An AP® Physics 2 Project

Transformers

in Early Radios

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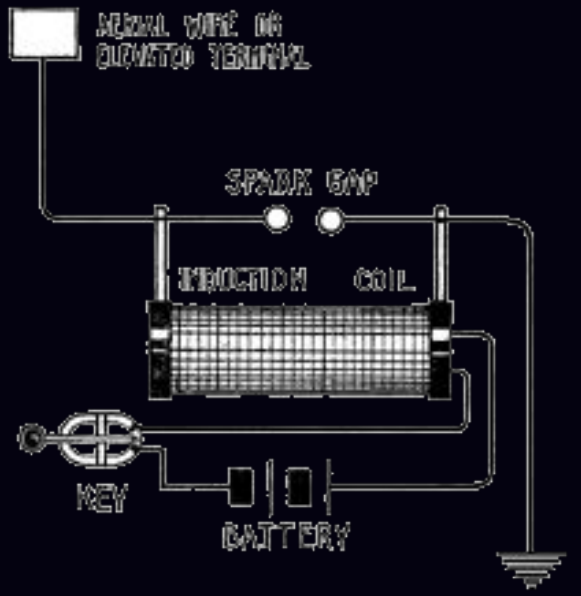


Overview

- The first radio transmitters were simply devices that created sparks.
- These sparks produced radio waves by exciting the electrons in the wire, which radiate radio waves into the air.
- Because of their simplicity, Spark transmitters were used for decades in the early days of radio

De-mo #1

Barbeque Lighter and
Radio.

(Backup video incase demonstration fails)

Overview (Continued)

- However, these radios could not transmit audio, because they could only be turned on or off. As a result these transmitters could only use morse code.
- The easiest way to create these sparks were with high voltage transformers

Objective of Presentation: To explain and demonstrate the workings of a Transformer and its use as a radio transmitter

Vocabulary

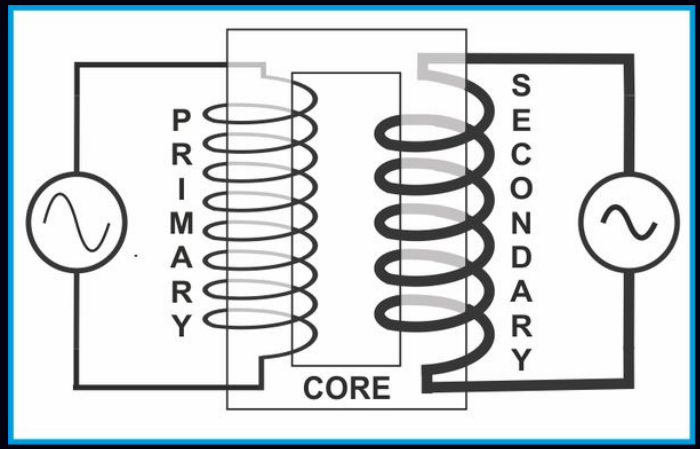
Transformer: A device consisting of two coils that is used to changes voltage.

Step-Up Transformer: A transformer that is used to *increase* voltage.

Step-Down Transformer: A transformer that is used to *decrease* voltage.

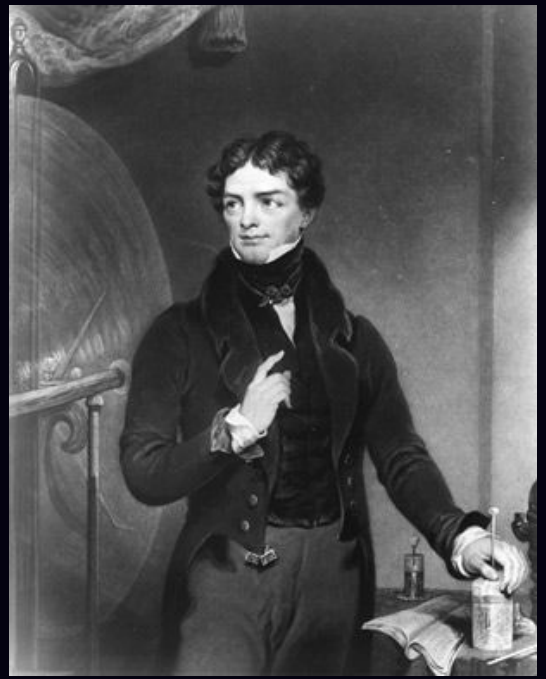
Primary Windings: The input side of the transformer

Secondary Windings: The output side of the transformer



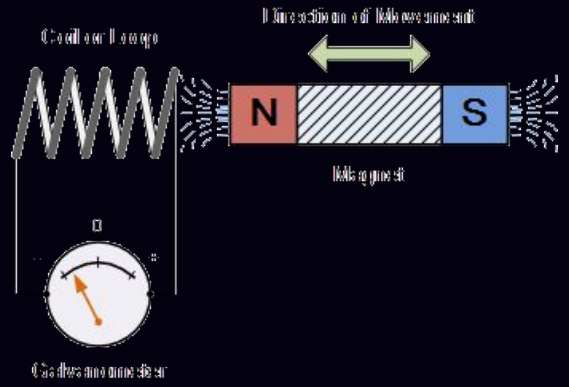
History and Background

Transformers work on the principle of Electromagnetic induction, which was discovered by Michael Faraday.



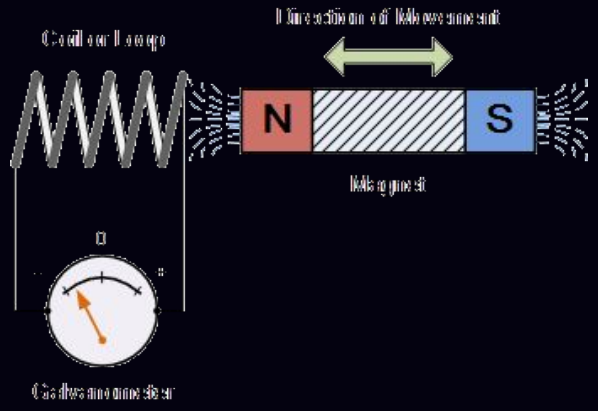
How it works (Conceptually)

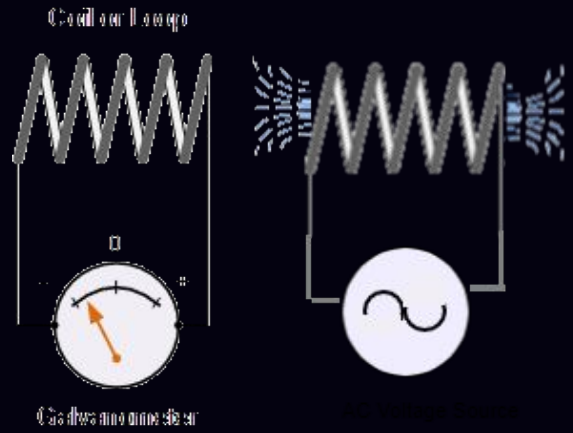
- The principle of Electromagnetic Induction states that if a changing magnetic field is placed near a coil, a Voltage will be created or induced in the coil.
- With a simple generator, a permanent magnet is moved back and forth to produce the changing field



How it works (Continued)

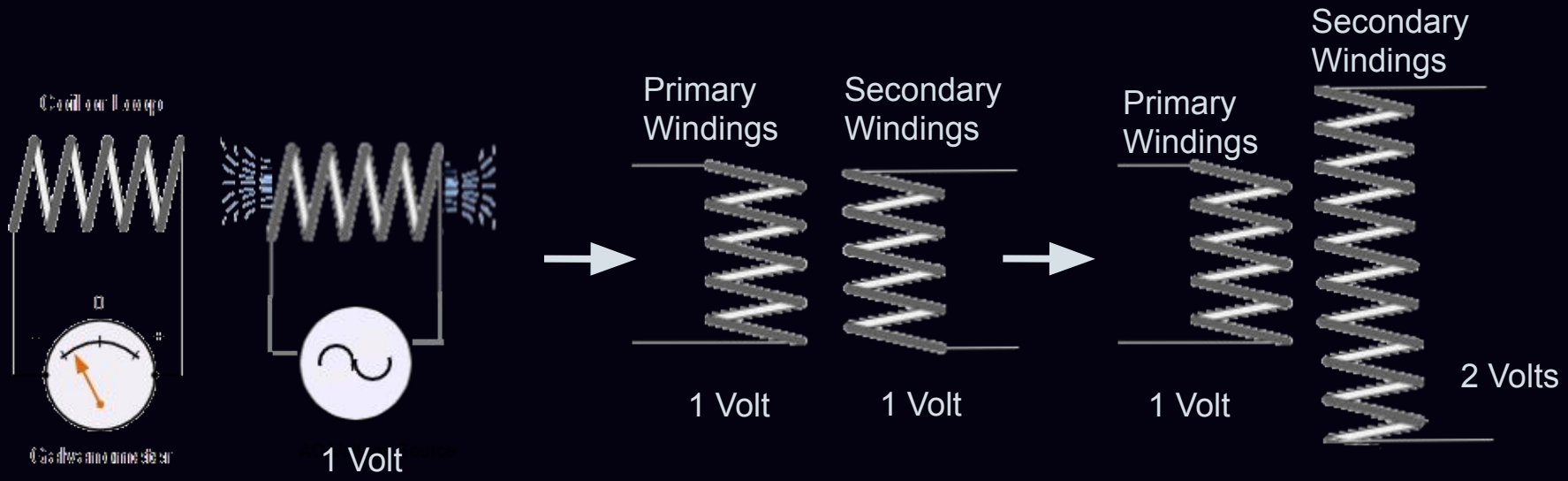
- A transformer works in a similar way.
- However instead of moving a *permanent magnet* to create a changing field, a transformer uses an electromagnet with a changing current to create the changing magnetic field.





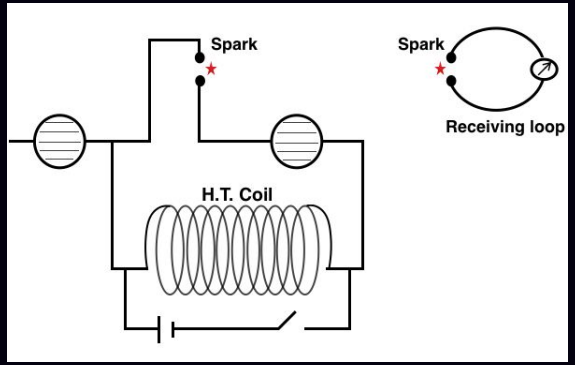
How it works (Continued)

- This electromagnet then becomes the primary, or input side of the transformer.
- By increasing the amount of turns in the secondary coil, you can also increase the voltage, and create a step-up transformer because it changes the amount of a conductor in the magnetic field.
- As a result the ratio between the number of turns in the primary coil and the number of turns in the secondary coil dictates the output voltage



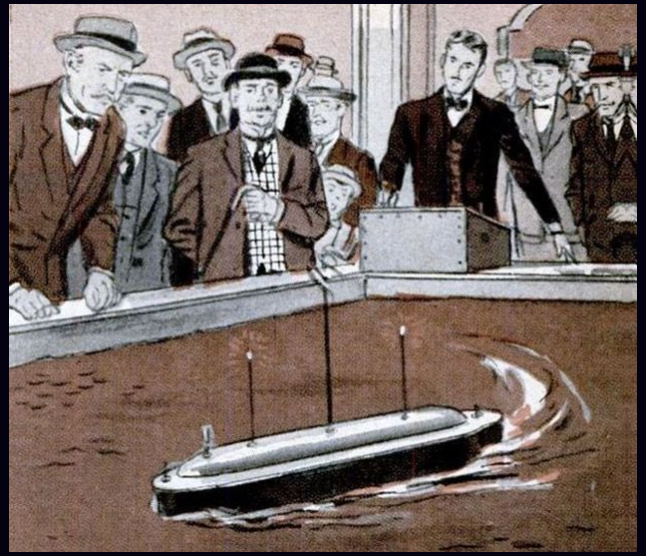
History of Transformers used as Radios

- Heinrich Hertz was a professor in Germany, who proved the existence of radio waves
- Hertz used a high voltage transformer as the transmitter



Numerous other scientists and inventors including Guglielmo Marconi and Nikola Tesla further developed radio technology based on Hertz's findings.

Marconi developed the first practical radios



Tesla developed the first Remote Controlled Vehicle

A transformer was also used as a radio transmitter was on the Titanic in 1912, and saved many lives.

Calculations

The output voltage of the transformer can be given by the equation:

$$V_s = V_p\left(\frac{n_s}{n_p}\right)$$

n_p is Number of primary turns, n_s is number of secondary turns, V_p is Voltage of primary, and V_s is Voltage of secondary.

Output Voltage equals **input voltage** multiplied by the **ratio of turns** in the secondary and primary.

Calculations (Continued [Derivation])

Faraday's Law of induction: $V = N(\frac{\Delta(B*A)}{\Delta t})$ or $\varepsilon = -\frac{\Delta \Phi_B}{\Delta t}$

Since the two coils are close together, the change in magnetic field remains the same over the change in time remains the same, so the two equations for each coil can be substituted:

Coil 1:

$$V_1 = N_1(\frac{\Delta(B*A)}{\Delta t})$$

$$(\frac{\Delta(B*A)}{\Delta t}) = \frac{V_1}{n_1}$$

Coil 2:

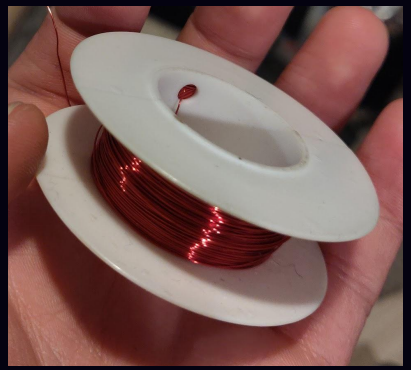
$$V_2 = N_2(\frac{\Delta(B*A)}{\Delta t})$$

$$(\frac{\Delta(B*A)}{\Delta t}) = \frac{V_2}{n_2}$$

$$\frac{V_1}{n_1} = \frac{V_2}{n_2}$$

Construction of a High Voltage Radio Transmitter

The wire used to make the primary coil



The wire used to make the secondary coil

A homemade High Voltage Transformer encased in wax

Predictions:

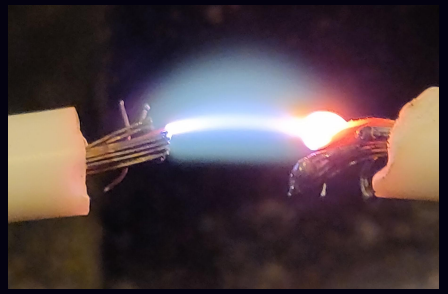
Number of turns in primary coil: 3
Number of turns in secondary Coil: ~790
Input Voltage: 12 Volts

$$V_s = V_p\left(\frac{n_s}{n_p}\right) \longrightarrow V_s = 12V\left(\frac{790}{3}\right)$$

V_s = 3,160 Volts or 3.16 kV

Calculated Voltage = 3.16 kV

Results:



- The actual voltage of the transformer can be roughly measured by measuring the length of the longest spark.
- Because the breakdown voltage for air is 3 kV/mm, we can multiply the spark length by 3 to get the actual output voltage.

$$Voltage = (\frac{3kV}{mm}) * 2.17mm$$

Measured Voltage = 6.51 kV or 6,510 Volts

Conclusion: (Error Analysis)

$$PercentError = 100(\frac{|Estimated - ActualValue|}{ActualValue})$$

$$PercentError = 100(\frac{|3.16kV - 6.51kV|}{6.51kV})$$

Percent Error = 51%

This rather large percent error is most likely due to the method used to measure the voltage. The method of using the spark length was inaccurate as it highly depends on the humidity, wire shape, pressure, and other factors that can change results

Demo

Back up VId #2

Works Cited

Brett, A. (2012). Radio Story - Wireless and the Titanic. Retrieved from Jproc.ca website: http://jproc.ca/radiostor/titanic.html

Electromagnetic Induction and Faradays Law. (2018, December 28). Retrieved from Basic Electronics Tutorials website: https://www.electronics-tutorials.ws/electromagnetism/electromagnetic-induction.html

Elert, G. (2009). Glenn Elert. Retrieved June 5, 2019, from Hypertextbook.com website: https://hypertextbook.com/facts/2000/AliceHong.shtml

Hertz's Experiments (1887). (2019). Retrieved from Harvard.edu website: http://people.seas.harvard.edu/~jones/cscie129/nu_lectures/lecture6/hertz/Hertz_exp.html

Krewaldt, R. (2018). File:Heinrich Rudolf Hertz.jpg - Wikimedia Commons. Retrieved June 5, 2019, from Wikimedia.org website: https://commons.wikimedia.org/wiki/File:Heinrich_Rudolf_Hertz.jpg

Spark Coils. (2019). Retrieved June 5, 2019, from Sparkmuseum.com website: http://www.sparkmuseum.com/SPKCOILS.HTM

The history of amateur radio - 3. (2019). Retrieved June 5, 2019, from Astrosurf.com website: http://www.astrosurf.com/luxorion/qsl-ham-history3.htm

Transformer Basics and Transformer Principles of Operation. (2018, August 16). Retrieved June 5, 2019, from Basic Electronics Tutorials website: https://www.electronics-tutorials.ws/transformer/transformer-basics.html

Turi, J. (2014, January 19). Tesla's toy boat: A drone before its time. Retrieved June 5, 2019, from Engadget website: https://www.engadget.com/2014/01/19/nikola-teslas-remote-control-boat/