Electric Fields

I. **Electric Field**

A. **Symbol –**

B. **Definition:** The electric field at any point in space is the

Electric Force that a positively charged test object would

experience when placed at that location **divided** by the

charge on the test object.

C. The Electric Field is a **VECTOR** so you must give both

Direction and **Magnitude**. You must also use **Vector Math**.

D.   **Units -**   or   "see later in course"

Ex: Given that you have a uniform electric field of 3.0 N/C in the +

x-direction, what is the electric force experienced by a

A.   2.0 nC charge

B.   -3.5 nC charge

The process in the example is similar to calculating the weights of

different objects once you know $\vec{g}$ using $\vec{F}=m\,\vec{g}$.

Question: Why did we develop the concept of the Electric Field?

Answer: Initially, it was a device when doing several electric force calculations to reduce our calculation work. If we know the Electric field, we can easily find the force applied by the field on the charge. Today, we know the field is real with verifiable properties and all modern physics is based upon "field theories."

Calculating the electric field for different charge configurations is often mathematically difficult just as it is difficult to calculate the gravitational field (also called acceleration due to gravity), $\vec{g}$, for different mass configurations (i.e. the Milky Way galaxy)!!

Earlier, you worked mostly problems near the Earth where $\vec{g}$ was 9.8 m/s^2 toward the center of the earth. This was a special case where we assumed that the Earth is a spherical mass and neglected its spinning to make the problems simpler. In this idealized version you didn't have to calculate $\vec{g}$. Instead, you just used the value and

direction given to you which was closely matches experimental results for many problems. Only engineer and scientists who design missiles and rockets or are concerned with other precise experiments must worry about the errors that these assumptions cause.

We often cannot limit ourselves in electricity to just dealing with spherical or point charges. Many different and practical configurations of charges including charged metal plates are used. These give different electric fields which must be calculated rather than memorized. The next part of the notes and the section on Gauss' Law in your reading will provide you with tools to calculate the Electric Field!!

E. Special Case: Electric Field Due To A Point Charge Q or Spherical Charge Q (NOT A GENRAL FORMULA)
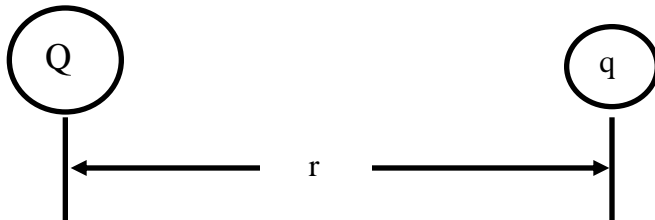
** MEMORIZE

Proof:

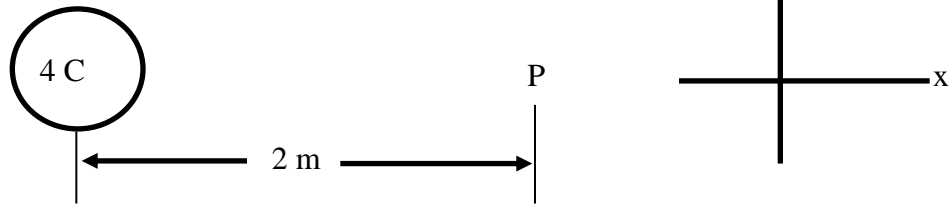Place a test object of charge q at a distance r from our point charge Q.

The force on the point charge is given by Coulomb's law.

We now find the electric field due to the point charge by using the definition of the Electric field.

EXAMPLE:

a) What is the electric field at point P (located a distance of 2m from a 4 C point charge)?

Solution:

Step 1: Find the magnitude of the electric field

Step 2: Find the direction of the field from your diagram

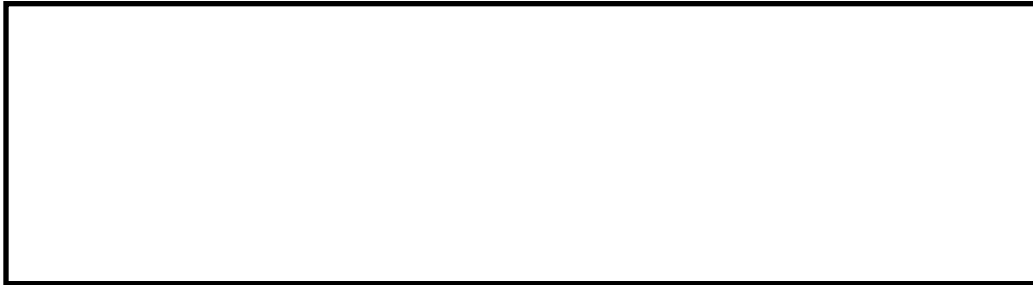**b)** What is the force that a -3 nC charge would experience if

placed at point P?

c) What is the force that a +5 nC charge would experience if

placed at point P?

II. Electric Field Due To Multiple Charges

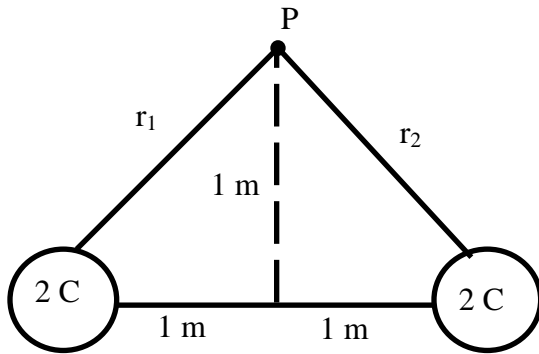**A.** Like any vector, the Electric Field vector obeys the <u>law of superposition</u>.

B. System of Point Charges

EXAMPLE:

What is the electric field at point P in the diagram below:

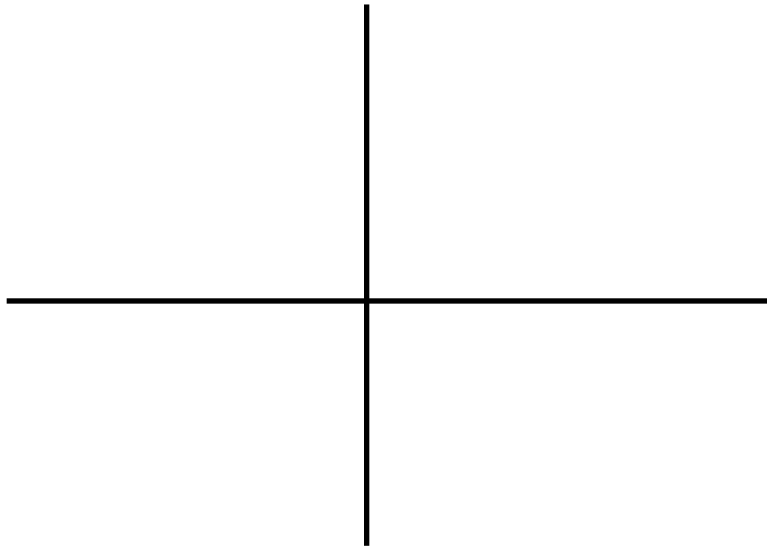**Step 1:** Find the magnitude of E-field produced by each charge.

Step 2: Draw diagram for point P showing the electric field created by each charge and find its direction.

Step 3: Break all electric fields into components.

Step 4: Add components to find the total electric field.

Step 5: Find the magnitude and angle if required.

c.

III. Electric Field Lines

A. **Purpose –** A <u>graphical</u> way of representing the electric field

Although we owe a great debt to James Clerk Maxwell and his use of Vector Mathematics to describe electromagnetism, much of the original work in electricity and magnetism was done by the self taught genius Michael Faraday. Because Faraday had a very limited education, he was weak in math. Yet he made tremendous discoveries with his graphical approach. Faraday saw the electric field in terms of "lines of force" originating from positive charges and terminating on negative charges.

B. **Definition -** An electric field line is a curve drawn such that the electric field vector is tangent to it everywhere.

C. **Rules:**

1. Lines must begin on a positive charge or at infinity and they must end on a negative charge or at infinity.

2.   The number of lines leaving a positive charge or entering a

negative charge must be proportional to the magnitude of the

charge.

3.   No two field lines can cross.

4.   The density of the lines at any place in space is proportional

to the strength of the field.

Example:

Draw the electric field lines for the following charge configuration.
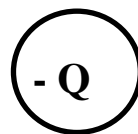
Steps For Drawing Electric Field Lines:

1. Draw a field line straight from the positive charge to the negative charge.

2. In order to account for the fact that the +3Q charge needs three times as many field lines as the –Q charge, we draw two lines leaving the positive charge and going to infinity.

3. Draw two more field lines from the positive charge to the negative charge. (One on top and one on bottom)

4. Draw four more lines from the positive charge and terminating at infinity.

5. Continue the same process as in steps 3 & 4 till your drawing is sufficiently detailed.
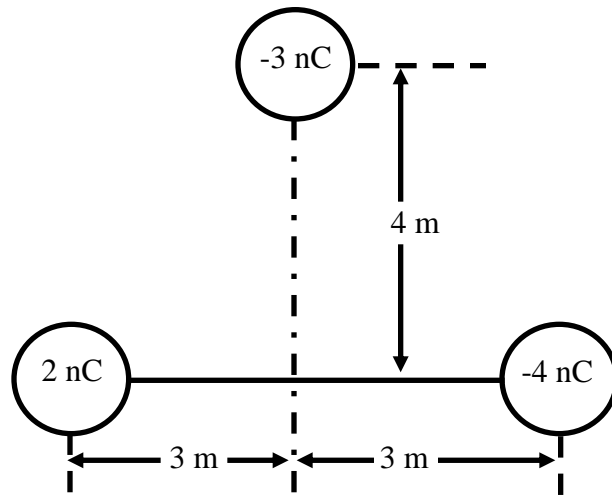
BOARD WORK – ELECTRIC FIELDS

1 a)   A –2 nC point charge is placed at the origin. What is the electric field at x = 2 m

on the x-axis?

Solution:

1 b)   What force would a +3 nC point charge experience if it was placed at x = 2m?

Solution:

2.   Three point charges are distributed as shown in the diagram below. What is the

electric field at point P?

Solution: