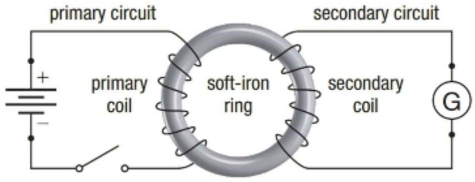
SPH3U 13.1 Electromagnetic Induction

1. Discovery

Induction:	one action causing another action
Chapter 12:	current can cause a magnetic field.
Chapter 13:	can magnets induce an electric current?
stationary magnet	no.
moving magnet	yes! proved by Michael Faraday, 1831.
Law of electromagnetic induction:	any change in the magnetic field near a conductor induces a voltage (and current) in the conductor.

Faraday's ring:	current in the left loop induces a magnetic field, which induces current in the right loop when it changes (when the left circuit is turned on/off).



2. Factors affecting induction

Coiled conductor:	coils increase current (vs. straight)
Number of loops:	↑ loops, ↑ current.
Change in magnetic field:	Faster change in field, ↑ current.
Magnetic field strength:	stronger field, ↑ current.

3. Applications of electromagnetic induction

Induction cooking:	heats metal pots by induction.
Metal detectors:	detects induced currents.
Induction chargers:	coils in charger and device (eg. cell phones).

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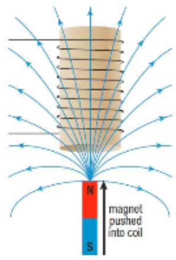
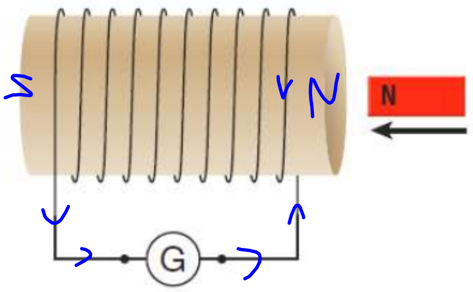


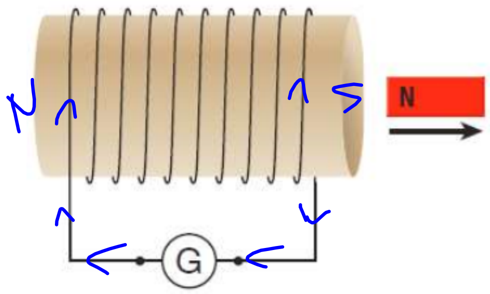
SPH3U 13.2 Lenz's Law

1. Direction of induced current

Lenz's question:	which direction is the induced current? (1834).

Newton's 3rd law:	action and reaction forces, opposite directions.
applied to induced currents	if the magnet pushes the electrons, the electrons must push the magnet back in the opposite direction.
Lenz's Law:	an induced current will produce a magnetic field opposite to the magnetic field change that induced it.





2. Drop-tower rides

Drop-tower rides:	Free-fall from over 70m up.
brakes	need to be reliable and not wear out.
solution	

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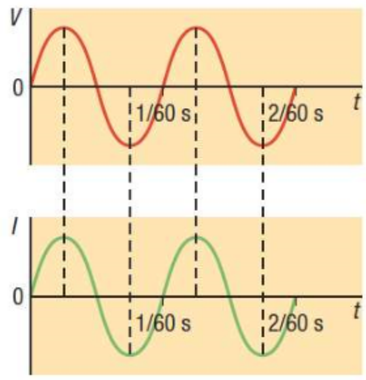
SPH3U 13.3 Alternating Current

1. Alternating current

Continuous current:	can't move a magnet in the same direction forever
solution	have the magnet move back and forth.
Alternating current:	electric current that reverses direction periodically.
DC vs. AC:	Thomas Edison built a DC power grid in 1882; Nikola Tesla built an AC power grid in 1896. AC is better (less problems), and won out.
Canada's electricity:	AC, 60 Hz, 120/240 V, 50-200 A (for homes).
RMS voltage:	"root mean squared", the effective voltage (not maximum).



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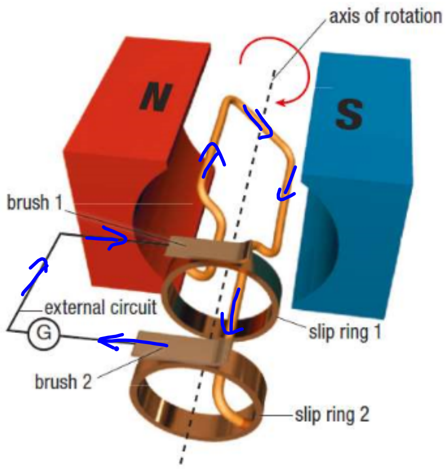
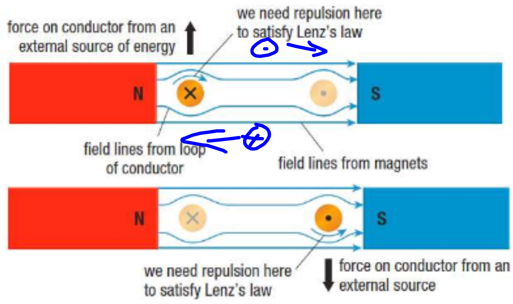
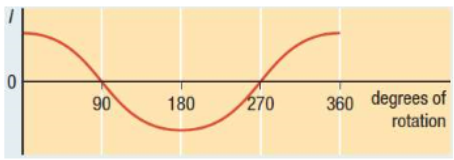
SPH3U 13.4 Electricity Generation

1. The AC generator

Design:	like a split-ring commutator, but instead we turn the circuit (externally) and measure the resulting current.

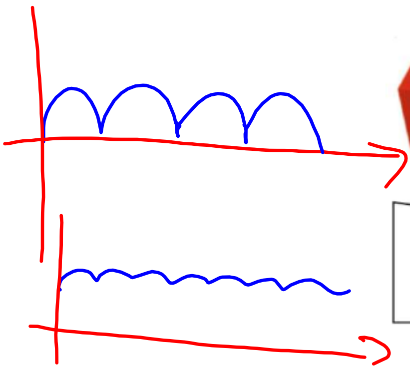


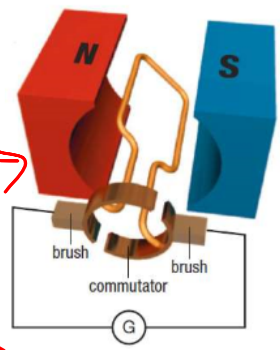




2. The DC generator

Design:	even more like a split-ring commutator.





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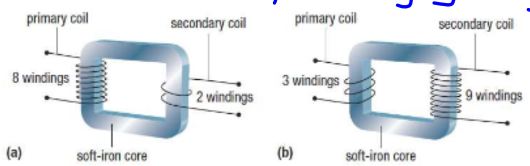
SPH3U 13.5 Transformers

1. How transformers work

Transformer:	a device that can raise or lower voltage.
AC	transformers only work in AC!
how it works	like Faraday's ring. a coil of wire on the left induces current in a coil on the right. the AC means a constantly changing magnetic field!



Step-down transformer:	reduces voltage (increases current). secondary windings < primary windings.
Step-up transformer:	increases voltage (decreases current). secondary windings > primary windings.
Conservation of energy:	$\therefore P_s = P_p$. $\because P = VI$, $V_p I_p = V_s I_s$.
Equations:	$\frac{V_p}{V_s} = \frac{N_p}{N_s}$, $\frac{I_s}{I_p} = \frac{N_p}{N_s}$, $\frac{I_s}{I_p} = \frac{V_p}{V_s}$

A step-down transformer used in an adapter for a laptop has a primary voltage of 120 V. There are 250 windings in the primary coil and 25 windings in the secondary coil. Calculate the voltage in the secondary coil.

$$\frac{V_p}{V_s} = \frac{N_p}{N_s} \rightarrow V_p = \frac{V_s N_p}{N_s} \rightarrow V_s = \frac{V_p N_s}{N_p} = \frac{(120)(25)}{250} = \underline{\underline{12\text{ V}}}.$$

A step-down transformer used in the adapter for a cellphone charger has a primary voltage of 120 V and a secondary voltage of 5.0 V. The current in the primary coil is 0.10 A. Calculate the current in the secondary coil.

$$\frac{I_s}{I_p} = \frac{V_p}{V_s} \rightarrow I_s = \frac{V_p I_p}{V_s} = \frac{(120)(0.10)}{5} = \underline{\underline{2.4\text{ A}}}.$$

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SPH3U 13.6 Power Plants and the Electrical Grid

1. Transmission efficiency

Power loss:	when current runs through a wire, some voltage is lost (based on the wire's resistance).
equation	$P = VI = (IR)I = I^2R$
efficiency	lower current = less power lost.

A generator produces 300 MW (3×10^8 W) of power at a current of 30 kA and a voltage of 10 kV. That power travels through a transmission wire with a resistance of 0.1 Ω. How much power is lost (in MW and in % of the total)?

$$P = I^2R = (30\times10^3)^2(0.1)$$
$$= 9\times10^7 \text{ W}$$
$$= 90 \text{ MW}$$

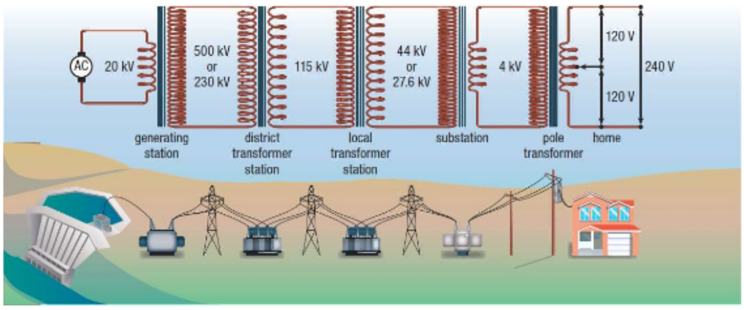
$$\frac{90}{300}\times100\% = 30\%$$

Now a step-up transformer is used to increase the voltage to 100 kV before sending it over the wire. This lowers the current to 3 kA ($V_PI_P = V_SI_S$). What is the new power loss?

$$P = I^2R = (3\times10^3)^2(0.1)$$
$$= (9\times10^6)(0.1)$$
$$= 9\times10^5$$
$$= 0.9 \text{ MW}$$

$$\frac{0.9}{300}\times100\% = 0.3\%$$

2. The power grid



AC generators:	sometimes use a DC electromagnet inside the AC generator instead of a permanent magnet.

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