

### 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?

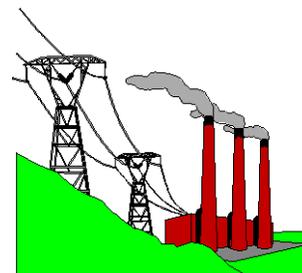
How is a transformer used to increase or decrease an AC voltage?



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

- Follow all safety instructions.

**THINK SAFETY**  
**ACT SAFELY**  
**BE SAFE!**

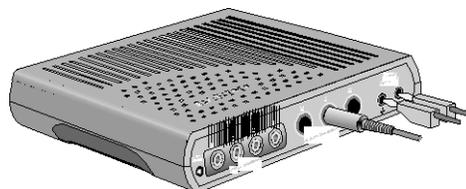
#### For You To Do

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.

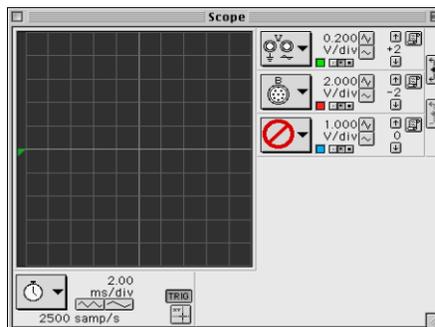
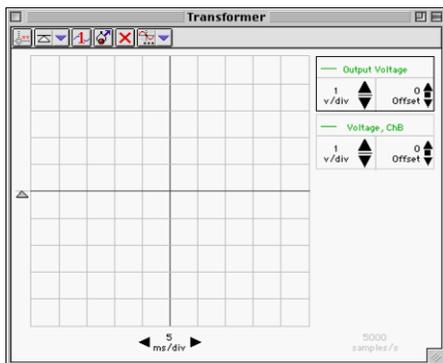


**PART IA: Computer Setup for Step-Up Transformer**

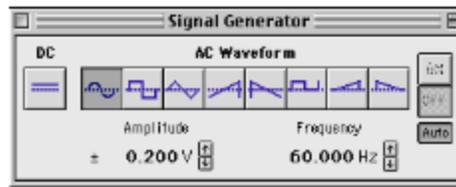
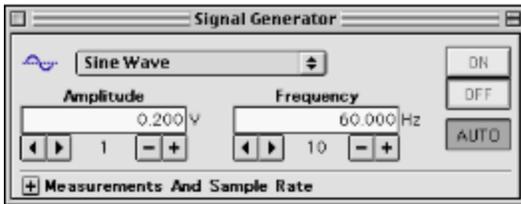
1. Connect the *ScienceWorkshop* interface to the computer, turn on the interface, and turn on the computer.
2. Connect the Voltage Sensor DIN plug into Analog Channel B.
3. Connect banana plug patch cords into the ‘OUTPUT’ ports on the interface.
4. Open the document titled as shown:

<i>DataStudio</i>	<i>ScienceWorkshop</i> (Mac)	<i>ScienceWorkshop</i> (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.

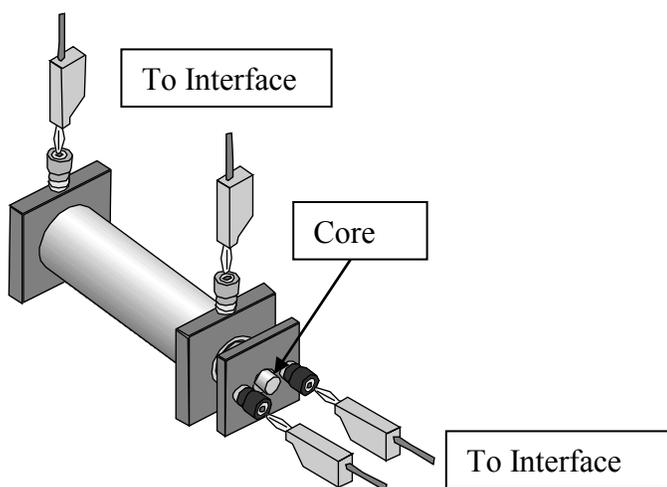


- See the pages at the end of this activity for information about modifying a *ScienceWorkshop* file.
  - The Scope display shows the voltage from the ‘Output’ of the interface to the primary coil and the input voltage from the Voltage Sensor.
  - The Signal Generator is set to produce a sine wave at 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**

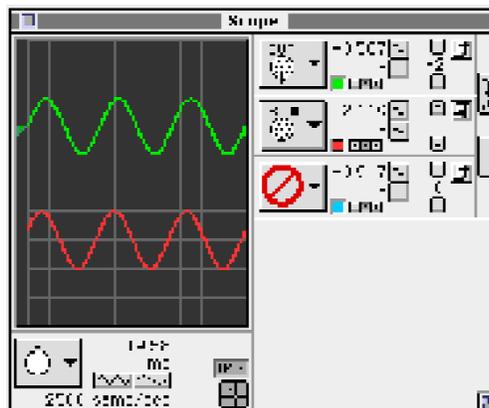
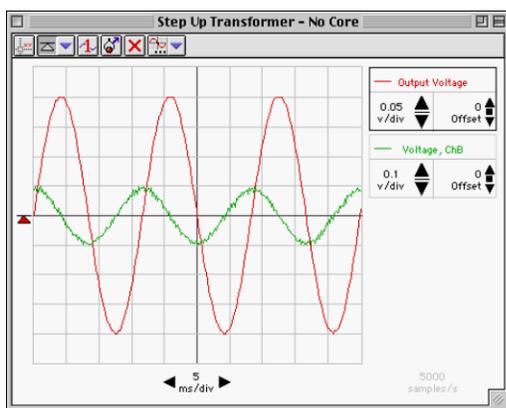
- You do not need to calibrate the Voltage Sensor.
  - The Primary and Secondary Coils consist of an inner coil with about 200 turns of heavy gauge wire, an outer coil with about 2000 turns of thinner gauge wire, and an iron core that fits inside the inner coil. The inner coil fits inside the larger outer coil.
1. To build a step-up transformer, use banana plug patch cords to connect the inner coil to the ‘OUTPUT’ ports of the interface.
  2. Connect the Voltage Sensor’s banana plugs to the outer 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.

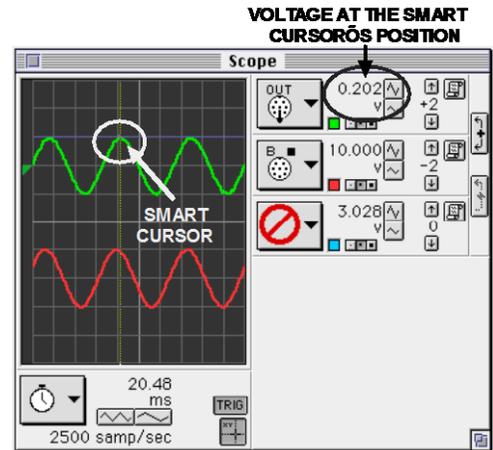
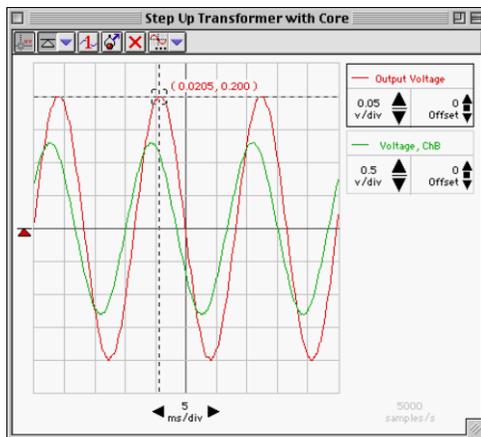
**PART IIIA: Data Recording for Step-Up Transformer**

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 outer coil. Connect the Voltage Sensor's banana plugs to the inner 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?

**Data****Part A: Step Up Transformer**

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

Step-Up Transformer	$V_S / V_P$	$N_S / N_P$	Efficiency
With core			
Without core			

**Part B: Step Down Transformer**

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

Step-Down Transformer	$V_S / V_P$	$N_S / N_P$	Efficiency
With core			
Without core			

$$\text{Efficiency} = \frac{V_S / V_P}{N_S / N_P} \times 100$$

### 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?
2. Why did the secondary voltage change when the iron core was pulled out of the inner coil?
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?
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?
5. Why did you have to use AC voltage in this laboratory activity instead of DC?

Name \_\_\_\_\_

Class \_\_\_\_\_

Date \_\_\_\_\_



Name \_\_\_\_\_

Class \_\_\_\_\_

Date \_\_\_\_\_