L 26 Electricity and Magnetism [4]

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

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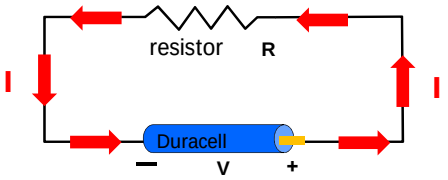
A direct current (DC) circuit

- **DC: current always flows in the same direction**
- **Batteries provide direct currents.**
- **Current flows in direction that + charges would move**



OHM'S LAW
I(Amps) = V(volts) / R(Ohms)

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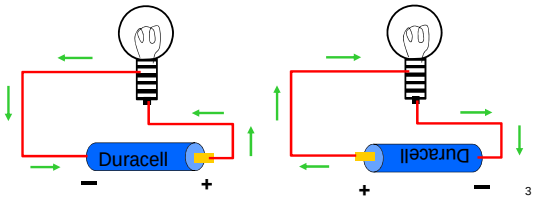
Direct Current DC

- 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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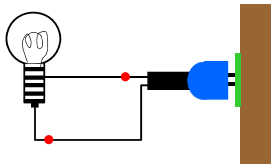
Alternating Current (AC)

- In an AC circuit the current reverses direction periodically
- AC is what you get from the power company
- Tesla and Edison fought over the use of AC vs. DC for NYC. Tesla won, and AC was in!



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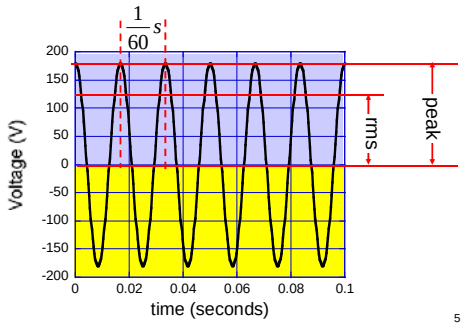
How does the line voltage change in time?



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AC power

- The line voltage reverses polarity 60 times a second or 60 Hertz (in Europe 50 Hz)
- 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 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!

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Advantages of AC over 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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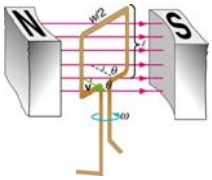
The electric generator

- when a coil of wire is rotated inside a magnet, AC electricity is produced
- the voltage depends on how much wire the coil has and how fast it is rotated.
- devices called transformers can make the voltage higher or lower
- transformers only work with AC
- Energy is required to rotate the coil



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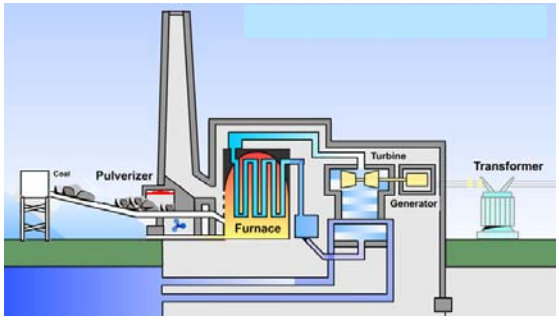
Coal fired power plant



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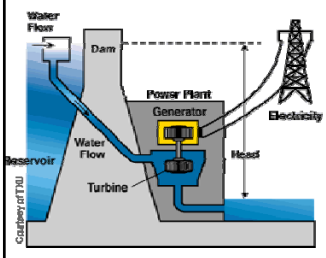
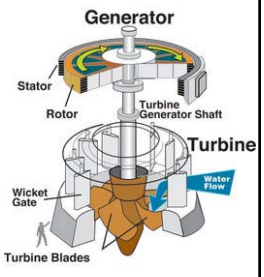
Hydroelectric power





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Hydroelectric power: Hoover Dam

Wind Power

- Large wind turbine has diameter of about 100 m
- Generates several megawatts of power (UI has 25 MW)
- Investment 1M$/MW, but the wind is free!
- Disadvantages:
  - Require frequent and costly maintenance
  - between 100,000 and 200,000 birds killed each year in collisions with wind turbines

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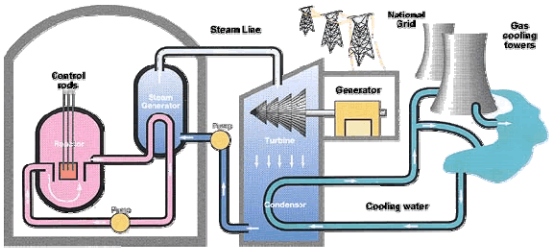
Nuclear power plant



Nuclear Energy → Heat Energy → Kinetic Energy → Electrical Energy

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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. ***Transformers only work with AC.***

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Bodily Effects of Electrical Currents
60 Hz AC, 1 mA = 0.001 A

MEN	WOMEN	EFFECT
0.4 mA	0.3 mA	Slight sensation experienced
1.1 mA	0.7 mA	Threshold of perception
9 mA	6 mA	Painful, but voluntary muscle control maintained
16 mA	10.5 mA	Painful, unable to let go
23 mA	15 mA	Severe pain, difficulty breathing
100 mA	100 mA	Possible heart fibrillation after 3 seconds → death

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ELECTROCUTION

Human lethality is most common with alternating current at 100–250 volts.

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Electric outlets

- The current is supposed to flow from the hot side (black wire) to the neutral (white wire), if too much current flows the fuse blows or the circuit breaker trips.
- the ground (green wire) 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 interrupter. If current accidentally flows through anything other than the hot or neutral it interrupts the circuit very quickly (in about 25 milliseconds, before fibrillation can occur)

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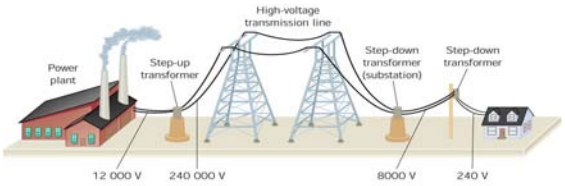
Electric power generation and distribution



- 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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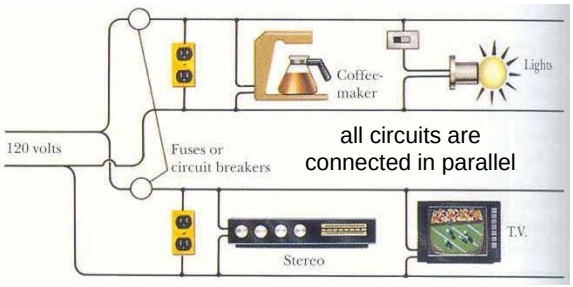
House wiring



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electrical power

- the power is how much electrical energy is used per second = 1 Watt.
- 1 Watt = 1 Joule / 1 second
- Power (Watts) = current (A) × voltage (V)
- some appliances require high power, like your electric range or clothes dryer, they operate at the higher voltage (240 V), 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 (KWH)

- 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 (hours) we get total energy in KWH
- The cost per KWH varies from about 6¢ in SD to 17¢ in HI, the average is about 10¢

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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 (24 hours)
- Solution
  - 100 W = 0.1 kW
  - # KWH = 0.1 kW x 24 hr = 2.4 kWh
  - **cost** = 2.4 kWh x $0.10/kWh
    = $0.24 = 24¢
- for one month the cost is $7.20

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Your carbon footprint

- 1 ton (2000 lbs) of coal produces about 6000 KWH of electric power
- a 100 W light on 200 hours uses 1 lb of coal
- an average US household uses about 10,000 KWH of electricity per year
- Each household consumes about 1.7 tons of coal each year for its electricity usage
- US coal reserves estimate: 300 billion tons!
- US is now #1 natural gas producer in world.
- Energy density (energy/volume) is an important issue in choosing energy sources, e.g., 1 kg of nuclear fuel has the same energy content of 1 million kg of coal.
- Many US power plants switching to natural gas, which produces far less pollution and less than half of the CO_2 compared to coal.

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Incandescent *vs.* Fluorescent ?

- Incandescent lights must produce heat to make light: they are inefficient
- Fluorescent lights (gas discharges) produce the same amount of light using less electricity
- Fluorescent lights can take several seconds to come to full brightness because they contain a small amount of mercury (*environmental issue*) which must first heat up for the light to work well
- Fluorescent lights do not work well as outdoor lights in the coldest climates

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