TRANSFORMER

OBJECTIVE:

You will understand the principle of electromagnetic induction and will construct a model transformer to demonstrate how it is used to change the voltage of an alternating current.

INTRODUCTION:

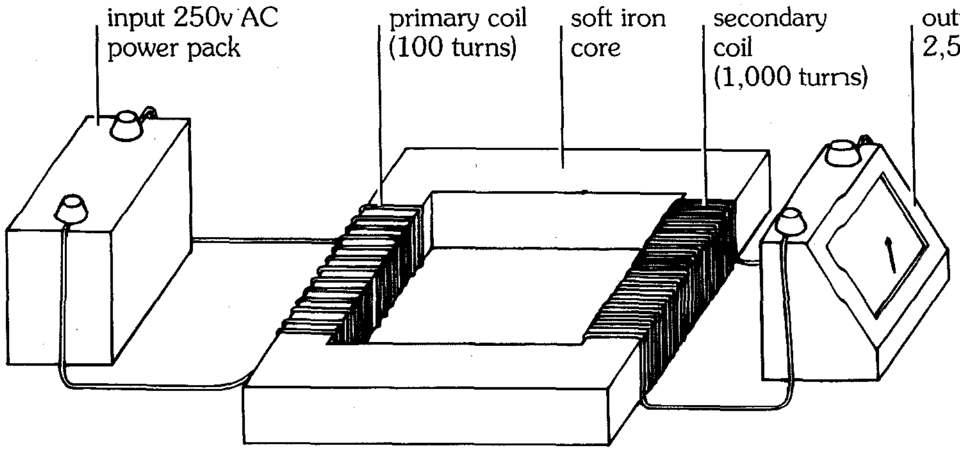
A transformer is an electrical device that transfers electrical energy from one coil of wire to another. In so doing it allows the voltage of the current to be increased or decreased. The coils are not connected electrically to one another; instead the influence of one coil on the other is a magnetic effect—called electromagnetic induction.

The principle of electromagnetic induction was first described by the American physicist Joseph Henry (1797–1878) in 1830. He was able to show that the inductive effect was a highly efficient way to transfer an alternating electric current from one circuit to another. In 1831 English physicist Michael Faraday (1791–1867) invented the induction coil, which demonstrated the inductive effect and was a precursor to the transformer. In 1850 German instrument maker Heinrich Daniel Ruhmkorff (1803–1877) invented the first true transformer that used alternating current (AC) electricity. When generators began to be used to supply electricity to the public in the 1880s, they produced only direct current (DC) electricity. This was inefficient, because the electricity had to be used at the same voltage at which it was generated, and because high voltages would be dangerous to users, power was generated at low voltages. The transformer made it possible to alter the voltage; its development heralded the revolution in electrical power supplies which took place in the late nineteenth and early twentieth centuries.

In a transformer, if the two coils have the same number of turns then the voltage induced in the second coil will be about the same size as that in the first. If the energized (primary) coil has more turns than the receiving (secondary) coil, then the voltage is reduced. If the receiving coil has more turns than the energized coil, then the voltage is increased (see figure 1). AC electricity (or DC electricity which is switched on and off) is needed to run a transformer because the inductive effect of one coil on another depends on an electromagnetic field that is constantly changing.

Because of their simple, rugged construction, transformers need little care and maintenance. The efficiency of a transformer is high, typically 95–99%. Because of this, and their ability to vary voltage easily, transformers are the main reason for the extensive use of alternating current in delivering electrical power to homes and businesses. They are also used to make the voltage changes required to transmit electricity from power stations (where it is sent out at very high voltages for greater efficiency) to users (where the voltage is decreased for safety).

Figure 1 A step-up transformer (increased voltage)



TIME NEEDED:

1 hour

MATERIALS:

AC/DC power pack
AC/DC high-impedance galvanometer with center zero
150cm length of bell wire
2 75cm lengths of bell wire
4 60cm lengths of bell wire
insulating tape
wire strippers
screwdriver with chrome-plated steel blade about 20 cm long and 0.6–0.7 cm in diameter

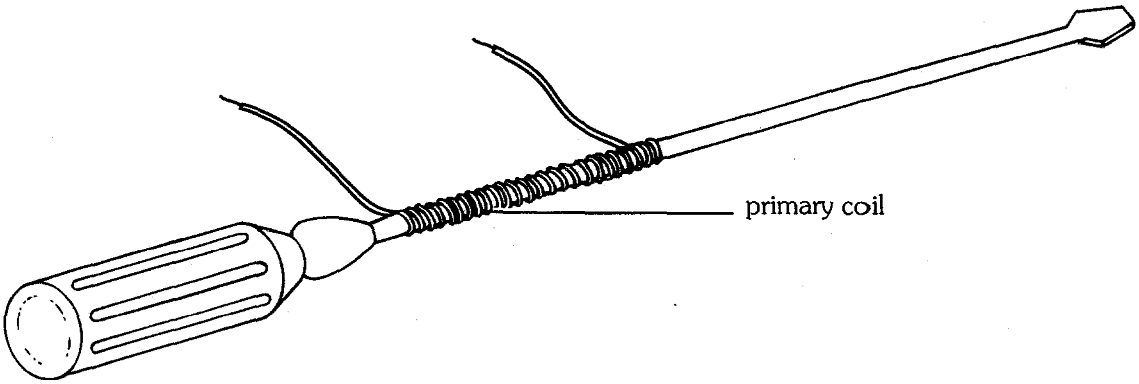
Safety Precautions

Adult supervision required. Please read and copy the safety precautions at the beginning of this book. Make sure all bell wire connections are protected with insulating tape before using the wire in an electrical circuit.

PROCEDURE:

1. Using wire strippers, strip 1 cm of insulation off both ends of all lengths of bell wire.
2. Wind a 75cm length of bell wire 25 times around the end of the screwdriver blade nearer the handle as shown in figure 2, leaving at least 10 cm of wire hanging free at both ends. This will form the primary (energized) coil. Wind the other 75cm length of bell wire around the screwdriver blade in the same way, but leaving a 2.5cm gap between this coil and the first. This will form the secondary (receiving) coil.

Figure 2



3. Complete the electrical circuit for the primary coil by connecting a 60cm length of bell wire to each of the wire ends extending from the coil with insulating tape. Connect the other ends of the 60cm wires to the power pack (see figure 3). Wrap insulating tape around each connection so that no bare wire is left exposed.
4. Repeat step 3 for the secondary coil, connecting it to the galvanometer instead of the power pack (see figure 3).
5. Switch the power pack to DC and turn on the voltage supply to 3 volts, at the same time noting the reading on the galvanometer in the secondary coil circuit. Then turn the DC power pack off, again noting any change in reading on the galvanometer.
6. Switch the power pack to AC and repeat step 5.
7. Remove the secondary coil on the screwdriver and replace it with a 150cm length of bell wire coiled 50 times around the screwdriver blade (see figure 4). Now repeat the procedure in step 6, switching the AC power supply to 3 volts and then switching it off again, while noting the readings on the galvanometer.

Figure 3

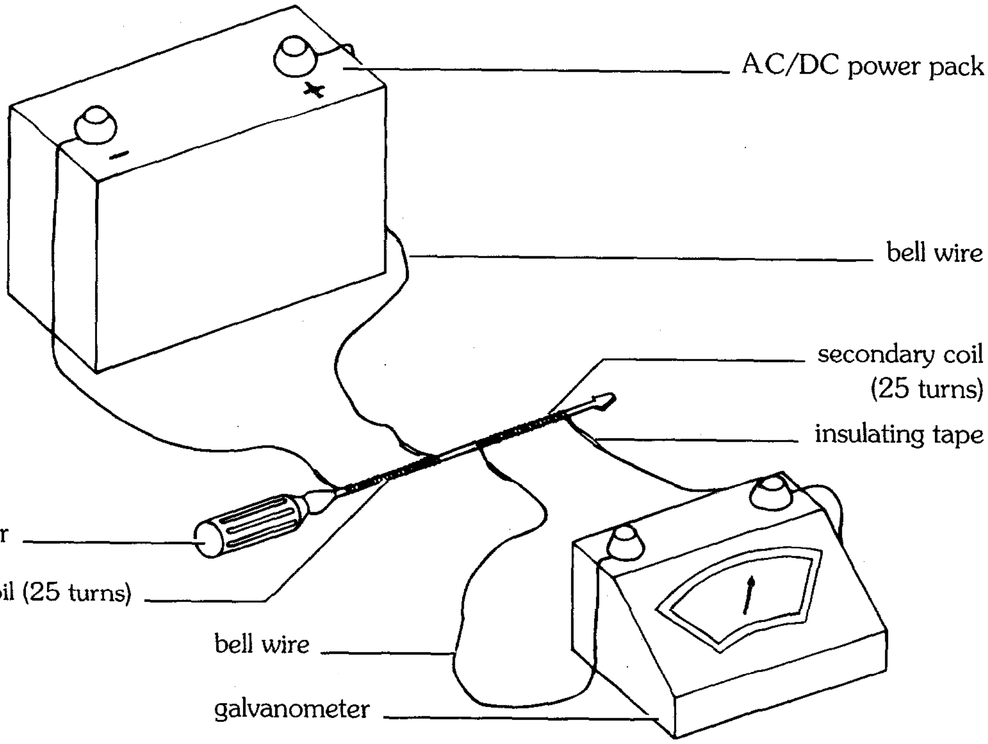
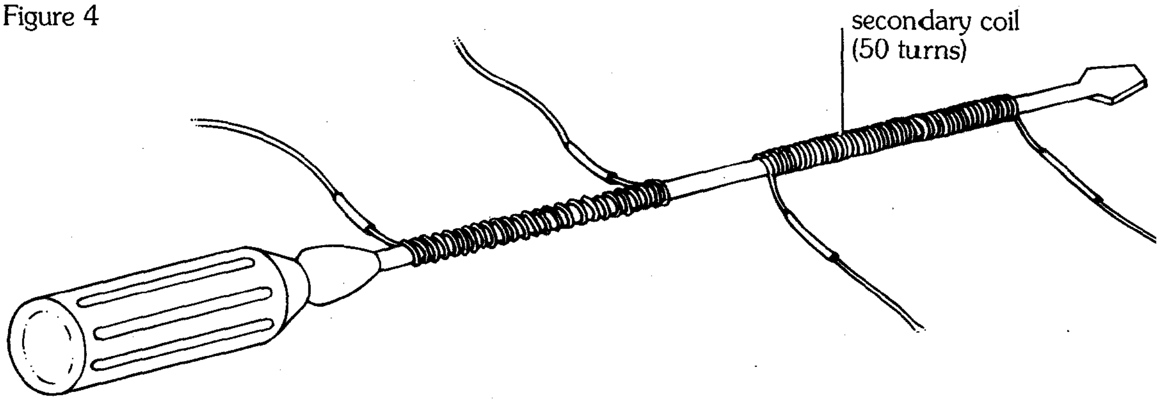


Figure 4



ANALYSIS:

1. In step 5, what did the galvanometer reading show when the power pack was turned on? What did it show when the power pack was turned off? What conclusion can you draw about this?
2. In step 6, what happened to the galvanometer reading when you turned the power pack on and then off?
3. Taking into account your observations in steps 5 and 6, what causes the galvanometer readings you observe?
4. In step 7, what were the readings when you turned the power pack on and then off?
5. Based on your observations in step 7, predict what the galvanometer reading would be if you used a secondary coil with a 225cm length of bell wire wound 75 times around the screwdriver blade. How did you arrive at your prediction?
6. Do some research to find out:
   a) What is the turns ratio as applied to transformers?
   b) What is the relationship between the turns ratio, the applied voltage in the primary coil, and the induced voltage in the secondary coil?
   c) What is the turns ratio in a step-up transformer? What is the turns ratio in a step-down transformer?

OUR FINDINGS:

Click on above link to see what we found.

SPECIAL SAFETY NOTE TO INVESTIGATORS

Each invention includes any special safety precautions that are relevant to that particular project. These do not include all of the basic safety precautions that are necessary whenever you are working on a scientific investigation. For this reason, it is absolutely necessary that you read, copy, and remain mindful of the General Safety Precautions that follow this note.

Experimental science can be dangerous, and good laboratory procedure always includes carefully following basic safety rules. Things can happen very quickly when you are constructing or demonstrating a model invention. Things can spill, break, even catch fire. There will be no time after the fact to protect yourself. Always prepare for unexpected dangers by following basic safety guidelines the *entire* time you are carrying out the project, whether or not something seems dangerous to you at a given moment.

We have been quite sparing in prescribing safety precautions for the individual projects. We made this choice for one reason: We want you to take very seriously every safety precaution that is printed in this book. If you see it written here, you can be sure that it is here because it is absolutely critical to your safety.

One further note: The book assumes that you will read the safety precautions that follow, as well as those in the box within each project you are preparing to perform, and that you will *remember* them. Except in rare instances, these precautions will not be repeated in the procedure itself. It is up to you to use your good judgment and pay attention when performing potentially dangerous parts of the procedure. Just because the book does not say BE CAREFUL WITH HOT LIQUIDS or DON'T CUT YOURSELF WITH THE KNIFE does not mean that you should be careless when simmering water or stripping an electrical wire. It does mean that when you see a special note to be careful, it is extremely important that you pay attention to it.

If you ever have a question about whether a procedure or material is dangerous, wait to perform it until you find out for sure that it is safe.

GENERAL SAFETY PRECAUTIONS

Accidents caused by carelessness, haste, insufficient knowledge, or taking unnecessary risks can be avoided by practicing safety procedures and being alert while carrying out these projects. Be sure to check the individual projects in this book for additional safety regulations and adult supervision requirements. If you will be working in a lab, do not work alone.

PREPARING:
—Clear all surfaces before beginning projects
—Read the instructions before you start
—Know the hazards of the procedures and anticipate dangers

PROTECTING YOURSELF:
—Follow the directions step-by-step; do only one project at a time
—Locate exits, fire blanket and extinguisher, master gas and electricity shut-offs, eye wash, and first-aid kit
—Make sure there is adequate ventilation
—Do not horseplay
—Wear an apron and goggles
—Do not wear contact lenses, open shoes, loose clothing, or loose hair
—Keep floor and work space neat, clean, and dry
—Clean up spills immediately
—Never eat, drink, or smoke in laboratory or work space
—Do not eat or drink any substances tested unless expressly permitted to do so by a knowledgeable adult

USING EQUIPMENT WITH CARE:
—Set up apparatus far from the edge of the desk or bench
—Use knives and other sharp or pointed instruments with caution
—Pull plugs, not cords, when removing electrical plugs
—Clean glassware before and after use
—Check glassware for scratches, cracks, and sharp edges
—Clean up broken glassware immediately
—Do not touch metal conductors
—Use only low voltage and current materials such as lantern batteries
—Be careful when using stepstools, chairs, and ladders
—Never look directly at the sun with your observation devices

USING CHEMICALS:
—Never taste or inhale chemicals
—Label all bottles and apparatus containing chemicals
—Read labels carefully
—Avoid chemical contact with skin and eyes (wear goggles, apron, and gloves)
—Do not touch chemical solutions
—Wash hands before and after using solutions
—Wipe up spills thoroughly

HEATING SUBSTANCES:
—Use goggles, apron, and gloves when boiling water
—Keep your face away from test tubes and beakers
—Never leave apparatus unattended
—Use safety tongs and heat-resistant mittens
—Turn off hot plates, bunsen burners, and gas when you are done
—Keep flammable substances away from heat
—Have fire extinguisher on hand

FINISHING UP:
—Thoroughly clean your work area and glassware
—Be careful not to return chemicals or contaminated reagents to the wrong containers
—Don't dispose of materials in the sink unless instructed to do so
—Wash your hands
—Clean up all residue and put in proper containers for disposal
—Dispose of all chemicals according to all local, state, and federal laws

BE SAFETY CONSCIOUS AT ALL TIMES

Our Findings

VIII. ELECTRICITY

8.05 Transformer

1. When the power pack is turned on the galvanometer deflects in a positive direction; when it is switched off it deflects in a negative direction. A rise or fall in the voltage in the primary coil causes an induced voltage in the secondary coil.
2. In step 6, as long as the power pack is on, the voltage recorded across the secondary coil is similar to that across the primary coil.
3. The induced voltage in the secondary coil is set up by a changing voltage in the primary coil—either by switching a DC supply on and off, or by the changing voltage of an AC current.
4. In step 7, when the primary coil is receiving a 3-volt alternating current the voltage reading across the secondary coil is about double this value—probably 5–6 volts.
5. The voltage across the secondary coil would be about three times that of the primary coil—probably 8–9 volts. In step 7, doubling the number of turns in the secondary coil approximately doubles the induced voltage; other things being equal, tripling the number of turns should approximately triple the voltage.
6. a) The turns ratio is the ratio of the number of turns in the secondary coil to the number of turns in the primary coil of a transformer—i.e.:

$$\text{turns ratio} = \frac{\text{no. of turns in secondary coil}}{\text{no. of turns in primary coil}}$$

b) The turns ratio is equal to the induced voltage divided by the applied voltage:

$$\text{turns ratio} = \frac{\text{no. of turns in secondary coil}}{\text{no. of turns in primary coil}} = \frac{\text{induced voltage in secondary coil}}{\text{applied voltage in primary coil}}$$

c) In a step-up transformer (one where the voltage is increased), the turns ratio is greater than 1. In a step-down transformer (one where the voltage is decreased), it is less than 1.