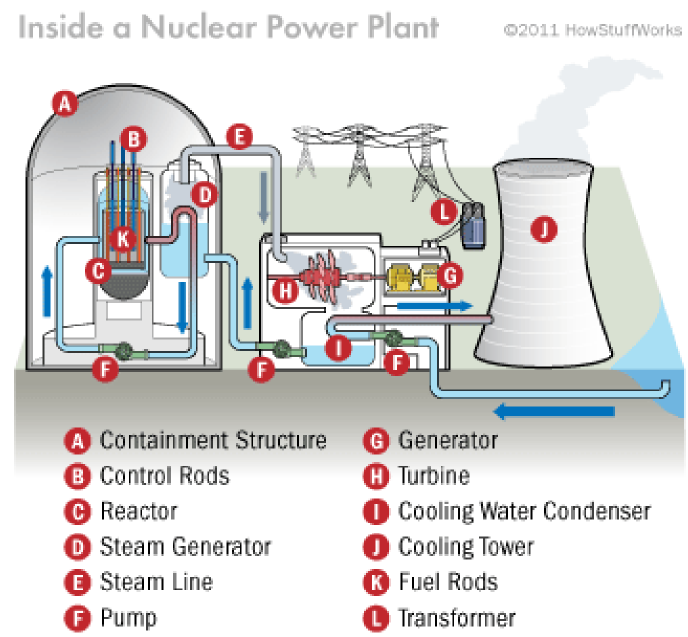
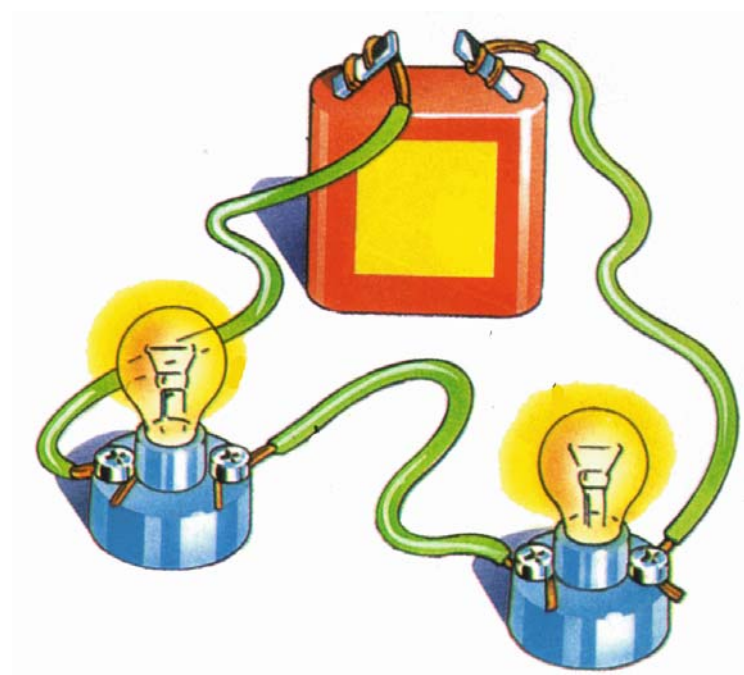
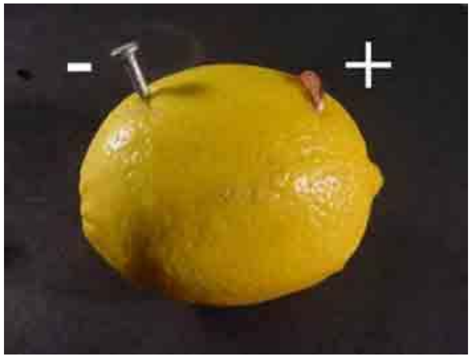
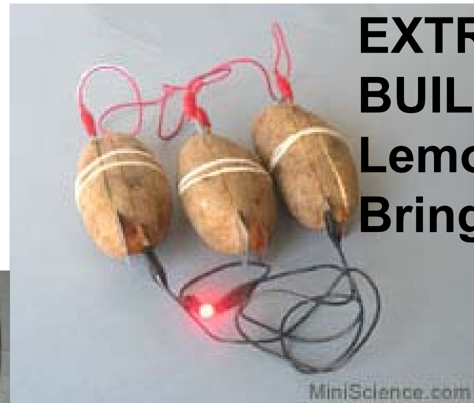

Inside a Nuclear Power Plant
©2011 HowStuffWorks
A B C D E F G H I J K L
A Containment Structure
B Control Rods
C Reactor
D Steam Generator
E Steam Line
F Pump
G Generator
H Turbine
I Cooling Water Condenser
J Cooling Tower
K Fuel Rods
L Transformer

AC/DC

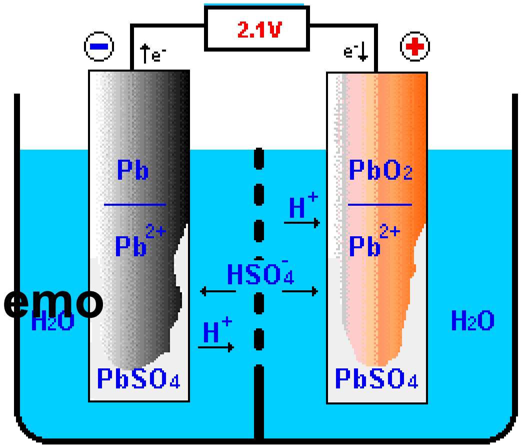


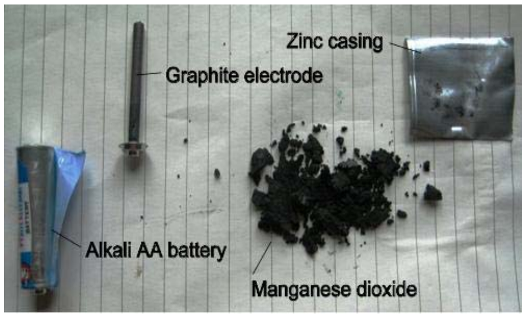


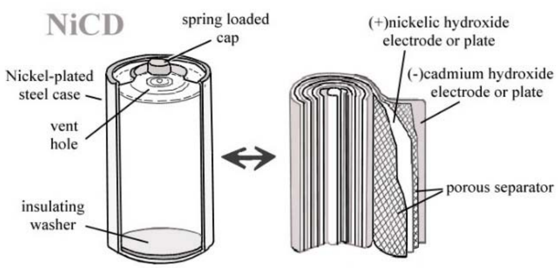
Creating DC current



EXTRA CREDIT
BUILD A BATTERY
Lemon or Potato'
Bring in with light to demo



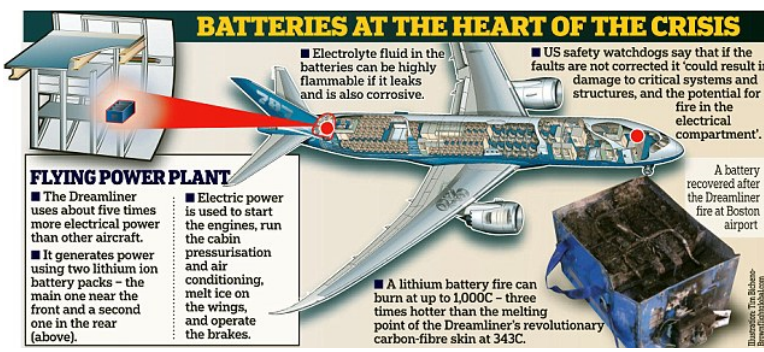




Lithium Battery Technologies

Chemical Name	Material	Abbreviation	Applications
Lithium cobalt oxide	$LiCoO_2$	LCO	Cell phones, laptops, cameras
Lithium manganese oxide	$LiMn_2O_4$	LMO	Power tools, EVs, medical, hobbyist
Lithium iron phosphate	$LiFePO_4$	LFP	Power tools, EVs, medical, hobbyist
Lithium nickel manganese cobalt oxide	$LiNiMnCo0_2$	NMC	Power tools, EVs, medical, hobbyist
Lithium nickel cobalt aluminum oxide	$LiNiCoAlO_2$	NCA	EVs, grid storage
Lithium titanate	$Li_4Ti_5O_{12}$	LTO	EVs, grid storage

Source: batteryuniversity.com

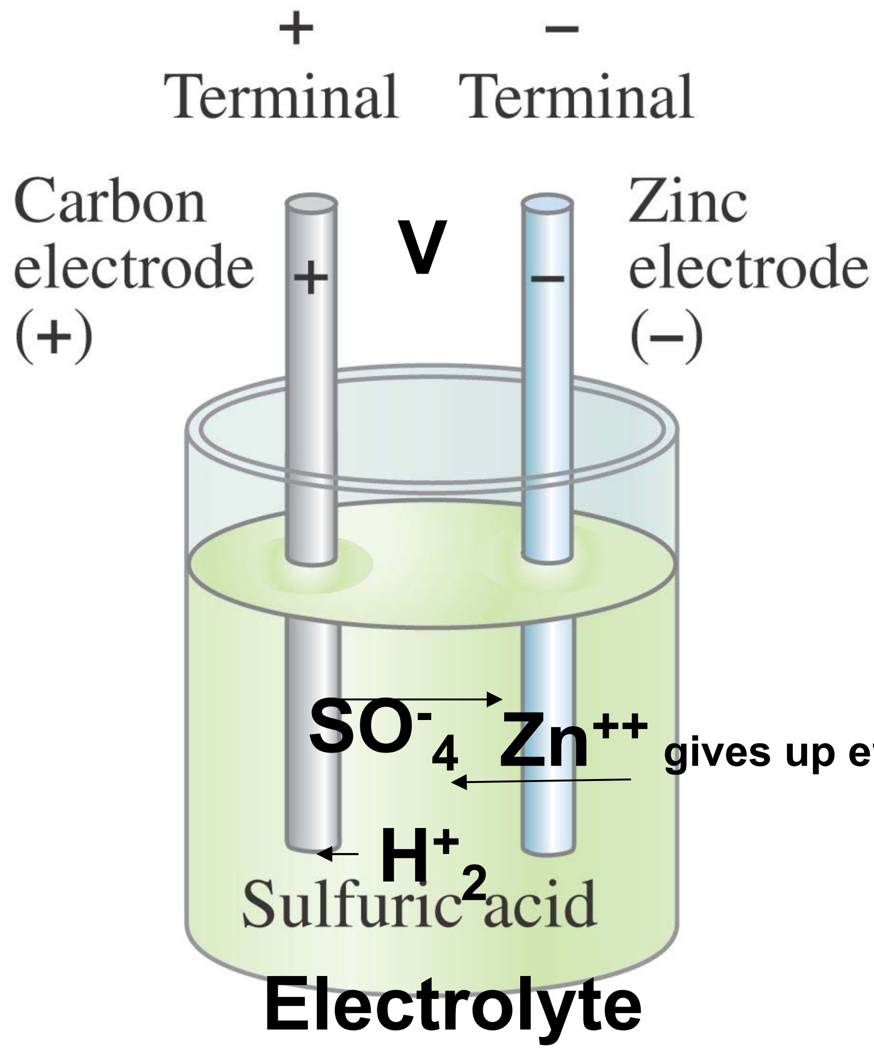


25-1 The Electric Battery DC!

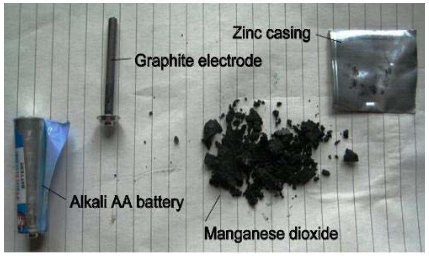
Volta discovered that electricity could be created if dissimilar metals were connected by a conductive solution called an electrolyte.

This is a simple electric cell.

Acid dissolves Zn eventually
Zn electrode is used up and cell dies. V is created and stays even If a current is flowing but ends When the electrode is dissolved Here.



A battery transforms chemical energy into electrical energy.



Carbon Zinc Battery

Chemical reactions

In a zinc–carbon dry cell, the outer zinc container is the negatively charged terminal. The zinc is oxidised according to the following half reactions:

Anode (marked -)

$Zn(s) \rightarrow Zn^{2+}(aq) + 2\,e^{-}$ [E° = −0.7626 V]

Cathode (marked +)

$2MnO_2(s) + 2\,e^{-} + 2NH_4Cl(aq) \rightarrow Mn_2O_3(s) + 2NH_3(aq) + H_2O(l) + 2\,Cl^{-}$ [E° ≈ +0.5 V]

There are other possible side-reactions, but the overall reaction in a zinc–carbon cell can be represented as:

$Zn(s) + 2MnO_2(s) + 2NH_4Cl(aq) \rightarrow Mn_2O_3(s) + Zn(NH_3)_2Cl_2(aq) + H_2O(l)$

If zinc chloride is substituted for ammonium chloride as the primary electrolyte, the anode reaction remains he same but the cathode reaction is:

$MnO_2(s) + H_2O(l) + e \rightarrow MnO(OH)(s) + OH(aq)$

and the overall reaction:

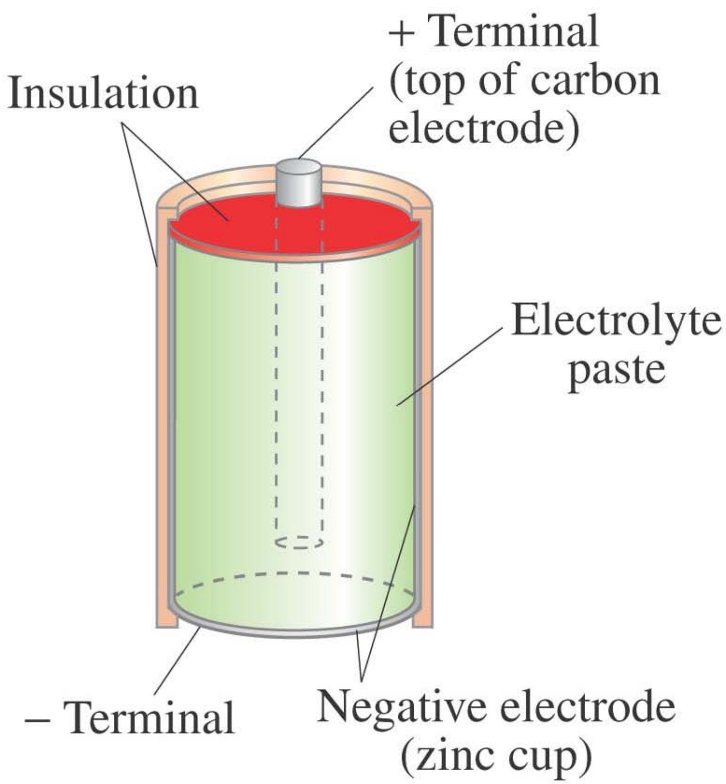
$4Zn(s) + 8MnO_2(s) + ZnCl_2(aq) + 9\,H_2O(l) \rightarrow 8\,MnO(OH)(s) + Zn(OH)Cl(aq) + 5H_2O + 4ZnO$

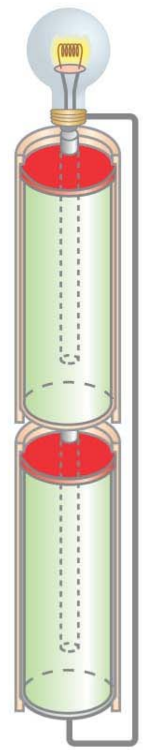
The battery has an electromotive force (e.m.f.) of about 1.5 V. T he approximate nature of the e.m.f is related to the complexity of the cathode reaction. The anode (zinc) reaction is comparatively simple with a known potential. Side reactions and depletion of the active chemicals increases the internal resistance of the battery, and this causes the e.m.f. to drop.

25-1 The Electric Battery

Several cells connected together make a battery, although now we refer to a single cell as a battery as well.

D cell and 2 AA's in series





25-2 Electric Current

Electric current is the rate of flow of charge through a conductor:

$$\overline{I} = \frac{\Delta Q}{\Delta t}.$$

The instantaneous current is given by:

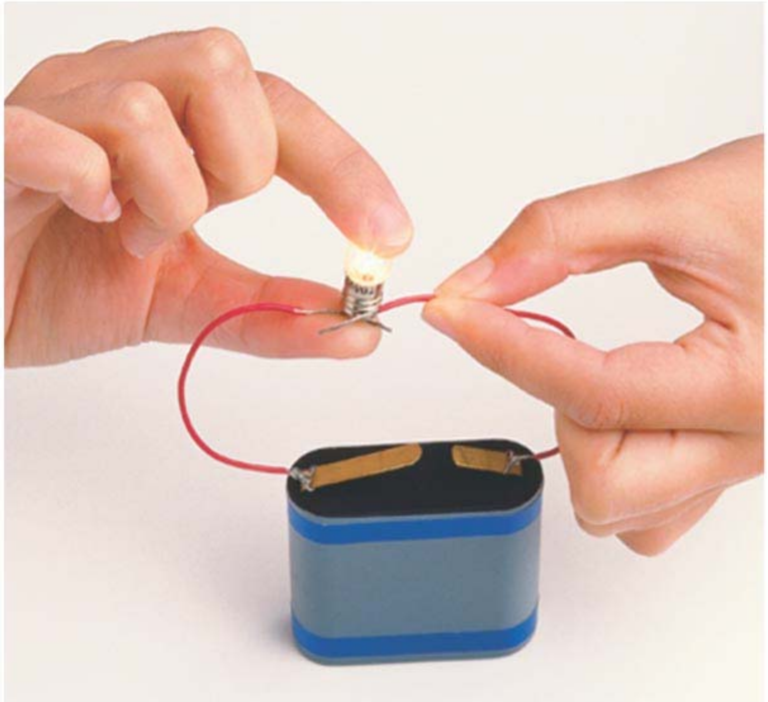
$$I = \frac{dQ}{dt}.$$

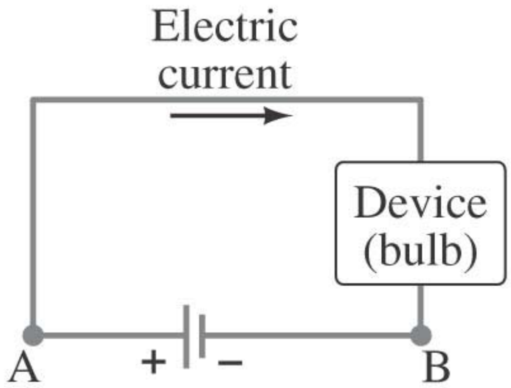
Unit of electric current: the ampere, A:

1 A = 1 C/s. we use mA's and even μA

25-2 Electric Current

A complete circuit is one where current can flow all the way around. Note that the schematic drawing doesn't look much like the physical circuit! This is a complete or closed circuit, if a break (switch) occurs the circuit is said to be "open". Charge is conserved so is the same at A and B or anywhere in the circuit.





25-2 Electric Current

Example 25-1: Current is flow of charge. A steady current of 2.5 A exists in a wire for 4.0 min. (a) How much total charge passed by a given point in the circuit during those 4.0 min? (b) How many electrons would this be? Recall relationship I=Q/t Class problem!

a. I=2.5 A t=4.0m=240s I=Q/t
Q=It=2.5A (C/s) x240s =600C

b. e=1.6 x 10^{-19} C
#N=Q/e = 600C/1.6 x 10^{-19} C =3.75 x 10^{21}

HAND IN HW. Recall by first Sketch, set up equations, solve algebraically then plug in numbers. All answers in Scientific notation.

58. A popular car battery is rated at 320 A-h. This indicates the amount of electric charge the battery can deliver. Express 320 A-h in coulombs? 2411

59. A 20-A current flows for three minutes. 2501
(a) How much charge has passed through this circuit?
(b) How many electrons have passed any point in the circuit?

60. An experimenter wishes to silver plate a microwave electronic component with a thickness of silver of 0.02 mm over an area of 6 cm^2. With a solution of Ag + and a current of 1.8 A, how long will it take to deposit the desired amount of silver (density 10.5 g/ cm3, atomic mass 108 amu)? 2412
HINTS: Volume of silver needed? Got density how much Mass in g? Recall 1 amu in g contains Avogadro's number of atoms =6.02×10^{23}. Total mass/amu in grams =# of Avogadro's needed. Each Ag+ has a charge equal to an electron. Now you have the total charge needed. And you have the current!

25-2 Electric Current

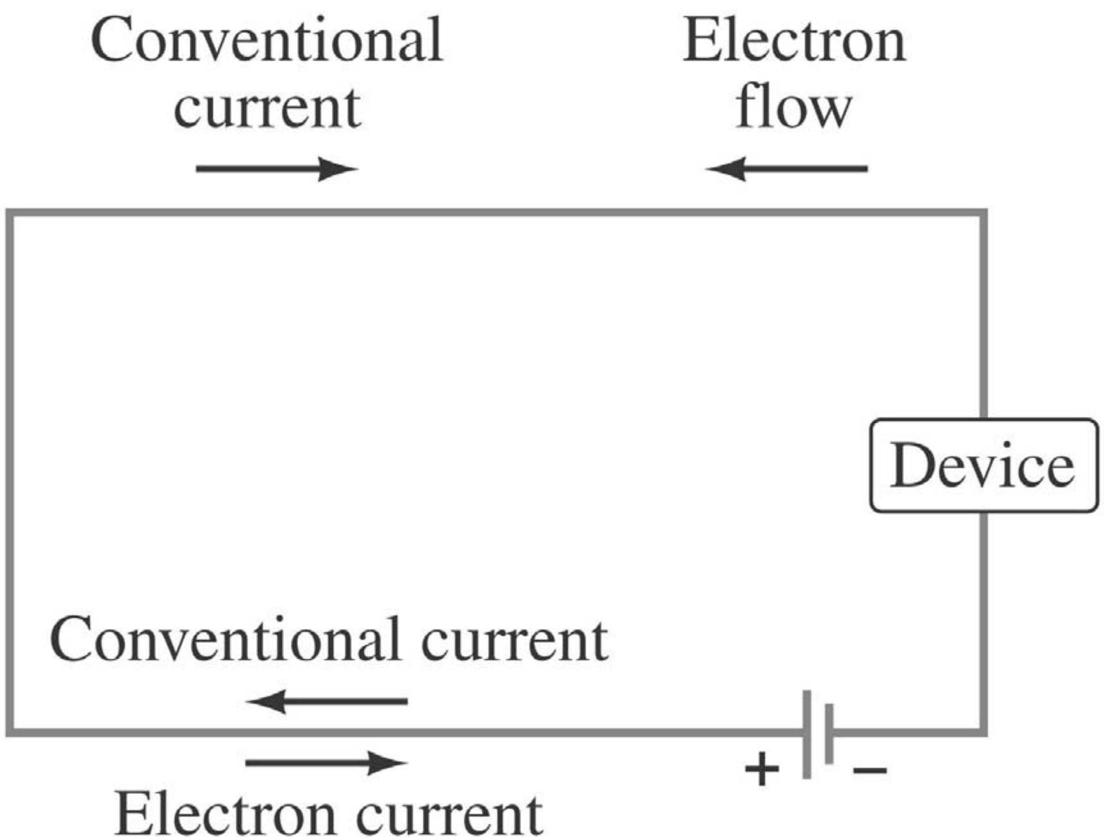
Conceptual Example 25-2: How to connect a battery.

What is wrong with each of the schemes shown for lighting a flashlight bulb with a flashlight battery and a single wire?

25-2 Electric Current

By convention, current is defined as flowing from + to -. (convential current). Electrons actually flow in the opposite direction, but not all currents consist of electrons (eg. Ions).

In some circuits wires are connected to a common conductor called the "ground". Eg. Body of a car!



25-3 Ohm's Law: Resistance and Resistors

Experimentally, it is found that the current in a wire is proportional to the potential difference between its ends:

$$I \propto V.$$

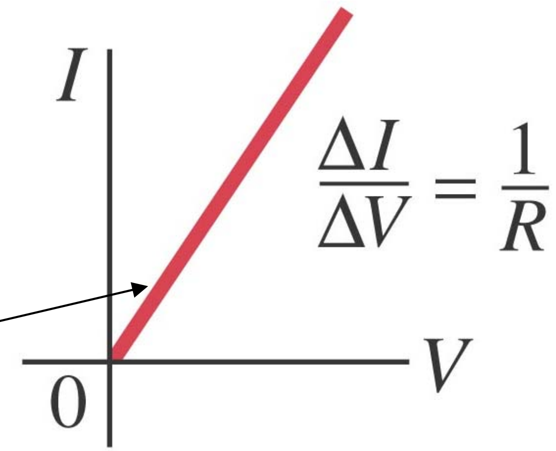
The ratio of voltage to current is called the resistance:

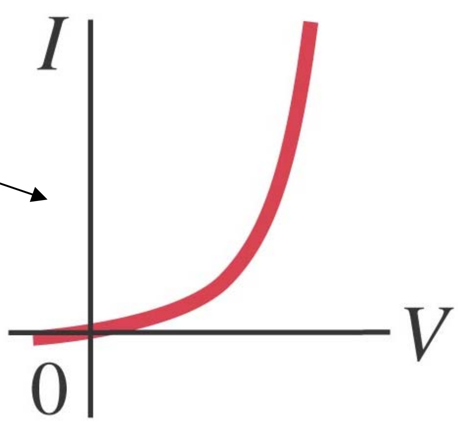
R=V/I

Thus also I=V/R and V=IR

25-3 Ohm's Law: Resistance and Resistors Voila' your LAB!

In many conductors, the resistance is independent of the voltage; this relationship is called Ohm's law (R=constant!). Materials that do not follow Ohm's law are called nonohmic.





Unit of resistance: the ohm, Ω: R=V/I

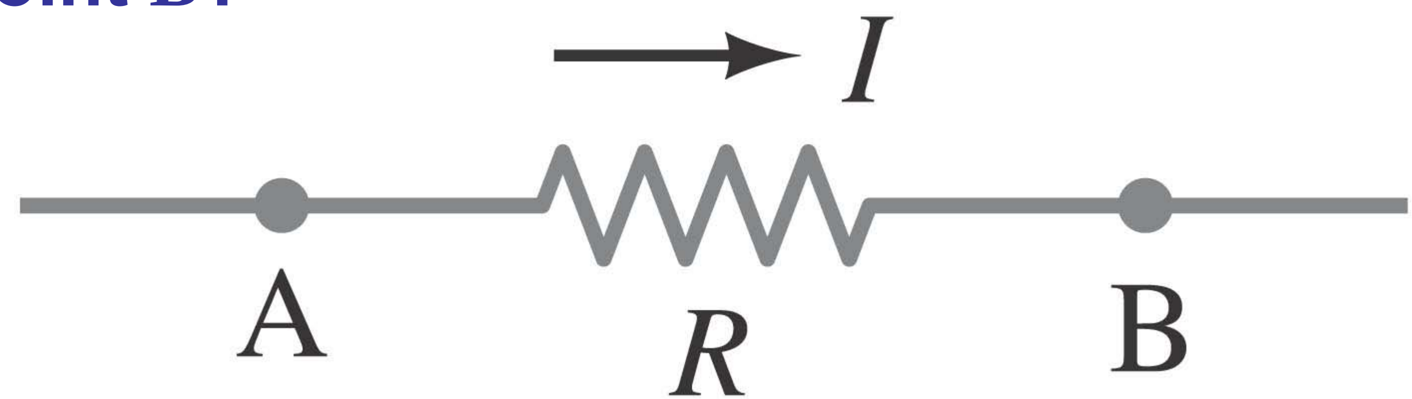
1 Ω = 1 V/A.

NOTE: $R = V/I = f(V)$ eg. $R = Ae^{+0.4V}$

25-3 Ohm's Law: Resistance and Resistors

Conceptual Example 25-3: Current and potential.

Current I enters a resistor R as shown. (a) Is the potential higher at point A or at point B? (b) Is the current greater at point A or at point B?

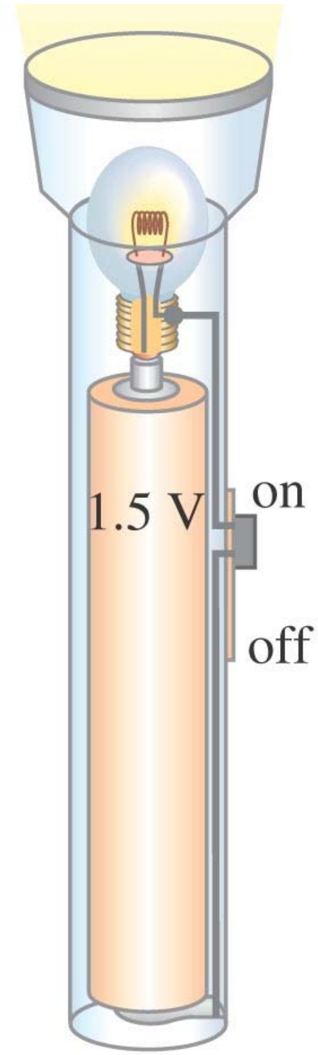


A higher for + and $I_A = I_B$ Conservation of charge!

25-3 Ohm's Law: Resistance and Resistors

Example 25-4: Flashlight bulb resistance. SEE this BAD TEXT EXAMPLE WHY?? Recall you lab work?

A small flashlight bulb draws 300 mA from its 1.5-V battery. (a) What is the resistance of the bulb? (b) If the battery becomes weak and the voltage drops to 1.2 V, how would the current change? IN CLASS!



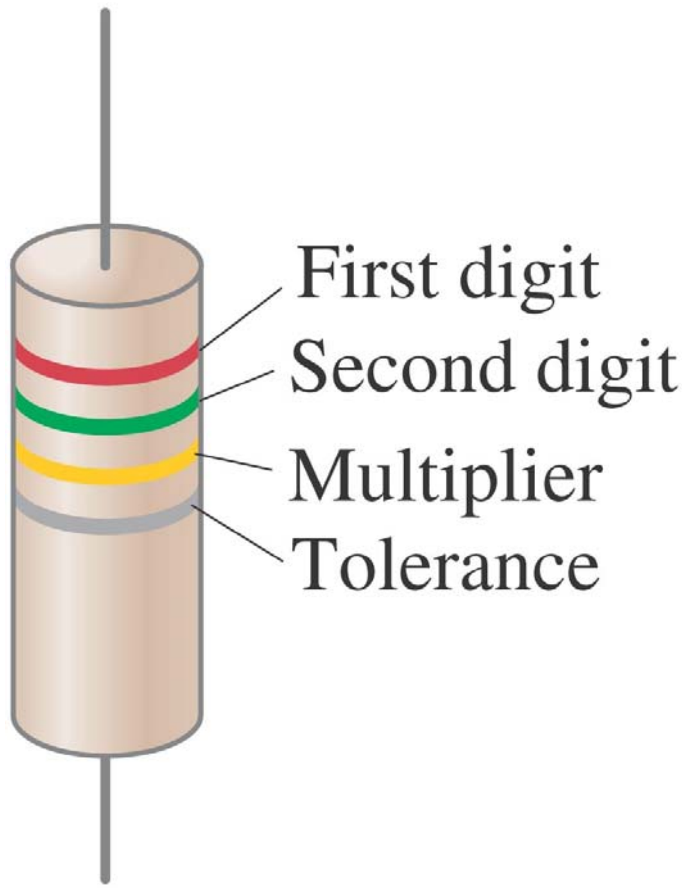
25-3 Ohm's Law: Resistance and Resistors

Standard resistors are manufactured for use in electric circuits; they are color-coded to indicate their value and precision.

Rainbow colors

Resistor Color Code

Color	Number	Multiplier	Tolerance
Black	0	1	
Brown	1	10^1	1%
Red	2	10^2	2%
Orange	3	10^3	
Yellow	4	10^4	
Green	5	10^5	
Blue	6	10^6	
Violet	7	10^7	
Gray	8	10^8	
White	9	10^9	
Gold		10^{-1}	5%
Silver		10^{-2}	10%
No color			20%



R for this resistor Is?

HAND IN HW. Recall by first Sketch, set up equations, solve algebraically then plug in numbers. All answers in Scientific notation.

61. A 8000 Ω resistor is connected across 225 V. What current will flow?

62. What is wrong with Example 25-4 in the text? Explain.?

63. You need a typical cylinder resistor of 10% tolerance with a value of 13000 Ω. Draw a cylinder And indicate the first,second digits, multiplier and Tolerance colors on it?

25-3 Ohm's Law: Resistance and Resistors

Some clarifications:

- **Batteries maintain a (nearly) constant potential difference; the current varies. Consider them a source of potential difference, not putting out current. Current is drawn by resistors.**

- **Resistance is a property of a material or device and current through the material depends on this resistance and V put on the material ie. $I=V/R$ I is the response to V!**

- **Current is not a vector but it does have a direction, always parallel to a wire (like water in a pipe). Actually we see later how the electrons move thru a material in almost random motion!**

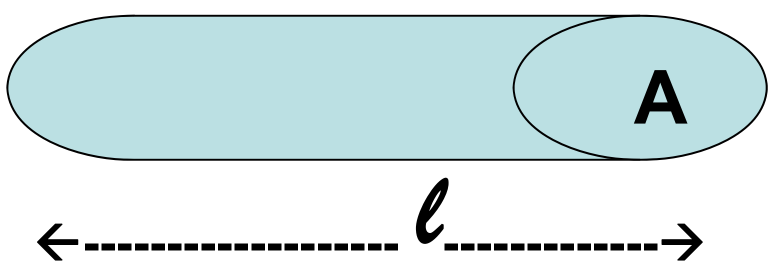
- **Current and charge do not get used up. Whatever charge goes in one end of a circuit comes out the other end. Conservation of electric charge.**

25-4 Resistivity, ρ, a property of the material Resitance , R, of a wire depends on ρ (ie material) and the Length, l, and cross sectional area, A, of the wire(loosely the Width).

The resistance of a wire is directly proportional to its length and inversely proportional to its cross-sectional area

$$R = \rho \frac{\ell}{A}.$$

The constant *ρ*, the resistivity, is characteristic of the material. UNITS are? Ω m



Longer the wire R goes up;
Wider the wire R goes down;
Does this make sense? Why?

25-4 Resistivity a property of the material

- For any given material, the resistivity normally increases with temperature, ρ_0 at 20^0 C only in the table

$$\rho_T = \rho_0[1 + \alpha(T - T_0)].$$

NOTE (values of ρ_0)

TABLE 25–1 Resistivity and Temperature Coefficients (at 20°C)

Material	Resistivity, ρ ($\Omega \cdot$ m)	Temperature Coefficient, α $(\mathrm{C}^\circ)^{-1}$
Conductors		
Silver	1.59×10^{-8}	0.0061
Copper	1.68×10^{-8}	0.0068
Gold	2.44×10^{-8}	0.0034
Aluminum	2.65×10^{-8}	0.00429
Tungsten	5.60×10^{-8}	0.0045
Iron	9.71×10^{-8}	0.00651
Platinum	10.60×10^{-8}	0.003927
Mercury	98.00×10^{-8}	0.0009
Nichrome (Ni, Fe, Cr alloy)	100.00×10^{-8}	0.0004
Semiconductors[†]		
Carbon (graphite)	$(3-60) \times 10^{-5}$	-0.0005
Germanium	$(1-500) \times 10^{-3}$	-0.05
Silicon	$0.1-60$	-0.07
Insulators		
Glass	$10^{9}-10^{12}$	
Hard rubber	$10^{13}-10^{15}$	

[†] Values depend strongly on the presence of even slight amounts of impurities.

Best and worst conductor is?

Semiconductors are complex materials, and may have resistivity's that decrease with temperature

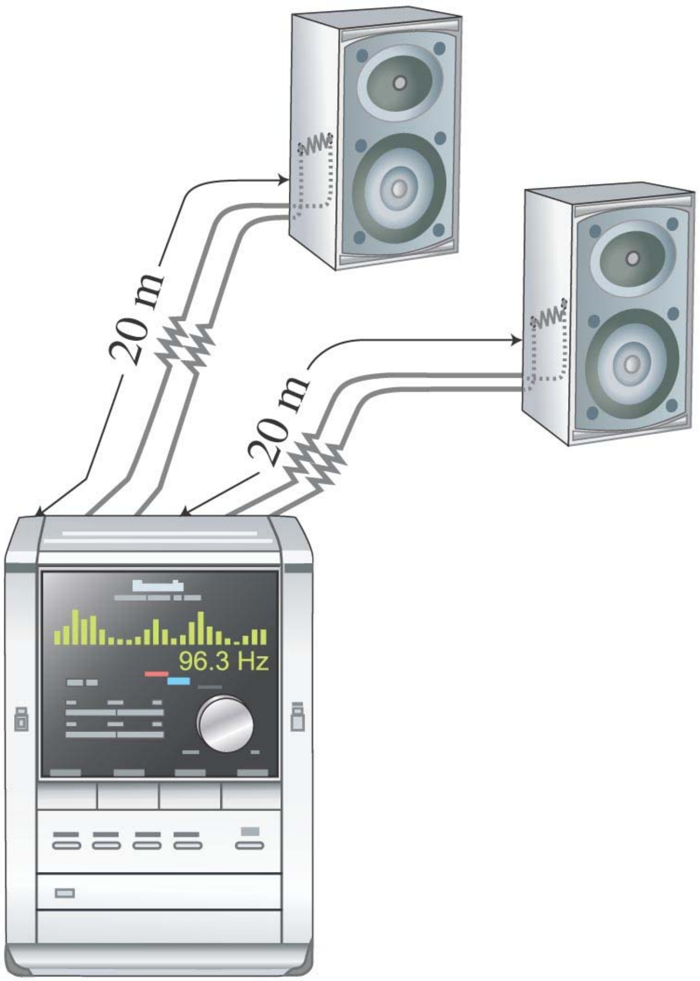
$\sigma=1/\rho$ **is called the**

Conductivity!

25-4 Resistivity a nice example for wire speakers

Example 25-5: Speaker wires.

Suppose you want to connect your stereo to remote speakers. (a) If each wire must be 20 m long, what diameter copper wire should you use to keep the resistance less than 0.10 Ω per wire? (b) If the current to each speaker is 4.0 A, what is the potential difference, or voltage drop, across each wire? IN CLASS



a. d=? $R=\rho l/A$ algebra $A=\rho l/R=$
$1.68 \times 10^{-8}\ \Omega m \times 20 m/0.10\Omega$
$3.36 \times 10^{-6}\ m^2$
$A=\pi d^2$ $d=(A/\pi)^{1/2}$ $=1.03 \times 10^{-3}$ m $=1.03$mm

b. Assuming ohmic wires, which is true
As long as they do not heat up much!
$V=IR=4.0A \times 0.10\Omega=0.40V$

25-4 Resistivity(R =f(Temp) also)

$$R = \rho \frac{\ell}{A}.$$

$$\rho_T = \rho_0\left[1 + \alpha\left(T - T_0\right)\right].$$

Combining $R=\rho_T\ L/A=\rho_0 L/A\ (1+\alpha(T-T_0))$

We see that at $T=T_0$ **we have** $R_0=\rho_0 L/A$

We now have $R=R_0\,(1+\alpha(T-T_0))$

Example 25-7: Resistance thermometer.

The variation in electrical resistance with temperature can be used to make precise temperature measurements. Platinum is commonly used since it is relatively free from corrosive effects and has a high melting point. Suppose at 20.0°C the resistance of a platinum resistance thermometer is 164.2 Ω. When placed in a particular solution, the resistance is 187.4 Ω. What is the temperature of this solution? $\alpha = 3.927 \times 10^{-3}$ /C^0 IN CLASS?

We now have **$R=R_0 (1 + \alpha(T - T_0))$ to solve this!**

Solve algebra for T?

$$R = R_0 + \alpha R_0 (T - T_0) \;\; \text{->} \;\; (T - T_0) = (R - R_0)/(\alpha R_0)$$

Or

$$T = T_0 + (R - R_0)/(\alpha R_0)$$

Numbers

$T = 20.0\ C^0 + (187.4\ \Omega - 164.2\ \Omega.)/(3.927 \times 10^{-3}\ /C^0 \times 164.2\ \Omega)$

$T = 55.979\ C^0 = 56.0\ C^0$

HAND IN HW. Recall by first Sketch, set up equations, solve algebraically then plug in numbers. All answers in Scientific notation.

64. A lead wire of resistance R is drawn through a die so that its length is doubled, while its volume remains unchanged. What will be its new resistance in terms of its initial resistance?
HINT:Recall Vol =AL for a cylinder.

65. A platinum wire is used to determine the melting point of indium. The resistance of the platinum wire is 1.050 Ω at 20°C and increases to 4.872 Ω as indium starts to melt. What is the melting point of indium? (The temperature coefficient of resistivity for platinum is 3.9×10^{-3} /C^0 .

66. A tungsten wire of diameter 0.40 mm and length 40 cm is connected to a 36-Vpower supply. We need the current does it carries at 20 ° C and at 800 ° C? At 20 ° C the resistivity of tungsten is 5.6×10^{-8} Ω-m (at 20 ° C) and α = 4.5×10^{-3} /° C.
HINT This is a guided solution.

a. **First find the Resistance at 20 ° C ?**
b. **Find the resistivity at 800 ° C ?**
c. **Find the resistance at 800 ° C use the results of b?**
d. **Current at 20 ° C is?**
e. **Current at 800 ° C is ?**

25-5 Electric Power

Power, as in kinematics, is the energy transformed by a device per unit time: P=E/t J/s is a what?

If we change the potential energy in a short time. We have power for example 1hp = 550lb lifted 1 foot in 1 sec =550lbft/s

Change in electricity is to consider the change in Potential energy ΔU per s = P as charge, dq, moves in a current its potential energy is changing since work, W, is acting on it.

Consider W= ΔU = Fd=qEd=qV since Ed=V
THUS ΔU =qV but $\Delta U/t$=P= Vq/t = VI =P

IN SUM: For uniform field E (V is the potential difference)
So a change in potential energy for a dq moving
Through a V is dU=dqV but P=dU/dt (watt=J/s)
so

Electric Power DC USEFUL Equations

$$P = \frac{dU}{dt} = \frac{dq}{dt}V$$

I=dq/dt

$$P = IV.$$

V=IR ohmic Device, so

$$P = IV = I(IR) = I^2R$$

$$P = IV = \left(\frac{V}{R}\right)V = \frac{V^2}{R}.$$

Reminder: The unit of Power is derived from energy./sec or Joule/sec is a What?

WATT

25-5 Electric Power

What you pay for on your electric bill is not power, but energy – the power consumption multiplied by the time.

We have been measuring energy in joules, but the electric company measures it in kilowatt-hours, kWh:

$$1\ \text{kWh} = (1000\ \text{W})(3600\ \text{s}) = 3.60 \times 10^6\ \text{J}.$$

Example 25-9: Electric heater.

An electric heater draws a steady 15.0 A on a 120-V line. How much power does it require and how much does it cost per month (30 days) if it operates 3.0 h per day and the electric company charges 9.2 cents per kWh? IN CLASS

I = 15.0 A V=120 V

P =IV= 15.0A x 120V =1800W

E=Pt =1800 W x 3h x30 =1.8 kW x 90hrs =162kWh

Cost = 162kWh x $0.092/kwh=$14.904 =$15

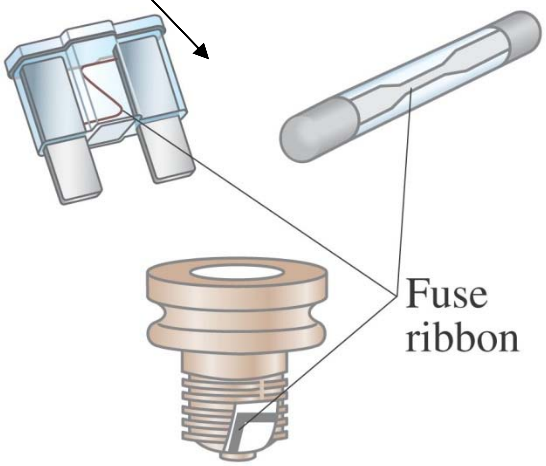
25-6 Power in Household Circuits

The wires used in homes to carry electricity have very low resistance. However, if the current is high enough, the power will increase and the wires can become hot enough to start a fire.

To avoid this, we use fuses or circuit breakers, which disconnect when the current goes above a predetermined value.

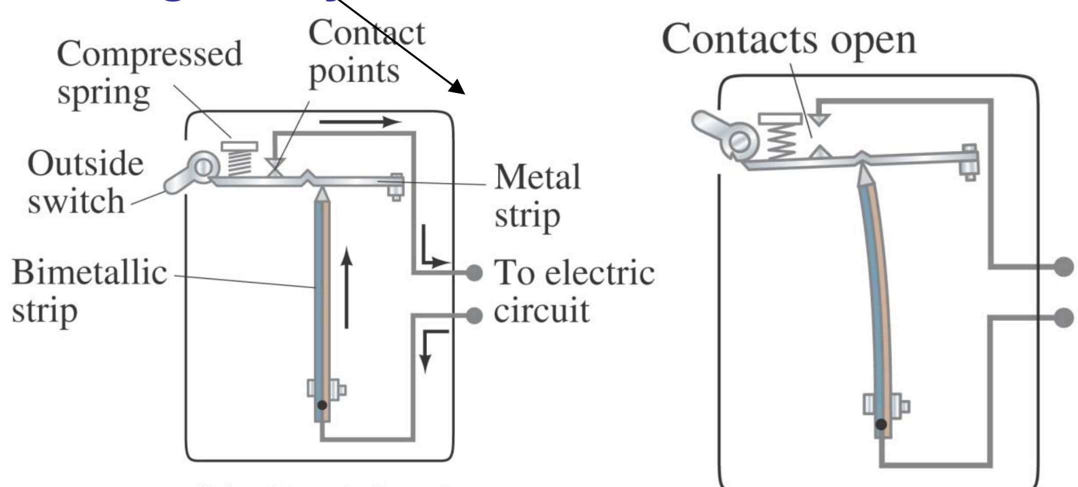
25-6 Power in Household Circuits

Fuses are one-use items – if they blow, the fuse is destroyed and must be replaced.



(a) Types of fuses

Circuit breakers, which are now much more common in homes than they once were, are switches that will open if the current is too high; they can then be reset.



(b) Circuit breaker (closed)

(c) Circuit breaker (open)

Wikipedia Bimetallic strip

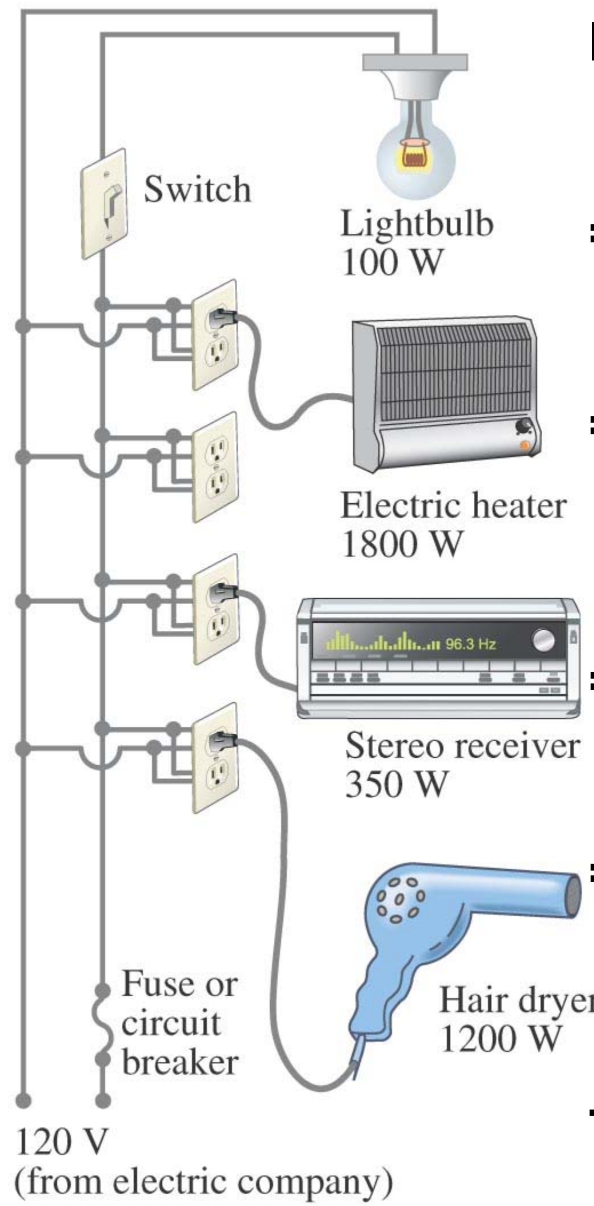
A **bimetallic strip is used to convert a temperature change into mechanical displacement. The strip consists of two strips of different metals which expand at different rates as they are heated, usually** steel and copper, or in some cases steel and brass. The strips are joined together throughout their length by riveting, brazing or welding. The different expansions force the flat strip to bend one way if heated, and in the opposite direction if cooled below its initial temperature. The metal with the higher coefficient of thermal expansion is on the outer side of the curve when the strip is heated and on the inner side when cooled.

25-6 Power in Household Circuits

Example 25-11: Will a fuse blow?

Determine the total current drawn by all the devices in the circuit shown. IN CLASS?

Solution NOTES: The current is given by I = P/V, where V = 120 V. Adding the currents gives 28.7 A, which exceeds the usual 20-A circuit breakers found in most household applications. The electric heater should probably be on its own circuit.



I=P/V

=100W/120V=0.83A

= 1800W/120V =15A

=350W/120V =2.92A

=1200W/120V= 10A

TOTAL ~ 28.7A

HAND IN HW. Recall by first Sketch, set up equations, solve algebraically then plug in numbers. All answers in Scientific notation.

67. A certain flashlight operates on two 1.5-V batteries connected in series. The lamp draws a current of 0.50 A. (a) What electrical power is delivered to the lamp? (b) What is the resistance of the lamp filament?

68. A 400-W computer (computer plus monitor) is turned on 7.0 hours per day. If electricity costs 10 cents per kWh, how much does it cost to run the computer annually?

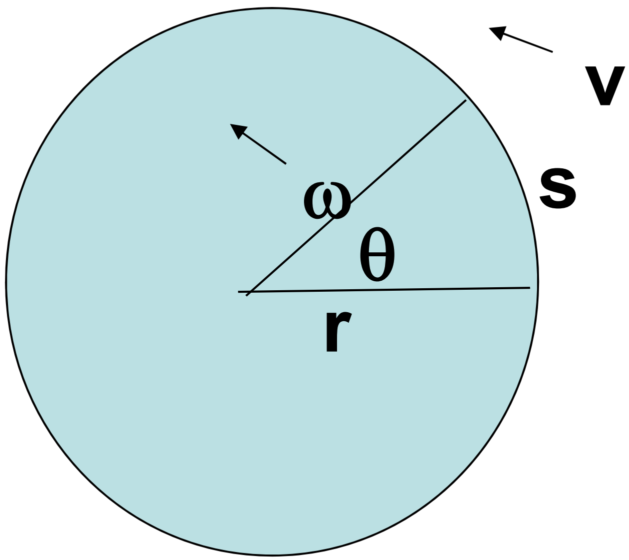
69. The South American eel Electrophorus electricus generates 0.80-A pulses of current at a voltage of about 640 V. At what rate does it develop power when giving a shock to its prey? If the shock

70. The resistance of a certain component on the Enterprise decreases as the current through it increases, as described by the relation
$R= 80/(12 + 4I^3)$,
a. Determine the current that results in maximum power in the unit
b. and the maximum power delivered to the unit.
HINT you have R(I) : maximum power will be for the I that maximizes R.
How do you get the maximum of function R(I) and the current that will do it?
That current will give you maximum power I_m we recall $P=(I_m{}^2R\ (I_m)$
Reminder R will change with I in this case!

25-7 Math for Alternating Current

Discover π =C/D =C/2r → **S =rθ (radians) s/r=θ**

e.g. C/r =2π or C=2πr

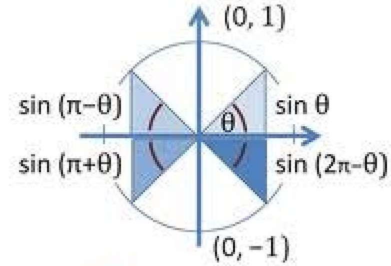


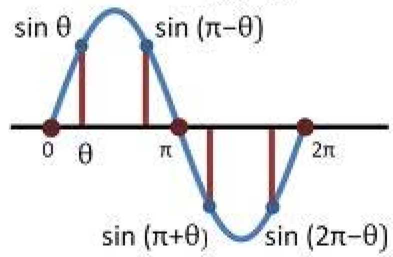
Moving around v=ds/dt= d (rθ)/dt = rdθ/dt
ω=dθ/dt
Or v=rω
ω=angular velocity= Radian/sec
The number of times around the full circle(2π) per second is the
ω/2π We call this the **Frequency, f: f=ω/2π**

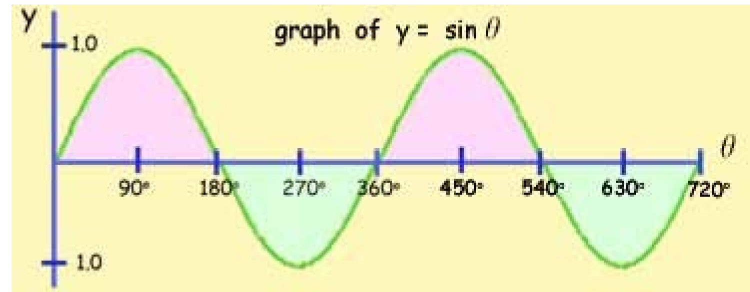
e.g. if ω =2π rad/sec then f=1cycle/sec=1Hz
ω=π/4 rad/sec (90^0/sec) then f=1/4cycles/sec=1/4Hz
ω=4π rad/sec (720^0 /sec) f=2 cycles/sec=2Hz

Alternating current more math

Though $\sin\theta$ originally
Defined to 90^0 it was
Extended using the
4 quadrant “butterfly”
Repeating the pattern
Beyond 360^0 (2π)



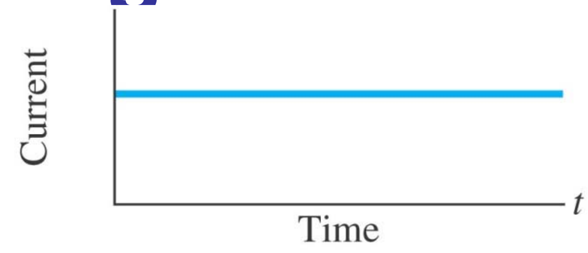




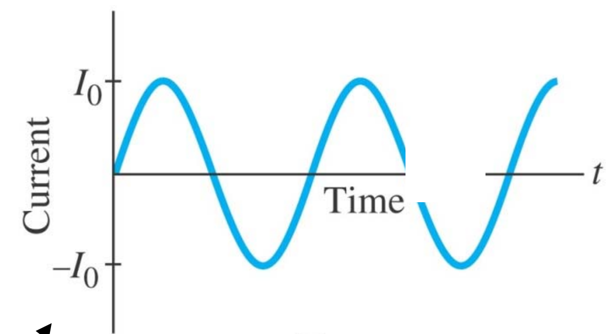
We use the extended $y=\sin(\theta)$ but $\theta(t)$ changes
In time $y=\sin\theta(t)$.
Since $\omega=d\theta/dt$ will be constant for AC circuits
then $\theta=\omega t$
So $y=\sin\theta(t)=\sin\omega t$
Recall $f=\omega/2\pi$ is the repetition so $\omega=2\pi f$
Thus $y=\sin 2\pi ft$
Also $y=\cos 2\pi ft$ can be used(90^0 phase
Difference).
Any signal or event or phenomena that is
Cyclic can be represented by these trig functions

25-7 Alternating Current

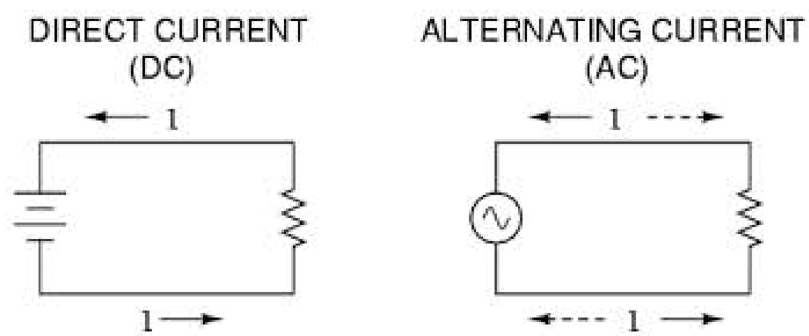
Current from a battery flows steadily in one direction (direct current, DC). Current from a power plant varies sinusoidally (alternating current, AC).



(a) DC



(b) AC



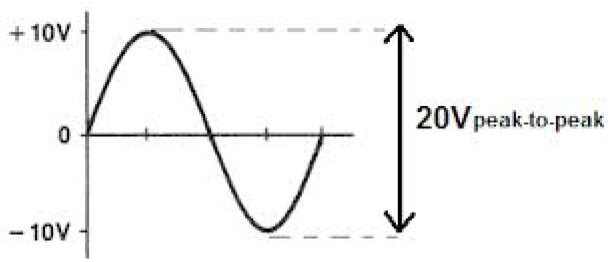
Note: we say the voltage variation is sinusoidal! So is the current

25-7 Alternating Current

The voltage in AC is sinusoidal with time and it is expressed as $V = V_0 \sin 2\pi f t = V_0 \sin \omega t,$

as does the current in a R since ohms law holds in $I = \frac{V}{R} = \frac{V_0}{R} \sin \omega t = I_0 \sin \omega t.$

V_0 is the peak voltage, I_0 is the peak current



V=10sinωt

When we say we have an AC voltage of 120V it's a special average of V! since the actual average of V and I are zero! Can you see that?

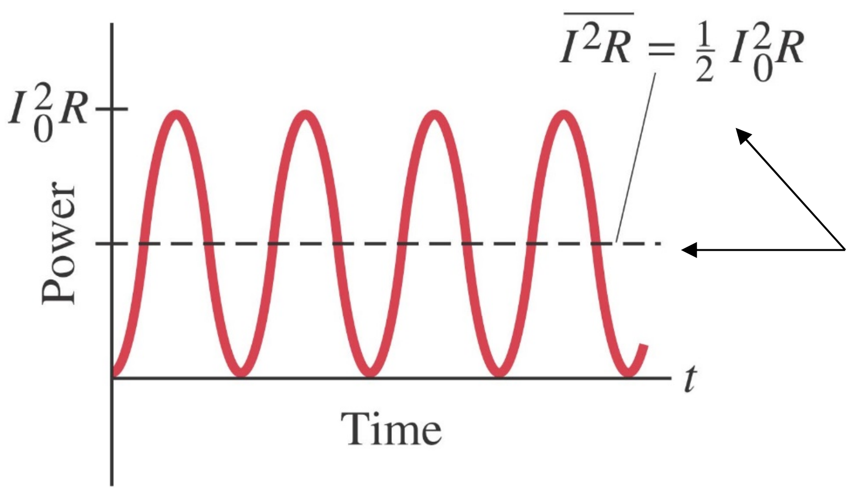
so we need ways to Mathematically express AC V and I. This is done by a special way to get values to avoid the zeros

25-7 Alternating Current
Power on a Resistor (current expression)

As we saw The power in a Resistor, R with a current, I, is $P = I^2 R$ which holds also for AC

$I = I_0 \sin\omega t$ so $P = I^2 R = (I_0 \sin\omega t)^2 R$

So $P = I_0^2 R \sin^2 \omega t$ and plotting this result in time gives



We see P is always>0 And the peak value of P is I_0^2R
recall I_0 was the peak current
The average value of the power is Just ½ of the latter or $1/2\ I_0^2R$
As indicated on the curve
Thus in AC circuits with current
$I = I_0 \sin\omega t$ in a resistor, R
$P_{avg} = 1/2\ I_0^2R$

25-7 Alternating Current
Power on a Resistor (Voltage expression)

We have the average power in terms of the AC Current on a resistor. We can also get it in terms of the AC Voltage on the Resistor using $P = V^2/R$

Since $V = V_0 \sin\omega t$ V_0 is the peak voltage
$P = V^2/R = (V_0 \sin\omega t)^2/R = (V_0^2/R)\sin^2\omega t$
$P = (V_0^2/R)\sin^2\omega t$

One can see this expression is also always >0 and the average value is half of the peak which is V_0^2/R
Thus $P_{avg} = \frac{1}{2} V_0^2/R$
In sum:

$$\overline{P} = \frac{1}{2} I_0^2 R \qquad \overline{P} = \frac{1}{2}\frac{V_0^2}{R}.$$

AC values of I and V

The current and voltage both have average values of zero, so like the power we square them to obtain some number representing the AC current and voltage

$I = I_0 \sin\omega t$ and $V = V_0 \sin\omega t$ become

$I^2 = I_0^2 \sin^2\omega t$ and $V^2 = V_0^2 \sin^2\omega t$

As before these curves are all positive and the average value of the curves is ½ the peak values of I_0^2 and V_0^2

Thus we have the average of the squares of I and V

$I^2_{avg} = \frac{1}{2} I_0^2$ and $V^2_{avg} = \frac{1}{2} V_0^2$

But its more use full to just take the square root of these average values and use that in our instruments to specify the current and voltage in AC circuits. We call them the root-mean-square (rms) value. Note the expression especially the last in terms of the peaks!

$I_{rms} = (I^2_{avg})^{1/2} = (\frac{1}{2} I_0^2)^{1/2} = I_0/(2)^{1/2} = 0.707\, I_0$

$V_{rms} = (V^2_{avg})^{1/2} = (\frac{1}{2} V_0^2)^{1/2} = V_0/(2)^{1/2} = 0.707\, V_0$

More useful AC power expressions

Recall we obtained P_{avg} =1/2 I_0^2R and P_{avg} = ½ V_0^2 /R

We also obtained I_{rms} =$(½\ I_0^2)^{1/2}$ V_{rms} =$(½\ V_0^2)^{1/2}$

which means I^2_{rms} =½ I_0^2 and V^2_{rms} =½ V_0^2

Hence P_{avg} = I^2_{rms} R and also P_{avg} = V^2_{rms}/R

These latter are useful when we are dealing with the power a resistor experiences. But when we have a measured AC current and Voltage and want to know the power then to the DC formula P=IV we use P =$I_o V_0 (\sin\omega t)^2$ or P_{avg} = ½ $I_0 V_0$

since I^2_{rms} =½ I_0^2 & V^2_{rms} =½ V_0^2 so $I_0 = (2)^{1/2} I_{rms}$ & $V_0 = (2)^{1/2} V_{rms}$

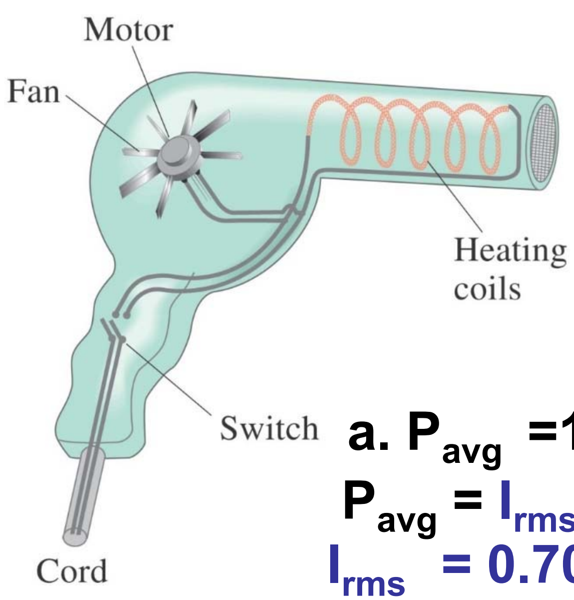
THUS P_{avg} =½ $I_0 V_0$ = ½ $(2)^{1/2} I_{rms} (2)^{1/2} V_{rms}$ = $I_{rms} V_{rms}$

in sum P_{avg} = $I_{rms} V_{rms}$

25-7 Alternating Current

Example 25-13: Hair dryer.

(a) Calculate the resistance and the peak current in a 1000-W hair dryer connected to a 120-V line. (b) What happens if it is connected to a 240-V line in Britain (assume R is the same (not true it heats up))? IN CLASS!



HINTS: We are given the AC power P_{avg} and the AC rms V. We are being asked for the Peak current I_0 and R (ohms law holds)=V/R

Useful is $P_{avg} = I_{rms} V_{rms}$ and $P_{avg} = V^2_{rms}/R$

And the definition of I_{rms} in terms of I_0

$I_{rms} = 0.707\ I_0$

a. P_{avg} =1000W & V_{rms} =120V

$P_{avg} = I_{rms} V_{rms} \rightarrow I_{rms} = P_{avg} / V_{rms}$ =1000w/120V=8.33A

$I_{rms} = 0.707\ I_0 \rightarrow I_0 = I_{rms} / 0.707 = 11.8A$

Ohms law $R = V_{rms} / I_{rms}$ =120V/ 8.33A =14.4Ω

Note $R= V_0 / I_0$ **=14.4Ω also check it out!**

b. Assuming R is a constant then with higher V More current will flow and the power will increase

$P_{avg} = V^2_{rms}/R = (240V)^2 / 14.4\Omega = 4000W$

HAND IN HW. Recall by first Sketch, set up equations, solve algebraically then plug in numbers. All answers in Scientific notation.

71. A 500-W device is connected to a 120-V ac power source.

a. What rms current flows through this device?

b. What is the peak voltage across this device?

72. Calculate the peak current in a 2.7kΩ resistor connected to a 220 V ac source ?

73. An 1800W arc welder is connected to a 660V ac line. Calculate

a. The peak voltage?

b. The peak current?

74. A heater coil connected to a 240 V ac line has a resistance of 44Ω .

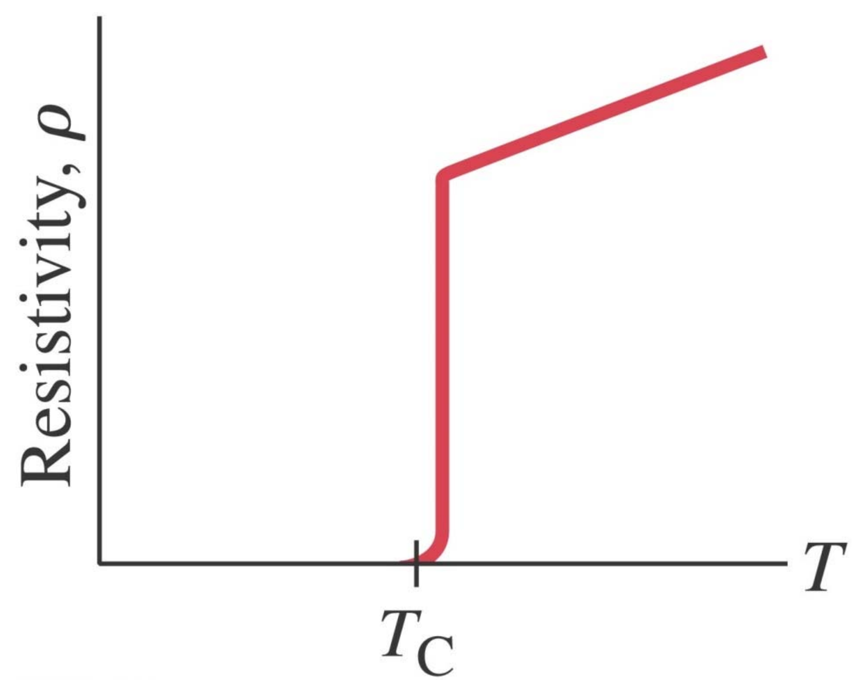
a. What is the average power used?

b. What is the maximum and minimum values of the instantaneous power? HINT: visualize the curve used for getting the average power.

The following topics are to be read but no problems will be assigned

25-9 Superconductivity

In general, resistivity decreases as temperature decreases. Some materials, however, have resistivity that falls abruptly to zero at a very low temperature, called the critical (or transition) temperature, T_C.



25-9 Superconductivity

Experiments have shown that currents, once started, can flow through these materials for years without decreasing even without a potential difference.

Critical temperatures are low; for many years no material was found to be superconducting above 23 K.

Since 1987, new materials have been found that are superconducting below 90 K, and work on higher temperature superconductors is continuing.

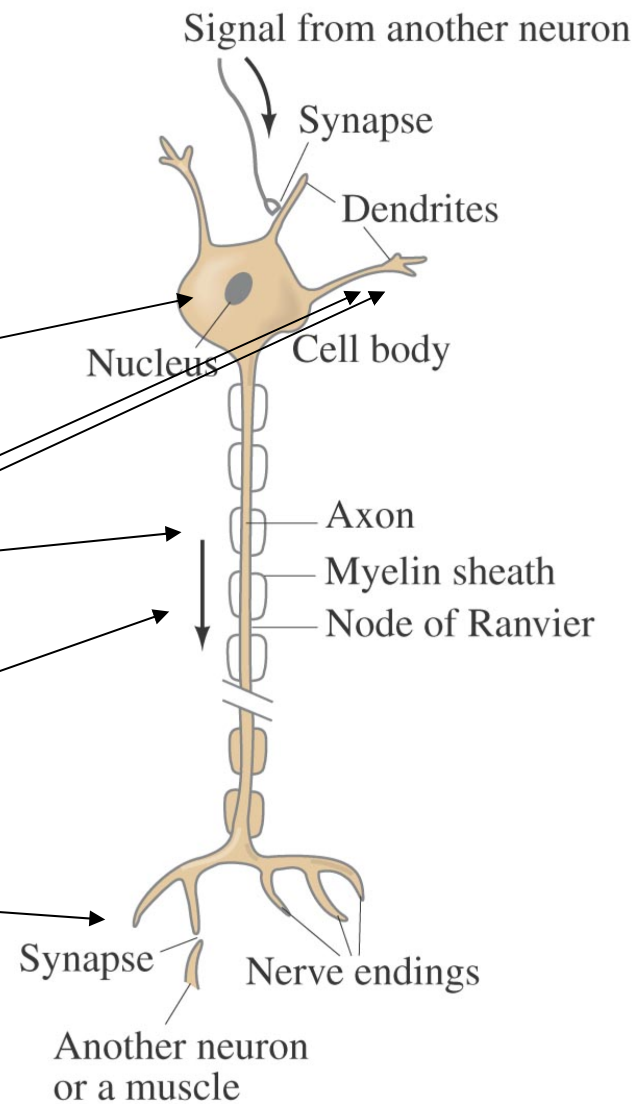
25-10 Electrical Conduction in the Nervous System

The human nervous system depends on the flow of electric charge.

The basic elements of the nervous system are cells called neurons.

Neurons have a main cell body, small attachments called dendrites, and a *long tail* called the axon.

Signals are received by the dendrites, propagated along the axon, and transmitted through a connection called a synapse.



25-10 Electrical Conduction in the Nervous System (still a lot of mystery involved!)

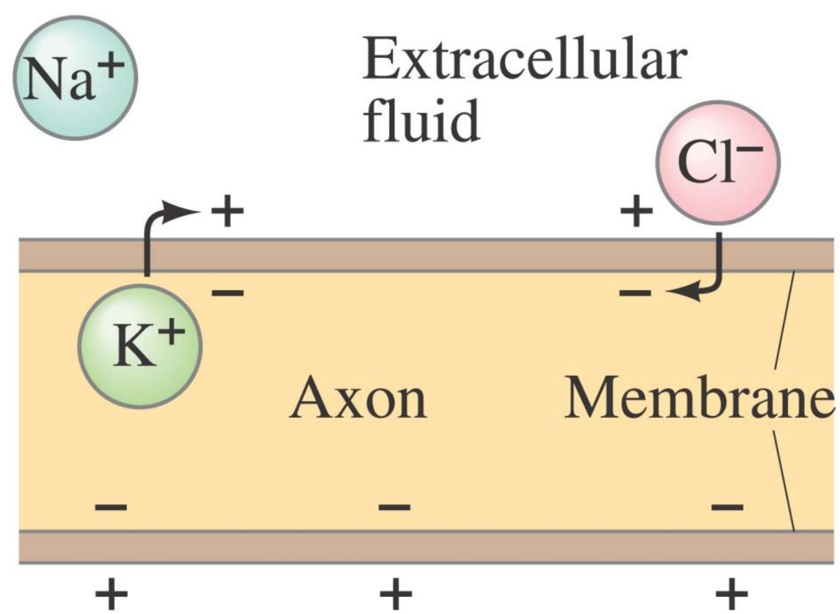
This process depends on there being a dipole layer of charge on the cell membrane, and different concentrations of ions inside and outside the cell.

Before a neuron transmits an electrical signal it is in a "resting state "
+ charge on outside and negative on inside create a dipole layer with
A resting potential =V_{inside} –$V_{outside}$ ~ -60mV **to -90**mV

Concentration gradients of
Na+,CL- ,K+ in the resting state

Initially cause diffusion of K^+ from inside to the outside where they stick. Ditto Cl^- diffuse to the inside And sticks and thus the dipole forms. Equilibrium forms (balance of diffusion And electrical potential-> no more K and Cl ions diffuse. Charge already there is Strong enough to stop migration.

Note that Na^+ cannot migrate in this resting state.

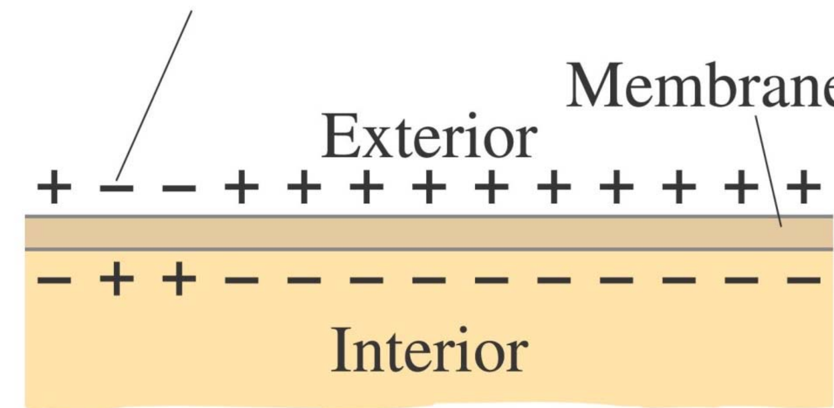


Why do they stick? EC

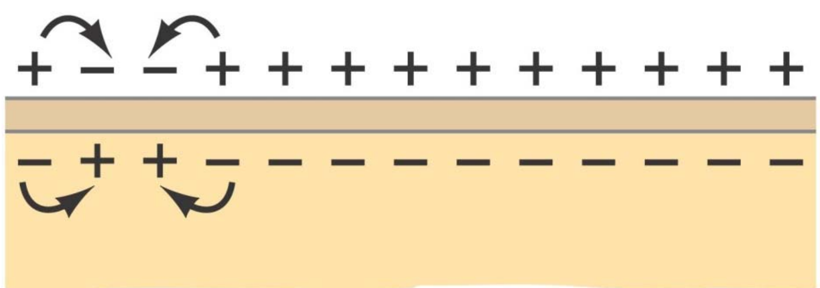
25-10 Electrical Conduction in the Nervous System

Response to stimulus. (thermal,chemical,pressure,light, brains electrical signal etc.) if greater than some threshold a voltage pulse will travel down the axon. This "action potential" propagates along the axon membrane.

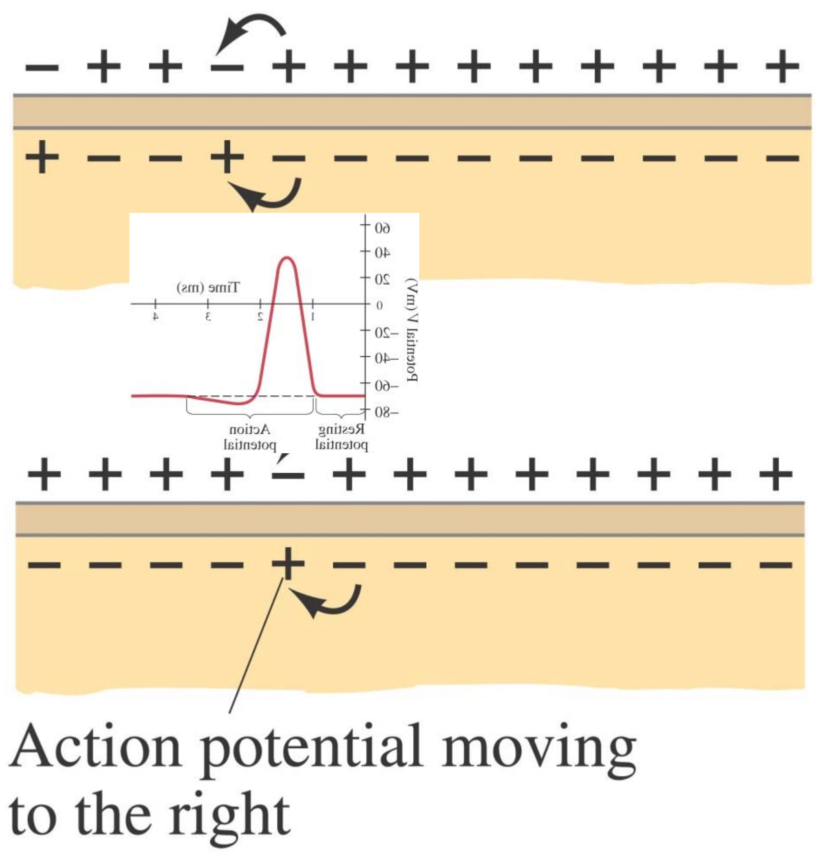
Na+ rush in.



Near by charges are attracted

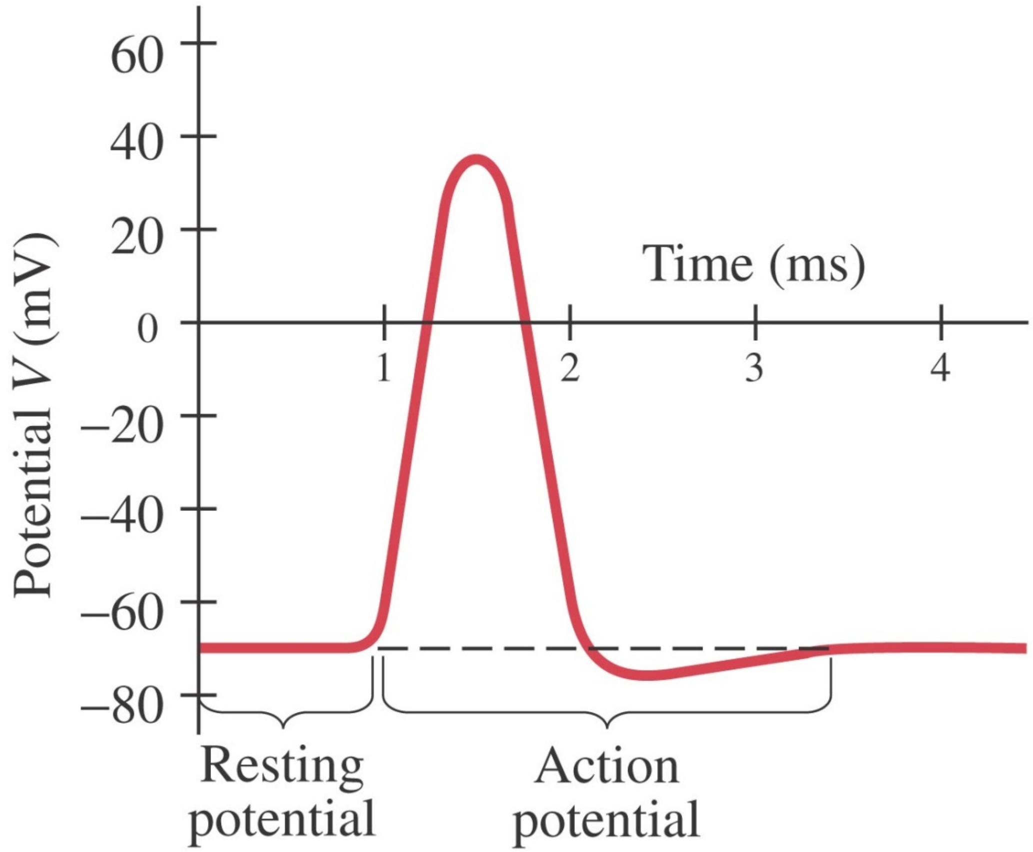


Attraction cascades down axon!



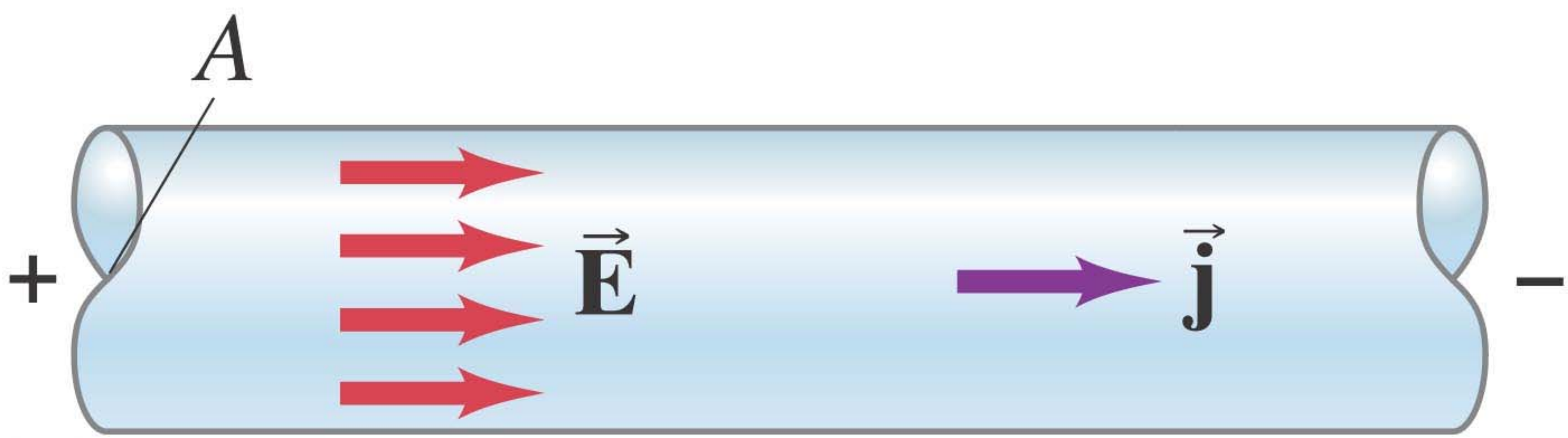
25-10 Electrical Conduction in the Nervous System

This applies to most cells in the body. Neurons can respond to a stimulus and conduct an electrical signal. This signal is in the form of an action potential.



25-8 Microscopic View of Electric Current: Current Density and Drift Velocity

Electrons in a conductor have large, random speeds just due to their temperature. When a potential difference is applied, the electrons also acquire an average drift velocity, which is generally considerably smaller than the thermal velocity.



25-8 Microscopic View of Electric Current: Current Density and Drift Velocity

We define the current density (current per unit area) – this is a convenient concept for relating the microscopic motions of electrons to the macroscopic current:

$$j = \frac{I}{A} \quad \text{or} \quad I = jA.$$

If the current is not uniform:

$$I = \int \vec{\mathbf{j}} \cdot d\vec{\mathbf{A}}.$$

25-8 Microscopic View of Electric Current: Current Density and Drift Velocity

This drift speed v_d is related to the current in the wire, and also to the number of electrons per unit volume, n =N(#)/V   OR N=nV

Amount of charge that moves

ΔQ = Nx e =nVe = nAde   d = distance charge move or d=$v_d\,\Delta t$

So ΔQ =n$Av_d\,\Delta t$e or thus the current I is (e is neg)

$$I = \frac{\Delta Q}{\Delta t} = -neAv_{\rm d}.$$

25-8 Microscopic View of Electric Current: Current Density and Drift Velocity: See the solution in the text

Example 25-14: Electron speeds in a wire.

A copper wire 3.2 mm in diameter carries a 5.0-A current. Determine (a) the current density in the wire, and (b) the drift velocity of the free electrons. (c) Estimate the rms speed of electrons assuming they behave like an ideal gas at 20°C. Assume that one electron per Cu atom is free to move (the others remain bound to the atom).

25-8 Microscopic View of Electric Current: Current Density and Drift Velocity

The electric field inside a current-carrying wire can be found from the relationship between the current, voltage, and resistance. Writing $R = \rho\, l / A$, recall ρ = *resistivty*

$I = jA,\ V = El$,

and substituting in Ohm's law gives:

V=IR

$El = jAR = JA\,\rho\, l / A = j\rho\, l$ ***or***

$J = E/\rho = \sigma E$ recall $\sigma = 1/\rho$ *is called conductivity*

25-8 Microscopic View of Electric Current: Current Density and Drift Velocity: see the solution in the text.

Example 25-15: Electric field inside a wire.

What is the electric field inside the wire of Example 25–14? (The current density was found to be 6.2×10^5 A/m^2.)