produce.

After finishing this Learning Material, you are expected to:

1. Describe using a diagram charging by rubbing and charging by induction (STEM_GP12EMIIIa-1)
2. Explain the role of electron transfer in electrostatic charging by rubbing (STEM_GP12EMIIIa-2)
3. Describe experiments to show electrostatic charging by induction. (STEM_GP12EMIIIa-3)
4. Calculate the net electric force on a point charge exerted by a system of point charges. (STEM_GP12EMIIIa-6)
5. Describe an electric field as a region in which an electric charge experiences a force. (STEM_GP12EMIIIa-7)
6. Calculate the electric field due to a system of point charges using Coulomb's law and the superposition principle. (STEM_GP12EMIIIa-10)
7. Calculate electric flux. (STEM_GP12EMIIIb-12)

Jumpstart

Electricity is either static or dynamic. Here, we will be discussing the basic concept of static electricity. Let us begin with a simple activity on how to produce a static electric charge.

Activity 1. Are You Positive or Negative?

What You Need

4” x 4” polyethylene plastic (the one use to cover your notebook), old newspaper or any scratch paper

Direction: Follow the procedure below.

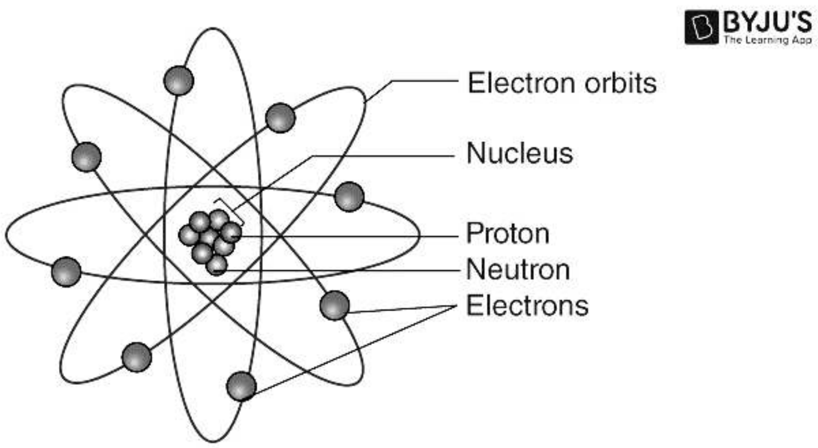
1. Take a polyethylene plastic (the same plastic that you use in covering your notebooks) and place it flat on a clean table top, then take a piece of newspaper, crumple it and rub it once or twice on the plastic sheet. Next hold it and lift it up briskly. Pass the plastic sheet near your arms.
   What did you feel?____
   ____
2. Place the same charged plastic near your ears. What did you feel?
   ____
   ____
3. Charge the plastic sheet once more and place it against a wall or against a flat vertical surface like the blackboard or the sides of a table. What did you observe?
   ____
   ____
4. Charge the plastic once more and place near the hair of your classmate. What happened? Why? ____
   ____
5. This time you need to work with a classmate near you. You may work by two’s. Charge your plastic sheets in the usual manner. Holding only the tip of the corner of the plastic, bring your plastic sheets near the plastic sheets of your classmates. See to it that the plastic sheets would come towards each other face to face. What happened?____
   ____
   Did the plastic sheets attract each other? ____________________________
   How did each react to the other?

6. Tear little bits (2 to 3.5 mm) of newspaper or tissue paper (about 30 pieces) and place them on the table. Take your plastic sheet, charged it as before and place it over the little bits of paper at a height of about 4 cm. Describe what happened to the little bits of paper. ____
____

Discover

ELECTRIC CHARGE

From the previous activity, you were able to produced and observed electric charges. From the Electron Theory, we learned that any material is composed of atoms of different kinds. Each atom on the other hand is made up of protons, neutrons and electrons. Different materials have different numbers of protons and electrons in their atoms.



The Structure of Atom

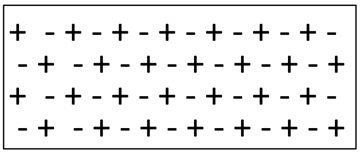
Atomic structure refers to the structure of atom comprising a nucleus (center) in which the protons (positively charged) and neutrons (neutral) are present. The negatively charged particles called electrons revolve around the center of the nucleus.

Normally, materials are electrically neutral, however when they come in intimate contact and are separated one gets a positive charge while the other gets a negative charge. The intensity of the charge depends on the nature of the 2 materials, the rapidity of separation and the insulating property of the air at the time of separation

In many ways, it is similar to the quantity we call mass of a particle determines how it reacts when a force acts on it. The mass of a particle is a measure of the amount of matter it carries, whereas the charge of a particle is a measure of the amount of “electric-ness” it carries. An ***electric charge*** is the amount of charge that is “on” or “carried by” a particle determines how the particle reacts to electric fields.

TWO KINDS OF CHARGE

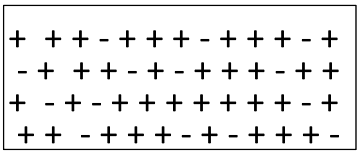
A neutral material has equal number of protons and electrons in it.



Neutral object

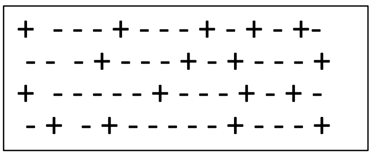
Rubbing or by contact of two different materials may result into an electric charge, one will be positive charge and the other one, negative charge.

1. **Positively charge**. A material is a positive charge if it lacks electrons. When a material losses electrons, leaving more protons, it becomes positively charge. The number of protons exceeded the number of electrons



Positive charge

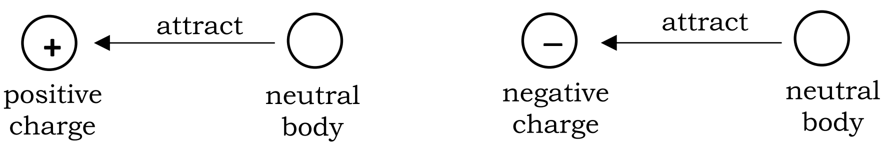
2. **Negatively charge**. When a material gains electrons, it becomes negatively charge due to excess number of electrons. The number of electrons is more than the number of protons



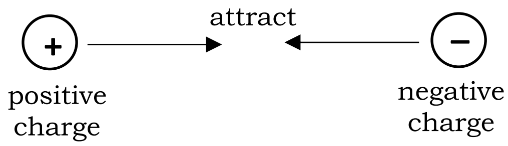
Negative charge

LAWS OF CHARGES

1. A charge body (positive or negative) attracts a neutral body.



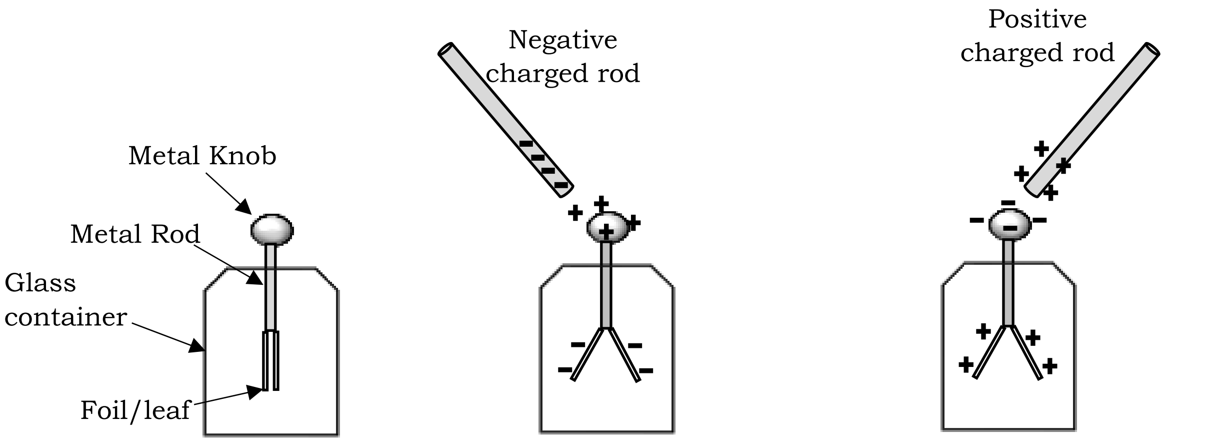
2. Unlike charges attract each other



3. Like charges repel each other

ELECTROSCOPE

An electroscope is a device that detects the presence of electric charges on objects. It is a made of a small compartment mostly made of glass (a glass jar, for example) with a metal rod inserted into it through an insulator cap.



Neutral Electroscope

Electroscope approached with a negative rod. Like charge foils repel

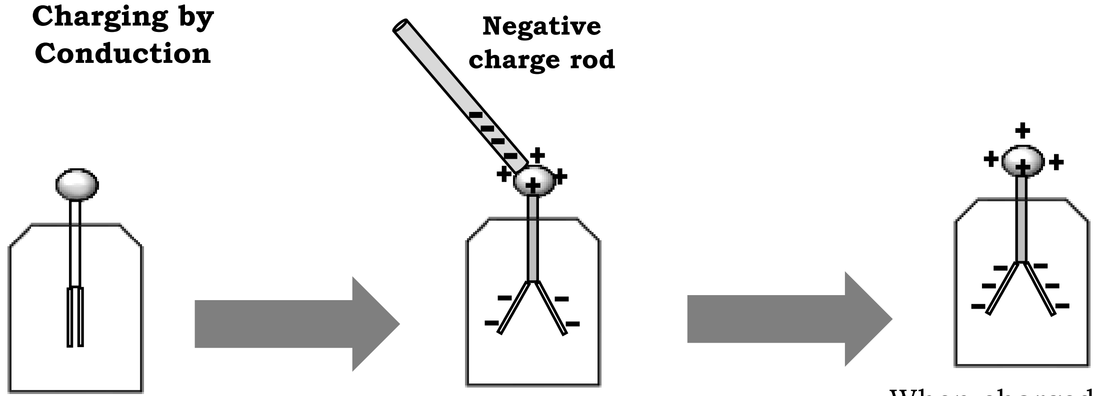
Electroscope approached with a positive rod. Like charge foils repel

Detecting charge by an electroscope

The end of the rod that is inside the compartment has two small metal foils (aluminum , gold, or another metal) hinged to it that are free to open up like the wings of a butterfly. The outer end is connected to a metal sphere or a pan. When a charged object (no matter positive or negative) is brought into contact with the outer sphere or pan, some of the charges get transferred to the foils via the metal rod. The foils become charged up with like charges that repel each other causing the foils to separate and open up. That is how the foils indicate that some electric charges are transferred to them. Even if a charged object is held near the sphere or the pan with no physical contact, the foils still open up, but if the object is taken away from the pan, the foils drop down again.

CHARGING THE ELECTROSCOPE

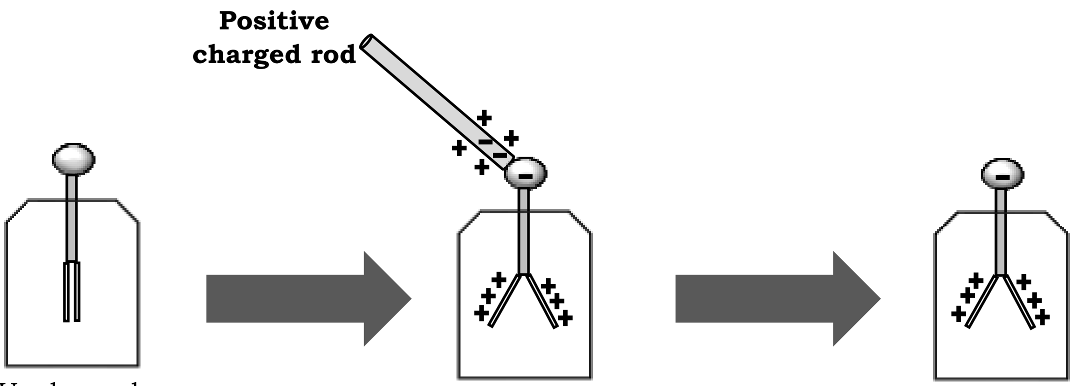
Charging by Conduction



Uncharged Electroscope

Electroscope made contact with a negative rod. Excess electrons transferred to the electroscope

When charged rod is removed, the electroscope is now charged. It has the same charged as the rod

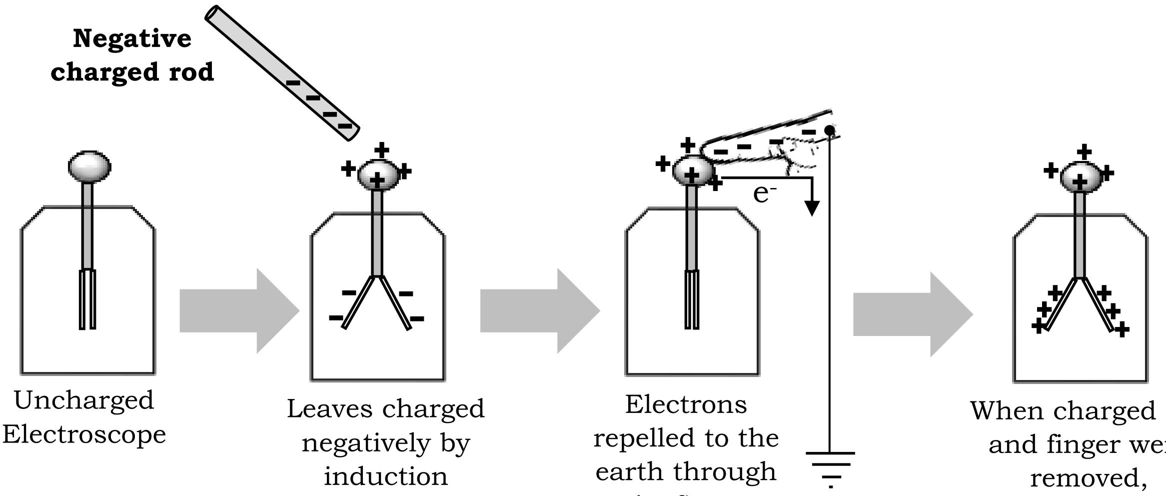


Uncharged Electroscope

Electroscope made contact with a positive rod. Electrons from the electroscope transferred to the rod.

Electroscope is **positive** charged

Charging by Induction using a Negative Rod



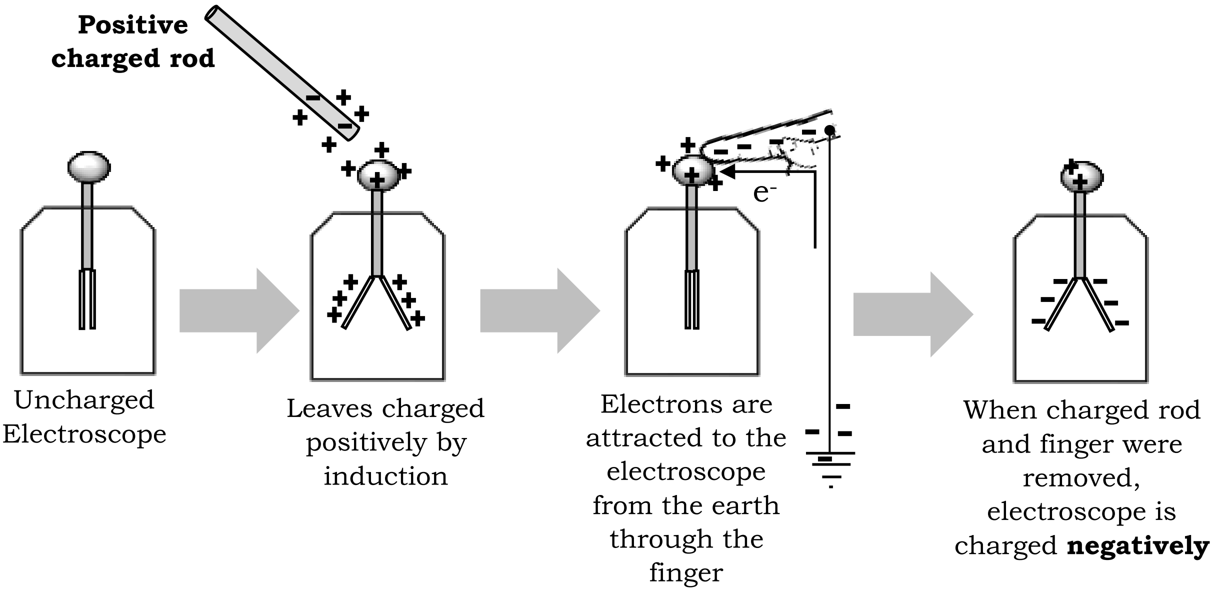
Uncharged Electroscope

Leaves charged negatively by induction

Electrons repelled to the earth through the finger

When charged rod and finger were removed, electroscope is charged positively

Charging by Induction using a Positive Rod



ELECTRIC FIELDS AND ELECTRIC FORCE

In the SI system of units, electric charge is measured in *coulombs* (C) in honor of French physicist Charles de Coulomb. The charge on a single electron is

electron charge, -e = -1.60×10^{-19}C
proton charge, +e = $+1.60 \times 10^{-19}$C

Charles Coulomb first described electric field strengths in the 1780's. Using a device called the torsion balance, he found that for point charges, the electrical force varies directly with the product of the charges. In other words, the greater the charges, the stronger the field. And the field varies inversely with the square of the distance between the charges. This means that the greater the distance, the weaker the force becomes. That is Coulomb's Law, in equation,

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

where:
F – force between charges expressed in Newtons (N)
q_1 and q_2 – point charges expressed in coulomb (C)
r – distance between the two charges expressed in meter (m)
$k = 9 \times 10^9$ N.m^2/C^2

Another way to write Coulomb's law is:

$$F = \frac{q_1 q_2}{4\pi\epsilon_0 r^2}$$

$\epsilon_0 = 8.85 \times 10^{-12}$ C^2 /N.m^2

Example 1. A point charge q_1 has a magnitude of 2×10^{-6}C. A second charge q_2 has a magnitude twice as the first point charge and is located 0.1 m from the first charge. Determine the electrostatic force each charge exerts on the other.

Given:

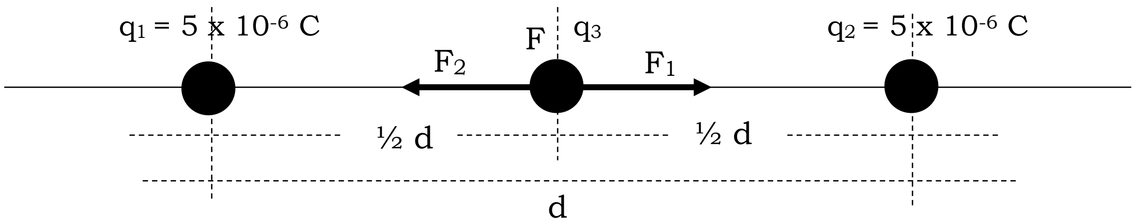
$q_1 = 2 \times 10^{-6}$ C $\quad$ $q_2 = 2 \times q_1$ $\quad$ r = 0.1 m $\quad$ $k = 9 \times 10^9$ N.m^2/C^2

F = ?

$$F = k\frac{q_1 q_2}{r^2} \qquad = \frac{(9 \times 10^9\ N.m^2/C^2)(2 \times 10^{-6} C)(2)(2 \times 10^{-6}\ C)}{(0.1\ m)^2}$$

$$F = 7.2\ N$$

Example 2. Two identical particles of charge 5 x 10-6 C are separated by a distance, d, as shown in the figure below. What is the net force on the third charge q_3 placed between these two charges?



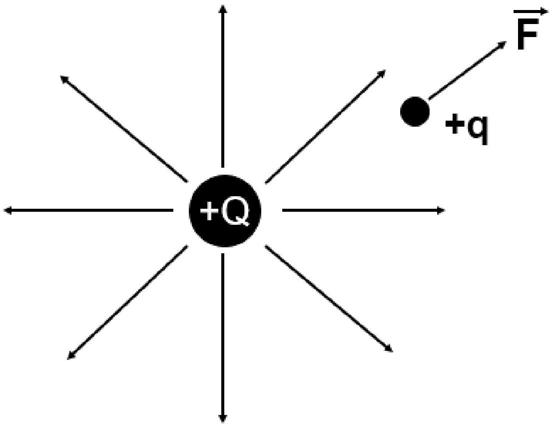
The net force on q_3 is equal to the sum of the forces from charges q_1 and q_2. Since the charges are identical, both charges exert an equal force to q_3, therefore,

$$F = F_1 + (-F_2) = 0$$

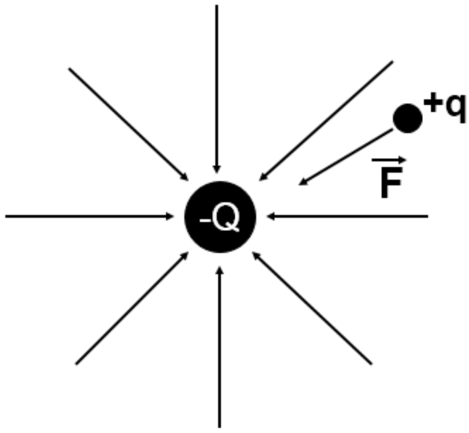
ELECTRIC FIELDS

Let us think of an electric charge as creating an electric field in the region of space surrounding it. That field, in turn, exerts a force on any other charge in that region. The electrical interaction between charged particles can be reformulated by using the concept of electric field.

Whenever you have a charge Q placed anywhere in space, it will be surrounded by a region such that if you will put any other charge q at any point P in this region, the charge q will be acted upon by an electric force F. We call this region around Q the ***electric field E*** of Q.



Electric field lines or lines of force around a positive charge Q



Electric field lines or lines of force around a negative charge Q

The strength of the electric field is operationally defined as the ratio of the electric force F to the charge q placed at that point in the field. In symbols,

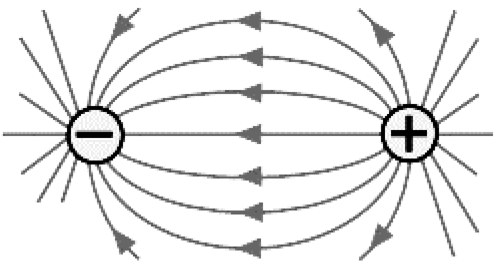
$$E = \frac{F}{q}$$

where:

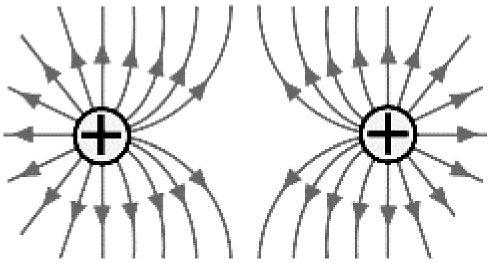
E – is electric field expressed in N/C

F – is the electric force due to the charge expressed in newton, N

q – is the charge within the electric field expressed in coulomb, C



Electric lines of force between unlike charges



Electric lines of force between like charges

https://images.app.goo.gl/dbDZiaPTygiSt4R3A

Example 1. A charge of 3.0 μC present in an electric field produces a force of 0.08N. What is the intensity of the electric field?

Given:

$q = 3.0 \times 10^{-6} C$ $\quad$ $F = 0.08\ N$ $\quad$ $E = ?$

$$E = \frac{F}{q} = \frac{0.08\ N}{3.0 \times 10^{-6} C} = 26\ 666.7\ N/C$$

Example 2. A charge of 0.000025 C is placed in an electric field whose intensity is 8.0×10^6 N/C. How strong is the force acting on the charge?

Given:

q = 0.0025C E = 8.0×10^6 N/C F = ?

E = Fq = (8.0×10^6 N/C)(0.000025 C) = 200 N

Example 3. Determine the charge of a point charge in an electric field of 6.5×10^3 N/C and experienced an electric force of 4×10^{-2} N

Given:

E = 6.5×10^3 N/C F = 4×10^{-2} N q = ?

$$q = \frac{F}{E} = \frac{4 \times 10^{-2} N}{6.5 \times 10^3 C} = 6.15 \times 10\text{-}6 \text{ C or } 6.15\mu C$$

Electric Field of a Dipole

According to Coulomb's law, the magnitude of the electric force exerted on the test charge q is

$F = kQq/r^2$

Inserting this expression into our relation for the electric field gives

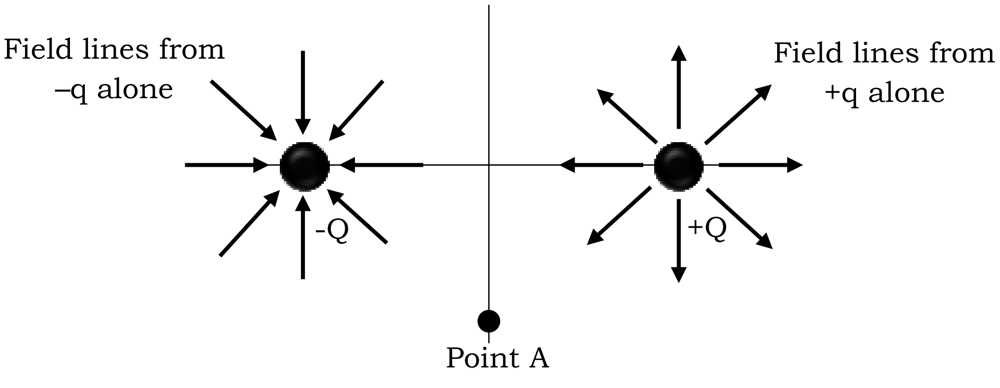
$FkQq/r^2 = qE$

which leads to

$E = kQ/r^2$

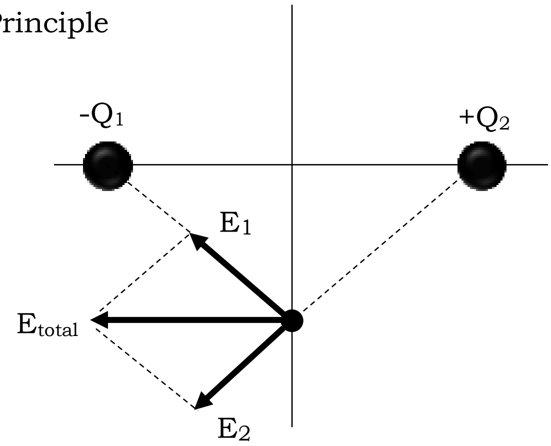
Consider an electric dipole consisting of two charges +q and –q as sketch in the figure. They might be an electron and a proton, or negative and positive ions that make up part of a molecule.

Make a qualitative sketch showing the magnitude and direction of the electric field at points A in the vicinity of this dipole.



To find the total field E_{total} at point A, we need to add the electric fields from the point charge

Recognize the Principle



Determine the electric fields exerted by each charges,

$$E_1 = k\frac{Q_1}{r^2} \qquad E_2 = k\frac{Q_2}{r^2}$$

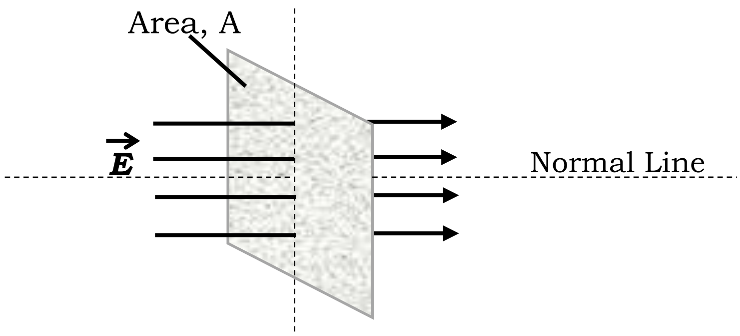
To determine the E_{total}, apply Pythagorean Theorem

$$E_{total} = \sqrt{E1^2 + E2^2}$$

Electric Flux

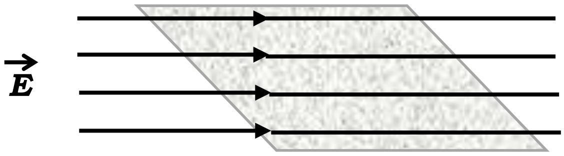
The total number of electric field lines passing a given area in a unit time is defined as the ***electric flux***. Electric flux is the amount of electric field penetrating a surface area.

Electric Flux it is the product of the electric field and the area of the surface. Electric flux is denoted by the symbol **(Φ_E).** If the electric field E is perpendicular to the surface having a total area A, its just the product of A and E.



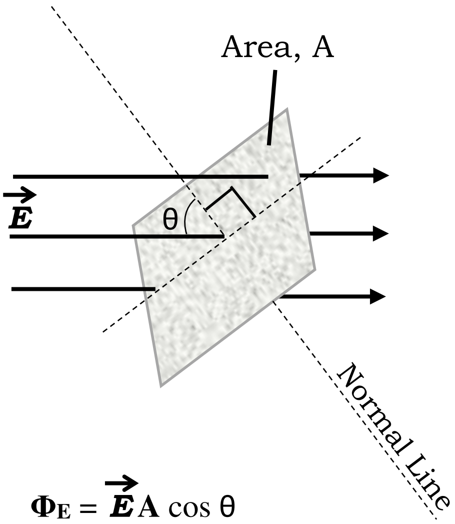
$$\mathbf{\Phi_E = \vec{E}A}$$

If E is parallel to the surface, no electric field lines cross the surface and flux is zero.



$\Phi_E = 0$

If the electric field makes an angle with the direction normal to the surface, the magnitude of the flux is proportional to the component of the field perpendicular to the surface.



$\Phi_E = \vec{E} A \cos\theta$

Example 1. A uniform electric field E = 6 000 N/C passing through a flat square area A = 8 m^2. Calculate the electric flux.

Given:

E = 6 000 N/C
A = 8 m^2
Φ_E = ?

$\Phi_E = \vec{E} A$
$= (6\,000\ N/C)\ (8\ m^2)$
$= 48\,000\ N.m^2/C$

Example 2. A uniform electric field E = 12 000 N/C passing through a flat square area A = 0.5 m^2. The angle between the electric field direction and a line drawn perpendicular to the area is θ = 50^o). Determine the electric flux.

Given:

E = 12 000 N/C
A = 0.5 m^2
θ = 50^0
Φ_E = ?

$\Phi_E = \vec{E} A \cos\theta$
$= (12\,000\ N/C)\ (0.5\ m^2) \cos 50^0$
$= 3\,856.7\ N.m^2/C$

Example 3. A spherical ball has a radius of 0.2 m and electric charge is 20μC in its center. Calculate the electric flux pass through the spherical ball.

Given:

$r = 0.2$ m

$Q = 20\mu C$

$\mathbf{\Phi_E} = ?$

$\mathbf{A} = 4\Pi r^2$

$\mathbf{E} = k\frac{Q}{r^2}$

$\mathbf{\Phi_E} = \vec{E}\,\mathbf{A}$

$$\mathbf{\Phi_E} = (k\frac{Q}{\cancel{r^2}})(4\Pi\cancel{r^2})$$

$$\mathbf{\Phi_E} = (9 \times 10^9\ N.m^2/C^2)\ (20 \times 10^{-6}\ C)\ (4)\ (3.1416)$$

$$= 2\ 261\ 952\ N.m^2/C$$

Explore

You are now ready to apply what you have learned from the previous

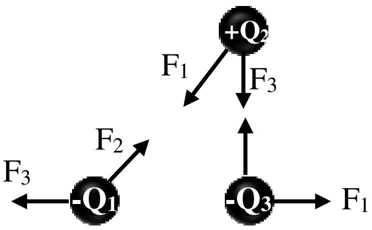
Activity 1. Coulomb's Law Analysis

In the illustrations of charges, draw arrows representing the electric force exerted by each charge, then, write the type of force that exists among the forces.

Example 1:

Force between Q_1 and Q_2 = <u>repulsive</u>

Example 2:



Force between Q_1 and Q_2 = attractive

Force between Q_1 and Q_3 = repulsive

Force between Q_2 and Q_3 = attractive

Do the illustrations of charges below!

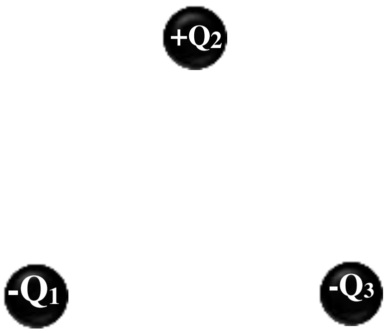
Illustration 1.

a.) Force between Q_1 and Q_2 = ____________________

b.) Force between Q_1 and Q_3 = ____________________

c.) Force between Q_2 and Q_3 = ____________________

Illustration 2.

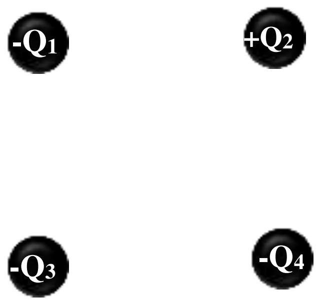


a.) Force between Q_1 and Q_2 = ____________________

b.) Force between Q_1 and Q_3 = ____________________

c.) Force between Q_2 and Q_3 = ____________________

Illustration 3.



a.) Force between Q_1 and Q_2 = __________________

b.) Force between Q_1 and Q_3 = __________________

c.) Force between Q_1 and Q_4 = __________________

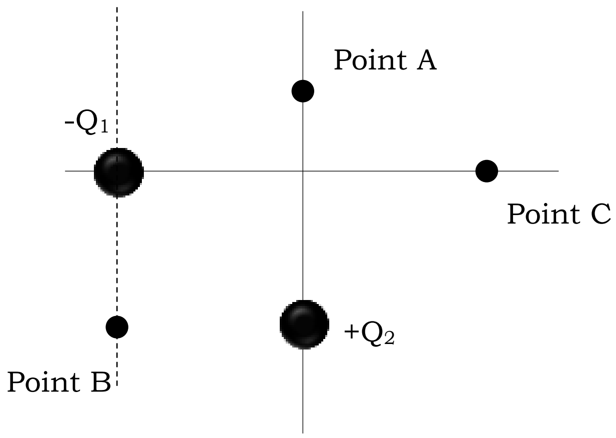
d.) Force between Q_2 and Q_3 = __________________

e.) Force between Q_2 and Q_4 = __________________

f.) Force between Q_3 and Q_4 = __________________

Activity 2. Electric Field Analysis

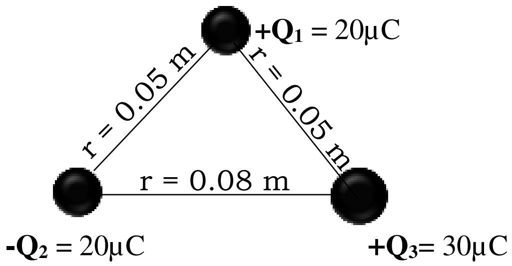
Use arrows to represent the electric fields at points A, B, and C due to Q_1 and Q_2. Then apply the parallelogram method to represent the **net electric field** in that point.



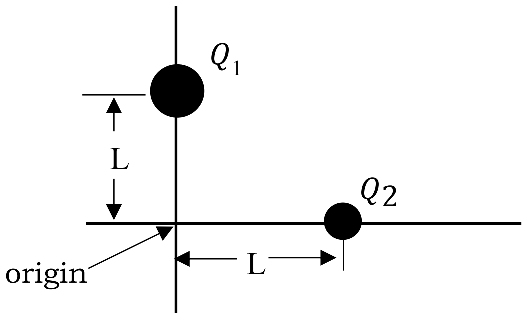
Deepen

Problem Set. Solve the different problems applying the different equations of Coulomb's Law and Electric field analysis. You may use a separate sheet of paper for your solution.

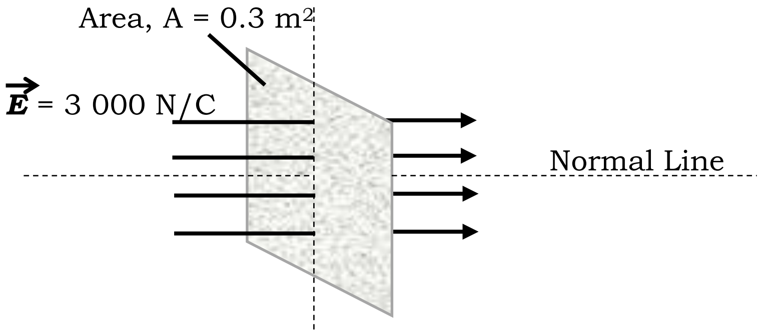
1. Determine the magnitude of the electrostatic force between Q_1 and Q_2; Q_1 and Q_3; and Q_2 and Q_3 arranged in the figure.



2. Two point charges with Q_1 = 8μC and Q_2 = -4μC are arranged as shown in the figure. If L = 0.03 m, what is the electric field at the origin?



3. The electric field due to a static electric charge is 3 000 N/C and passes through a surface area of 0.3 m^2. Calculate the electric flux.



Gauge

Direction. Select the ***BEST*** answer. Write the corresponding **CAPITAL LETTER** of your choice in a separate sheet of paper. Write **E** if you find no correct answer.

1. Which of the following is true about electric charge?
   A. It can be lost
   B. It can be destroyed
   C. It is created from a chemical reaction
   D. it can be transferred from atom to atom

2. What happens when a positively charged rod is brought near a neutral plastic ball?
   A. protons on the ball are attracted to the positive rod and move to the near side of the ball
   B. electrons in the ball are attracted to the near side of the ball
   C. electrons in the ball are repelled to the far side of the plastic ball
   D. the protons on the ball repelled by the positive rod and move to the far side of the ball

3. A neutral object
   A. is repelled by a negatively or a positively charged object
   B. is attracted to positively charged objects only
   C. is attracted to negatively charged objects only
   D. is attracted to either a negatively or a positively charged object

4. How can object becomes positively charged?
   A. It loses electrons
   B. Protons are added to it
   C. The number of electrons is increased
   D. Neutrons are removed from it

5. Electron spins around a nucleus of an atom. What is the charge of an electron?
   A. $-1.06 \times 10^{-19}C$
   B. $-6.10 \times 10^{-19}C$
   C. $-1.60 \times 10^{-19}C$
   D. $-1.60 \times 10^{19}C$

6. What do you call the law that quantifies the force of attraction and repulsion between charged bodies?
   A. Newton's Law
   B. Faraday's Law
   C. Coulomb's Law
   D. Cavendish's Law

7. The direction of electric field due +Q positive charge is......
   A. away from the charge
   B. towards the charge
   C. Both A and B
   D. None of the above

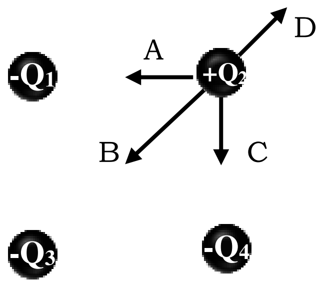
8. The electric field intensity at a point situated 4 metres from a point charge is 200 N/C. If the distance is reduced to 2 metres, the field intensity will be
   A. 400 N/C
   B. 600 N/C
   C. 800 N/C
   D. 1200 N/C

9. Which, among the following is the correct expression for an electric field?
   A. E=F/C
   B. E=FC
   C. E=F/Q
   D. E=FQ

10. What is the charge of an electroscope done by induction?
   A. same charge as the charging body
   B. opposite charge as the charging body
   C. a neutral charge
   D. a static electric charge

For numbers 11 – 13, refer to the figure.

11. Four point charges, each of the same magnitude, with varying signs as specified, are arranged at the corners of a square as shown. Which of the arrows labeled, A, B C and D, gives the correct direction of the net force which acts on the charge Q_2 at the upper right corner.



12. What is the kind of force exists between charges Q_1 and Q_2?
   A. attractive force
   B. repulsive force
   C. neutral
   D. no force

13. What is the kind of force exists between charges Q_3 and Q_4?
   A. attractive force
   B. repulsive force
   C. neutral
   D. no force

14. If Q_2 and Q_3 are separated by a distance of 20 cm and have the same charge of 50μC, what is the magnitude of the force between them?
   A. 562.5 N
   B. 112.5 N
   C. 1.125 N
   D. 0.056 N

15. Which among the following equations is ***<u>incorrect</u>***?

   A. $\Phi_E = \frac{q}{\epsilon_0}$

   B. $\Phi_E = EA$

   C. $\Phi_E = EA \cos \theta$

   D. $\Phi_E = \frac{E}{A}$

Answer Key

Deepen

1. Force between Q_1 and Q_2
   $F = 1\ 440\ N$

   Force between Q_1 and Q_3
   $F = 2\ 160\ N$

   Force between Q_2 and Q_3
   $F = 843.78\ N$

2. $E = 8.94 \times 10^7\ N/C$

3. $\Phi_E = 900\ N.m^2/C$

Explore

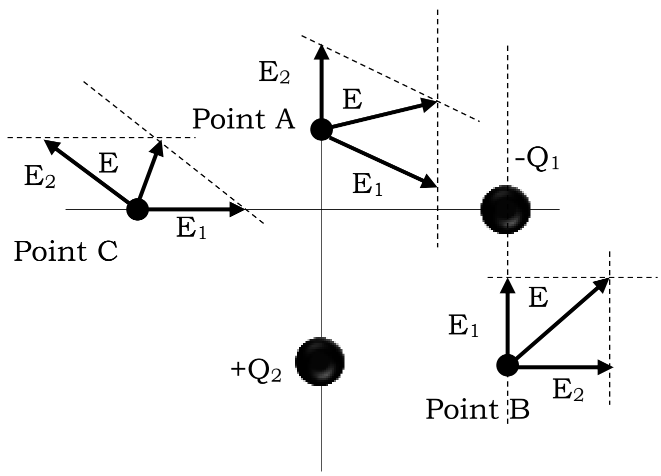
Activity 1.

Illustration 1.
- a.) attractive
- b.) repulsive
- c.) attractive

Illustration 2.
- a.) attractive
- b.) repulsive
- c.) attractive

Illustration 3.
- a.) attractive
- b.) repulsive
- c.) repulsive
- d.) attractive
- e.) attractive
- f.) repulsive

Activity 2



Gauge

1. D
2. B
3. D
4. A
5. C
6. C
7. A
8. C
9. C
10. B
11. B
12. A
13. B
14. A
15. D

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