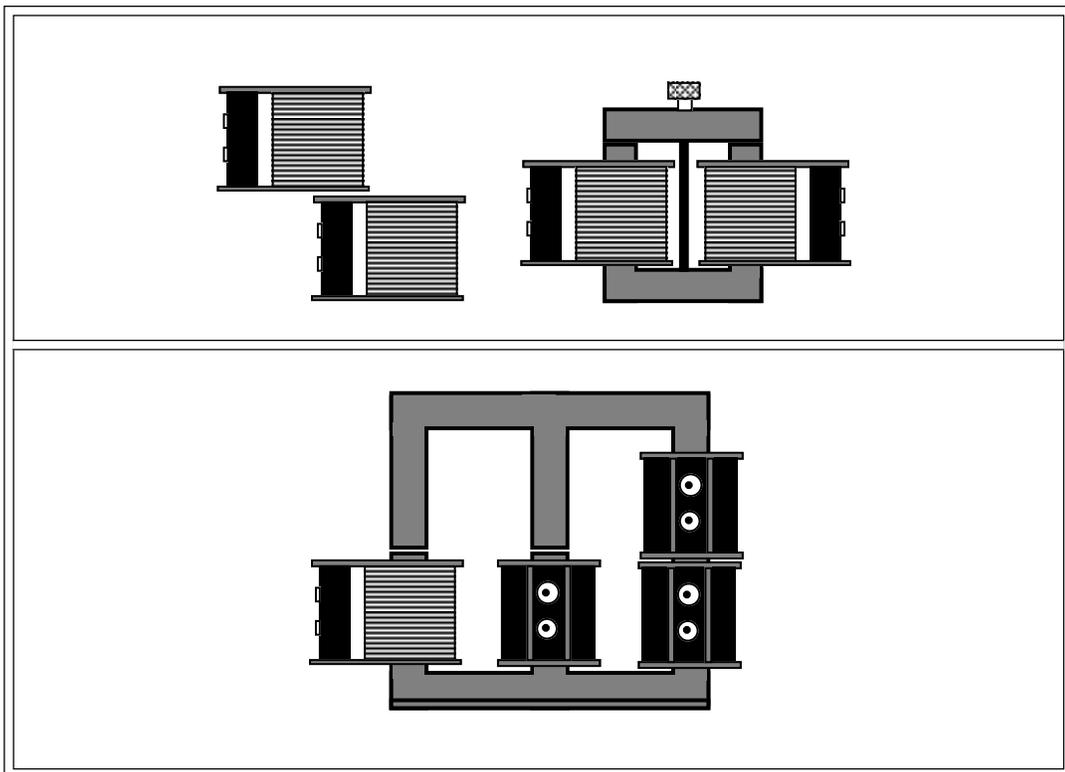


***Instruction Manual
and Experiment Guide
for the PASCO scientific
Model SF-8616 and 8617***

012-03800A
11/89

COILS SET



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\$15.00

How to Use This Manual

The best way to learn to use the PASCO Basic Coils Set or the PASCO Complete Coils Set (referred to collectively as PASCO Coils Set) is to spend some time experimenting with it. We've organized this manual to get you started as quickly as possible. We strongly recommend that you read the Introduction and Experiments sections first. These are

followed by 4 experiments for your students to get started on. The experiments are ready to send to the copy room.

The Appendix contains technical data on the construction and operation of the coils.

Introduction

The PASCO scientific SF-8616 Basic Coils Set and SF-8617 Complete Coils Set provide necessary parts to experimentally investigate relationships involved with electromagnetism and electromagnetic induction. Coupled with a galvanometer, an accurate A.C. voltmeter, an A.C. ammeter, an oscilloscope and an A.C. power supply, little else is needed to carry out studies in this important area.

Additional equipment which is recommended includes small but strong magnets such as the ones found in the PASCO SE-8604 Bar Magnet Set, low constant springs, ring stands, a magnetic compass and iron filings.

One can study basic electromagnetism. The direction of the windings is shown on the top of each coil, allowing the relationship between current direction and the direction of the resulting magnetic field to be studied. See Figure 1.

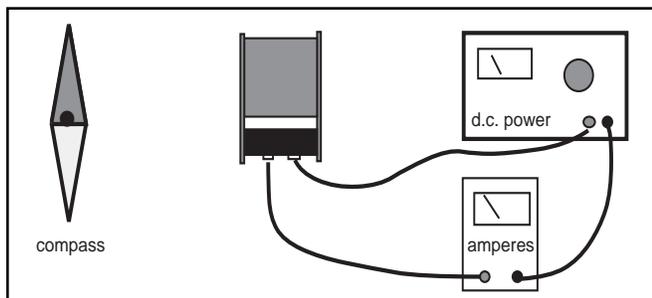


Figure 1

Using a coil from either kit, it is easy to demonstrate that a moving coil of wire near a magnet, or a moving magnet near a coil of wire will induce a voltage, and therefore a current. Simply move a magnet into the coil as shown in Figure 2, and a galvanometer will show a current flow.

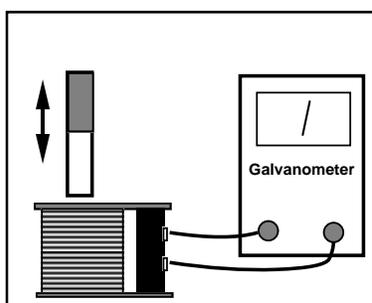


Figure 2

Moving the magnet back out will yield a current in the opposite direction. Reversing the magnet will reverse the relative currents, also. Leaving the magnet at rest inside the coil will produce no current. Thus, a change in relationship

between the magnet and coil is needed. The effect of moving slow versus moving fast can be demonstrated.

Finally, changing the number of coils of wire and repeating the process will complete an initial investigation. These investigations are generally semi-quantitative, focusing on relative sizes and directions. Another way to change the magnetic field is to provide an alternating magnetic field through the use of a second coil and an alternating current. See Figure 3.

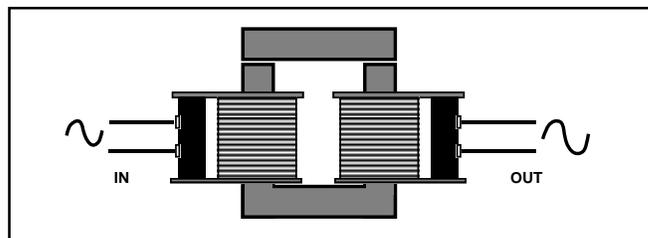


Figure 3

The Coils Set provides multiple coils and cores to experiment with this principle. These investigations lead to the basic relationships involved in transformers, and lead to more advanced studies of self- and mutual-induction.

With the addition of two magnets and small springs, a classic interaction of induced current and electromagnetic effects, plus simple harmonic motion, can be studied. See Figure 4.

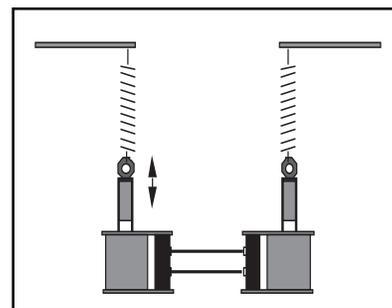


Figure 4

Suggested Experimental Approach

Demonstrate the basic principle of using the core and two coils to make a transformer. Show coils, core(s), supplies, loads, meters, etc. Have students develop areas of investigation and then proceed to carry them out. "Research teams" could investigate different factors and then combine their results for a comprehensive look at transformers.

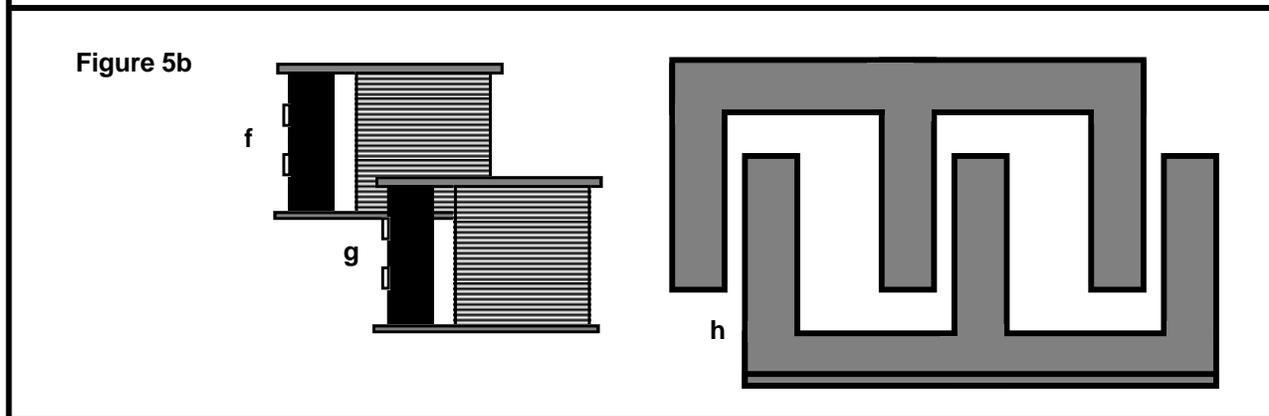
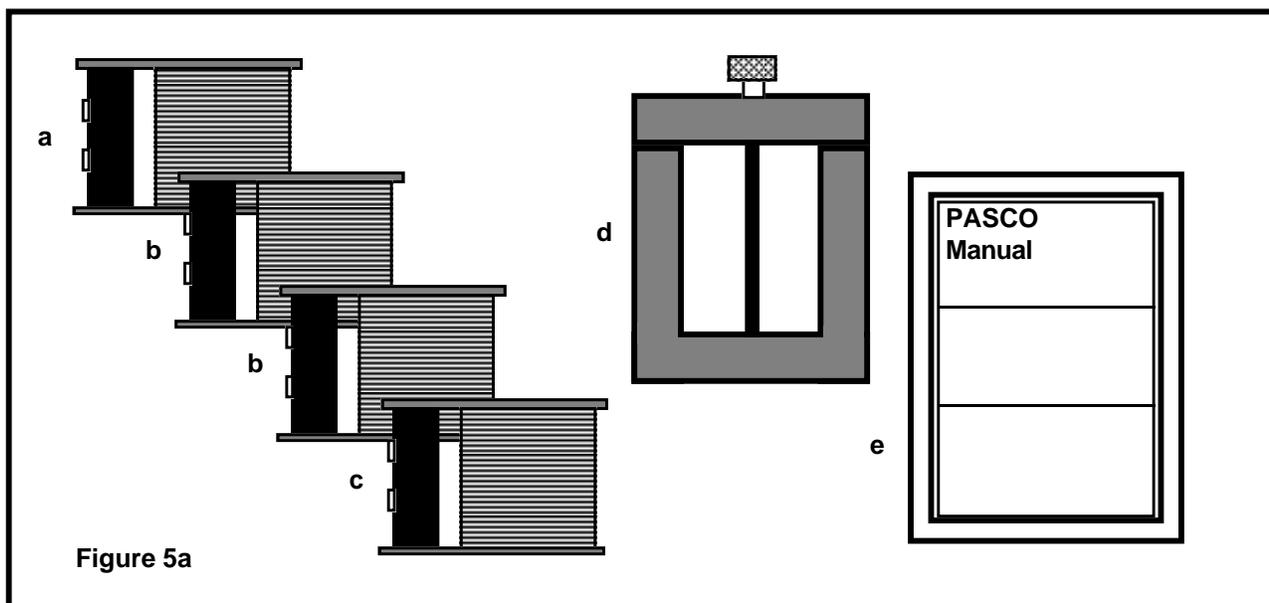
Equipment Supplied

Your SF-8616 Basic Coils Set comes with the items shown in Figure 5a:

- a. (1) SF-8609 200-turn Coil
- b. (2) SF-8610 400-turn Coils
- c. (1) SF-8611 800-turn Coil
- d. (1) SF-8614 U-shaped Core
- e. (1) Manual

Your SF-8617 Complete Coils Set comes with all of the items in the SF-8616 Basic Coils Set along with the following additional items, as shown in Figure 5b:

- f. (1) SF-8612 1600-turn Coil
- g. (1) SF-8613 3200-turn Coil
- h. (2) SF-8615 E-shaped Core



Experiments

Nature of Magnetic Field from an Electromagnet

The coils from your PASCO Coils Set can be used in conjunction with a d.c. power supply or a battery to produce constant magnetic fields. Three possible experiments are shown below.

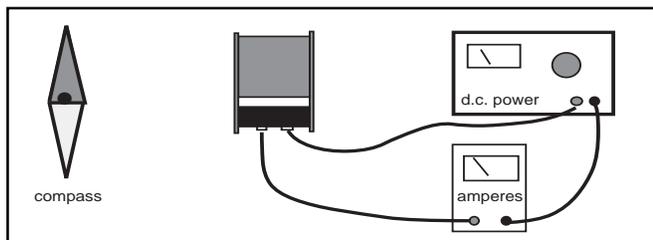


Figure 6

In Figure 6, a d.c. power supply is connected to the coil. A nearby magnetic compass is used to show the presence of a magnetic field and its direction. By noting the direction of the windings on the coil (See Figure 7), students can develop the rule for current direction and the resulting magnetic field direction. This experimental setup can be quantified, leading to a determination of how much current, through how many turns, is needed to produce a magnetic field equal to the earth's field. Specifics of the experimental design are left to the teacher and student.

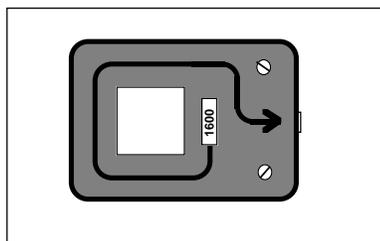


Figure 7

In Figure 8a and 8b, a coil is shown with its magnetic axis parallel to the table. A piece of cardboard is mounted so that it can be inserted into the center of the coil and extend beyond it on all sides. Iron filings are then sprinkled on the cardboard around the end of the current carrying coil. The magnetic field pattern can be quickly demonstrated.

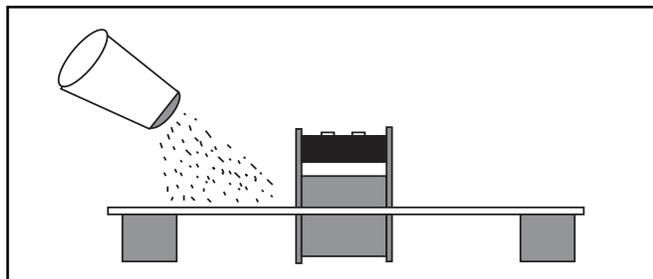


Figure 8a

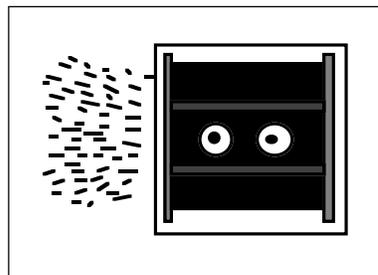


Figure 8b

ALTERNATIVE: Small magnetic compasses can be used to probe around the coil to show its magnetic field.

Figure 9 shows a current carrying coil with a magnetic field inside. The cross-piece from the U-shaped Core is shown inserted in the coil, although the same experiment can be performed without the core. The strength of the electromagnet thus produced could be tested in a number of ways, including the use of the PASCO SF-8606 Digital Gauss/Tesla Meter. Note that the dramatic increase in magnetic field strength with the addition of a core can be clearly demonstrated.

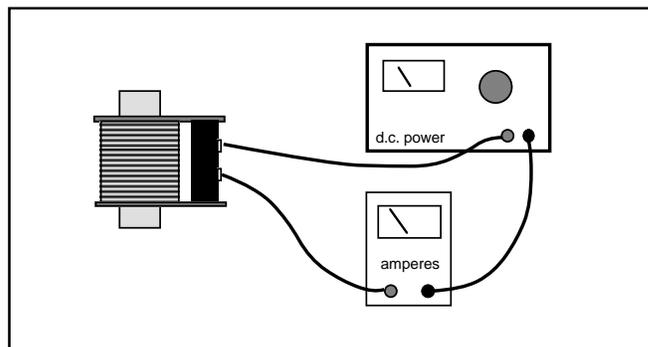


Figure 9

Solenoid

If the cross piece from the U-shaped Core is inserted into a coil, but not centered, it will be pulled into the coil when the alternating current is turned on. This demonstrates the basic action of a solenoid. In experiments with the 400-turn coil, a voltage of 8-10 volts A.C. was successful in demonstrating this principle. See Figure 10.

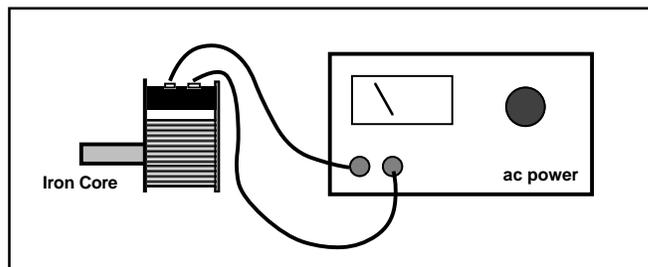


Figure 10

Electromagnetic Induction

Use a small, relatively strong bar magnet to demonstrate electromagnetic induction. It is only necessary to move the magnet up and down in the center of the coil. If the coil is attached to a galvanometer, the relative size of the induced current and the direction can be noted. See Figure 11.

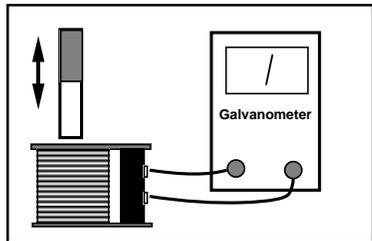


Figure 11

A second way of showing the effect is to connect the coil to an oscilloscope. See Figure 12

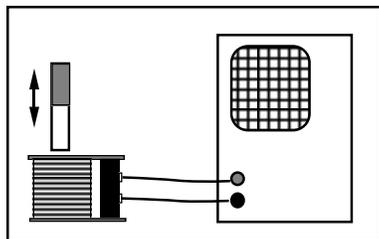


Figure 12

NOTE: A galvanometer shows the current produced, which should be proportional to the size of the induced voltage. Due to mechanical damping, galvanometers do not rise to the maximum value, but give useful semi-quantitative measurements of the maximum currents. An oscilloscope shows the size of the induced voltage directly, and gives a more instantaneous value.

The set-up below gives a method of “automatically” showing the induced voltage. A light spring which gives a nice simple harmonic motion with the attached magnet is needed. Note that the method of attaching the magnet is via a machine nut which is hooked to the spring and held by the magnetic field of the magnet. See Figure 13.

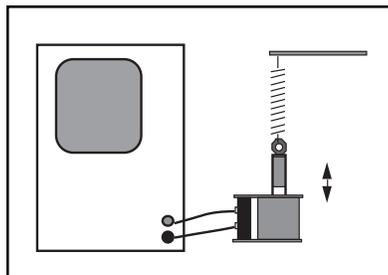


Figure 13

TRANSFORMERS

Leading directly to the study of transformers, the setup in Figure 14 allows students to see how induction can proceed by passing magnetic field between the two coils. Using air as the medium between the two coils, PASCO's experiments

showed a drop-off to an output voltage of less than 20% from the input voltage when the two 400-turn coils were used in this manner.

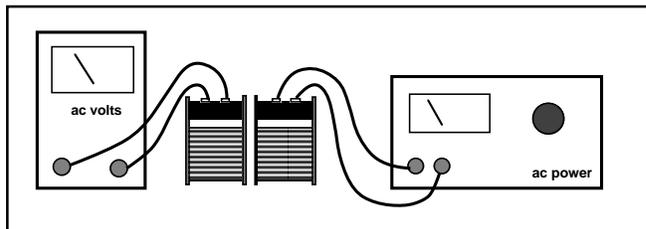


Figure 14

To improve the mutual induction, an iron core can be introduced. See Figure 15. Using the cross piece from the U-shaped core, the induced voltage increased to almost 50% of the primary voltage under the same conditions as above.

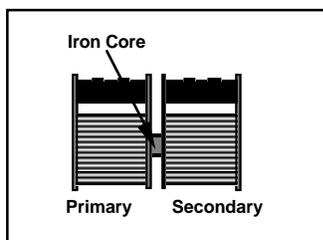


Figure 15

Numerous modifications of the cores which are provided can be investigated. In each case, the ratio of secondary voltage to primary voltage is noted. The variables in this situation thus become: Primary Number of Turns, Secondary Number of Turns, Existence of a Core, Shape of the Core, Primary Voltage, Primary Current, Secondary Voltage and Secondary Current. Students can be led on directed studies, or given the materials to develop their own experiments. Some possibilities are shown in Figure 16 below.

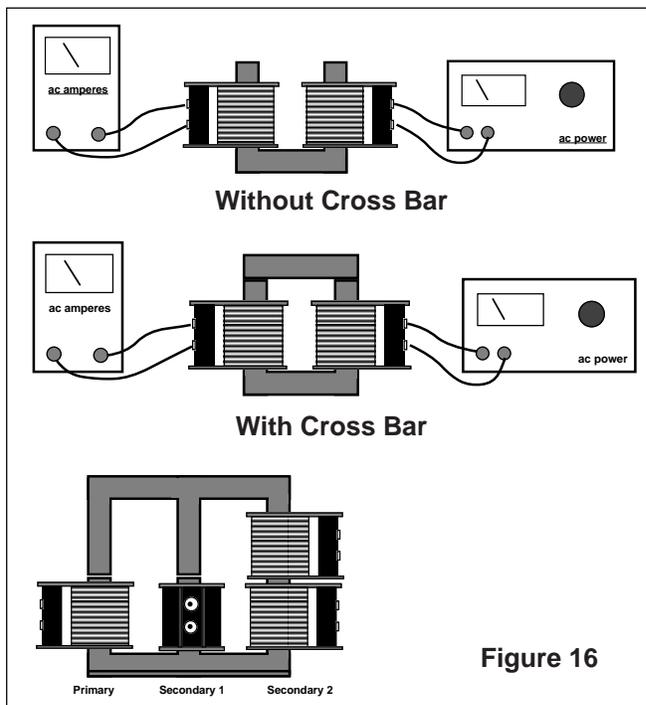


Figure 16

Experiment 1: Transformer Basics I

Introduction

When an alternating current passes through a coil of wire, it produces an alternating magnetic field. This is precisely the condition needed for the electromagnetic induction to take place in a second coil of wire. In this lab you will investigate several of the factors influencing the operation of a transformer.

Equipment Needed - Supplied

1. The four coils from the PASCO SF-8616 Basic Coils Set
2. The U-shaped Core from the PASCO SF-8616 Basic Coils Set
3. Optional: the additional coils from the PASCO SF-8617 Complete Coils Set

Equipment Needed - Not Supplied

1. Low voltage ac power supply 0-6 VAC, 0-1 amp such as PASCO Model SF-9582
2. AC voltmeter 0-6 VAC
3. Banana connecting leads for electrical connections

Procedure

1. Set up the coils and core as shown in Figure 1. In the diagram, the coil to the left will be referred to as the primary coil, and the one to the right will be the secondary coil. Note that we are putting in an alternating current to the primary at one voltage level, and reading the output at the secondary.

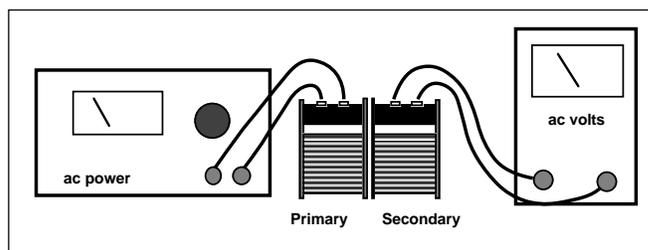


Figure 1

2. With the 400-turn coil as the primary and the 400-turn coil as the secondary, adjust the input voltage to 6 volts a.c. Measure the output voltage and record your results in Table 1.1.
3. Repeat step 2 after inserting the straight cross piece from the top of the U-shaped core. Record your results. (See Figure 2.)

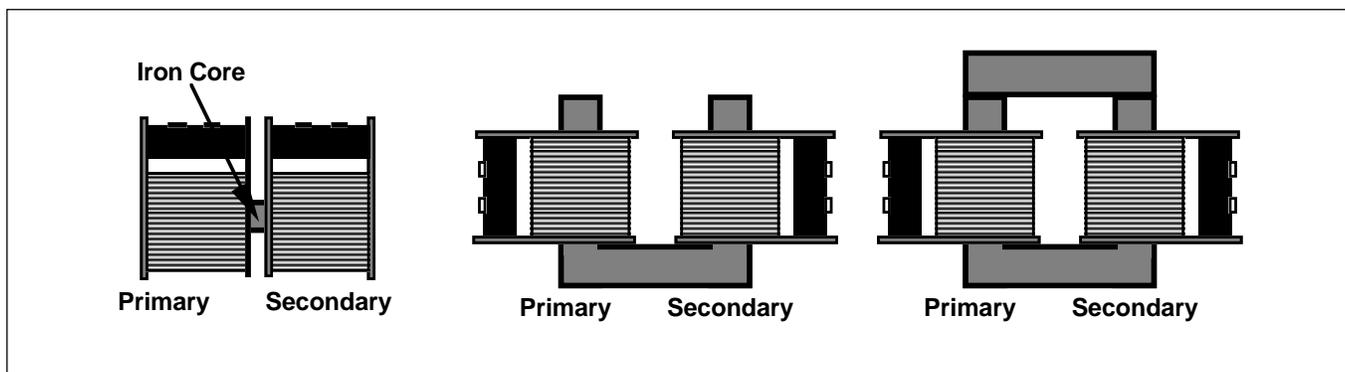


Figure 2

4. Repeat step 2 after placing the coils on the sides of the open U-shaped core. Record your results.
5. Finally, repeat step 2 after placing the cross piece over the U-shaped core. Record your results.
6. Using the core configuration which gives the best output voltage compared to input voltage, try all combinations of primary and secondary coils. Use a constant input voltage of 6.0 volts a.c. Record your data in Table 1.2.

Analysis

1. Which core configuration gives the maximum transfer of electromagnetic effect to the secondary coil? Develop a theory to explain the differences between configurations.
2. From your data in table 1.2, for a primary having a constant number of turns, graph the resulting output voltage versus the number of turns in the secondary. What type of mathematical relationship exists between numbers of turns of wire and the resulting output voltage? Is the data ideal? Why or why not?
3. Consider further improvements to your transformer. What additional changes might you make to increase the transfer from one coil to the other?

Data and Calculations

Table 1.1

Number of Turns		Input V	Output V	Core
Primary Coil	Secondary Coil			

Table 1.2

Core Configuration: _____

Number of Turns		Input V	Output V	Core
Primary Coil	Secondary Coil			

Experiment 2: Transformer Basics II

Introduction

In this lab you will investigate several of the factors influencing the operation of a transformer. In Experiment 1, the output factor was voltage as measured when there was nothing connected to the secondary (infinite resistance). In this lab, you will investigate input and output currents, in addition to voltages, with normal sized resistances in the secondary circuit.

Equipment Needed - Supplied

1. The four coils from the PASCO SF-8616 Basic Coils Set
2. The U-shaped Core from the PASCO SF-8616 Basic Coils Set
3. Optional: the additional coils from the PASCO SF-8617 Complete Coils Set

Equipment Needed - Not Supplied

1. Low voltage ac power supply 0-6 VAC, 0-1 amp such as PASCO Model SF-9582
2. One or two AC ammeters 0-2 A
3. Three resistors: 10Ω , 2 Watt; 100Ω , 2 Watt; 1000Ω , 2 Watt
4. Banana connecting leads for electrical connections

Procedure

1. Set up the coils, core and $1000\text{-}\Omega$ load resistor as shown in Figure 1. In the diagram, the coil to the left will be referred to as the primary coil, and the one to the right will be the secondary coil. Note that we provide an alternating current at the primary at one voltage level, and read the output at the secondary at possibly a different value.
2. With the 400-turn coil as the primary and the 400-turn coil as the secondary, adjust the input voltage to 6.0 volts a.c. With a load resistance of $1000\ \Omega$ connected to the secondary, measure the input current, the output voltage and the output current. Record your results in Table 2.1.
3. Repeat step 2 after connecting in a $100\ \Omega$ load resistance.
4. Repeat step 2 after connecting in a $10\ \Omega$ load resistance.
5. Finally, repeat steps 2-4 after changing the secondary coil. Continue changing the coils until you have tested all combinations of input and output coils.
6. Replace the secondary coil with a relatively large diameter wire (18-20 gauge) wound around the core 5-6 times. See Figure 2. Again set the input voltage to the primary at 6.0 vac. Connect the ammeter to this new secondary, measuring the current when the resistance is only that of the ammeter. With the ammeter disconnected, measure the output voltage.
7. If you have the SF-8617 Complete Coils Set, arrange the primary and secondary coils as shown in Figure 3. Run the same set of experiments you did in steps 2-4, collecting the same items of data.

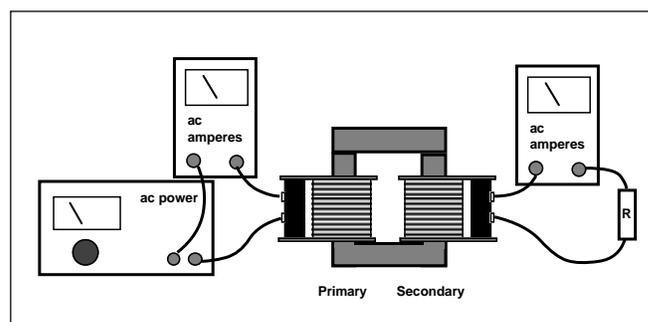


Figure 1

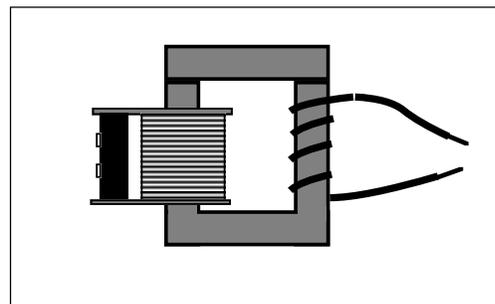


Figure 2

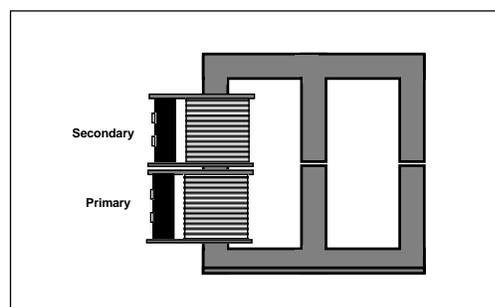


Figure 3

Note: Other configurations can be investigated once you have the E-shaped core. At your instructor's direction, investigate other methods of arranging the primary and secondary coils.

8. If there are more than one PASCO Coils Sets in the laboratory, set up a series of transformers such as the one diagrammed below in Figure 4. Measure input and output voltages, input and output currents at various places in the chain. Keep careful track of your measurements and draft your observations based on these measurements.

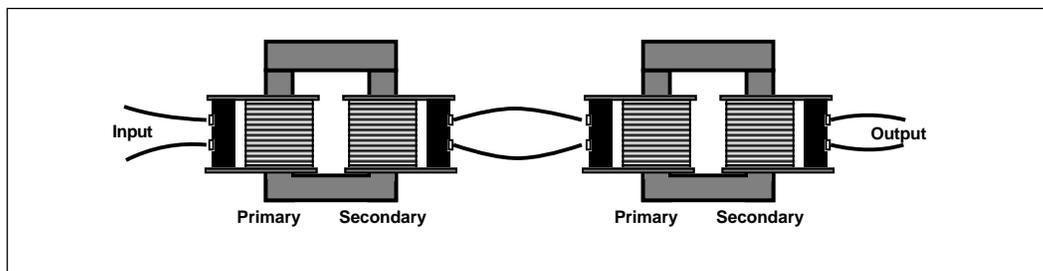


Figure 4

Analysis

1. Calculate the quantities asked for in Table 2.2. Note the suggestion at the bottom of the page. If you were able to carry out the modification in step 7, a separate data table should be constructed.
2. What relationship exists between the output current and the input current for different coils given a constant load resistance? How does varying the load resistance change the output current/input current relationship for a given combination of coils? Is the effect the same for all combinations? Elaborate and make an educated hypothesis on why your experiment behaved the way it did.
3. The ideal voltage gain is equal to the number of turns in the secondary divided by the number of turns in the primary. How did the actual voltage gain (V_{out} / V_{in}) compare to the ideal?
4. Ideally, transformers convert alternating current from one voltage to another with very little power loss (almost 100% efficient). Looking at your power gain (P_{out} / P_{in}), how did your transformers do compared to ideal transformers?
5. What combination of voltage and current is gained by having few coils of wire in the secondary? (step 6)
6. Analyze the behavior of the coils in the E-shaped core, and compare this to the U-shaped core. Is there a distinct advantage of one over the other? Why? Can an advantage gained be further enhanced by other changes? What might they be? (step 7)
7. If you began and ended with the same number of turns in your coils (step 8), how did the input and output voltages compare? How did the input and output power for the total combination compare? Were principles you experimented with previously in evidence during this part of the lab?

Data and Calculations

Table 2.1

Trial #	Number of Turns		Load R	Input V	Input I	Output V	Output I
	Primary	Secondary					

Table 2.2

Trial #	Input P	Output P	Voltage Gain	Power Gain

NOTE: It is recommended that the data collected above in Table 2.1 be gathered into a spread sheet program. Calculations of the input and output power, the voltage gain and power gain for Table 2.2 can quickly and easily be made using the spread sheet. Additionally, the data can be rearranged quickly to make it easy to analyze.

Notes:

Experiment 3: Springing into Electromagnetic Induction

Introduction

In this lab an interesting arrangement will allow you to investigate some of the subtleties of electromagnetic induction. The results will be qualitative, contrary to many of the labs you have done recently!

Equipment Needed - Supplied

1. The PASCO Model SF-8616 Basic Coils Set

Equipment Needed - Not Supplied

1. Two small, relatively strong magnets
2. Two springs with low force constants
3. Several machine nuts
4. Two ring stands
5. Banana connecting leads for electrical connections

Procedure

1. Set up the two 400-turn coils, the magnets, springs and ring stands as shown in Figure 1. See Figure 2 to see how the springs “attach” to the magnets.

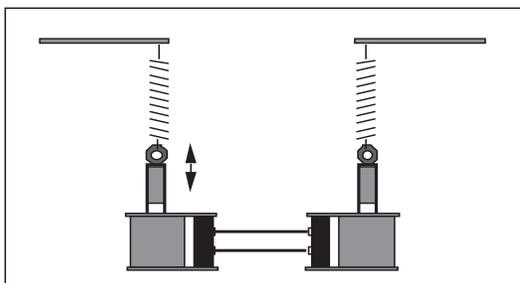


Figure 1

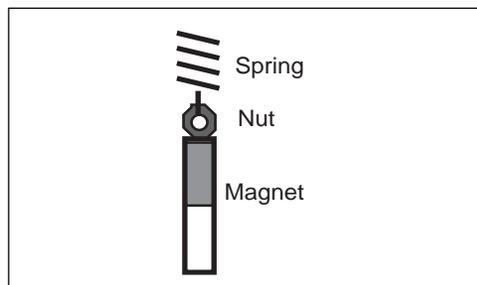


Figure 2

2. Move the magnet in one coil upward and then release it so that it sets up simple harmonic motion. Note the reaction of the second magnet. Can you arrive at an explanation as to why this is happening?
3. PREDICTION 1: What will happen if you reverse the leads in one of the two coils and repeat step 2? Try it to see if your prediction is accurate.
4. PREDICTION 2: What will happen if you were to use additional masses on one magnet, thereby increasing its period of SHM? Try this by adding several machine nuts onto the bottom of the magnet. Adjust the height of the ring stand as needed.
5. PREDICTION 3: What will happen if you were to use a different spring on one magnet? Try it.
6. PREDICTION 4: What will happen if you use a different number of coils on one side? Try it.
7. PREDICTION 5: What will happen if you insert another coil into the circuit, as shown in Figure 3? Try it. Does it make a difference if different coils are used? Try it.
8. PREDICTION 6: What will happen if you put a core into the third coil that you used in step 6? Why? Try it.

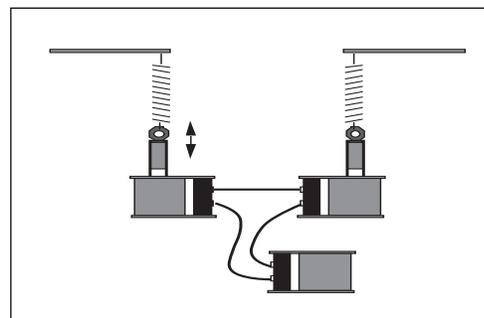


Figure 3

Analysis

1. Why did the magnets behave as they did? How does your observation relate to electromagnetic induction?
2. What was the effect of changing the polarity of the leads connecting the two coils? Why?
3. Why did the behavior change as a result of changing the mass of the magnet and/or the spring which was used?
4. Try to develop an explanation to cover the observations you made in steps 6-8. You may wish to begin considering energy!

Experiment 4: Intermediate Transformers

Introduction

In this lab you will continue investigating transformers. You will investigate additional core configurations and work into d.c. power supplies, one of the key applications of transformer technology.

Equipment Needed - Supplied

1. The PASCO SF-8617 Complete Coils Set

Equipment Needed - Not Supplied

1. Low voltage ac power supply 0-6 VAC, 0-1 amp such as PASCO Model SF-9582
2. AC voltmeter 0-6 VAC
3. AC ammeter 0-2 A
4. Oscilloscope
5. Two diodes 1 amp, 50 PIV (min) rectifiers such as 2N4007
6. Resistor 1000 Ω , 2 Watt
7. Capacitor 470 μ F
8. Banana connecting leads for electrical connections

Procedure A

1. Set up the coils and core as shown in Figure 1. In the diagram, the coil to the left will be referred to as the primary coil, and the center one will be the secondary coil.
2. With the 200-turn coil as the primary and the 800-turn coil as the secondary, adjust the input voltage to 6.0 volts a.c. With a resistance of 1000 Ω connected to the secondary, measure the input current, the output voltage and the output current. Record your results in Table 4.1.
3. Now replace the 800-turn coil with the two 400-turn coils, stacked on the same arm of the E-shaped core. With the two coils connected as shown in Figure 2, with a load resistance of 1000 ohms, measure the input and output currents and voltages. Record your results in Table 4.1.
4. Reverse the leads to one of the coils and re-measure the currents and voltages. Record your results. How did the results compare with step 3? What did you change and why did you get the results you did?
5. Now move the two 400-turn coils to the third arm of the core. How do the values for current and voltage compare to those seen in the previous position of the coils? How would these values compare with a single 800-turn coil? Set up the single 800-turn coil and test your hypothesis.
6. Measure the individual voltages and currents of the 400-turn coils of the secondary when they are connected to the 1000- Ω resistance in the configuration which gave you the biggest output voltage and current. How do the two values compare with one another? Do they add or subtract to any specific values? Do the values you obtain in the experiment support your understanding of basic series circuits? Change the leads on one coil and re-measure the individual voltages and the total voltage. Why do you get your end result?

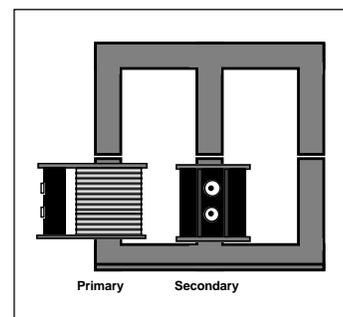


Figure 1

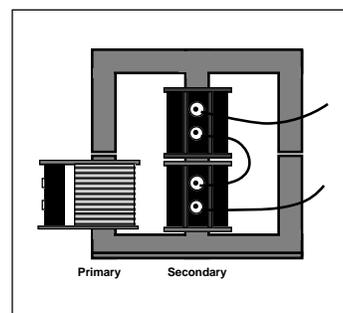


Figure 2

Procedure B

- Set up the 200-turn coil as primary, and the 800-turn coil as the secondary. Put a diode into the circuit as shown in Figure 4, and leave the 1000- Ω resistor in as a load.
- In this step, set the triggering of your oscilloscope to "LINE". This stabilizes the sweep so that it is synchronized with the a.c. line voltage. Now connect the ground lead (often a clip lead) from your oscilloscope to point A in Figure 3, and the probe to point B. Note the waveform. With the probe at point C, again note the waveform and also any differences between that and the one found at point A. How would you describe this difference?

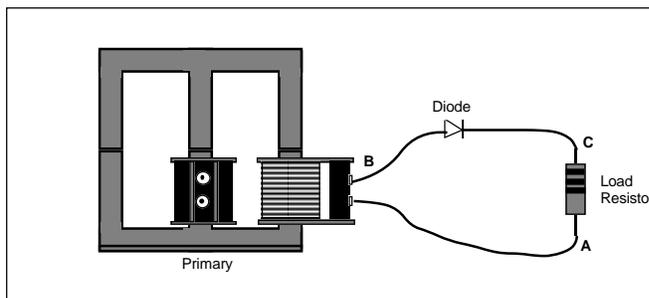


Figure 3

- The waveform seen across the load resistance (A to C) is called a half-wave rectified signal. Half of the full sine wave passes through the diode, with the other half being blocked. This produces a directional current (d.c.) but one that is constantly changing in magnitude. To be useful, the voltage level must be made constant. The addition of an electronic "damper" should accomplish this.
- Add the 470 μF capacitor as shown in Figure 4. What is the new waveform across the load resistor? Is it still varying as much as it did previously? What is the d.c. level of the resulting voltage?
- Now change the 1000- Ω resistor to a 10- Ω resistor in the same circuit. How does this affect the waveform? How does it affect the d.c. voltage?

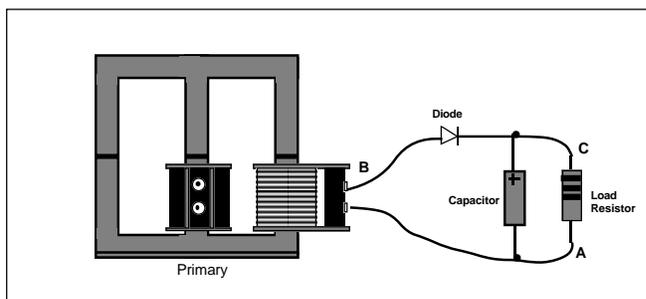


Figure 4

Procedure C

- Now connect the two 400-turn coils so that they have maximum voltage and current output. With the 1000- Ω resistor as a load, connect the leads of the oscilloscope between points A and B as shown in Figure 5. What is the shape of the wave form? What is the waveform between points A and C? How does the size of the waveform between A and B compare to that between A and C?
- In this step, set the triggering of your oscilloscope again to "LINE". Connect the ground lead (often a clip lead) from your oscilloscope to point B in Figure 5. With the probe at point A, note the waveform. With the probe at point C, again note the waveform and also any differences between that and the one found at point A. How would you describe this difference?
- Now we will make the difference in waveforms useful to us. Connect two diodes into your apparatus as shown in Figure 6. How does the waveform across the load resistance look? How does it differ from the waveforms you have seen in previous steps? Is this still alternating current, or is it directional (direct) current?

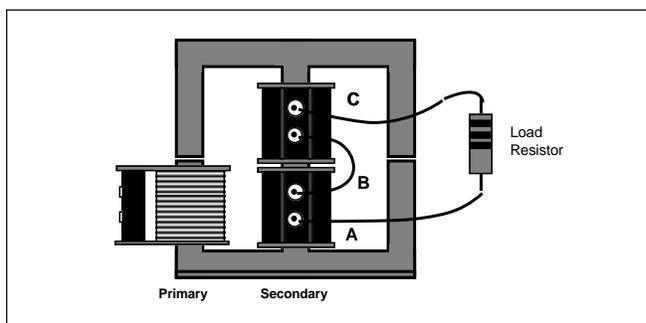


Figure 5

15. The end result in step 14 is the production of a full-wave rectified signal, one which is directional in nature, although it varies in amplitude over time. We will now add in a 470- μF capacitor as shown in Figure 7.
16. What is the new waveform across the load resistor? Do you have d.c., yet? What is the d.c. voltage you've produced?
17. Now replace the 1000- Ω load resistance with a 10- Ω resistor. What is the effect on the d.c. voltage compared to the 1000- Ω resistance? What is the effect on the waveform?

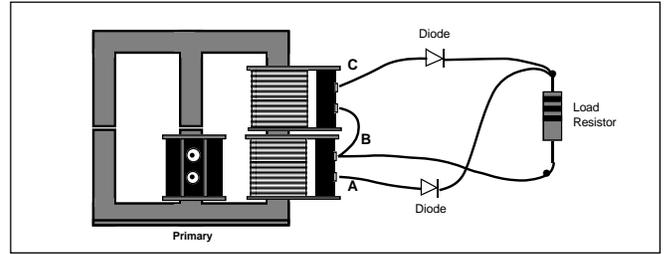


Figure 6

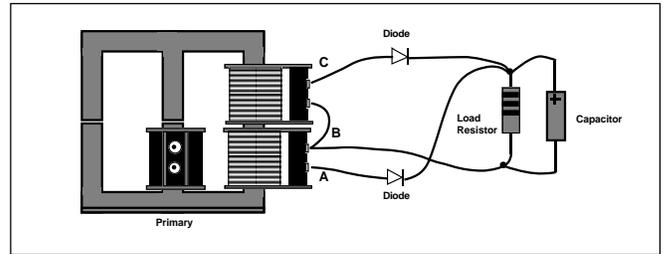


Figure 7

Analysis

1. Answer the questions which have been posed along the way during the procedure.
2. Why do you get such different results if you place the secondary coil(s) on the second or third leg of the E-shaped core? Think about the magnetic circulation that must take place within the core.
3. Compare the results of lowering the load resistance on a half-wave rectified circuit with lowering the load resistance on a full-wave rectified circuit. If you were to try to stabilize the output of a power supply, which would be better, a half-wave or full-wave rectified signal?
4. This experiment has introduced the concept of transformers and power supplies. Further reading and experimentation can easily begin from here and lead to profitable new understanding.

Data and Calculations

Table 4.1

Number of Turns		Input V	Input I	Load R	Output V	Output I
Primary	Secondary					

Appendix

Technical Data

PASCO Part No.	Number of Turns in Coil	Wire dia. mm	Maximum Current rms Amperes	DC Resistance ohms	AC Impedance ohms		Self- inductance mH
					50 Hz	60Hz	
SF-8609	200	0.9	2 A	0.6	0.64	0.65	0.67
SF-8610	400	0.65	1 A	2.2	2.4	2.5	3.2
SF-8611	800	0.45	0.5 A	7.7	8.7	9.1	13.5
SF-8612	1600	0.33	0.25 A	35.4	39	40.5	52
SF-8613	3200	0.22	0.125 A	151	164	170	207

Technical Support

Feed-Back

If you have any comments about this product or this manual please let us know. If you have any suggestions on alternate experiments or find a problem in the manual please tell us. PASCO appreciates any customer feed-back. Your input helps us evaluate and improve our product.

To Reach PASCO

For Technical Support call us at 1-800-772-8700 (toll-free within the U.S.) or (916) 786-3800.

Contacting Technical Support

Before you call the PASCO Technical Support staff it would be helpful to prepare the following information:

- If your problem is computer/software related, note:

Title and Revision Date of software.

Type of Computer (Make, Model, Speed).

Type of external Cables/Peripherals.

- If your problem is with the PASCO apparatus, note:

Title and Model number (usually listed on the label).

Approximate age of apparatus.

A detailed description of the problem/sequence of events. (In case you can't call PASCO right away, you won't lose valuable data.)

If possible, have the apparatus within reach when calling. This makes descriptions of individual parts much easier.

- If your problem relates to the instruction manual, note:

Part number and Revision (listed by month and year on the front cover).

Have the manual at hand to discuss your questions.

