Calculating Electric Fields and Forces

Charge

There are two kinds of charge: positive (protons) and negative (electrons).

It has been determined, through careful examination, that protons and electrons have exactly the same amount of charge. This has led to the idea of an **elementary charge** that can be defined as the charge on a single proton or electron. We often abbreviate elementary charge with the symbol *e*.

Electric charge is measured in coulombs (*C*). One coulomb is equal to the amount of charge on a very specific number (6.24×10^{18}) of protons (or electrons).

$$1\ e = 1.60 \times 10^{-19}\ C$$

Thus, each proton has a charge of $+1.60 \times 10^{-19}\ C$, and each electron has a charge of $-1.60 \times 10^{-19}\ C$.

According to modern theories of electric charge, and object is neutral when it contains equal numbers of protons and electrons. Positively charged objects contain more protons than electrons, and negatively charged objects contain more electrons than protons.

All charges should, therefore, be some multiple of the charge on a single proton or electron (the elementary charge). This can be expressed mathematically:

$$q = \pm N \cdot e$$

where N is the number of excess charges on an object.

Example 1

When you rub a balloon against your hair, electrons are transferred from your hair to the balloon. If 7.2×10^{10} electrons are transferred,

a) what is the charge, in coulombs, on the balloon?
b) what is the sign of the charge on the balloon?

The Electric Field and Force

The electric field at a point in space is calculated as the amount of electric force acting on a charge divided by the magnitude of the charge placed at that point.

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

If a point charge q is placed into an electric field of known strength, then the electric force acting on the charge can be calculated using

$$F_E = q \cdot E$$

The electric force and electric field are in the same direction for positive charges; they are in opposite directions for negative charges.

Example 2

A test charge of $q = +5.00\ C$ is placed a distance of $2.00\ m$ to the right of a positive point charge. The strength of the electric field produced by this charge is $10.0\ N/C$ at the location of charge q. What is the electric force acting on the charge q?

Example 3

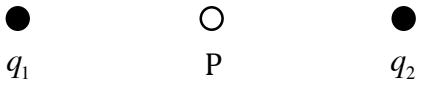
A test charge of $q = +5.00\ C$ is placed a distance of $2.00\ m$ to the right of a negative point charge. The strength of the electric field produced by this charge is $10.0\ N/C$ at the location of charge q. What is the electric force acting on the charge q?

Example 4
A charge of $-5.0\ mC$ is placed in an electric field that is $250\ N/C$ to the east. Determine the amount and direction of the electric force that the charge experiences at this location.

Electric Field due to Multiple Charges

If there are two point charges located near each other, the electric field around these charges will be the vector sum of the electric field due to the first charge and the electric field due to the second charge.

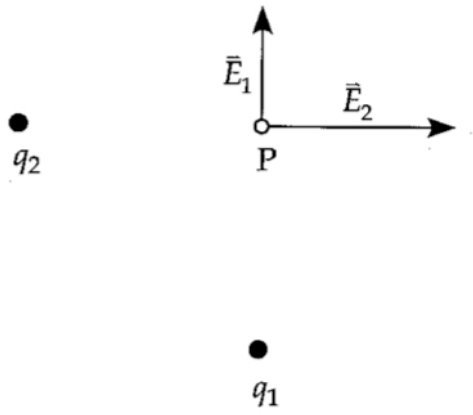
Example 5
In the diagram below, there are two charges. The positive charge, q_1 creates an electric field of $10.0\ N/C$ to the right at position P. The positive charge q_2 creates an electric field of $15.0\ N/C$ to the left at position P. What is the total electric field at point P?



If a charge of $2.0\ C$ was placed at point P, what electric force would it experience?

Example 6

Two charges are arranged as shown below. The positive charge q_1 creates an electric field of $10.0\ N/C\ [North]$ while the charge q_2 creates an electric field of $15.0\ N/C\ [East]$. What is the total electric field at point P?



Electric Fields Worksheet #2

1. A negative charge of $2.0\times10^{-8}\ C$ experiences a force of $0.060\ N$ to the right in an electric field. What are the magnitude and direction of the field? ($3.0\times10^{6}\ N/C$ [*left*])

2. A positive test charge of $5.0\times10^{-4}\ C$ is in an electric field that exerts a force of $2.5\times10^{-4}\ N$ on it. What is the magnitude of the electric field at the location of the test charge? ($0.50\ N/C$)

3. You are probing the field of a charge of unknown magnitude and sign. You first map the field with a $1.0\times10^{-6}\ C$ test charge, then repeat your work with a $2.0\times10^{-6}\ C$ test charge.
   a) Would you measure the same forces with the two test charges? Explain.
   b) Would you find the same fields? Explain.

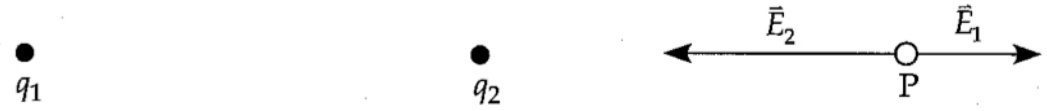
4. A positive charge of $1.0\times10^{-5}\ C$ experiences a force of $0.20\ N$ when located at a certain point. What is the electric field intensity at that point? ($2.0\times10^{4}\ N/C$)

5. What charge exists on a test charge that experiences a force of $1.4\times10^{-8}\ N$ at a point where the electric field intensity is $2.0\times10^{-4}\ N/C$? ($7.0\times10^{-5}\ C$)

6. A test charge experiences a force of $0.20\ N$ on it when it is placed in an electric field intensity of $4.5\times10^{5}\ N/C$. What is the magnitude of the charge? ($4.4\times10^{-7}\ C$)

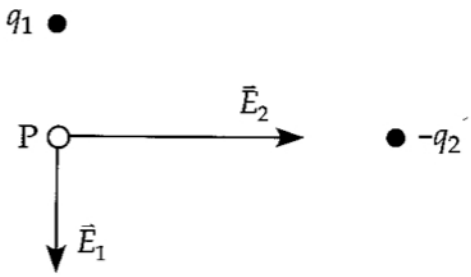
7. A positive test charge of $8.0\times10^{-5}\ C$ is placed in an electric field of $50.0\ N/C$ intensity. What is the strength of the force exerted on the test charge? ($4.0\times10^{-3}\ N$)

8. A positive charge q_1 produces a field $E_1 = 5.0\ N/C$ at location P, as shown. A negative point charge q_2 produces a field $E_2 = 10.0\ N/C$ at the same location, as shown.



   a) Determine the magnitude and direction of the total electric field at P.
   b) If a $4.5\ C$ charge was placed at P, what is the magnitude and direction of the force experienced by this charge?

9. A positive charge q_1 produces a field $E_1 = 5.0\ N/C$ at location P, as shown. A negative point charge q_2 produces a field $E_2 = 10.0\ N/C$ at the same location, as shown.



a) Determine the magnitude and direction of the total electric field at P.
b) If a $4.0\ C$ charge was placed at P, what is the magnitude and direction of the force experienced by this charge?