Electricity en masse

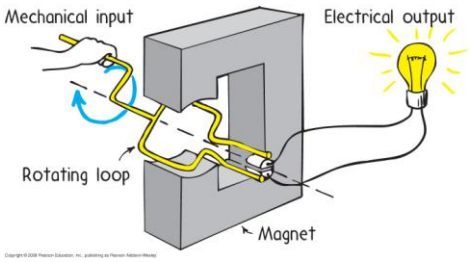
Last time……

- The voltage induced in a coil of wire by a moving magnet is given by Faraday's Law:

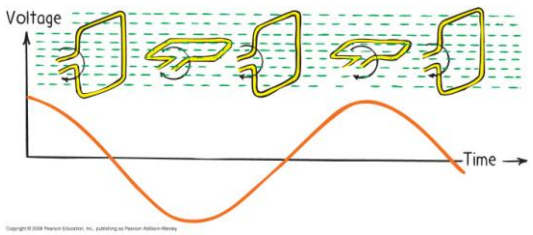
$$V_{ind} = -\frac{\Delta\Phi_B}{\Delta t}$$

- Lots of applications of Faraday's Law
- Generators and transformers

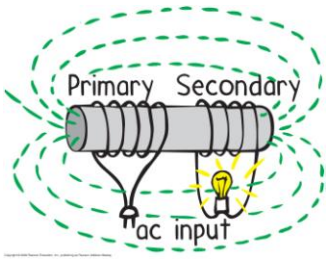
Electrical generator: Motor in reverse



Electrical generator



Transformers



Primary voltage/Number of primary turns=Secondary voltage/Number of secondary turns

Transformers

- Alternating current (AC) through a primary coil creates a changing magnetic field thereby inducing a voltage in the secondary coil
- Generators and transformers allow for efficient transmission of electricity on a large scale

Electrical power en masse

- In the US, generators are arranged so that voltage alternates 60 times each second (In Europe, 50 alternates per second)
- Electrical energy is useful because it can (1) manipulated in circuits, (2) transmitted in the power grid and (3) easily transformed into other useful forms of energy
- Challenge: Distribution of power with low loss

Power transmission problem

- A household may use 1200 W. At 120 V, I=10 A.
- All households in a city are in parallel across wires from the generator.
- If a city has 10,000 households, at 120 V, Total I=100,000 A and total P=120,000,000 W.
- Can we supply power to the city without putting most of the power in the wires?

Power transmission problem

- If we allow for 10 percent power loss in transmission wire, what will the resistance of the transmission wire need to be?

$$\frac{P_{loss}}{P_{tot}} = \frac{P_{tot}}{V^2} R_{wires}$$

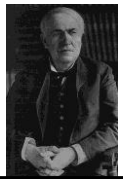
- Then the total resistance in the transmission wires is 0.0001 Ohms. If the wire is 30 miles long, it would need to be a diameter of several meters---pretty thick!

High voltage transmission

- Supply each household's 1200 W as 120 kV, then the whole city uses only 100 A.
- Now the 30 mile power transmission wires can have a total resistance of about 100 Ohms, which translates to a diameter of millimeters. This is more practical!
- Step up transformer to transmit the high voltage along the lines and then step down transformer near the house to be able to safely use the electricity---the reason for AC as opposed to DC!

The tale of two wizards

- Edison: Promoted DC transmission of electricity
- Telsa: Promoted AC transmission of electricity
- AC won out over DC ultimately since transformers work with AC only



Electricity use in daily life

- Typical electric appliance uses about 100 W
- But hair dryers use about 2 kW and electric stove uses 12 kW
- Can check power rating on nameplate of appliance (sometimes gives current, multiply it by 120 V to find power rating in Watts)

Cost of electricity

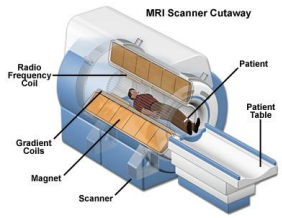
- Electric utilities bill for electrical energy: E=Pt
- Utility bills figured in units of kilowatt-hours
- Multiply power use in kW by duration of use in hours to find energy in kWh
- Let's say National Grid charges 10 cents per kWh and "my" bill was $85 last month----850 kWh
- There are 720 hours in 30 days, so "my" household uses 1.2kW

Superconductivity

- Electrical resistivity of conductors decreases with temperature
- In superconductors, the electrical resistivity drops to zero when they are cooled below their "critical temperature"
- Zero resistance----electrons move without atomic collisions
- Discovered by Onnes in 1911—solid mercury becomes superconducting at 4K

A use of superconductivity

- Superconducting magnets are used in MRI machines



Review strategy for exam

- Build your own formula sheet
- Write down the major themes discussed
- Go over homework problems and labs and lecture notes
- Try some practice problems: "Show that" problems in the book

Practice problem

- A flip coil is a device used to measure a magnetic field. It is a coil of radius r with N turns and electrical resistance R and is initially perpendicular to a magnetic field of strength B. The coil is connected to a device that measures the total charge running through the coil. To measure the field, the flip coil is flipped upside down. (a) What is the change in magnetic flux through the coil in one flip.? (b) If the time interval for the flip is t, what is the induced voltage in the coil? (c) Current? (d) Charge?