

LECTURE 1  
Ch. 21

PHY 122: CHARGES

PHY 121: KINEMATICS : HOW OBJECTS MOVE (trajectory,  $v$ ,  $a$ ,  $t$ )

DYNAMICS : WHY OBJECTS MOVE (mass, force, work,  $E$ )

↳ CONSERVED QUANTITIES: ENERGY (kinetic + potential)  
MOMENTUM

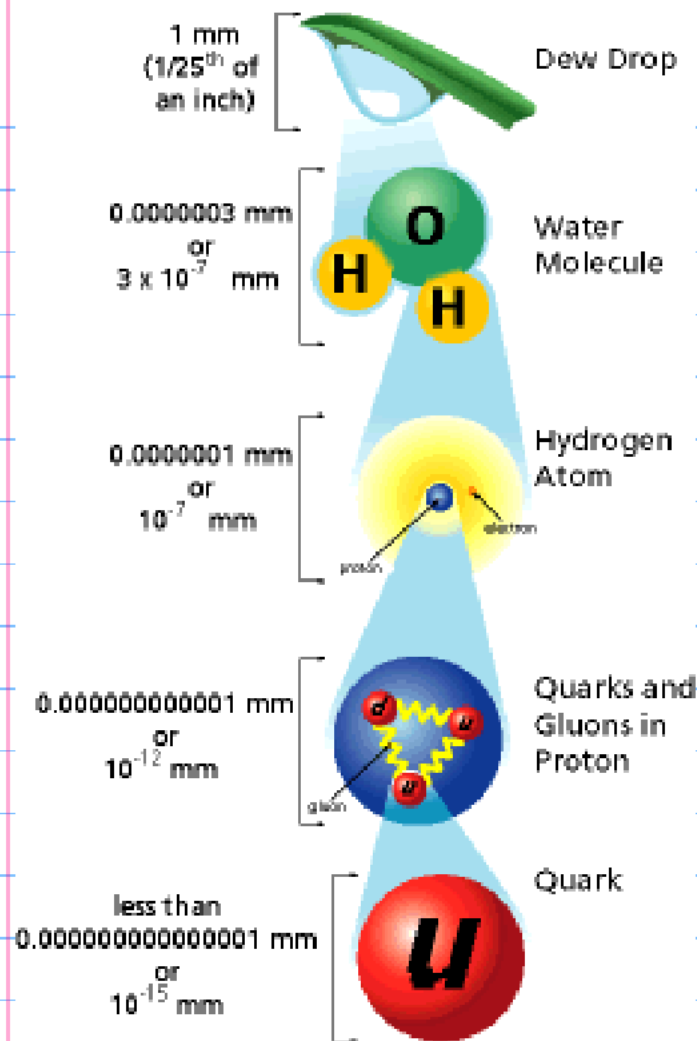
MAIN FORCES YOU HAVE DEALT WITH:

GRAVITY, TENSION, NORMAL, FRICTION

THESE REALLY DON'T DESCRIBE THE STRUCTURE OF MOST THINGS!

LARGE NUMBER OF PHENOMENA ARE OF ATOMIC ORIGIN

ATOMIC STRUCTURE IS DEFINED BY ELECTROMAGNETISM



ATOMS HAVE STRUCTURE : **NUCLEUS** + **ELECTRONS**

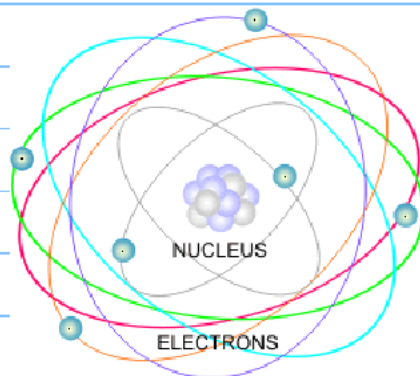
**NUCLEUS** : PROTONS AND NEUTRONS

✓  
 HAVE POSITIVE CHARGE      HAVE NEUTRAL CHARGE

**ELECTRONS** : HAVE NEGATIVE CHARGE

PROTONS AND NEUTRONS ARE MADE OF QUARKS

**QUARKS AND ELECTRONS ARE (SO FAR)**  
**ELEMENTARY = UNBREAKABLE.**



# ELECTRICITY

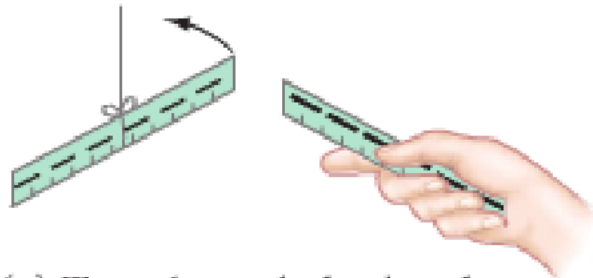
TWO KINDS OF ELECTRIC CHARGE:  
+ and -

LIKE CHARGES: ++ AND -- REPEL

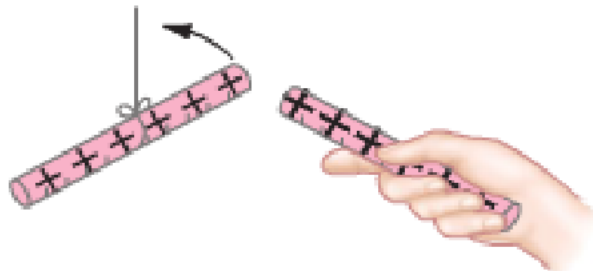
UNLIKE CHARGES: +- ATTRACT

THE CHARGES THAT WE SEE IN  
THESE EXPERIMENTS COME FROM ATOMS:  
ELECTRONS AND IONS

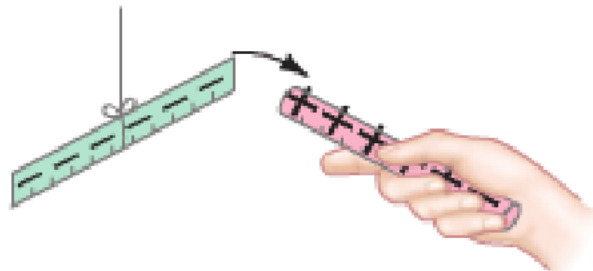
FRICTION (RUBBING) SEPARATES THEM



(a) Two charged plastic rulers repel



(b) Two charged glass rods repel



(c) Charged glass rod attracts  
charged plastic ruler

# ELECTRIC CHARGE

THE ELECTRIC CHARGE IS CONSERVED

MEASURED IN COULOMBS [C]

ELECTRON HAS A NEGATIVE CHARGE:  $-e = -1.6 \times 10^{-19} \text{ C}$

PROTON HAS A POSITIVE CHARGE

ATOM IS ELECTRICALLY NEUTRAL

NUCLEUS IS HEAVY, ELECTRON IS LIGHT: USUALLY CHARGE IS TRANSPORTED BY ELECTRONS.

OBJECTS THAT ACQUIRE  $e^-$  BECOME NEGATIVELY CHARGED

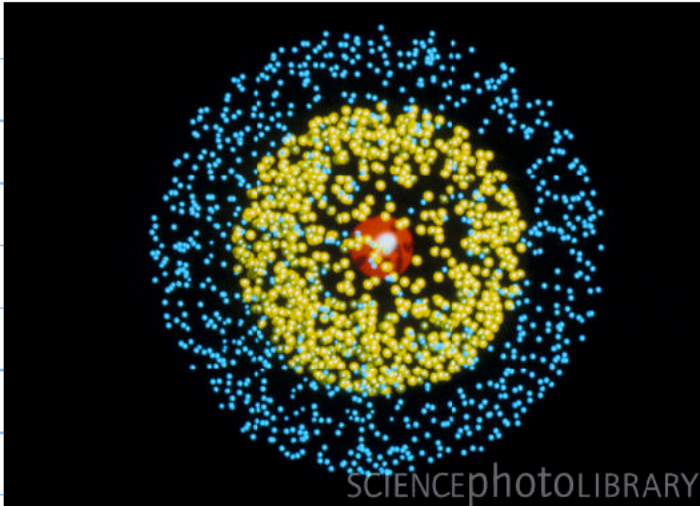
$$Q = -N_e^{\text{gained}} e$$

OBJECTS THAT LOSE  $e^-$  BECOME POSITIVELY CHARGED.

$$Q = +N_e^{\text{lost}} e$$

## INSULATORS AND CONDUCTORS

IN SOLIDS, ATOMS AND THEIR NUCLEI ARE LOCKED IN THEIR POSITION AND HARD TO MOVE.



Lithium atom ( $Z=3$ , metal)  
computer representation of 3D  
structure of orbitals.

Red: nucleus

Yellow: 1s orbital (2 electrons)

Blue: 2s orbital (1 electron)

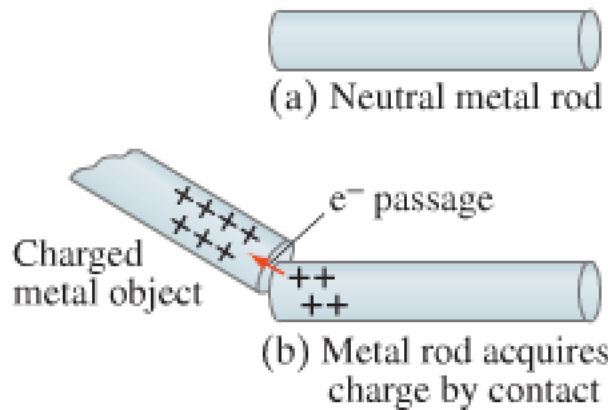
**INSULATORS:** HAVE COMPLETE OR ALMOST COMPLETE ELECTRON SHELLS  
ELECTRONS ARE HARD TO MOVE AROUND

EXAMPLE: WOOD, PLASTIC

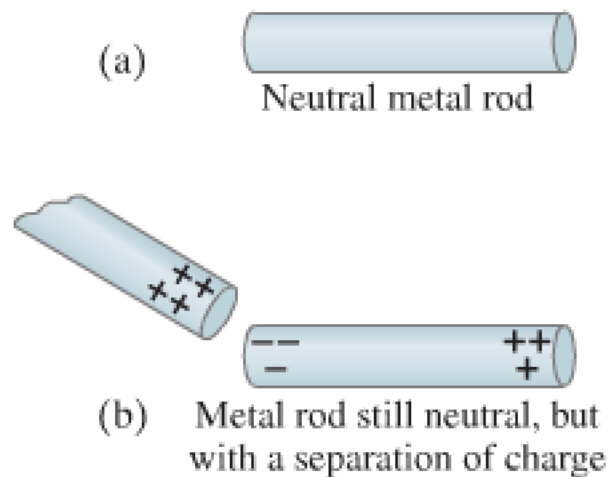
**CONDUCTORS:** HAVE ONE OR TWO ELECTRONS ON THE OUTER SHELL  
"FREE" ELECTRONS ARE EASY TO MOVE AROUND OBJECT.

EXAMPLE: METALS

## INDUCED CHARGE: BODIES CAN BE CHARGED BY



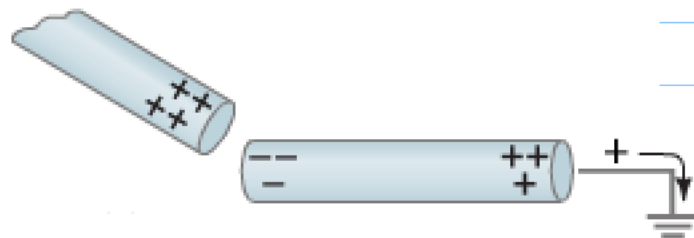
CONDUCTION: DIRECT CONTACT



INDUCTION: CREATE CHARGE SEPARATION

BREAK INTO PIECES

"GROUND" ONE END:  
CHARGE LEAKS INTO THE EARTH



ALWAYS THINK WHERE  
ELECTRONS WENT. THEY ARE  
THE ONES TO MOVE.

## Quiz 1:

1.1 Two electrically neutral materials are rubbed together.

One acquires a net positive charge. The other must:

- A. have lost electrons
- B. have gained electrons
- C. have lost protons
- D. have gained protons

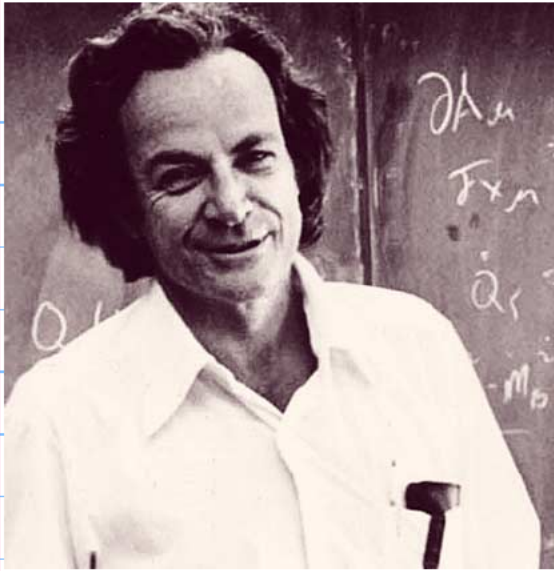
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## EXTRA:



Richard Feynman (Nobel laureate, and legendary educator) in the Feynman Lectures:

If you were standing at **arm's length** from someone and each of you had **one percent more electrons than protons**, the repelling force would be incredible. How great? Enough to lift the Empire State building? No! To lift Mount Everest? No! The repulsion would be enough to lift a **'weight' equal to that of the entire earth!**

### SHOULD WE BELIEVE FEYNMAN?

### HOW MANY ELECTRONS IN A PERSON?

ASSUME CHEMICAL COMPOSITION OF A PERSON IS ONLY WATER (SIMPLIFICATION). MOLECULAR WEIGHT OF WATER = 18.

WHAT IS THE NUMBER OF ELECTRONS/GRAM IN A PERSON?

$$\frac{6 \times 10^{23} \text{ molecules/mole}}{18 \text{ g/mole}} \times 10 e^-/\text{molecule} = 3.3 \times 10^{23} e^-/\text{g}$$

ASSUME 80 kg FOR PERSON:  $3.3 \times 10^{23} e^-/\text{g} \times 80 \text{ kg} = 2.6 \times 10^{28} e^-$

HOW MUCH CHARGE IS 1% OF ELECTRONS IN A PERSON?

$$1\% \times 2.6 \times 10^{28} e^- \times 1.6 \times 10^{-19} \text{ C}/e^- = 4.2 \times 10^7 \text{ C}$$

WHAT IS THE FORCE BETWEEN TWO PEOPLE AT ARMS LENGTH IF THEY EACH HAD 1% EXCESS ELECTRONS?

$$F = k \frac{Q_1 Q_2}{r^2} = 9 \times 10^9 \frac{\text{Nm}^2}{\text{C}^2} \left( \frac{4.2 \times 10^7 \text{ C}}{0.75 \text{ m}} \right)^2 = \underline{2.8 \times 10^{25} \text{ N}}$$

WHAT IS THE "WEIGHT" OF THE EARTH?  $W = Mg$

$$W = 6 \times 10^{24} \text{ kg} \times 9.8 \text{ m/s}^2 = \underline{5.9 \times 10^{25} \text{ N}}$$

SO, YES! FEYNMAN WAS CORRECT!

GRAVITY IS EXTREMELY WEAK !! IT INVOLVES HUGE MASSES.

ELECTRICITY IS  $10^{36}$  TIMES STRONGER THAN GRAVITY.