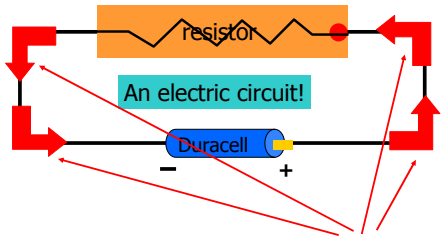
L 27 Electricity and Magnetism [4]

- simple electrical circuits – direct current DC
- Alternating current (AC) vs
  direct current (DC)
- electric power distribution
- household electricity
  - household wiring
    - GFIC's
  - the kilowatt-hour (what you pay for)

Electric circuits

- a circuit must provide a closed path for the current to circulate around
- when the electrons pass through the light bulb they loose some of their energy → the conductor (resistor) heats up
- we refer to conductors as resistors because they impede (resist) the flow of current.
- the battery is like a pump that re-energizes them each time they pass through it
- *the direction of current flow is defined, by convention, to be the direction that positive charges would flow*
- *it is the direction opposite to the direction of electron flow.*

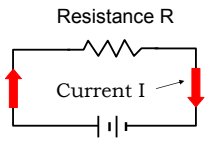
Direction of current flow



The electrons go one way but the current goes the other way by convention.

REVIEW: Current, Voltage and Resistance➔ OHM'S LAW

- Ohm's law is a relation between current, voltage and resistance
- Ohm's law:
- **I = Voltage / Resistance = V / R**
  V in volts, R in ohms,
  I in amps
- V = I R, R = V / I



symbol for Ohms: Ω (Omega)

Heat produced in a resistor

- The collisions between the electrons and the atoms in a conductor produce heat.
- The amount of energy converted to heat per second is called the power loss in a resistor
- If the resistor has a voltage V across it and carries a current I the power dissipated is given by → Power $P = I \times V$ or $I^2 \times R$

Heat produced in a resistor

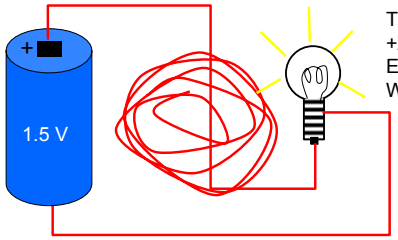
- Power (energy/time) ➔ $P = I \times V$ or $I^2 \times R$
- Power is measured in **Watts = amps × volts**
- All wire is rated for the maximum current that it can handle based on how hot it can get
- To carry more current you need wire of a larger diameter → this is called the wire gauge, the lower the gauge the more current it can carry
- Using extension cords can be dangerous!

extension cords and power strips

- extension cords are rated for maximum current → you must check that whatever is plugged into it will not draw more current than the cord can handle safely.
- power strips are also rated for maximum current → since they have multiple imputs you must check that the total current drawn by everything on it does not exceed the current rating

Simple direct current (DC) electric circuits

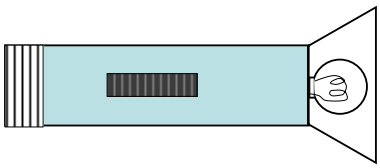
Exercise: given a battery, some wire and a light bulb, connect them so that the bulb is on.



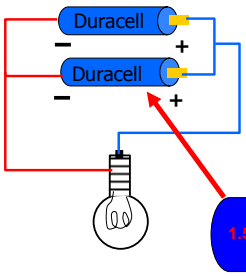
The battery polarity +/- does not matter, Either way the bulb Will be on.

Proper connections

Connecting two 1.5 volt batteries gives like this gives 3.0 volts.

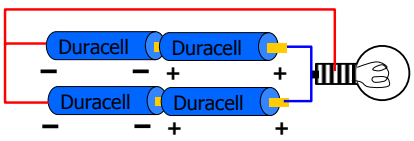


Batteries in parallel



This connection still gives 1.5 volts but since there are 2 batteries it will provide electrical current for a longer time

Longer lasting power



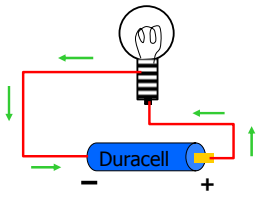
This connection provides 3.0 volts and will provide power for a longer amount of time

What is DC?

- With DC or direct current the current always flows in the same direction
- this is the type of current you get when you use a battery as the voltage source.
- the direction of the current depends on how you connect the battery
- the electricity that you get from the power company is not DC it is AC (alternating).

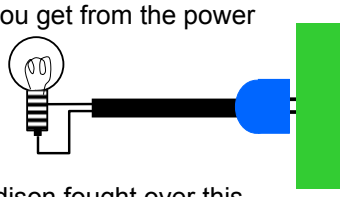
Direct Current DC

- a circuit containing a battery is a DC circuit
- in a DC circuit the current always flows in the **same direction**



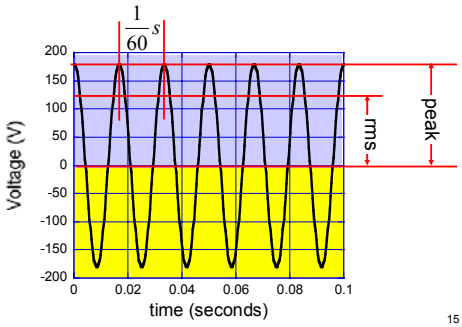
Alternating Current (AC)

- In an AC circuit the current reverses direction periodically
- AC is what you get from the power companies



- Tesla and Edison fought over this, and Tesla won!

How does the line voltage change in time?



AC current

- The line voltage reverses polarity 60 times a second (60 Hertz) see
- the current through the bulb reverses direction 60 times a second also
- for heaters, hair dryers, irons, toasters, waffle makers, the fact that the current reverses makes no difference
- battery chargers (e.g., for cell phones) convert the AC to DC

Why do we use AC ?? (DC seems simpler ??)

- AC power is easier to generate
- late 1800's → the war of the currents
- Edison (DC) vs Tesla (Westinghouse) (AC)
- Edison opened the first commercial power plane for producing DC in NY in 1892
- Tesla who was hired by George Westinghouse believed that AC was superior
- Tesla was right, but Edison never gave up!

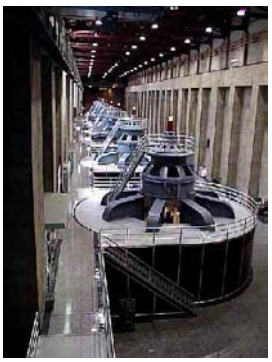
Why AC is better than DC

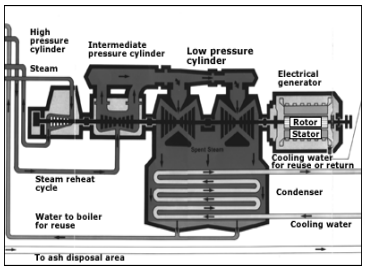
- DC power is provided at one voltage only
- AC power can be stepped up or down to provide any voltage required
- DC is very expensive to transmit over large distances compared to AC, so many plants are required
- DC power plants must be close to users
- AC plants can be far outside cities
- by 1895 DC was out and AC was in

The electric generator

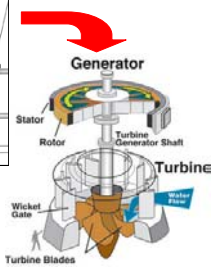
- When a coil of wire is rotated inside a magnet, electricity is produced
- http://www.wvic.com/how-gen-works.htm
- this electricity is AC
- the voltage depends on how much wire the coil has and how fast it is rotated.
- devices called transformers can make the voltage bigger or smaller
- transformers only work with AC ←

Hoover Dam





Coal fired power plant



Hydroelectric power

Wind Power

Bodily Effects of Electrical Currents

BODILY EFFECT	DIRECT CURRENT (DC)	60 Hz AC	10 kHz AC
Slight sensation felt at hand(s)	Men = 1.0 mA Women = 0.6 mA	0.4 mA 0.3 mA	7 mA 5 mA
Threshold of perception	Men = 5.2 mA Women = 3.5 mA	1.1 mA 0.7 mA	12 mA 8 mA
Painful, but voluntary muscle control maintained	Men = 62 mA Women = 41 mA	9 mA 6 mA	55 mA 37 mA
Painful, unable to let go of wires	Men = 76 mA Women = 51 mA	16 mA 10.5 mA	75 mA 50 mA
Severe pain, difficulty breathing	Men = 90 mA Women = 60 mA	23 mA 15 mA	94 mA 63 mA
Possible heart fibrillation after 3 seconds	Men = 500 mA Women = 500 mA	100 mA 100 mA	

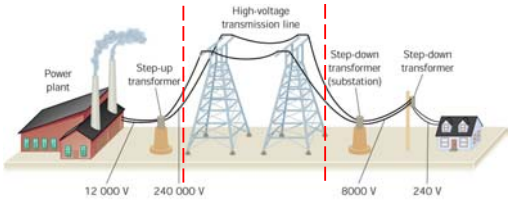
http://www.allaboutcircuits.com/vol_1/chpt_3/4.html

Transformers

This is a typical step-down transformers used to bring the line voltage down from 5000 V to 240 V before it gets to your home

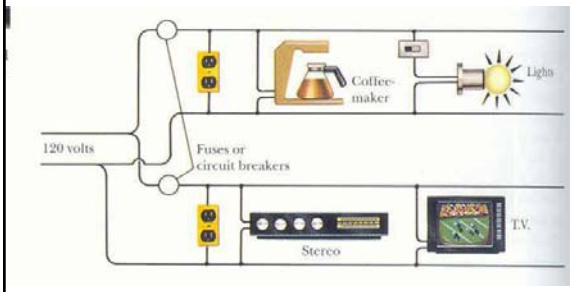
In your home two voltages are available: 240 V &120 V. The 240 is used for the high power appliances like the clothes dryer, oven, etc. The 120 V is for everything else.

Electric power generation and distribution



- It is more efficient to transmit electrical power (P = IV) at high voltage and low current.
- The losses along the transmission lines are reduced compared to transmission at low V.

House wiring



all circuits are connected in parallel

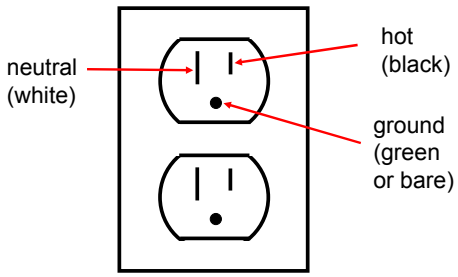
electrical power

- the power is how much electrical energy used per second = 1 Watt (1000 W = 1 kW)
- Power = current x voltage
- the appliances required high power, like your electric range or clothes dryer operate at the higher voltage, so less current is used.
- we pay for the total energy (not power) used each month - KW-hours (KWH)

Circuit overload

- if you have too many things plugged into the same circuit, the voltage may drop.
- you may notice that a lamp plugged into the same outlet as a hair dryer dims a bit when you turn on the hair dryer because a hair dryer draws a lot of current
- according to Ohm V = I R, a big I can cause enough drop in the voltage to be noticeable!

What everybody needs to know about electricity



Electric outlets

- The current is supposed to flow from the hot side to the neutral, if too much current flows the fuse blows or the circuit breaker trips.
- the ground is there for protection → to provide a safe path for current in the event of a short circuit
- on some circuits (kitchens and bathrooms) there is additional protection →**GFCI** → ground fault circuit interrupt. If current accidentally flows through anything other than the hot or neutral it interrupts the circuit very quickly

Man says live wire in bath was to save marriage

Thursday, October 28, 2004 Posted: 7:53 AM EDT (1153 GMT)

LA CROSSE, Wisconsin (AP) -- A man who said he threw a live electrical wire into his wife's bath hoping a near-death experience would save their marriage was convicted of attempted first-degree intentional homicide Wednesday.

William Dahlby said in court he was only trying to scare his wife the evening of May 9. He told jurors the wire was hooked to a **"ground fault interrupter"** designed to cut the electricity when the cord encountered water. His wife was not hurt.

Paying for electricity

- You pay for the total amount of electrical energy that is used
- the energy is measured in kilowatt-hours
- the kilowatt (kW) = 1000 W is the energy used per unit time
- When kW are multiplied by a time unit (hrs) we get total energy

$$$ example $$$

- At a rate of 10 cents per kWh, how much does it cost to keep a 100 W light bulb on for one day?
- **Solution**: First 100 W = 0.1 kW, one full day has 24 hours, so

  cost = 0.1 kW x 24 hours x $0.10/kWh

  = $0.24 = 24 ¢

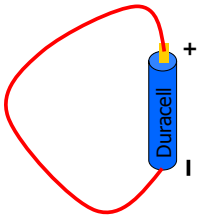
→ for one month that amounts to $7.20

Energy consumption

- Power (Watts) = energy used per unit time (J/s)
- energy(KWH) = power × time = kilowatts (kW) × hours
- 1 kilowatt = 1000 Watts
- 1 ton of coal produces about 6000 KWH of electric power
- an average US household uses about 10,000 KWH of electricity per year
- we pay for the number of KWH used each month
- It takes 10,000/6000 = 1.66 tons (3000 lbs) of coal per year for each household
- US coal reserves: 300 billion tons!

connecting batteries → do's and don'ts

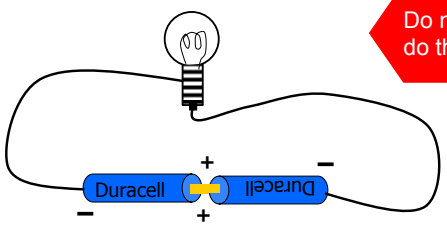
don't connect a wire from the + side to the – side, this shorts out the battery and will make it get hot and will shorten its lifetime.



Do not do this

dueling batteries

Do not do this



The batteries are trying to push currents in opposite directions → they are working against each other. This does not work.

example

- How much current is drawn by a 60 Watt light bulb connected to a 120 V power line?
- **Solution:** P = 60 W = I x V = I x 120

  so I = 0.5 Amps (A)
- What is the resistance of the bulb?
- **Solution:** V = I R→ 120 V = ½ A x R

  so R = 240 Ω, or R = V/I