Conserving Electricity

What is Power?

$$KE = \frac{1}{2}mv^2$$

$$(\mathrm{kg})\left(\frac{\mathrm{m}^2}{\mathrm{s}^2}\right) = \mathrm{Nm} = \mathrm{J}$$

$$\mathrm{P} = \frac{\mathrm{Energy}}{\mathrm{t}}$$

$$\mathrm{w} = \frac{\mathrm{J}}{\mathrm{s}}$$

Rating Your Appliance

The electric company actually bills you for the amount of energy that you use. But your appliances are rated by the amount of power that they use. You can easily find the amount of energy used by solving the power equation for energy. You get:

$$\text{Energy} = P\ t$$

units of kilowatt hours

Calculating your electric bill

- Now all you need to know is how much your electric utility or company charges you for energy. This will usually be in the units of $ per kw hr. Then you just multiply the kw hrs by the $ per kw hr, and you end up with the cost for that appliance for the amount of time that you have used it.

Sample Calculations

- Let's say that you found that your microwave oven has a power rating of 120 watts. To convert that into kilowatts you must divide by 1000 as follows. Place this number in the table.

$$120\text{w}\left(\frac{1\text{kw}}{1000\text{w}}\right)=0.12\text{kw}$$

Sample Calculations

- You estimate that your microwave oven is used 3 hours per day. Multiply by 365 days per year to get the hours used per year as follows:

$$\frac{3\text{hr}}{\text{day}}\left(\frac{365\text{ hr}}{1\text{ yr}}\right)= 1095\text{ hr/year}$$

Sample Calculations

- Now you can calculate your energy consumption by multiplying the power in kw times the time used in hr/yr as follows:

$$\text{Energy} = P\ t$$

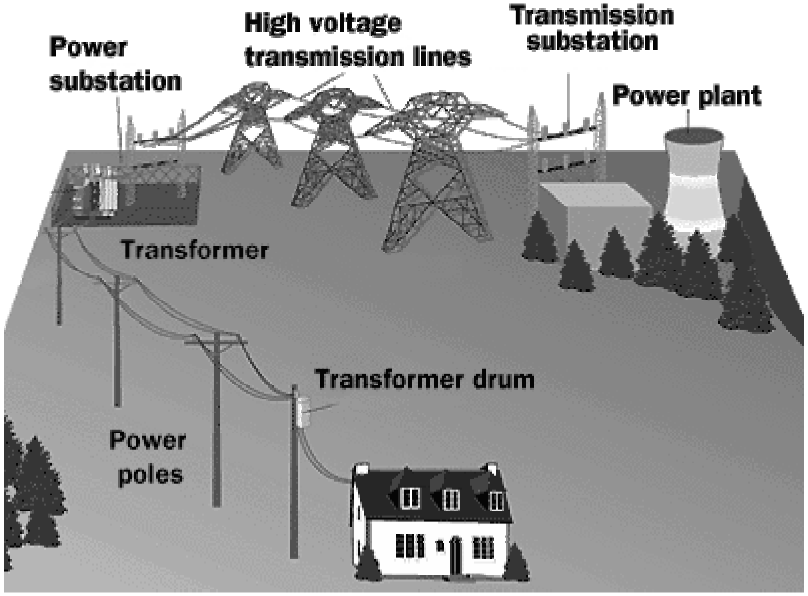
$$E = (0.12\ \text{kw})(1095\ \text{hr/yr}) = 131.4\ \text{kw hr/yr}$$

$$\text{Cost} = (131.4\ \text{kw hr/yr})(0.077\ \$/\text{kw hr}) = \$10.12\ /\ \text{yr}$$

Ohm's Law

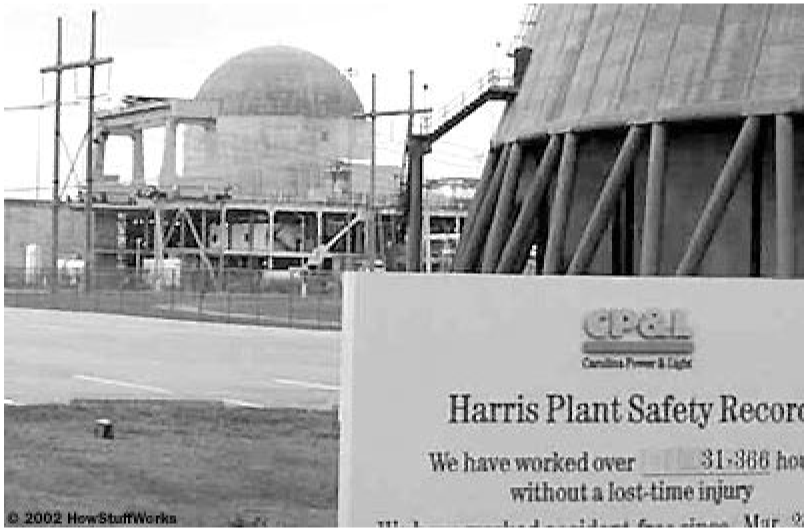
- $V = I R$
- $P = V I$
- $P = V^2/R$

How Power Distribution Grids Work



Power Plant

- power plant consists of a **spinning electrical generator**. Something has to spin that generator -- it might be a water wheel in a hydroelectric dam, a large diesel engine or a gas turbine. But in most cases, the thing spinning the generator is a **steam turbine**. The steam might be created by burning coal, oil or natural gas. Or the steam may come from a nuclear reactor like this one at the Shearon Harris nuclear power plant near Raleigh, North Carolina:



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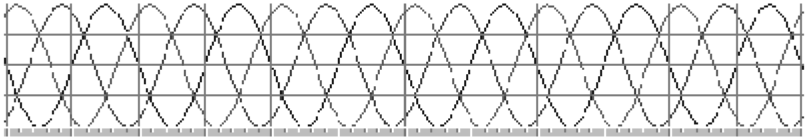
Single-phase power

- household electrical service 120-volt AC (**alternating current)**
- Peak voltage=170 volt
- 120 volt = rms (root mean square)

- AC has at least three advantages over DC in a power distribution grid:

1. Large electrical generators happen to generate AC naturally, so conversion to DC would involve an extra step.
2. Transformers must have alternating current to operate, and we will see that the power distribution grid depends on transformers.
3. It is easy to convert AC to DC but expensive to convert DC to AC, so if you were going to pick one or the other AC would be the better choice.

- three phases are **offset 120 degrees** from each other
- There are four wires coming out of every power plant: the **three phases** plus a neutral or **ground**



Why three phases?

- at any given moment one of the three phases is nearing a peak. High-power 3-phase motors (used in industrial applications) and things like 3-phase welding equipment therefore have even power output
- Four phases would not significantly improve things but would add a fourth wire, so 3-phase is the natural settling point

Transmission substation

- substation uses large transformers to convert the generator's voltage (which is at the thousands of volts level) up to extremely high voltages for long-distance transmission on the transmission grid.
- . Typical voltages for long distance transmission are in the range of 155,000 to 765,000 volts in order to reduce line losses
- transmission distance is about 300 miles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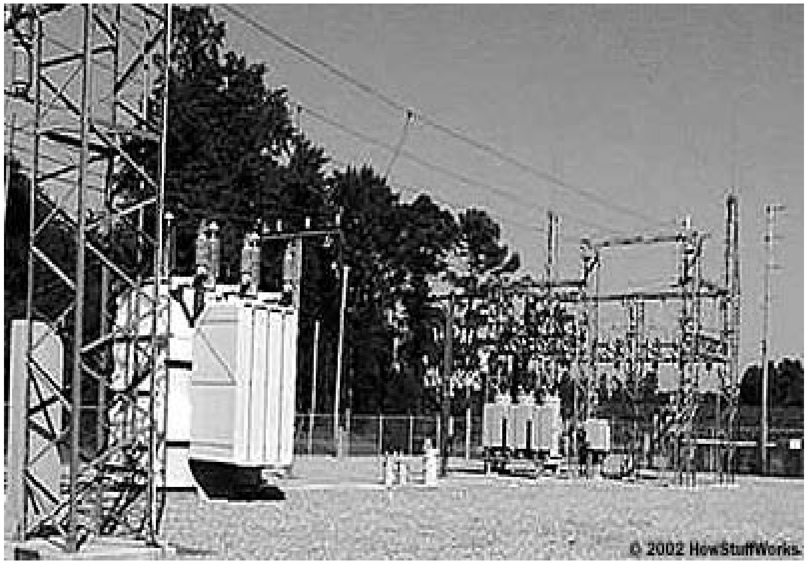
High Power Transmission Line

- All power towers like this have three wires for the three phases. Many towers, like the ones shown above, have extra wires running along the tops of the towers. These are ground wires and are there primarily in an attempt to attract lightning.

Power substation

- It has transformers that step transmission voltages (in the tens or hundreds of thousands of volts range) down to distribution voltages (typically less than 10,000 volts).
- It has a "bus" that can split the distribution power off in multiple directions.
- It often has circuit breakers and switches so that the substation can be disconnected from the transmission grid or separate distribution lines can be disconnected from the substation when necessary.



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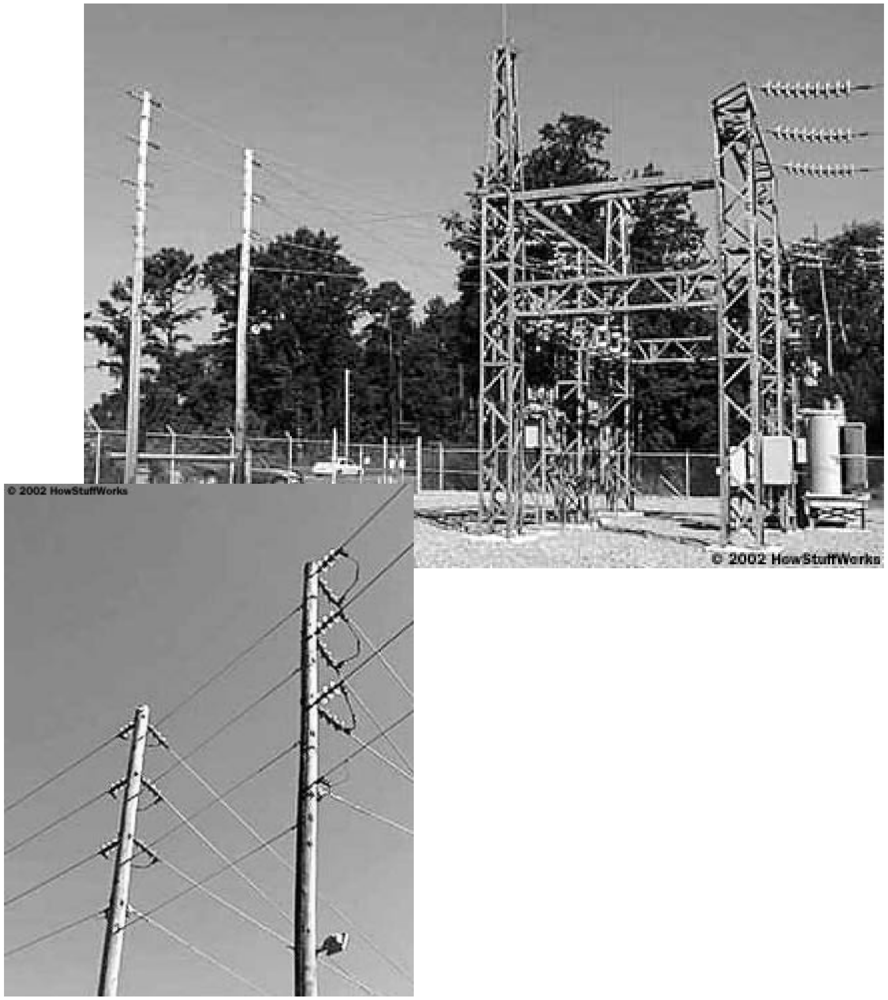
Distribution Bus

- The bus distributes power to two separate sets of distribution lines at two different voltages. The smaller transformers attached to the bus are stepping the power down to standard line voltage (usually 7,200 volts) for one set of lines, while power leaves in the other direction at the higher voltage of the main transformer. The power leaves this substation in two sets of three wires, each headed down the road in a different direction



Distribution Bus

- In the typical scene pictured on the right, the three wires at the top of the poles are the three wires for the 3-phase power. The fourth wire lower on the poles is the ground wire. In some cases there will be additional wires, typically phone or cable TV lines riding on the same poles.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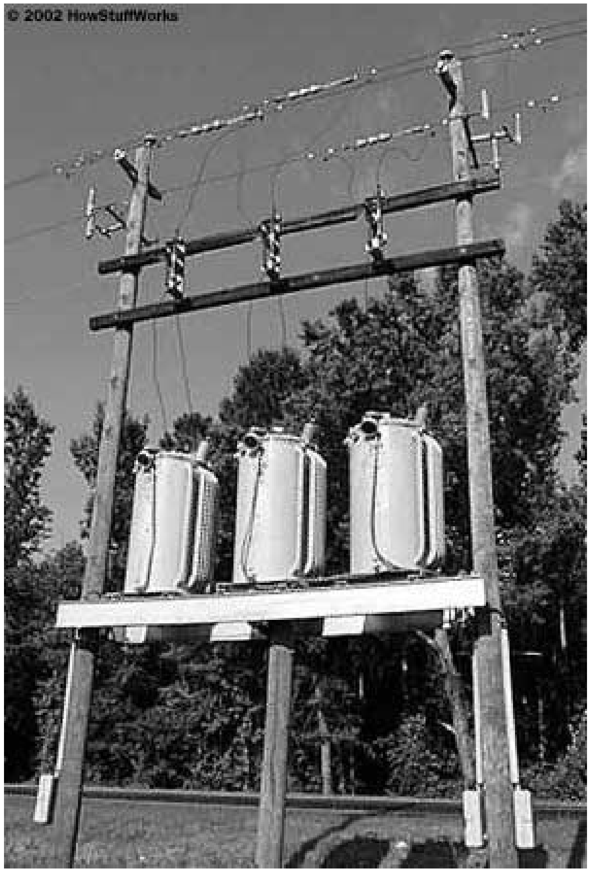
Regulator Bank

- You will also find regulator banks located along the line, either underground or in the air. They regulate the voltage on the line to prevent undervoltage and overvoltage conditions.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Regulator bank

- Up toward the top are three switches that allow this regulator bank to be disconnected for maintenance when necessary:

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Neighborhood Bus line

- At this point, we have typical line voltage at something like 7,200 volts running through the neighborhood on three wires (with a fourth ground wire lower on the pole):


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Tap

- A house needs only one of the three phases, so typically you will see three wires running down a main road, and **taps** for one or two of the phases running off on side streets. Pictured below is a 3-phase to 2-phase tap, with the two phases running off to the right

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2 phase to 1 phase tap

- Here is a 2-phase to 1-phase tap, with the single phase running out to the right:


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- And finally we are down to the wire that brings power to your house! Past a typical house runs a set of poles with one phase of power (at **7,200 volts**) and a ground wire (although sometimes there will be two or three phases on the pole, depending on where the house is located in the distribution grid). At each house, there is a **transformer drum** attached to the pole, like this:
- **underground** and there are green transformer boxes at every house or two


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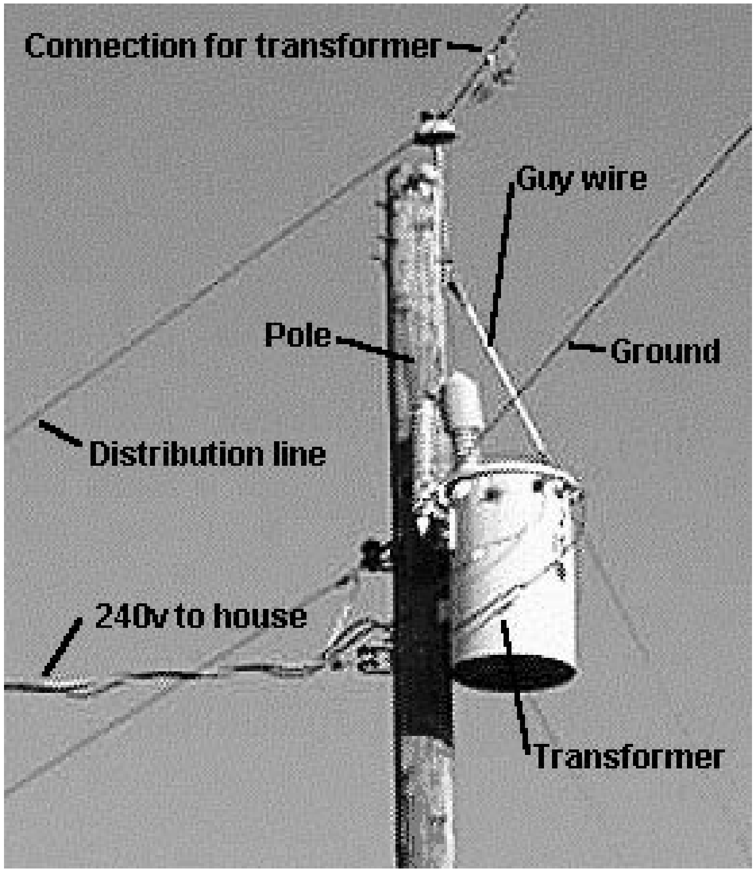
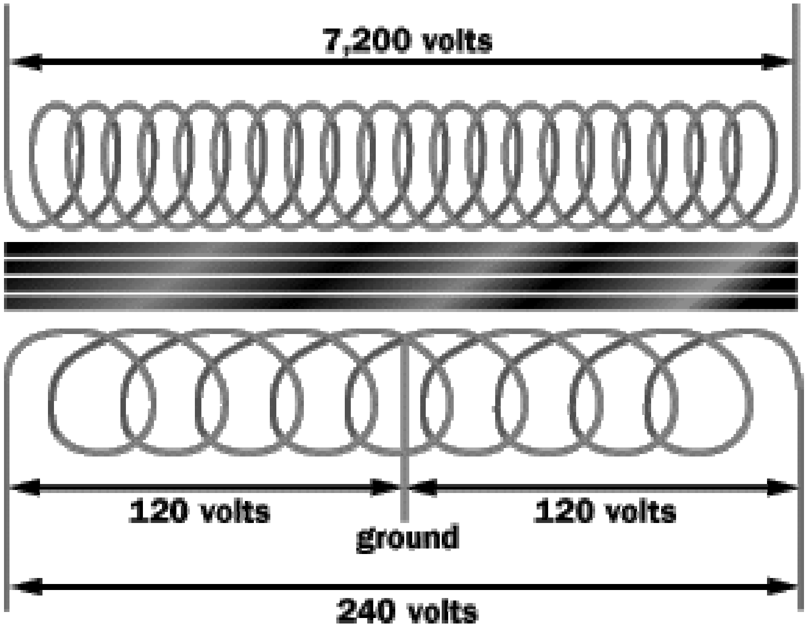
Transformer

- The transformer's job is to reduce the 7,200 volts down to the **240 volts** that makes up normal household electrical service. Let's look at this pole one more time, from the bottom, to see what is going on:



- There is a bare wire running down the pole.
  This is a grounding wire. Every utility pole on the planet has one. If you ever watch the power company install a new pole, you will see that the end of that bare wire is stapled in a coil to the base of the pole and therefore is in direct contact with the earth, running 6 to 10 feet (1.8 to 3 m) underground. It is a good, solid ground connection. If you examine a pole carefully, you will see that the ground wire running between poles (and often the guy wires) are attached to this direct connection to ground.
- There are two wires running out of the transformer and three wires running to the house.
  The two from the transformer are insulated, and the third one is bare. The bare wire is the ground wire. The two insulated wires each carry 120 volts, but they are 180 degrees out of phase so the difference between them is 240 volts. This arrangement allows a homeowner to use both 120-volt and 240-volt appliances. The transformer is wired in this sort of configuration:



Meter

- The 240 volts enters your house through a typical **watt-hour meter** like this one:

Fuses and Circuit Breakers

- Fuses and circuit breakers are **safety devices**. Let's say that you did not have fuses or circuit breakers in your house and something "went wrong." What could possibly go wrong? Here are some examples:
- A fan motor burns out a bearing, seizes, overheats and melts, causing a direct connection between power and ground.
- A wire comes loose in a lamp and directly connects power to ground.
- A mouse chews through the insulation in a wire and directly connects power to ground.
- Someone accidentally vacuums up a lamp wire with the vacuum cleaner, cutting it in the process and directly connecting power to ground.
- A person is hanging a picture in the living room and the nail used for said picture happens to puncture a power line in the wall, directly connecting power to ground.

circuit breaker panel

Fuses and Circuit Breakers

- **Fuse** uses a thin piece of foil or wire quickly vaporizes when an overload of current runs through it
- **circuit breaker** uses the heat from an overload to trip a switch, and circuit breakers are therefore resettable.

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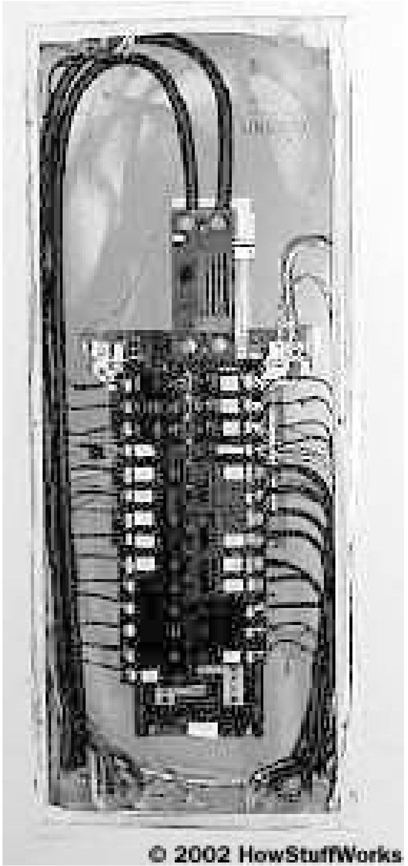
Fuses and Circuit Breakers

- The main breaker lets you cut power to the entire panel when necessary. Within this overall setup, all of the wires for the different outlets and lights in the house each have a separate circuit breaker or fuse:



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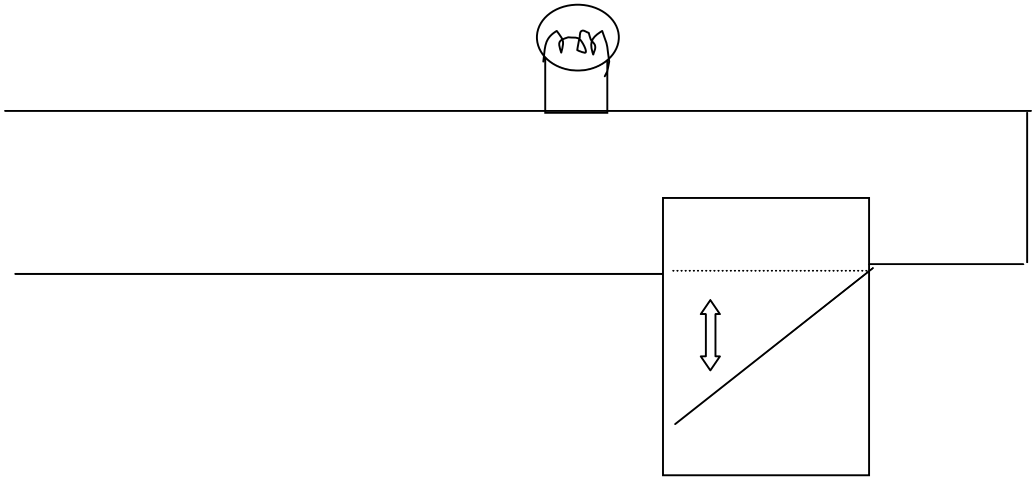
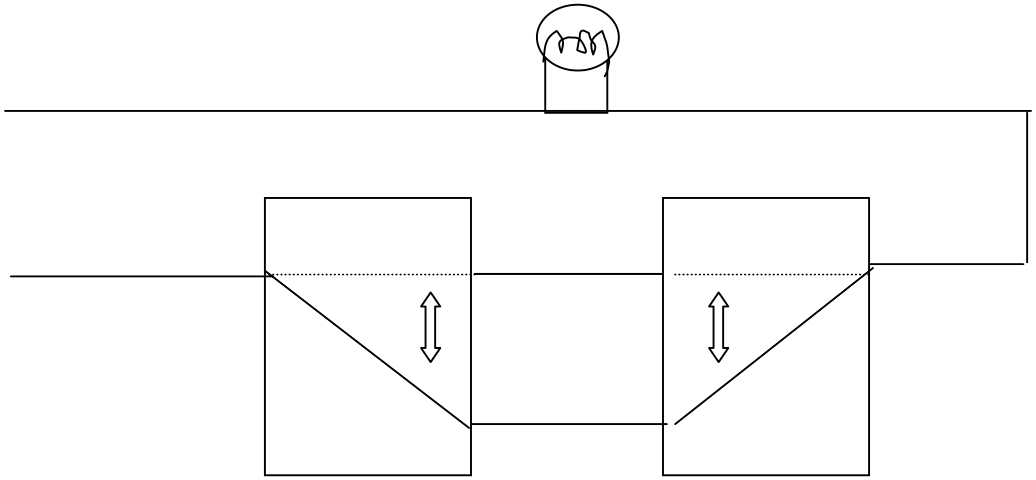
Outlet

- If the circuit breaker is on, then power flows through the wire in the wall and makes its way eventually to its final destination, the **outlet** or **Light switch**

Single switch wiring



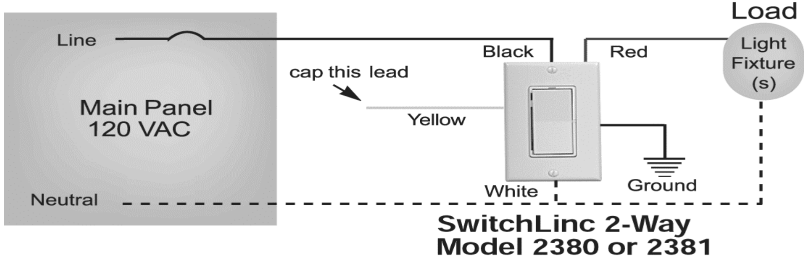
Two switches wiring



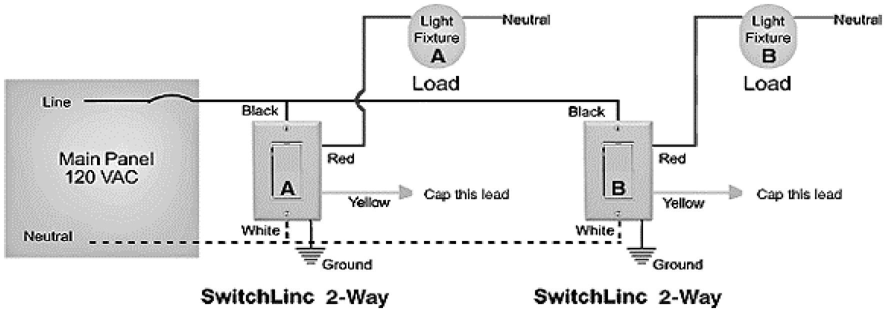
Electrical Wiring

SwitchLinc 2-Way Wiring Diagram

(One switch controlling the load)



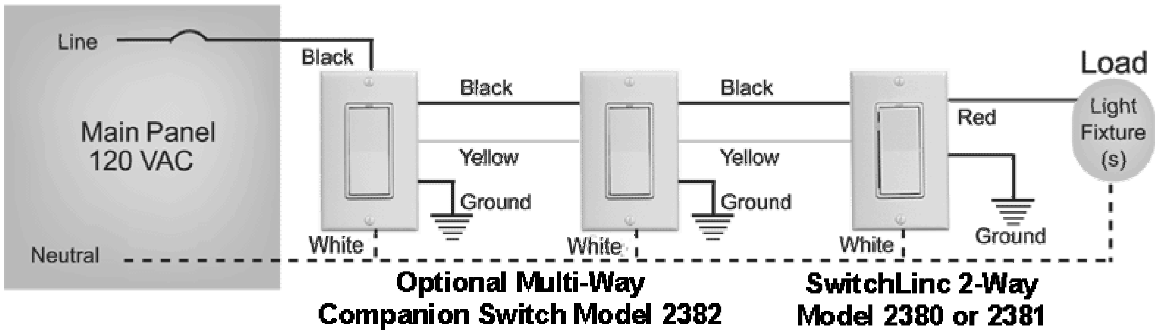
Using 2 SwitchLincs to Create a Virtual 3-Way Circuit



Light fixtures A & B will work as if they were part of the same 3-way circuit. Either switch A or B can be used to turn on/off (dim/brighten for dimmers) lights A & B even though there is no "traveller" wire.

SwitchLinc Multi-Way Wiring Diagram

(Two or more switches controlling the load)



Assignment

- **Can you connect a switch to a light fixture? (10%)**
- **If you have more than one entrance to a room, it's handy to have more than one switch to turn the lights on and off.**
- **Can you figure out any other ways of connecting two switches? (20%)**
- **Can you explain the way the current flow across the switches? (20%)**

- **Can you do the three switches configuration? (20%)**
- **How many different ways of wiring can you come up? (20%)**
- **How to connect multiple light fixture to single or multiple switches? (10%)**
- **Any other configuration you can think of connecting the wire in your house safely? (extra credit (50%)**