PHYSICS 570 – Master's of Science Teaching

"Electricity"
Lecture 10 – Current, Power, Resistance, and Ohm's Law.

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Big ideas

If you know Voltage, Current and Resistance … you know a lot.

We know Voltage (lectures 8/9) … now we meet current and resistance.

Current is the flow of electric charge.

Electrons bump into the atoms in conductors, this atomic-scale "friction" causes resistance.

Conductors

To conduct electricity, you need a conductor.

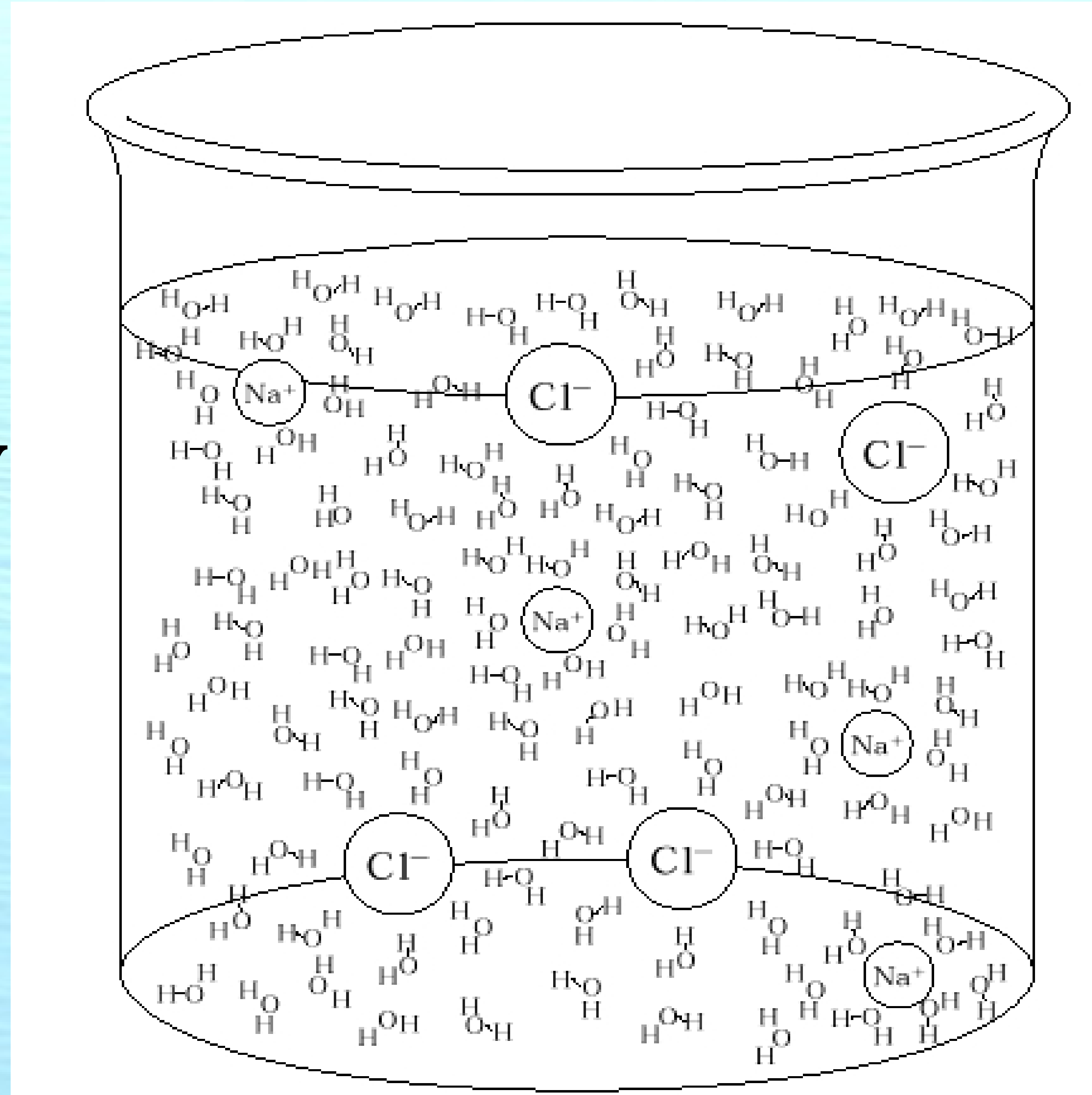
Conductors have charges that are free to move. (They are still usually electrically neutral).

Salt water and blood are conductors. Copper is a conductor.

Ionic Conductors

Salt water
Is electrically
Neutral …

The ions
Can move.



Why are metals conductors of electricity while most gasses, oxides and plastics are insulators?

Metals have charges that are free to move.

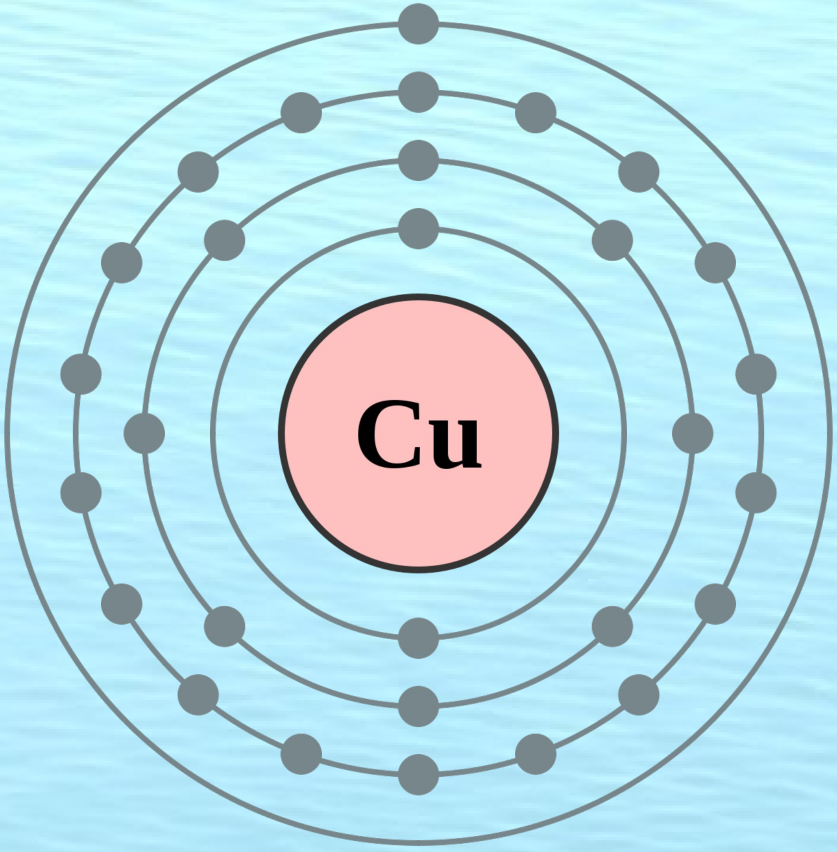
Insulators bind all their electrons tightly to their atoms.

You can “break down” an insulator by ripping its electrons from its atoms.

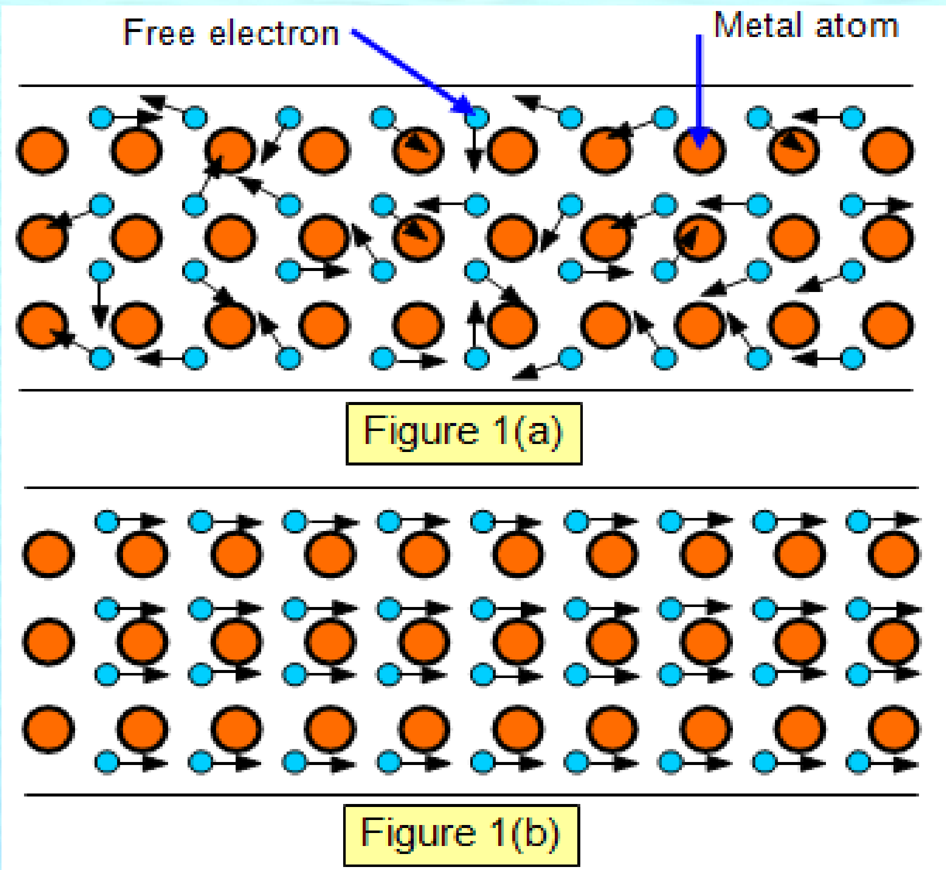
Copper conducts electricity because its lone 4s electron is free to “wander”

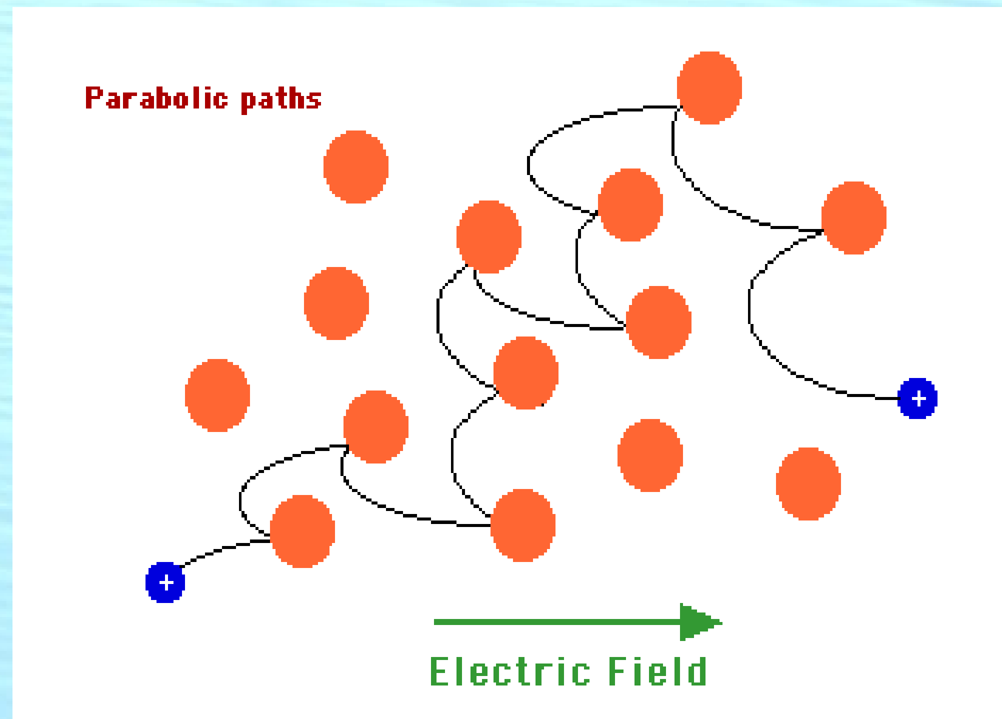
http://www.schoolphysics.co.uk/animations/Electric_current/index.html

29: Copper **2,8,18,1**



Metal wires are actually “tubes” for electrons (the internet is a series of tubes!)





Water current is total mass that passes an observer per second.

Electrical current is charge flow rate past a fixed point.
Units (C/s)

$$I = \frac{\Delta Q}{\Delta t} = \frac{dQ}{dt}$$

Hydraulic Analogy

(Homework 10-3)

http://en.wikipedia.org/wiki/Hydraulic_analogy

Mass of water (M)	Charge (Q)
Water current (dM/dt)	Current (I = dQ/dt)
Water pressure (P)	Voltage (V)

The charge of a single electron is

1.60×10^{-19} C *(Homework 10-4)*

The number of electrons in a coulomb is:

$(A) 1$

$(B) 6.02\times10^{23}$

$(C) 6.25\times10^{18}$

The charge of a single electron is

$$1.60\times10^{-19}\ \mathrm{C}$$

The number of electrons in a coulomb is:

Wire "W" carries 1.5 Amperes. A current of one Ampere means a coulomb of electrons pass a point every second.

(Homework 10-5)

How many electrons pass through W every second?

$(A)\, 1.5$

$(B)\, 1.5 \times 10^{-19}$

$(C)\, 9 \times 10^{18}$

$(D)\, 6.02 \times 10^{23}$

$$I = \frac{\Delta Q}{\Delta t} = \frac{dQ}{dt}$$

Wire "W" carries 1.5 Amperes. A current of one Ampere means a coulomb of electrons pass a point every second.

How many electrons pass through W every second?

$$I = \frac{\Delta Q}{\Delta t} = \frac{dQ}{dt}$$

Calculus Bonus Problem … *(not required!)*

The charge on a capacitor is given by $Q=12-\frac{4}{t^2}+\frac{1}{t}$

What is the current after 1 second?

$$I=\frac{\Delta Q}{\Delta t}=\frac{dQ}{dt}$$

(A) 9 Amps
(B) 7 Coulombs
(C) 3 Amps
(D) -9 Amps
(E) 7 Amps

Calculus Bonus Problem *… (not required!)*

The charge on a capacitor is given by $Q = 12 - \frac{4}{t^2} + \frac{1}{t}$ $\quad I = \frac{dQ}{dt}$

What is the current after 1 second?

Power, Current, and Voltage

(Homework 10-6)

The voltage coming out of a wall outlet in North America is 120 V. How much current does it take to operate a 1800 Watt hair dryer?

$(A)\ 15\ \text{Amps}$

$(B)\ \frac{1}{15}\ \text{Amps}$

$(C)\ 9\times10^{18}\ \text{Amperes}$

$(D)\ 1800\ \text{A}$

$P = IV$

Power, Current, and Voltage

The voltage coming out of a wall outlet in North America is 120 V. How much current does it take to operate a 1800 Watt hair dryer?

$$P = IV$$

Power, Current, and Voltage

$P = I V$

High power appliances like electric dryers often run on 240 V instead of 120 V.
How much current does it take to run a 5000 W (5 kW) dryer at 240 V?
What if you tried to run the dryer at 120 V?

(Homework 10-7)

Power, Current, and Voltage

$$P = IV$$

If you look at the power-brick for your laptop (or iPad) you might see that it provides 500 mA at 12 Volts.

(Homework 10-8)

How much power does your laptop use?

Power, Current, and Voltage

Voltage is Energy per unit
Charge

Power is Work per unit time
(or Energy expended per
Unit time)

For constant voltage (e.g.
Current coming from a battery
Or an electric outlet)

Power, Current, and Voltage

Voltage is Energy per unit Charge

$$V = \frac{U}{Q} \rightarrow U = QV$$

Power is Work per unit time (or Energy expended per Unit time)

$$P = \frac{W}{\Delta t} = \frac{\Delta U}{\Delta t}$$

For constant voltage (e.g. Current coming from a battery Or an electric outlet)

$$\frac{\Delta U}{\Delta t} = \frac{\Delta Q}{\Delta t} V = I V$$

$$P = I V$$

Ohm's Law

Not as universal as P=IV or U=qV
Or F=ma or Coulomb's law – but it
does work for things called “resistors”.

Resistors have resistance, measured in
Ohms (Ω)

$$V = IR \quad \text{Ohm's Law}$$

What's a resistor … Why do I want one?

Resistors are devices that are meant to resist current flow. They obey Ohm's law.

They make a good way of turning electricity into heat (hair-dryers, electric stoves, space-heaters)

They stop batteries from discharging all at once.

They are unavoidable – because even if you don't want one, all wires have some resistance (except superconductors!).

Body tissues have resistance.

Resistance is one of the “big three” basic circuit properties (capacitance and inductance are the other two)

Time for the Ohm's law sim and the battery + resistor sim.

(Homework 10-9)

An electric burner with 35 Ohms resistance consumes 1.5 kiloWatts. At what voltage does it operate?

(A) 120 V
(B) 230 V
(C) 52,500 V
(D) 14,400 V
(E) 42.8 V