Basic Electricity and Electronics

Magnetism and Electromagnetism

F.A.C.E.T.®
by
Lab-Volt®

Student Workbook

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Table of Contents

Introduction

This Student Workbook provides a unit-by-unit outline of the Fault Assisted Circuits for Electronics Training (F.A.C.E.T.) curriculum.

The following information is included together with space to take notes as you move through the curriculum.

- The unit objective
- Unit fundamentals
- A list of new terms and words for the unit
- Equipment required for the unit
- The exercise objectives
- Exercise discussion
- Exercise notes

The **Appendix** includes safety information.

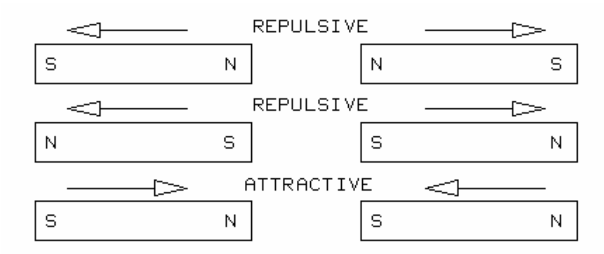
UNIT 1 – MAGNETISM

UNIT OBJECTIVE

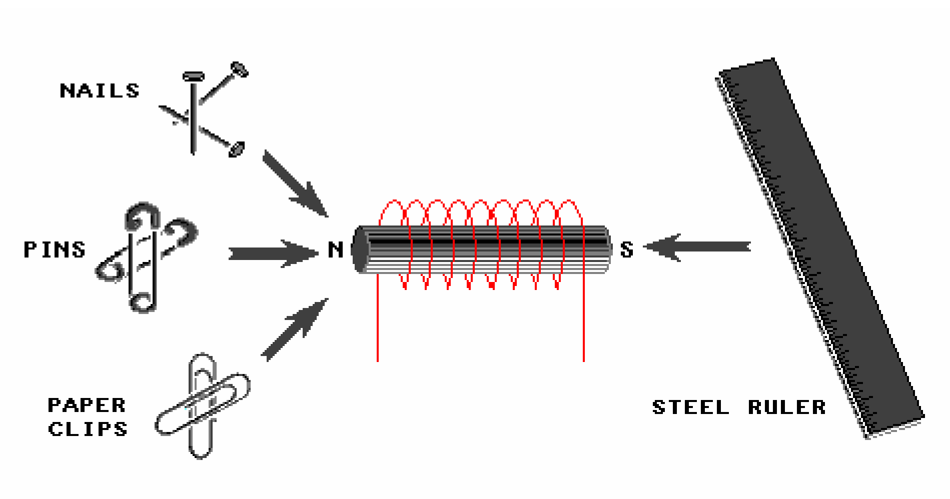
At the completion of this unit, you will be able to describe and demonstrate the effects of magnetism by using magnets and a compass.

UNIT FUNDAMENTALS

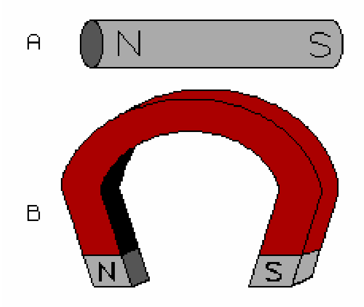
Magnetism is a phenomenon that occurs naturally in some metallic materials. It can also be produced by electrical currents (electromagnetism). In this unit, you will learn about natural **magnets**.



Magnets exert a force on other magnets. This force may cause the magnets to attract each other (**attractive force**) or to repel each other (**repulsive force**).

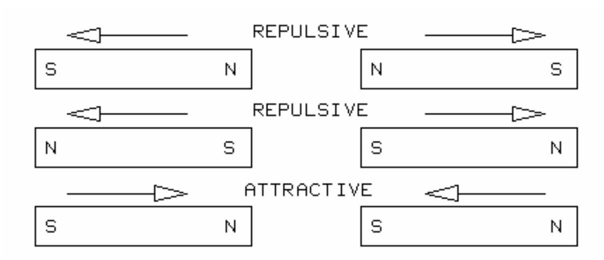


Magnets also exert a force on other magnetic materials that are not magnets themselves. These materials will be discussed later.

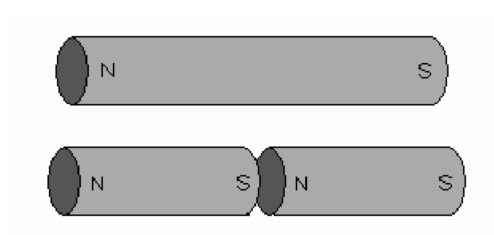


Two of the most familiar types of magnets are the bar magnet (A) and the horseshoe magnet (B). Their names reflect their physical shape.

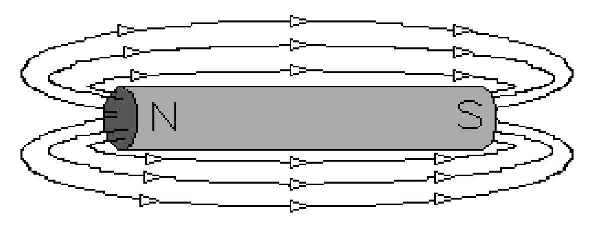
A magnet's **pole** is the area where its magnetic force is strongest. Magnets of virtually any shape have a north (N) pole at one end and a south (S) pole at the other. The type of pole determines whether the magnet will attract or repel a particular pole of another magnet.



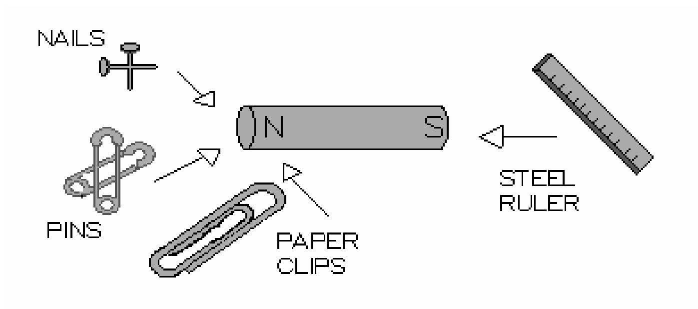
These arrows represent the direction of the attractive or repulsive magnetic forces. If a pole of one magnet is moved toward the similar pole of a second magnet (north to north or south to south), the magnets repel, or push away from, each other. If a pole of one magnet is moved toward the opposite pole of a second magnet (north to south), the magnets attract, or pull toward, each other. This relationship can be stated simply: opposite poles attract and like poles repel.



Breaking a magnet in half results in two smaller, weaker magnets, each with its own north and south pole. It does not result in one magnet having just a north pole and the other having just a south pole.



The direction of a bar magnet's force is shown here by **lines of force** which originate from the north pole and travel to the south pole. The lines of force closest to the magnet represent the strongest magnetic force. The force becomes progressively weaker for the lines of force further away from the magnet. You can't see a magnet's lines of force, but you can see their effects.



A magnet also exerts a force on objects that are not magnets themselves but that are made of iron or have an iron content. The force is attractive only, and it is exerted by both the north and south poles of the magnet. Magnets are used in many electric and electronic devices, including telephones, televisions, radar, audio speakers, alarms, and motors. Magnets come in all sizes. Some are small enough to hold in your hand, and others, such as the large electromagnets found in junkyards, are powerful enough to lift several tons of scrap metal.

NEW TERMS AND WORDS

magnets - objects having a magnetic field that attracts or repels magnetic materials.
attractive force - a force that tends to pull 2 objects toward each other. A magnet's pole attracts magnetic objects or the opposite pole of another nearby magnet.
repulsive force - a force that tends to push 2 objects away from each other. A magnet's pole repels the similar pole of another nearby magnet.
pole - the area on a magnet where magnetic force is strongest. Every magnet has 1 north pole and 1 south pole.
lines of force - invisible lines that represent the strength and density of a magnetic materials.
magnetic field - an area where magnetic force is present.
permanent magnets - pieces of hardened steel or other magnetic material which has been so strongly magnetized that they retain the magnetism indefinitely.
temporary magnet - a magnet whose field quickly loses its magnetic power.

EQUIPMENT REQUIRED

F.A.C.E.T. base unit
Multimeter
MAGNETISM/ELECTROMAGNETISM circuit board

NOTES

Exercise 1 – The Compass

EXERCISE OBJECTIVE

When you have completed this exercise, you will be able to explain and demonstrate the function of a compass by using a bar magnet. You will verify your results with a compass.

DISCUSSION

- One of the most familiar applications of a magnet is the compass.
- A compass needle is actually a small magnet that is loosely suspended at its center so there is as little friction as possible to impede movement.
- Earth itself is actually a large magnet.
- The north pole of the compass needle, when not affected by other nearby magnetic forces, always points to Earth's geographic north pole.
- The south pole of Earth's magnet is commonly called **magnetic north** because it attracts a compass needle's north pole.
- Similarly, the north pole of Earth's magnet is commonly called **magnetic south**.
- Because of the compass's magnetic relationship to Earth's poles, it has been used for centuries as a navigational device.
- When a bar magnet is suspended loosely from a string or rubber band, it simulates the action of a compass needle.
- A loosely suspended bar magnet moves so that its north pole points to magnetic north and its south pole points to magnetic south.

NOTES

Exercise 2 – Magnetic Fields

EXERCISE OBJECTIVE

When you have completed this exercise, you will be able to identify the invisible field around a magnet by using iron filings. You will verify your results by observing patterns formed by the filings.

DISCUSSION

- A magnet has lines of force that originate at its north pole and flow to its south pole.
- The lines of force surrounding a magnet make up its **magnetic field**.
- The lines near the magnet's poles have the highest density (are closest together), so the magnetic force is strongest here.
- Midway between the poles, the lines are farthest apart, so the magnetic force here is weakest.
- The lines of force for a horseshoe magnet are strongest where the poles are closest to each other.
- Weaker lines of force radiate outward between the poles.
- Additional weaker lines travel completely around the outside of the magnet's shape.
- A common way to demonstrate the configuration of a magnetic field is with iron filings.
- In the presence of a magnet, iron filings align themselves with the magnet's field.

NOTES

Exercise 3 – Making a Magnet

EXERCISE OBJECTIVE

When you have completed this exercise, you will be able to make a magnet by using parts included with the MAGNETISM/ELECTROMAGNETISM circuit board. You will verify your results with an ordinary paper clip.

DISCUSSION

- The types of magnets discussed in the previous exercises, such as bar magnets and horseshoe magnets, are **permanent magnets** because they are always surrounded by their own magnetic field.
- A **temporary magnet** is an object that becomes a magnet only when placed in a magnetic field.
- A temporary magnet retains its own magnetic field for a short period of time, then loses it.
- You can make a temporary magnet from an object made of iron or one that has an iron content, such as an iron nail.
- The north pole of the bar magnet creates a south pole at the adjacent end of the nail.
- The south pole of the bar magnet creates a north pole at the opposite end of the nail.
- A nail magnetized in this way retains a weaker magnetic field of its own even after the permanent magnet is removed.
- The nail loses its magnetic field if it is subjected to a sharp blow or dropped on a hard surface.

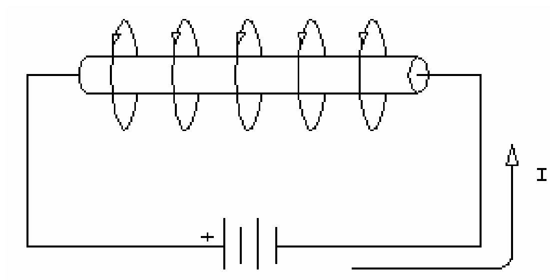
NOTES

UNIT 2 – ELECTROMAGNETISM

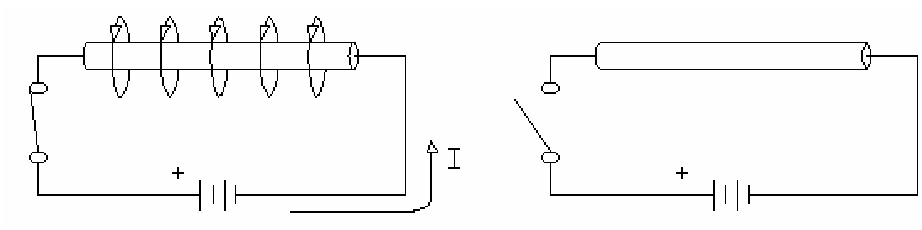
UNIT OBJECTIVE

At the completion of this unit, you will be able to describe and demonstrate electromagnetism by using electromagnetic devices. You will verify your results with a solenoid and a relay.

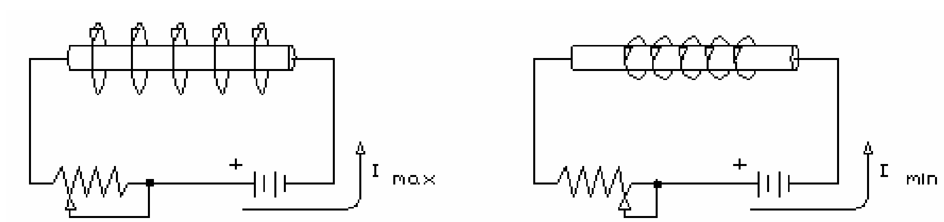
UNIT FUNDAMENTALS



Electromagnetism is a form of magnetism created when current flows through a conductor. When current is present, it generates a magnetic field around the conductor similar to that of a permanent magnet. When current is removed, the magnetic field disappears.



One way an electromagnet differs from a permanent magnet is that you can switch an electromagnet's field on and off by simply switching current on and off.



You can also vary the strength of an electromagnet's field by increasing or decreasing the applied current.

Electromagnets are used extensively for recording media such as magnetic tapes and disks. They are also used in the automotive, communications, scientific, and many other industries. Familiar examples of electromagnets are relays, solenoids, alarm bells, car alternators, and electric motors.

NEW TERMS AND WORDS

Electromagnetism - the magnetic field around a wire or other conductor when current passes through it.
left-hand rule - when the left hand is placed around a current-carrying conductor so that the thumb points in the direction of current (electron) flow, the other fingers will point in the direction of the magnetic field; when the fingers of the left hand are placed around an electromagnet in the direction of current (electron) flow, the thumb will point to the north magnetic pole.
field intensity - the strength of a magnetic field.
solenoid - an electromagnet with a sliding core.
plunger - the sliding core of a solenoid.
stroke - the range of motion of a solenoid's sliding core.
relay - an electromechanical device with contacts that are opened and closed by an electromagnet.
armature - a relay's moving element, which is attracted by an electromagnet.
hysteresis - the difference between a device's response to an increasing signal and a decreasing signal.
isolation - the separation between a device's response to an increasing signal and a decreasing signal.

EQUIPMENT REQUIRED

F.A.C.E.T. base unit
Multimeter
MAGNETISM/ELECTROMAGNETISM circuit board

NOTES

Exercise 1 – The Electromagnet

EXERCISE OBJECTIVE

When you have completed this exercise, you will be able to explain the operation of an electromagnet by using a coil of wire. You will verify your results with a compass and an iron nail.

DISCUSSION

- An electromagnet is an electrical conductor that generates a magnetic field around itself when current passes through it.
- To determine the direction of the field lines, you can use a convention known as the **left-hand rule**.
- When you grasp the conductor with your left hand so that your thumb points in the direction of current (electron) flow, the magnetic field flows in the direction that your other fingers curl around the conductor.
- A conductor formed into a loop has a more concentrated magnetic field at the center of the loop.
- The field can be concentrated further by winding the conductor into a coil and inserting an iron core in the center.
- The strength, or intensity, of the magnetic field is proportional to the applied current and the number of turns of the coil. It is also inversely proportional to the length of the coil.
- Just like the permanent magnet, the electromagnet has a north and a south pole, and it attracts only objects made of iron or that have an iron content.
- You can use the left-hand rule to determine the poles of an electromagnet.
- When you grasp the coil with your left hand so that your fingers curl in the direction of current (electron) flow, your thumb points to the electromagnet's north pole.
- You can reverse the north and south poles by reversing either the direction of current flow or the direction in which the wire is wound around the coil.

NOTES

Exercise 2 – The Solenoid

EXERCISE OBJECTIVE

When you have completed this exercise, you will be able to describe and demonstrate the operation of a solenoid by using an electromagnet. You will verify your results by visual observations.

DISCUSSION

- An iron core partially inserted into an electromagnet's coil is pulled into the coil when you apply current.
- This device, called a solenoid, can be very useful in electromechanical systems because it translates electrical power into a mechanical motion.
- In practice, an iron core slightly smaller than the coil's inside diameter is used in a solenoid. This allows the core to slide freely back and forth in a straight line.
- The moving core of a solenoid is also called a **plunger**.
- In many cases, a return spring is attached between the movable plunger and a fixed point.
- The plunger travels back and forth between two distinct points.
- The plunger's range of motion is called its **stroke**.
- Practical solenoids have strokes ranging from a fraction of an inch up to 3 inches.
- This two-position linear motion is useful in many practical applications such as operating a valve, opening and closing one or more electrical circuits, engaging gears, and operating clutches and brakes.
- Solenoids are designed in a variety of sizes, configurations, and strokes. They are available for a wide range of ac and dc voltages.

NOTES

Exercise 3 – The Relay

EXERCISE OBJECTIVE

When you have completed this exercise, you will be able to demonstrate the operations of a relay by using several relay circuits. You will verify your results with visual observations.

DISCUSSION

- A **relay** is a type of switch operated by an electromagnet.
- The relay's electromagnet has a stationary core.
- The **armature** is a moving element that is attracted to the core when the coil is energized.
- When the coil is de-energized, the magnetic field disappears, and a spring returns the armature to its original position.
- When the armature moves up and down, it operates a set of switch contacts.
- The common contact is mounted to the armature. It alternately connects to the normally open (NO) and normally closed (NC) contacts.
- You can configure relays to have many other multiple-pole switches by stacking additional contacts on the armature.
- Like the solenoid, the relay translates electrical power into mechanical motion.
- Since the relay coil is an inductor, it is often represented schematic-ally by the inductor symbol.
- Another way to represent the coil is by a rectangle with two leads for the coil connections.
- The schematic symbol for relay contacts is similar to that of standard switch contacts.
- A dashed line indicates a mechanical connection (the spring-loaded armature) between the coil and the contacts.
- A relay coil has a nominal voltage rating (V_N) for ideal operation; however, the relay also operates at voltages below the nominal rating.
- If you start from 0V and increase voltage, you will reach the point at which the armature pulls in. This is the pull-in voltage (V_P).
- If you start from V_N and decrease voltage, you will reach a point at where armature is released. This is the dropout voltage (V_D).
- Pull-in (V_P) and dropout (V_D) occur at different voltages. The window between the pull-in and dropout is called **hysteresis**.
- If switching occurred at the same point for increasing and decreasing voltage (without hysteresis), the relay would chatter, which means it would turn on and off with every small change in voltage.
- An important feature of relays is the isolation between the input and output circuits. This means that no electrical connection exists between the coil and the switch contacts.

- Isolation allows you to switch one or more circuits having voltages and currents that are incompatible with those used to drive the relay coil. For example, a 10 Vdc relay coil can be used to switch a 220 Vac circuit.
- One common application for a relay is a buzzer, which can be used as an audible alarm or an attention getting device.
- You can make a buzzer by wiring the relay coil to a voltage source through a switch and the relay's contacts.
- The time needed for the armature to move down once the coil is energized is the relay's **pull-in time**.
- The time needed for the armature to return to its original position once the coil de-energizes is the **dropout time**.
- The pull-in and dropout times determine the frequency of the buzzing sound.
- Another common relay application is an electromechanical latch. The importance of the latch is that you can create a maintained contact by momentarily pushing a button.

NOTES

APPENDIX A – SAFETY

Safety is everyone's responsibility. All must cooperate to create the safest possible working environment. Students must be reminded of the potential for harm, given common sense safety rules, and instructed to follow the electrical safety rules.

Any environment can be hazardous when it is unfamiliar. The F.A.C.E.T. computer-based laboratory may be a new environment to some students. Instruct students in the proper use of the F.A.C.E.T. equipment and explain what behavior is expected of them in this laboratory. It is up to the instructor to provide the necessary introduction to the learning environment and the equipment. This task will prevent injury to both student and equipment.

The voltage and current used in the F.A.C.E.T. Computer-Based Laboratory are, in themselves, harmless to the normal, healthy person. However, an electrical shock coming as a surprise will be uncomfortable and may cause a reaction that could create injury. The students should be made aware of the following electrical safety rules.

1. Turn off the power before working on a circuit.
2. Always confirm that the circuit is wired correctly before turning on the power. If required, have your instructor check your circuit wiring.
3. Perform the experiments as you are instructed: do not deviate from the documentation.
4. Never touch "live" wires with your bare hands or with tools.
5. Always hold test leads by their insulated areas.
6. Be aware that some components can become very hot during operation. (However, this is not a normal condition for your F.A.C.E.T. course equipment.) Always allow time for the components to cool before proceeding to touch or remove them from the circuit.
7. Do not work without supervision. Be sure someone is nearby to shut off the power and provide first aid in case of an accident.
8. Remove power cords by the plug, not by pulling on the cord. Check for cracked or broken insulation on the cord.