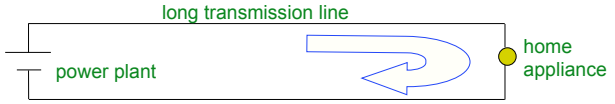
AC Electricity

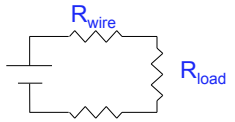
Why AC?
Distribution

Getting Power to Our Homes

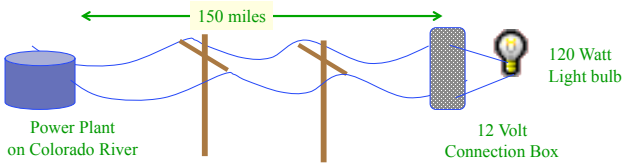
- Let's power our homes with DC power
  - DC means direct current: just like what batteries deliver
- But want power plants far from home
  - and ability to "ship" electricity across states
- So power lines are long
  - resistance no longer negligible



looks like:



Power Dissipated in an Electricity Distribution System



- Estimate resistance of power lines: say 0.001 Ohms per meter, times 200 km = 0.001 Ω/m × 2×10^5 m = 20 Ohms
- We can figure out the current required by a single bulb using $P = VI$ so $I = P/V$ = 120 Watts/12 Volts = 10 Amps (!)
- Power in transmission line is $P = I^2R = 10^2 \times 20 = 2{,}000$ Watts!!
- "Efficiency" is ε = 120 Watts/4120 Watts = 0.3%!!!
- What could we change in order to do better?

The Tradeoff

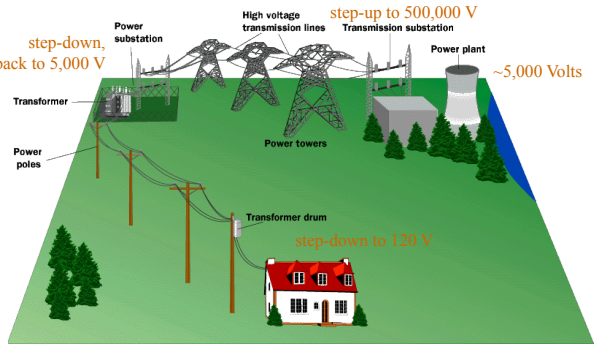
- The thing that kills us most is the high current through the (fixed resistance) transmission lines
- Need less current
  - it's that square in I^2R that has the most dramatic effect
- But our appliance needs a certain amount of power
  - $P = VI$ so less current demands higher voltage
- Solution is high voltage transmission
  - Repeating the above calculation with 12,000 Volts delivered to the house draws only
    I = 120 Watts/12 kV = 0.01 Amps for one bulb, giving
    $P = I^2R = (0.01)^2 20 = 20\times10^{-4}$ Watts, so
    P = 0.002 Watts of power dissipated in transmission line

Efficiency in this case is ε = 120 Watts/120.004 = 99.996%

DANGER!

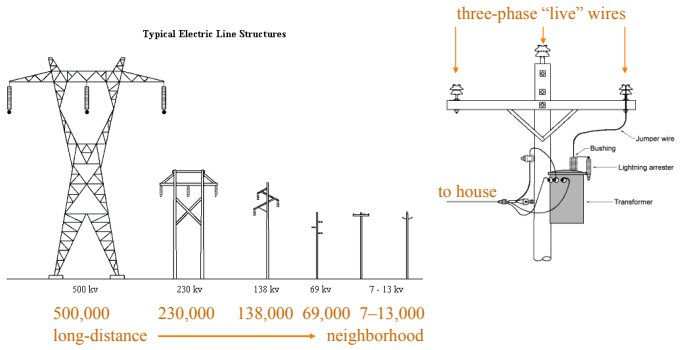
- But having high voltage in each household is a recipe for disaster
  - sparks every time you plug something in
  - risk of fire
  - not cat-friendly
- Need a way to step-up/step-down voltage at will
  - can't do this with DC, so go to AC

A way to provide high efficiency, safe low voltage:



High Voltage Transmission Lines
Low Voltage to Consumers

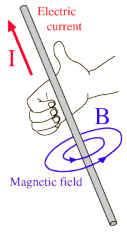
Transmission structures



500,000 230,000 138,000 69,000 7–13,000
long-distance → neighborhood

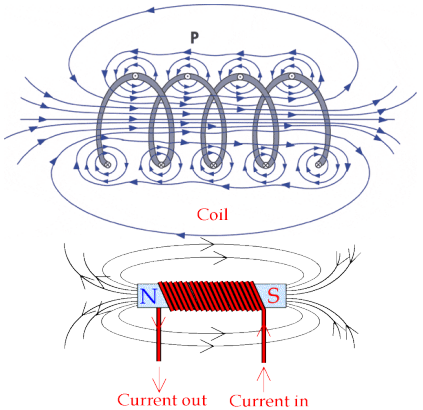
Why is AC the solution?

- AC, or *alternating current*, is necessary to carry out the transformation
- To understand why, we need to know something about the relationship between electric current and magnetic fields
- Any current-carrying wire has a circulating magnetic field around it:



Electromagnet Coil

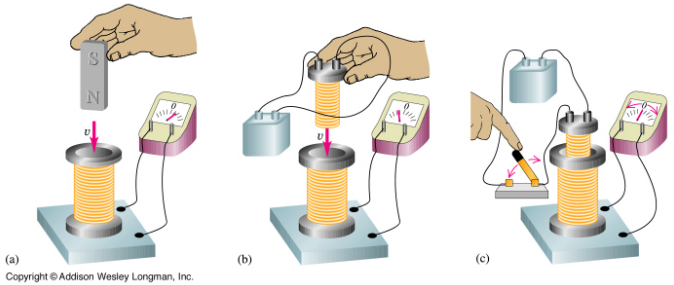
- By arranging wire into a loop, you can make the magnetic fields add up to a substantial field in the middle



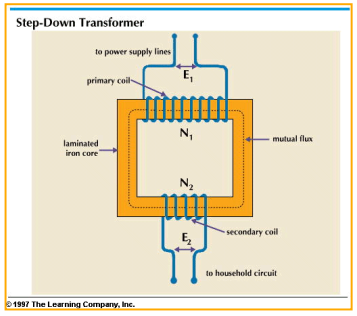
looks just like a magnet

Induced Current

- The next part of the story is that a *changing* magnetic field produces an electric current in a loop surrounding the field
  - called electromagnetic induction, or Faraday's Law



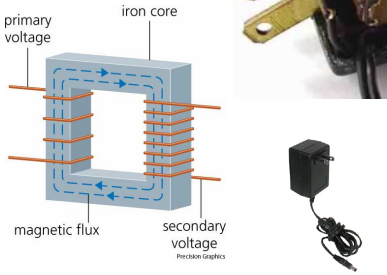
Transformer is just wire coiled around metal



- Magnetic field is generated by current in primary coil
- Iron core channels magnetic field through secondary coil
- Secondary Voltage is $V_2 = (N_2/N_1)\, V_1$
- Secondary Current is $I_2 = (N_1/N_2)\, I_1$
- But Power in = Power out
  - negligible power lost in transformer
- Works only for AC, not DC

If the primary wires and secondary wires don't actually connect, how does the energy get from the primary circuit to the secondary circuit?!

Typical Transformers

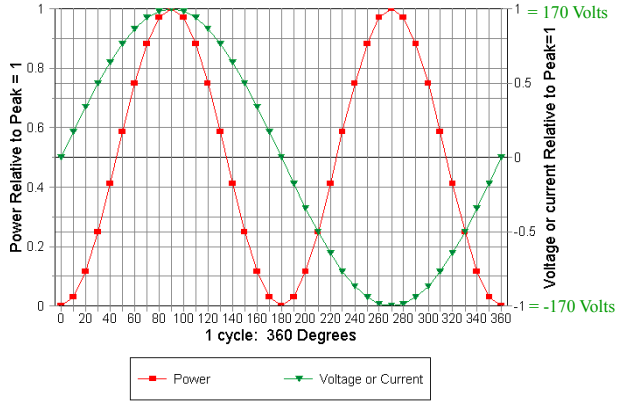


transformers usually heavy due to iron core

Alternating Current (AC) vs. Direct Current (DC)

- AC is like a battery where the terminals exchange sign periodically!
- AC sloshes back and forth in the wires
- Recall when we hooked up a bulb to a battery, the direction of current flow didn't affect its brightness
- Although *net* electron flow over one cycle is zero, can still do useful work!
  - Imagine sawing (back & forth), or rubbing hands together to generate heat

AC Voltage or Current and AC Power



120 VAC is a root-mean-square number: peak-to-peak is 340 Volts!

AC Receptacle

- Receptacles have three holes each
- Lower (rounded) hole is earth ground
  - connected to pipes, usually
  - green wire
- Larger slot is "neutral"
  - for current "return"
  - never far from ground
  - white wire
  - if wired correctly
- Smaller slot is "hot"
  - swings to +170 and -170
  - black wire
  - dangerous one

Assignment

- Read 6.9.1 on grounding