

INDUCTORS

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Inductors



- A passive two-terminal component that stores energy in a magnetic field when electric current flows through it.
- Also known as coils or chokes.
- Consists of a conductor wrapped into a coil around a core.
 - The “core” can be iron, ferrite, or air (conductive materials increase the magnetic field and the inductance).
- Inductors are characterized by their inductance (L).
- Inductance – the ratio of the voltage to the rate of change of the current. This is measured in henry (H).
- $$L = \frac{V}{\Delta I}$$



Capacitors vs. Inductors

- Capacitors
 - Resist changes in voltage
 - Quick voltage changes produce large currents
 - Store energy in electric fields
- Inductors
 - Resist changes in current
 - Quick current changes produce large voltages
 - Store energy in magnetic fields

Inductors resist changes in current

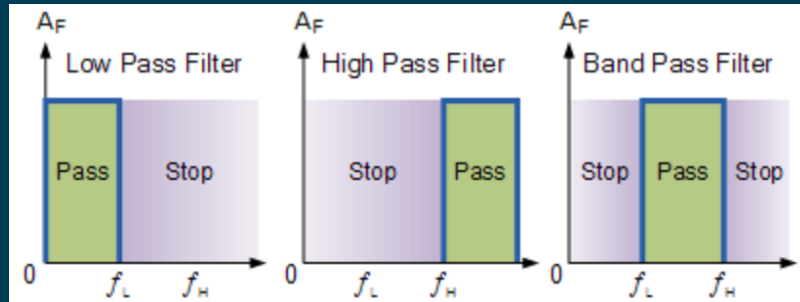
- An inductor opposes changes in current by developing a voltage across it proportional to the rate of change of the current.
- Change in current creates a directly proportional change in the magnetic field strength.
- Increasing the magnetic field requires energy, so the resistance of the inductor increases and there is a drop in the electric potential energy (voltage).
- Once the inductor has built up the magnetic field, the resistance returns to zero and there is no voltage drop.
- If the current decreases, the magnetic field must also decrease. The energy returns to the circuit causing a voltage rise.

Uses

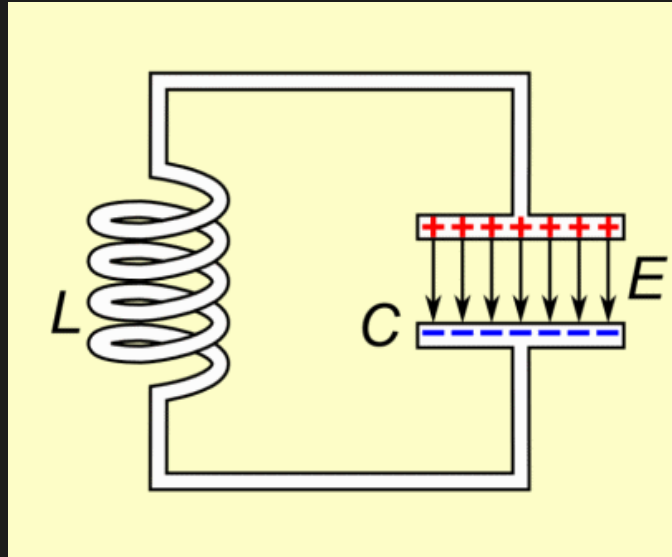
- Removes spikes from a power supply
- Can block AC and allow DC to pass
- Used with capacitors to make tuned circuits (LC)
- Coils in relays
- Solenoids
- Transformers
- Much more

LC Circuits

- Also known as resonant or tuned circuits.
- LC circuits are used either for generating signals at a particular frequency or picking out a signal at a particular frequency from a more complex signal.
- This function is called a bandpass filter.



Animated diagram showing the operation of a tuned circuit. The capacitor C stores energy in its electric field E and the inductor L stores energy in its magnetic field B (green). The animation shows the circuit at progressive points in the oscillation. The oscillations are slowed down; in an actual tuned circuit the charge may oscillate back and forth thousands to billions of times per second.

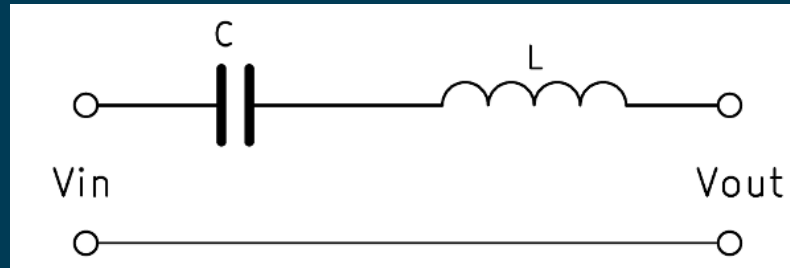


LC Circuit Uses

- Radio receivers
- Amplifiers
- Oscillators
- Filters
- Tuners
- Mixers
- Radio receivers
- Contactless cards (RFID, NFC)

LC Circuit – 1st Order

- $f_0 = \frac{1}{2\pi\sqrt{LC}}$
- $Z = \sqrt{\frac{L}{C}}$
- $C = \frac{1}{2\pi Z f_L}$
- $L = \frac{Z}{2\pi f_H}$



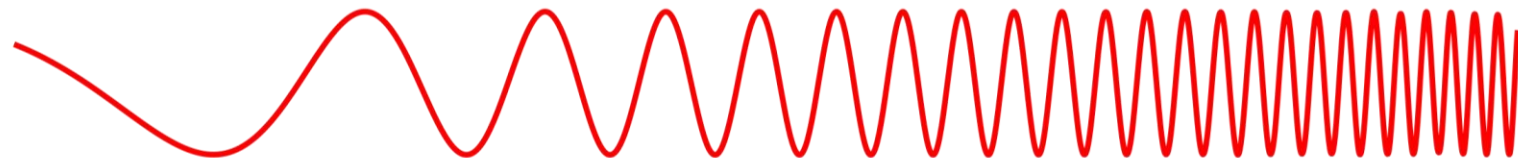
LC Circuit Simulation

- Ltspice Simulation
- $C = 1\mu\text{F}$, $L = 2\text{mH}$
- $f_L = 3535\text{ Hz}$, $f_H = 3580\text{ Hz}$, $f_0 = 3559\text{ Hz}$

Electromagnetic Spectrum

- The range of frequencies (the spectrum) of electromagnetic radiation and their respective wavelengths and photon energies.

Penetrates Earth's Atmosphere?



Radiation Type
Wavelength (m)

Radio
 10^3

Microwave
 10^{-2}

Infrared
 10^{-5}

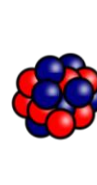
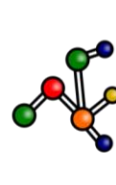
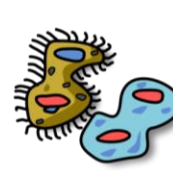
Visible
 0.5×10^{-6}

Ultraviolet
 10^{-8}

X-ray
 10^{-10}

Gamma ray
 10^{-12}

Approximate Scale
of Wavelength



Buildings

Humans

Butterflies

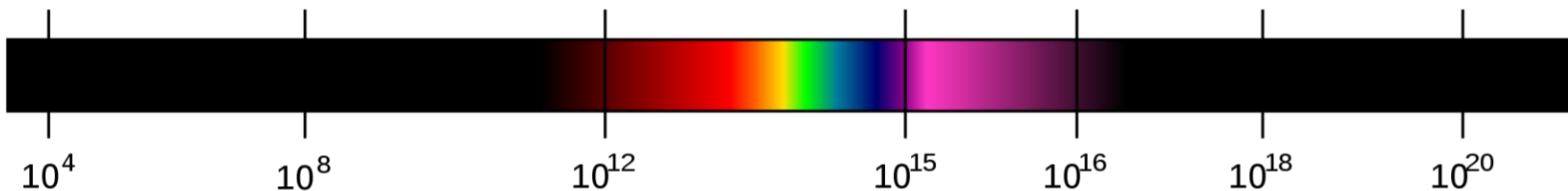
Needle Point Protozoans

Molecules

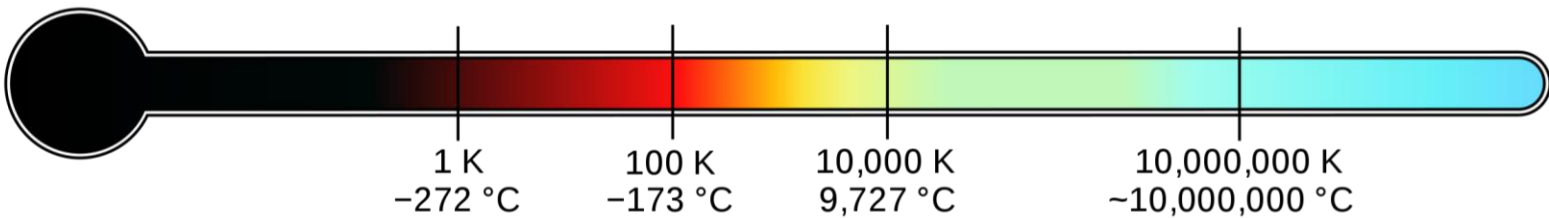
Atoms

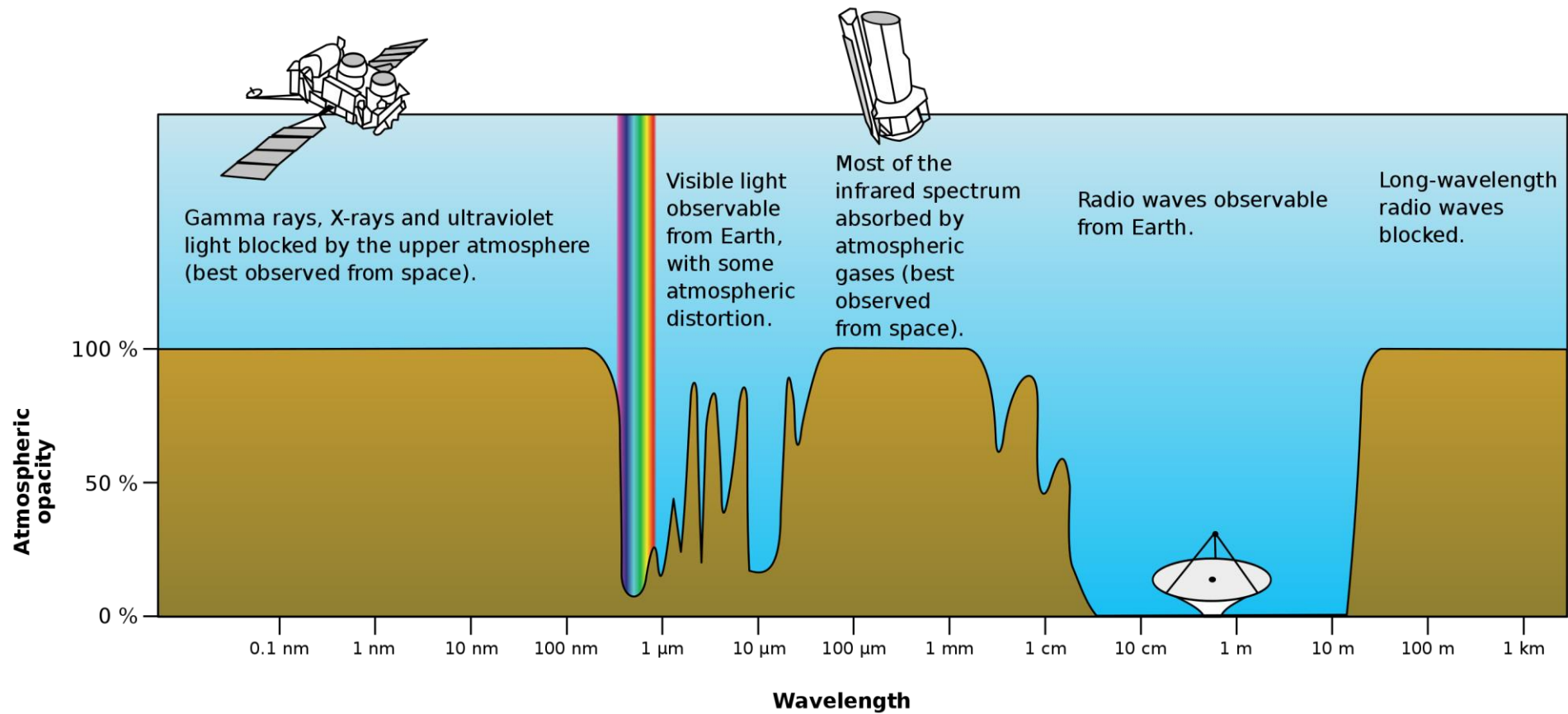
Atomic Nuclei

Frequency (Hz)

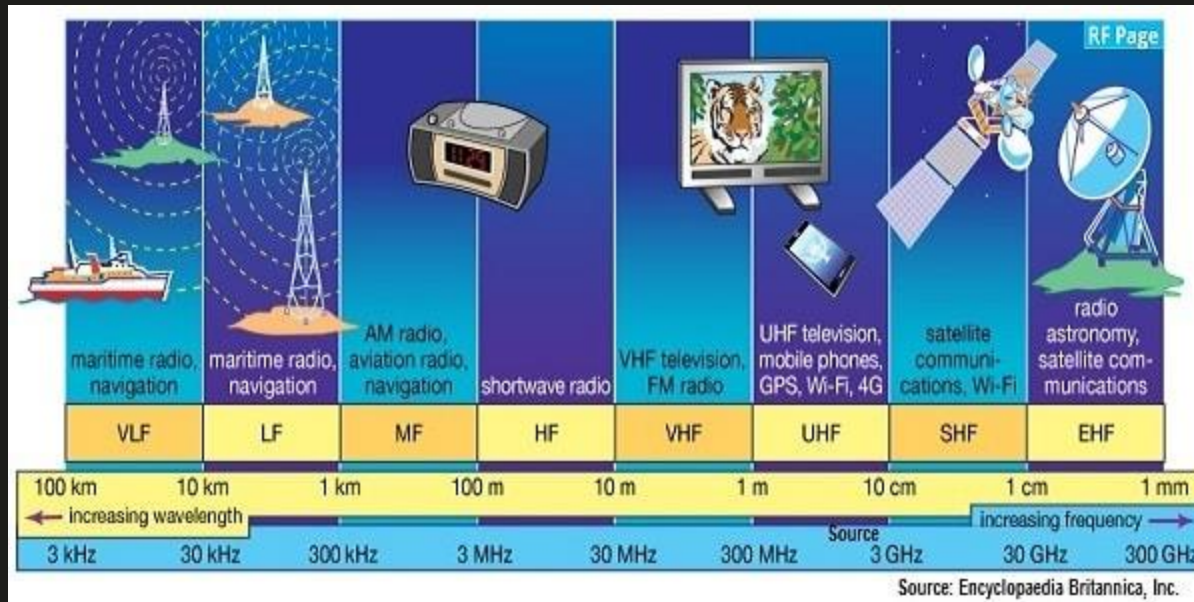


Temperature of
objects at which
this radiation is the
most intense
wavelength emitted





RF Frequency Spectrum



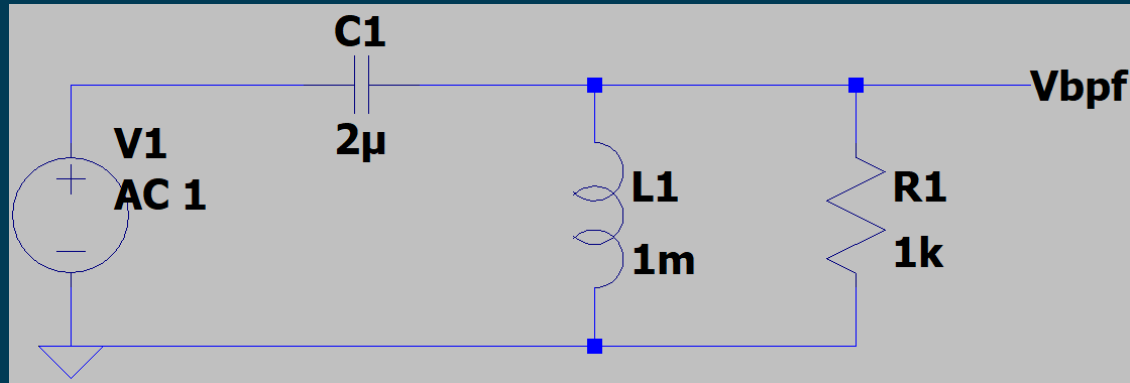
United States RF Spectrum

- Enforced by the FCC (Federal Communications Commission).
- https://en.wikipedia.org/wiki/File:United_States_Frequency_Allocations_Chart_2016_-_The_Radio_Spectrum.pdf

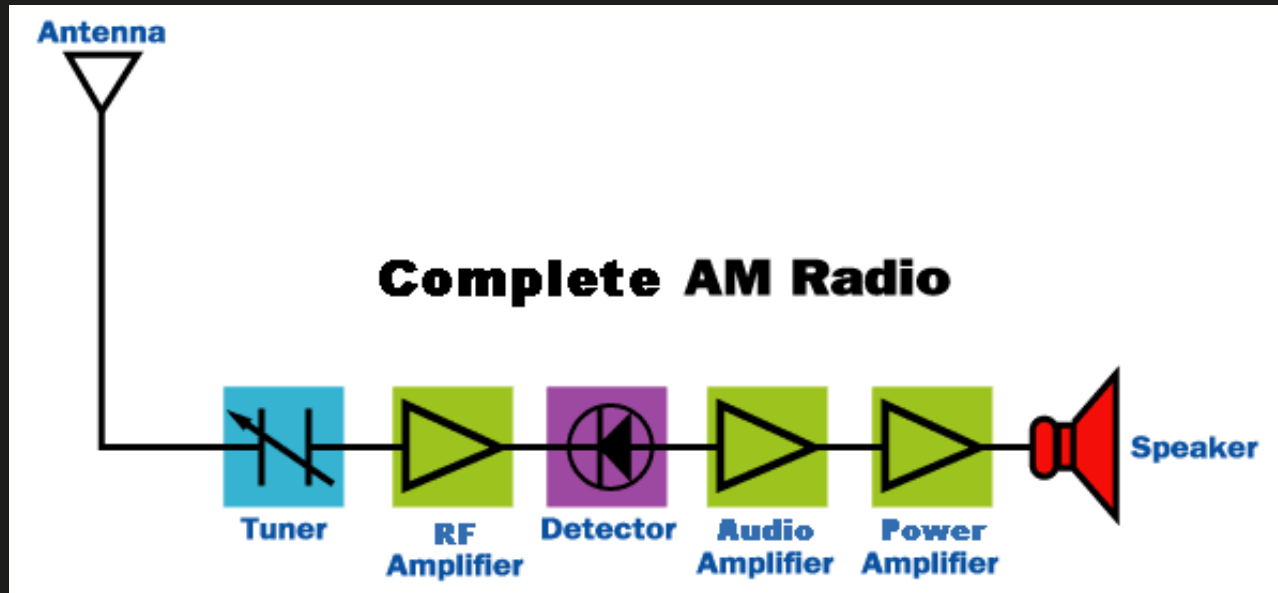
Activity: Build LC Tuning Circuit

- Can you design a first order LC tuning circuit to pick up AM radio station 1200?
- Calculate the f_0 , build the circuit, and test.
- Sadly, we won't be able to pick up the radio. Requires a lot of circuitry.

- $$f_0 = \frac{1}{2\pi\sqrt{LC}}$$



AM Radio Design

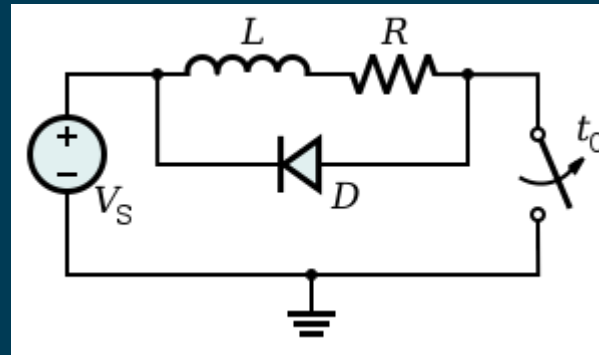


Why do we see a large voltage spike across the inductor when the current is stopped?

Flyback Diode

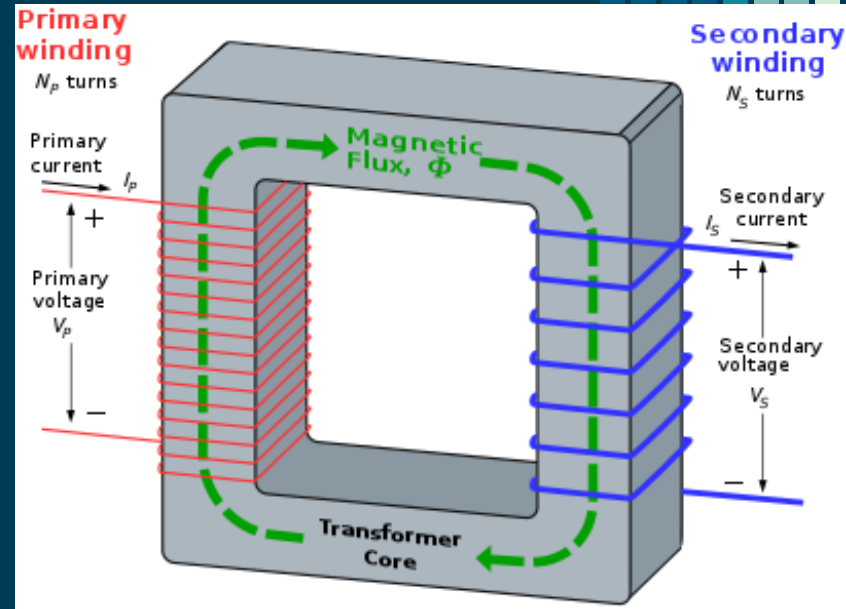
- When the current through an inductor is reduced or removed, there can be a large spike of voltage across the inductor.
- All of the energy stored in the magnetic field reenters the circuit and has nowhere to go.
- With the voltage now reversed across the inductor, the current can now flow through the diode and the voltage across the inductor is limited to the forward voltage of the diode.

Useful for relays, solenoids, and other similar inductor applications.



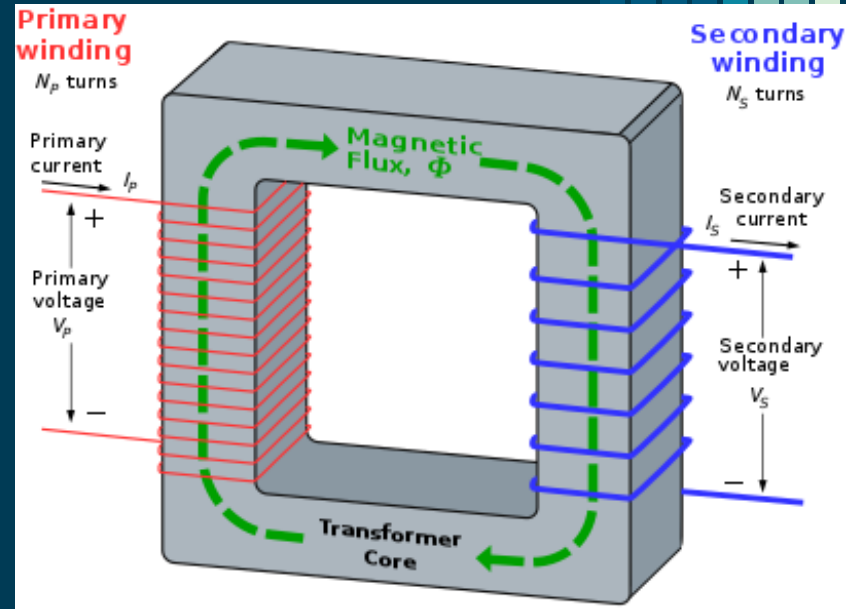
Transformer

- A static electrical device that transfers electrical energy between two or more circuits.
- Multiple coils that share 1 core.
- Used to either step up (higher voltage) or step down (lower Voltage).
- We don't create power,
We just transform it!
- Power in = Power out



Transforming power

- Turns – number of rotations coil makes around core.
- $\text{Turns Ratio} = \frac{N_p}{N_s} = \frac{\text{\# of turns on primary coil}}{\text{\# of turns on secondary coil}}$
- $\frac{V_p}{V_s} = \frac{N_p}{N_s}$
- Same ratios!
- $V_p \times I_p = V_s \times I_s$



Why don't transformers work on DC?

Transformer Example

- Our transformer has a 10:3 (pri:sec) ratio.
- This means 10 turns on the primary side and 3 turns on the secondary side. This means it is a step-down.
- If we have 120 V on the primary, how many volts will we have on the secondary?

Design a Transformer

- We need 240 V and 3 A.
- We have 120 V available from the wall.
- Will this be a step-up or step-down transformer?
- What will the turns ratio be?
- How much current will we draw on the primary side?

Inductors will be back!

- We will talk about inductors/coils more when we discuss generators.

