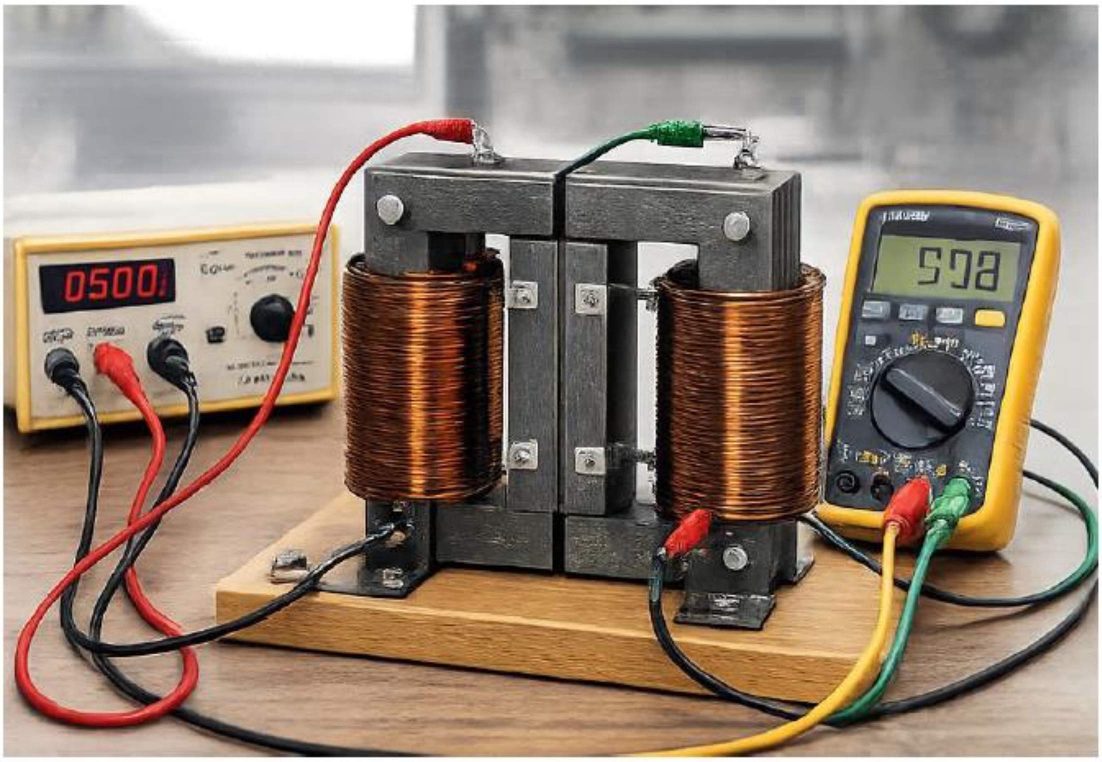
UNIVERSIDAD NACIONAL DE SAN LUIS
FACULTAD DE INGENIERÍA Y CIENCIAS AGROPECUARIAS

FISICA 2

Electricidad y magnetismo

Transformador



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Teacher's Guide - Activity P49: Transformer (Power Output, Voltage Sensor)

Concept	*DataStudio*	*ScienceWorkshop* (Mac)	*ScienceWorkshop* (Win)
Electricity	P49 Transformer.DS	(See end of activity)	(See end of activity)

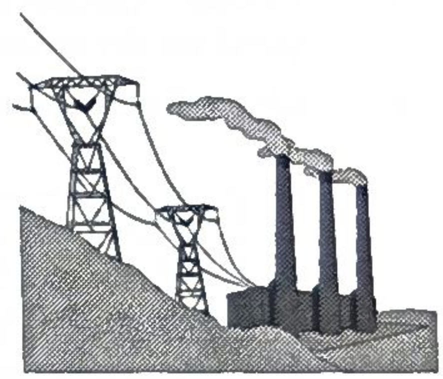
Equipment Needed	Qty	Equipment Needed	Qty
Voltage Sensor (CI-6503)	1	Primary/Second Coils (SE-8653)	1
Patch Cords (SE-9750)	2		

What Do You Think?

How is a transformer used to increase or decrease an AC voltage?

Take time to answer the 'What Do You Think?' question(s) in the Lab Report section.

Background



A transformer can be used to increase or decrease AC voltages. An AC voltage is applied to the **primary** coil of a transformer, which is surrounded by the **secondary** coil but is not electrically connected to it. The primary coil produces a changing magnetic flux through the secondary coil, which will induce an AC voltage in the secondary coil. If the number of turns of wire in the secondary coil is more than the number of turns in the primary coil, the voltage induced in the secondary coil will be more than the voltage in the primary coil. This is called a step-up transformer. 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. This is called a step-down transformer.

According to Faraday's Law of Induction, the induced emf (voltage) is proportional to the rate of change of magnetic flux through the coil ($d\phi/dt$) and the number of turns (N) in the coil:

$$\varepsilon = -N\frac{d\phi}{dt}$$

Since the rate of change in flux through both coils is the same, the ratio of the emfs (voltages) in the coils should be equal to the ratio of the numbers of turns in the coils:

$$-\frac{d\phi}{dt} = \frac{\varepsilon}{N} \rightarrow \frac{\varepsilon_s}{\varepsilon_p} = \frac{N_s}{N_p}$$

A core made of a ferrous material such as iron can change the amount of magnetic flux that influences the secondary coil.

SAFETY REMINDER	THINK SAFETY ACT SAFELY BE SAFE!
• Follow all safety instructions.	

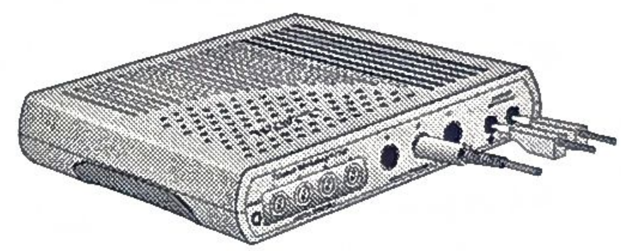
For You To Do

In the first part of this activity, put together a step-up transformer (number of turns in the secondary coil is greater than the number of turns in the primary coil). In the second part of this activity, use the same coils to put together a step-down transformer (number of turns in the secondary coil is less than the number of turns in the primary coil.)

Use the 'Output' feature of the *ScienceWorkshop* interface to supply a voltage to the primary coil in both transformer setups. Use the Voltage Sensor to measure the induced emf (voltage) in the secondary coil. Record the voltage in the secondary coil for two configurations: one with an iron core inside the inner coil, and one without the iron core inside the inner coil.

Use *DataStudio* or *ScienceWorkshop* to control the voltage output of the interface. Use the software to collect and display the voltages across both the primary coil and the secondary coil. Finally, compare the voltage in the primary coil to the voltage in the secondary coil.

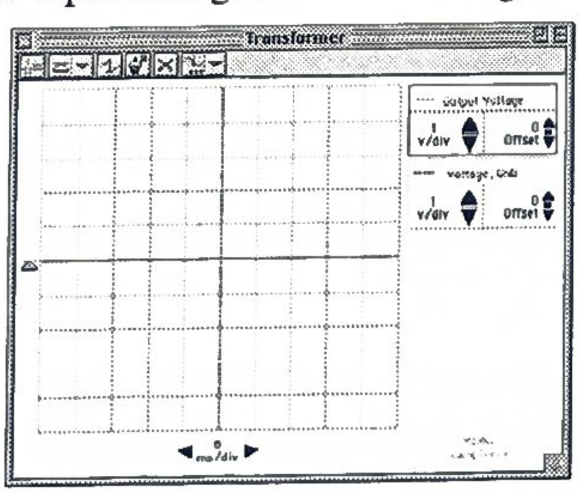
PART IA: Computer Setup for Step-Up Transformer

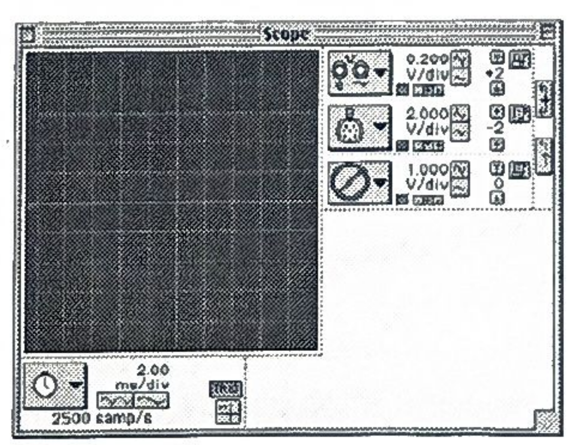


1. Connect the *ScienceWorkshop* interface to the computer, turn on the interface, and turn on the computer.
2. Connect the Voltage Sensor DIN plug into Analog Channel B.
3. Connect banana plug patch cords into the 'OUTPUT' ports on the interface.
4. Open the document titled as shown:

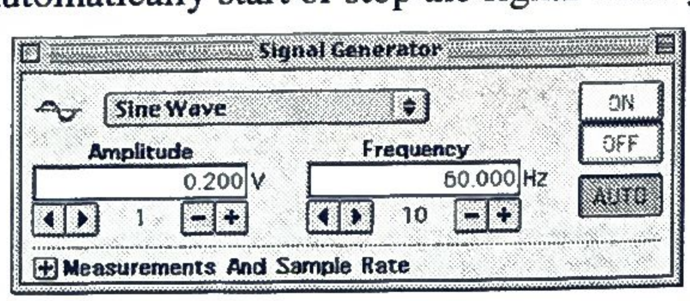
DataStudio	*ScienceWorkshop* (Mac)	*ScienceWorkshop* (Win)
P49 Transformer.DS	(See end of activity)	(See end of activity)

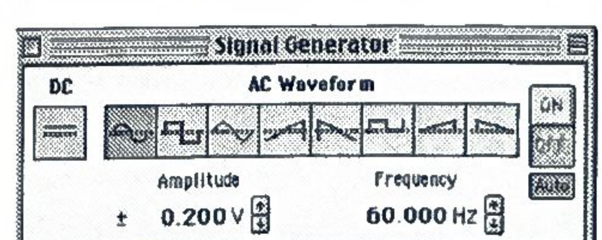
- The *DataStudio* document opens with a Signal Generator window and a Scope display. The document also has a Workbook display. Read the instructions in the Workbook.
- See the pages at the end of this activity for information about modifying a *ScienceWorkshop* file.
- The Scope display shows the voltage from the 'Output' of the interface to the primary coil and the input voltage from the Voltage Sensor.





- The Signal Generator is set to produce a sine wave at 60 Hz. It is set to 'Auto' so it will automatically start or stop the signal when you start or stop measuring data.



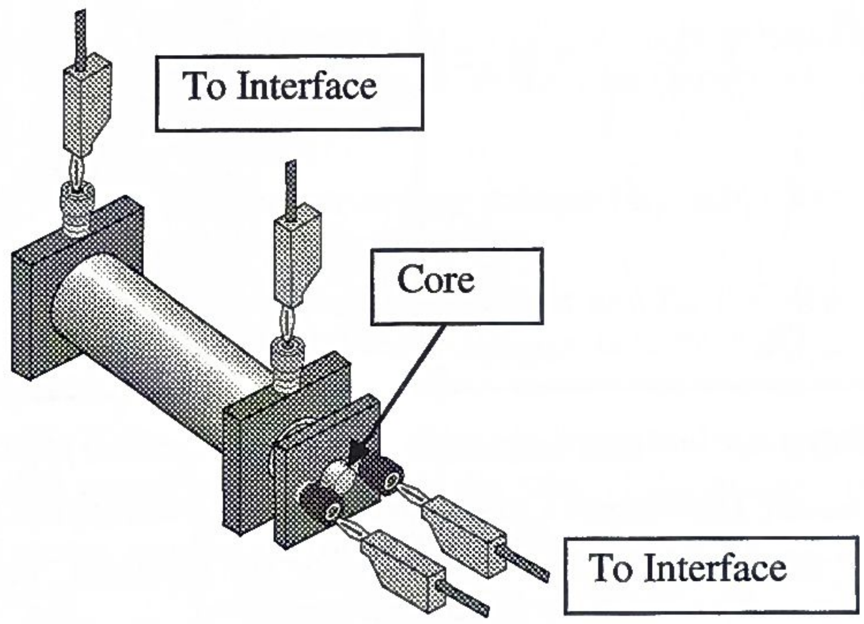


5. Arrange the Scope display and the Signal Generator window so you can see both of them.

PART IIA: Sensor Calibration and Equipment Setup Step-Up Transformer

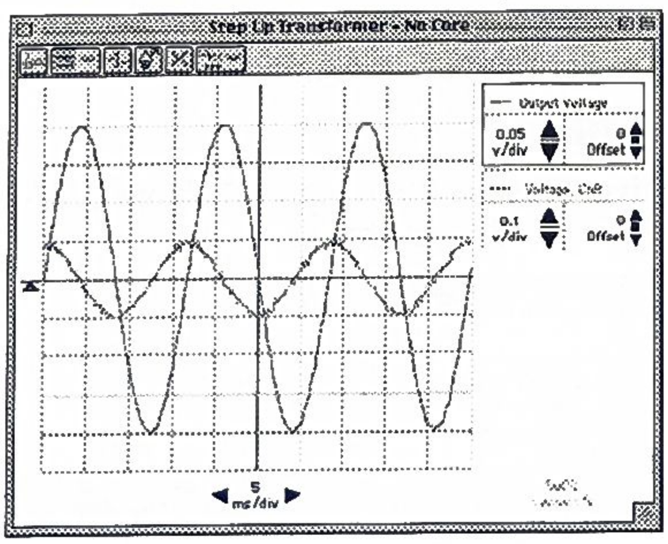
- You do not need to calibrate the Voltage Sensor.
- The Primary and Secondary Coils consist of an inner coil with about 200 turns of heavy gauge wire, an outer coil with about 2000 turns of thinner gauge wire, and an iron core that fits inside the inner coil. The inner coil fits inside the larger outer coil.

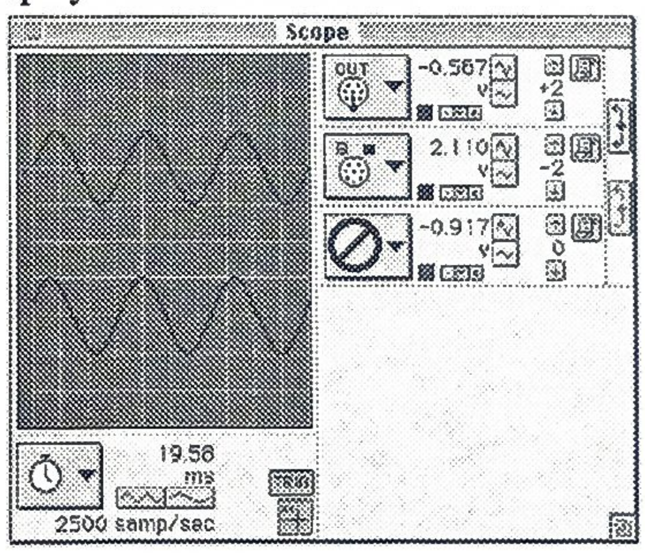
1. To build a step-up transformer, use banana plug patch cords to connect the <u>inner</u> coil to the 'OUTPUT' ports of the interface.
2. Connect the Voltage Sensor's banana plugs to the <u>outer</u> coil.
3. Put the inner coil completely inside the outer coil. Put the iron core as far into the inner coil as it will go.



PART IIIA: Data Recording for Step-Up Transformer

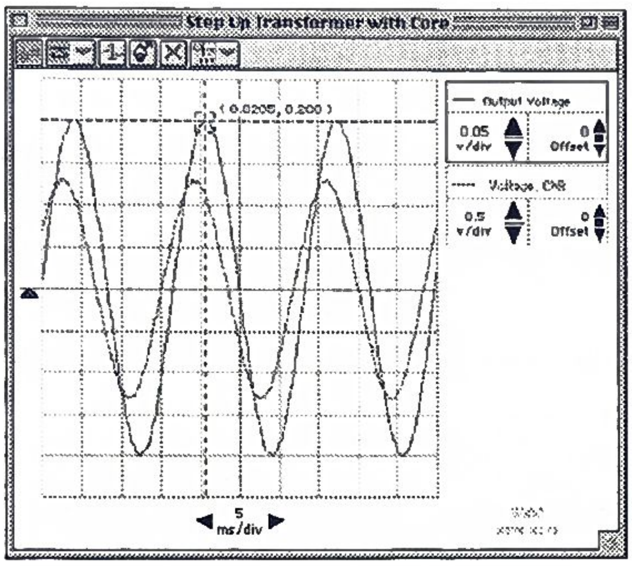
1. Start measuring data. (Click 'Start' in *DataStudio* or 'MON' in *ScienceWorkshop*.)
2. Observe the traces of voltage in the Scope display.

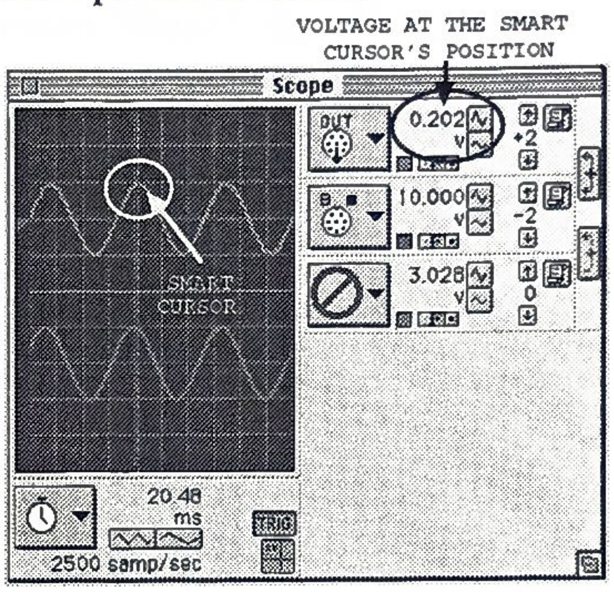




3. Use the Scope display's built-in analysis tools to determine the output voltage across the primary coil and the induced voltage across the secondary coil.

- Click the *ScienceWorkshop* 'Smart Cursor' or the *DataStudio* 'Smart Tool' button in the Scope display. The cursor changes to a cross-hair shape.
- Move the cursor/cross-hair to a peak of the top trace of 'Output' voltage (the primary coil voltage). In *DataStudio*, the value of the voltage at that point is the y-coordinate that is displayed adjacent to the cross hairs of the 'Smart Tool.' In *ScienceWorkshop* the value of voltage at that point is displayed next to the channel Input Menu button.

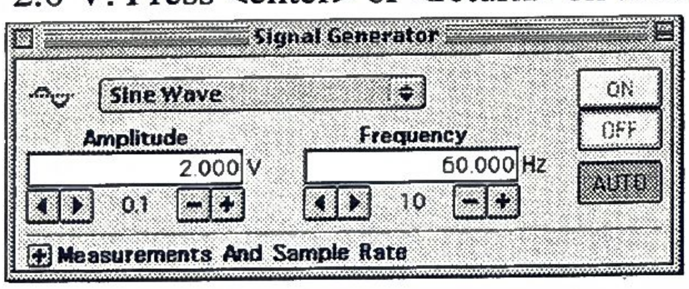


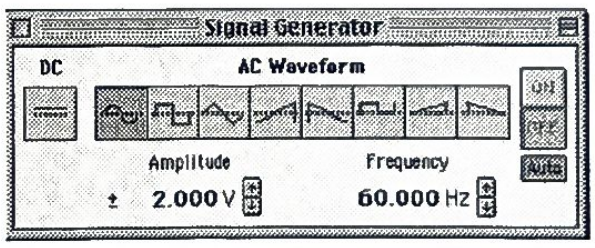


4. Record the 'Output' voltage across the primary (inner) coil in the Lab Report section.
5. Move the 'Smart Tool/Smart Cursor' to the corresponding peak of the 'Voltage, Channel B' trace (the secondary coil voltage). Record the voltage across the secondary (outer) coil.
6. Remove the iron core from the inner coil.
7. Use the 'Smart Tool/Smart Cursor' to once again find the 'Output' (primary) voltage and the 'Voltage, Channel B' (secondary voltage).
8. Record the new voltages across the primary (inner) and secondary (outer) coils when the core is removed.
9. Stop monitoring data. Turn off the switch on the back of the Power Amplifier.

PART IB: Computer Setup for Step-Down Transformer

1. Click the Signal Generator window to make it active. Change the Amplitude from 0.2 V to 2.0 V. Press <enter> or <return> on the keyboard to record your change.





2. Click the Scope display to make it active. Change the Sensitivity (volts per division) for both the 'Output' trace and the 'Voltage, Channel B' trace. Change the 'Output' trace from 0.200 v/div to 2.000 v/div. Change the 'Channel B' trace from 2.000 v/div to 0.200 v/div.

PART IIB: Sensor Calibration and Equipment Setup for Step-Down Transformer

1. Put the iron core back inside the inner coil.

- Change the transformer from step-up to step-down.

2. Disconnect the banana plug patch cords from the inner coil. Disconnect the Voltage Sensor from the outer coil.
3. Connect the banana plug patch cords from the 'OUTPUT' ports of the interface to the <u>outer</u> coil. Connect the Voltage Sensor's banana plugs to the <u>inner</u> coil.

PART IIIB: Data Recording for Step-Down Transformer

1. Repeat the data recording procedure outlined in Part IIIA.

- Hint: If the voltage appears to be too small to measure, change the volts per division in the 'Scope' display to 0.050 V/div.

2. Record the voltage across the primary (outer) coil and the voltage across the secondary (inner) coil for both 'with core' and 'without core' in the Lab Report section.

Analyzing the Data

1. Calculate the ratio of primary voltage to secondary voltage for each of the four measurements and record the ratios in the Data section.
2. Express your calculated ratios for the step-up transformer and for the step-down transformer in a way that shows by how much the voltage is increased or decreased (for example, '3 to 1').
3. The number of turns in the inner coil is 235 (#18 gauge wire) and the number of turns in the outer coil is 2920 (#29 gauge wire). Calculate the ratio of the number of turns.

Put your results in the Lab Report section

Lab Report – Activity P49: Transformer

What do you think?

How is a transformer used to increase or decrease an AC voltage?

Answers will vary. When an alternating current flows through the primary coil of the transformer, it generates an alternating (fluctuating) magnetic field. The changing magnetic field induces an alternating current in the secondary coil. The voltage of the current in the secondary coil compared to the primary coil depends on several factors, one of which is the ratio of the turns in the primary coil to the turns in the secondary coil. If the number of turns in the secondary coil is greater than the number of turns in the primary, the voltage in the secondary should be higher than the voltage in the primary. If the secondary has fewer coils than the primary, the voltage in the secondary should be lower than the voltage in the primary.

Data

Part A: Step Up Transformer

Step-Up Transformer	Primary (inner) Voltage (V)	Secondary (outer) Voltage (V)
With core	0.20	2.11
Without core	0.20	0.18

Step-Up Transformer	Ratio: V_p – to -V_s
With core	10.5 to1
Without core	0.9 to 1

Part B: Step Down Transformer

Step-Down Transformer	Primary (outer) Voltage (V)	Secondary (inner) Voltage (V)
With core	2.00	0.07
Without core	2.00	0.009

Step-Down Transformer	Ratio: V_p – to -V_s
With core	1 to 28.5
Without core	1 to 222

Ratio of turns = 12.4 to 1

Questions

1. When the inner coil (with core) was used as the primary coil, was the ratio of the voltages equal to the ratio of the number of turns? How do you account for any difference?

The ratio of voltages was somewhat less than the ratio of turns. It was slightly less due to imperfect coupling between the coils.

2. Why did the secondary voltage change when the iron core was pulled out of the inner coil?

The voltage changed because the iron core acts to concentrate the magnetic field in the solenoid. When the core is removed, the field is more spread and the transformer is less efficient.

3. When the outer coil (with core) was used as the primary coil, why is the voltage stepped down a different amount than it was stepped up when the inner core was the primary coil?

There is an air gap between the outer and inner coil. This gap contains flux that is not intercepted by the inner coil (When the inner coil is the primary, all of its flux is intercepted by the outer coil, since the inner coil is inside the outer.) This gap, with its corresponding unused flux, causes the voltage on the secondary to be less than the theoretical value.

4. Which had the greater effect: Pulling the core out of the step-up transformer (inner-primary) or pulling the core out of the step-down transformer (outer-primary)? Why?

Removing the core from the step-down transformer had the greater effect. The iron core concentrates the flux in the central region (inside the inner coil); but when it is removed, more of the flux is in the region between the coils. This lessens the flux intercepted by the inner coil and lessens the voltage on the secondary.

5. Why did you have to use AC voltage in this laboratory activity instead of DC?

It is change in flux that induces a voltage in a coil, not flux itself. A direct current (DC) voltage would not cause a change in flux, unless the coils are moving. (You may want to try the experiment with a DC current in the inner coil and watch the voltage on the outer coils as you move the inner coil in and out.)

Appendix: Modify a *ScienceWorkshop* File

Modify an existing *ScienceWorkshop* file.

Open the *ScienceWorkshop* File

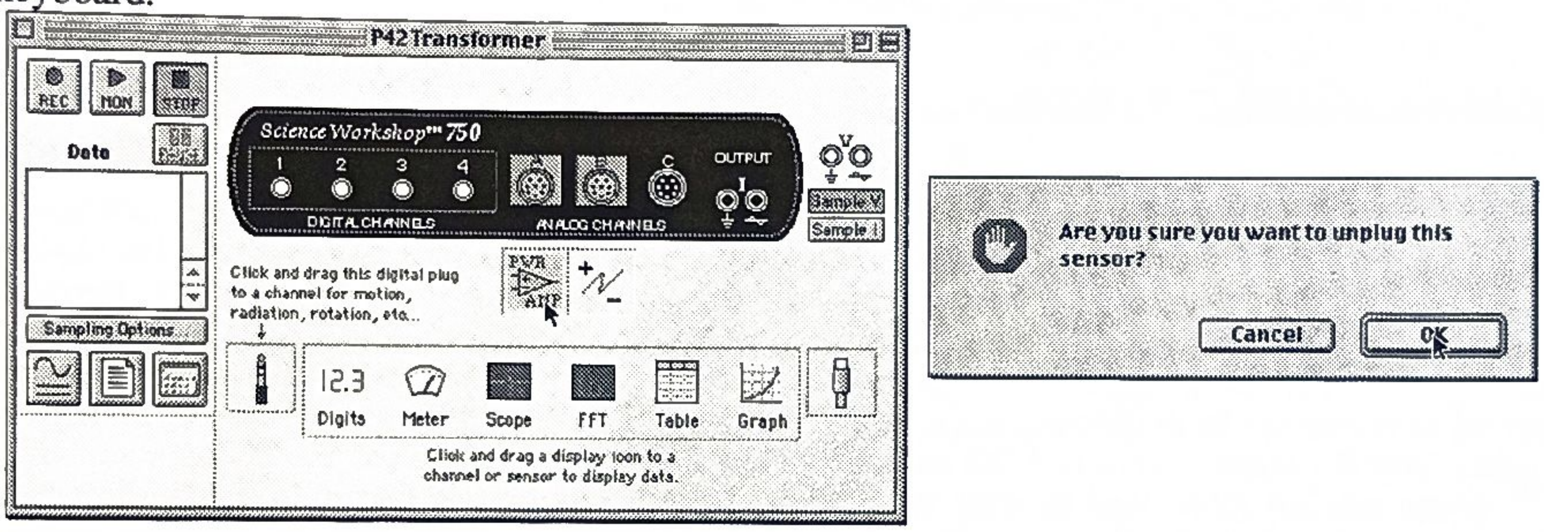
Open the file titled as shown:

ScienceWorkshop (Mac)	*ScienceWorkshop* (Win)
P48 Transformer	P48_XTRN.SWS

This activity uses the 'Output' feature of the *ScienceWorkshop* 750 interface to provide the output voltage. Remove the Power Amplifier in the Experiment Setup window.

Remove the Power Amplifier Icon

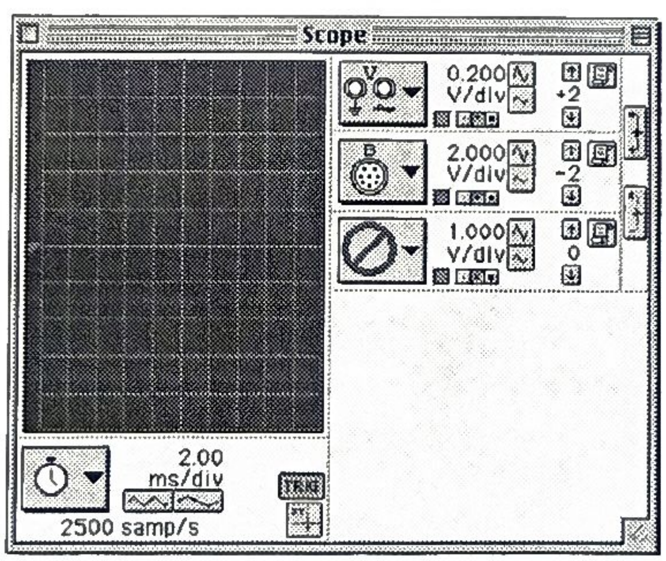
In the Experiment Setup window, click the Power Amplifier icon and press <delete> on the keyboard.



Result: A 'warning' window opens. Click 'OK' to return to the setup window.

Results

The *ScienceWorkshop* document has a 'Scope' (oscilloscope) display of 'Output' voltage (V) and 'Channel B' voltage (B) and the Signal Generator window which controls the output.



Time Estimates	Preparation: 15 min	Activity: 30 min

Objectives

Students will be able to…

- use the 'Output' feature of the ScienceWorkshop interface to supply the voltage (60 Hz AC sine wave) across the primary coil of a step-up transformer
- use the Voltage Sensor to measure the voltage across the secondary coil of the transformer
- use the Scope display to determine the ratio of voltage across the primary coil and the voltage across the secondary coil
- compare the ratio of the primary voltage to the secondary voltage to the ratio of the number of turns in the primary to the number of turns in the secondary
- repeat the process for a step-down transformer
- use the 'Output' feature of the ScienceWorkshop interface to measure the voltage across and the

Notes

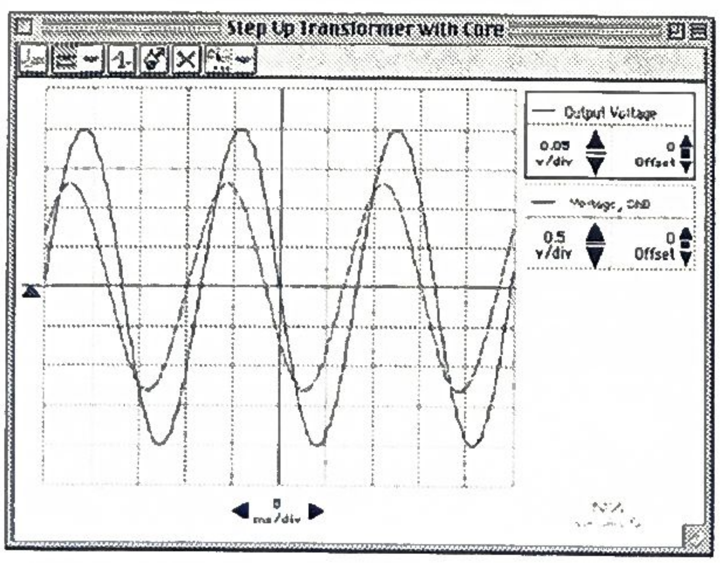
Near the turn of the nineteenth century Thomas Edison (1847-1931) and Nikoli Tesla (1857-1943) debated whether to make motors that operated on DC (direct) current or AC (alternating) current. The advantages of AC were huge, but not apparent at the time. First of all the electrical transmission of AC at high voltage and low current could occur over hundreds of miles without much in the way of line loss. Edison's DC, high current at low voltage, could only be transmitted economically over short distances, which forced the electrical generation of the power to be near the consumer. Once the electricity got to the consumer the DC had to be 'stepped-down' using resistors which in turned wasted much of the power in the form of heat. With AC one could either 'step-up' or 'step-down' the voltage with less loss of energy. The heat that does develop in AC transformers is primarily due to the internal resistance of the vast lengths of wire that make up the primary and secondary coils.

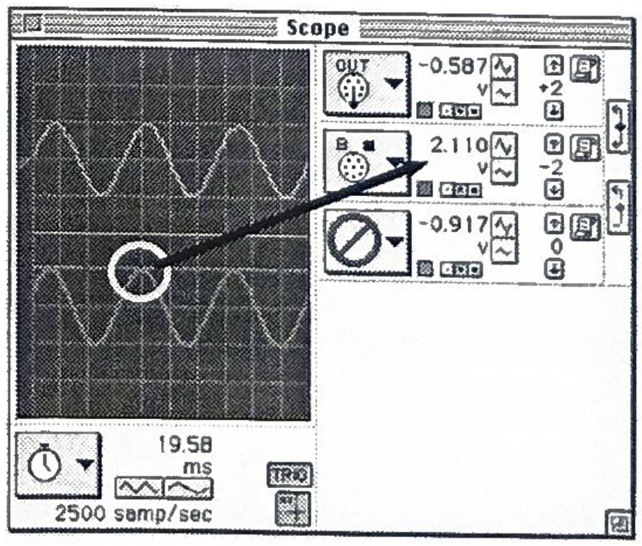
The data shown below corresponds to the PASCO Model SE-8653 Primary and Secondary Coils.

Sample Data

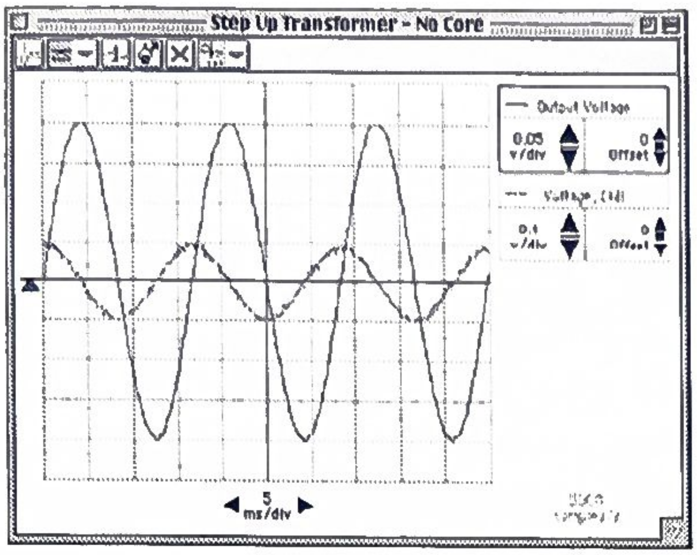
Note: DataStudio and ScienceWorkshop results were obtained during separate data runs and can not be compared to each other.

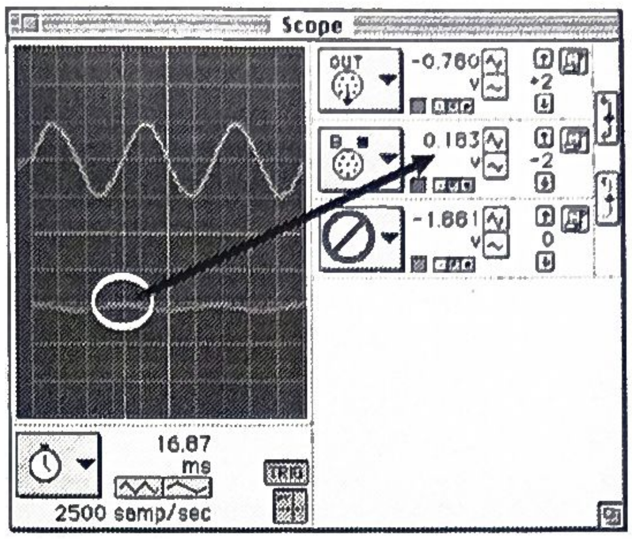
Step-Up Transformer with Core



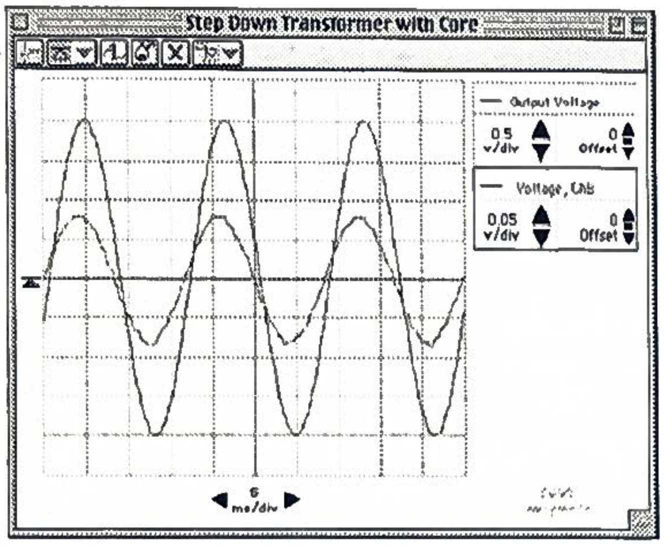


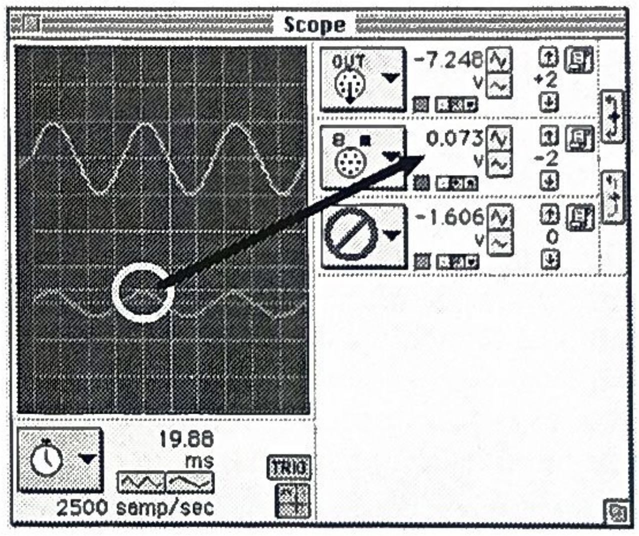
Step-Up Transformer with No Core





Step-Down Transformer with Core





Step-Down Transformer with No Core