Chapter 12

Electricity

Electric Charge

- Electric charge is a fundamental quantity of matter (like mass), not a derived quantity like energy. The symbol for charge is **Q** and the units are Coulombs (**C**). Unlike mass, electric charge can be both positive and negative.
- For example:
  - Q = 1.4 μC
  - Q = - 6.1 μC

Atoms

- Everything is composed of atoms. While we won't look at the detailed structure of the atom until later in the semester, we can say that they are made up of three sub-atomic particles.

Particle	Mass (kg)	Charge (C)
Electron	9.1×10^{-31}	-1.6×10^{-19}
Proton	1.67×10^{-27}	1.6×10^{-19}
Neutron	1.67×10^{-27}	0

Net Charge

- For any object, the **net charge** on that object is the sum of the charges on all of its components. Since all atoms in the periodic table have the same number of electrons and protons, the net charge for each is zero.
  - *If most atoms are charge neutral, how do we ever end up with objects that have a non-zero net charge?*

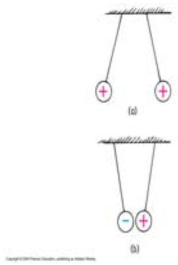
Charging by Friction

- Imagine that you rub a hard rubber rod with a piece of rabbit fur. As you do this, electrons are *stripped* from the fur and attach to the rubber rod.
- The means that the rod now has more electrons than protons so it is **negatively charged.**
  - **What is the charge on the fur?**

Charging by Friction (2)

- We can also charge a piece of glass by rubbing it with silk.
- Electrons will be stripped from the glass and accumulate on the silk. Therefore, the silk will have an excess of electrons and will be negatively charged.
- Similarly, the glass will have a deficiency of electrons and will be positively charged.

Interactions between charges



- In order to understand how the other charging methods work, we need to understand how charges interact. Like charges (++ or --) repel each other and opposite charges (+-) attract.

Charging by contact

- Imagine that you have a negatively charged object and a neutral one. When the two object touch each other, some of the extra electrons will flow to the neutral object (*why?*) and you will end up with two negatively charged objects.
  - *How does the new charge on each object compare to the original charge on the negatively charged object?*

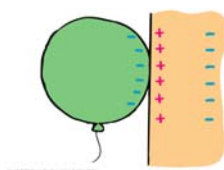
Charging by Contact (2)

- If we touch a positively charged object to a neutral one, electrons from the neutral one will be attracted to the positively charged object. The electrons will flow to the positively charged object and we will end up with two positively charged objects.

Charging by Contact (3)

Charging by Induction

- If a negatively charged object is brought near a neutral one, it will repel negative charges inside the neutral object. Now we have a positive side and a negative side. Now the neutral object is **polarized**



Coulomb's Law

- The force between two point charges is computed using Coulomb's Law:

$$F = \frac{kq_1q_2}{d^2}$$

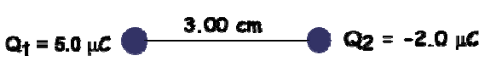
$$k = 9 \times 10^9 \frac{N \cdot m^2}{C^2}$$

Coulomb's Law (2)

- How do we use Coulomb's Law?
  - Always put your charges in as positive numbers (even if they are negative). If you include the negative sign you might get the right answer but you might not.
  - Determine the direction of the force using the fact that like charges repel and opposite charges attract.

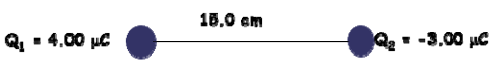
Example 1

- Find the force on each of the point charges due to the other.



Example 2

- Find the force exerted on each point charge by the other.



Example 3

- Find the force on the middle point charge due to the other two point charges.

Electric Field

- Electrical forces, like gravitational forces, act between objects that are **not** in contact with each other. Recall that the weight of an object is given by:

$$w = mg$$

- Where g is the acceleration due to gravity. From Newton's law of gravitation, we know that g is given by:

$$g = \frac{GM_E}{R_E^2}$$

Electric Field (2)

- This gravitational force is exerted on an object even though the source of the force (the Earth in this case) is not in direct contact with it. This non-contact force is exerted by the Earth's **gravitational field** which is represented by .
- *Can we express the electrostatic force in a similar way?*
- YES! If we look at our equation for the weight, it can be rearranged to solve for g:

$$g = \frac{w}{m}$$

Electric Field (3)

- So we can think of the gravitational field as the force per unit mass. In order to define the **electric field (E)**, we might try the force per unit charge.

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

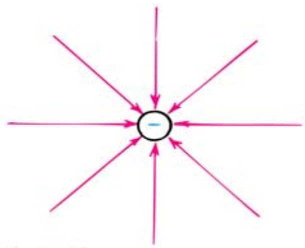
Example 4

- An electron is placed in a uniform electric field of 30 N/C to the right. What is the force on the electron? What is the acceleration of the electron?

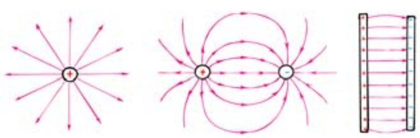
Rules for Electric Field Lines

- Field lines *start* at positive charges and end at negative ones.
- Field lines are always normal (perpendicular) to the surface of the charged object.
- Field lines never cross.

Field From a Point Charge



Other Field Distributions



Electric Potential (Voltage)

- Recall that the gravitational potential energy is PE = mgh. More generally, an object has gravitational potential energy based upon its position in a gravitational field.
- Similarly, a charged object has electric potential energy based upon its position in an electric field. Using this potential energy we can define:

$$V = \frac{PE_E}{q} = \text{voltage}$$

Example 4

- A charge of +0.25 C is moved from a position where the electric potential is 10 Volts to a position where it is 60 Volts. What is the change in potential energy of the charge?