Lecture 2

Electric Charge

Chapter 22

Electric Charge (7)

- Review from yesterday
  - There are 2 types of charge pos. and neg.
  - Like charges repel; unlike charges attract
  - Most objects are electrically neutral; there are equal numbers of neg. and pos. charges so the net charge = 0
  - An object becomes charged (net charge ≠ 0) by adding or removing electrons
  - Conductors are materials where some of the electrons can move freely
  - Insulators are materials where none of the charges can move freely

Electric Charge (8)

- An object can be given a charge by conduction or induction
- In conduction the charge is transferred between objects by direct contact. For example,
  - Rubbing a glass rod (an insulator) with silk
  - Connecting 2 conductors through a conducting pathway (such as a wire) or by grounding the object
    - See Sample Problem 22-3

Electric Charge (9)

- An electrically neutral object can have an induced charge when some of its positive and negative charges separate due to a nearby charge
- Neutral object will display characteristics of a charged object even though there is no net charge
- Can we get an induced charge with an insulator?

Electric Charge (10)

- Take induction of charge one step further
- Induce a charge on a conducting sphere by bringing a charged object nearby
- Ground the sphere keeping the charged object nearby
- Remove the connection to ground, move the charged object away and conducting sphere becomes uniformly charged
    - See diagram on board

Electric Charge (11)

- The magnitude of the electrostatic force, F, between 2 charged particles with charges q_1 and q_2, respectively, and separated by a distance r is defined as

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

- This is Coulomb's law where k is a constant
- The forces on 2 point charges are equal and opposite, pointing to (away from) the other particle for unlike (like) charges

Electric Charge (12)

- Coulomb's law should remind you of Newton's equation for the gravitational force

$$F = \frac{Gm_1 m_2}{r^2}$$

- *k* is called the electrostatic constant

$$k = \frac{1}{4\pi\varepsilon_0} = 8.99 \times 10^9 \, N \cdot m^2 / C^2$$

- ε_0 is called the permittivity constant

Electric Charge (13)

- Electrostatic force and gravitational force are both inverse square laws involving a property of the interacting particles
- Both obey the superposition principle:
  - The net force acting on any charge is the vector sum of the forces due to each of the remaining charges in a given distribution

$$\vec{F}_{1,net} = \vec{F}_{12} + \vec{F}_{13} + \vec{F}_{14} + \ldots + \vec{F}_{1n}$$

Electric Charge (14)

- Have 2 shell theorems for electrostatics
  - A shell of uniform charge attracts or repels a charged particle that is outside the shell as if all the shell's charge were concentrated at its center
  - If a charged particle is located inside a shell of uniform charge, there is no net electrostatic force on the particle from the shell
- Electrostatic force differs from gravitational:
  - Can be either attractive or repulsive
  - Holds for all experimental tests and over all ranges

Electric Charge (15)

- Charge is quantized – comes in discrete values
  – Proven by Millikan oil-drop experiment (section 23-8)

- Electric charge q is an integer multiple of the fundamental (or elementary) charge constant e
- $q=ne$ where n = ±1, ±2, ±3 and $e = 1.60 \times 10^{-19}$ C

Particle	Electric Charge	Mass
Electron	$-e$ = -1.6E10^{-19} C	M_e=9.11E10^{-31} kg
Proton	$+e$ = 1.6E10^{-19} C	M_p=1.672E10^{-27} kg
Neutron	0	M_n=1.674E10^{-27} kg

Electric Charge (16)

- Net charge of an object is the difference between the number of protons and electrons in it times *e*

- Charge is conserved
  - Net charge of any isolated system cannot change
  - Same as energy, linear and angular momentum