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

$$\begin{align*}
\text{long transmission line} \\
\text{power plant} \\
\text{home appliance}
\end{align*}$$

Power Dissipated in an Electricity Distribution System

- Estimate resistance of power lines: say 0.001 Ohms per meter, times 200 km = 0.001 \( \Omega \)/m \( \times \) 2\( \times \)10^{6} m = 20 Ohms
- We can figure out the current required by a single bulb using \( P = VI \) so \( I = P/V = 120 \text{ Watts}/12 \text{ Volts} = 10 \text{ Amps} \) (!)
- Power in transmission line is \( P = FR = 10^{2} \times 20 = 2,000 \text{ Watts} \)!!
- “Efficiency” is \( \epsilon = 120 \text{ Watts}/4120 \text{ Watts} = 0.3\% \)!!
- 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 \( FR \) 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
    \( I = 120 \text{ Watts}/12 \text{ kV} = 0.01 \text{ Amps} \) for one bulb, giving
    \( P = FR = (0.01)^{2}20 = 2 \times 10^{-4} \text{ Watts} \), so
    \( P = 0.002 \text{ Watts} \) of power dissipated in transmission line
    Efficiency in this case is \( \epsilon = 120 \text{ Watts}/120.004 = 99.996\% \)
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

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.

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 \( V_2 = (N_2/N_1) \cdot V_1 \).
- Secondary Current is \( I_2 = (N_1/N_2) \cdot I_1 \).
- But Power in = Power out:
  - negligible power lost in transformer.
- Works only for AC, not DC.

Typical Transformers

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