

Electric Transformer

Safety and Equipment

- Computer with PASCO 850 Universal Interface and PASCO Capstone
- Coils Set
- 2 Double Banana Cable
- 2 Banana to Alligator Cables
- PASCO Voltage Sensor (DIN to Banana cable with slip-on Alligator Clips)
- 10 Ω and 100 Ω resistor

Introduction

A device designed to increase or decrease AC voltages is called an electric transformer. The design of a transformer is based upon a principle of mutual electromagnetic induction. Two coils share the same magnetic field, but they are not electrically connected to each other. When an AC voltage is applied to the one coil (called the **primary** coil), the resulting alternating current in the primary coil produces a changing magnetic field. The other coil (the **secondary** coil) thus has a changing magnetic flux. This, in turn, induces an AC voltage in the secondary coil.

A core made of a ferrous material such as iron is used in transformers to increase the magnetic flux that influences the secondary coil. This also helps make sure the amounts of flux in the two coils are equal.

According to Faraday's Law of Induction, the induced emf (voltage) is proportional to the rate of change of magnetic flux **through each loop of the coil** ($\Delta\Phi/\Delta t$) and the number of turns (N) in the coil:

$$\mathcal{E} = -N \frac{\Delta\Phi_B}{\Delta t}$$

Specifically, for each coil:

$$\mathcal{E}_p = -N_p \frac{\Delta\Phi_B}{\Delta t} \quad \text{and} \quad \mathcal{E}_s = -N_s \frac{\Delta\Phi_B}{\Delta t}$$

Since the rate of change in flux through single loop of each coil are approximately the same,

$$-\frac{\Delta\Phi_B}{\Delta t} = \frac{\mathcal{E}_p}{N_p} = \frac{\mathcal{E}_s}{N_s}$$

Which means:

$$\frac{\mathcal{E}_s}{\mathcal{E}_p} = \frac{N_s}{N_p} = \text{Turns Ratio}$$

In a **step-up transformer**, the number of turns of wire in the secondary coil is **more** than the number of turns in the primary coil, which makes the voltage induced in the secondary coil greater than the voltage in the primary coil. If the number of turns in the secondary coil is **less** than the number of turns in the primary coil, the voltage will be reduced. A transformer set up that way is referred to as a **step-down transformer**.

Another important aspect of the transformer is that it cannot create energy. This means the power coming into the primary must equal the power supplied by the secondary.

Objectives:

- To verify the relationship of the voltage, current, and number of turns in the secondary and primary coils of a transformer.

Part #1: The effect of the Iron Core on AC Voltage Transfer.

When an alternating current passes through a coil of wire, it produces an alternating magnetic field. If another coil of wire is placed in vicinity of the original coil, the coils will share the magnetic flux. Changes in magnetic flux will induce an electric field in the secondary coil through the process known as an electromagnetic induction. Ideally, if there is no power loss, the voltage induced in the secondary coil should be equal the voltage in the primary coil when both coils have identical number of turns. However, this is not always true and this part of the experiment investigates how Core influences the voltage transfer.

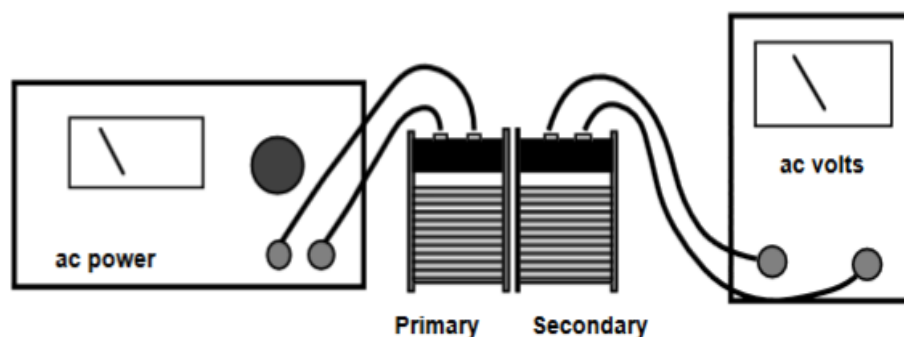


Figure 1. Primary and Secondary Coils connected correspondently to the power supply and voltmeter

1. **Very Carefully** insert the Voltage Sensor into Analog Input A and temporarily remove Alligator clips.
2. Place two 400-turn coils side by side while connecting one coil to AC Power supply (Output 1 of the 850 Universal Interface, two rightmost ports) and another coil to the voltmeter (PASCO Voltage Sensor). See Figure 1.
3. Open Capstone file "Electric Transformer" from Blackboard Lab page.
4. Go to Page #1 "Core Configurations" and start recording.
5. After a short time, click "Stop".
6. Adjust the axes of both displays so you could see three or four oscillations across the screen.
7. Using the Coordinate Tool, measure the **peak voltage** of the primary coil and enter it as Primary Voltage in Table 1.
8. Using the Coordinate Tool, measure the **peak voltage** of the secondary coil and record it as Secondary Voltage in Table 1.
9. Compare Primary and Secondary Voltage by calculating percent voltage lost in transfer.

Core configuration	Primary Voltage (V)	Secondary Voltage (V)	% Voltage Loss $\frac{(V_P - V_S)}{V_P} * 100$
No Core			
Straight Cross Piece			
Open U-shaped Core			
Closed U-shaped Core			
<i>Closed and Bolted</i> U-shaped Core			

Table 1. Measured and Calculated parameters of an Isolation (equal number of turns) Transformer.

10. Insert the straight cross piece into both coils (Figure 2.a) and repeat measurements from steps 4-9.

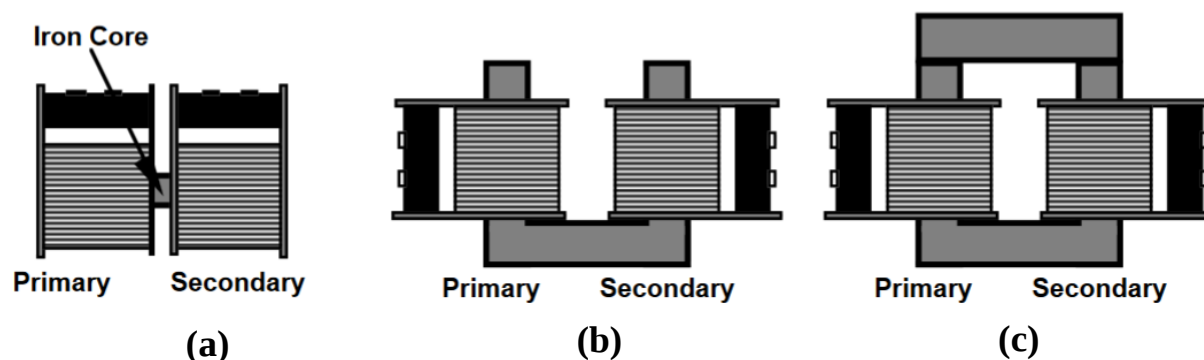


Figure 2. Different Core configurations

11. Replace the straight cross piece with the open U-shaped Core (Figure 2.b) and repeat steps 4-9.

12. Close the U-shaped core (Figure 2.c) but don't bolt down the iron frame.

13. Repeat measurements from steps 4-9.

14. Tightly bolt the frame down and repeat all the measurements once more.

15. To analyze the effect of the Core Configuration on the Voltage loss during the transfer, plot % *Voltage Loss against the Core Configuration* as a bar diagram.

16. Include a statement about the effect of the Core Configuration on voltage transfer into the abstract; argue the efficiency reason.

Part #2: Step-Down Transformer

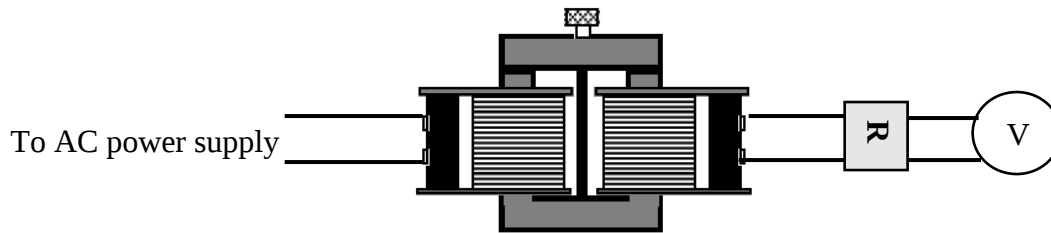


Figure 3. Schematic diagram for a circuit with a transformer

1. Assemble a step-down transformer by placing 800-turn and 200-turn coils on closed U-shaped Core.
 - o Make sure to secure the crossbar with the screw
2. Connect 800-turn coil (primary) to the Output 1 of the 850 Universal Interface.
3. Place Alligator slip-on clips back and connect 200-turn coil (secondary) to the 10Ω load resistor and to the Voltage Sensor, in parallel (Figure 3).
4. In Capstone, *move to next page labeled “Step-Down Transformer”* and start recording.
5. After a short time, click “Stop”.
6. Adjust the axes of the displays so you could see three or four oscillations across the screen.
7. Using the Coordinate Tool, measure the **peak voltage** of the primary coil.
8. Using the Coordinate Tool, measure the **peak current** of the primary coil.
9. Using the Coordinate Tool, measure the **peak voltage** of the secondary coil.
10. Using the Ohm’s Law, calculate the **peak current** of the secondary coil. (DO NOT use Turns Ratio).
11. Calculate the RMS values of the voltages and currents, and use them to calculate the average power for the Primary and Secondary coils.
12. Calculate the ratios in each column (secondary / primary). Express the **power ratio as a percent**, because it describes the efficiency of the transformer.

Step - Down Transformer	# Turns	Peak Voltage (V)	Peak Current (A)	rms Voltage (A)	rms Current (A)	Average Power (W)
Primary Coil						
Secondary Coil						
Ratio						

Table 2. Measured and Calculated parameters of Step-Down Transformer.

Part #3: Step-Up Transformer

1. Switch the primary and secondary coil connections, so that the coil with 200- turns is the primary and the coil with 800-turns is the secondary.
 - Make sure to secure the crossbar with the screw
2. Replace the 10Ω load resistor with the 100Ω load resistor
3. ***Switch to the Step-Up Transformer page in Capstone.*** This page is set up so that Output 1 is a small AC voltage that can be amplified by the transformer.
4. Repeat the measurements 4-12 of Part #2, and present the results in a table similar to Table 2 but labeled as Table 3.
5. Analyze how well the calculated ratios for each type of the transformer follow the rule for an ideal transformer.

$$\frac{V_p}{V_s} = \frac{N_p}{N_s} \quad \frac{N_p}{N_s} = \frac{I_s}{I_p} \quad \frac{P_p}{P_s} = 1$$

6. Include the statement about validation of this rule in the abstract along with the expected discrepancy based on Power Ratios.

Requirements for the Formal Report:

The report must contain a **Header** at the top (Title of Lab, Authors, and Date)

The **Abstract** is a summary of the Main Body, so write it last. Place **Abstract** at the top of report.

The **Main Body** of the report must address the following:

- The **Introduction** should have background information about Transformers including how they operate, the governing law of transformers, and their uses. Include the objectives of the lab.
- The **Methods** should describe broadly what was done, using what tools, and what was measured/recorded.
 - Part 1: Describe the general procedure for measuring voltage in each coil with or without any iron pieces. Then, describe each iron core configuration that was used.
 - Part 2: Describe the experimental setup for the Step-Down Transformer. Explain what data was measured and what data was calculated.
 - Part 3: You can say that the same values were measured and calculated as in Part 2, but explain changes in the experimental setup required for the Step-Up Transformer.
- The **Discussion** should incorporate the following:
 - Discuss the effect of the Iron Core Configuration on voltage transfer in the isolation transformer. Explain why some Configurations yielded less/more voltage loss than others. Use the data in Table 1 and the bar graph to back up your statements.
 - For the Step-Down Transformer, analyze how well the ratios from Table 2 follow the rule for an ideal transformer (i.e. Turns Ratio). Explain why there are discrepancies in the ratios and why the efficiency of the transformer (i.e. Power Ratio) is not close to 100%.
 - For the Step-Up Transformer, analyze how well the ratios from Table 3 follow the rule for an ideal transformer. Explain why there are discrepancies in the ratios and why the efficiency of the transformer is not close to 100%.
 - The lab manual contains several imperatives in each part of the lab that will guide you with the Discussion. Make sure to incorporate the imperatives from the lab manual in the text.
- **Conclusions** based on the quantitative results.
- **Data Section** must contain the following:
[Each table and graph should be labeled and descriptively captioned.]
 - 3 Tables
 - 1 Bar Graph