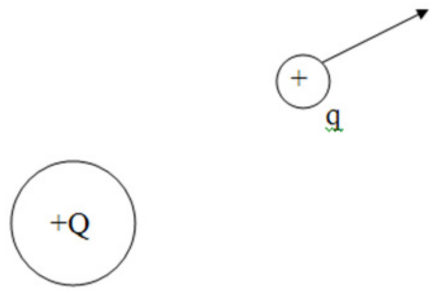
Lesson 4

Electric Field Lines

Consider a positively charged sphere, Q, producing an electric field as shown.



The force exerted on the test charge, q, will depend on the strength or intensity of the field at the point where the test charge is placed. The force is larger the closer the test charge is to the sphere.

Electric Field Strength (Ɛ):
The force per unit charge on a positive test charge placed at that point in the field.

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

Where ε = electric field strength (N/C)
F_E = electric force (N)
q = positive test charge (C)

Note that this equation is very similar to the gravitational force **(see p. 533)**

$$g = \frac{F_G}{m}$$ **force per unit mass**

Example:
A charged rubber balloon has an electric field around it. At a particular point in the field, a test charge of 1.5 μC experiences an electric force of 3.0×10^{-4} N. What is the electric field strength at that point?

Another equation can also be derived for electric field strength.

Recall Coulomb's law:

$$F_E = \frac{kQ_1Q_2}{r^2}$$

For a charged object Q and a test charge q, this becomes:

$$F_E = \frac{kQq}{r^2}$$

$$\frac{F_E}{q} = \frac{kQ}{r^2}$$

But,

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

Thus:

$$\varepsilon = \frac{kQ}{r^2}$$

Where:

ε = electric field strength (N/C)
k = Coulomb's constant
Q = charge on object producing the field (C)
r = distance separating Q and q (m)

This equation lets us find ε without knowing the test charge.

Example:
The ball of a Van der Graaff generator has a charge of 7.0 nC. What is the electric field strength 200.0 cm from the ball?

Example:

a) **What is the net electric field strength at point A?**
b) **What force is exerted on a charge of 4.5×10^{-6} C placed at point A?**

Electrical Potential Energy (E):

The total electrical energy (work – W) required to move charge against an electric field. (see p. 558)

$$W_{12} = E_2 - E_1$$
$$W_{12} = F_E d_2 - F_E d_1$$
$$W_{12} = F_E (d_2 - d_1)$$
$$W_{12} = \varepsilon q (d_2 - d_1)$$

Electric Potential (V):

Electric potential energy per unit charge, as the charge is moved in the electric field.
The work per unit charge then becomes:

$$W_{12} = E_2 - E_1$$
$$\frac{W_{12}}{q} = \frac{\Delta E}{q}$$
$$V = \frac{\Delta E}{q}$$

V = electric potential (Volts)
E = electric potential energy (J)
q = charge (C)

This is also known as a volt and has units of J/C. Electric potential is always with reference to the zero potential level.

Charges can also be moved from a potential having a value other than zero (eg. from a region of low potential to high potential).

Electric Potential Difference (also V):

The energy required (or work done) per unit charge to move that charge from any point of low potential to any other point of higher potential.

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

same as electric potential, but not a zero reference level.

In the next section, electric potential difference will be studied as voltage.

Example:
In order to move a charge of 0.080 C from point A to point B in an electric field, 0.24 J of work are required. What is the electric potential difference between A and B?

Example:

The work done on a charge of 1.0 × 10^{-6} C in moving it a distance Δd against an electric field is 2.5 × 10^{-5} J.

a) **What is the change in electric potential energy of the charge for this displacement?**
b) **What is the potential difference between these two positions?**

1 electronvolt = the energy of one electron after it has been accelerated through a potential difference of 1 volt.

$$E = q\Delta V$$
$$1eV = (1.602x10^{-19}C)(1.00V)$$
$$1eV = 1.602x10^{-19}V \cdot C$$
$$1eV = 1.602x10^{-19}\frac{J}{C} \cdot C$$
$$1eV = 1.602x10^{-19}J$$

Example:
What potential difference is required to increase the energy of an electron from 0 to 200 eV?