Physics

Lesson Plan #12
Static Electricity
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Electrical Charge

Objectives: Recognize that objects that are charged exert forces, both attractive and repulsive; Demonstrate that charging is the separation, not the creation of electrical charges; Describe the differences between conductors and insulators.

- Charged Objects
    - You are aware of static electricity – when winter comes, often you reach for a door knob only to hear a crack of electricity and you see a spark jump from your hand to the knob, but why only in the winter, and why after walking across a carpet, or sliding across a car seat?
    - **Electrostatics** is the study of electrical charges that can be collected and held in one place.
    - Combing your hair will create a charge on your comb that will pick up small pieces of paper – against the force of gravity!
        - This must be a new relatively strong force causing the upward acceleration, because it is greater that the downward acceleration due to gravity.
        - If you wait awhile, the force disappears and will no longer pick up or hold paper to the comb. Gravity on the other hand never goes away.
    - The ancient Greeks were aware of this effect when you rubbed a piece of amber – the Greek word for amber is electron – today this attractive property is called electrical.
        - An object that exhibits electrical interaction after rubbing is said to be charged.
        - Like charges repel and dislike charges attract.
    - In 1890 JJ Thompson discovered the negatively charged electron surrounding an atom. About 20 years later Ernest Rutherford discovered that the nucleus of an atom is massive and positively charged. If the positive charge of the nucleus is same quantity, but opposite value for the charge of the electrons for an atom, the atom is said to be **neutral.**
    - If an atom is missing electrons then it has a positive charge, if an atom has extra electrons then the atom has a negative charge.
        - Notice that in both cases we speak in terms of transferring electrons
        - Rubbing two neutral objects can cause the objects to become charged
            - Wool and rubber
            - Rubber tires on pavement
            - Processes inside a thunderstorm can cause the top of the cloud to become positively charged while the bottom of the cloud has a negative charge

- Not all materials will store a charge – those that will are called **insulators**, those that will not store a charge are called **conductors.**
  - Glass, dry wood, most plastics and dry air are insulators
  - Most all metals are conductors.
- Air typically is an insulator, but under the correct conditions can be come a conductor
  - Such as when that spark jumps from your hand to the doorknob, or when lighting discharges from a cloud.
  - A conductor must have charges that are free to move – with lighting the charge is great enough to remove electrons from normally neutral molecules in the air. These electrons and positively charged atoms become free to move. They form a conductor that is plasma, thought which the lighting moves.
  - In the case of your hand and the doorknob, it is called a spark.

Electrical Force

Objectives: Summarize the relationship between forces and charges; Describe how an electroscope detects electric charge; Explain how to charge by conduction and induction; Use Coulomb's law to solve problems relating to electrical force; Develop a model of how charged objects can attract a neutral object.

- Forces on Charged Bodies
  - Much like the experiments for determining the gravitational constant, it was found that by hanging a charged bar and calibrating how much force would cause the bar to twist, the force of a charge could be determined.
    - There are two type of electrical charges – positive and negative
    - Charges exert force one other charges over a distance
    - The force is stronger when the charges are closer together
    - Like charges repel, opposite charges attract
  - The simplest detector of static charges is an electroscope
    - A conductive rod with a thin leaf bent over the end. When a charge is applied to the rod, the charge is transmitted to the leaves, which repel each other
  - Charging by Conduction
    - When a negatively charged rod is touched to an electroscope, electrons are added to the knob – these spread over the entire metal rod, including the leaves causing them to repeal each other.
    - Placing a charge on a neutral body by touching it with a charged body is called **charging by conduction**.
  - Separation of Charge
    - When a neutral charged object is brought near a charged object, there is an attraction – but why if one object is neutral?
    - Suppose you had a positively charged comb – when you bring it near your hair, then the negative charges in your neural hair are drawn nearer the comb, while the positively charges in your hair are repealed away.
    - This is the separation of charges on neutral objects
    - The strong negative charges at the bottom of a thundercloud can cause the Earth to undergo separation of charge, making the area under a such a

cloud positively charge, thereby opening the possibility of a lighting strike.

- Charge by Induction
  - Without touching an object, separation of charge can be used to place a charge on an object.
  - If 2 neutral objects are touching, and a negatively charged object is brought near, the separation of charge will cause the nearer object to become positively charged while the farther object will become negatively charged.
  - If the 2 objects are then separated while the charged object is near, they will retain their negative and positive charge – this is called **charging by induction**.

- Coulomb's Law
  - Now that we have established that like charges repel and opposite charges attract, what strength of forces are we talking about?
  - French physicist Charles Coulomb answered this question in 1785, using an apparatus similar to the one we saw when we were dealing with the attraction of gravity between two objects.
    - An insulating rod was suspended by a wire – the rod had a ball on each end.
    - A neutral ball of the same mass and size was placed next to one of the balls on the sphere and the balls were charged by induction – this gave an equal but opposite charge to each sphere.
    - By measuring the force and distance on the wire when the two charged balls were brought near each other, Coulomb was able calculate that the force F varied inversely with the square of the distance between the centers of the spheres
      - $F \propto \frac{1}{d^2}$
  - By taking another free standing sphere, also the same size and touching it to the other free standing sphere, they now shared charge that had been on the 1st free standing sphere – what Coulomb now found was that the force generated by a sphere with ½ the original charge was only ½ as the fully charged sphere.
    - So using q_A and q_B as the charges on the spheres, Coulomb found that $F \propto q_A q_B$
  - After many such experiments, Coulomb summarized his findings in what is now known as **Coulomb's Law** – the magnitude of the force between charged body q_A and charged body q_B is proportional to the magnitude of the charges and inversely proportional the square of the distance between them - $F \propto \frac{q_A q_B}{d^2}$
  - The Unit of Charge
    - While the amount of charge is difficult to measure, Coulomb proved that the quantity of charge could be related to force.

        - Today the SI unit of measure for charge is called the **coulomb** (C), and is the charge of 6.25 x 10^{18} electrons or protons – remember, charge can be positive or negative.
            - The charge on a typical lighting bolt is 10 C
    - The charge on a single electron is 1.60 x 10^{-19} C and is called the **elementary charge**.
        - While everything about you has a large number of electrons, there is normally an equal number of protons to balance the charge to neutral.
        - A charge of 10^{-9} C can result in large forces.
    - The final version of Coulomb's law equation appears as $F = K\frac{q_A q_B}{d^2}$, where K is a fudge factor equal to 9.0 x 10^9 N·m^2/C^2, q's are measured in coulombs, and distance is in meters
    - This equation gives the magnitude of the force that q_A exerts on q_B and that q_B exerts on q_A, which according to Newton is an opposite but equal force.
    - The electrical force is a vector quantity – but coulomb's law only supplies a magnitude – no direction. To determine the direction you must draw a diagram and interpret the charge relations

- Real life examples of using static charges
    - Removing soot from smoke stacks – reducing pollution
    - Charging paint drops to accurately control spray painting
    - Laser printers
    - The original ink jet printer from IBM used a single nozzle that was would deflect a drop of ink vertically to position it on the paper