ASE 6 - Electrical Electronic Systems

Module 9

Electro-Magnetic Induction

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Module 9 – Electro-Magnetic Induction

Objective

At the end of this section, the technician will be able to explain the use and operation of automotive circuit components that use electromagnetic induction, including relays, solenoids, and transformers.

Magnetism

Magnetism provides a link between mechanical energy and electricity. By the use of magnetism, an automotive generator converts some of the mechanical power developed by the engine to electromotive force potential (EMF). Going the other direction, magnetism allows a starter motor to convert electrical energy from the battery into mechanical power to crank the engine.

A magnet can be any object or device that attracts iron, steel, and other magnetic materials. There are three basic types of magnets:

Natural

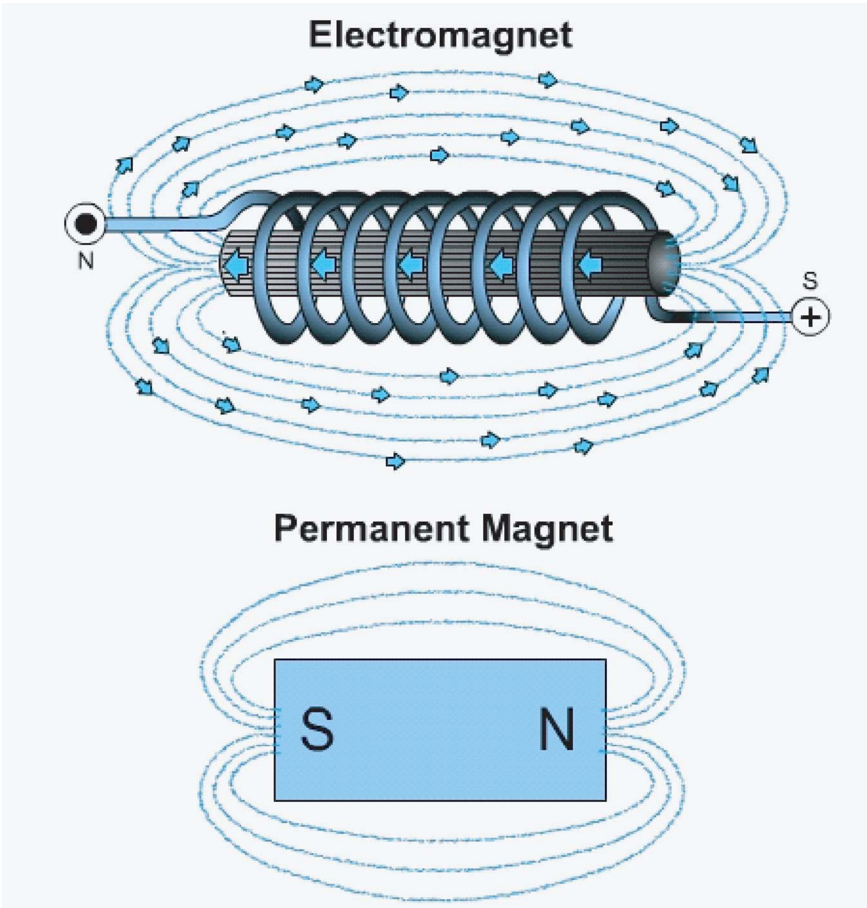
Man-made

Electromagnets

Magnetic materials occur naturally as small stones. These stones are actually Iron ore. Man-made magnets are typically made of metal bars, which have been subjected to a very strong magnetic field. Electromagnets use electric current to create a magnetic field.

A magnet has two poles; we call these the north and south poles. In a bar magnet, the poles are located at opposing ends. Poles behave somewhat like electrical charges, in that like poles repel and unlike poles attract.

A magnetic field is made up of many invisible lines of force. These lines are called "lines of flux." They come out of one pole and enter the other pole. The flux lines are concentrated at the poles and spread out into the areas between the poles.



A weak magnet has relatively few flux lines; a strong magnet has many. The number of flux lines is sometimes described as “flux density.” A magnet with high flux density has many lines and is, therefore, a strong magnet, while a magnet with low flux density has relatively few lines, and is a weak magnet.

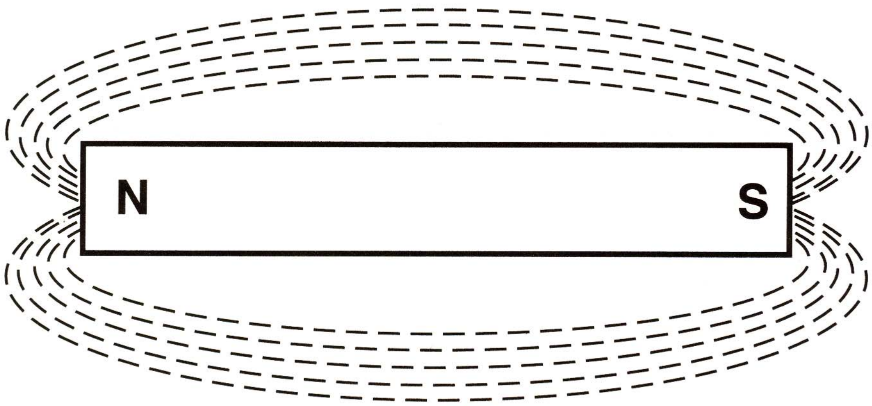


Figure 9-1, Lines of Magnetic Flux

Magnetic Force

Magnetic lines of force pass through all materials; there is no known insulator against magnetism. However flux lines pass more easily through materials that can be magnetized than through those that cannot. Materials that do not readily pass flux lines are said to have "high magnetic reluctance." Air has high reluctance; iron has low reluctance.

Electric current flowing through a wire creates magnetic lines of force around the wire. Thee lines form small circles around the wire. Because such flux lines are circular, the magnetic field has no north or south pole. However, if the wire is wound into a coil, individual circular fields merge. The result is a unified magnetic field with north and south poles. As long as current flows through the wire, it behaves just like a bar magnet.

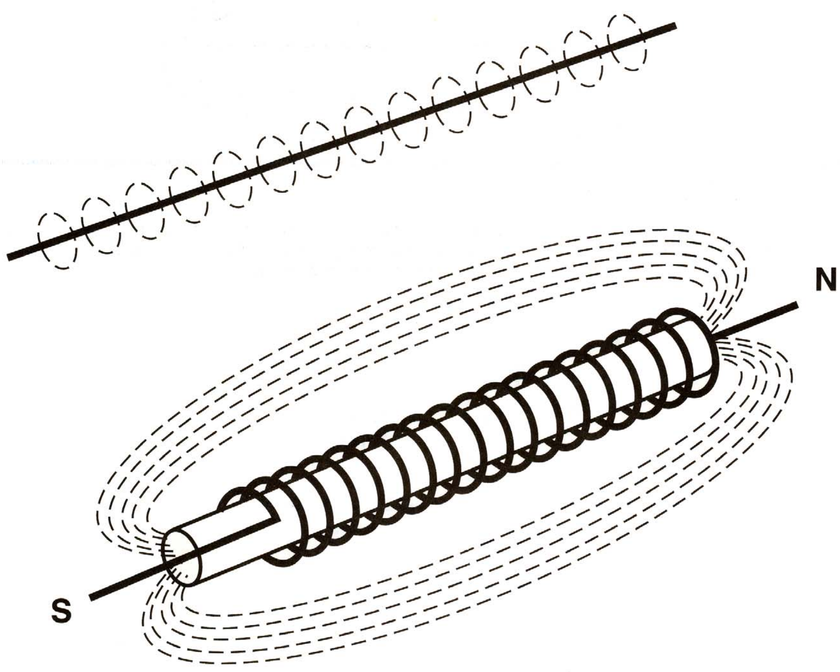


Figure 9-2, Electromagnetic Fields

The electromagnetic field remains as long as current flows through the wire. However, the field produced on a straight wire does not provide enough magnetism to do work. To strengthen the electromagnetic field, the wire can be formed into a coil, The magnetic strength of an electromagnet is proportional to the number of turns of wire In the coil and the current flowing through the wire. Whenever electrical current flows through the coil of wire, a magnetic field, or lines of force, builds up around the coil.

If the coils are wound around a metal core, like iron, the magnetic force strengthens considerably.

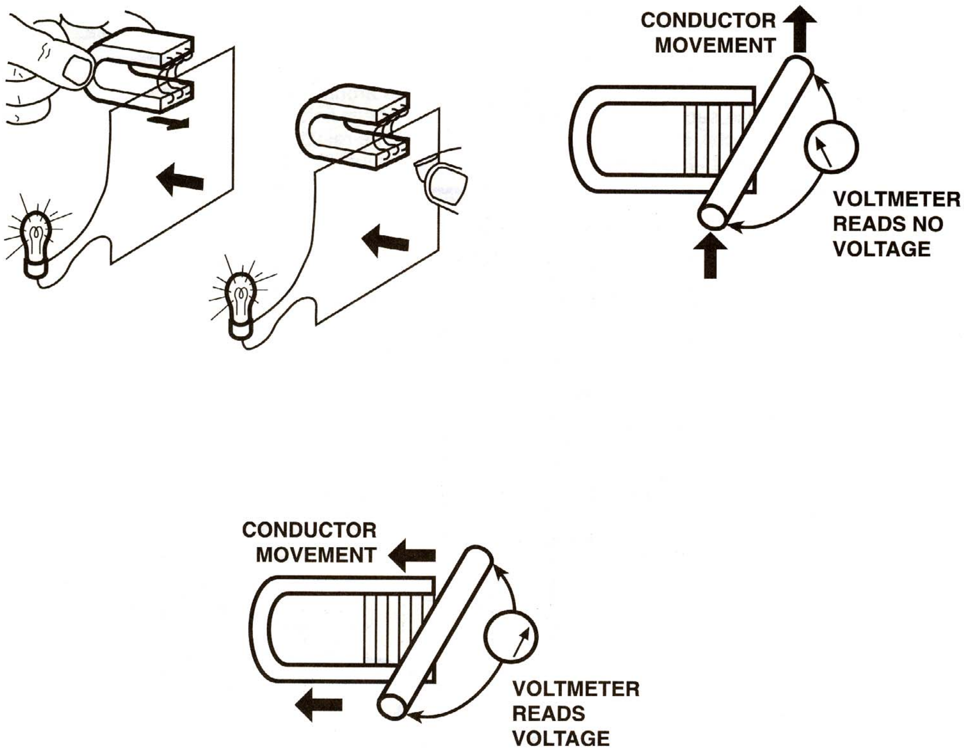


Figure 9-3, Wire Passing Through a Magnetic Field

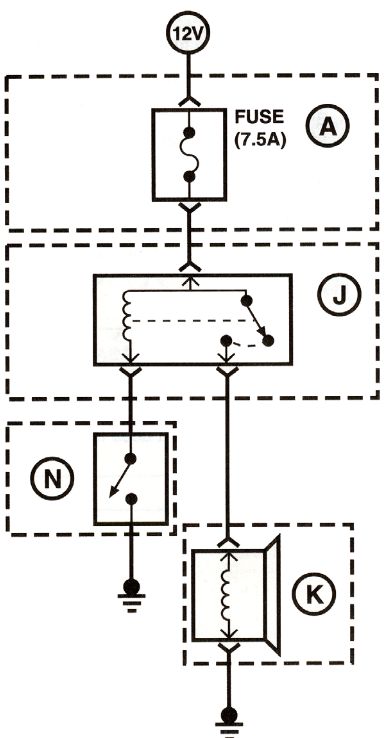


Figure 9-4, Current Flow Creates a Magnetic Field

Another way electromagnetic fields can be used is to produce voltage. If a wire is passed through a magnetic field, such as a wire moving across the magnetic field of a horseshoe magnet, voltage is induced. If the wire is wound into a coil, the voltage Induced strengthens. This method is the operating principal used in speed sensors, generators, and ignition coils. In some cases the wire is stationary and the magnet moves. In other cases, the magnet is stationary and the wiring moves.

Experiment 9-1

Experiment Objective: Demonstrate that current flowing through a coil creates a magnetic field.

You will find a door lock actuator among the parts in your project board. Use the relay and door lock actuator schematic on the previous page as a guide to assemble a circuit that can operate the door lock actuator with a push-button (momentary contact) switch. Briefly depress the switch to activate the door lock actuator. Use the compass as a "detector" to confirm the magnetic field generated by the coil.

1. Does the compass move when the relay is activated?

   ____

2. Measure the current through the coil of the relay:_____________________ amps

3. Measure the current through the door lock actuator side of the circuit _____________ amps.

4. What is the purpose of the relay In the circuit?

   ____

5. When the relay was energized, the compass moved. What does the movement of the compass prove?

   ____

   ____

Relays

Relays use the principle of electromagnetism to electrically operate a switch. A relay is made up of an electromagnetic coil, a "set of contacts", and an armature. The armature is a moveable device that allows the contacts to open and close.

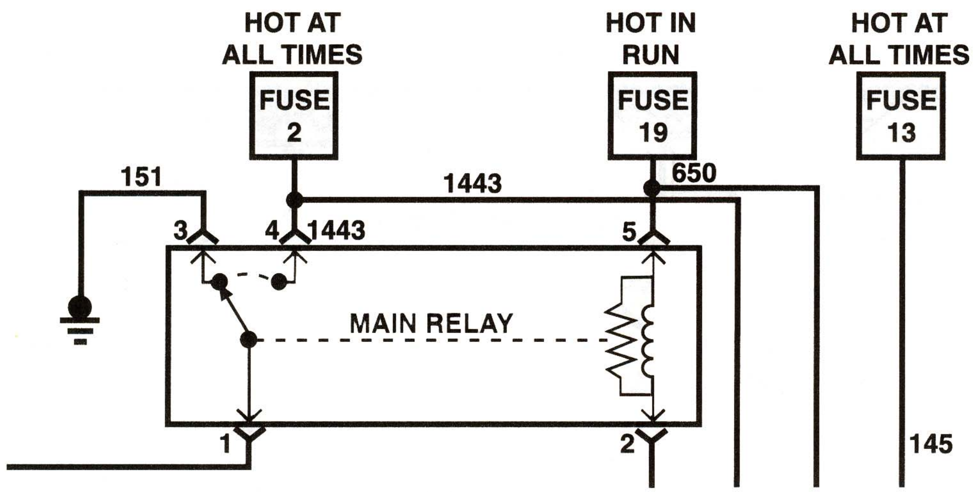


Figure 9-5, Schematic of a Relay

Notice that the schematic symbol for the relay also shows the coil, contacts, and armature. In most cases, the contacts are held in the open position by spring tension.

Relays typically use a small electrical current to switch a larger electrical current on or off. A starter-Solenoid circuit where the ignition switch uses a small current to control the high current starter-motor circuit. In the relay shown here, a small amount of current flows through the relay coil. The electromagnetic force moves the armature that closes the circuit. This allows the larger current to run through the relay contacts. The contacts of a relay are either normally closed (allowing current flow with the relay off) or normally open (requiring the relay to be energized to flow current).

Solenoid

A solenoid is another device that uses electromagnetism. Like a relay, the solenoid has an electromagnetic coil. Inside the coil is a moveable iron core that is connected to an operating device. When current flows through the coil, electromagnetism pushes or pulls the core into the coil. Solenoids are used to create linear, or back and forth movements, that can be used to engage a starter motor, or control shifts in an automatic transmission.

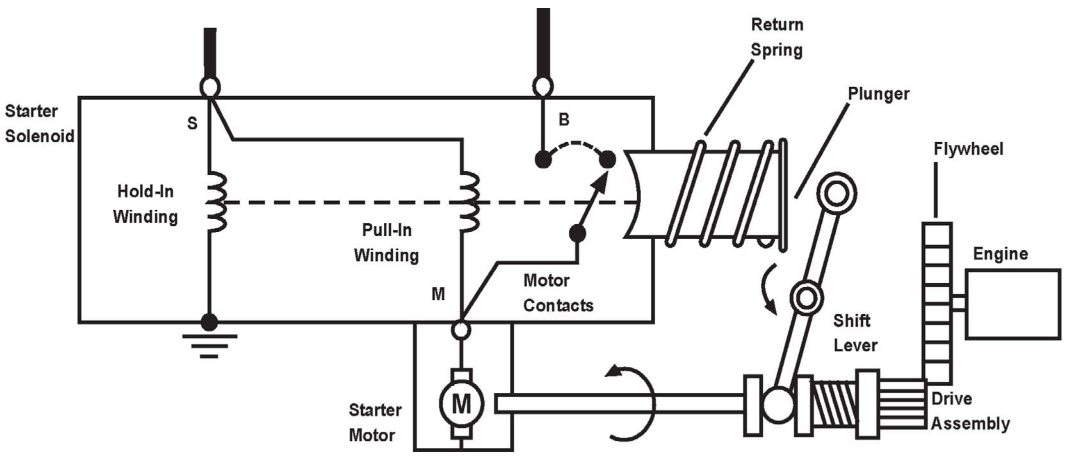


Figure 9-6, Solenoid

Transformers

Transformers work on the principle of electromagnetic induction and are most often used to increase voltage and amperage.

Transformers are typically constructed of a primary winding, a secondary winding, and a common core. Pulsating direct current or alternating current is used to control transformers.

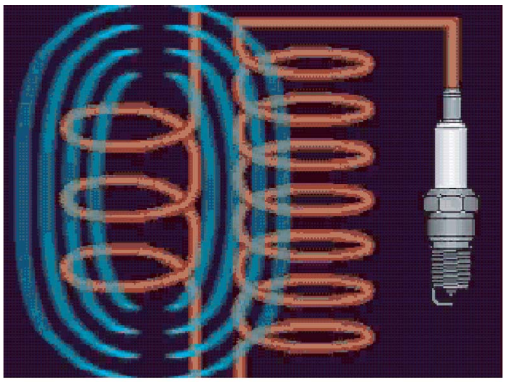


Figure 9-7

Figure 9-8, Transformer

Here is how one type of transformer, the ignition coil, operates. When current flows through the primary windings (12-volt side), it creates a magnetic field. When the current stops, or is interrupted, the magnetic field collapses and the lines of force rapidly cut across the secondary windings. This action induces high voltage powerful enough to fire the spark plug.

Electromagnetic Induction

The effect of creating a magnetic field with current has an opposite: It is also possible to create current with a magnetic field. The process is called "electromagnetic Induction." It happens when the flux lines of a magnetic field cut across a wire (or any conductor). It does not matter whether the magnetic field moves or the wire moves. When there is relative motion between the wire and the magnetic field, a voltage is produced in the conductor. The induced voltage causes a current to flow. When the motion stops, the current stops.

Movement In the opposite direction causes current flow In the opposite direction. Therefore, back and forth motion produce. AC voltage (current).

In practical applications, multiple conductors are wound into a coil. This concentrates the effects of electromagnetic Induction and makes it possible to generate useful electrical power with a relatively compact device. In a generator, the coil moves and the magnetic field is stationary. In an alternator, a magnet is turned inside a stationary coil.

The strength of an induced voltage depends on several factors:

Strength of the magnetic field

Speed of the relative motion between the field and the coil

Number of conductors in the coil

Experiment 9-2

Experiment Objective: Demonstrate electromagnetic induction.

The instructor will divide the class into two teams. Each team will go to a classroom vehicle to measure the ABS wheel speed sensor signal as they spin the wheel by hand.

Note: The front of the classroom vehicle must be supported on jack stands or a hoist, and the transmission must be placed in neutral.

Reference the eSI for ABS Wheel Sensor information

Team 1: ____________ Team 2: ____________

Sensor Resistance ____________ Sensor Resistance ____________

Sensor to Ground ____________ Sensor to Ground ____________

MAX DC volts ____________ MAX DC volts ____________

MAX AC volts ____________ MAX AC volts ____________

MAX frequency ____________ MAX frequency ____________

Why did rotating the toothed wheel in front of the wheel speed sensor produce a voltage?

____

____

____

____

Exercise 9-1

Read each question carefully and answer by filling in the blanks.

1. Magnetism makes it possible to convert ____________.
   a. electrical energy Into mechanical energy
   b. mechanical energy Into electrical energy
   c. electrical energy Into chemical energy
   d. all of the above

2. A ________________ uses electromagnetism to work.
   a. relay
   b. solenoid
   c. starter motor
   d. all of the above

3. The coil in a relay is used to open and close a

   ____

4. The process of converting mechanical energy Into electrical energy Is called ____________________.
   a. electromagnetic induction
   b. electromagnetism
   c. magnetic flux
   d. conventional theory

5. A (An)______________ is an example of a device that uses electromagnetic induction.
   a. alternator
   b. relay
   c. solenoid
   d. thermistor

6. An ignition coil is an example of a _______________.
   a. solenoid
   b. switch
   c. transformer
   d. relay