LIFEPAC®

# SCIENCE

STUDENT BOOK

## 12th Grade | Unit 8

Alpha Omega
PUBLICATIONS

# SCIENCE 1208
# MAGNETISM



**LIFEPAC Test is located in the center of the booklet.** Please remove before starting the unit.

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Alpha Omega PUBLICATIONS

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# Magnetism

## Introduction

Science LIFEPAC® 1207 dealt with the nature of electric current and was the second unit on *electrophysics*: the relation of the electrical nature of matter to physical systems. Science LIFEPAC 1208 will deal with the force laws for natural and man-made magnets, and with the subject of electromagnetism.

The flow of the electrical charge is a current; when the current flows, a magnetic field is created. You will see that understanding of electromagnetism is being used daily, often without our knowledge. Electromagnetism generates the power that comes to our homes, and transformers send it from the generators over long distances to our homes.

The laws of electromagnetic induction are so regular that an entire power distribution system may be designed for a city, including generators and transformers; and its performance would be predictable before a single wire is connected. Such is the regularity of these electromagnetic laws.

This LIFEPAC will introduce you to the electromagnetic world that the Lord has provided. God has power-generating stations around the earth in the upper regions of the ionosphere, about 100 kilometers above the earth's surface. Above the equator, the equatorial electrojet uses the tidal motion of the atmosphere to generate a 100,000 ampere current in that region. This electrojet is part of his invisible creation.

Colossians 1:16 credits God with all Creation, which certainly includes electricity. We cannot see the flow of electrons, but we can observe the results of the flow's effect, including magnetism and electromagnetism.

## Objectives

**Read these objectives.** The objectives tell you what you will be able to do when you have successfully completed this LIFEPAC. When you have finished this LIFEPAC, you should be able to:

1. Sketch various magnetic fields.
2. Write the force law for magnetic pole interactions.
3. Describe forces on charges in magnetic fields.
4. Explain how electric and magnetic fields interact.
5. Describe the application of electromagnetic induction.
6. Interpret electric and magnetic deflection of electron beams.
7. Explain the operating principles of a cathode-ray tube (CRT).

Survey the LIFEPAC. Ask yourself some questions about this study and write your questions here.

# 1. FIELDS AND FORCES

**Magnetic fields** are around us everywhere. The earth's magnetic field is with us wherever we go, as is the gravitational field. We are more aware of the force of gravity, without which we could not walk across the street. The forces due to a magnetic field are more subtle, and we are exposed to these every day. When we walk under electrical power lines, we are exposed to both alternating magnetic fields and the earth's magnetic field. The effects of these fields on the body are not well understood, but their effects on electrical conductors and on currents of electrical charge are well known. This section will introduce the laws for forces between **magnetic poles** (magnets), and the forces on moving electrical charges in magnetic fields.

## Section Objectives

**Review these objectives.** When you have completed this section, you should be able to:

1. Sketch various magnetic fields.
2. Write the force law for magnetic pole interactions.
3. Describe forces on charges in magnetic fields.

## Vocabulary

**Study these words to enhance your learning success in this section.**

| | | | |
|---|---|---|---|
| **aurora borealis** | **electrojet** | **field line** | **ionosphere** |
| **left hand rule** | **magnetic field** | **magnetic pole** | **solenoid** |

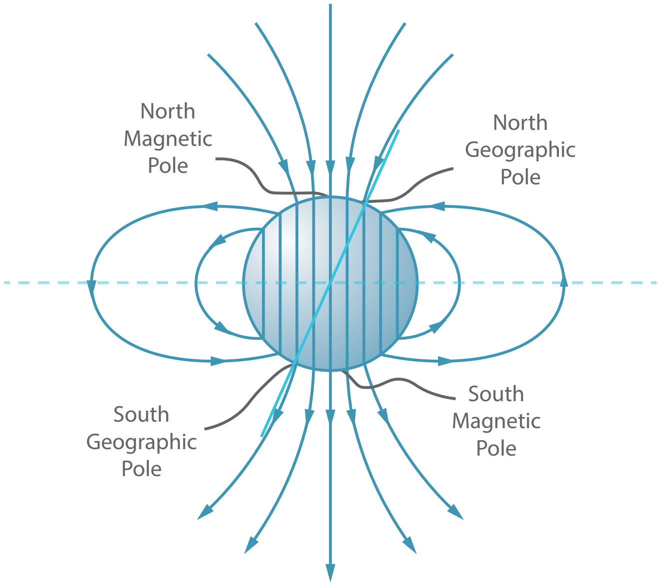
**Note:** *All vocabulary words in this LIFEPAC appear in* **boldface** *print the first time they are used. If you are not sure of the meaning when you are reading, study the definitions given.*

# FIELDS

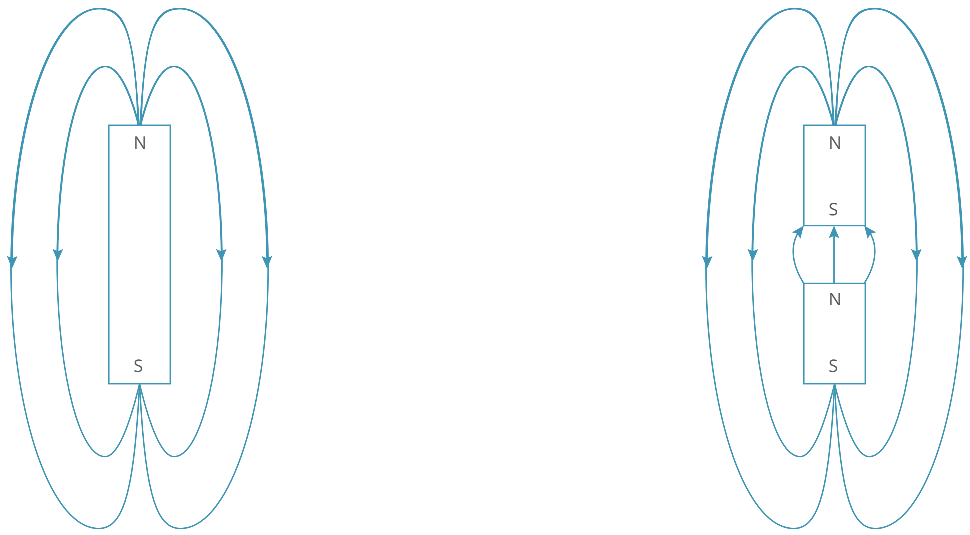
The region around a magnetic pole (magnet) in which a bit of iron experiences a force is called a **magnetic field**. It is the magnet's "sphere of influence." The magnetic field has direction, as defined by the force on a test north pole at any point in the field. The path followed by the test north pole describes a magnetic line of force, or a magnetic **field line**.

Magnetic fields, such as the earth's magnetic field, occur in nature and around such man-made objects as the bar magnet and the **solenoid**.

**Natural fields.** Magnets have been known to man since the dawn of history. They were probably first regarded with an air of mystery; later they were used as navigational tools. The earth's magnetic field is used as a direction-finding aid. Suspended magnetic needles, acting as compasses, follow the direction of the earth's field lines.




| Earth's magnetic field




a. Bar magnet field

b. Bar magnet cut in half

| Bar magnet fields

The magnetic field of the earth extends from the center of the earth, up through the oceans, and into outer space. It influences the outer atmosphere in particular (the **ionosphere**) and has a strong influence on the flow of currents in that region. At great distances from the earth, the earth's magnetic field controls the flow of electrical currents that come from the surface of the sun. The current systems closer to the earth are called **electrojets**. One exists in the region near the North Pole and is called the *auroral electrojet*, which helps to produce the northern lights of high latitudes. Another high current system is near the equator and is called the *equatorial electrojet*. Both current systems are controlled and, to a degree, are generated by the earth's magnetic field.

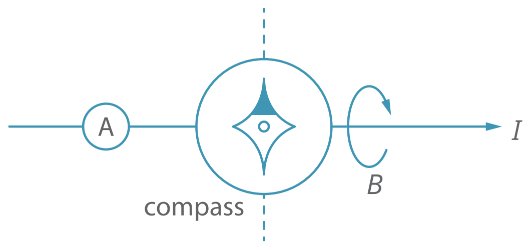
An estimated 1 million amperes of current flow every night in the auroral electrojet. The Inuit depend upon the northern lights to enable them to see at night.

The northern lights (**aurora borealis**) are a marvelous display of multicolored and beautifully formed sheets of light in the sky. Currents from outer space funnel down the earth's magnetic field lines to form these beautiful displays. Thus the natural magnetic field of the earth has a profound influence on nature and the outer atmosphere. You will study this field and will discover some of its properties and attributes.

**Man-made fields.** A simple example of a man-made magnetic field is the bar magnet. The magnet has two poles.

The pole that points toward the earth's north pole is termed the *north-seeking pole*, or simply the *north pole*, of the magnet. If the magnet is floated in water on a piece of cork, it will again align itself with the earth's field, with its north pole pointing toward the earth's north pole. The poles behave somewhat like electric charges: Like poles repel and unlike poles attract.

The form of the magnetic field around a bar magnet will be found by experiments you will perform. The direction of the field lines can be traced and will generally be considered to "flow" from the north pole outside the magnet to the south pole. In other words, the presence of a magnetic field is sensed by a test north pole. The similarity to the case of two opposite electric charges ends at this point, because when a bar magnet is cut in half, two new smaller magnets are formed, each complete with a north pole and a south pole. A magnetic field is formed when a current flows in a wire. A compass brought near a current-carrying wire will align itself as shown in Figure 1.

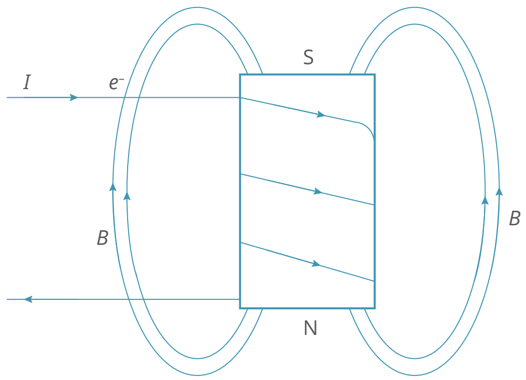



| Figure 1

The magnetic field *B* will form as indicated by the compass needle's direction. The needle aligns with the magnetic field.

When the wire is wound into a coil, the fields around the wires add to form a *solenoid*. A solenoid is a coil of wire designed to produce a magnetic field by means of a current passed through its windings.

The field around the solenoid will be similar to the one around a bar magnet, with north and south poles as shown. This field is termed an *electromagnet*. Increasing the electric current will produce a stronger magnetic field.




| Electromagnet

**Choose the correct answer.**

**1.1** The earth's magnetic field extends _______ .

a. from the earth's surface to the upper atmosphere
b. from the center of the earth to the sun
c. from the earth's core to outer space

**1.2** The earth's magnetic field captures the flow of current from _______ .

a. the moon  b. Saturn  c. the sun  d. the center of the earth

**1.3** High natural currents flow above the earth's atmosphere in _______ .

a. the aurora  b. upper clouds
c. outer space  d. the asthenosphere

**1.4** Two north poles will _______ .

a. attract each other  b. repel each other
c. experience neither attraction nor repulsion  d. cancel each other

**1.5** A north compass needle points to the _______ .

a. north magnetic pole  b. south magnetic pole
c. north geographic pole  d. south geographic pole

**1.6** The field around a solenoid is _______ .

a. similar to a bar magnet  b. unipolar  c. nonsymmetrical

**Try this activity to investigate the nature of magnetic fields.**

**These supplies are needed:**

- 2 bar magnets
- 3 sheets of stiff cardboard
- iron filings

**Follow these directions and complete the activities. Put a check in the box when each step is completed.**

- [ ] 1. Place the sheet of stiff cardboard over one of the bar magnets so that the cardboard is level.
- [ ] 2. Sprinkle the iron filings on the cardboard.
- [ ] 3. Tap the cardboard to help the filings align with the magnetic field lines.

**1.7** Sketch the magnetic field lines or take a photograph.

**1.8** Indicate where the magnetic field lines appear to be concentrated.

- [ ] 4. Place the north pole of one magnet 1 inch from the south pole of the other magnet.
- [ ] 5. Place the second cardboard over the two magnets.
- [ ] 6. Sprinkle iron filings on the cardboard.
- [ ] 7. Tap the cardboard.

**1.9** Sketch the field lines or take a photograph.

**1.10** Indicate where the magnetic field lines appear to be concentrated.

- [ ] 8. Place the north pole of one magnet 2 inches away from the north pole of the second magnet.
- [ ] 9. Place the third cardboard over the two magnets.
- [ ] 10. Sprinkle iron filings on the cardboard.
- [ ] 11. Tap the cardboard.

**1.11** Sketch the field lines or take a photograph.

**1.12** Indicate the concentration of field lines and where the field lines seem to be opposing rather than adding.

**Answer these questions.**

**1.13** Where are the magnetic field lines concentrated in Activity 1.7? ______________________

**1.14** Are the magnetic field lines continuous between the poles in Activity 1.9? ______________________

**1.15** Are the lines of force continuous between the poles in Activity 1.11? ______________________

## Magnetic Fields Experiment

Without the magnet, the filings are without any order. When the magnet is brought near, the filings themselves become little magnets, having magnetism induced into them. The filings have north poles and south poles, similar to the big bar magnet.

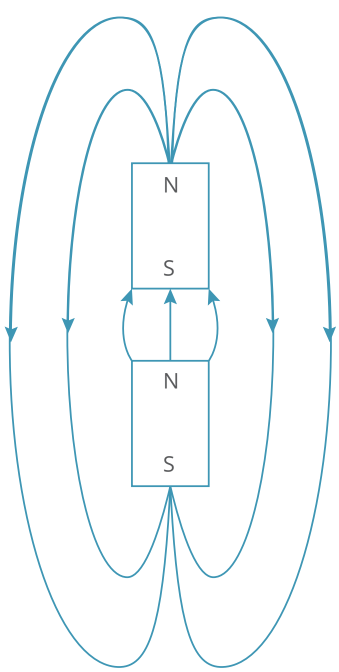
## FORCES

Forces are pushes and pulls. Magnets both attract and repel each other through empty space. Magnetism is one of the three forces that operate without an intervening medium, the others being gravity and electrostatics.

Magnets also produce currents in conductors and exert forces on current-carrying conductors.

**Forces of attraction or repulsion.** The laws of attraction and repulsion for magnetic poles are similar to Coulomb's law for electrical charges. The force will be repulsive if the poles are alike, and will be attractive for dissimilar poles.

An example is the splitting of a bar magnet. When a bar magnet is cut in half, two new north-south magnet pairs are formed. Each will be similar to the unbroken magnet. A force of attraction exists between the two magnet halves. The unlike poles (north and south) of the two magnet ends will attract each other.




Individual magnetic poles cannot exist. A north pole cannot exist without a corresponding south pole. In other words, a separate north pole cannot be moved completely away from its south pole. The two opposite poles always exist in pairs.

The force of attraction between two magnetic poles is expressed in a form similar to Coulomb's law:

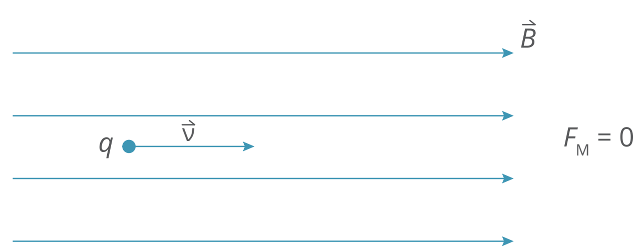
$$F_M = K\frac{M_1M_2}{r^2}$$

$M_1$ is the strength of magnetic pole $M_1$, $M_2$ is the strength of magnetic pole $M_2$, $r$ is the separation between $M_1$ and $M_2$, and $K$ is a constant that is dependent upon the units used in the formula (usually the metric system).

The sign of the pole is used in the formula, as in Coulomb's law. Like poles repel and unlike poles attract. The product of $M_1$ and $M_2$ will be negative for attraction and positive for repulsion, similar to Coulomb's law.

If the distance between the two poles is cut in half the force $F_M$ will be increased four times, the result of the *inverse square relationship* in the formula. Similarly, if we cause the distance between two magnetic poles to be tripled, the force between them will be reduced to one-ninth of its previous value.

**The Biot-Savart force law.** Consider an electric charge in motion in a magnetic field. The moving charge will experience a magnetic force $F_M$. The magnitude of the force will depend on the magnitude of the charge, its velocity, and the direction in which the charge moves relative to the field direction. Experiments determine the relationship between these quantities.




| Zero Force Condition

A charge $q$ moving parallel to the field experiences no force because no field lines are crossed. If the opposite condition is chosen and a charge is moved *normal* to the field lines, the force on the charge is the maximum force $F_{max}$.

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