

## PHY132 Introduction to Physics II

### Class 8 – **Outline:**

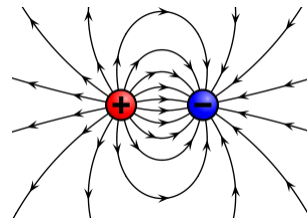
- Ch. 25, sections 25.1-25.4
- Developing a Charge Model
- Electric Charge
- Insulators and Conductors
- Coulomb's Law



Dielectric strength of air:  $3 \times 10^6$  V/m

[Photo by David He Aug. 9, 2009. <http://www.flickr.com/photos/davidymhe/3809482563/>]

### Reading Question



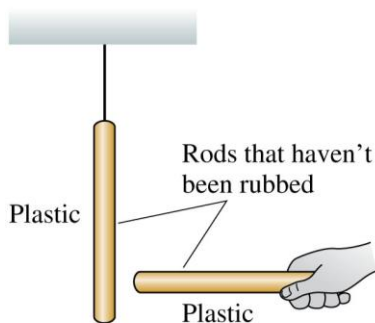
- What is the SI unit of electric charge?
  - A. Coulomb
  - B. Faraday
  - C. Ampere
  - D. Ohm
  - E. Volt

## What's a volt?



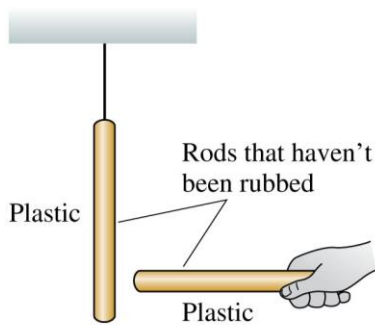
- “High Voltage”, as you probably know, is dangerous: you can get shocked!
- But why?
- At the heart of voltage is **Ohm’s Law** and electric current.
- *But first:* you should know about electric potential.
- *But first:* you should know about electric fields.
- *But first:* you need to know about the **electric force**.

## Discovering Electricity: Experiment 1



- Take a plastic rod that has been undisturbed for a long period of time and hang it by a thread.
- Pick up another undisturbed plastic rod and bring it close to the hanging rod.
- Nothing happens to either rod.
- No forces are observed.
- We will say that the original objects are **neutral**.

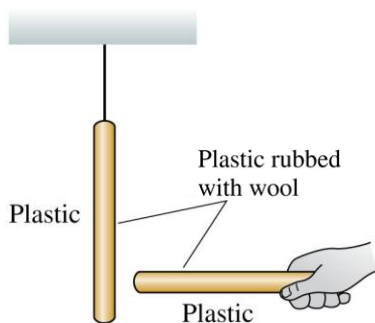
## Discovering Electricity: Experiment 1



### ■ Conclusion:

- Most things are “neutral”, which is why we don’t often observe the electric force.

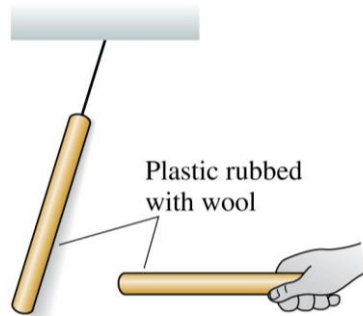
## Discussion Question



- Rub two plastic rods with wool.
  - Hang one from a string
  - Place the other near it.
  - What will happen?
- A. Nothing: no force observed
- B. The hanging rod will be repelled, and move to the left
- C. The hanging rod will be attracted, and move to the right

## Discovering Electricity: Experiment 2

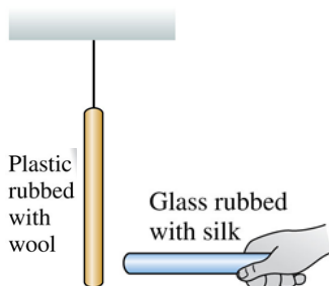
# Conclusion



There is a *long-range repulsive force*, requiring no contact, between two identical objects that have been charged in the *same way*.

**We call this the “Electric Force”.**

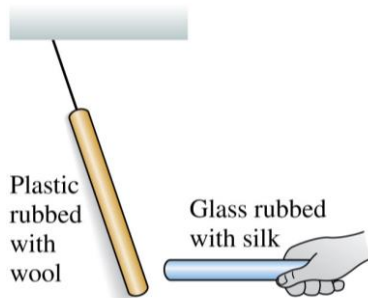
### Discussion Question



- Rub a plastic rod with wool, and hang it from a string.
  - Rub a glass rod with silk, and place it near the hanging rod.
  - What will happen?
- A. Nothing: no force observed
- B. The hanging rod will be repelled, and move to the left
- C. The hanging rod will be attracted, and move to the right

## Discovering Electricity: Experiment 3

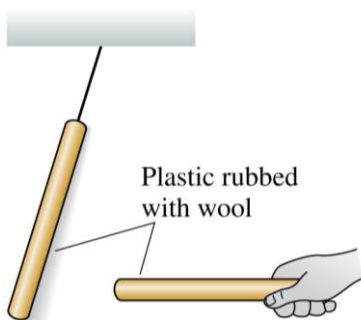
# Conclusion



These particular two types of rods are different materials, charged in a somewhat different way, and they *attract* each other rather than repel.

**This is also the “Electric Force”.**

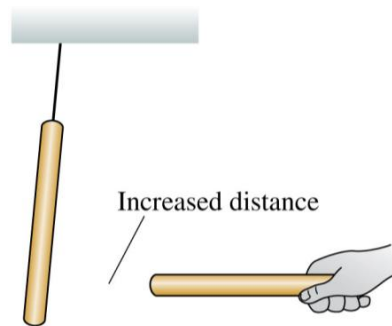
### Discussion Question



- Rub two plastic rods with wool, hang one from a string, place the other near it so it repels the hanging rod.
  - What happens if you increase the distance between the two rods?
- A. Nothing: no change in force
  - B. The repulsive force will decrease
  - C. The repulsive force will increase

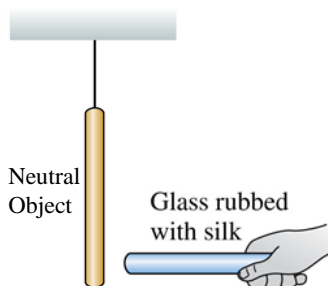
## Discovering Electricity: Experiment 4

# Conclusion



The electric force between two charged objects depends on the distance between them; the greater the distance, the less the force.

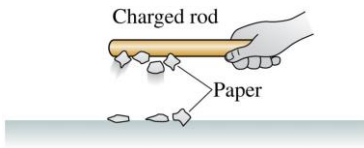
### Discussion Question



- Hang a neutral object from a string.
- Rub a glass rod with silk, and place it near the hanging object.
- What will happen?

- A. Nothing: no force observed
- B. The hanging object will be repelled, and move to the left
- C. The hanging object will be attracted, and move to the right

## Discovering Electricity: Experiment 5 Conclusion



- Neutral pieces of paper leap up and stick to a charged glass rod.
- A neutral stream of water bends toward a charged plastic comb.

There is an attractive force between a charged object and a *neutral* (uncharged) object.

**This is also the electric force, but it's weaker, and a bit difficult to understand..**



In Class Discussion Question

A sock has just come out of the dryer. You hypothesize that the sock might have a positive charge.

To test your hypothesis, which of the following experiments would work?

- See if the sock attracts a negatively charged plastic rod.
- See if the sock repels a positively charged glass rod.
- Either A or B would work.

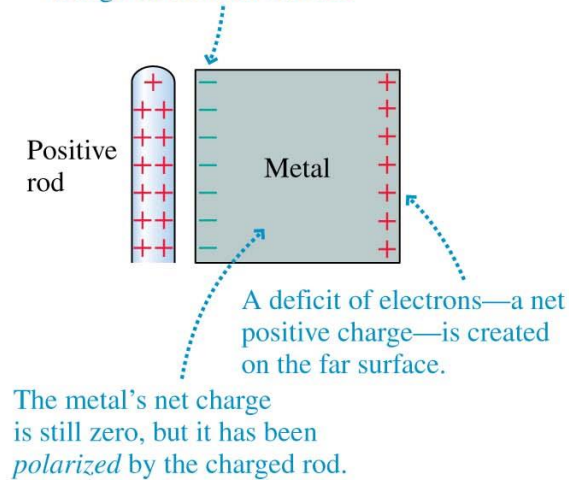
(Compare with Stop To Think 25.1 from your reading.)



## Charge Polarization

**FIGURE 26.12** A charged rod polarizes a metal.

- (a) The sea of electrons is attracted to the rod and shifts so that there is excess negative charge on the near surface.



## Charge Polarization

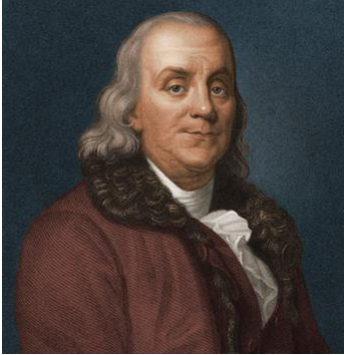
- When two small electrically charged objects are brought together, opposites attract and same repel.
- When the objects have finite size and one of them is neutral or has very little charge on it, it will become *polarized*.
- The resulting force is *always attractive*. Both positive and negative objects tend to attract neutral objects due to *charge polarization*.



[Image from <https://barefootinsuburbia.wordpress.com/tag/math-facts/> ]



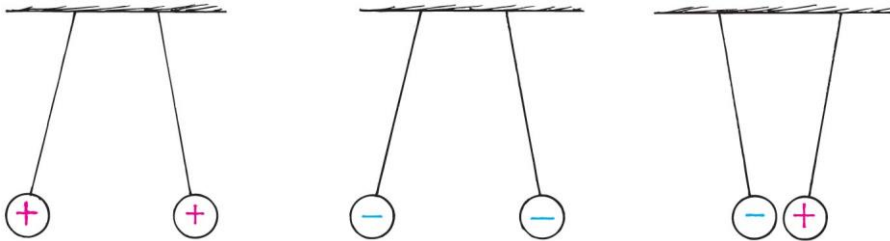
## Benjamin Franklin (1706-1790)



- Recognized that there were two types of electric charge.
- When a glass rod was rubbed with silk, it became charged in one way; Franklin called this “positive”
- When a piece of amber was rubbed with animal fur, it became charged in the opposite way; Franklin called this “negative”.

## Electric Force

- The rule for the electric force is:  
Opposite charges attract one another;  
like charges repel.



# 20<sup>th</sup> Century Discovery: Atomic Structure

## Protons

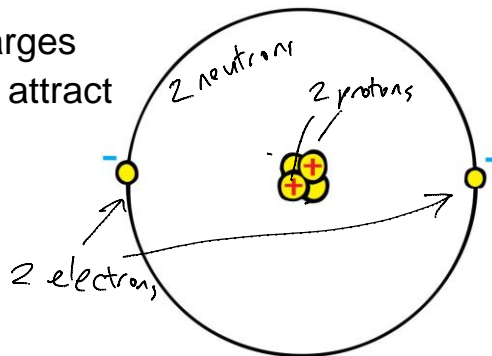
- Positive electric charges
- Repel positives, but attract negatives *Helium atom.*

## Electrons

- Negative electric charges
- Repel negatives, but attract positives

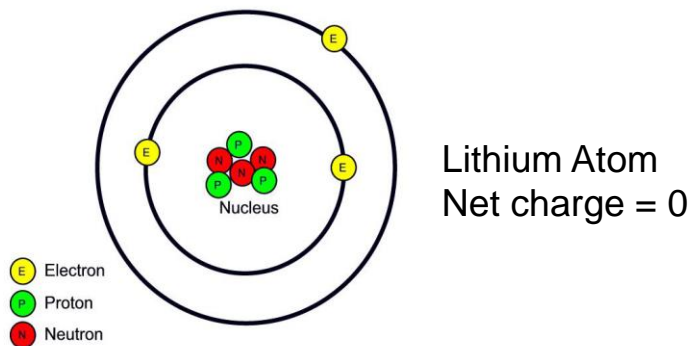
## Neutrons

- No electric charge
- "neutral"



## Fundamental facts about atoms

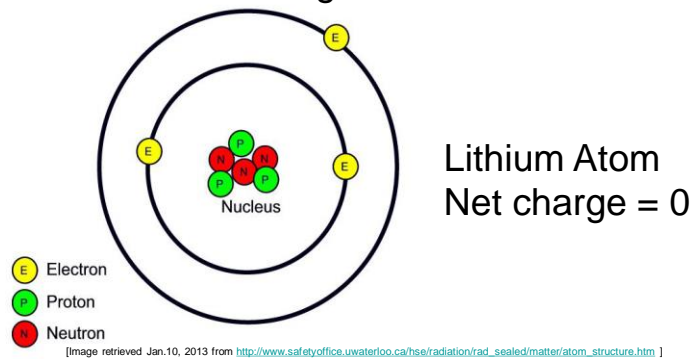
1. Every atom is composed of a positively charged nucleus surrounded by negatively charged electrons.
2. Each of the electrons in any atom has the same quantity of negative charge and the same mass.



[Image retrieved Jan.10, 2013 from [http://www.safetyoffice.uwaterloo.ca/hse/radiation/rad\\_sealed/matter/atom\\_structure.htm](http://www.safetyoffice.uwaterloo.ca/hse/radiation/rad_sealed/matter/atom_structure.htm) ]

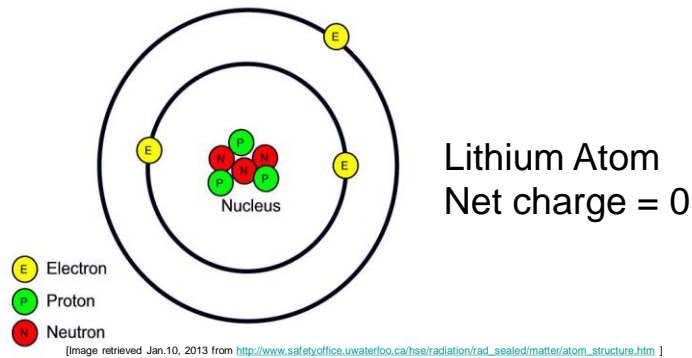
## Fundamental facts about atoms

3. Protons and neutrons compose the nucleus. Protons are about 1800 times more massive than electrons, but each one carries an amount of positive charge equal to the negative charge of electrons. Neutrons have slightly more mass than protons and have no net charge.



## Fundamental facts about atoms

4. Atoms usually have as many electrons as protons, so the atom has zero net charge.



## An “Ion” is a charged atom

- Positive ion — an atom which has lost one or more of its electrons, and so has a positive net charge.
- Negative ion — an atom which has gained one or more electrons, and so has a negative net charge.

### Electric Force and Charges CHECK YOUR NEIGHBOR

When you rub a glass rod with silk, the glass rod becomes positively charged. (As per Benjamin Franklin’s definition of “positive”.)

What is most likely going on here?

- A. The silk is adding electrons to the glass.
- B. The silk is adding protons to the glass.
- C. The silk is removing electrons from the glass.
- D. The silk is removing protons from the glass.
- E. The frictional force is creating new protons within the glass.

## Electric Force and Charges

### CHECK YOUR NEIGHBOR

When you rub a plastic rod with fur or wool, the plastic rod becomes negatively charged. (As per Benjamin Franklin's definition of "negative".)

What is most likely going on here?

- A. The fur or wool is adding electrons to the plastic.
- B. The fur or wool is adding protons to the plastic.
- C. The fur or wool is removing electrons from the plastic.
- D. The fur or wool is removing protons to the plastic.
- E. The frictional force is creating new electrons within the plastic.

**TABLE 26.1** Protons and electrons

Particle	Mass (kg)	Charge
Proton	$1.67 \times 10^{-27}$	$+e$
Electron	$9.11 \times 10^{-31}$	$-e$

- Any object has net charge,  $q$ :

$$q = N_p e - N_e e = (N_p - N_e)e$$

where  $N_p$  and  $N_e$  are the number of protons and electrons contained in the object.

- The process of removing or adding an electron from the electron cloud of an atom is called **ionization**.
- An atom with fewer electrons than protons is called a *positive ion*. An atom with more electrons than protons is called a *negative ion*.

## Electrons in an atom

- Innermost—attracted very strongly to oppositely charged atomic nucleus
- Outermost—attracted loosely and can be easily dislodged



## Examples:

- When rubbing a comb through your hair, electrons transfer from your hair to the comb. Your hair has a deficiency of electrons (positively charged).
- When rubbing a glass rod with silk, electrons transfer from the rod onto the silk and the rod becomes positively charged.

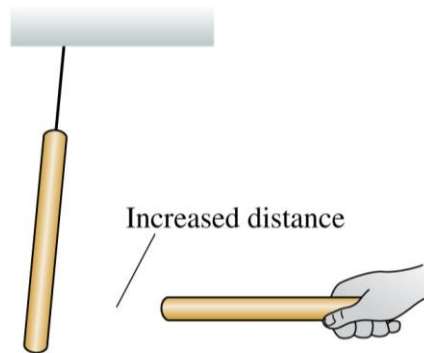
[image from <http://www.sciencebuddies.org/blog/2011/02/the-shock-of-static-electricity.php> ]

## Conservation of Charge

In any charging process, no electrons are created or destroyed. Electrons are simply transferred from one material to another.

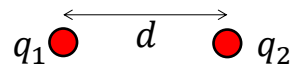


## Recall: Discovering Electricity: Experiment 4



The force between two charged objects depends on the distance between them.

### Coulomb's Law



- The magnitude of the force,  $F$ , between two point charges depends on the product of their charges, and the distance between them.
- In equation form:  
$$F = k \frac{q_1 q_2}{d^2}$$

*Coulomb's constant*  
 $k = 9 \times 10^9 \text{ Nm}^2/\text{C}^2$
- Unit of charge is **coulomb**, C
- Similar to Newton's law of gravitation for masses
- Underlies the bonding forces between molecules
- Electrical forces may be either attractive or repulsive.
- Gravitational forces are only attractive.

### Discussion question.

Charges A and B exert repulsive forces on each other.  $q_A = 4q_B$ . Which statement is true?



A.  $F_{A \text{ on } B} > F_{B \text{ on } A}$

B.  $F_{A \text{ on } B} < F_{B \text{ on } A}$

C.  $F_{A \text{ on } B} = F_{B \text{ on } A}$

## Conductors and Insulators

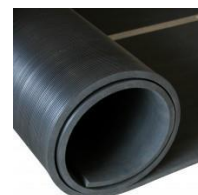
- **Conductors:** Materials in which one or more of the electrons in the outer shell of its atoms are not anchored to the nuclei of particular atoms but are free to wander in the material

– Example: Metals such as copper and aluminum



- **Insulators:** Materials in which electrons are tightly bound and belong to particular atoms and are not free to wander about among other atoms in the material, making them flow

– Example: Rubber, glass





## Conductors and Insulators CHECK YOUR NEIGHBOR

When you buy a water pipe in a hardware store, the water isn't included. When you buy copper wire, electrons

- A. must be supplied by you, just as water must be supplied for a water pipe.
- B. are already in the wire.
- C. may fall out, which is why wires are insulated.
- D. None of the above.

## Before Class 9 on Monday

- Problem Set 3 on MasteringPhysics due Sunday at 11:59pm on Ch.25
- For Monday please read Pgs. 736-756
- Ch. 25, section 25.5  
Ch. 26, sections 26.1 and 26.2
- Please do the short pre-class quiz on MasteringPhysics by Monday morning.
  
- Something to think about: What *is* the electric field? Is it real, or is just something that people made up?