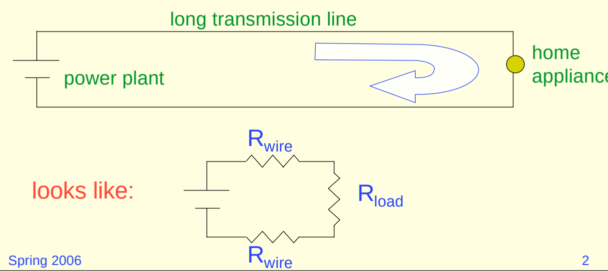
AC Electricity

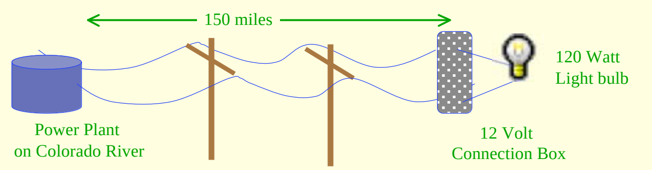
Our Everyday Power Source

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



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%

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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

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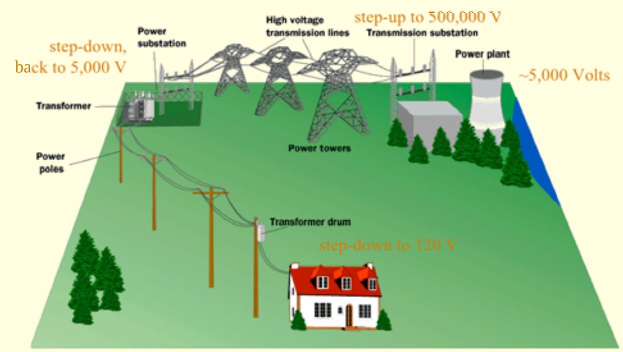
A way to provide high efficiency, safe low voltage:



High Voltage Transmission Lines
Low Voltage to Consumers

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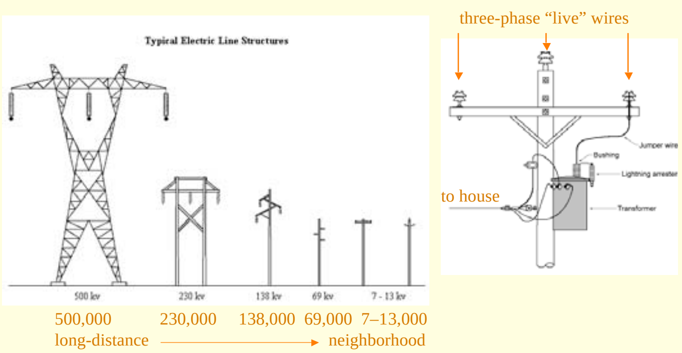
Transmission structures



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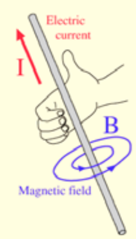
Why is AC the solution?

- 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:



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Electromagnet Coil

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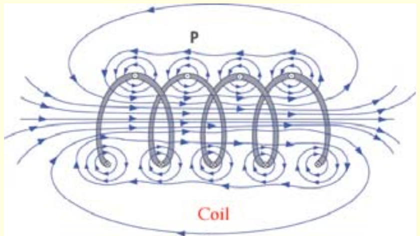
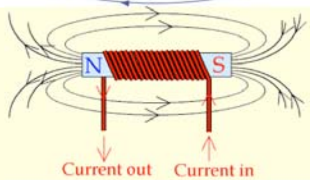
- By arranging wire into a loop, you can make the magnetic fields add up to a substantial field in the middle



looks just like a magnet



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Induced Current

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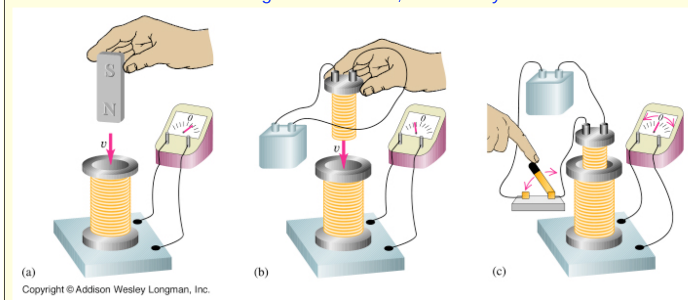
- The next part of the story is that a *changing* magnetic field produces an electric current in a loop surrounding the field
  - called electromagnetic induction, or Faraday's Law



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Transformer is just wire coiled around metal

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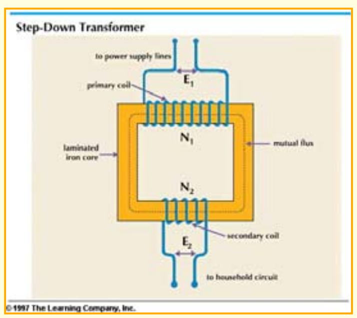

- Magnetic field is generated by current in primary coil
- Iron core channels magnetic field through secondary coil
- Secondary Voltage is $V_2 = (N_2/N_1)\, V_1$
- Secondary Current is $I_2 = (N_1/N_2)\, I_1$
- But Power in = Power out
  - negligible power lost in transformer
- Works only for AC, not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

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Typical Transformers

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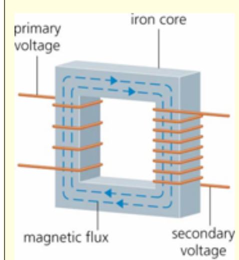

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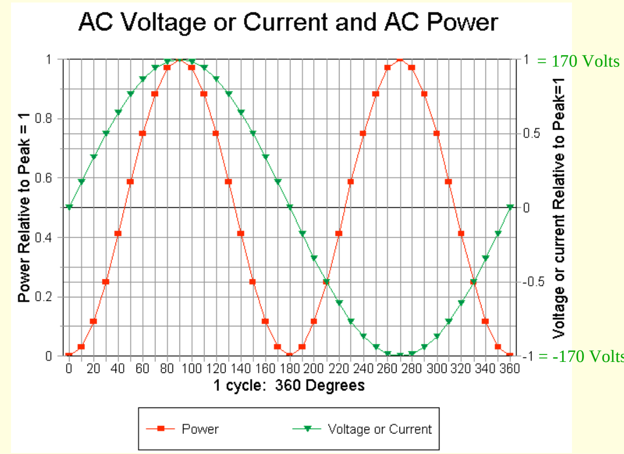
Alternating Current (AC) vs. Direct Current (DC)

- 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



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, usu.
  - 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

Assignments

- Read pp. 353–368 to accompany *this* lecture
- Read pp. 391–392, 398–403 (don't fret over the complicated explanation of the diode)
- HW #3: Chapter 10: E.2, E.10, E.32, P.2, P.13, P.14, P.15, P.18, P.19, P.23, P.24, P.25, P.27, P.28, P.30, P.32
- Q/O #2 due 4/28
- Midterm 5/04 (next Thu.) 2PM WLH 2005
  - will prepare study guide and post online
  - will have review session next week (time TBA)