TOPIC 4.3: MAGNETIC FIELDS

The student will be able to:

S3P-4-20: Define the magnetic field as the region of space around a magnet where another magnet will experience a force.

S3P-4-21: Demonstrate and diagram magnetic fields, using lines of force.

Include: bar magnet, horseshoe magnet, between like poles, between unlike poles

S3P-4-22 Describe the concept of magnetic poles and demonstrate that like poles repel and unlike poles attract.

S3P-4-23: Describe magnetism, using the domain theory.

Include: ferromagnetic materials, the attraction of iron objects to north and south poles

S3P-4-24: Investigate the influence and effects of the magnetic field of the Earth.

Include: auroras, magnetic declination and inclination

GENERAL LEARNING OUTCOME CONNECTION

Students will…

Employ effective communication skills and utilize information technology to gather and share scientific and technological ideas and data (GLO C6)

SPECIFIC LEARNING OUTCOMES

S3P-4-20: Define the magnetic field as the region of space around a magnet where another magnet will experience a force.

S3P-4-21: Demonstrate and diagram magnetic fields, using lines of force.

Include: bar magnet, horseshoe magnet, between like poles, between unlike poles

SUGGESTIONS FOR INSTRUCTION

Entry-Level Knowledge

Students have completed treatment of the concepts of gravitational and electric fields.

Notes to the Teacher

The field concept is useful in describing and relating magnetic fields to gravitational and electric fields. By this time, students should be familiar with the basic field concept. However, an introduction to the basics of magnetism is required at this point.

While we cannot easily “demonstrate” electric and gravitational field lines, we can easily map magnetic fields, using magnets and iron filings. This visual aspect of magnetic fields helps to reinforce the previous discussions of field lines.

In magnetic fields, a line of force indicates the direction the force would act on a north pole in the field. The number of lines per unit area represents the intensity of the field.

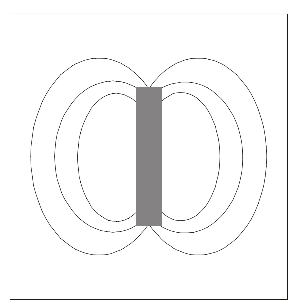
Student Activities

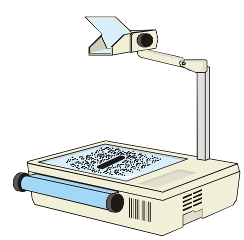
A lab on basic magnetism is essential. Field mapping should be included in the activity.

The cardboard backing from a ream of paper can be placed over a magnet. Iron filings are sprinkled on the cardboard. By tapping the cardboard lightly, the iron filings line up along the magnetic field lines. Different configurations can be used (e.g., horseshoe magnet, two like poles, two unlike poles).

Teacher Demonstration

Place a magnet under a piece of Plexiglas® and sprinkle iron filings around the magnet on top of the Plexiglas®. The field can be projected on an overhead.





SKILLS AND ATTITUDES OUTCOME

S3P-0-2c: Formulate operational definitions of major variables or concepts.

GENERAL LEARNING OUTCOME CONNECTION

Students will…

Evaluate, from a scientific perspective, information and ideas encountered during investigations and in daily life (GLO C8)

SUGGESTIONS FOR INSTRUCTION

Senior Years Science Teachers' Handbook Activities

Journal Entry: Students respond in their journals to questions (e.g., in your home, where do you find magnetic fields, gravitational fields, electric fields? List some examples of each field.).

Compare and Contrast Frames: Students answer the following questions: What is the same about gravitational, electric, and magnetic fields? What is different?

SUGGESTIONS FOR ASSESSMENT

Laboratory Report

Students write a lab report including diagrams of various fields from a variety of magnet types.

SUGGESTED LEARNING RESOURCES

AAPT Potpourri of Physics Teaching Ideas, 160–168.

Kagan, D. (1993) "Building a Magnetic Levitation Toy." *The Physics Teacher* 31: 432.

GENERAL LEARNING OUTCOME CONNECTION

Students will...

Recognize that scientific knowledge is based on evidence, models, and explanations, and evolves as new evidence appears and new conceptualizations develop (GLO A2)

SPECIFIC LEARNING OUTCOMES

S3P-4-22: Describe the concept of magnetic poles and demonstrate that like poles repel and unlike poles attract.

S3P-4-23: Describe magnetism, using the domain theory.

Include: ferromagnetic materials, the attraction of iron objects to north and south poles

SUGGESTIONS FOR INSTRUCTION

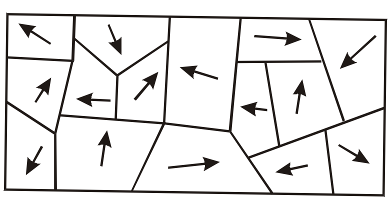
Notes to the Teacher

Students may not have had a hands-on opportunity to investigate magnetism. Introduce magnetism, using a hands-on lab.

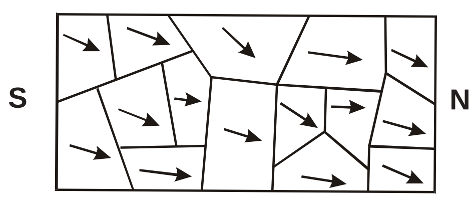
The domain theory is a simple model of magnetism, which states that all materials are made up of tiny regions called domains. The domains behave like magnets. When they are distributed randomly their magnetic effects cancel, and when the domains become aligned the material is magnetized. Additionally, the domains that are already with the field can grow in size, while those not aligned shrink due to the atoms on the boundary (the domain "wall").

Student Activity

Students suspend a magnet from a pivot and bring another magnet nearby to demonstrate attraction and repulsion of like and unlike poles.



Domains aligned randomly
(no magnetic effects)



Domains aligned

SKILLS AND ATTITUDES OUTCOMES

S3P-0-2c: Formulate operational definitions of major variables or concepts.

S3P-0-2f: Record, organize, and display data using an appropriate format.

Include: labelled diagrams, tables, graphs

GENERAL LEARNING OUTCOME CONNECTION

Students will...

Understand how stability, motion, forces, and energy transfers and transformations play a role in a wide range of natural and constructed contexts (GLO D4)

SUGGESTIONS FOR INSTRUCTION

Teaching Notes

SUGGESTIONS FOR ASSESSMENT

Research Report/Presentation

Students complete a research report on magnetic phenomena, using diagrams to illustrate concepts.

Recognizing the Role of Evidence

Students discuss their personal understanding of what a magnetic field represents, and resolve competing diagrams.

SUGGESTED LEARNING RESOURCES

Appendix 4.3: Student Sampler: Magnetic Fields

General Learning Outcome Connection

Students will…

Demonstrate appropriate scientific inquiry skills when seeking answers to questions (GLO C2)

Specific Learning Outcome

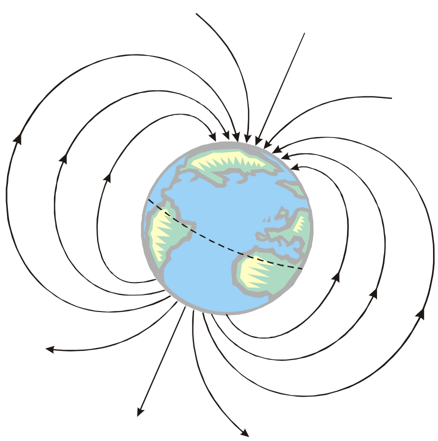
S3P-4-24: Investigate the influence and effects of the magnetic field of the Earth.

Include: auroras, magnetic declination and inclination

Suggestions for Instruction

Notes to the Teacher

Ancient mariners believed that somewhere in the north was a magnetic mountain that was the source of attraction for their compasses. It was not until 1600 that William Gilbert, in his treatise *Physiologia Nova de Magnete,* suggested that the Earth itself behaved like a giant magnet. In simple terms, the Earth can be thought of as a bar magnet and the force that attracts the compass originates inside the Earth.



Magnetic field lines radiate between Earth's north and south magnetic poles. Magnetic fields are produced by the motion of electrical charges (see the next unit on electromagnetism). The Earth's magnetic field is not completely understood, but is thought to be associated with electrical currents produced by the rotational effects in the liquid outer core of Earth's interior. Consequently, the Earth's magnetic field reverses itself approximately every 250,000 years.

Auroras (the northern and southern lights) are caused by high-energy particles from the solar wind trapped in the Earth's magnetic field. As these particles oscillate along the magnetic field lines, they enter the atmosphere near the north and south magnetic poles. These energetic electrons collide with the oxygen and nitrogen molecules in the atmosphere. The collisions excite the molecules and, when they decay from the excited states, they emit the light that we see in the auroras.

The magnetic poles are not in the same location as the geographic poles. Declination is the angle between true north and magnetic north. This angle changes, depending on your location. For example, it is 20°E in Victoria, B.C., but in St. John's, Newfoundland, it is 23°W. Knowledge of magnetic declination is important for navigational purposes. According to the National Geomagnetism Program, the north magnetic pole is a feature unique to Canada, and monitoring its position and motion is of prime importance to Canadian cartography.

Skills and Attitudes Outcome

S3P-0-1c: Relate the historical development of scientific ideas and technology to the form and function of scientific knowledge today.

General Learning Outcome Connection

Students will…

Understand how stability, motion, forces, and energy transfers and transformations play a role in a wide range of natural and constructed contexts (GLO D4)

Suggestions for Instruction

At each location on the Earth, the magnetic field lines intersect the Earth's surface at a specific angle of inclination. Near the equator, the field lines are approximately parallel to the Earth's surface (see diagram below) and the inclination angle in this region is close to 0°. As one travels north from the equator, the angle of inclination increases. At the magnetic pole, the field lines are directed almost straight down into the Earth and the inclination is 90°. Thus, the angle of inclination varies with latitude. It has been suggested that some animals have the ability to distinguish between magnetic inclination angles and therefore "know" their latitude, particularly migratory animals.

Magnetic inclination (also called the magnetic dip) is the angle that the geomagnetic field makes with the surface of the Earth. Magnetic inclination varies from 90° (perpendicular to the surface) at the magnetic poles to 0° at the equator.

Suggestions for Assessment

Research Report/Presentation

Students research and report on the characteristics of magnetic fields of other planets in our solar system.

Science Journal Entries

Students research Earth's "dynamo" mechanism, and use the results to explain why Venus has no field and why the Sun has an oscillating field.

Suggested Learning Resources

Websites

Geomagnetism: <http://www.ngdc.noaa.gov/seg/potfld/geomag.shtml>

Geology: Plate Tectonics: <http://www.earth.nwu.edu/people/seth/107/>

<http://www.platetectonics.com/index.asp>

When the Earth Moves—Discoveries in Plate Tectonics and Seafloor Spreading: <http://www.beyonddiscovery.org/>

Plate Tectonics—A Paradigm Under Threat: <http://ourworld.compuserve.com/homepages/dp5/tecto.htm>

General Learning Outcome Connection

Students will…

Demonstrate appropriate scientific inquiry skills when seeking answers to questions (GLO C2)

Specific Learning Outcome

S3P-4-24: Investigate the influence and effects of the magnetic field of the Earth.

Include: auroras, magnetic declination and inclination

Suggestions for Instruction

When magnetic minerals are free to reorient themselves, they can align with the Earth's magnetic field. As molten rock containing ferromagnetic minerals (e.g., magnetite) cools below the Curie Point, the iron-bearing mineral grains preferentially orient themselves to the prevailing magnetic field of Earth. This orientation becomes locked in place as the rocks cool and harden. This magnetic inclination allows geologists to speculate about where on the globe a volcanic rock might have formed. Unfortunately, only the approximate latitude at the time of formation of the rock can be "locked in"—not the longitudinal position on the globe.

During the 1950s and 1960s, the science of ***paleomagnetics*** provided crucial novel facts to the development of new theories about the mobility of the ocean floors. Eventually, it was the rock magnetic data that turned many geologists away from the acceptance of permanent continents and oceans to the more innovative notions of continental drift, sea-floor spreading, and the theory of plate tectonics in the early 1970s. See the references for further sources on this connection between physics and geology.

Student Activities

Students can address several questions with respect to the study of paleomagnetism.

- What magnetic orientations would we expect to see in rocks at different spots on the Earth's surface, such as the north pole, Manitoba's north, or the Equator?
- What conditions must exist for the minerals to move around and thus be able to align themselves with the Earth's magnetic field?
- How does a rock preserve the magnetic orientation of its iron-bearing minerals?
- If we were to measure the inclination angle recorded in volcanic rocks, where on the Earth would we note a 0-degree angle of inclination? How about 90 degrees down? How about 90 degrees up?

Senior Years Science Teachers' Handbook Activities

Students research contributions of early Arctic explorers in locating the true magnetic north (e.g., Sir John Ross, Roald Amundsen).

SKILLS AND ATTITUDES OUTCOME

S3P-0-1c: Relate the historical development of scientific ideas and technology to the form and function of scientific knowledge today.

GENERAL LEARNING OUTCOME CONNECTION

Students will…

Understand how stability, motion, forces, and energy transfers and transformations play a role in a wide range of natural and constructed contexts (GLO D4)

SUGGESTIONS FOR INSTRUCTION

Teaching Notes

SUGGESTIONS FOR ASSESSMENT

Major Explanatory Stories of Science

Students explore the contents of William Gilbert's tract *Physiologia Nova de Magnete* of 1628, and describe details of his "physiological" approach to understanding magnetic phenomena. Produce a "tract" or pamphlet for distribution to Grade 3 students in your community who also study magnetism. (See Appendix 4.5: William Gilbert and the Earth's Magnetic Field.)

SUGGESTED LEARNING RESOURCES

Websites

Many interesting photos of auroras can be found in the astronomy picture of the day archive at: <http://antwrp.gsfc.nasa.gov/apod/archivepix. html>

For an aurora over Winnipeg, see: <http://antwrp.gsfc.nasa.gov/apod/ap011105.html>.

References

Brush, Steven. (1997) "Whole Earth History." *Historical Studies in the Physical Sciences* 17.2: 345-355. <http://punsterproductions.com/~sciencehistory/WEH.htm>

Appendix 4.5: William Gilbert and the Earth's Magnetic Field

NOTES