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Honors Physics II Project
H2

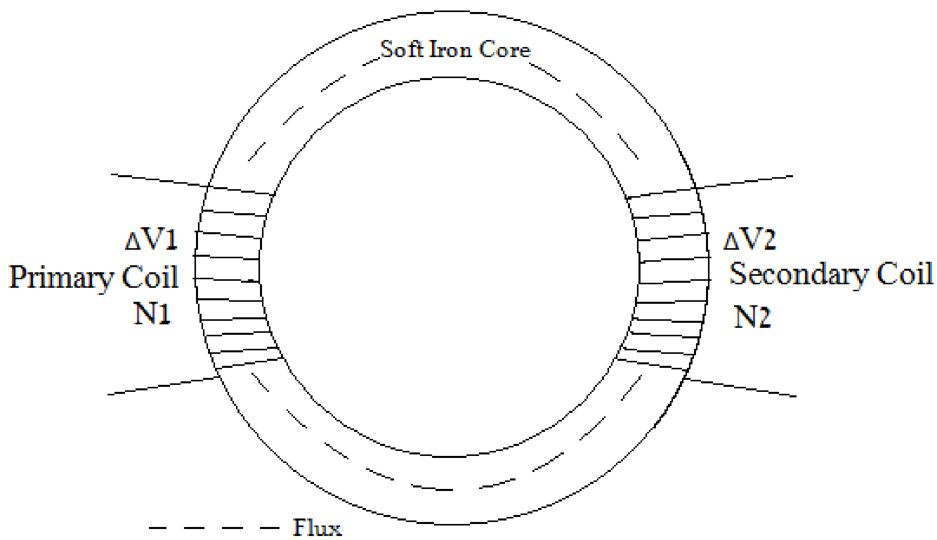
Objective:

The objective was to set up a device that connected a disposable cameras capacitor to different versions of transformers, expecting different outcomes. This didn't exactly work as well as expected. In each of the test, the outcome was the same. After connecting the capacitor to the transformer, leaving a spark gap on the output side of the transformer, charging the capacitor, and closing the circuit, nothing happened at the gap. This was very disappointing. The decision was made to test the different transformers and see if they were working the way they were supposed to. After collecting much data it was found that although the different designs didn't step-up the voltage, things were happening, but weren't following the general equations.

Physics:

In an ideal transformer Faradays Law and the properties of mutual inductance play very important roles. The way a transformer is supposed to work revolves around the idea that magnetic flux can be created and directed, to induce *emf*. The basic design of a transformer, illustrated in Figure A**,** is that there are two coils, which either have the same number of turns or different number of turns, wrapped around a soft iron core. The soft iron core is used because it has ferromagnetic qualities, which means it can easily be magnetized. If there are different numbers of turns for each coil, the *emf*, or voltage, is either stepped up or stepped down in the second coil. In the case of an ideal transformer the *emf* can be found by taking the negative number of turns in the first coil times the derivative of the flux, or using this equation $\Delta V_1 = -N_1 \frac{d\emptyset}{dt}$. The same equation could be used on the other coil using its number of turns, but only if the flux is the same in both coils. There is a simple ratio regarding a transformer based on the ideas stated above, $\frac{\Delta V_2}{\Delta V_1} = \frac{N_2}{N_1}$.(Calvert) Another equation that can be used in an ideal transformer follows that the energy should be conserved throughout the transformer, defined by the Law of Conservation of Energy.(Nave) To find if energy is conserved in a transformer it is necessary to know the current and voltage either going into or coming out of the transformer, and multiply them together. This would be represented as $P_{in} = I_{in}V_{in} = I_{out}V_{out} = P_{out}$, where "I" is the current and "V" is the voltage, and the units are Watts (Nave).

Figure A:



Experimentation:

These equations were used to learn more about the "homemade" transformers, but after doing some calculations it was found that these equations might not be representative of these transformers. Tables 1 and 2 represent two different sets of data on transformers. If the transformer from table 2 followed the rules, then given any V_{in} a V_{out} should be found. To test if this was true a voltage with value of 15 millivolts was used in the simple ratio equation above, which was rearranged to find the V_{out}. The voltage out should have been around 450 millivolts, from solving this equation, $\Delta V_2 = \left(\frac{N_2}{N_1}\right)\Delta V_1 = \left(\frac{81}{9}\right)(51.6mV) = 464.4mV$, but in reality it was only $1.5mV$. Some reasons that might explain this discrepancy might include the transformer having an inability to direct the voltage to the output wires before losing most of the original voltage. It is also possible that the core that was used wasn't composed of a very ferromagnetic material, which would make the current not flow very completely or easily.

Another test was done to see if the "homemade" transformers complied with the Law of Conservation of Energy. The setup for this test was very similar to the first test, where a "homemade" transformer was hooked up to a function generator, and two multi-meters were used to find the voltage going into and out of the transformer, but two extra multi-meters were used. The placement of these multi-meters can be seen in Figure B, each were set to find current, and the one at the input wires was hooked in series with the function generator. After setting the function generator to several different frequencies Table 3 was completed. To find if this transformer functioned as an ideal or did something different, the power going into and out of the transformer was calculated, using $P = I * V$. Table 4 has the results of these calculations and along with what the power out should have been if this transformer had been ideal. The data that was found didn't correspond very well with how an ideal transformer would have functioned. After discussion with Dr. Stewart, it was found that the only possibility for the input and output values of power to differ would be if the voltage and current were experiencing phasing. This is when the waves are similar (i.e. both sine waves) but are slightly separated. The energy in this system will be conserved but the equation that would show this is more complicated than the one used.

Figure B:

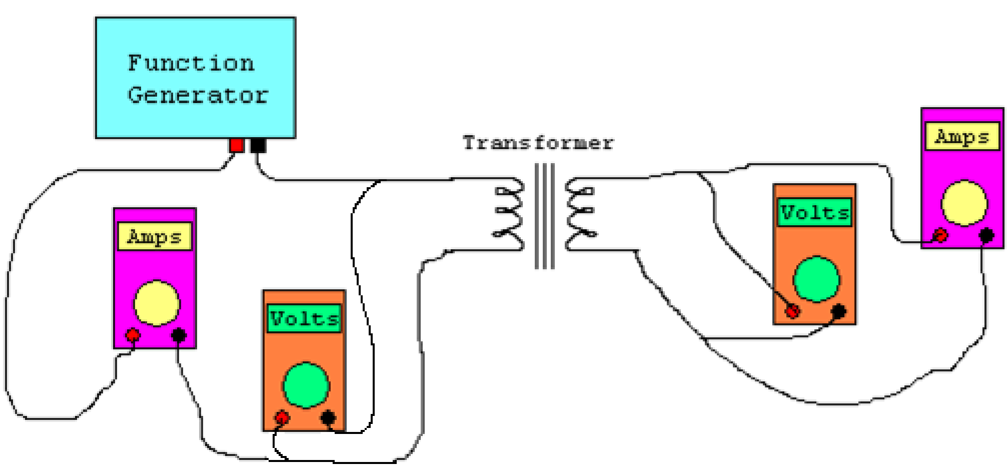


Table 1:

Transformer from Disposable Camera		
Frequency (Hz)	**V_{in}(millivolts)**	**V_{out} (millivolts)**
0002	0.2	4.0
0015	2.3	23.5
0017	2.4	22.4
0019	2.5	21.9
0020	2.2	18.0
0025	2.7	20.0
0030	2.8	17.8
0197	2.9	5.2

Table 2:

Homemade Transformer 1, N_1=9 (Primary Coil) and N_2=81		
Frequency (Hz)	**V_{in} (millivolts)**	**V_{out} (millivolts)**
0002	50.2*	0.00
15	51.6	1.5
30	50.7	3.2
45	50.6	5.0
60	50.7	6.6
196	51.6	20.8

*very scattered reading

Table 3

Homemade Transformer 2, N_1=55 (Primary Coil) and N_2=470				
Frequency (Hz)	**V_{in}(millivolts)**	**I_{in}(amps)**	**V_{out}(millivolts)**	**I_{out}(amps)**
20	54.0	0.11	5.1	0.40
1000	111.8	0.13	25.6	2.01
3400	192.0	0.12	23.5	1.84

Table 4

Calculations testing Law of Conservation of Energy (using table 3 values)			
Frequency (Hz)	**P_{in}(watts)**	**$P_{out, homemade}$(watts)**	**$P_{out, ideal}$(watts)**
20	5.94	2.04	5.94
1000	14.53	51.46	14.53
3400	23.04	43.24	23.04

Challenge of the Capacitor-Transformer Circuit:

After all of this data was compiled it is not surprising that when the “homemade” transformers were in circuit with the capacitors, a spark through the transformer failed to happen. There are many factors that would have to be exactly correct for a spark to really happen. Since the capacitor is being charged by a single battery, discharging in an instant with a spark, where energy and volts would be lost, trying to get enough current and voltage to move from the primary to secondary coil is almost just a matter of luck. During one experiment, the circuit included one camera capacitor and a transformer from another camera. When this circuit was closed three sparks emitted, one where the circuit was connected, one in between the input and output wires in the transformer, and one at the gap from the output wires from the transformers. This was so unexpected that there is no evidence to support its occurrence, and when the exact same setup was tried again (with camera ready) only the spark at the beginning emitted. No more than two sparks ever emitted during the rest of the project.

Conclusion:

Although this project took less than a semester to work on, many transformers were wrapped, data was taken, strange things happened, thumbs were injured, and things sparked. These factors, along with the fact that more experimentation and research could be done, make this experiment one worth continuing. This project is reminiscent of a statement that Albert Einstein made, "[a]s for the search for truth, I know from my own painful searching, with its many blind alleys, how hard it is to take a reliable step, be it ever so small, towards the understanding of that which is truly significant." (A.S.L. & Assoc.)

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