

## 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
    - GFCI's
  - the kilowatt-hour (what you pay for)

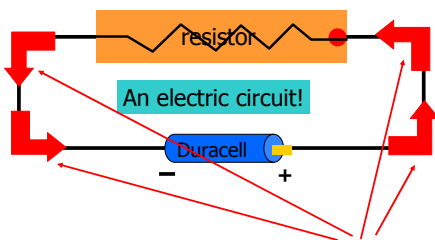
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## Electric circuits

- a circuit must provide a closed path for the current to circulate around
- when the electrons pass through the light bulb they lose 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.

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## Direction of current flow



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

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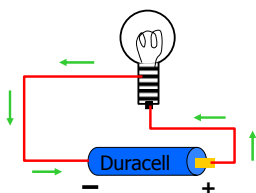
## What is DC?

- 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).

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## Direct Current DC

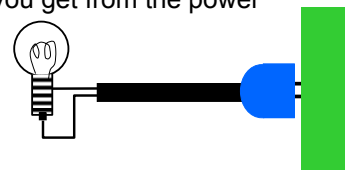
- a circuit containing a battery is a DC circuit
- in a DC circuit the current always flows in the **same direction**



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## Alternating Current (AC)

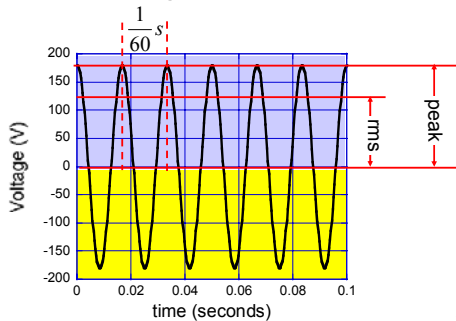
- In an AC circuit the current **reverses direction** periodically
- AC is what you get from the power companies



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

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## How does the line voltage change in time?



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## 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

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## 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 plant 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!

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## 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

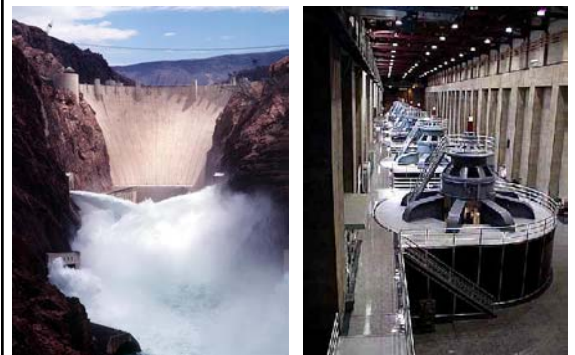
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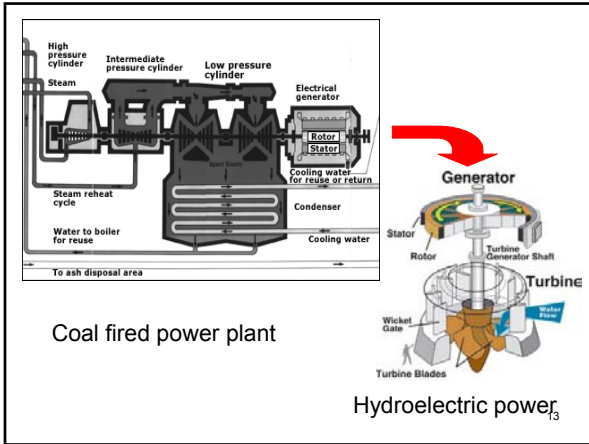
## The electric generator

- 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 ←

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## Hoover Dam





## Wind Power

- Large wind turbine has diameter of about a football field
- Generates several megawatts of power
- Investment 1M\$/MW

UI power plant is 25 MW

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## 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](http://www.allaboutcircuits.com/vol_1/chpt_3/4.html)

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## 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.

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## 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!

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## What everybody needs to know about electricity

hot (black)

neutral (white)

ground (green or bare)

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## 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

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## Man says live wire in bath was to save marriage

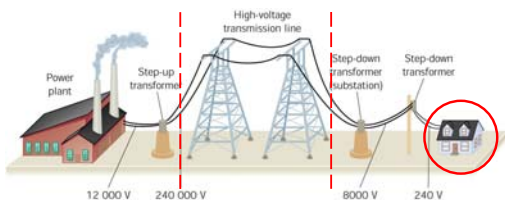
Thursday, October 28, 2004 Posted: 7:53 AM EDT (1153 GMT)

**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.

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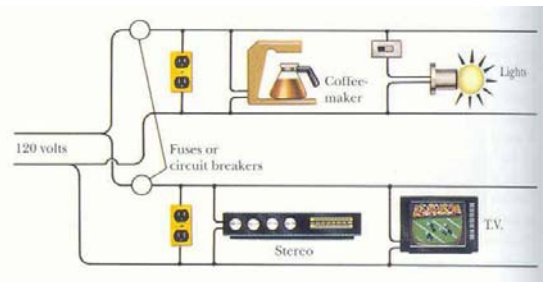
## Electric power generation and distribution



- electrical power  **$P = I V$** , energy per unit time  
Joules/s = **WATTS (watts = amps x volts)**
- It is more efficient to transmit electrical power at **high voltage and low current**.
- The losses along the transmission lines are reduced compared to transmission at low V.

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## House wiring



all circuits are connected in parallel

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## 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)**

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## 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

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## \$\$\$ 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

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## Your carbon footprint

- 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!

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## Incandescent vs. Fluorescent ?

- Incandescent lights (ordinary light bulbs) produce a lot of heat as well as light and are inefficient
- **Fluorescent lights produce the same amount of light output while using less power**
- Why do they take several seconds to come to full power → they contain a small amount of mercury which must heat up to form a vapor
- **Fluorescent lights may not work as outdoor lights in cold climates, like Iowa winters!**

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