MagLab: Alpha

EdVentures in Science

Produced by:

The National High Magnetic Field Laboratory
Florida State University
Tallahassee, FL
32306

Jack Crow
Director, NHMFL

Hans Schneider-Muntau
Director, Magnet Science and Magnet Science & Technology

Jim Ferner
Director, Facilities & Administration

Janet Patten
Director, Public Relations

Executive Producer, MagLab: Alpha
Sam Spiegel
Director, NHMFL K-12 Educational Programs

Producer, Alpha Guide
Pat Dixon
Educator, NHMFL K-12 Educational Programs

Producer, Alpha Interface
Karl Hook
Educator, Florida State University School

Acknowledgements

Producer, Alpha Pack
Elizabeth Viggiano
Educator

Administrative Support
Deborah Brooks
Bridget Hillyer
Staff, K-12 Educational Programs

Computer Graphic Artists
Henry Allen
Will Harkins
Staff, K-12 Educational Programs

Graphic Artist
Debi Barrett-Hayes
Educator, Florida State University School

Student Interns
Daniel Harper
David Godwin
Nathan Kennedy
Arian Quimbo
Kyle Young
Marleni Young
P.L.U.N.G.E, Florida State University School

Gil Cancel
Tallahassee Community College

Graduate Assistants
Shawn Goldstein
Robby Stanley
Florida State University

Narrations
Rachel Dixon
Sam Spiegel

The producers wish to express their appreciation
to the following individuals and groups.

NHMFL Researchers
Jack Crow
Allan Marshall
Vincent Salters
Benoit Boulat
Dan Duffy
Mark Bird
James Brooks
Gang Cao
Mike Davidson
Peter Fajer
Steven Gibbs
Stephen Hill
Jurek Krzytek
Wolfgang Loffelbein
W. Denis Markiewicz
John Miller
John Sarrao
Justin Schwartz
Robert Schrieffer
Christian Wolters

NHMFL Technical Support
Shawn Finke
Mike Gonzalez
Kathy Hedick
Curtis Hendrickson
Wally Thorner

Advisory Council
Elizabeth Jakubowski
Tom Baird
Elizabeth Graham
George Dawson
Angelo Collins

Star Tree Participants
Wally Allen
Pat Dixon
Elizabeth Graham
Phyllis Green
Cynthia Holland
Karl Hook
Jennine Jordan
Glenda Paul
Elizabeth Viggiano

Florida State University School
Terry Castelow
Ashley Melton

Leon County Schools
Bill Montford
Linda Valenzuela

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FOREWORD

As the director of the National High Magnetic Field Laboratory and a member of the international science community, I am enormously excited about this new educational product that we hope will promote a greater understanding of magnetism and its impact and importance in our daily lives. Magnetism is that great invisible force that underpins nearly every modern technology and material -- including electric lights, computers, motors, plastics, high speed trains, semiconductors, and magnetic resonance imaging -- and magnet-related research allows us to gain a greater understanding of the molecular structure of matter, and of chemical and living structures.

The National High Magnetic Field Laboratory was established by the National Science Foundation in 1990, with substantial recurring support from the State of Florida. The laboratory is operated by a consortium of institutions, comprised of Florida State University, the University of Florida, and Los Alamos National Laboratory, with unique research facilities at all three sites. The mission of the laboratory is to develop and operate state-of-the-art user facilities for multidisciplinary research in high magnetic fields, and we work closely with the private sector to advance magnet technology. Members of the distinguished, multicultural NHMFL faculty and the international user community represent a wide range of disciplines, including physics, biology, engineering, materials science, chemistry, geochemistry, and structural biology, who conduct research activities at the frontiers of science.

Another very important aspect of the laboratory's mission centers around education. Because we are the only laboratory of its kind in the United States (and one of a few in the world), we are in a unique position to develop new avenues through which to promote science education at all levels. MagLab: Alpha, which was developed by Florida teachers, students, and scientists, enhances science and mathematics education through the study of magnets and magnetism and is consistent with current reform efforts. The development team ensured that the first release of the MagLab: Alpha curriculum package fulfills the vision of science education as articulated in the 1996 National Science Education Standards for students:

- To experience the richness and excitement of knowing about and understanding the natural world;
- To use appropriate scientific processes and principles in making personal decisions;
- To engage intelligently in public discourse and debate about matters of scientific and technological concern; and
- To increase their economic productivity through the use of knowledge, understanding, and skills of the scientifically literate person in their careers.

Foreword

MagLab: Alpha represents new ways for approaching classroom science and provides a model for the way science is done in real-world science research institutions. In order to face the competitive challenges of the 21st century, the United States must ensure the scientific and technological literacy of its people and nurture excellence in mathematics and science. As a national laboratory, the NHMFL is committed to using its unique facilities and human resources to launching new science and mathematics learning opportunities, and MagLab: Alpha begins what we hope will be a series of important and exciting new tools for students and teachers.

Dr. Jack E. Crow,
Director, NHMFL
1997

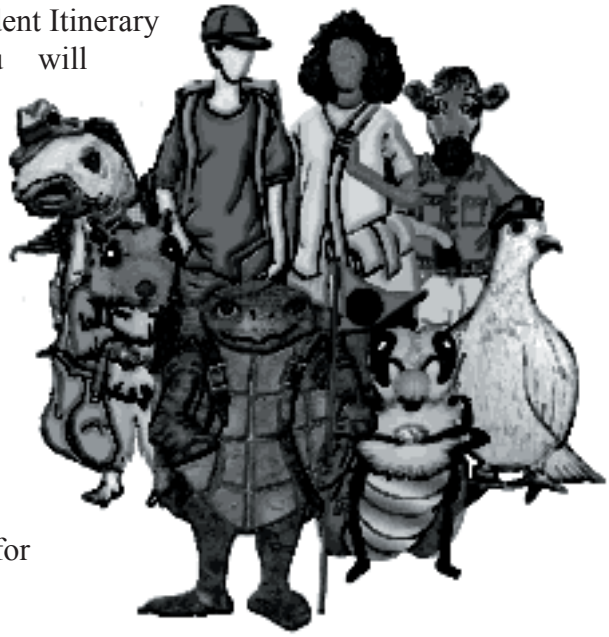
MagLab: Alpha

EdVentures in Science

MagLab: Alpha launches students on a series of Expeditions and Explorations in search of a greater understanding of magnets and magnetism. As students complete each Expedition, they are encouraged to take advantage of suggested Excursions that link magnets and magnetism to mathematics, literature, language arts, geography, history, world cultures, art, and music. MagLab: Alpha was created by teachers, scientists and students to provide materials and experiences that expand students' knowledge of magnets, magnetism and related concepts beyond observable phenomenon.

The MagLab: Alpha program was designed using a team metaphor to model how students, working with each other and the teacher, could investigate magnets, magnetism and related concepts and applications. Teamwork is essential because both learning and scientific processes utilize cooperative and collaborative efforts. The Alpha Team consists of six creatures based on real-life animals that rely on magnets or magnetic fields for migration, locating nesting sites, navigation and even disease prevention. They will help you and your students as you work through the activities or reference the CD-ROM for additional information.

- Tesla Turtle identifies by number each Expedition.
- Bitter Bird identifies Excursions into activities that tie into other subject areas.
- Curie Cow leads students on Explorations of medical applications and other practical uses of magnetism.
- The Alpha Team appears on each Student Itinerary to easily identify those pages that you will need to reproduce.
- Ferrite Fish appears on the Itinerary pages to alert students that they will be recording data, observations or ideas in their Alpha Logs.
- Gilbert Gerbil acts as the quartermaster for the team. He appears to remind the students that they need to assemble equipment from the Alpha Pack.
- Bearing Bee is found only on the CD-ROM to lead students to the next screen for additional information about a concept.



The Alpha Guidebook consists of 20 similarly-formatted Expeditions and 5 Explorations. Although each Expedition or Exploration can be used independently, it is recommended that MagLab: Alpha be completed as a unit.

The Alpha Pack contains all the gear necessary for 36 students to go on Expeditions to discover ways to make magnets and magnetism relate to their world.

The Alpha Interface‡ (CD-ROM) introduces the team that guides and orients students in their quest for information to support the Expeditions, Explorations, and Excursions. Each member of the Alpha Team has a specific job and a well-articulated reason for having joined the team (refer to the CD-ROM).

MagLab: Alpha is an all-inclusive resource package to use to study magnetism. Each part of MagLab: Alpha is explained in this section with ideas and suggestions as to how it can best be used. Of course, each classroom teacher is the best judge of how materials such as these can be used with individual classes and students. Expeditions, Explorations and the Excursions that accompany them are designed to be adaptable to individual schools and classrooms, as well as the constraints under which the typical classroom teacher operates: class size, space, equipment, supplies, and time. In spite of the fact that we have tried to include everything, there is no alternative for knowing one's students, nor is there a substitute for the teacher's imagination.

As you find new and better ways to use these resources, drop by the discussion room on our web site and share your findings. Collegial conversations, for which teachers have little time, are a great way to clarify ideas about teaching and learning in general and specifically in the science classroom. The materials contained in your Alpha Pack, Alpha Guidebook and Alpha Interface were developed by middle school teachers working with research scientists at the National High Magnetic Field Laboratory in Tallahassee, Florida, for use in their own classrooms. Being immersed in the research experience at a national laboratory provides a different perspective on science education. Obviously, science in the real world is considerably different than science in the classroom; however, MagLab: Alpha is one attempt to reconcile these two worlds.

With more and more talk about educating citizens of the twenty-first century, teachers are called upon to use techniques such as cooperative and collaborative learning, interdisciplinary activities, integrated learning, reflective writing, and use of prior knowledge to enhance new concepts. State and national standards imply accountability on the part of the classroom teacher. Expeditions and Explorations are cross-referenced with the standards to help you articulate in your planbook how and why you are using these activities.

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ALPHA PACK

Gear. All items in the Alpha Pack are nonconsumable (with the exception of the paper clips, masking tape and epoxy) so there should be little refurbishing of materials necessary. The pack contains all the gear required for a class of 36 students in groups of 4. Expeditions are flexible, however, and there are enough materials to support this flexibility. Some Expeditions, Explorations, and Excursions require supplies other than those provided in the Alpha Pack; for example, crayons, markers, posterboard, and shoeboxes. These are delineated clearly at the start of each Expedition and are listed under "Suggested Additional Gear" below.

Contained in your Alpha Pack are:

18 wand magnets
18 ring magnets
18 bar magnets
250 square magnets
40 magnetic marbles
1 cow magnet
5 containers iron filings
36 pieces (200 cm) insulated wire
20 D cell rechargeable batteries
1 battery recharger
18 battery holders
18 iron rods
18 aluminum rods
18 wooden dowels
1 box paper clips
54 wooden rectangles
20 rulers
10 rolls masking tape
9 plastic picture frames
18 compasses
9 grease pencils
9 pieces of plastic
1 tube epoxy
9 thermometers

Suggested Additional Gear. The following list includes supplies not included in the Alpha Pack that may be necessary for Excursion and Exploration assessment tasks. These items are not required but could expedite and enhance classroom and homework activities.

protractors
Slinky
drawing paper
crayons and markers
paper clips
aluminum foil
glass, wood, and metal items
cardboard, posterboard, foamboard
construction paper
highlighters
styrofoam packing pieces
straight pins
petri dishes or small margarine tubs
pie plates
corks
mineral oil
clay
thread
plastic bags
hot plate
styrofoam cups
balance scales

Special Tips. It is suggested that you contact students, teachers, and parents as well as the public library for copies of the following magazines (and others) that could serve as excellent resources for expository reading samples: Earth, Science News, Smithsonian, Aviation Weekly, Sky and Telescope, Odyssey, National Geographic, Discover, Nature, Scientific American.

Use the list of suggested supplies above to generate your own list of household items that parents and students can bring from home over the course of the school year. Many parents are willing to contribute to the science program when they find out that all you are asking for are items they can readily and inexpensively obtain. Send home a "wish list" of these items at the beginning of each semester and on any open house nights or parent nights.

ALPHA GUIDEBOOK

Expeditions are group-oriented, hands-on activities designed to help develop greater understandings of magnets, magnetism and related concepts. Excursions are recommended tasks that encourage an interdisciplinary approach to magnetism integrating art, music, literature, mathematics, geography, and history. Explorations lead students to research on applying the concepts related to magnetism mastered in the Expeditions.

Each Expedition is formatted in the same manner. They include the following sections that are explained in detail below: Planning Your Expedition, For Your Planbook, Background Information, Excursions, and the Student Itinerary. The Guidebook is designed for ease of use. For example, as you work on long-term plans for the school year, "For Your Planbook" will provide all the information necessary to justify both classroom and homework assignments; explain assessment; allow for choice to support varying learning styles; reference National and State Standards; determine the amount of time for each activity; and plan for materials. The consistency will assist you in choosing the resources that best suit your program. It is recommended that you read through all Expeditions before beginning even the first one.

EXPEDITIONS

Planning Your Expedition: Each Expedition begins with this section explaining what you will be asking your students to do, why it is an appropriate and necessary activity for them to be completing, what you will need to support the Expedition, and how you can facilitate the Expedition. Some Expeditions have special information at the beginning to inform you of any special needs or requirements: for example, reminding you to charge the batteries well in advance of attempting the Expedition or anticipating possible problems that may occur.

Background Information: Background information is provided for both you and the student for each Expedition and Exploration. Although the material provided for you is often more detailed, how much or how little of this background information is shared with the students, and in what way, is up to you. There is enough information to present a formal lesson or for you to familiarize yourself with what is being discussed. Additional background information is presented on the CD-ROM that clarifies concepts, provides biographical information of people identified in the background information, or defines terms that are used.

The intention of providing this information is for you to have a deep enough knowledge of magnets and magnetism to answer questions that may come up during the course of the Expedition or Exploration. Much of the information is useful for many more activities than just the one with which it is found. The information contained in this section is often reproduced for the students, sometimes in a simpler form. It is suggested that, if you have questions about any of the information, or find that something is there that led you on another path and you wish to share this with other teachers, visit the discussion room on our web site for collegial conversations.

Excursions: Each of the Excursions can stand alone and, although related to the concept being explored, does not need to be aligned with any one particular Expedition. Excursions link magnets, magnetism and related concepts to mathematics, literature, language arts, geography, history, world cultures, art, music, and current issues. This portion of the Alpha Guidebook encourages you to integrate science instruction and exploration with other areas of study.

Excursions can be used as additional assessment or can be used as the basis of an interdisciplinary unit and are separately linked to both National Science Education Standards and Florida's Sunshine State Standards. The intention is to find a way to engage all students, not just those who indicate a serious interest in science. Short stories, novels, current issues in science and technology, computer resources, art, music, and popular entertainment are ways to link magnetism with other areas of interest.

For Your Planbook:

Suggested Time: Each Expedition and Exploration can be adapted to conform to individual time constraints. The assessment that you choose as well as your choice of assigning and reviewing homework will determine how long each Expedition will take. The choices are designed to allow you flexibility in planning as well as meeting grading requirements and the level of the class you teach.

Gear: All materials necessary for the completion of the Expedition are listed in this section. Keeping magnets away from compasses will ensure that your equipment will be in the best shape each time you are ready to use it. A class member or several (one from each group) could be assigned on a rotating basis to make sure that at the end of the activity or at the end of the school day the materials are stored properly.

National Science Education Standards: Standards are referenced so that you can easily record them in your planbook. If you are asked to identify the standards covered with each unit you teach, this is easily facilitated. To check all National Science Education Standards and incorporate Professional Development standards, order from National Academy Press, 2101 Constitution Avenue, NW, Box 285, Washington, DC 20055 or access them electronically (http://www.nas.edu).

National Mathematics Standards: After conversations with noted mathematics educators it was decided that these standards would not be included since the National Mathematics Education Standards are in the process of being revised. Future editions of MagLab: Alpha will include these standards. To check the current standards order from NCTM, Curriculum and Evaluation Standards for School Mathematics, Reston, VA or access them electronically (http://www.end.org/reform/index.htm).

Sunshine State Standards: Florida initiated the standards in 1994 as an attempt to

raise the level of achievement through the state. Since standards will be monitored by both the Florida Writes! test and the Florida Comprehensive Assessment Test (FCAT), teachers are required to correlate their curriculum with those standards. Standards are referenced in several ways: (1) each Excursion has listed with it the Sunshine State Standards covered for science, mathematics, language arts, and social studies; (2) every "For Your Planbook" section has the Sunshine State Standards for science, mathematics, language arts, and social studies that are covered in the activity itself, the homework and assessment; (3) each Exploration has Sunshine State Standards for science, mathematics, language arts, and social studies listed; and (4) charts in Appendix A cross-reference Expeditions, Excursions, and Explorations with all standards. To get a copy of the standards you can write to Sunshine State Standards, Florida Department of Education, Tallahassee, FL or electronically (http://www.firn.edu/doe/menu/sss.htm).

Homework and Homework Assessment: Homework assignments are included to be used at your discretion. They are given as an option for each Expedition but could be used with any of the Expeditions or Excursions because the tasks are about magnets, magnetism, and related concepts in general. Each homework assignment requires little in the way of supplies, textbooks, or materials. Most are meant to be assigned well in advance. Allow sufficient time for students to research and reflect on the question or activity. Do not expect a one-day turnaround. Some assignments are designed to be given as preparation for an Expedition, while others are designed as follow-up. It is clearly indicated whether an assignment is best done before or after the Expedition.

A separate "homework assessment" is written for each assignment that suggests goals for the students. This also clarifies for the student why it is appropriate to do this work at this particular time. Methods are suggested to "check" the homework without having to gather papers and grade them. Rather, you are encouraged to use the assignments to enhance the work being done in class.

Assessment: This portion of MagLab: Alpha is designed to be assessment that improves teaching and learning. However, how you opt to use this section is a decision that only you can make based upon your school and classroom needs and the individual personality of each class.

Every assessment task in MagLab: Alpha has been designed to conform with National Science Education Assessment Standards (see discussion of standards). The assessments are designed so they can be used both as formative and summative. We assume that you know best which task to choose for which purpose at certain times. *Formative* assessment is used to gather information so that you can plan future work for your students. Formative assessment is a diagnostic tool that helps you decide how to proceed. *Summative* assessment, on the other hand, is used to determine where the students are along a certain continuum. Summative assessment answers the question, "How far have my students come?" It is the type of information that you would provide to parents -- a summary of the child's progress.

Each assessment that you assign should have a reason for being assigned. If you ask students to complete an assignment, they should be learning something from it. Furthermore, students should be able to identify what it is they are learning. New curriculum products that address current science curriculum reform efforts require new assessment techniques. Each task is accompanied by suggestions to help you determine whether the students you teach with their specific and particular needs, abilities and interests, have successfully met the goals for the

assignment: What have students learned? How did they learn it? Why did students find it important? What connections have students made with other disciplines? Where can students go from here? What can be done with what they learned?

Student Itinerary: MagLab: Alpha is not meant to be a prescriptive unit of study. Thus, the Student Itineraries are NOT worksheets, but are the suggestions and guiding questions with which each group will work. Each Itinerary provides instructions for completing the Expedition, the materials needed, background information, and questions for students to answer in their Logbooks. Although it would appear at first glance to be a step-by-step set of instructions, instead the Student Itinerary provides support for students to maintain a consistent level of performance.

Each Itinerary tells the students which issues should be addressed in their Alpha Log and when to consult you. The Itinerary is designed to assist you as a facilitator of science learning rather than the holder of science knowledge. The intention is that, once you have introduced the information and conducted discussions about homework and assessment issues, students will need support rather than instruction. Task-oriented groups will need little assistance; other groups, depending upon their level of sophistication, may need more help. Rather than you helping groups as they meet with difficulties, it is suggested that students go to one another for assistance. For example, a group that is obviously successful in their work could help a group that is having difficulty. Your job, then, becomes one of facilitator and then sponsor as you encourage, cajole, and support your students' quest to complete their own Explorations.

Student Itineraries are reproducible for your convenience. If you choose to laminate them or place the Itinerary in a protective plastic sleeve the same Itineraries could be left out for all groups. Itineraries are also useful if a student is absent and needs to know what he or she missed.

Alpha Log: There are several ways to approach a science notebook. Primarily, however, it is advisable to decide ahead of time why you are asking your students to do this. The benefits of writing in science are well documented and there is considerable evidence that writing across content areas raises test scores and contributes to the overall literacy of all students. A large part of being successful in science (and other disciplines) both in school and out is being able to communicate one's findings to others in the same field, outside of the field, and to the general public.

The Alpha Log is a way for students to express themselves, clarify ideas, criticize their own thinking, reflect on ideas, and examine their own work. Students can do this in a number of ways. Some students will choose to keep records in written form while others will use visual tools to help them conceptualize ideas (see Hyerle, D., Visual Tools for Constructing Knowledge). Still others will reflect upon what was done in a day or class period in an attempt to gain a deeper understanding of material covered or an investigation completed. Just how and when students do this in their Alpha Log will be determined by you well in advance of beginning this unit of study.

You may decide to set up guidelines for the Alpha Log before you begin this unit of study so that you only look at the Logs once every 2 weeks or even once a semester, depending upon the number of Logs you are required to review and how closely you choose to review them. You

could pick up one Log per group each week to keep a closer eye on the progress being made by each collaborative group. With a more sophisticated class, you could decide to look at the Alpha Log once, twice, or three times during this course of study. You can require students to be responsible for their own Logs or you may decide to keep the Alpha Logs in the classroom. A cardboard box for each class in the back of the room could work well for you depending upon the level of class. This system would cut down on students forgetting their work or losing the Log. However you choose to set this up, there are some suggestions for you to think about before setting up your guidelines.

First, the Alpha Log is a way to model how scientists work in a real-world laboratory situation. Most scientists not only keep a notebook, but they leave their notebooks out for others to use when doing a collaborative investigation. Second, the Alpha Log is referenced in the Student Itinerary as a place to accumulate valuable information to facilitate the Expedition. Third, maintaining the Alpha Log teaches students the value of keeping work in an organized fashion for future reference. Instead of viewing daily work as looked at once and forgotten, the work becomes a resource to be referred to at a later date and also becomes evidence of work completed.

Along with the required entries, you could have students do reflective writing from time to time, preferably on a regular basis. At the end of each week, or at the end of each Expedition, students could respond to a set series of questions. For example,

1. What went well for your group while completing this Expedition?
2. What could your group improve upon before the next Expedition?
3. What new information about magnets, magnetism, or related concepts did you discover while completing this Expedition?
4. How can you use this information to help you, either in school, at home, or elsewhere?
5. Name one person that you shared this information with and state why you chose to discuss it outside of class.

Alpha Logs could be used as a place to do a "warm-up" question or response. For example, at the beginning of class (while you are taking attendance, dealing with late passes, listening to announcements, and otherwise completing all those tasks that take time away from the students), write a statement on the chalkboard for students to respond to; or ask a question that relates to the previous day's work in an attempt to help your students clarify what they learned. A sample warm-up question could be: In yesterday's Expedition, your group chose one design plan over another. Briefly explain what led you to support one particular design over another. Another option is a sample statement to which you are asking students to respond: Some people believe that, because of the vast amount of knowledge that they have, scientists are dangerous. React to this statement.

However you choose to utilize the Alpha Log, your students are required, as a major part of this experience, to keep a class notebook. The form is your choice: spiral bound notebook, loose-leaf-type book, composition book, or folder. Whatever you decide on and however you choose to set this up, students must be informed at the start of your expectations. Providing a rubric for the Alpha Log allows students to take ownership of their grade and determine to what level they will be responsible for their own work. For example, A = work is neat, complete (based on the Student Itinerary questions), shows revisions, includes all diagrams and reflective and/

or warm-up responses; B = work is neat, complete (based on the Student Itinerary questions), includes all diagrams and reflective and/or warm-up responses; C = work is complete (based on the Student Itinerary questions), includes all diagrams and reflective and/or warm-up responses; D = work is incomplete (based on the Student Itinerary questions), includes most diagrams and some reflective and/or warm-up responses.

EXPLORATIONS

Explorations can be used at any time during the course of the unit of study. Using an Exploration between Expeditions is recommended rather than attempting to complete all five Explorations at the end of the time you have set aside to complete MagLab: Alpha. Since they are project-based, Explorations can be used as the basis for Science Fair projects or projects that are displayed for an Open House, Science Exposition, or other special event. There are five Explorations leading students to research or technologies that apply the concepts they mastered while completing the Expeditions. Explorations are project-oriented and are intended for students to complete with little supervision. There is no homework presented for the Explorations since it is assumed that students will work on their chosen projects at home over a predesignated period of time. The period of time you choose to allow for the projects will be based on the complexity of the projects your students are choosing and/or the amount of time that you have available or wish to spend.

Although students could work in pairs or groups to create their projects, it was intended that these Explorations be completed individually. Since the entire unit of study is a collaborative effort, this could be a chance for students to take individual ownership of their project. The choice is yours. Each of the recommended projects lends itself equally well to individuals, pairs, or larger groups and are designed to appeal to each student's individual learning style. Although a choice of projects is given, there are certainly many more that could be created by students and it is suggested that you allow students the freedom to propose projects for your approval. Providing a checklist for students will ensure that everyone is aware of the expectations and has the best chance for success. Set a time limit, objectives, and schedule several days for students to present their projects publicly.

Planning the Exploration: This section contains ideas and suggestions for presenting the subject matter covered in each particular Exploration. Connections between Expeditions already completed and Explorations are made, as well as ideas for projects other than those listed. Reasons for using each subject as a jumping off point for projects related to magnetism are given as are links to other disciplines and other areas of scientific study.

Background Information: Enough background is given so that you can suggest alternate projects for students with specific interests or talents. However, the intention of the Explorations is that students delve further into these areas on their own in ways that are comfortable for each individual. The background information will give you enough information to send students on various paths and will help you determine how much time you wish to spend on each one. Should you need further information, reference is made to books and articles (see

Appendix C, Annotated Bibliography).

For Your Planbook: As in the Expeditions, the following parts are contained in this section: Suggested time, Gear, National Science Content Standards, Sunshine State Standards Benchmarks (science and other disciplines), Homework, and Assessment.

Although a suggested time is given, you will decide how much time to devote to the activity, based on the level of the class, the amount of time available to you, and your purpose for assigning the project.

The Gear will be based on the type of project that students choose to complete. If you choose to allow class time for students to work on their projects, you will either need to inform students that they must bring their own supplies to class, or you will need to accumulate certain materials to make sure that all students can use the time constructively.

Homework takes a different form since the Explorations are project-oriented. The homework is an ongoing process as the student works on his or her project outside of school.

Assessment is not differentiated from the tasks in this case. Each one contains ideas for the student and for you about how to complete that particular project.

ALPHA INTERFACE

Comprised of a CD-ROM and web-based references, this resource is closely aligned with the Alpha Guidebook to provide support for both teachers and students. The interface resources can directly support learning in the Expeditions and Explorations, or it can be used to launch a deeper probe into areas of special interest. The Alpha Interface can be used apart from the Expeditions and Explorations as a research tool on magnets, magnetism, and related concepts. Each feature of the Alpha Interface is described below.

TOOLS

There are four tools to support Expeditions, Explorations, and research, but they are not limited to these uses. Tools could be used to support other units of study and other disciplines. When MagLab: Alpha is used as the basis for an interdisciplinary unit of study, for example, the Language Arts teacher could use the Alpha Interface to facilitate writing, vocabulary study, or spelling tasks.

The interpreter contains vocabulary words used in all parts of MagLab: Alpha. As students work their way through the Expeditions and Explorations there will be words that they do not understand. The Interpreter explains those words and can be accessed either directly or through individual Expeditions or Explorations. The Interpreter also explains words other than those directly related to magnets and magnetism in the belief that the student must understand all the words being used to fully comprehend each task.

Formulas are supplied to support those Expeditions and Explorations that deal with metrics and require conversion either from the Metric System to the English System of measurement or vice versa. This is a resource that can be used with any science or mathematics unit of study.

A calculator is supplied to facilitate application of the formulas necessary to complete Expeditions, Explorations, or homework assignments.

Scales are provided to support all relationships discussed in the activities. Temperature scales -- Farenheit, Celsius, and Kelvin -- are included as reference for several Expeditions and homework assignments and can be accessed either directly or from the Expedition itself.

RESOURCES

The five resources go beyond the Background Information supplied with each Expedition and Exploration. They are available to support assignments or to provide additional information on subjects of special interest to students.

Careers in fields related to magnets and magnetism are described to give students a sense of the practical aspects of MagLab: Alpha, linking the classroom with the real world. The variation in careers will further point out employment opportunities that are associated with the study of science.

Web links to sites that relate to magnets and magnetism are provided to further enhance each Expedition and Exploration. Assessment tasks require the use of web sites; the web link feature of the Alpha Interface facilitates that use.

Visuals include pictures, charts, movies, and animations that illustrate the concepts dealt with in each Expedition and Exploration. As an accompaniment to definitions and explanations, the visuals allow students to see a MagLev train, for example, or the Earth's magnetic field lines. When students have a difficult time grasping a particular concept, a visual can sometimes be all that is necessary to solidify a student's understanding.

The library contains explanations of major concepts, and biographies of men and women mentioned in Expeditions, Explorations, and Excursions. References are provided for further definition of terms and concepts. An Index is provided to guide students to the most suitable reference quickly and easily.

MagE! guides students and teachers to movies, magic, and entertainment technology that use magnets and magnetism to enhance a story. Students and teachers will be surprised at the many uses of magnetism in the entertainment industry. Also explained here are ways that magnetism is used in the technology that allows us to view videotapes and listen to audiotapes, for example. The way in which technology uses magnets and magnetism is fully explained to enhance students' appreciation of these concepts in everyday life.

MODES

Students can access Alpha Interface resources in a number of ways, each one designed to help students find necessary information quickly and efficiently. Each mode provides a different way to access resources based on student or teacher need.

Expedition mode accesses each Expedition by name and number. The background information with related vocabulary, references, biographies, scales, visuals, web links, and careers specific to the particular Expedition are highlighted.

Exploration mode allows students and teachers to access each Exploration by name and number. Similar to the Expedition Mode, background information for the particular Exploration

appears with links to vocabulary, references, biographies, scales, visuals, web links, and careers that are appropriate to that Exploration.

Research mode is available whenever you or students require additional information to enhance an Expedition, Exploration, Excursion, homework, or other assessment task. The Research Mode allows students to choose particular subjects to be researched regardless of which Expedition or Exploration they are working on.

Training mode explains the Alpha Interface to the first-time user. Each feature of the Interface is defined and explained and is there to assist teachers and students as they use the Alpha Interface. It can be accessed at any time to facilitate research.

TODAY'S SCIENCE CLASSROOM

CLASSROOM ISSUES

What are your students expected to know? The MagLab: Alpha unit of study expects that your students will use certain skills or will acquire those skills as they complete each Expedition, Exploration, and Excursion. Many students come to the middle grades classroom with a whole repertoire of problem-solving and critical thinking skills. However, it cannot be assumed that all students have these skills when they enter the science classroom. It is advisable to determine at the beginning of the school year those skills that you will want to develop.

Brainstorming: Students clarify ideas in either small or large groups without judgments being made as to "right" or "wrong" answers. Groups generate a large number of ideas from which to choose. Brainstorming encourages different perspectives and allows each person to contribute without question.

Draw conceptions: If students have never been asked to draw their idea of something, they may need some guidance. In the case of MagLab: Alpha, students will draw, for example, their idea of a magnet. The drawing supplies a permanent document that can be revisited at a later time, added to, or subtracted from. In some cases, students are not able to articulate their ideas, but can draw them. When asked to explain their drawings to you or another student, students can often better express what they are thinking.

Group roles: Regardless of how you choose to design your groups (you choose, students choose, same groups all semester, or rotating roles in static groups, for example), students should have assigned roles. The roles represent tasks that need to be completed with some discussion of the fact that the defined tasks are not the sole responsibility of one person; rather, the group maintains responsibility for the total product. Examples of group roles are: recorder, spokesperson, materials manager, and timekeeper. These roles could rotate on a regular basis or be chosen by you based on identified areas in which students excel.

Articulate ideas and reach group consensus: With each Expedition and Exploration, you are asking your students to make decisions as a group. This is a skill that many middle school students may not have. You will need to guide some groups with a discussion of decision- making

and listening skills. You may need to speak about leadership versus authoritative behavior and leadership versus dominance. Although students may have previously worked in groups, they may not be familiar with working collaboratively.

Critical analysis skills: Some skills that will be developed through these Expeditions and Explorations are distinguishing between similarities and differences, being able to compare and contrast, identifying the main idea in a paragraph or article, and distinguishing between fact and fiction.

Plan, test, and implement a design: Delineating the parts of the design process is probably new to some middle grades students. They are used to being told to "make something" or "draw something," but creating a plan first, discussing the feasibility of the plan, revising a plan, and then implementing the plan are steps that they may not have taken before. You, as a facilitator, will assist students with this process.

Graphing and measurement skills: Competence in these two mathematics skills are necessary for a number of the MagLab: Alpha Expeditions and Explorations. When students use skills learned in one class to enhance their success in another class, they begin to realize that each subject is not studied in isolation.

Centers: MagLab: Alpha lends itself well to setting up areas of interest in the classroom. If you are comfortable with groups working their way through a series of Expeditions and/or Explorations, set up the materials and equipment necessary for individual Expeditions in different places around the room. One center could have a computer, project supplies, and reference books and be the assessment area where students could complete assignments. Other centers could be for using the CD-ROM, completing two or more of the Expeditions, or an Exploration center. The decision you make will be based on the number of students in your class, their ability to take responsibility, the physical layout of the classroom, and your comfort with student activity and noise.

Group work/Cooperative Learning: MagLab: Alpha is designed with groups of four children in mind. Groups of six will work with middle level students but the smaller the better. How groups are chosen is up to you. What is most important is that students realize that working in a group is not working near another person but with other people. The collaborative nature of the Expeditions requires students to have a familiarity with working in groups; that familiarity may have come from elementary school or it may develop through the MagLab: Alpha series of Expeditions and Explorations.

There are several ways to set up for group work: you choose the groups based on areas of expertise; students choose their own groups for the maximum comfort level; or groups are chosen randomly. Regardless of how you decide to implement the groups, there is some preliminary discussion that is necessary about your expectations, group roles and responsibilities, and ultimately what is expected of the final product. In the case of the Alpha Logs, it is imperative at the start of MagLab: Alpha that you make it very clear that the Logs are individual notebooks based on the collaborative work.

Training Lab Assistants: It is a good idea to train 2-3 students from each class as helpers either for individual Expeditions or sets of activities. Once students are familiar with your purpose for the unit, the basic concepts you will be covering, and how the activities will work,

they can be given a number of responsibilities: charging the batteries, helping other students, explaining procedures to groups, conveying in "kid words" your expectations, consulting on homework, etc. The limit of responsibility is, of course, your choice and depends upon the time you have to set this up. However, it is well worth your time and the students' since ultimately this will be of great help to you. It is particularly helpful with large classes.

There are several ways to accomplish this: (1) during your planning period, arrange with other teachers to excuse those students you want to work with; (2) train students while the rest of the class is finishing other work; or, (3) arrange for students to come in before or after school.

Incentives/rewards: Several of the MagLab: Alpha Expeditions suggest that you offer rewards for certain accomplishments. Students enjoy competitions and, although they also like being rewarded, the actual item is unimportant. We suggest that you purchase inexpensive pencils, erasers, stickers, markers, crayons, or folders and keep a box in your room for occasions when you choose to reward students. Taking photographs as students work, displaying them, and then allowing students to keep the pictures is a wonderful reward.

Reflective Writing: Included in all MagLab: Alpha materials are opportunities for students to reflect on what they have learned. A simple three to five question paper at the end of each week serves several purposes. First, it allows students to stop and think for a few minutes about what they have learned. Second, it gives students a chance to tell you privately what is going on in their groups or with their work. Third, you can evaluate whether your students are learning what you thought they were learning. Last, student comments are usually a good indication of your teaching style. Students' reflective writing provides a glimpse into what they see.

Teaching and Learning Issues

TYPES OF ASSESSMENT

Performance assessment: Students engage in tasks for a long period of time and do something that results in a product. Performance assessment is embedded in each Expedition as well as in each recommended assessment. Each time you ask a student to solve a problem using the concepts and content in an Expedition, that student is required to demonstrate a knowledge that goes beyond memorization of facts for a multiple-choice test. If students measure the temperature of water, they are demonstrating that they are proficient in using a thermometer. Taking a measurement to show proficiency in measurement is a performance assessment. When you look around your classroom, and you observe students working in groups, simulating real-world decision making situations, this is performance assessment. Other examples of performance assessment tasks include brainstorming, using content and concepts in unstructured ways, relating science concepts to other areas of study, using multiple methods of communication to present science concepts to others, reading and writing about science, or analyzing data in a coherent way.

Portfolio Assessment: Any method of collecting work in an organized fashion as evidence of learning can be considered a "portfolio." Portfolio assessment can take many forms. For example, the Alpha Log (laboratory notebook) that the students maintain for this series of investigations can be considered a portfolio since it will contain most of the information and analysis required for each Expedition; students can identify writing samples, charts, diagrams, or analyses that indicate growth or ones that they are especially proud of to include in the portfolio.

Authentic assessment: Authentic assessment means that the students are thinking like scientists and are doing tasks like scientists do. In the case of the Alpha Log, keeping a record of information is something scientists do. In addition, since the students know the purpose of the notebook and its role in the Expedition, keeping the notebook is an authentic task.

Choice: Current theories about assessment in classrooms encourage teachers to give students choices about how they can best display their newfound knowledge. This is not to say that with each assignment, students should be allowed to do whatever they please; rather, students need a repertoire of resources from which to select the one that allows them to best demonstrate what they have learned. Certainly there are times when you decide what is to be completed, how, and when. By suggesting a variety of ways in which students can display their knowledge, you enable students to select the best assessment tasks and display strategies. There are many more assessment tasks suggested in each Expedition than would be practical to do in the limited time a teacher has. The intention of including so many assessment tasks is for students to be given a choice. By making a conscious selection of one option from an array of tasks, the student frequently takes ownership of that particular assignment.

Learning styles: Each person has a personal way of learning and of presenting evidence of that learning. A learning style should not be confused with intelligences as presented by Howard Gardner. A style is a way of approaching learning that is usually applied to all content. Some

students learn well by listening and repeating information orally; others demonstrate what they have learned by creating artwork. Still other students can incorporate science concepts into creative writing material; while some students do well with graphic organizers such as charts, graphs and concept maps. There are students who prefer a multiple choice-type test to demonstrate what they have learned. More and more frequently students create multimedia projects to display their learning. It is the aim of MagLab: Alpha that the assessment materials provide you and your students with enough choices to accommodate the learning styles of all the students that are in your classroom.

Rubrics: A rubric is part of the process of scoring student work by determining a standard of performance based upon the students you teach. (I refer you here to the National Science Education Standards discussion of assessment.) Setting up a rubric for each assessment task serves several purposes including clarifying teacher expectations and providing students with a clear guide to measure how well they are meeting these expectations. There is no question about whether a student is successful with a particular assessment activity if there is a clear understanding about what is required when the task is assigned. An example of a rubric for a diagram about magnets might be:

A = the diagram includes all 3 types of magnets labeled with their names, has a title, field lines are included for all magnets, and all poles are labeled;

B = the diagram includes all 3 types of magnets labeled with their names, field lines are included for all magnets;

C = the diagram includes all 3 types of magnets labeled with their names, field lines are included for 2 of the 3 magnets;

D = the diagram does not include all 3 magnets labeled with their names and field lines are incomplete;

F = the diagram only includes drawings without field lines, labels, or title.

To encourage students to further take part in self-evaluation, you could have the class decide on the rubric. Discussing the criteria of a certain task helps students clarify what they need to do to be successful. Being certain that your expectations are clearly defined for students is, in many instances, the key to their success or failure. Further, it makes your job easier, since many questions have been addressed ahead of time. Students will not come back to you later with questions about why they got a certain grade.

An excellent resource for further information on assessment in science and mathematics classrooms is Science Assessment in the Service of Reform edited by Gerald Kulm and Shirley M. Malcom, American Association for the Advancement of Science, 1992. ISBN 0-87168-426-8.

CURRENT ISSUES

Any time students make the link between what is happening in the science class and real

life, it is a victory for the science teacher. A simple comment such as "I saw a movie last night and the hero used a magnet to help him escape," becomes a teacher's badge of honor. Using magazines, videos, television, and newspapers in the classroom is a valuable technique, especially in science. Scientific research and development laboratories announce new discoveries every day. Sometimes in the course of just one school year a discovery or invention is announced and soon thereafter is repudiated or, worse, rejected as fraudulent. Students are more aware now than ever before of issues such as AIDS, cloning, space travel, and environmental problems. Tapping into their natural curiosity about such issues can alleviate fears and address questions that students have. Analyzing or summarizing a newspaper article related to scientific discovery is a difficult task for middle level students. It is strongly recommended that not only current issues but the effect that these issues have on our lives be a part of the overall science curriculum as it is of MagLab: Alpha.

INTERDISCIPLINARY/INTEGRATED APPLICATION

Science, either in the classroom or in a research laboratory, is not done in isolation. Even scientists who have a very specific area of interest are influenced by current events, history, literature, art, and music. To study science in a classroom that is devoid of these other areas of interest is not only artificial but sends the wrong message to middle level students. Regardless of the science discipline being studied, it is imperative that students begin to make connections between what they are studying and real-world applications. Using the knowledge gained in their science classroom to enhance the study of geography or language arts reinforces the interdisciplinary nature of science. When students find relationships between and among the subjects that they study they are more likely to find intrinsic value in the knowledge they are gaining.

MISCONCEPTIONS IN SCIENCE

One of the most difficult jobs a middle level teacher has is determining what students know, what they think they know, and how to use that information to facilitate further understanding. Many students come to science classrooms with misconceptions about the world, how the world works, and where they fit in. This is partially due to misinformation, misunderstanding, and attempts to understand concepts that are too big to even contemplate without good models. Using a misconception as a jumping off place for science exploration can be a good strategy because the student is already comfortable with it -- it is a familiar idea. Correcting a misconception requires that students clarify concepts and then find a replacement for the mistaken idea. A video that will help you understand the attachment that even the most gifted science students have for their misconceptions is "A Private Universe," distributed by The Astronomical Society of the Pacific, 390 Ashton Avenue, San Francisco, CA 94112.

READING IN SCIENCE

Reading is not limited to factual, nonfiction material just because it is being done in a science classroom. Science materials do not have to be unwieldy or complex to be of value. There

is a great deal of well-crafted fiction and nonfiction material written for young adults that can enhance any science program. Different techniques will be necessary for the different types of materials, however, and when reading articles from science journals, it may be necessary to guide students' reading until they are comfortable on their own. With a little practice, students will quickly become adept at picking out science facts from the fiction books they read both for school and on their own. Examples of some books that can be used in the science classroom are provided in Appendix C, Annotated Bibliography).

SCIENCE FICTION

As students attempt to determine what parts of a science fiction story could be true and the parts that could not be possible, they begin to describe what they know. In order to identify and defend the factual portions of a science fiction story students need to find evidence to back up their claims. Science fiction helps students discover the effect that science has on their lives and how science could affect the future. Science becomes much more than a collection of facts. It takes on new meaning as students try to imagine the future. This requires that students take a look at society today in order to imagine how it will be in the future. Current technological advances form the basis for inventing new modes of transportation, new ways of getting information, and ways of understanding new scientific research breakthroughs (for example, cloning).

VISUAL/ORGANIZATIONAL TOOLS

Concept maps, graphic organizers, webs, clusters, and Venn diagrams are recommended throughout MagLab: Alpha as options for students to present information, clarify ideas, or work through a problem. Visual tools allow teachers and students to create a model of how they perceive a certain concept. The variety of visual tools offers students and teachers different ways to analyze the same information. Often students make brand new connections and recognize models that they previously did not see. The nonlinear nature of visual aids adds another dimension to students' understanding and to your understanding of how the students that you teach learn. (See Appendix C, Annotated Bibliography, for resources on organizational tools.)

WRITING IN SCIENCE

Communication is vital to scientists doing real-world research and development. Submitting work for review and scrutiny by colleagues is an ongoing process that can be modeled in the

science classroom through presentation of student work. Being able to share results and ideas with others is a dynamic process that happens every day in science. The portrayal of science as a body of information or a collection of facts to be memorized precludes writing understandable research reports, readable biographies, nonfiction accounts of scientists, or fictional stories. Writing of any sort in the science classroom extends student learning as he or she is articulating science concepts. Further, presenting results or knowledge for public scrutiny requires a great deal of confidence which can be gained from believing you have accurate information.

Writing is not limited to presentation of results or science projects. Journal writing and reflective writing are undoubtedly one of the best ways for students to clarify their thinking and articulate science concepts. These techniques also provide you with a unique insight into how your students learn and what they are learning.

WHAT IS A MAGNET?

PLANNING YOUR EXPEDITION

Most people understand magnets at the level of observable phenomena. That is, they are aware that magnets are attracted to certain metals and that they are attracted to one another; or that they repel one another depending on the orientation of the poles or ends of the magnets (opposites attract). This activity is designed to go one step beyond these observations by helping your students articulate why these things occur as well as to formulate new questions and answers about magnets. Working in groups your students will communicate what they are thinking to others. This serves a number of purposes: (1) explaining an idea is the best way to see if it makes sense; (2) combining several ideas into one might help define concepts; and (3) scientists in the real world attempt to validate their ideas by discussing them with others.

The activity is a good place to start, but could be used at any time in combination with other activities in MagLab: Alpha. It could be repeated as students become more sophisticated in their thinking about magnets and magnetic fields.

1. Set up groups of 2-4 students choosing a recorder, a spokesperson, a materials manager, and a technology specialist. These roles represent the tasks that groups must accomplish to successfully complete this activity. Each group should have access to a variety of magnets and materials (see Gear section in "For Your Planbook") as they attempt to answer the question, "What is a magnet?"
2. Students draw what they think a magnet looks like and share their drawings with others in the group, discussing similarities and differences, and proposing possible reasons for these differences.
3. From the discussion in Step 2, groups will create a list of what they know about magnets and how they know this. Lists could also be expanded to include what students would like to find out. [For example, students will state that they know that magnets stick to the refrigerator because that is how the shopping list is done at home or the answers could be as sophisticated as knowing that magnetic characteristics of videotapes are what enables us to watch and listen to rented movies.]
4. Through the recorder or spokesperson, the group should attempt an explanation of why the similarities and differences in the drawings exist, then share it with another group. Any refinement of the explanation for these similarities and differences should be done here. This explanation plus information from the lists created in Step 3 will become the group's theory about magnetism that will need to be tested and should be shared with other groups or representatives of other groups. During this process students will be writing in their Alpha Logs, modeling what scientists do when they work in laboratories.
5. Using the CD-ROM, web sites, or other reference materials, students will research how early investigators explained the phenomena identified in Step 3. In doing so, groups will record their information in a way that will allow them easy access to

the research.

6. Groups brainstorm ways to support/measure the phenomena in Step 3, producing a plan of action which they may share with other groups and with the teacher. This plan will be used to complete the activity, "What Objects Do Magnets Attract?" You will want to approve the plan before students are allowed to move on.

BACKGROUND INFORMATION

Materials exhibit certain characteristics because of the way in which the atoms that make up the material are aligned. In order for a material to be magnetic there must be moving electrons. Materials with magnetic qualities have domains, each of which are made up of billions of atoms. The way in which these domains are configured determines the magnetic ability of the material. For instance, if the domains are mostly aligned (the electrons are all spinning in the same direction), the material will exhibit strong magnetic characteristics.

Each magnet has a north and south pole, the regions on the magnet where the force generated by the magnet is the greatest. Like poles repel like and opposites attract. Scientists have attempted to isolate one of the poles but have been unsuccessful. If a magnet is cut in half, two magnets each with a north and south pole are created. No matter how small, each piece will still have a north and south pole. The smallest magnet is the electron orbiting a nucleus.

Magnets have different strengths that are dependent on several factors: the material from which the magnet is made, how the magnet is made, and how the magnet is treated. Some materials like lodestone (which contains iron) are found naturally in the earth and have magnetic properties because when they formed, all of the tiny "magnets" (atoms) lined up (north poles facing in the same direction).

EXCURSIONS

Assign "A Sound of Thunder" by Ray Bradbury. You may want to direct students' reading to the portion about the floating walkway to help them make the connection to Maglev train technology which uses magnetic properties to propel a vehicle. One question they could address is: Would magnets/magnetic fields have already changed the environment? This could lead to a discussion on whether or not it is theoretically possible to travel back in time without affecting the future. Being able to identify science facts in fiction is a way for the students to apply newfound knowledge about magnets and magnetism. In addressing the issue of the floating walkway, students should make the connection between the "floating" and

like poles repelling each other. Have students write a review of "A Sound of Thunder" that answers the question: How does the author incorporate the concept of magnetism in this story? Did knowing about magnetism enhance your enjoyment or understanding of the story?

SC.B.2.3.1-2, SC.C.2.3.2, SC.D.2.3.2, SC.F.2.3.4

LA.A.2.3.5, LA.B.1.3.1-2, LA.D.2.3.2, LA.E.1.3.1-2, 2.3.6

Write a fiction story about a sports team that is affected by an invention that magnetizes some aspect of their game. (For instance, a magnetized basketball hoop and basketball.) Students will be applying their knowledge of attraction and repulsion outside the context of the science classroom.

SC.C.2.3.1-3

LA.B.1.3.1-2, LA.D.2.3.2

Create a science fiction story/movie/play about using a giant magnet to change the course of a meteorite heading toward your hometown. Students will need to answer the following: Is this theoretically possible? How would you generate a strong enough magnetic field? In analyzing these issues, students will apply knowledge of magnetism in a different context.

LA.B.1.3.1-2, LA.D.2.3.2

Submit a proposal for creating "magnetic art" for your classroom or school that will educate other students about the properties of magnetism. The proposal requires students to describe magnetism, explain how it relates to making art, and apply their knowledge to a product that serves a practical purpose. A further extension would be to encourage students to follow through on the plan.

SC.C.2.3.1-3

LA.D.2.3.1-2

Write a research report or create a poster, media presentation, or web page to be presented to the class about one of the early scientists investigating magnetism using web sites, the CD-ROM, or print media. Presentations will exhibit students' application of basic principles of magnetism and their understanding that science is an activity affected by history; that it is based upon what was done by others.

SC.H.1.3.1-3, 1.3.6, 3.3.5-7

LA.B.1.3.1-3, 2.3.4

SS.A.2.3.2-3, 2.3.6, 3.3.1, 4.3.3

Notes:

FOR YOUR PLANBOOK: What Is A Magnet?

Suggested Time: 1-3 hours (teacher's choice)

Gear: various magnets, drawing paper, crayons.. Have available for those who need them paper clips, aluminum foil (or a substitute like a soda can), wooden objects, glass, metal rods, coins, etc., although the intention is for the students to find a variety of materials themselves.

CD-ROM for historical information and vocabulary definitions

National Science Content Standards: A, B, G

Sunshine State Standards Benchmarks: SC.C2.3.1, SC.C2.3.2, SC.C.2.3.3, SC.H.1.3.1, SC.H.1.3.2, SC.H.1.3.3, SC.H.1.3.4, SC.H.1.3.6, SC.H.1.3.7, SC.H.2.3.1, SC.H.3.3.5, SC.H.3.3.6

Sunshine State Standards Benchmarks—Language Arts: LA.A.1.3.3, 2.3.1, 2.3.4, LA.A2.3.5-6, LA.B.1.3.1, 3, LA.C.3.3.3, LA.E.1.3.5.

Assessment: Check student Alpha Logs entries for neatness and attention to detail, such as including in the lists what they know about magnets and how they know this. The Alpha Log should reflect an attempt to answer the question, "What is a magnet?" and will include drawings, lists, and working notes.

Have students present to you their plans of action to be used in Expedition 2. This plan of action should be approved by the teacher and will include: (1) the group's theory; (2) how the group will test the theory; (3) what materials they will need; and (4) how the group will present their plan and findings to the class.

Have students provide evidence that they have successfully used a web site or CD-ROM to gather information (in the form of a disk, printout, or diary of sites used) on early scientists who noticed the phenomenon of magnetism. The information that is collected will be used later on in a research report. Evidence should be in a form which can be shared with the group.

WHAT IS A MAGNET?

Itinerary

This activity is a chance for your group to share beliefs about magnets and magnetism so that you can answer the question, "What is a magnet?" After completing the steps, you will discover that there are many ways magnets are used and different ways that magnetism affects our lives. The Plan of Action that you create in Step 7 will be used in the next activity as you conduct an investigation into the kinds of objects that magnets attract.

Before completing the individual parts of this assignment, read through all of them to get a general idea of what it is you are trying to accomplish. If you have any questions, discuss them with your teacher, or as a group before you begin.

1. Assign individual roles. You will need a recorder, a spokesperson, a materials manager, and a technology specialist. Each member should enter this role in his or her Alpha Log.

2. The materials manager should make sure that your group has the following items: magnets, drawing paper, and crayons.

3. Each person draws his or her idea of a magnet: what it looks like, what it does, etc., to be shared with the whole group when finished. List the similarities and differences you discovered, after comparing drawings, in your Alpha Log.

4. Generate a list of what the group knows about magnets and magnetism and include it in individual Alpha Logs. You may choose to also include what you would like to learn about magnetism. Once you have completed the list, compare it to another group's list. Notice how they are alike and how they are different. If there are things on the other group's list that you would like to include on yours, add them now.

5. How did early investigators test their ideas about magnetism? Use the CD-ROM, web sites, or print resources to research scientists who first noticed the phenomenon (for example, Luigi Galvani, William Gilbert, Hans Christian Oersted, Giovanni Aldini, Michael Faraday). Organize your information in a way that can be shared with the group and that can be used later on as a resource.

6. Your group should now form its own ideas about magnets and magnetism that you will eventually test. Your theory may be in answer to the original question "What is a magnet?" or it could be the group's hypothesis as to why certain materials exhibit magnetic characteristics and others do not. This theory will be based upon the lists you created in Steps 3 and 4 and should be entered in

WHAT OBJECTS DO MAGNETS ATTRACT?

PLANNING YOUR EXPEDITION

As an extension of "What Is A Magnet?" or standing alone, this activity is intended to allow students to explore the magnetic qualities of various materials. Maintaining the groups set up for the previous activity provides continuity and a forum through which students can test ideas. Articulating theories about magnetism before testing them can save time and will help students make sense of what they are trying to accomplish.

Creating a data table and then using this data to answer a question or solve a problem is a skill that is used frequently in the science classroom. Recording the data table in the Alpha Log enables students to use the data again and again, if necessary. Whether the students come up with their own action plan or, whether you provide the parameters within which they will work, a data table is recommended. Students will then be asked to classify the data and use it in a writing assignment.

Students might choose other ways to present data based upon personal learning styles. It is important to the understanding of complex concepts, such as magnetism, that the information collected makes sense to every student. Creative ways to demonstrate mastery could be through the use of graphic organizers, concept maps, lists, graphs, or computer-generated representations of the data.

The concept of atoms could be introduced or reintroduced here depending upon the class level and students' prior experience. The CD-ROM offers graphically-presented background information on atoms in a way that is understandable for a middle school student.

1. Groups of 2-4 students are assigned specific roles: recorder, spokesperson, materials manager, and technology specialist (see discussion on group roles in "Classroom Issues"). Discuss the task with the whole class, beginning with the question, "What objects in and around this room are attracted to a magnet?" Instruct groups that they will be responsible for recording observations, confirming the data, and then presenting it to the class.
2. If the groups have previously completed "What Is A Magnet?" they will use the plan already designed and approved by you to test their theory or theories about magnetism.
3. Students will investigate at least 15 items in and around the classroom, predicting whether each one will be attracted to a magnet and recording the results on a data table or other method of data collection preapproved by you.
4. When all information has been collected, groups will design a method of presenting the results to the whole class.
5. Groups should be encouraged to use technology other than paper and pencil to present their findings (for example, a computer, overhead projector, or instant photographs). At this point, students could role-play, write song lyrics, or suggest other ways of presenting their findings. However,

the presentation should be substantive, including that magnetism is the result of the movement of electrons, that some materials are attracted to magnets and others are not, that these materials can be classified, and that magnets have a north and south pole.

BACKGROUND INFORMATION (see also Background Information "What Is A Magnet?")

All matter is made of atoms. Atoms can be broken down into three smaller particles: protons, neutrons, and electrons. It is one of these smaller particles, the electron, that is very important to magnetism, since only it is able to move around in magnetic materials. The movement of protons is so slight that they are of little consequence to the discussion of magnetism.

In most materials, electrons occur in pairs. However, some materials have unpaired electrons. Unpaired electrons can move freely through some metals, and they arrange themselves so that they spin in the same direction, causing the metals to become attracted to a magnet. The alignment can occur in natural or manmade materials.

EXCURSIONS

Have students create an invention that uses magnetism, describe the purpose of the invention, who would be most likely to use it, how it works, and the purpose of using magnetism as part of the invention.

SC.C.2.3.1-3, 6

LA.B.1.3.1-3

Using the results from the interview questions (homework assignment) students create posters to be displayed around the school, making sure that there is included in this display a way to educate others as to what magnetism is and its everyday applications.

SC.C.2.3.2, SC.H.3.3.5-7

LA.A.2.3.5, LA.B.2.3.3, LA.D.2.3.2,5

Read aloud The Secret Life of Dilly McBean about a boy with magnetic hands. The class could discuss how the novel relates to what they are studying in class. There could be written summaries, drawings, role-playing activities when the book is finished. This is an excellent way to introduce the connection between literature and science, especially discussing that the story itself is enhanced by the knowledge of scientific concepts and facts.

SC.C.2.3.1-3, SC.D.2.3.1

LA.A.2.3.1-4, LA.C.1.3.1-4, LA.E.1.3.1-3, 2.3.1-4, 6

Investigate various authors. Students will find it surprising that many highly successful authors did not set out to write

books and, in fact, may have begun their adult careers in science. For instance. Elaine Konigsberg (E.L. Konigsberg) was a science major at Carnegie Mellon before writing The Mixed Up Files of Mrs. Basil E. Frankweiler and has recently won the Newbery Award for her latest book about a middle school brain bowl team. Arthur C. Clarke (2001: A Space Odyssey) combines both a successful career as a science fiction author and scientist. Michael Crichton (The Andromeda Strain, Jurassic Park) began his career as a medical doctor. Students could come up with others to present to this class or share in Language Arts.

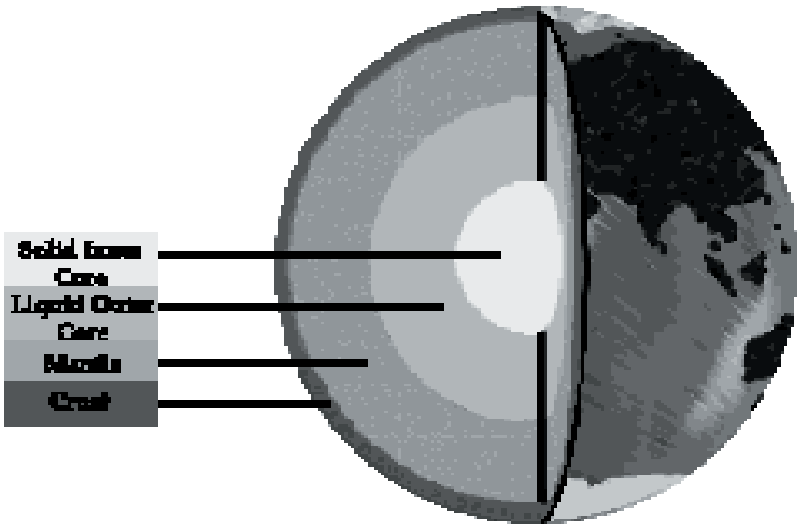
SC.H.3.3.5

LA.A.2.3.4, LA.E.1.3.1-3, 2.3.1-4, 2.3.8

Students research the origin of the word "magnet" using web sites, CD-ROM, or print media. Students will attempt to answer in writing "What's in a name? Does it matter what we call it?" This might lead to discussion of other word origins; for instance in Earth Science, the layer between the crust and the mantle known as the Moho; the names of the different temperature scales; in Life Science, Latin names of animals and plants; in chemistry, the naming of elements.

SC.C.2.3.2-3, SC.H.1.3.1-7, SC.H.2.3.1, SC.H.3.3.5-7

LA.A.2.3.5-8, LA.B.2.3.4, LA.D.1.3.2,4



Notes:

FOR YOUR PLANBOOK: What Objects Do Magnets Attract?

Suggested time: 1-2 hours

Gear: magnets, classroom objects. Have available a variety of objects such as paper clips, aluminum foil, wooden dowels, metal rods, coins, glass, etc., for those students who are unable to bring them to class.

Optional: tape recorder and audiotapes if you choose to record classroom discussions.

National Science Content Standards: A, B, G

Sunshine State Standards Benchmarks: SC.A.1.3.4, SC.A.2.3.2, SC.C.2.3.1, SC.C.2.3.2, SC.C.2.3.3, SC.C.2.3.6, SC.H.1.3.1, SC.H.1.3.2, SC.H.1.3.4, SC.H.1.3.7, SC.H.3.3.6, SC.H.3.3.7

Sunshine State Standards Benchmarks -- Language Arts: LA.C.1.3.1, 1.3.4

Homework: Have students create three interview questions to probe someone's understanding about magnets and magnetism. Sample questions might be: What is a magnet? Why are some materials magnetic while others are not? Where would you find magnetic fields? Are there magnetic fields in nature? Students should conduct at least two interviews with adults (high school age or above) to share with their group.

Homework Assessment: Use homework interview questions to discuss misconceptions about magnets/magnetism, the general public's knowledge of the subject, what the implications are, what information is lacking, etc. Classroom discussions could be tape-recorded and replayed for further clarification after more magnetism activities are completed. In this way students can correct any misconceptions that they might have had at the start of the series of activities.

Assessment: Data collection record includes a table that is easily readable without detailed instructions indicating that students investigated 15 objects after predicting whether or not they will be attracted to a magnet. Tables should indicate that no nonmetals were attracted to a magnet and only some metals (not all) were attracted to a magnet.

Presentation to the class should be creative, well thought out, use technology other than paper/pencil, include a conclusion as to which materials are attracted to the magnet and why, and should reflect participation by all group members.

Alpha Logs include preparation of the data table, interpretation of results, one paragraph listing characteristics of magnets, and conclusions drawn after completing the investigation. There should be some indication that students have improved in their ability to predict which objects are not attracted to a magnet.

A computer-generated table or graph, saved on disk, becomes a part of the general Alpha Log demonstrating use of technology.

Students create a written product (list or paragraphs) that demonstrates how their group classified objects that are attracted to a magnet. This requires that the group found a way to organize and articulate their assumptions.

WHAT OBJECTS DO MAGNETS ATTRACT?

Itinerary

All matter is made of atoms. Atoms can be broken down into three smaller particles: protons, neutrons, and electrons. It is one of these smaller particles, the electron, that is very important to magnetism. Magnetism is a force that can attract or repel objects. This attraction or repulsion is caused by the arrangement of electrons in a material. An object is said to have magnetic properties if it can be affected by a magnet.

In most materials, electrons occur in pairs that spin in opposite directions. However, some materials have unpaired electrons. Unpaired electrons can move freely through some metals, and they arrange themselves so that they spin in the same direction, causing the metals to become attracted to a magnet.

You will be investigating objects in and around your classroom to determine how each one interacts with a magnet. This activity will help you answer the question,

"What objects are attracted to a magnet?" Not only will you answer it, but you will present your answer to the class so that you can check your results against those of the rest of the students. You will be modeling what scientists do in real-world situations. As they work, scientists post their data, or e-mail other scientists to get feedback before they go further. Use either the plan that you developed previously or one suggested by your teacher to test objects and record information.

1. Assign individual roles or keep your roles from the previous activity: a recorder, a spokesperson, a materials manager, and a technology specialist. Each member should enter this role in his or her Alpha Log and the Materials Manager will pick up a magnet.

2. You will need to investigate at least 15 different objects to see whether or not your magnet attracts these objects. Identify the objects in a data table in your Alpha Log. Include in the table your prediction of whether the object will be attracted to the magnet. If you have chosen another form of recording, make sure this has been approved by your teacher.
3. Once you have finished investigating your samples, make a list in your Log of those objects that are attracted to a magnet and those that are not. Share your results with another group. Recheck those items where there is disagreement. Record the new results in your Log with an explanation as to why you repeated the test.
4. Write one paragraph about the characteristics of objects that are attracted to a magnet. If you have difficulty identifying characteristics of objects that stick to a magnet, a table that lists metals, nonmetals, smooth surface, etc., may help you organize your ideas.
5. With the whole group, create a brief presentation of your results. Have your

VIEWING A MAGNETIC FIELD

PLANNING YOUR EXPEDITION

Prepare your Magnetic Field Viewers (MFVs) ahead of time (see Appendix B) or have iron filings and plastic trays available.

Use this activity with half the class; the other half will complete Expedition 4, "Visualizing Magnetic Field Lines." Students will compare four magnets and the shape of the field that each one generates.

The observations and drawings that the students produce as well as the questions they will be asked to address are designed to be exploratory and to help students formulate and clarify their ideas about magnetic fields. Conceptualizing magnetic fields not only as "real," but as forces that can be manipulated, prepares students for dealing with the idea of magnetic fields so large that they *cannot* be seen. Since the next activity in the series introduces students to the Earth's magnetic field, the connection needs to be made either in this activity or the next. Look for this when assessing student work.

Before students complete this activity, it would be interesting to have them go back to their very first exploration about magnetism and review what they wrote in their Alpha Logs. This would be a good time for some reflective writing in their Logs. How have their ideas about magnetism changed? How would they draw a magnet now? Would the drawing be different or the same?

Using reflective writing activities to guide students' conceptualization of the "big ideas" can help both the teacher and students. From a teacher's standpoint reading students' journals, Alpha Logs, or reactions to statements helps identify misconceptions that students continue to hold even after activities are completed. It can be a tool you use to evaluate where students are in relation to your expectations. Weekly reflections that clarify what was accomplished by the group, identify what was important to the individual, and state questions yet to be answered could be looked at on a weekly or biweekly basis. Or, depending upon the level of the class, it might never be looked at. A truly reflective piece of writing is of use only to the person writing it. Reflective discussion might be more appropriate if you are looking for answers to *your* questions. (See also Reflective Writing in "Today's Science Classroom.")

1. Students will place four magnets on the magnetic field viewer to determine if the shape of the magnet has any bearing on the pattern of the magnetic field. We have come a long way from the conception of a horseshoe-shaped magnet (which was probably what most of the students drew in "What Is A Magnet?"). Your students have discovered that magnets come in many shapes and sizes; what they have yet to discover is how the magnetic fields are related to their shapes.
2. Throughout this activity there are a number of questions that students will address in their Logs. Answers should be supported by diagrams. Whether you evaluate these or not is a matter of personal preference.

BACKGROUND

Some discussion of magnetic field lines is appropriate at this point. Detailed information beyond what is defined here can be found in the accompanying CD-ROM. The magnet generates a magnetic field which extends to the area around the magnet. The magnetic field is visible by using iron filings to illustrate the shape of the field, the field lines, and the fact that fields are strongest near the poles. Field lines spread out from the north pole and circle back around to the south pole.

Magnets can be shielded so that magnetic fields go around the object blocking the field. Magnetic fields can also pass through materials which can be easily demonstrated by placing two magnets on either side of a piece of paper or a student's hand; or a magnet on the underside of the desk and a paper clip or other magnet on the top. The degree to which this is observable depends upon the strength of the magnet, the material between an object and the magnet, or the distance between the magnet and the object. This will be observed in the Expedition "Blocking the Field."

The unit of measure of a magnetic field is gauss or Tesla. A refrigerator magnet typically equals 1 Tesla; the Earth's magnetic field, 5×10^{-5} Tesla. The nucleus of a hydrogen atom equals 14 Tesla. Ten thousand gauss equals 1 Tesla which is 20000 times as strong as the Earth's magnetic field. An analogy that could be used here is ounces and pounds or miles and light years.

EXCURSIONS

If you have chosen to read The Secret Life of Dilly McBean as recommended in "What Objects Do Magnets Attract?" students could draw what they think the magnetic field lines would look like emanating from Dilly's hands. Successful completion of this assignment will further extend students' thinking on the shape of magnetic fields being related to the shape of the magnet. The poles should be indicated on the drawing as the basis for the field lines.

LA.A.1.3.3, LA.C.1.3.1, 2, 4, LA.E.2.3.8

SC.C.2.3.1-3

Using the K-12 Educational Programs homepage at the National High Magnetic Field Laboratory in Tallahassee, students could begin research on what high magnetic fields are and how they are used in research. How much further you wish to go with this information depends upon the level of sophistication of the group as well as the time available to devote to this subject. Some practical applications of high magnetic fields will be dealt with in later activities.

SC.C.2.3.1-3, SC.H.1.3.1-7, 3.3.4-7

LA.A.1.3.3-4, LA.B.2.3.4

Research the work of Pieter Zeeman as it relates to the study of astronomy. His work solidified the relationship between light and magnetism; and the existence of magnetic fields in space. The discoveries that have been made since Zeeman's initial work in 1896 can be related to the Big Bang Theory, stars, galaxies, and planets. This assignment provides yet another link between magnetism and other scientific disciplines.

SC.C.1.3.1-2, 2.3.1-3, SC.E.2.3.1, SC.H.1.3.1-7, 2.3.1, 3.3.5-6

LA.A.1.3.1, 2.3.1-8, LA.B.2.3.3

FOR YOUR PLANBOOK: Viewing a Magnetic Field

Suggested Time: 1 hour

Gear: magnetic field viewers, wand magnets, bar magnets, round magnets, square magnets, rulers

National Science Content Standards: A, D, E, F, G

Sunshine State Standards Benchmarks: SC.A.2.3.1, SC.B.1.3.2, SC.B.1.3.3, SC.B.2.3.1, SC.C.2.3.1, SC.C.2.3.3, SC.E.1.3.1, SC.E.1.3.4, SC.E.2.3.1, SC.H.1.3.1, SC.H.1.3.2, SC.H.1.3.3, SC.H.1.3.4, SC.H.1.3.5, SC.H.1.3.6, SC.H.1.3.7, SC.H.2.3.1, SC.H.3.3.5, SC.H.3.3.6, SC.H.3.3.7

Sunshine State Standards Benchmarks -- Language Arts: LA.A.1.3.1-3, LA.B.2.3.1-4, LA.C.1.3.1-2, 1.3.4, 3.3.2-3

Homework: Have students design their own homework assignment relative to magnetism. For example, a wordsearch using vocabulary words, a crossword puzzle, an art piece based on the patterns of magnetic fields, a collage of things in nature and things human-made that are affected by magnetism, a research paper on a scientist or scientific discovery, a creative story with magnetism as a theme, etc. Allow at least one week for this assignment based on the class schedule.

Homework Assessment: Integrating magnetism with another theme will result in a positive evaluation. For example, if students use definitions in a crossword that indicate they not only know what the word means but know how the word is commonly used, that would demonstrate successful mastery of the words. A research paper on a scientist or scientific discovery that includes a piece on how far science has come since that discovery or because of that discovery demonstrates that the student understands how scientific work leads to more questions and

further experimentation.

Assessment: Check Alpha Logs for answers to activity questions. Answers should reflect that the shape of a magnet determines the pattern of field lines. Students at this point will predict the shape of the field based on the shape of the magnet to successfully complete the assignment.

Drawings should mirror written answers to in-text questions. To successfully complete this assignment, students will demonstrate their knowledge of the names of types of magnets by labeling the drawing; show that they know that a bar magnet, for example, creates a certain pattern every time; and distinguish between each type of magnet.

Student paragraphs will summarize the activity and must include some information about field lines, their length and density, that the magnetic field exists within the field lines and on the lines themselves, and that fields are strongest at the poles (and/or where lines are closest together).

In sharing paragraphs, students demonstrate to you that they can articulate an explanation of magnetic fields and magnetic field lines. This particular manner of assessment requires no grading. If you wish to assign a grade, it would be appropriate to look at the paragraphs as clarification of each student's theory. For example, "If a magnet is round, then the shape of the magnetic field will. . . ." "Bar magnets will always cause iron filings to appear in the shape of . . . ."

VIEWING A MAGNETIC FIELD

Itinerary

A magnet generates a magnetic field which extends to the area around the magnet. The magnetic field is visible by using iron filings to illustrate the shape of the field, the field lines, and the fact that different regions on the magnet may have different strengths. Field lines spread out from the north pole and circle back around to the south pole. Using your magnetic field viewer and differently shaped magnets, you will be observing these things.

Magnetic fields can be shielded so that magnetic fields go around the object blocking the field. Magnetic fields can also pass through materials, which can be easily demonstrated by placing two magnets on either side of a piece of paper or your hand; or, a magnet on the underside of the desk and a paper clip or other magnet on the top. The degree to which this is observable depends upon the strength of the magnet, the material between an object and the magnet, or the distance between the magnet and the object.

The unit of measure of a magnetic field is gauss or Tesla. A refrigerator magnet equals 10000 gauss; the Earth's magnetic field, 1/2 gauss. Ten thousand gauss equals 1 Tesla which is 20000 times as strong as the Earth's magnetic field.

1. The Materials Manager will collect the materials necessary to complete this task: a magnetic field viewer, a wand magnet, a bar magnet, a square magnet, a round magnet, and a ruler.

2. Place the bar magnet on top of the magnetic field viewer so that the magnet is in the middle. Tap the viewer until you get a clear view of the magnetic field. Draw and label a diagram of what you see and then answer the following in your science Alpha Log:
   1. How far does the field extend out from the magnet?
   2. How far apart are the field lines?
   3. Are they the same distance apart everywhere in the field?

4. If not, where are they closer together?
5. Do the field lines run in the same direction?
6. If not, what pattern do they form?
7. Are all the field lines the same length?

3. Repeat Step 2 for each of the remaining three magnets, recording diagrams and answers in your Alpha Log.
4. When you have finished your investigation, write several paragraphs summarizing what you have learned. Be sure to include information about the distance between field lines.
5. Share your paragraph with another student. If there are any findings in conflict, retest them together and record your observations in your Log.

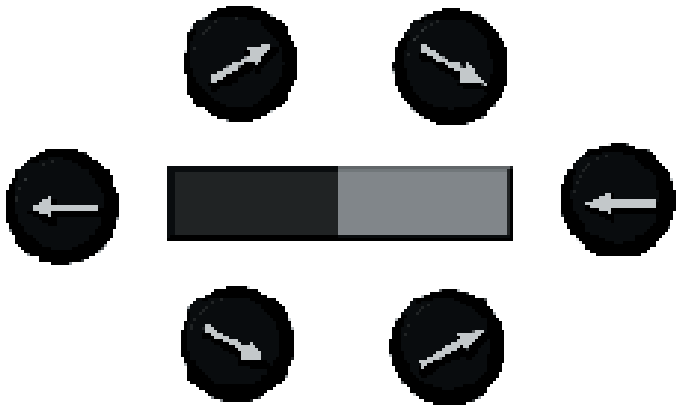
VISUALIZING MAGNETIC FIELD LINES

PLANNING YOUR EXPEDITION

Students will be looking at magnetic field lines in this activity by observing the effect that the lines have on compasses. The other activity that deals with this subject is Expedition 3, "Viewing a Magnetic Field." You can use one in place of the other, or both at the same time, depending upon your group and the time you have.

This is another activity designed to help students visualize a magnetic field. It could be used before "Making a Map Using a Compass" but can stand alone and be used at any time. This is the type of activity that can be revisited from time to time, and Excursions from any of the activities would be appropriate.

1. Students predict how they think compasses will respond to the magnetic field. The rest of the activity will either confirm or refute their prediction.
2. Students place a bar magnet on the desk with the north pole pointing away from them. They will place 6 compasses randomly around the magnet.
3. Placing the magnetic field viewer on top of the magnet *and* compasses, students begin gently tapping the side of the MFV to get a clear picture of the field.
4. Compass needles will point in the direction of the nearest field line and student drawings should reflect this. Some students may have difficulty recognizing this. If, after a few trials, they still do not see the connection, it may be helpful to suggest that students arrange all of the compasses in an arc along one side of the magnet.
5. Encourage students to move the compasses around as many times as they wish; also encourage them to use more than one magnet (2 bar magnets pushed together).



BACKGROUND INFORMATION

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Magnetic fields can be shielded so that they go around the object blocking the field. Magnetic fields can also pass through materials; this can be easily demonstrated by placing two magnets on either side of a piece of paper or a student's hand; or a magnet on the underside of the desk and a paper clip or other magnet on the top. The degree to which this is observable depends upon the strength of the magnet, the material between an object and the magnet, or the distance between the magnet and the object. This will be observed in the activity "Blocking the Field."

The unit of measure of a magnetic field is gauss or Tesla. A refrigerator magnet typically equals 1 Tesla; the Earth's magnetic field, 3×10^{-5} Tesla. The nucleus of a hydrogen atom equals 14 Tesla. Ten thousand gauss equals one Tesla which is 20000 times as strong as the Earth's magnetic field. An analogy that could be used here is ounces and pounds or miles and light years.

EXCURSIONS

Conduct a class discussion or debate about health concerns of people living near high power lines. Some people believe that the magnetic fields created by these high power electrical lines are harmful. **Recent research done by the medical community indicates that this is not true.** A worldwide web search or print media search could turn up many articles on this subject. Choose four class members for each side and the rest of the class becomes the audience at a town meeting called by concerned citizens. At the end of the debate, the audience decides whether or not to pay to evacuate citizens that live in the affected area. This exercise takes a real-world concern/current issue and allows students to use their knowledge of magnetic fields. They will be modeling a process that is widely used by communities to discuss issues of concern. The New York Times Book of Science Literacy (ISBN 0-06-097455-9) has a short article on this subject.

SC.C.2.3.1-3,

SC.H.1.3.1-7, 3.3.1-4

LA.A.1.3.1-4, 2.3.1-8, LA.C.3.3.1-3

SS.C.2.3.6-7, SS.D.1.3.1-3, 2.3.1-2

A search of worldwide web sites about magnetism will reveal a large number of products for sale that claim to have medical benefits.. Have students research these -- let each group choose one -- and then report back to the class. Becoming educated, responsible consumers is important, especially when students realize that they control a large percentage of dollars spent on consumer goods.

SC.H. 1.3.1-7, 3.3.1-4

LA.A.1.3.1-4, 2.3.1-8

SS.C.2.3.1-3, SS.D.1.3.1-3, 2.3.1-2

FOR YOUR PLANBOOK: Visualizing Magnetic Field Lines

Suggested time: 1 hour

Gear: compasses, bar magnets, magnetic field viewers

National Science Content Standards: A, B, E, F , G

Sunshine State Standards Benchmarks: SC.C.1.3.1, SC.C.2.3.1, SC.C.2.3.2, SC.C.2.3.3, SC.D.2.3.1, SC.D.2.3.2, SC.E.1.3.1, SC.H.1.3.1, SC.H.1.3.2, SC.H.1.3.4, SC.H.1.3.5, SC.H.2.3.1, SC.H.3.3.1, SC.H.3.3.4

Sunshine State Standards Benchmarks -- Language Arts: LA.A.1.3.1-4, 2.3.1-8

Homework: Allow students about a week to complete this assignment. That will ensure that everyone has an opportunity to get a newspaper. Students find a newspaper article that describes an instrument used to look at or understand something else. For example, a microscope, telescope, binoculars, eyeglasses, camera, contact lenses, computer, magnifying glass, watch, television, mirror, etc. Make sure students know that they will be expected to read, summarize, and report on their choice.

Homework Assessment: If students bring in an article that they have summarized, they will have met the requirements of this assignment. When presenting the summary, if students make some analogy to the magnetic field viewer, or any other model that is used to understand magnetic fields, they will have articulated the relationship that you are looking for. Students should realize at this point that technology does not always mean computers but can be anything that enhances what a person does.

Assessment: Alpha Logs will contain answers to the questions asked on the Student Itinerary. Answers should reflect the fact that magnetic fields affect a compass and, without a magnetic field, a compass would be useless. Answers to questions will explain why magnetic fields vary in intensity.

Have students draw their diagrams in the Alpha Log. Drawings should indicate that compass needles line up along magnetic field lines. An explanation with the drawing will predict that adding another magnet will change the field lines, and compasses will still line up with those lines. Combining a drawing with verbal explanation requires that students identify the basic concepts that this activity addresses.

VISUALIZING MAGNETIC FIELD LINES

The magnet generates a magnetic field which extends around the magnet. Iron filings help to illustrate the shape of the field, the field lines, and the fact that the fields are strongest near the poles. The field lines spread out from the north pole and circle back around to the south pole. In this activity you will be observing how these field lines affect a compass needle in order to understand the limitations and advantages of this instrument.

1. You will be placing a number of compasses around a magnet. In your Alpha Log and in consultation with group members, predict how the compasses will react. Draw a picture of what you think the compasses and magnet will look like, paying particular attention to the direction in which the compass needles will point.
2. Have your Materials Manager collect the items you will need to complete this activity: 6 compasses, 1 bar magnet, 1 magnetic field viewer.

   After each trial of this experiment, remove the magnets and let the compasses realign so that you control the starting configuration each time.

   Be careful not to work too close to another group's magnet.
3. Place the magnet on your desk with the north pole pointing away from you. Put the compasses randomly around the magnet.
4. Put the MFV on top of the magnet and compasses and tap the sides or top of the MFV in order to get the clearest view of the magnetic field lines.

5. Observe how the compasses respond to the magnet and record your observations in your Alpha Log. Draw a picture of what you see.
6. Remove the MFV and rearrange the compasses. Place the box on top of the magnet and compasses again and reconstruct the field. Observe again how the compasses respond and record your observations in your Log drawing the new picture.
7. Based on your two observations, what do you think is happening? Is it what you predicted? Does this confirm what you thought about magnetic fields?

DRAWING MAGNETIC FIELD LINES

PLANNING YOUR EXPEDITION

Using a navigational compass your students will be studying magnetic field lines produced by a permanent bar magnet. One advantage to doing this activity is that it can be used as a model for Earth's magnetic field. Some textbooks describe our magnetic field by comparing the Earth to a "big bar magnet." The connections that you make with this activity will depend how far you wish to take it.

By using a compass, students will see that measuring devices can be used in a variety of ways and not always for the purpose for which they were intended. Perhaps you can introduce this activity by brainstorming common items that we use in a variety of ways; for example, using a knife as a screwdriver.

Students will reexamine their drawings from any of the activities for which they drew magnetic field lines, or they could place their bar magnet under the plastic box and pour iron filings in the box to test their drawings, or use the magnetic field viewer if it is already assembled (see Appendix B). Whether you choose to extend the activity this far will be up to you as you determine students' levels of understanding.

This activity is best done individually or in pairs. Groups will be too large for all group members to get the full benefit of drawing the magnetic field lines.

This activity is more prescriptive than some of the others in that students must follow the directions carefully in order to draw the magnetic field lines. They will be answering the question, "Can I draw the lines of magnetic force by using only a compass? Will that be an accurate representation of magnetic field lines?" There may be other questions that students will answer based upon their own preconceptions of magnetic field lines.

1. Students place the bar magnet in the middle of a large piece of paper. They will be moving a compass around the magnet, so depending upon the level of your students, you may want students to tape the magnet to the paper.
2. Place the compass at one end of the magnet and make a dot at both ends of the arrow.
3. Then put the compass down again so that the tail of the arrow is over the dot where the point of the arrow was. Students will keep moving the compass in this manner until they reach the other end of the magnet, or until they lose the magnetic field.
4. By connecting the points marked on the paper students will be drawing the magnetic field lines.

BACKGROUND INFORMATION

The magnet generates a magnetic field which extends into the area around the magnet. Iron filings show the shape, strength, and extent of the magnetic field. The field lines spread out from the north pole and circle back around to the south pole.

Magnetic fields can be shielded so that they go around an object blocking the field. Magnetic fields can also pass through materials which can be easily demonstrated by placing two magnets on either side of a piece of paper or a student's hand; or a magnet on the underside of the desk and a paper clip or other magnet on the top. The degree to which this is observable depends upon the strength of the magnet, the material between an object and the magnet, or the distance between the magnet and the object. This will be observed in the activity "Blocking the Field."

The unit of measure of a magnetic field is gauss or Tesla. A refrigerator magnet typically equals 1 Tesla; the Earth's magnetic field, 3 X 10^{-5} Tesla. The nucleus of a hydrogen atom equals 14 Tesla. Ten thousand gauss equals 1 Tesla which is 20000 times as strong as the Earth's magnetic field. An analogy that could be used here is ounces and pounds or miles and light years.

EXCURSIONS

Use any excursions that apply to magnetic field lines, in particular those that deal with health issues (see Expeditions 4 and 9).

Science and nature have inspired artwork for centuries. Have groups of students (or, if you wish, pairs or individuals) find one example of science influencing art. Encourage them to use various resources, for example, the worldwide web (they can check out the National High Magnetic Field Laboratory for Mike Davidson's work in photo-microscopy: http://micro.magnet.fsu.edu), print media, videos, films, music (audiotapes or scores of shows, operas, etc.), museums, and poster shops. Students will realize that science is not something done in isolation but that it influences the culture in which it is an enterprise. Have students compare what they have found.

SC.D.2.3.1, SC.H.1.3.6, 3.3.4-5, 7

LA.A.2.3.6

SS.A.2.3.3, 7, 3.3.1

FOR YOUR PLANBOOK: Drawing Magnetic Field Lines

Suggested time: 1 hour

Gear: bar magnets, large drawing paper (18" x 24"), compasses (enough of each for students to complete this activity individually or in pairs), masking tape

National Science Content Standards: A, B, D

Sunshine State Standards Benchmarks: SC.C.2.3.1, SC.C.2.3.2, SC.C.2.3.3, SC.C.2.3.1, SC.C.2.3.2, SC.C.2.3.3, SC.D.2.3.1, SC.H.1.3.4, 6, SC.H.2.3.1, 3.3.4-5,7

Sunshine State Standards Benchmarks -- Language Arts: LA.A. 2.3.6

Sunshine State Standards Benchmarks -- Social Studies: SS.A. 2.3.3, 2.3.7, 3.3.1

Homework: This assignment is intended for use after the activity has been completed. In view of what you have learned about magnetic field lines, imagine that you are a farmer and the power company in your area will be putting high voltage power lines on your property. You object because you believe that the electromagnetic fields surrounding these lines might affect the health of your livestock as well as your family. Can you visit another site of high voltage power lines and figure out how far the electromagnetic fields extend? Devise a plan that you will use to figure this out and that you could use as evidence to support your opinion.

Homework Assessment: Student plans should include some way of measuring the field lines. If students attempt to do this using a compass, although this would be unreliable at best, it is a natural extension of the activity and should be accepted as their attempt to find a relationship between the classroom and the outside world; between real life problem solving and classroom theorizing. If students propose writing a letter of inquiry to the power company and/or calling to get already published information, this should be acceptable as well. Any attempt at measuring how far the field lines extend is a successful completion of the assignment.

Assessment: Alpha Logs will contain a drawing of magnetic fields. By completing this diagram, students will have modeled magnetic field lines in a way that is transferable to other applications. Students will then be able to predict field lines for differently shaped magnets.

Often science and nature are the inspiration for artwork (see Extensions). Have students develop an art project that incorporates magnetic field lines. This could be a collage, a 3-dimensional model, a drawing, a sketch, sculpture, poster, or any artwork that they can defend as having something to do with magnetism. In doing this assignment, students become aware that science, technology, art, and culture are interwoven.

By walking around the room looking at what the students are accomplishing and talking with them, you can determine whether the students are identifying the relationship between the magnetic field lines and their affect on a compass. By doing so, students will be demonstrating that they recognize the relationship between evidence (the drawing of the lines) and explanation (why does the compass allow you to do this?).

DRAWING MAGNETIC FIELD LINES

Itinerary

You will be using a compass to draw the magnetic field lines of a small bar magnet in order to look at their direction and magnitude. This will be a good model for supporting what you already know about magnets. You will clearly see how the magnetic field is concentrated at the poles and field lines are more spread out the further you get from the poles of the magnet.

The magnet generates a magnetic field which extends to the area around the magnet. The field lines spread out from the north pole and circle back around to the south pole.

The unit of measure of a magnetic field is gauss or Tesla. A refrigerator magnet typically equals 1 Tesla; the Earth's magnetic field, 3 X 10^{-5} Tesla. The nucleus of a hydrogen atom equals 14 Tesla. Ten thousand gauss equals one Tesla which is 20000 times as strong as the Earth's magnetic field. An analogy that could be used here is ounces and pounds or miles and light years.

1. Gather the materials you will need to complete this activity: a small bar magnet, a large piece of paper, and a compass.
2. Place the bar magnet in the middle of the paper. Trace the outline of the magnet. That way if it gets bumped or moved you can put it back in exactly the same position. If you do not complete this activity in one sitting, you will know where to start tomorrow.
3. Place the compass at the end of the magnet (near the edge) and make a dot where the compass arrow points (see picture).
4. Move the compass so that the bottom of the arrow is at the dot and make a new mark where the tip of the arrow is pointing. Keep doing this until you reach the other end of the magnet.

5. Connect the dots as you move around the magnet.
6. Go back and begin again placing the compass about 1/4 inch along the edge of the magnet.

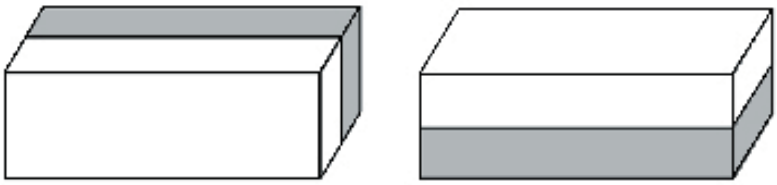
   Repeat the steps connecting the dots as you go along.
7. Repeat the process until you have drawn as many lines as you can for both ends of the magnet. You will now have a representation of magnetic field lines.

NORTH & SOUTH POLES—NOT JUST POLAR BEARS AND PENGUINS!

PLANNING YOUR EXPEDITION

Mark the set of blocks before you begin this activity (see Appendix B for directions).

Reinforcing the idea that opposite poles attract and like poles repel one another, this activity requires that students use this information to figure out the pole alignment of wand magnets (the poles on these magnets are different than some of the others they have been using). They first use their sets of blocks as models and then attempt to identify the poles on the magnets. This will be particularly useful in Expedition 15, "Build a Simple MagLev Train Model." This activity asks students to rethink their conception of where poles are located on a magnet.



There are three possible ways that the two poles can be positioned within a magnet. These arrangements are modeled by the sets of wood blocks. Students may or may not need to model the position of north and south poles. Some students will move directly to investigating the wand magnets themselves.

1. In response to questions on the Itinerary, students will predict the behavior of magnets and write the predictions in the Alpha Log.
2. After several attempts at predicting the behavior of magnets of different configurations, students will explain the location of the poles in the wand magnet. The poles are not "top and bottom," but are one side and the other.

BACKGROUND INFORMATION

Materials exhibit certain characteristics because of the way in which the atoms that make up the material are aligned. In order for a material to be magnetic there must be moving electrons. Materials with magnetic qualities have domains which are each made up of billions of atoms. The way in which these domains are configured determines the magnetic ability of the material. For instance, if the domains are mostly aligned (the atoms are all pointing in the same direction), the material will exhibit strong magnetic characteristics.

Each magnet has a north and south pole -- the regions on the magnet where the magnetic force is the greatest. Like poles repel and opposites attract. Scientists have attempted to isolate one of the poles but have been unsuccessful. If a magnet is cut in half, two magnets, each with a north and south pole, are created. No matter how small, each piece will still have a north and south pole. The smallest magnet is an atom with its electrons orbiting a nucleus.

Magnet strength depends on several factors:the material from which the magnet is made, how the magnet is made, and how the magnet is treated. Some materials like lodestone (which contains iron) are found naturally in the earth and have magnetic properties because when it formed, all of the tiny magnets lined up (north poles facing in the same direction).

EXCURSIONS

Have students read "The Wind From the Sun" by Arthur C. Clarke, in Science Fiction Stories edited by Edward Blishen, 1988 Kingfisher Books, NY (ISBN 1-85697-889-3). Students will compare and contrast the design problems that Merton had and those that they have experienced in science class and other classes.

SC.B.1.3.1-5, 2.3.1, SC.C.2.3.1-2, SC.E.3.1.4, SC.H.2.3.1, 3.3.5-7

LA.A.1.3.1-4, 2.3.1-8, LA.D.1.3.1-4, 2.3.1-2, LA.E.1.3.1-5

Assign "Reinventing the Wheel" (found in Autoweek, March 3, 1997). After reading the article, have students relate the flywheel technology to the concept of like poles repelling like poles and opposite poles attracting each other. Students will write a short review of the article addressing this issue. Students will make the connection between classroom explorations and real-world applications.

SC.H.1.3.1-3, 3.3.5-7

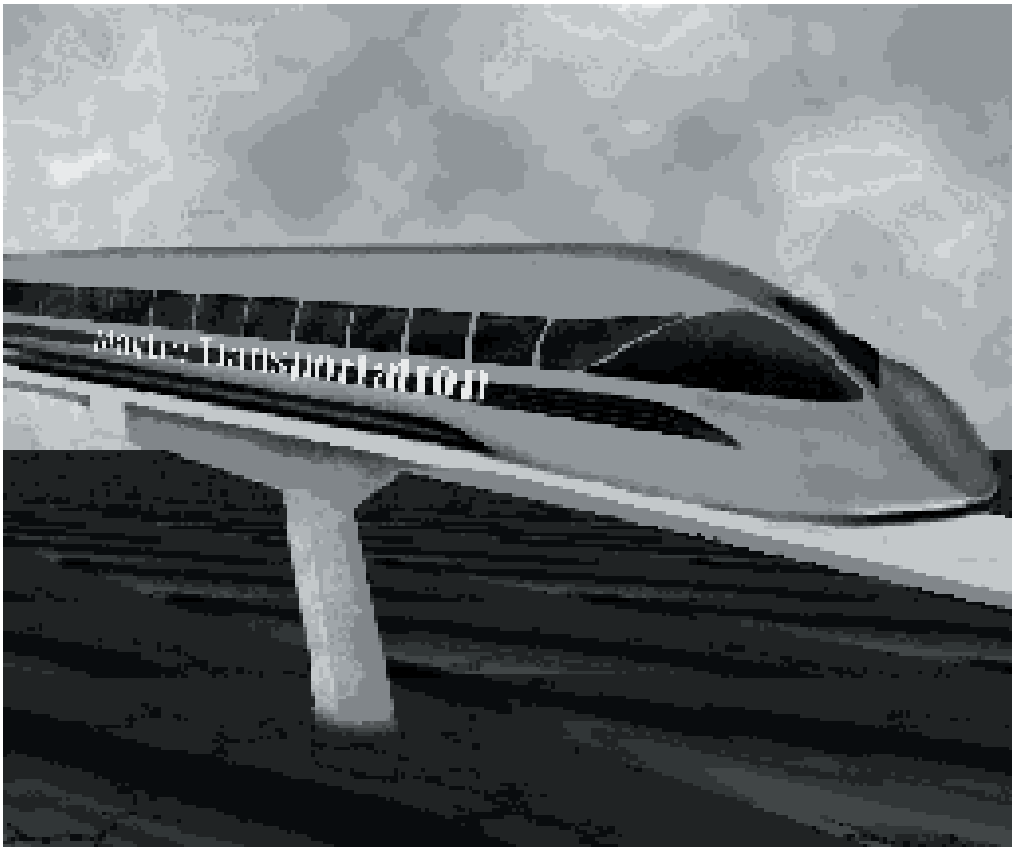
LA.A.1.3.1-4, 2.3.1-8, LA.B.1.3.1-3,

2.3.1-4, LA.D.1.3.1-4, 2.3.1-2

Research current technology (trash separators, MagLev trains) that use the principle of likes repelling and opposites attracting. Students will develop a way to present the results of their research to the class; a poster, written report, oral report, or computer presentation, would be appropriate. Encourage students to make phone calls, explore the Internet, and research current magazines (Popular Science, Autoweek, Discover, etc.) for articles. Students will articulate to their classmates how classroom science is being used in practical applications.

SC.D.2.3.1-2, SC.G.2.3.3-4, SC.H.1.3.1-3, 3.3.5-7

LA.A.1.3.1-4, 2.3.1-8, LA.B.1.3.1-3, 2.3.1-4, LA.D.1.3.1-4, 2.3.1-2



Notes:

FOR YOUR PLANBOOK: North and South Poles - Not Just Polar Bears And Penguins

Suggested Time: 1 hour

Gear: 2 wand magnets per group, 1 set of blocks (colored)

National Science Content Standards: A, B, G

Sunshine State Standards Benchmarks: SC.C.2.3.1, SC.C.2.3.2, SC.C.2.3.3, SC.H.1.3.1, SC.H.1.3.4, SC.H.1.3.5, SC.H.1.3.7

Sunshine State Standards Benchmarks -- Language Arts: LA.B.1.3.1-3, 2.3.1-4, LA.D.2.3.1-2, LA.E.1.3.5

Homework: Have students attempt to answer the following question: How could I turn a Slinky into a magnet?

Homework Assessment: Student responses should have some mention of electric current being passed through the coils of the slinky. This answer will reiterate the fact that moving electrons produce a magnetic field. If students also add that a permanent magnet placed in the coils would produce a stronger magnetic field, that indicates a deeper level of knowledge. Additionally, if students deal with insulated versus noninsulated wire or mention superconducting wire as having little resistance to the flow of electricity, then students have demonstrated mastery of the concept.

Assessment: Student Alpha Logs reflect their knowledge that "likes repel; opposites attract." Drawing the poles of wand magnets demonstrate that students have recognized that poles can be located in positions other than "top and bottom." The Log work allows those students who were still unsure of this concept to revisit it with yet another model.

Have students write a science fiction story that uses the concept either of poles being in different configurations on magnets (not always top and bottom) or of opposites attracting and like poles repelling. If they need a "story starter," you could use the Excursion from "What Is A Magnet?": Write a fiction story about a sports team that is affected by an invention that magnetizes some aspect of their game (for instance, a magnetized basketball hoop and basketball). Or, an alien visits Earth and is examining a magnet; how would you explain it to someone with absolutely no knowledge of magnets?

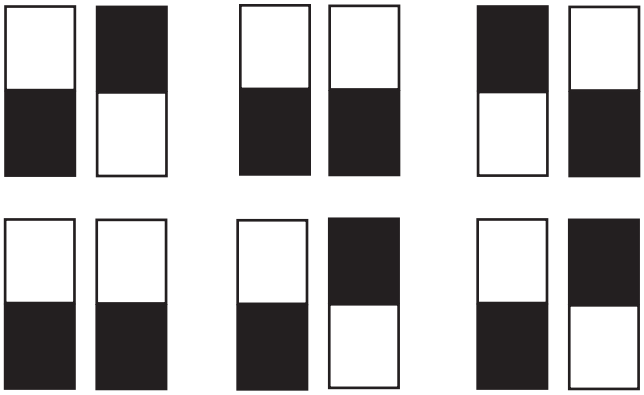
Have students design a piece of jewelry that uses magnetism in its construction. The results could be displayed by diagram or in writing and should include materials used in making a prototype. Products will reflect student understanding of forces acting at a distance and through certain materials; design will take into consideration magnet strength, etc.

NORTH AND SOUTH POLES -
NOT JUST POLAR BEARS AND PENGUINS!

Itinerary

In this activity, your group will be looking at the arrangement of a wand magnet to determine how the poles are aligned. Each magnet has a north and south pole, the regions on the magnet where the force is the greatest. Like poles repel and opposites attract. Scientists have attempted to isolate one of the poles but have been unsuccessful. If a magnet is cut in half, two magnets each with a north and south pole are created. No matter how small, each piece will still have a north and south pole. The smallest magnet is an atom with its electrons orbiting a nucleus.

There are three possible ways that the two poles can be positioned within a magnet. These arrangements are modeled by the three sets of wood blocks that you have. Examine each magnet. Where are the poles? You probably cannot tell just by looking at it. The magnets you have are not divided into colored regions indicating their poles. So, how can you figure out how the poles are arranged in your magnets? Answer these two questions in your Alpha Log in the form of a prediction.



1. The diagram shows your magnet models in certain arrangements. Draw arrows to show the direction each magnet would move if placed next to another magnet as indicated.

2. Choose one set of wood models. Begin by placing the two blocks together with the colored surfaces facing each other. What do you think would happen if these were actual magnets? Record your prediction in your Log.

3. With the same set of blocks, place the colored surface of one block next to the uncolored surface of the other block. What do you think would happen if these were actual magnets? Record your prediction in your Log.

4. Repeat steps #2 and #3 with the other two sets of wood blocks. Be sure to record your predictions in your Log.

6. How are the polar regions arranged in your magnet? Draw a picture of a wand magnet in your Log, indicate the poles and draw the magnetic field lines.

EARTH'S MAGNETOSPHERE

PLANNING YOUR EXPEDITION

At this point students should be making some inferences on their own about magnetism, magnetic fields, and their application in the real world. The subject of Earth's magnetic field seems to get buried in the discussion of either the North and South Poles or Earth's gravity. This activity will illustrate the difference between Earth's magnetic north and south pole and geographic North and South Pole.

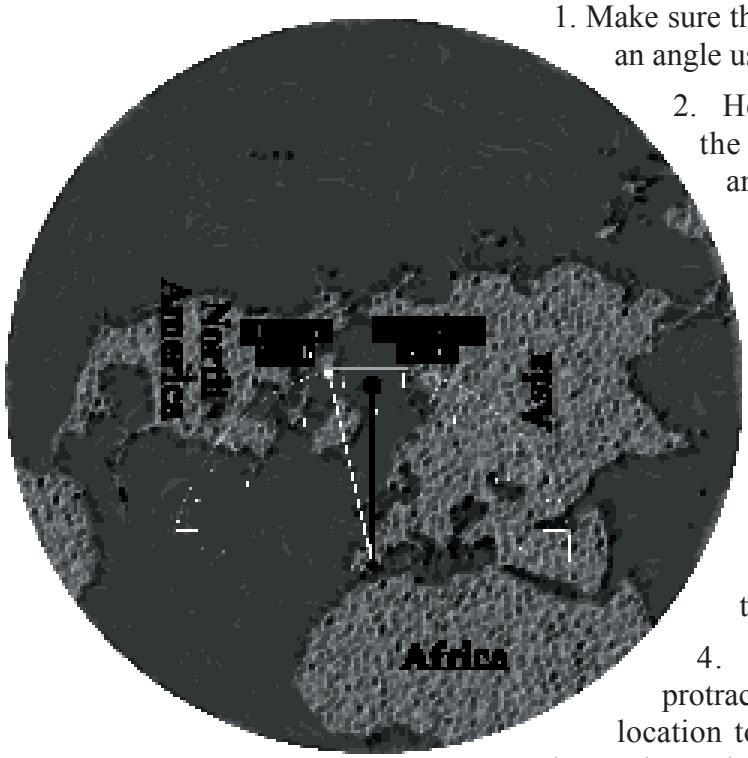
This is an ideal place to begin reading aloud a nonfiction book about either the North or South Pole (see "For Your Planbook" section). Linking both fiction and nonfiction to science content makes the information more meaningful; likewise, linking what one is reading to what one is learning at the time makes the literature more meaningful. Reading aloud is also an excellent management tool. Setting aside the last 10 minutes of a class period for reading to students allows them time to get ready for the next class, time to finish up, or time to gather their thoughts or clarify thoughts before moving on to another subject.

It might be useful to ask your students how many of them believe that gravity and the Earth's magnetic field are the same thing. There are probably some students who think that magnetism causes tides. Identifying the misconceptions that students bring with them to the classroom is important to your practice.

Students have looked at a number of magnets, but have they considered the Earth as a magnet? They probably have heard of the magnetic field surrounding the Earth. Students may even know a little about it, but have they thought of the planet as a magnet? In this activity, students will discover that there are many ways to think about things in science. This will be a new way to think about their planet.

The recommended assignments related to this subject are somewhat different than those that preceded it since there is no experiment to be done or investigation to be conducted. This is an activity that makes the distinction between Earth's magnetic poles and geographic poles and includes gathering of information to support prior knowledge. It is an enhancement of prior activities and provides information that will help students better understand the compass activities to follow.

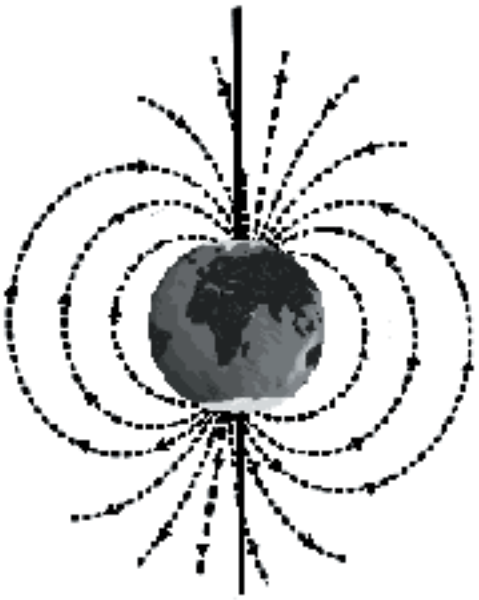
In January 1997, Earth's magnetosphere was in the news as a cloud of gas weighing a billion tons distorted the Earth's magnetic field. It was the most likely cause of the destruction of a communications satellite estimated to be worth $200 million. Whether students believe this to be of use or interest to them, it is still important for a well-educated person to be able to read a magazine or newspaper article with some degree of understanding, such as the many articles that appeared following the January 1997 event. Because of their understanding of magnetism, magnetic field lines, and Earth's magnetic field, your students will be better consumers of information.

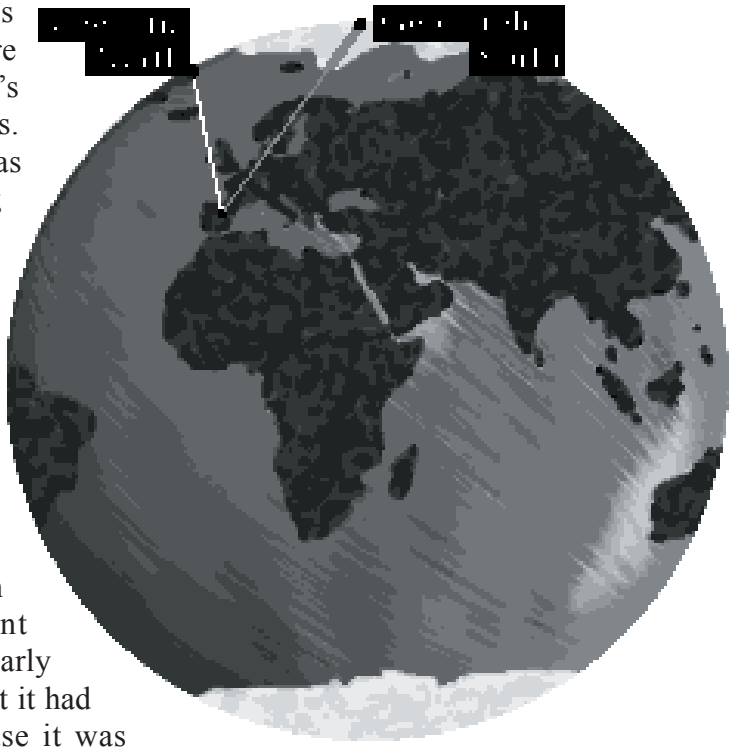


1. Make sure that students know how to measure an angle using the protractor.
2. Help students distinguish between the polar projection (Appendix D) and other types of maps.
3. Each group will choose 10 cities in the northern hemisphere and locate them on the map so they will need geography books or world maps to work with. Make sure that they represent areas close to and far away from the poles. Encourage students to choose at least one location with which they are familiar or a place that they have visited.
4. Using the straightedge of the protractor students draw a line from the location to each of the poles and measure the angle, and record the number of degrees of declination in the Alpha Log. Students will determine that the farther the city is from the poles, the smaller the angle of declination will be.
5. Finally, students answer the question: What implications does this information have for explorers, adventurers, cartographers, or travelers?
6. If students need extra help using the protractor, refer them to the CD-ROM tutorial.

BACKGROUND

The Earth acts like a magnet in space due to the rotation of the inner core. Since the inner core is most likely made of solid iron and nickel, as it spins the material takes on magnetic characteristics and creates a magnetic field. The magnetic field created by a bar magnet is a good model of the Earth's magnetic field and is a good visualization tool. As the earth rotates on its axis, the spinning inner core creates a magnetic field that extends from approximately 1000 kilometers to 64000 kilometers depending whether the earth is facing the sun.





Modeled in the illustration, Earth's magnetic north and south poles are in a different location than Earth's geographic North and South Poles. The magnetic poles represent areas that exhibit magnetic qualities; geographic poles are those that represent the earth's axis.

A solar wind pushes the magnetosphere out into space on the side of the earth away from the sun. This phenomenon is intensified from time to time creating a magnetic cloud that disturbs the magnetosphere depending upon the speed at which the cloud is traveling. A recent magnetic cloud event was particularly significant, not because of the effect it had on the magnetosphere, but because it was the first time that humans could monitor the phenomenon from the time it started until the effect was no longer apparent. Because there are a number of satellites that do nothing but look at the sun, scientists at NASA's Goddard Space Flight Center in Greenbelt, Maryland, were able to study the solar cloud and its significance to the earth's magnetic field. (Some sample sources for researching this phenomenon are The New York Times, Thursday, January 23, 1997; Science News, January 11, 1997, February 1, 1997; Time, September 9, 1996., Aviation Week & Space Technology, January 27, 1997.)

The magnetosphere is made up of positively charged protons and negatively charged electrons that are caught by the earth's magnetic field and are concentrated in areas called the Van Allen Radiation Belts. These areas of trapped radiation are a form of protection since they trap radiation and prevent it from reaching the earth's surface.

If students ask, "So what?" The answer is one that affects students personally: their cable television stations are disrupted, satellite communications, credit card records, radio communications, and airplane travel are also interrupted.

EXCURSIONS

This would be applicable to more sophisticated science students who are competent readers. Have students read "Does the Sun Trigger Outbursts From Earth's Magnetosphere?" Science, Vol. 271, March 15, 1996 and "Solar Cloud Hits Earth's Magnetosphere," Science News, Vol. 151, February 1, 1997. Not only will students get a great deal of information and enhanced understanding of the sun's influence on the magnetosphere, but they will attempt to answer the question, "How does the 1997 information support the explanation proposed in the 1996 article?" Also, "Is this a comparatively long time for a scientist to wait for information to support or disprove a theory?" In answering these questions, students will do two things: first they will read about a scientist proposing a new idea from gathering data over a period of time; second, students will articulate that this is a very short time to wait for an answer in science. Many scientists *never* get this kind of answer.

SC.H.1.3.1-3, 7

LA.A.1.3.1-4, 2.3.1-8, LA.B.2.3.3, LA.D.2.3.3-6

Have students answer the question: What do the Van Allen Belts and the ozone layer have in common? Why is their purpose so important to life on earth? What would happen if they ceased to exist? Comparing and contrasting two aspects of the earth's atmosphere that play a protective role, students link magnetism and magnetic fields to issues of great practical importance.

SC.C.1.3.2, SC.D.1.3.5, SC.H.1.3.1-7, 2.3.1, 3.3.5-7

A natural tie-in here would be to the earth's layers. Going one step beyond identifying the earth's layers and what they are made of, students could study new theories and recent discoveries about what the earth's interior "looks" like. From this study, students understand the dynamic nature of science; that it is constantly changing and new ideas are being proposed and theories proved. An article of interest is "Anti-Matters," Earth, August 1995, that is taken from Naked Earth: The New Geophysics by Shawna Vogel.

SC.H.1.3.1-3, 7

Either read aloud to students or have them read "Antarctic Christmas" by Captain Robert F. Scott, found in Heroic Stories chosen by Anthony Masters, ISBN 1-85697-983-0. This experience could be used as a lead-in to student creative writing about being away from home at a significant time or about difficult conditions and how they can be overcome. It could also be the beginning of a discussion of geography and attempting to answer why the journey became so much more difficult than the team anticipated as they made preparations. Have students create lists of what equipment and supplies they would take if undertaking a journey such as Scott's. What would they do differently? What limitations would be set for them and what limits would they set for themselves? Is it possible to generate such a list now that would have been feasible at that time? A lively class discussion will help students clarify the differences between attempting travel in Antarctica then and now.

LA.A.1.3.1-4, LA.B.1.3.1-3, LA.C.1.3.1-4, LA.E.2.3.1-8

FOR YOUR PLANBOOK: Earth's Magnetosphere

Suggested Time: 1-3 hours

Gear: compass, protractor, polar projection, world maps or geography books.

Begin reading aloud to students: With Byrd at the Bottom of the World by Norman Vaughn, "Antarctic Christmas" in Heroic Stories, or Dr. Kane of the Arctic Seas by Pierre Berton (see Appendix C, Annotated Bibliography, for more information).

National Science Content Standards: A, E, G

Sunshine State Standards Benchmarks: SC.A.2.3.1, SC.B.1.3.1, SC.B.1.3.3, SC.B.1.3.6, SC.B.2.3.1, SC.C.1.3.2, SC.C.2.3.1, SC.C.2.3.2, SC.C.1.3.3, SC.G.1.3.4, SC.H.1.3.1, SC.H.1.3.2, SC.H.1.3.3. SC.H.1.3.4, SC.H.1.3.5, SC.H.1.3.6, SC.H.1.3.7

Sunshine State Standards Benchmarks—Language Arts: LA.A.2.3.4, LA.A.2.3.5, LA.A.2.3.6, LA.A.2.3.8, LA.C.1.3.4, LA.C.2.3.1, LA.C.3.3.3, LA.D.1.3.3, LA.E.2.3.8

Sunshine State Standards Benchmarks—Math: MA.A.4.3.1, MA.B.1.3.2, MA.B.1.3.4, MA.B.4.3.2

Sunshine State Standards Benchmarks—Social Studies: SS.A.2.3.4, SS.B.1.3.1, SS.B.1.3.7

Homework: Have students either create a concept map for the information that is covered in this activity (magnetosphere) or create one with some information already given to lead students to that which must be filled in.

Homework Assessment: Concept maps should have categories of information that include, but are not limited to, facts about the magnetosphere, implications (who does it affect?), and features created by the magnetosphere.

Assessment: Assign a creative writing story or a nonfiction report about the relationship between the Van Allen Belts and space travel. Student stories should reflect (at least) the knowledge that space explorers and space vehicles would need protection from the concentrated radiation in this area. Nonfiction reports would contain this information as well as data about the discovery of these areas in 1958. This is an example of real world problems being created by natural phenomena and the solutions created.

Check Alpha Logs for use of vocabulary, i.e., line of declination, angle of declination, geographic north, magnetic north. Use of correct language indicates that students have made the leap from the activity to articulating the information gained from the activity.

Scrutinize answers to the questions from the Itinerary for understanding of the difference between magnetic and geographic north. Answers should indicate understanding that the farther away a location is, the smaller the angle will be (and vice versa). There should also be some indication that students realize that the compass is actually flawed as an instrument if the person using it is expecting to go toward geographic north. Students are using the information they collected from measuring angles to determine its importance on a personal level.

Have students relate the book that is being read aloud to classroom study by drawing pictures that demonstrate mastery of the difference between the two poles; by writing a prediction from the title and book jacket of what will happen in the book; by creating a model of a scene or chapter from the book; by giving a book talk about the book and its relationship to classwork. Whichever task students choose, it should be a reflection of their content knowledge. At this point, students should be blending the specific content from the most recent activity with their overall knowledge of magnetism.

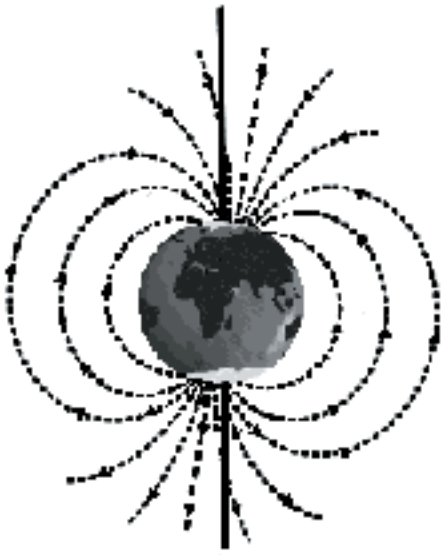
EARTH'S MAGNETOSPHERE

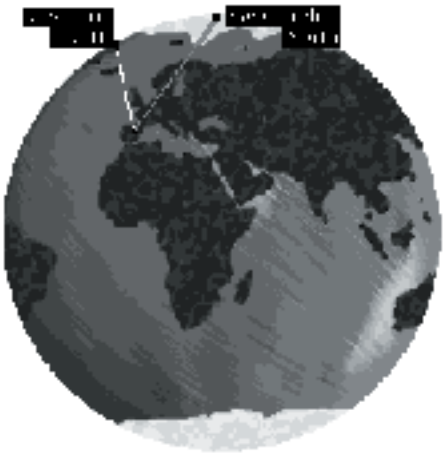
Itinerary

The Earth acts like a magnet in space due to the rotation of the inner core. Since the inner core is most likely made of solid iron and nickel, as it spins the material takes on magnetic characteristics and creates a magnetic field.

The magnetic field created by a bar magnet is a good model of the Earth's magnetic field. As the earth rotates on its axis, the spinning inner core creates a magnetic field that extends from approximately 1000 kilometers to 64000 kilometers depending upon whether it is facing the sun.

Modeled in the illustration, Earth's magnetic north and south poles are in a different location than Earth's geographic North and South Poles. The magnetic poles represent areas that exhibit magnetic qualities; geographic poles are those that represent the earth's axis.





1. The Materials Manager should accumulate all materials you will need for this activity: compass, protractor, and polar projection.

2. Choose 10 locations in the northern hemisphere being sure to include one with which your group is familiar. Record these in your Alpha Log.
3. One at a time, measure the angle of declination (difference between the geographic North Pole and magnetic north pole) indicating the difference between magnetic north and geographic north. Draw a line to magnetic north and a line to geographic north. This will help you determine where to place your protractor. As you measure each angle, enter it in your Log.
4. Which location that you chose is farthest away from the poles? Which one is closest? Which location had the largest angle between the two poles? Which location had the smallest? What conclusion(s) can you draw from these answers? After discussing the answers with the group, write all of the answers to these questions in your Log.
5. Now, as a group, consider the following questions and write the answers in your Log: To which of the poles does your compass point? What does this mean? Why would the angle of declination be important? Who would need this information?
6. Discuss your answers with two other groups until you are all satisfied. Write the results of this discussion in your Log.

BLOCKING THE FIELD

PLANNING YOUR EXPEDITION

Students at this point have an understanding that the shape of a magnetic field can be predicted by the size and shape of a magnet, and the arrangement of its poles. In experimenting with various magnets and objects that are attracted to them, students will also have found that magnetic properties go through things. For instance, in "Viewing a Magnetic Field," there was some discussion of this phenomenon, and students probably tested this by placing a piece of paper between two magnets or putting a paper clip on the desk and a magnet underneath to make the paper clip move around. In doing this activity, students will answer the question "Can you block the magnetic field of a magnet?"

This activity is best when used shortly after completing Expedition 3, "Viewing a Magnetic Field," but it could be used on its own. It is fun for students to use the magnetic marbles. Also, they will be exposed to yet another magnet shape. Introducing this activity with a discussion of the magnetic marble as a model of the Earth and predicting the shape of the field will tie in nicely with the previous Expedition, "Earth's Magnetosphere."

Up to this point the activities have been structured to provide basic information on magnetism and magnetic fields. Now it is time for students to extend their thinking to phenomena that are not easily observable. Science requires the use of models to help scientists, teachers, and students form theories about objects or phenomena that are too large or too abstract to see. Putting these into concrete form that can be manipulated aids us in using what we already know to help us understand what we do not know. It is important for students to understand that this is a real world strategy; for example, models of hurricanes and tornadoes help scientists determine how these storms are formed and why they form sometimes and not other times even though conditions seem to be the same. Other models that could be used to help students answer the question, "Why do we use models in science?" are maps and globes, solar system models that represent planet sizes and distances from the sun, and cross-sectional models that allow us to look "inside" of things.

1. Using a ruler with a groove in the middle, students will place a magnet at one end of the "track" and a magnetic marble at the other.
2. Slowly pushing the marble with a pencil or a wooden dowel, and stopping when the marble is attracted to the magnet, students will determine an average distance from the magnet that the marble travels before the attraction is felt.
3. Then, students will attempt to "block the field" by placing a number of items from around the classroom in the way of the magnetic marble. This will determine whether or not they are capable of blocking the magnetic field (or distorting it).
4. All observations, conclusions, and answers to questions will be written in the Alpha Log.
5. Students will discuss their findings with other students and keep a written record of the results of these conversations in their Logs.

BACKGROUND INFORMATION

Magnetic fields are treated separately from magnets and magnetism by scientists. The discovery of magnetic fields, by James Clerk Maxwell (and the fact that they had properties distinct from those of magnets) were based the work of Michael Faraday. Maxwell (1831-1879) linked the study of magnetic fields with that of electrical fields which became the basis for Field Theory. Field Theory states that fields can be mathematically manipulated and treated as separate entities. With this in mind, it is not necessary to know what is causing the magnetic field in order to study its effects. This theory, however, did not explain how forces can act at great distances and, until Richard Feynman proposed quantum electrodynamics (QED) in the 1950s (for which he won the Nobel Prize), it was the predominant theory in explaining magnetic fields.

The magnetic field lines that your students are producing with iron filings in the magnetic field viewer illustrate that magnetic field lines are one way of determining how strong a field is being generated. The closer lines are, the stronger the magnetic field is; the further apart, the weaker the magnetis field is. Scientists use lines in many ways (see Excursions) and this can help you incorporate other facets of science instruction.

EXCURSIONS

Richard Feynman is an interesting biographical study for students. His influence transcended science and his many and varied interests demonstrate for students that scientists are not one-dimensional characters in lab coats working with test tubes in a sterile environment. Students could create a timeline of Feynman's accomplishments; could role-play an incident from Feynman's life; or could create a poster after researching his life on the worldwide web or in print media. There are several biographies, three autobiographical works currently in print, and CDs of some of his Cal Tech lectures available.

SC.D.2.3.1, SC.H.1.3.1-3, 6-7, 3.3.5-6

LA.A.2.3.5-7, LA.B.2.3.4, LA.D.2.3.2-5

SS.A.1.3.1-2

Lines are used to display a great variety of scientific information. Isobars (lines that connect areas of equal barometric pressure), isotherms (lines that connect areas of equal temperature), contour lines (that connect areas of equal elevation), and magnetic field lines are examples. How close or far apart these lines are represent important information to meteorologists, map makers, geologists, and physicists. Students could investigate the use of lines by obtaining sample maps from various sources that are then shared with the class. (The U.S. Geological Survey, local weather stations or television meteorology departments, the public library, university departments, and departments of transportation are some sources.)

SC.H.2.3.1

MA.A.1.3.1, 3-4, MA.E.1.3.1, 3

SS.B.1.3.1

FOR YOUR PLANBOOK: Blocking the Field

Suggested Time: 1 hour

Gear: ruler (with groove down the middle), magnetic marbles, wooden stick (or pencil), Alpha Log, other items from around the classroom

National Science Content Standards: A, B, D, E, G

Sunshine State Standards Benchmarks: SC.A.2.3.1, SC.A.2.3.2, SC.B.1.3.6, SC.B.2.3.2, SC.C.1.3.2, SC.C.2.3.1, SC.C.2.3.3, SC.C.2.3.4, SC.C.2.3.5, SC.C.2.3.6, SC.H.1.3.1, SC.H.1.3.2, SC.H.1.3.4., SC.H.1.3.5, SC.H.1.3.7, SC.H.3.3.4, SC.H.3.3.5, SC.H.3.3.6, SC.H.3.3.7

Sunshine State Standards Benchmarks—Math: MA.A.3.3.2, MA.A.3.3.3, MA.B.4.3.2, MA.E.1.3.3

Sunshine State Standards Benchmarks—Language Arts: LA.A.2.3.2, LA.A.2.3.4, LA.A.2.3.5, LA.A.2.3.6, LA.B.1.3.2, LA.B.1.3.3, LA.B.2.3.3, LA.E.2.3.8

Assessment: Check Alpha Logs for evidence of student conversations that include statements about whether or not it is possible to block a magnetic field. If students' comments reflect the fact that they are speaking of "fields" as phenomena apart from magnets, this will indicate a great deal of sophistication in their knowledge of magnets and magnetism. This is the level of understanding you want your students to reach.

Have students answer the following questions: Did any of your tests of classroom objects indicate that you had changed the shape of the field? If so, how did you test this? If not, how could we test for this? In answering these questions, students will indicate that they can use information from their Logs to form hypotheses and use the data that they have collected to support them. Answers will also demonstrate students' knowledge of variables and manipulating variables.

As a large group brainstorm models that are used in science and in the classroom. Then have students use the information from the brainstorming session to create a concept map, cluster, or other visual tool to display what they have learned about models. These should indicate that students are able to distinguish between models used to explain an abstract idea (for instance, the protons, electrons, and neutrons in an atom) and models that are created to understand something that is otherwise too large to observe (solar system model, ocean floor model).

BLOCKING THE FIELD

Itinerary

Magnetic fields are treated separately from magnets and magnetism by scientists. The discovery, by James Clerk Maxwell, of magnetic fields and the fact that they had properties distinct from those of magnets were based on the work of Michael Faraday. Maxwell (1831-1879) linked the study of magnetic fields to that of electrical fields.

This activity will be a fun way to "see" if you can block the magnetic field of a magnet. You will have the opportunity to investigate a magnetic field to see if placing different objects in a field will block it.

1. The Materials Manager should collect the following: a ruler with a groove in the middle, one magnetic marble, magnets, a piece of paper, a wooden dowel or pencil. Other items that you will identify later can be found in and around your classroom. All students should have Alpha Logs to record work.
2. Place the ruler on the table on top of the paper. Put the magnet on one end of the ruler and a magnetic marble on the other end of the "track."
3. Slowly push the marble with a wooden dowel or a pencil along the track until it is attracted by the magnet. Mark this distance on the paper and record it in your Log.
4. Repeat this five times. Record the distance measurement for each of the five trials. Find the average distance and record it in your Log.
5. Try to block the magnetic field by testing five objects (one at a time) from around your classroom. Place an object in the groove of the ruler or across the ruler between the magnet and the point you determined to be the average distance in #4 above. Push the marble down the ruler and record where it now feels the attraction to the magnet. Record in your Log the results for each item that you use to try to block the magnetic field.
6. In your Log, answer the following questions: What happens to the magnetic field when you block it? Where does it go?
7. Discuss your results with another group of students and record this conversation in your

Alpha Log paying particular attention to areas where you disagree. If you disagree, find a

way to reach an understanding with which the whole group is satisfied. You may need to retest certain items or check the accuracy of your notes.

8. Answer the following in your Log: Does placing an object into the magnetic field of the magnet block or distort the field?

USE ELECTRICITY TO MAKE A MAGNET

PLANNING YOUR EXPEDITION

This activity can be used alone or can be the first in a series of activities in which your students attempt to build stronger electromagnets by manipulating a number of variables: material around which the wire is wound, number of winds of wire, and style of wrapping. If you are choosing to use this as a first activity in a series, refer to the activity entitled "Can You Build a Stronger Electromagnet?" Using a directional compass as a measurement tool models the creative, innovative way that scientists use equipment in the real world. When there is a need, a scientist finds a way to use what is available to satisfy that need.

Batteries will need to be charged for this activity. This is a task for which you might want to train lab assistants. Before you begin each unit it is a good idea to train 2-3 students from each class as helpers. Once these students are familiar with your purpose for the unit, the basic concepts you will be covering, and how the activities will work, they can be given a number of responsibilities: charging the batteries, helping other students, explaining procedures to groups, conveying in "kid words" your expectations, consulting on homework, etc. The limit of responsibility is, of course, your choice and depends upon the time you have to set this up. However, it is well worth your time and the students' since ultimately this will be of great help to you. It is particularly helpful with large classes. See "Today's Science Classroom" for ways to implement this.

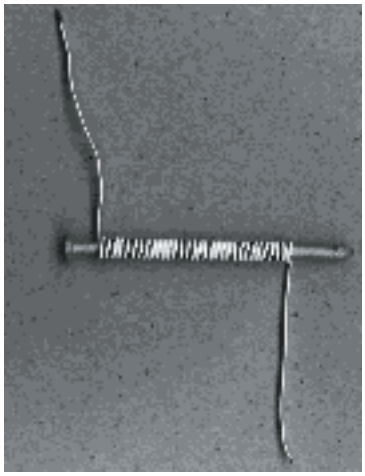
It is important for students to keep a detailed record of observations and results of trials in their Alpha Logs. The Log can be a way for you to assess students' progress, grasp of concepts, and organizational skills. The individual pieces of work that are produced can either be kept in the Log or can be treated separately. You can pre-establish categories of work done in the classroom so that students will know ahead of time which types of work are expected to be in their Logs. Use of the Alpha Log can vary depending upon the activity.

Questions that you will expect students to answer at the conclusion of this activity include, but are not limited to, the following: How can electricity be used to make a magnet? Why do the winds with an iron rod inside of them pick up paper clips when the iron rod alone or the winds alone will not? Winds is a term used by magnet scientists to describe wire being wrapped around a core material.

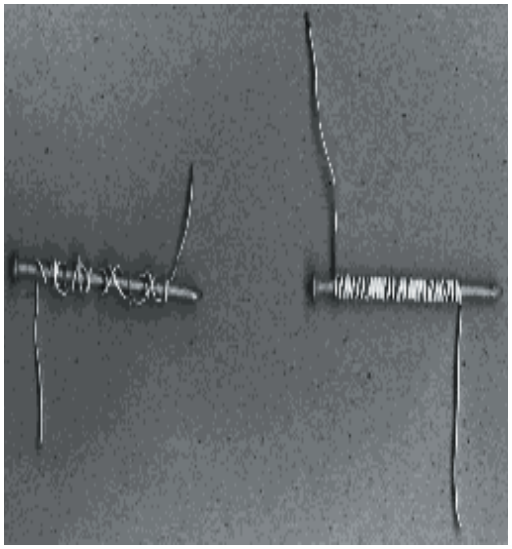
Have on hand copies of the story of how Hans Christian Oersted made the connection between magnetism and electricity (see Background). Students could read this as a homework assignment before the activity.

As in all activities dealing with electricity and magnetism, warn your students that heat is generated. The iron rod, the battery holder, and the wire will become warm as they work.

1. In groups, students will gather their equipment and, using the Itinerary, will begin to construct an electromagnet. It is important for their data collection that they be encouraged to read through all the steps of the activity before beginning so students will know what is expected of them.



2. Before groups begin their task, there should be some discussion of any areas that are unclear or any questions or problems that resulted from their last group activity. Since students are working in groups a great deal there should be some mechanism in place through which they can address their concerns to the teacher, either in private or in group discussion. A general discussion with each group as to what worked well and what needs improvement helps clear the air and clarify what is expected of the group by the teacher.
3. Students will be using a compass as a measuring device. The deflection of the compass needle indicates the presence of a magnetic field. Using a compass in this manner will demonstrate to students how scientists are creative in their use of tools.
4. First, students will substantiate that there is a magnetic field created by a connection of the insulated wire to the battery. Second, they will intensify this field by wrapping an iron rod with the wire and will again substantiate that the strength of the magnetic field has increased by observing the action of the compass needle.
5. Students will also notice that the battery holder gets warm as does the iron rod. Although the activity does not have a component for measuring change in temperature, this is an extension that you may choose to include.



BACKGROUND INFORMATION

Until 1820 scientists believed that the relationship between electricity and magnetism was purely coincidental. One scientist, Hans Christian Oersted, thought that there was a connection that he hoped to demonstrate, but until he could actually substantiate it to his colleagues, he kept silent. Even after he decided to present his ideas he was still unsure as to whether or not his simple experiment would work. Not until he was in front of a group of scientists to whom he was lecturing did he demonstrate his findings. It is this demonstration that your students will be recreating. Oersted connected a platinum wire to a source of electricity and noticed that it caused a compass needle to deflect. This would only happen if a magnetic field were being created by the electricity running through the wire.

Magnetism is the result of electrons moving in very particular ways within the atoms that make up a magnetic substance. Since it is the movement of electrons that can cause a material to generate magnetic forces, a weak magnetic field can be generated when electrons flow through a wire. If the wire is wound, the movement of electrons will be enhanced (concentrated) so that the tighter the wire is wound, the stronger the magnetic field will be.

EXCURSIONS

There are some people who believe that high voltage wires create a magnetic field that is dangerous to the health of those who live near them. **Although the medical establishment has said that this is NOT true,** these beliefs persist. Students could research this issue using print media, the CD-ROM, websites, or personal interviews. Students then find a way to present this information to the class or you can evaluate each one individually. A concise, straightforward article on this subject can be found in The New York Times Book of Science Literacy, Richard Flaste, editor, 1991, ISBN 0-06-097455-9.

SC.A.2.3.3, SC.B.1.3.4, SC.D.2.3.1-2, SC.G.2.3.4, 3.3.5-7, SC.H.1.3.1-7, 3.3.4

LA.A.1.3.1-4, 2.3.5-7, LA.B.1.3.1-3, 2.3.3-4, LA.D.1.3.3, 2.3.3-7

SS.A.1.3.2, SS.C.2.3.1-4, 2.3.5-7

Either read aloud or have students read "The Mysterious Rays" by Angela Bull, in Heroic Stories, Anthony Masters, editor, 1994, ISBN 1-85697-983-0. Discuss why Pierre and Marie Curie did not connect Pierre's illness with their research. Encourage students to read more on Marie Curie, particularly about her own illness. Did the Curies not realize that their illnesses were caused by the use of radium in their research; or, was there a reason why they could not publicly make the connection?

SC.H.1.3.1-7, SC.H.3.3.1-4, SC.H.3.3.5-7

LA.A.1.3.1-4, LA.E.2.3.1-8

Numerous misconceptions about magnetism exist that could be explored individually or in groups. One possibility is to assign a misconception to each group and then have the students report back to the larger group. Students may come into the classroom with their

own **misconceptions** about magnetism (or science in general) -- a good place to start an investigation. Some common misconceptions are: north and south poles are the same as plus (+) and minus (-); field lines start at one pole and end at the other pole; magnetic fields and electric fields are the same; magnetic field lines hold you on Earth; iron and steel are the only magnetic materials; geographic North Pole and magnetic north pole are the same.

SC.C.2.3.1-3, SC.G.3.3.5-7, SC.H.1.3.1-7

LA.B.2.3.3-4

Research Hans Christian Oersted using various media. Students can either write a research report, create a poster describing his life and work, role-play the original presentation of his results, or write a paper describing the impact that Oersted's work had on the study of magnetism. Students plan a debate of Oersted's work with one side of the argument representing that his demonstration *did* show the relationship between electricity and magnetism and the other side providing evidence that it was not sufficient to demonstrate such a relationship. Any of these activities show the relationship between past scientists and present discoveries demonstrating that science is not done in isolation.

SC.C.2.3.1-3,2.3.4,6, SC.G.3.3.5-7,

SC.H.1.3.1-7, 3.3.4

LA.A.1.3.1-4, 2.3.1-8, LA.B.2.3.3-4

SS.A.1.3.1-3, 2.3.2-3

Read The Time Machine by H. G. Wells. Use the premise of the novel as a start for a creative writing assignment going back in time to visit with an early scientist to whom magnetism was an important concept (for example, Luigi Galvani, William Gilbert, Hans Christian Oersted, or Alessandro Volta). An interesting connection to time travel (among other ideas) is made in The Physics of Star Trek by Lawrence M. Krauss (1995), ISBN 0-465-00559-4.

SC.G.2.3.4, 3.3.5-6

LA.D.1.3.2-4, LA.E.1.3.1-5, 2.3.5-8

SS.A.2.3.2-3

Assign a biography (student's choice) of a scientist or other professional whose life was in some way affected by magnets, the discovery of magnetism as it relates to electricity, the use of magnetism in his or her work, etc. Students could then design their own culminating project that is well- suited to their own learning style. For instance, dioramas, posters, book talks, book report/synopsis, or role playing the character in the book. Students should be encouraged to choose a scientist to read about. This is an opportunity to demonstrate the great diversity in the scientific community: minorities and women in science or contemporary scientists, for example.

SC.D.2.3.1, SC.H.1.3.1-7, 3.3.5-7

LA.A.1.3.1-4, 2.3.1-8, LA.B.1.3.1-3, 2.3.1-4, LA.D.1.3.4, 2.3.1-2

SS.A.1.3.1-3, 2.3.2-3

FOR YOUR PLANBOOK: Use Electricity to Make a Magnet

Suggested time: 1 hour

Gear: 1 D-cell battery, 1 battery holder, 200 cm insulated wire, compass, iron rod, wooden dowel, aluminum rod, paper clips

National Science Content Standards: A, B, E, F, G

Sunshine State Standards Benchmarks: SC.A.1.3.3, SC.A.2.3.2, SC.A.2.3.3, SC.B.1.3.5, SC.C.2.3.1, SC.H.1.3.1, SC.H.1.3.2, SC.H.1.3.3., SC.H.1.3.4., SC.H.1.3.5, SC.H.1.3.6, SC.H.1.3.7, SC.H.3.3.1, SC.H.3.3.4, SC.H.3.3.5, SC.H.3.3.6, SC.H.3.3.7

Sunshine State Standards Benchmarks -- Language Arts: LA.A.1.3.1-4, 2.3.1-8, LA.B.1.3.1-3, 2.3.1, 3, LA.C.1.3.1, LA.D.2.3.1-6, LA.E.1.3.5, 2.3.5-8

Homework: Allow one week for students to find an article in a newspaper or magazine that deals with magnetism. Encourage them to find articles about magnetic fields and/or electricity as it relates to magnetism. Students can approach this task from a variety of angles: for instance, article on Earth's magnetic field, magnetic fields in medical research (MRIs), magnetism and health concerns. Remind students that there are many kinds of print media, some of which can be accessed through the worldwide web: for instance, the The New York Times or newspapers from around the world. Have students either bring the articles to class to write the assessment or assign it to be done at home (see below).

Homework Assessment: Students hand in the article with their written assignment, each paragraph answering one of the following questions: What is the source of the article and why did you choose this source? What

is the article about (a brief summary)? How does the article relate to our study of magnetism? Who would be most interested in reading this article (other students, scientists, teachers, or parents)?

Students present the information to the class as a whole with a statement explaining the connection between the article and magnetism.

Assessment: Students construct an electromagnet that influences a compass needle. They also create a way to test their electromagnet by picking up paper clips or some other item. This provides evidence that students have linked electricity to magnetism.

Alpha Logs reflect a plan, include question(s) to be answered, observations, conclusions, and a short summary of what was learned. Accurate record keeping is directly linked to how others view a person's work. Students demonstrate that their work can be replicated by others who might question their results.

Students write a science fiction story about a sailor whose voyage is affected by the presence of a magnetic field. Science fiction should have the following characteristics: tells a good story, uses science fact, presents strange and unusual events, and includes some facet of human nature.

USE ELECTRICITY TO MAKE A MAGNET

Itinerary

Magnetism is the result of electrons moving in very particular ways within the atoms that make up a magnetic substance. Since it is the movement of electrons that can cause a material to generate magnetic forces, a weak magnetic field can be generated when electrons flow through a wire. It is possible to use this idea to build a magnet. In this activity, you will use electricity to create magnetic fields.

In fact, by completing this investigation, you will be duplicating the work of Hans Christian Oersted. He was not the first scientist to notice a connection between electricity and magnetism, but Oersted was the first to believe it was more than just coincidence. Proving his theory, however, turned out to be more difficult than he thought. In 1820 Oersted brought his theory to his colleagues in a public lecture during which he showed the attending scientists the same demonstration that you will recreate today.

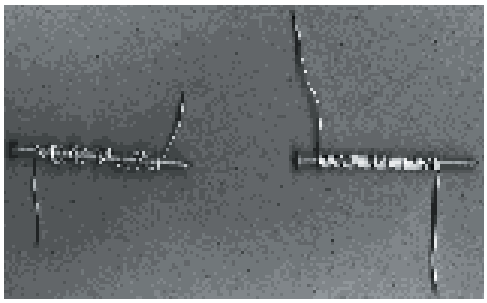
All observations should be recorded and all questions answered in your Alpha Log. You will use these observations to help you figure out how to construct your electromagnet. The conclusions that you draw from completing this activity will also help you in later activities about electromagnets.

1. Collect all materials that you will need to complete this activity: 1 D-cell battery, 1 battery holder, 200 cm insulated wire, a compass, iron rod, wooden dowel, aluminum rod, and paper clips.
2. Before you begin to build your electromagnet, check to see if the iron rod is a magnet. Describe the procedure that you use to determine if the iron rod is a magnet in your Alpha Log. Answer the questions: Is the iron rod by itself a magnet? Is the iron rod by itself magnetic? What is the difference between being a magnet and being magnetic?

3. Construct your electromagnet. Begin by connecting the insulated wire to the battery. (Leave enough wire at each end to connect the magnet to the battery.) Place the compass underneath the wire. Is there any reaction?
4. Now wrap the wire around the iron rod 15 times before connecting the wire to the battery. Record your observations. Answer the following questions in your Alpha Log: Can you pick up paper clips with the iron rod? Are there any unexpected results? Place your compass under the wound wire and record your results. Is this reaction different from what you saw when you placed the compass underneath the straight wire?
5. Remove the iron rod from the wire without unwinding it. Will the wire pick up any paper clips?

Will the rod alone pick up any paper clips? How can you explain your observations?

6. Use the wooden dowel and then the aluminum rod as a core around which you will again wrap the insulated wire 15 times. Do either of these pick up paper clips? Explain your results.
7. Place your compass under the wound wire. Do you get the same reaction as you did when you observed the compass in Step 4? How can you explain this?



8. Write an explanation of what you have learned from this activity. This can be a summary of what happened and why. When your group has reached agreement on this issue (if you **do** agree), compare your results with those of at least two other groups. Note in your Log how your results were different and how they were alike. Scientists often confirm the results of their work with others before going on to further investigation, research, or study. This communication can save time, energy, and money in the real world.

BUILD A STRONGER ELECTROMAGNET

PLANNING YOUR EXPEDITION

Batteries will need to be charged for this activity. Students should be warned about the heat generated when working with electromagnets.

Using these activities in conjunction with "Use Electricity to Make a Magnet" allows students to extend their experience to include working with specifications, defining parameters, manipulating variables, graphing the results of their work, publicly presenting the results, and defending the procedures they chose. This is a series of activities that asks students to apply math concepts to analyze data. Each part of the Itinerary addresses a different variable.

There is great value in modeling science as a human endeavor, rather than something done by men in lab coats in isolation. In reality, scientists have many constraints upon the way in which they conduct their research and are often working to others' requirements and specifications. Scientists are also subject to the same issues as others in the workforce, for example consideration of environmental issues, regard for how the work they are doing reflects upon the scientific community, and how their work affects the community in general.

Scientists in real-world settings reflect upon their work and discuss it in both large and small groups. In this way men and women involved in scientific endeavors clarify their thoughts and validate their research. Giving students the opportunity to manipulate variables and data and then design a way to present their findings models how scientists work and also models how private industry conducts business that impacts our everyday lives. Diverse groups of people are often required to work together to achieve a common goal; they may not speak the same language or follow the same customs; their cultures may be so varied that understandings need to be mutually decided upon, but the assigned task must be completed.

Some processes that students will employ in completing this activity are prediction, explanation, description, and analysis. These will be apparent as students answer questions posed by the activity in their Alpha Logs. It is expected that, at the end of this series of investigations, students will write up their results in a manner that can be presented to someone who was not involved in the activities.

1. Provide students with options for recording their data: a teacher-generated data table or

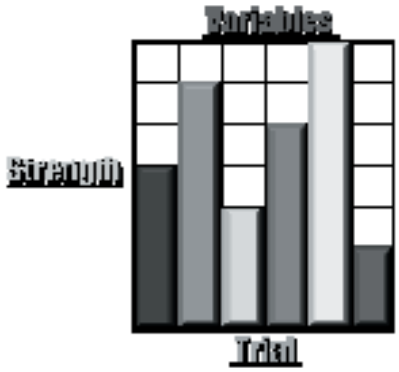
instruct the groups to design their own.* After gathering materials, students will first test the effect of the number of winds of insulated wire. Groups then must decide how they will measure the strength of their magnets. Students should be instructed to use any device **other than paper clips.**

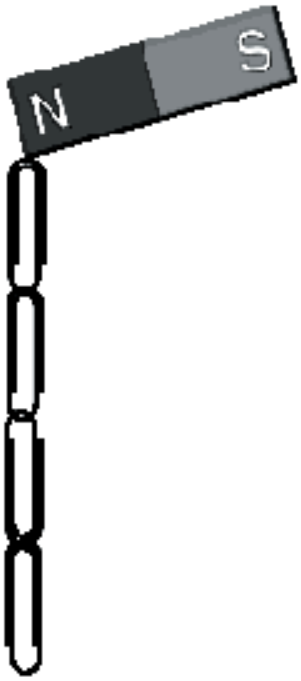
*If you decide to create a data table for the students to fill in, it should have the magnet numbers listed vertically with "winds," "style," "core material," and "average strength" as column titles. Interpreting tables is a skill that students will be required to use in all subjects in school. Creating their own method for recording and maintaining data will give students a deeper knowledge of the kinds of information that are best displayed on tables as opposed to graphs, lists, or diagrams.

2. Students will need to choose one variable to manipulate (the number of winds, the style of the winding, or the core material) and make predictions about the effect of that variable before constructing and testing the magnet.

3. Step 2 is repeated for each variable.

4. Students will construct a graph of the strength of each of the five magnets they made. One line graph could be used with a different color for each magnet; a bar graph could display magnets side by side. The x-axis (horizontal) should be the variable and the average strength of the magnet (determined by 5 trials) on the y-axis (vertical).





5. **As a culminating activity,** groups are assigned a certain number of paper clips to be picked up by the electromagnet that they construct. The group that constructs a magnet that picks up that particular number (no more and no less) most quickly receives a reward of your choosing (bonus points, extra credit, students of the week, a certificate, or some other incentive already in place in your classroom). A certificate is included in Appendix D. There is no Itinerary for this part of the activity since you will want your students to use any and all of the materials that are available in order to meet your specifications.

BACKGROUND INFORMATION

Variable refers to the one factor that is being tested or observed in an experiment. Most often, scientists work with only one variable at a time. There are many variables that can affect the strength of an electromagnet. For example, the number of winds, the size of the wire, the style of the winding, the core material, the coil diameter, or the amount of current. Students may add to the list length of the wire, size of the battery, or the core diameter. This activity, however, will deal only with number of winds, style of winding, and core material.

Encourage students to come up with other variables and ways to test them. With the available materials, allow students to experiment and test their ideas. Students will discover that testing one variable at a time is the only way to generate accurate information. Urge students to bring other materials to class and, after getting your approval, test these variables as well. You could offer some incentive like bonus points, extra credit, group of the week, etc., to give added incentive to students to launch their own investigations.

EXCURSIONS

Research an historical experiment, invention, or innovation. Report on how variables were manipulated to achieve the desired outcome. The report could be in the form of role-playing, videotape reenactment, poster presentation, written report, timeline, or diary. Student products demonstrate use of technology to complete research and knowledge of the fact that the questions that arise when one scientific discovery is made lead to further scientific inquiry and discovery.

SC.H.1.3.1-7, 3.3.5-7

LA.A.1.3.1-4, 2.3.1-8, LA.B.1.3.1-3, 2.3.1-4

SS.A.1.3.1-3, 2.3.2-3, 3.3.1-2, SC.H.1.3.1-7, 3.3.5-7

Students could design another competition (other than the paper clip speed competition) that could be held using only the materials they have at their disposal in the classroom. The design should show that students understand that by manipulating any of a number of variables, they can affect the performance of the electromagnet.

SC.C.2.3.1-3, SC.H.1.3.1-7, 3.3.5-7

MA.A.4.3.1, MA.B.1.3.2-4, 3.3.1, 4.3.1-2, MA.E.2.3.1

Have students design an invention that is based on one of their magnets. Describe the problem that the invention solves, identify who would use this product, and explain how the invention would be used. Include a labeled diagram of the invention, a list of materials and their approximate cost, as well as the final cost to the consumer. This assignment blends the experimental with the practical in that students will realize that there are many steps involved in taking a scientific discovery or innovation from the laboratory to general usage.

SC.C.2.3.1-3, SC.H.1.3.1-7, 3.3.5-7

MA.B.1.3.2-4, 3.3.1, 4.3.1-2

LA.B.1.3.1-3, 2.3.1-4, LA.D.2.3.1-2

SS.A.2.3.2-3

Notes:

FOR YOUR PLANBOOK: Build A Stronger Electromagnet

Suggested time: 1-5 hours

Gear: 1 D-cell battery, 1 battery holder, 200 cm insulated wire, iron rod, wooden dowel, aluminum rod, paper clips, graph paper.

National Science Content Standards: A, B, C, D, E, F, G

Sunshine State Standards Benchmarks: SC.B.1.3.4, SC.C.2.3.1, SC.C.2.3.2, SC.D.1.3.3, SC.D.2.3.2, SC.G.1.3.4, SC.G.2.3.3, SC.G.2.3.4, SC.H.1.3.1, SC.H.1.3.2, SC.H.1.3.3, SC.H.1.3.4, SC.H.1.3.5, SC.H.1.3.6, SC.H.1.3.7

Sunshine State Standards Benchmarks -- Math: MA.A.4.3.1, MA.B.3.3.1, MA.B.4.3.2, MA.D.1.3.1, MA.D.1.3.2, MA.E.1.3.1, MA.E.3.3.1

Sunshine State Standards Benchmarks -- Language Arts: LA.A.1.3.1-3, 2.3.1-4, LA.C.3.3.3, LA.D.1.3.1-4, 2.3.1-2

Homework: Have students list things in nature that depend upon cooperation or working in groups. Examples may range from complex food webs, food chains, entire ecosystems, and habitats to animals that live in packs/pods, etc. Earth Science students could make the connection between human interaction and the atmosphere or the ocean.

Cooperation at all levels is necessary for survival -- even if it is survival in science class or getting a good grade for finishing the activity. Getting students to reflect on their groups and each person's contribution to getting the job done will improve the group's dynamics.

Homework Assessment: Have students compare and contrast the group that they identified in nature with their group in science class. Students hand in the comparison in table or written form. Assignments should reflect the idea that each of the components of the group is dependent upon the others for survival (or a grade); that each group member has a well-defined job; and that the task could not be completed by only one member.

Assessment: Individually or in groups, students produce graphs that display variables on the x-axis and magnet strength on the y-axis. In a student-teacher conference, students explain their choice of data display and what it means to someone from outside of the classroom looking at the data. The graphs could be computer-generated or drawn by hand. There should be a graph for each of the variables investigated. Students demonstrate that they can construct a graph and understand that a graph is one of many ways to compare data.

Write a summary of the results of all parts of this investigation. The summary should discuss the three variables, results for each, and suggestions for other experiments involving the strength of an electromagnet. The results should be understandable to someone who was not involved in this series of activities.

Alpha Logs include analysis of results based on their answers to critical questions included in the Itinerary, explanations of (in written or graphic form) variables that were manipulated, and observations made during the trials. Answers to questions indicate that the more winds of the wire, the stronger the electromagnet becomes. Answers should also state that the wire and battery holder get warmer as the magnet gets stronger. If the wire is overlapped and pointing in one direction, the magnet will be stronger but if the wire is overlapped and pointing in different directions, the magnet will become weaker. Answers to questions in the activity should also state that the movement of electrons is what is causing the magnetic field.

Presentation of results for each group indicates participation of each group member and displays evidence that students distinguished between constants and variables, that they were able to replicate their results, and that they chose a graphic representation to compare results from each trial.

Culminating Activity: Electromagnets are manipulated so that the group picks up the exact number of paper clips assigned. For example, present the challenge to pick up only 8 paper clips, no more and no less. Or, one group could challenge another group to pick up a designated number of paper clips (e.g., 15) or some other item of their choosing. If groups choose the items involved in the challenge, the choice would demonstrate their knowledge of those objects that can be picked up by a magnet and those that cannot.

BUILD A STRONGER ELECTROMAGNET

Itinerary - Part I

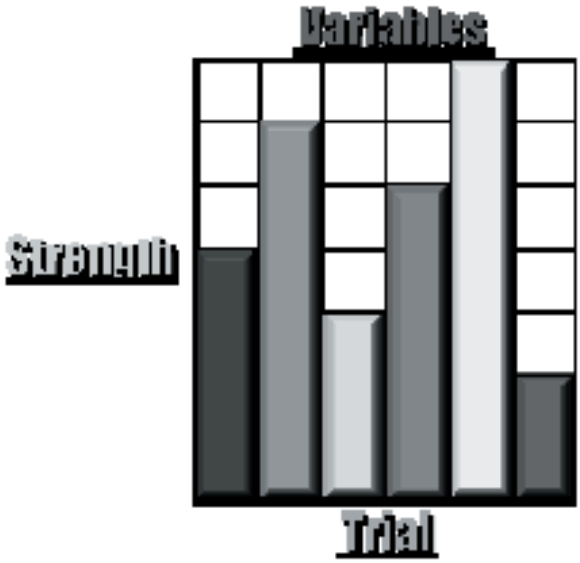
Variable refers to the one factor that is being tested or observed in an experiment. Most often, scientists work with only one variable at a time. There are many variables that can affect the strength of an electromagnet. Using what you already know about an electromagnet, what do you think some of these variables might be? Record the answer in your Alpha Log.

Variables that you will manipulate to try to increase the strength of your electromagnet will be: (1) the number of winds; (2) the style of the winding; (3) the core material.

Why would you manipulate only one of the above variables at a time if you are trying to build a stronger electromagnet? Record your explanation in your Alpha Log.

1. Assemble all of the materials that you need to run this series of experiments: 1 D-cell battery, 1 battery holder, 200 cm insulated wire, an iron rod, a wooden dowel, an aluminum rod, paper clips. You will also need graph paper.
2. Prepare your Log to record all data, observations, answers to questions, and drawings.
3. Invent a way to measure your magnet that **does not involve the use of paper clips.**
4. Construct an electromagnet by winding the iron rod with between 20 and 30 winds of wire. Make sure you leave enough wire at both ends to connect to the battery. Record the exact number of winds, then test the strength of your magnet using the system you have devised in Step 3. Repeat this test 5 times to verify the strength of the magnet and then calculate the average strength of your magnet.
5. Do you think the strength of the magnet would be affected by adding more winds? Write your prediction in your Log and add more winds to the iron rod to test your prediction. Use a total of 40 winds. Again, record the exact number of winds in your Log and measure the strength of your magnet. Repeat this test the same number of times that you chose in Step 2.
6. Add more winds so that you have between 50 and 60 winds in your magnet. How strong do you think your magnet will be now? Write your prediction in your Log and then test your magnet to determine its strength. (Remember: repeat each test 5 times to determine an average strength.)

7. Add more winds to your magnet so that you have between 65 and 75 winds, test and record your results as before.
8. Make a graph of the average strength of the five magnets you made. Plot the number of winds on the x-axis (horizontal) and the strength of the magnet on the y-axis (vertical). If you were to wind your magnet with 500 winds, how strong would you predict it to be?
9. Why is it necessary for you to determine the average strength of each of your magnets? What conditions exist that could explain why your magnet becomes either weaker or stronger in each of the 5 trials? Record your answers in the Log.

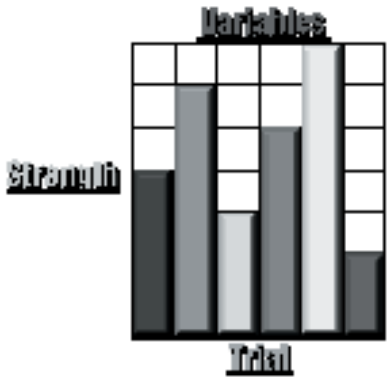


In this part of the experiment, you will change the manner in which you wind the wire around the iron core to determine what effect, if any, the style or compactness of the wire winds has on the strength of the magnet. Use the same system that you devised in Part I to measure the strength of your magnets. Again, as in Part I, you will want to replicate (repeat) each of the trials 5 times to determine average magnet strength.

1. Construct your electromagnet, sloppily winding the wire around the iron rod to make 20 winds. Do not worry about neatness or in which direction the wire is wound but leave enough space at the ends to connect the wire to the battery. Test the strength of the magnet; repeat the test five times and record your data in the Alpha Log.
2. Make another electromagnet with 20 winds. This time, wind the wire neatly around the rod taking care to place the winds next to, but not overlapping, each other. Test the magnet's strength, repeat the test five times, and record the data.
3. Now you will investigate the effect of the compactness of the wire on the strength of the magnet. As you construct your electromagnet, spread out the winds so that they are not touching. Try to have the same space between each wind. Measure the space between each so that they are consistent. Perform five tests to measure the strength of your magnet and record your results. You can determine the average distance between the winds by dividing the length of the winds by the number of winds. You will need this information later when constructing your graph.
4. Using the electromagnet that you have created, spread the winds even farther apart, leaving the same amount of space between each wind. Perform five tests of the strength of your magnet and record the results in your Log.
5. Find the average strength for each of the coil compressions (how close together they are). What conclusions can you draw about the importance of the compression of the winds?
6. Using the techniques from Part I, make a graph of the average strengths of each of the coil compressions, with average distance between the winds on the x-axis (horizontal) and the strength of the magnet on the y-axis (vertical).

In this experiment, you will work with the final variable, core material, to determine what effect, if any, it has on the strength of the magnet. The procedure will be the same as in the first two parts of this Expedition: you will repeat the tests five times; record your data on a table, compute average strength, and then make a graph. This time you will be expected to share all of your results with the class.

1. Using one of the core materials (iron rod, wooden dowel, aluminum rod, pen, or pencil), make an electromagnet as you have done before, with 30 winds of the insulated wire. Test the strength of your magnet five times and record your results in the Alpha Log.
2. Using a second core material, make another electromagnet also with 30 winds. Test its strength.
3. Make three additional electromagnets using each of the remaining core materials. Test each magnet five times and record your data.
4. Find the average strength for each of the core materials. What conclusions can you draw about the importance of the core material? Record your answers and any other observations in your Log..
5. Make a graph of the average strength of each of the core materials. Plot the core material on the x-axis and the average strength of the magnet on the y-axis.



AURORAS, MOON ROCKS, AND MAGNETISM

PLANNING THE EXPEDITION

For this activity you will need to gather articles on auroras or the use of moon rocks to study the composition of the moon and the earth. Good sources would be Earth , Science News, Smithsonian, Odyssey, Aviation Week & Space Technology, educational materials supplied by NASA or the Jet Propulsion Laboratory. Encyclopedia articles or explanations from reference books will work equally well.

Once students begin exploring magnetism, they will discover, as will you, that the study of magnets and magnetic fields leads to unexpected links with astronomy, astrogeology, meteorology, and geography. This activity explores two links which will hopefully lead to others. Even if some students are not particularly excited by this unit, there are many ways to connect to subjects that they *are* curious about.

As we look for different ways to engage students in the science classroom, creativity and flexibility become qualities that are vital for both teachers and the students they teach. No connection is too far afield if it makes sense to the person making that link. For example, it might not make sense to you at this point to talk about moon rocks while studying magnets, but some students could easily make the conceptual leap between the magnetic qualities of some moon rocks and theories as to how the moon became our satellite (see CD-ROM for more information on moon creation theories).

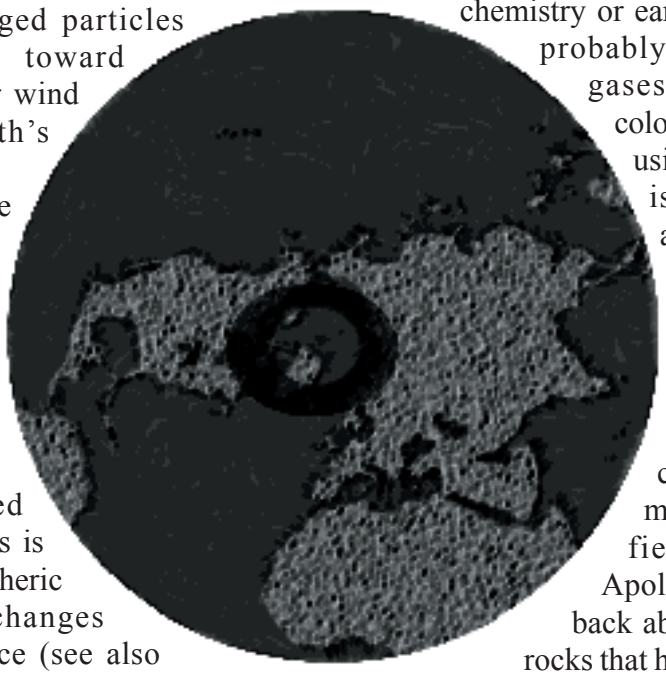
This activity is somewhat different than the others you have used. Rather than a hands-on exploration, it involves reading articles, gathering information, and applying that information to an assessment task of the student's choosing. It is a way for students to showcase their particular talents and utilize the learning style with which they are most comfortable.

Expository reading is required in all science classes but is not often approached separately. Instead, we assume that students can read a science textbook or a science article without providing them with the skills to do so. This activity will rectify this somewhat since you will be requiring the students to read critically several articles or to analyze information from web sites. You may choose to have students do this activity individually rather than in groups depending upon your resources. Whichever option you pick, students should share their information with others as a way of verifying the connections they have made.

1. Before beginning this activity, instruct students to write all they know in their Alpha Logs about auroras.
2. Using the worldwide web or other reference material, students will explore the phenomenon of auroras and/or moon rocks.
3. In their groups, or individually, students maintain a list of web sites visited and reference material consulted, indicating whether or not each is usable for them and indicating why or why not.
4. Hand out articles that you have copied and instruct students to read them for both the amount and quality of information they provide. Encourage students to highlight pertinent information.
5. Students will compare and contrast the use of the worldwide web and written articles. Making a table in their Alpha Logs, students will list advantages and disadvantages of each type of information.
6. Students will share their results with at least two others and answer questions that indicate that they have thought about why they may or may not agree with their classmates. This process indicates that they have critically reviewed the material.

BACKGROUND

Auroras (borealis in the northern hemisphere and australis in the southern hemisphere) are created by charged particles that are blown toward Earth by the solar wind (see "The Earth's Magnetosphere"). Because there is a direct link between auroras and magnetism, they occur only in ovals around the magnetic north and south poles. The area covered by the aurora ovals is affected by atmospheric conditions and changes at the sun's surface (see also "Excursions"). Auroras occur from 40-600 miles above the Earth, becoming most active when there are a lot of sunspots or solar flares.



The aurora borealis, sometimes called northern lights, changes color depending on the chemicals in atmospheric gases. This will make sense to students that have had chemistry or earth science. They are probably already aware that gases exhibit particular colors that can be observed using a spectroscope. It is, in effect, glowing air caused by charged particles from the sun passing through the Earth's magnetic field.

Another celestial connection to magnetism and magnetic fields is moon rocks. Apollo astronauts brought back about 380 kilograms of rocks that have been used to learn more about the moon and our own planet. That there is a small amount of magnetism present in moon rocks indicates, scientists think, an inner core similar for both bodies.

EXCURSIONS

Students can investigate the Sun's layers, in particular, the corona (the outer atmosphere). A detailed report of the corona will reveal the fact that it has recently been found to have many magnetic loops caused by the charged particles being unable to cross magnetic fields. Sunspots, which are commonly blamed for interrupting communications, are observable phenomena caused by magnetic fields. The Sun has a north and south pole which spin more slowly than the equator, because the Sun is rotating as a fluid, not a solid. The connection between Earth's magnetic poles and magnetic field is one that students should be able to make at this point. (One source of information on this subject is Odyssey magazine, June 1994. Back issues are available from Cobblestone Publishing, 1-800-821-0115.)

SC.A.2.3.3, SC.B.1.3.1-6, 2.3.1, SC.C.2.3.1-3, SC.D.1.3.5, SC.E.1.3.1-4

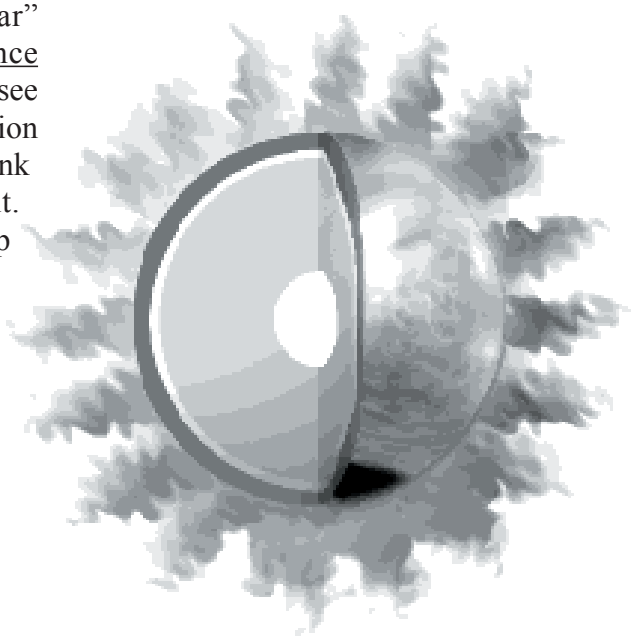
LA.A.2.3.1-8, LA.B.1.3.1-3, LA.D.2.3.1-2

Assign the short story "Bobo's Star" by Glenn Chandler, found in Science Fiction Stories by Edward Blishen (see Appendix C). In a large group discussion ask students if they can make any link between electromagnetism and light. Are there any theories that back up their ideas (perhaps black holes)? A concept that students will find in this story is that science must be done responsibly because there is danger (implied and otherwise) in scientific experimentation. Student responses should indicate that they realize science is not done in isolation and that much of scientific inquiry affects many people in various ways.

SC.B.1.3.1-6, SC.D.2.3.1-2, SC.E.1.3.1-4, 2.3.1, SC.H.2.3.1, 3.3.5-7

LA.A.2.3.1-8, LA.B.1.3.1-3, LA.E.2.3.1-4, 2.3.5-8

Star Trek fans can explore magnetic confinement beams in the book The Physics of Star Trek by Lawrence M. Krauss. The link between science fiction and science fact is particularly strong here because a great deal of research done has been done on Star Trek. Many of the ideas from the original Star Trek series have already come into everyday use (for example, cellular phones and space travel). Although there is much in the various Star Trek series and movies that is indisputably impossible, many of



the technological advances are based on present scientific theory and fact.

SC.H.1.3.1-7, 3.3.5-7

LA.A.2.3.1-8, LA.E.2.3.5-8

Students write an article for the school newspaper, literary magazine, or local newspaper that aims at teaching others about the link between magnetism and either auroras or moon rocks (or both). Explaining the information in a clear and concise way requires a solid background. Teaching someone else about the information asks students to make sense of their own ideas.

SC.E.1.3.1-4

LA.A.1.3.1-4, 2.3.1-8, LA.B.1.3.1-3, LA.D.2.3.1-2, 2.3.3-7. LA.E.1.3.1-5

Explore Mike Davidson's National High Magnetic Field Laboratory (http://micro.magnet.fsu.edu).

The photomicroscopy technique that Davidson's group has perfecteduses an optical microscope to photograph slivers of moon rocks. Shavings of these rocks allows scientists to analyze the crystalline structure revealing a great deal about the composition of the moon and characteristics of its crust (including the small amount of magnetism in moon rocks).

SC.H.1.3.1-7

MA.C.1.3.1

LA.B.2.3.4

Investigate other atmospheric phenomena that are observable from Earth, such as "atmospheric elves" (thought to be caused by lightning pulsing upward causing an electromagnetic charge above a storm cloud) or "atmospheric sprites" that have also been associated with storm clouds, and have students attempt to explain them. Students will be applying their knowledge of magnetism and magnetic fields to occurrences that *scientists* are still trying to explain. Their explanations will be no less important or correct.

SC.B.2.3.1, 1.3.1-6, SC.C.2.3.1-2, SC.D.1.3.5

FOR YOUR PLANBOOK: Auroras, Moon Rocks, and Magnetism

Suggested Time: 1-2 hours

Gear: articles on auroras or moon rocks, www access, Alpha Logs.

National Science Content Standards: A, D, E, F, G

Sunshine State Standards Benchmarks: SC.B.1.3.3, SC.C.2.3.1, SC.E.1.3.2, SC.E.1.3.3, SC.E.1.3.4, SC.H.1.3.1, SC.H.1.3.2, SC.H.1.3.3, SC.H.1.3.4, SC.H.1.3.6, SC.H.3.3.1, SC.H.3.3.4, SC.H.3.3.6, SC.H.3.3.7

Sunshine State Standards Benchmarks -- Language Arts: LA.A.2.3.1, LA.A.2.3.2, LA.A.2.3.4, LA.A.2.3.5, LA.A.2.3.8, LA.B.2.3.1, LA.B.2.3.4

Homework: Have students respond in writing to the following statement: "Much of the information that we have about the Earth's magnetic field, auroras, the Sun's activity and relationship to Earth's magnetic field, the composition of moon rocks, and the Earth's layers comes from the space program. Many people believe that the United States would be better off spending money elsewhere like on welfare programs, defense, or education, instead of spending many billions of dollars on space shuttles and space probes (not to mention developing a space station, a moon colony, or manned Mars missions)." How do you feel about this issue? Do you support space program expenditures? Do you think this money could be better spent elsewhere? What might we be giving up if we shut down NASA?

Homework Assessment: The students' written answers should be well-thought out as evidenced by a logical sequence of opinion statements. Upper level students might contrast fact and opinion to support their stance. Helping students to articulate their opinions encourages critical thinking and problem solving. A reasonable objective in science class

is for students to become discerning consumers of information considering the rapid rate at which scientific discoveries are being made. Much of the research leading to these discoveries is funded by tax dollars. As responsible, participating citizens, hopefully students will make well-informed decisions based on their ability to distinguish between reliable and unreliable data.

Assessment:

Alpha Logs will include a description of what students already know about auroras or an educated guess. The list will be either confirmed or not at the end of the activity. To demonstrate that students are able to navigate the worldwide web, they will have a list of sites visited. Identifying the one site that they would recommend as one with the best information requires that they analyze the information for accuracy and determine whether or not it suits their needs or is appropriate for a middle school study of magnetism. In doing so, students demonstrate a knowledge of magnetism as it relates to other phenomena, as well as the ability to distinguish between usable and unusable information. Finally, a table listing advantages and disadvantages of information from the websites versus written articles will extend students' thinking to include not just the information itself but the *kind* of information and whether it is of use to middle school students.

Have students write their own myths about auroras, the beautifully colored sky lights. Myths were attempts by early cultures to understand and explain natural phenomena. Ask students to imagine that they have no science knowledge other than that gained by experiencing natural occurrences in their lives (e.g., rain, cold, stars, or eclipses). As students assume this role they are forced to put into words ideas, impressions, and theories about how things work. As long as the final written product is focused on the subject of auroras, because it is the student's own explanation, accept all reasonable stories.

Students can draw their conception of an aurora or, instead of writing a myth, they can choose to illustrate one. Drawings should indicate some kind of wave-like pattern and might show Earth's surface to orient the height of the aurora (which occur anywhere from 40-600 miles above the Earth).

Instruct students to prepare their data to share with the class. This can be in the form of a media presentation, a written or oral report, a reenactment of a myth about auroras, a reference list of sources for information about auroras or moon rocks, or a visual presentation (poster or drawing) that explains how either of these subjects relates to magnetism or Earth's magnetic field. Evidence of successful completion of this assignment would be that the product demonstrates knowledge of the shape of the Earth's magnetic field and how that shape is affected by activity on the Sun's surface; or knowledge that one of the reasons for studying the moon is to understand more about our own planet.

Notes:

AURORAS, MOON ROCKS, AND MAGNETISM

Itinerary

Auroras (borealis in the northern hemisphere and australis in the southern hemisphere) are created by charged particles that are blown toward Earth by the solar wind (see "The Earth's Magnetosphere"). Because there is a direct link between auroras and magnetism they occur only in ovals around the magnetic north and south poles. The area covered by the auroral ovals is affected by atmospheric conditions and changes at the sun's surface. Auroras occur from 40-600 miles above the Earth, becoming most active when there are a lot of sunspots or solar flares.

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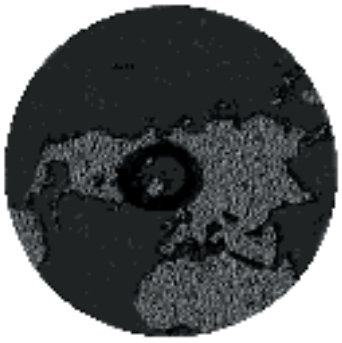


1. In your Alpha Log write everything you know about auroras. If this is the first time that you have even heard or seen the word, take an educated guess and record it in your Log.
2. Use the worldwide web to find and look at information about auroras or moon rocks (your choice). As you reach each site, record the location in your Log so that someone else can find it. Also make a note as to whether or not you think this is an appropriate site for use by middle school students and if you were able to use this information.

3. In your Log note the source (name of the newspaper or magazine, date, and page numbers) of each article that your teacher gives you. Read the articles and, with a highlighter, note the information that you would need if you were doing a research report. Again, in your Log indicate if this information is suitable (in your opinion) for middle school students and if it would be helpful in completing a research report. Another option would be to write an outline in your Alpha Log as you are reading the article. A third choice is to highlight and outline as you read.
4. Create a table in your Alpha Log that lists the different types of information you used and the advantages and disadvantages of each. Leave two columns, one for your opinion about suitability for middle school students and the other for your determination as to the value of the information for a research paper. Choose the one site or article that you found most useful and highlight it in your table.
5. Share what you have learned (your table and any notes that you might have made) with at least two other people. Answer the following in your Log: Did you all come to the same conclusion? If you answer "yes," why do you think this happened? If you answer "no," why do you think this happened?

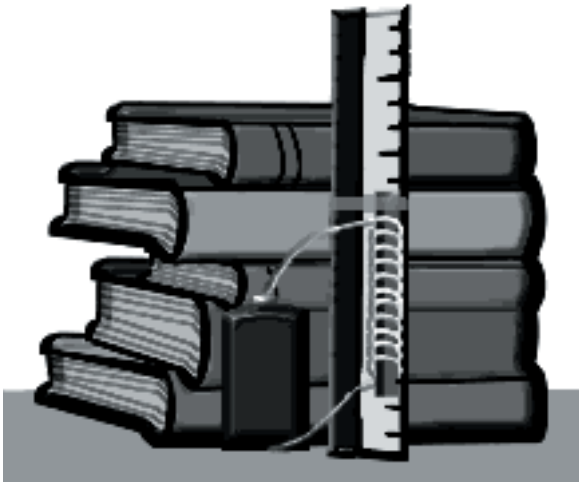
MAGNETS AND WORK

PLANNING YOUR EXPEDITION

Assign homework (see "For Your Planbook") before implementing the activity.

You will need a device from which the students can hang their electromagnets. You can approach this is in one of two ways: either provide clamps or some predetermined method of suspending the electromagnet or allow students to devise their own way of completing the task. (See picture below.)

As a companion to "Use Electricity to Make a Magnet" and "Build a Stronger Electromagnet" will help you and the students you teach conceptualize magnetic fields. It will encourage students to measure the force of the magnetic fields of the electromagnets they create. You may choose to use the electromagnets that they already constructed (Expeditions 7 and 8) or you may want to have the students build electromagnets as you discuss variables to be tested in this activity.



Students will be making the link between a magnetic field and energy as they convert energy to work. This is another way of thinking about the force that magnetic fields generate. Students will manipulate the strength of the magnetic field by changing the core material, adding or subtracting iron rods, or using another material altogether. Students will also be defining and distinguishing between energy and work. These concepts are difficult for students to grasp unless there is an experience that accompanies the information. Students will answer the following questions: How far does the magnet's influence extend? Can the magnetic field be used to do work? If so, how much work can the field produced by the electromagnet do, and what can we do to influence it?

Students will measure the mass of the items they are attempting to pick up with the electromagnet. This will give students practice in using balance scales and the metric system. This is a good place to review the concepts of mass, density, and volume since students will be using scales (see CD-ROM).

Choose either

1. After gathering their materials, students will set up the device you have designed for them to suspend their magnet (one that allows students to raise and lower it to complete various tests).

Or, 1. After gathering materials, students construct a device from which they can suspend their electromagnet (one that allows students to raise and lower it to complete various tests).

2. Students choose the item(s) they wish to work with and measure their mass before going any further with the Expedition.
3. Students are now ready to begin their investigation. They lower the magnet until their object is attracted to the magnet. Then, students measure the distance the object has been lifted.
4. Students use results to calculate how much work was done on the object by plugging their data into the formula w = f x d.
5. Encourage students to change the magnet to make it do more work and less work. They accomplish this by changing the core material or the amount of material (they can use two or more iron rods). Students again calculate the work that the magnetic field does and record all changes and answers in their Alpha Logs.
6. Students share their results and compare their methods and calculations with other groups and record the results of the conversations in Logs.

BACKGROUND INFORMATION

This activity introduces students to the concepts of energy, force, and work. For those students to whom you have already presented these ideas, demonstrating these concepts in a concrete way will enhance their understanding. It may help differentiate among the terms since they are words that students use every day; specifying the use of these words for science class may be difficult for some. Beginning with definitions and then applying the words deepens students' understanding of concepts that the words represent.

The definitions can be found in a standard physical sciences text. It is suggested, however, that students use one of the definitions that they looked up for homework. By doing so, you will be requiring the students to demonstrate their knowledge of the most appropriate definition for their particular task.

work: transfer of energy as an object is moved.

force: a push or pull exerted on an object.

energy: that which may be converted into work.

Mass is the measure of the amount of matter in an object. Weight is the measure of the amount of force gravity exerts on an object's mass. To calculate work being done, use the formula work (w) = force (f) x distance (d). Work is expressed in Newton-meters (Nm) or Joules (J); 1 Nm = 1 J. To find the force, multiply the mass by the conversion factor, 9.8 N/kg.

For example, the students' electromagnet generates a magnetic field that lifts a 5g object 10cm. Remember, students must convert mass to kilograms and distance to meters to use the formula. Students can refer to the CD-ROM for conversions.

5g = 1kg/1000g = 0.005kg

10cm = 1m/100cm = 0.1cm

w = f x d

w = (0.005kg x 9.8N/kg) x 0.10m

w = 0.049N x 0.10m

EXCURSIONS

Have students read "The Truth About Pyecraft" by H.G. Wells (see Appendix C). In a whole class discussion or short discussion paper, students will determine that Pyecraft was confused between mass and volume. By identifying that he was floating on the ceiling at the end of the story students will realize that he was still the same size although he had no weight. Pyecraft could have avoided this by defining of his terms before he asked for a magic solution to his weight problem.

SC.A.1.3.1-2,6, SC.D.2.3.1, SC.H.3.3.1-5

Have students brainstorm a list of songs, films, or television shows that have the words work, force, or energy in them. This will reinforce that these words are used in many and varied ways, and when doing science, one must be certain of the definition being used. When scientists communicate, use of words is vital to understanding of their work. Some examples: "Magnum Force," "I've Been Working On The Railroad," and "Force Ten From Navarone."

If you are still reading The Secret Life of Dilly McBean, discuss with students whether or not Dilly's hands are doing more work because they are magnetized. How do they know this? Can they prove it? Have students draw a picture of their favorite scene from the novel that in some way reflects their knowledge of magnets and magnetic fields.

SC.C.2.3.1-7, SC.H.3.3.1-4

Have students research the many ways that magnets are used to do work. Some examples to guide their thinking could be magnets as trash separators, magnets used in junkyards to separate metals and pick up compacted cars, or magnets as door latches. Students could prepare a poster presentation for the class to share their ideas and add to the general body of knowledge on magnetism. Each student, pair or students, or group of students sets up their posters and students are then encouraged to walk around the room and see what others have researched and how they have presented their findings. Posters should demonstrate that research was done in answer to the question "Where in real life do magnets perform work?" Posters should be visually attractive and include the information in both print and pictures. In this case, since you are creating a poster session for your classes, only posters will be allowed and all posters should be left up for other classes to view.

SC.C.2.3.1-7, SC.H.1.3.1-3, 6, 3.3.1-7

Magnets were used on the doors that separated water-tight compartments on the Titanic. This is an interesting connection between how magnets have been used and current science research. The sinking of the Titanic has been an event that has fueled much speculation among the general public as well as the science community. Recently, a scientific expedition attempted to find out why the Titanic sank so quickly. Students

could read articles about current efforts to find out more about the Titanic disaster. The Discovery Channel has a 2-hour video available on this subject.

SC.C.2.3.1-3. 3.3.1-4

FOR YOUR PLANBOOK: Magnets and Work

Suggested Time: 1 hour

Gear: Electromagnet or electromagnet materials from "Can You Build a Stronger Electromagnet?" or "Using Electricity to Make a Magnet," paper clips or other material that a magnet attracts, balance scale, masking tape, rulers

National Science Content Standards: A, B, E

Sunshine State Standards Benchmarks: SC.A.1.3.2, SC.C.2.3.1, SC.C.2.3.2, SC.C.2.3.4, SC.H.1.3.1, SC.H.1.3.2, SC.H.1.3.4, SC.H.1.3.5, SC.H.1.3.7, SC.H.3.3.4, SC.H.3.3.6

Homework: Have students define the words work, energy, and force using a dictionary (not a science book glossary). Since there are many definitions for these words, it may seem somewhat tedious, but instruct students to write down all definitions, counting them if there are more than three. Students will answer the following question: Which definition (that you wrote down) for each word do you think we will use in science class? Tell students to bring to class all definitions with the ones they choose underlined.

Homework Assessment: Your students will recognize that, although we use these words everyday, when the words are applied to specific tasks, or in certain situations, only one definition might suffice. Students will initially believe that these are "easy" words to define because they have heard these words all their lives. Because they have preconceived ideas of what the words mean, it may be difficult for students to apply the words properly and use them in the context of physical science. To successfully complete this assignment, students will have from 10-20 definitions of the word work; 5-10 definitions of force and the same for energy. They will have underlined the definition that matches those in the "Background Information" portion of this activity.

Assessment: Assign the following: Imagine that you are trying to explain this activity to a younger friend who is very interested in magnets. How will you explain what you have done? What will you say the purpose was for doing this activity? Why was it important to change the core of your magnet? Indicate the age of the person for whom you are writing. This assignment asks that students put into words what they have taken from this activity. The depth of their answer will depend upon how much *they* have learned rather than what *you* have taught, so all reasonable answers should be acceptable.

Have students draw a diagram of the device used to suspend the magnet, labeling all parts including the magnet, the items being picked up, and the measurement instrument. This will reinforce the concept of distance and force plus the fact that work is done by picking up paper clips or some other object(s).

Student Alpha Logs should indicate that students predicted outcomes before they proceeded with the investigation demonstrating that they have a good idea of the meaning of the words work, force, and energy. Logs should include a diagram of the device that students used (or developed) to complete their investigation indicating that they know how important it is for someone else to replicate their work. Questions should be answered in a way that shows you that students can use the work = force x distance formula; that they know which variables to "plug into" the formula.

Read aloud "Why Does the Knuckleball Behave That Way?" (from The New York Times Book of Science Literacy, Harper Perennial, 1992, ISBN 0-06-097455-9). Students will, in discussion in small groups, make the connection between sports and force, work, and energy.

MAGNETS AND WORK

Itinerary

Mass is the measure of the amount of matter in an object. Weight is the measure of the amount of force gravity exerts on an object's mass. To calculate work being done, use the formula work (w) = force (f) x distance (d). Work is expressed in Newton-meters (Nm) or Joules (J); 1 Nm = 1 J. To find the force, multiply the mass by the conversion factor, 9.8 N/kg.

Be sure that a definition for each of the words "work", "force", and "distance" are entered in your Alpha Log. As you work, enter all measurements and calculations in your Alpha Log, any questions that you have while doing this investigation and answers questions posed in the activity itself.

1. The materials manager will assemble everything needed to complete this activity: either the electromagnet you made in an earlier activity or the materials needed to make one; a device with which you can raise and lower your electromagnet or the materials to make one (see diagram); paper clips and other objects that are attracted to the magnet; a centimeter ruler; iron rods; insulated wire; and a balance scale.
2. Suspend your electromagnet from the magnet stand. Placing the paper clips (or other objects) on the bottom, slowly lower the magnet until they are attracted to the magnet. Measure the distance that the object traveled and enter this into the formula (w = f x d).
3. Using the balance scale, measure the mass of the objects in grams, convert to kilograms, and enter this data in your Alpha Log. Mass in kilograms times 9.8 N equals force. You are now able to calculate the amount of work done. How far does the magnet's influence

extend? Can the magnetic field be used to do work? If so, how much work can the field produced by the electromagnet do? What can we do to influence the magnetic field of the electromagnet? Complete all calculations and answers in your Log.

4. Now, using the answer from Step 3, modify your magnet so that it has a stronger magnetic field. Enter all data and calculations in your Alpha Log and answer the following question: How did you modify your magnet? If you make the statement: "Guess what? Magnetic fields can do work" and someone says to you, "Prove it!", what will you provide as evidence to back up your original statement? Enter this conversation in the Log.

5. Share what you have done with another group and record the results of this conversation in your Log.

MAGNETISM AND TEMPERATURE

PLANNING YOUR EXPEDITION

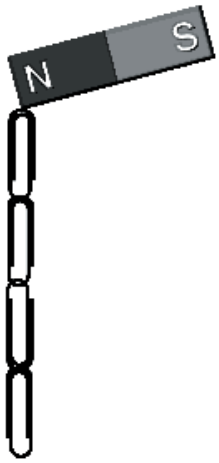
You will need to assemble all materials prior to the day that you are going to use this Expedition. A hot plate or an electric kettle is necessary because hot tap water will not yield noticeable results. If you wish to leave out the section with hot water, do so. The reason for doing this activity is to make a connection to superconductors, so the cold temperature magnet is the focus. Ice cubes will be required and you will need to copy the worksheet on temperature scales for the homework assignment to be completed.

This is a good time to revisit safety issues with your class.

Set up the class in groups of six (two students per magnet construction). In this activity your students will use the same procedure they used for "Use Electricity to Make a Magnet" or "Build a Stronger Electromagnet?" Once they have their electromagnet built, students will investigate yet another variable, temperature, and its affect on magnetic field strength. This investigation will lead directly into a discussion on superconductors, their discovery, and practical applications.

Remind students that they have dealt with variables in previous activities and, again, they will be manipulating only one variable at a time. Students should use ice water before hot water. Also, instruct students to keep cold and hot water results separate in their Alpha Logs. It is assumed at this point that your students are able to find a way to record their data so that it can be used later to create a graph. However, if you find it necessary, you can create a data table for them.

Students will be testing three electromagnets under three conditions: room temperature, very cold, and very hot. As they test and retest each condition, students will record all information in their Alpha Logs. Before they proceed , students make a plan for recording their data. At this point students should have enough experience with recording data to determine their own method.



NOTE: Instruct students to place paper clips on the magnet (or on one another) instead of just holding the magnet over a bunch of clips. Since the variations are so small (one or two paper clips), this is important (see diagram).

1. Students construct and test (using paper clips) three electromagnets.
2. Each of the electromagnets will be used to test a variable: room temperature water, hot water, and ice water.
3. After constructing three electromagnets, students test each by either leaving the solenoid as it is, by placing it in very hot water, or by submerging it in ice water.
4. Each condition should be tested 10 times to create a large enough data set to graph as a culminating activity.
5. In the Alpha Log, students answer questions regarding magnet strength and temperature. Anticipated results are that the cooler magnet will pick up the most paper clips and the very hot magnet the least number of paper clips.
6. Students will then devise a way to present their findings graphically to the rest of the class. Encourage students to use computer graphing capabilities to display all three test averages.

BACKGROUND INFORMATION

An overview of superconducting magnets can be found in Driving Force by James D. Livingston (ISBN 0-674-21645-8). A short article geared to middle school readers can be found in Odyssey Magazine, January 1997 (available from Cobblestone Publishing, 7 School Street, Peterborough, NH 03458). A concise book, Superconductivity: From Discovery to Breakthrough provides an excellent overview of the history and current status of this field (see Appendix C).

In order to understand the concept of superconductivity, it is necessary to do a short review of resistance, because it is the lack of resistance at very cold temperatures that is important. Metals are good conductors of electricity because of the number of free electrons per atom (one to three). A free electron is one that is not held by the electrical attraction of the nucleus. Materials that have no free electrons are insulators like glass or plastic. Materials that have a few are called semiconductors. Each atom of copper has one free electron, so it is a good conductor of electricity. The insulated wire that is used in these activities is copper. As electricity (from the battery) is "pushed through" the wire, the free electron bumps into other electrons resulting in resistance. Because of this the wire heats up. In many cases, this is desirable; for instance, in heaters. However, when creating high-field electromagnets, this resistance is a problem, because the magnets heat up to a point where they can no longer contain the heat so they explode.

Developing a material that would withstand the heat produced by a high magnetic field was the challenge that faced early experimenters with magnetism. Early in the twentieth century, a Dutch physicist, Heike Kamerlingh Onnes noted the relationship between lowering temperatures and, at the same time, lowering resistance. He began a search for absolute zero which is 0 Kelvin (-273.16 Celsius) at which there would be zero resistance. This led him to temperatures so low that gas would turn to liquid.

Superconductivity was found in certain metals; that is, they demonstrated no electrical resistance at extremely low temperatures. Onnes received the Nobel Prize for Physics in 1913 for his experiments. Subsequently, other scientists were awarded Nobel prizes for their work in superconductivity and magnets: John Bardeen, Leon N. Cooper, and John Robert Schrieffer in 1972 and J. Georg Bednorz and K. Alex Muller in 1987. (See the CD-ROM for more information.)

EXCURSIONS

Have students investigate superconductivity on the CD-ROM or other media (print or video). Their task will be to define terms including absolute zero and then to link this with the study of high magnetic fields. Reports should include practical applications of the technology created as a result of developing superconducting materials and present research efforts (what kinds of research are scientists doing right now in this area?). Encourage students to look at the National High Magnetic Field Laboratory homepage for answers to some of their questions (www.magnet.fsu.edu). Presentations of material could be in report form, a poster, an oral presentation, a demonstration, guest speaker, etc. Any form that students decide upon is acceptable if it indicates a relationship between the evidence from their experiments and the explanation of what is being done presently.

SC.B.1.3.4, SC.C.2.3.1-3, SC.H.1.3.1-7, 3.3.5-7

MA.A.1.3.1, 3-4

LA.A.1.3.1-4, 2.3.1-8, LA.B.1.3.1-3, 2.3.1-4, LA.C.3.3.3, LA.D.2.3.1-2

Students can research Nobel Prize winners associated with the study of superconductivity: Kamerlingh Onnes (1913), John Bardeen, Leon N. Cooper, and John Robert Schrieffer (1972), and J. Georg Bednorz and K. Alex Muller (1986). Encourage students to show in their research how each scientist or group of scientists built upon the work that came before them. This assignment points out that many individuals contribute to each discovery. Seldom are discoveries the work of just one person.

SC.B.1.3.4, SC.C.2.3.1-3, SC.H.1.3.1-7, 3.3.5-7

LA.A.1.3.1-4, 2.3.1-8, LA.B.1.3.1-3, 2.3.1-4, LA.D.2.3.1-2

SS.A.1.3.1-3, 2.3.3

For the more sophisticated students, an in-depth look at atoms and molecules would be appropriate here. Have students research various metals that are good conductors and diagram atomic and molecular structure. The diagram should explain the free electron concept so that if another student is still not clear about it, this could be a visual aid. Students could compare diagrams of conductors versus insulators. When finished, students should be encouraged to show other students and attempt to explain the concept using only their diagrams.

SC.A.1.3.3-4, 2.3.2, SC.C.2.3.1-3, SC.H.1.3.1-7, 3.3.5-7

MA.A.1.3.1-4

LA.B.2.3.1-4, LA.C.3.3.3, LA.D.2.3.1-2

An investigation of states of matter and the way that atoms are configured in the different states—gas, liquid, solid, plasma—would be appropriate at this point, particularly for more advanced students. Although a simple activity or discussion would suffice for some students, a more in-depth look

at the distance between atoms in each state would help clarify the discussion of superconductivity. Student research and presentation of findings take them from a look at the results of scientific endeavor to the science that led to those results. Students articulate why super cold temperatures create virtually no resistance.

SC.A.1.3.3-4, 2.3.2, SC.B.1.3.4-6, SC.C.1.3.2, 2.3.1-3, SC.H.1.3.1-7, 3.3.5-7

LA.A.2.3.1-8, LA.B.2.3.1-4, LA.C.3.3.3, LA.D.2.3.1-2

Have students read "A Day's Wait" by Ernest Hemingway (found in The Snows of Kilimanjaro and Other Stories ISBN 0-684-71807-3) or you can read it aloud to them. Discuss how easily confused a person could be about the difference in the Celsius and Fahrenheit scales. Brainstorm other commonly known temperatures (besides body temperature) that could be used in a story, for example the expression "room temperature" as recommended for certain foods or comfort, at 72 degrees Fahrenheit. You could take this one step further and have students write their own short stories.

SC.A.1.3.1, 1.3.3, 1.3.4, 2.3.3

LA.A.1.3.1-4, LA.B.1.3.1-3, LA.E.2.3.1-8

FOR YOUR PLANBOOK: Magnetism and Temperature

Suggested time: 1-2 hours

Gear: 3 D-cell batteries, 3 battery holders, insulated wire, 3 styrofoam cups, 3 iron rods, a thermometer, ice, very hot water, room temperature water, paper clips

National Science Content Standards: A, B, E, F, G

Sunshine State Standards Benchmarks: SC.A.1.3.3, SC.A.1.3.4, SC.A.2.3.2, SC.B.1.3.5, SC.H.1.3.1, SC.H.1.3.2, SC.H.1.3.3, SC.H.1.3.4, SC.H.1.3.5, SC.H.1.3.6, SC.H.1.3.7, SC.H.3.3.5, SC.H.3.3.6, SC.H.3.3.7

Sunshine State Standards Benchmarks -- Math: MA.A.1.3.1-4, MA.B.1.3.1-4, 2.3.1-2, 3.3.1, 4.3.1-2, MA.C.3.3.2, MA.D.1.3.1-2, MA.E.1.3.1-3, 2.3.1, 3.3.1

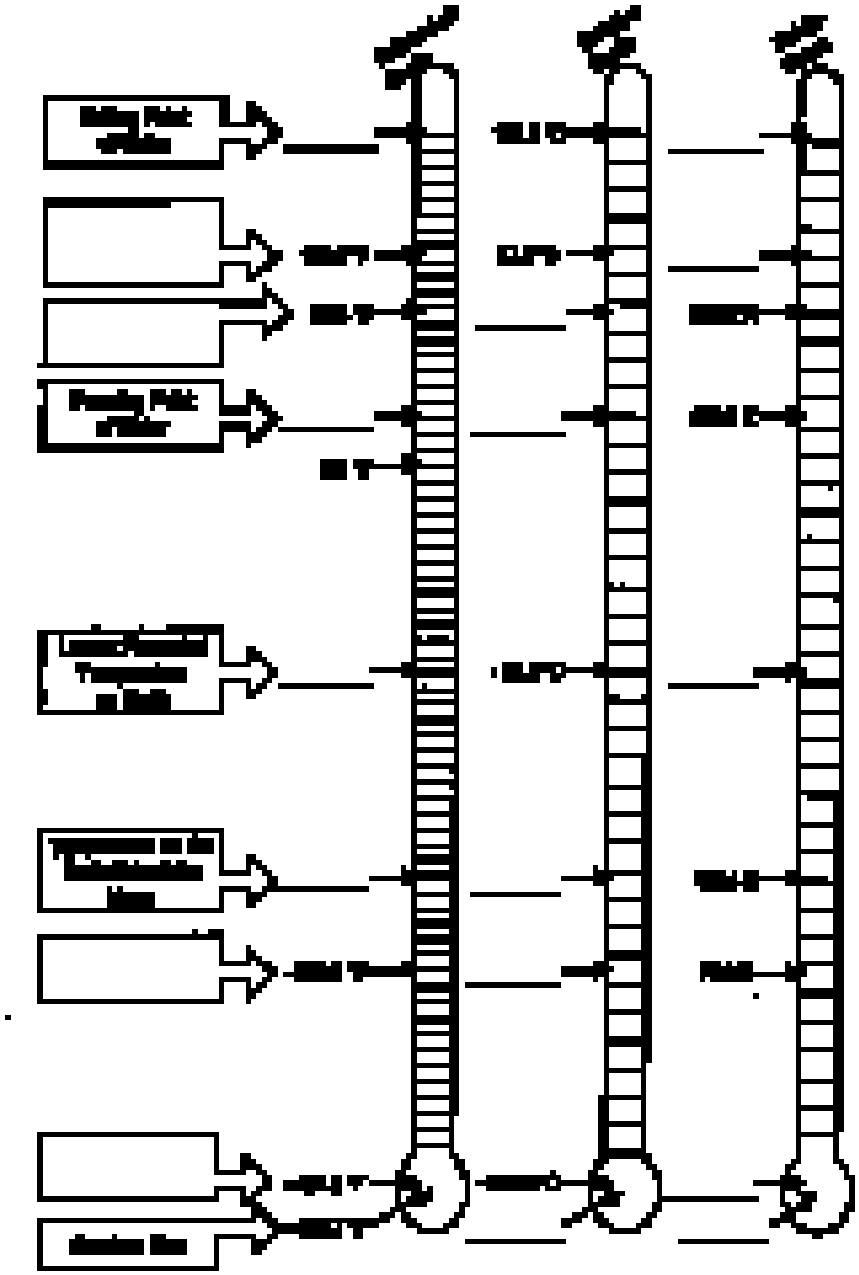
Homework: Compare the three temperature scales: Celsius, Fahrenheit, and Kelvin. Using the worksheet provided, students answer several questions comparing the three temperature scales giving them a frame of reference for completing this series of experiments. It is suggested that you allow several nights for the completion of this assignment.

Directions for the temperature worksheets: Have students complete the temperature comparison worksheet for homework before completing the Expedition. Explain the table and give an example or two of how to transfer the information to the thermometer worksheet itself. In addition to the worksheets, require students to answer the questions on the back of the worksheet. These questions ask students to make a critical analysis

of the relationship among the temperature scales.

Homework Assessment: Unless the students have some basic information, it will be difficult for them to imagine the ultra-cold temperatures represented by the Kelvin scale. Learning the correct way to write each measurement is necessary if students are going to describe their work to others. By completing this assignment students will be able to state relationships among the three scales as well as making sense of their predictions in the Expedition.

Assessment: Students' presentations of results of the series of experiments should reflect a relationship between the strength of the magnet and temperature. Cooler magnets should pick up more paper clips. Graphs should present this information so that they can be looked at separately and together. Some students will choose to use computer programs; others might use transparency overlays; still others will draw graphs by hand. However the information is displayed the result will be a clear communication of data modeling real-world information sharing that is done by scientists as they critique one another's work.



MagLab: Alpha

	Fahrenheit scale (˚F)	Celsius scale (˚C)	Kelvin scale (K)
Highest known temperature	918,000,000.0	509,999,982.2	510,000,255.4
Sun's core temperature	27,719,540.0	15,399,726.9	15,400,000.0
Sun's surface temperature	9,945.0	5,507.2	5,780.4
Hottest planet's (Venus) surface temperature	864.0	462.2	735.4
Lighted side of the moon	243.0	117.2	390.4
Boiling point of water	212.0	100.0	
Highest recorded temperature on Earth	136.0	57.8	
Average human body temperature	98.6	37.0	
Freezing point of water	32.0	0.0	
Lowest recorded temperature on Earth	-128.6	-89.2	
Dark side of the moon	-261.0	-162.8	
Liquid nitrogen	-320.8	-196.0	
Liquid helium	-452.2	-269.0	
Interstellar space	-454.0	-270.0	
Absolute zero*	-459.67	-273.15	

* The lowest temperature theoretically possible when all atomic motion stops

Answer the following questions in your Alpha Log:

1. Which is colder, the dark side of the moon, or the temperature of liquid nitrogen?

2. You take your temperature, and the thermometer reads 36.8˚C. Do you have a fever?

3. Which is warmer, 0˚F or 0˚C?

4. Below are four pairs of temperatures. Choose those that represent the same temperatures.

   a. 0.0˚C, 0.0K
   b. 32.0˚F, 273.2K
   c. 77K, -196.0˚C
   d. -270.0˚C, 0.0K

5. What is the lowest recorded temperature on Earth? Is 0.0K warmer or colder than the lowest temperature recorded on earth?

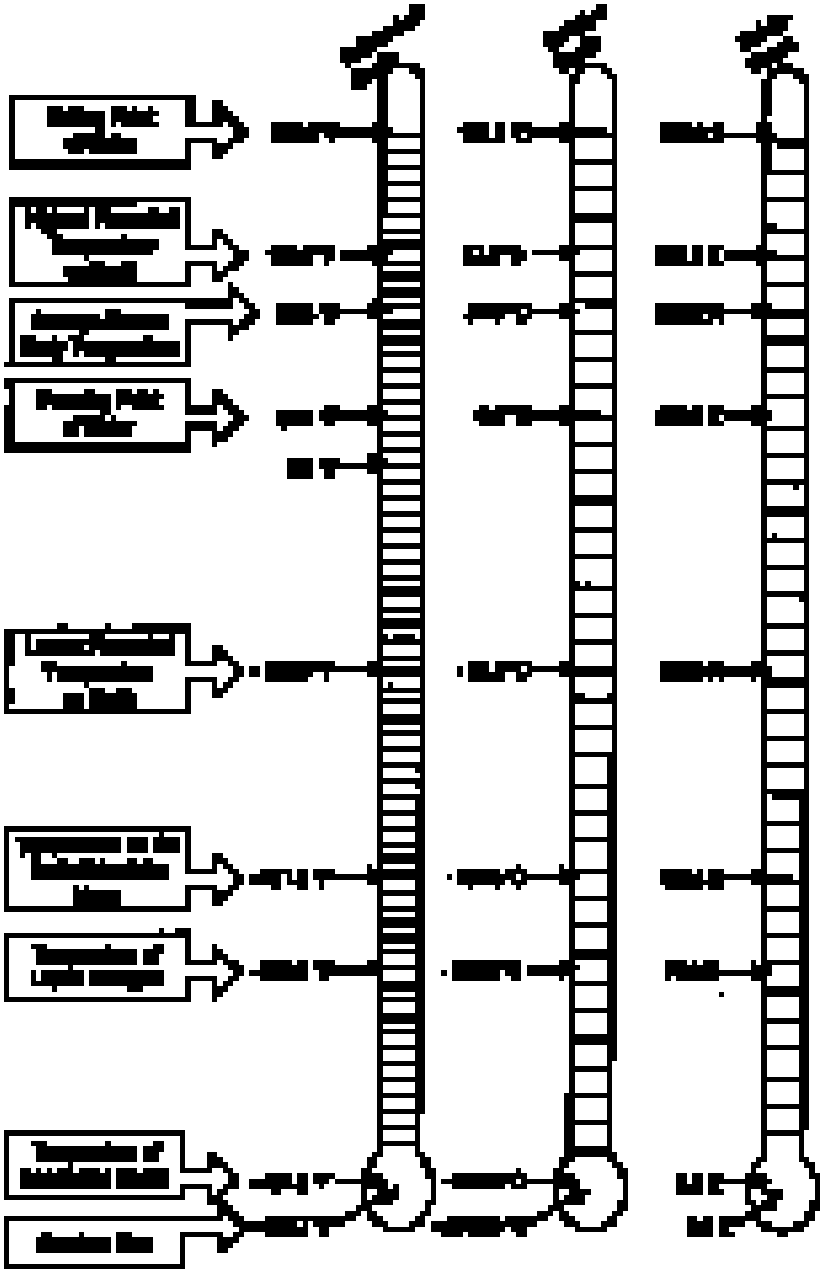
6. Consider these three temperatures: 0.0˚C, 273.2K, 32.0˚F. How are they related?

7. What is the name for the temperature at which all atomic motion is predicted to stop?

8. Write two temperatures representing absolute zero.

9. Rank these temperatures from coldest to warmest: 32.0˚F, 32.0˚C, 32.0K.

10. Why do you think scientists have developed three different temperature scales?



Answers

1. Which is colder, the dark side of the moon, or the temperature of liquid nitrogen?
   Liquid Nitrogen

2. You take your temperature, and the thermometer reads 36.8˚C. Do you have a fever?
   No. 37˚C is normal body temperature.

3. Which is warmer, 0˚F or 0˚C?
   0˚C

4. Below are four pairs of temperatures. Choose those that represent the same temperatures.

   a. 0.0˚C, 0.0K
   b. 32.0˚F, 273.2K
   c. 77K, -196.0˚C
   d. -270.0˚C, 0.0K

5. What is the lowest recorded temperature on Earth? Is 0.0K warmer or colder than the lowest temperature recorded on earth?
   -128.6˚F, or -89.2˚C, or 183.9K. 0.0K is colder.

6. Consider these three temperatures: 0.0˚C, 273.2K, 32.0˚F. How are they related?
   They are all the freezing point of water.

7. What is the name for the temperature at which all atomic motion is predicted to stop?
   Absolute Zero

8. Write two temperatures representing absolute zero.
   -459.7˚F, -273.15˚C, 0.0K

9. Rank these temperatures from coldest to warmest: 32.0˚F, 32.0˚C, 32.0K.
   32.0K, 32.0˚F, 32.0˚C

10. Why do you think scientists have developed three different temperature scales?

Notes:

MAGNETISM AND TEMPERATURE

Itinerary

You will be investigating the effect of temperature on magnets. In doing so, you will be manipulating (handling) a variable in two ways, so be sure to keep your results separate in your Alpha Log. In this experiment, you will be changing the temperature of the electromagnet to determine what effect, if any, temperature has on its strength.

Measure the strength of your magnets by the number of paper clips it can pick up. This will be the simplest and most graphic representation of the strength of the magnet.

In order to understand the concept of superconductivity, it is necessary to do a short review of resistance, because it is the lack of resistance at very cold temperatures that is important. Metals are good conductors of electricity because of the number of free electrons per atom (one to three). A free electron is one that is not held by the electrical attraction of the nucleus. Materials that have no free electrons are insulators like glass or plastic. Materials that have a few are called semiconductors. Semiconductors allow electricity to flow through them and are between insulators and conductors in terms of resistance. The insulated wire that is used in these activities is copper. Each atom of copper has one free electron, so it is a good conductor of electricity. As electricity (from the battery) is "pushed through" the wire, the free electron bumps into other electrons resulting in resistance. Because of this the wire heats up. In many cases, this is desirable; for instance in heaters. However, when creating high-field electromagnets, this resistance is a problem because the magnets heat up to a point where they can no longer contain the heat, so they explode.

Developing a material that would withstand the heat produced by a high magnetic field was the challenge that faced early experimenters with magnetism. Early in the twentieth century, a Dutch physicist, Heike Kamerlingh Onnes noted the relationship between lowering temperatures and, at the same time, lowering resistance. He began a search for absolute zero, which is 0 Kelvin (-273.16 degrees Celsius), the temperatures at which there would be no resistance. This led him to temperatures so low that gas would turn to liquid.

Superconductivity was found in certain metals; that is, they demonstrated no electrical resistance at extremely low temperatures. Onnes received the Nobel Prize for Physics in 1913 for his experiments. Other scientists received Nobel prizes for their work in superconductivity and magnets: John Bardeen, Leon N. Cooper, and John Robert Schrieffer in 1972 and J. Georg Bednorz and K. Alex Muller in 1987. (See the CD-ROM for more information.)

Part I

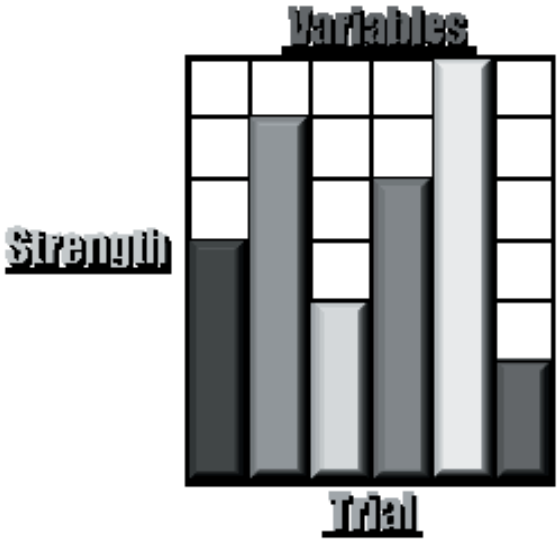
Your group will construct and test three electromagnets at one time. Divide the group so that two of you are testing the electromagnet at room temperature; two at very hot temperatures; and two at very cold temperatures.

1. The Materials Manager should assemble all of the materials that you need to run this experiment: 3 D cell batteries, 3 battery holders, insulated wire, 3 styrofoam cups, 3 iron rods, a thermometer, ice, very hot water (see your teacher about this), and paper clips.

2. Prepare your Alpha Log for recording the following data: magnet strength, temperature for 10 trials, average strength, and average temperature.
3. Construct three electromagnets as you did before. Wrap the iron rod with 60 coils of wire and record this in your Alpha Log so if you need to replicate your work to perform additional tests, you will use exactly the same specifications.
4. Test your electromagnets using the paper clips. Place the paper clips on the magnet. Record both the room temperature and the number of paper clips that your magnet picks up (its strength) in your Alpha Log. Repeat this test 10 times, recording each trial in your Alpha Log.
5. Figure out the average strength of your magnet at an average temperature and record both in your Alpha Log.
6. Now it is time to introduce the temperature variable. Respond to the following in your Alpha Log: Will reducing or increasing the temperature of the magnet affect its strength? Keeping in mind the background information that you read above, predict how many paper clips you think your cooled magnet will pick up and then do the same for the heated magnet.
7. Place the wrapped iron rod of the electromagnet in the styrofoam cup. Add crushed ice to cover the rod. Add enough water to make a slushy solution that covers the rod completely. Allow the rod to remain in the solution for a few minutes. Record the temperature of the ice water.
8. Take the coil from the cup and test the strength of your cooled magnet. Repeat the test 10 times. Remember as you repeat your strength test to record the temperature of the water each time. Then, calculate the average strength and the average temperature.

Part II

9. You will now run this experiment using hot water. With the experience and information that you gained from Part I, in your Alpha Log write a prediction about the effect that warming the magnet will have on its strength.
10. Place the magnet in the styrofoam cup and CAREFULLY pour in very hot water to cover the iron rod.
11. Record the temperature of the water in your Log and test the strength of your magnet. Repeat the test 10 times, each time recording the temperature of the water.
12. Calculate the average strength of your magnet (measured by the number of paper clips picked up) and the average temperature and record these in your Alpha Log.
13. Find the average strength for each of the three temperatures that you tested (room temperature, very cold, and very hot). What can you say about the results? Does temperature appear to affect magnet strength? How could you make an even stronger magnet?
14. Design a way to graph your results. Construct your graph in a way that can be shared with the class.



BUILD A MAGLEV TRAIN MODEL

PLANNING YOUR EXPEDITION

Models constructed in this activity will be used in Expedition #16 "Model Train Competition."

In this Expedition and its follow-up, "Model Train Competition," students will build models of a transportation system to demonstrate how magnets can be used in a practical way. Combining content issues like magnetism with real-world applications brings another dimension to science in the classroom.

It is possible to build a simple levitating train using some of the principles that your students already know about magnetism. Although a true MagLev train is a very complex device, students should be able to build a mock-up of a simple train that levitates along a 1-foot (approximately) track just by using permanent magnets and common materials.

Scientific advances bring both problems and benefits, and informed citizens need to understand how these advances impact their lives. Today's citizens must make decisions regarding scientifically based social issues, i.e., genetic engineering, cloning, energy consumption, or environmental conservation. These decisions will affect not only society as a whole but students' individual lives. Using real-world applications of science in classroom instruction provides opportunities for students to analyze the impact of science and technology on society and to determine their costs and benefits. Students engage in real world situations which motivate the learning of science content.

If students come up with ideas using other materials, encourage their creativity, and make other magnets or related materials available to them if possible.

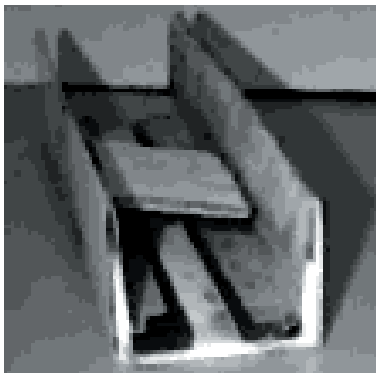
1. Students construct a base for a MagLev train from foam board, posterboard, or cardboard.

2. Using magnets, students will construct the track. As they do this, they will discover (if they did not realize this before they began) that the magnets must be aligned in a certain way for this to work. Students will also find that taping the magnets together so that like poles line up is not as easy as it first seems. It may be helpful for students to figure out which surface of each magnet represents the same pole, and mark an "X" on that surface before placing the magnets on the tape. (See graphic.)

3. Once the tracks are in place, students need to make a "train" that will float on the rails. They discover that weight and shape is important. Students need to experiment with several variables before arriving at the best design.

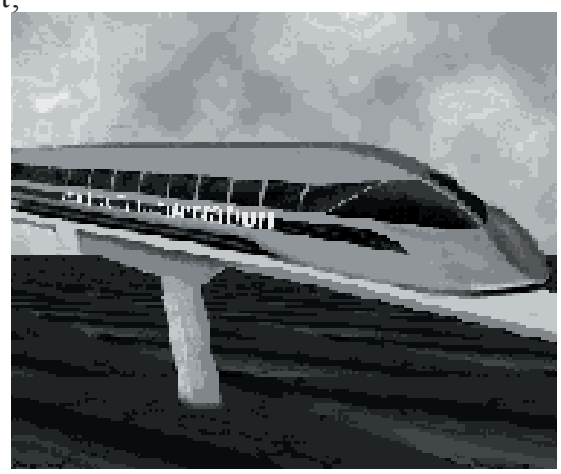
4. Encourage students to decorate their models and personalize them. They could develop a team name and logo.

5. Students will demonstrate their model for you and for other groups.



BACKGROUND INFORMATION

Fossil fuels are dwindling. They are also a source of pollution that is threatening our atmosphere. A magnetic levitation system consists of safe, quiet, nonpolluting vehicles. Worldwide there are two types of magnetic levitation trains: those that use superconducting magnets and those that use permanent magnets. Both systems can travel at very high speeds; both systems are nonpolluting. The German system relies on attraction; the Japanese system on repulsion. In both systems propulsion is similar in that the train rides on an electromagnetic wave. The German Transrapid has no wheels; electromagnets on board are attracted to a magnetic surface on top of the track. This lifts the train about 3/8 inch off the ground. The Japanese train rests on a set of wheels. When it reaches 100 mph it levitates 4 inches above the rails. Both systems rely on a lateral guidance system to keep the train in the middle of the track.



Using technology similar to that used to develop Maglev trains, scientists around the world are attempting to use this technology for other purposes. In Japan, for instance, engineers are working on a motor to propel elevators to greater heights in skyscrapers. The vertical linear motor will use the concept that magnetic forces act at a distance but will be limited, of course, as to the speed and acceleration that can be used since the elevators will contain human beings. Electromagnets have traditionally been the basis for motor design. However, permanent magnets are becoming more desirable due to the fact that they can be made smaller, stronger, and are advantageous environmentally. They need no electric current, thus no fossil fuels are used to create the electricity.

Another use, however, for this same technology is to build electromagnetic launchers to propel vehicles beyond Earth's gravity into space. These vehicles could carry, for example, parts and supplies for a space station or a

moon colony. Currently, most research that is being done in Japan and the United States is producing rail guns (also called rail launchers and coil guns).

Rather than propelling space vehicles, some electromagnetic launchers are being manufactured as modern weaponry. One such tested rail launcher is 2.23 meters long with a bore of 17.5mm x 39mm. The translation of technology from one use to another is common in science.

Other sources of information are: Richard P. Brennan (1990). Levitating Trains and Kamikaze Genes. New York: John Wiley & Sons; The Florida Department of Transportation, High Speed Program Office, Tallahassee, Florida; or, search on the worldwide web (www.hsgt.org).

EXCURSIONS

Either read or have students read a Jules Verne science fiction story. Using science fiction as a reference for science fact is a technique that is appealing to many students. When they realize that Jules Verne wrote about things in his novels that were decades away from being discovered, students gain a respect for fiction as a vehicle for understanding fact (some of the things that he imagined were submarines, space travel, television, mass transit, computers). By placing each of these novels in its historic context, students will be amazed at the foresight shown in each. In Paris in the Twentieth Century (1996, Random House, ISBN 0-679-44434-3), Verne talks about mass transportation (an issue in this activity and the one that follows).

SC.D.2.3.1-2, 3.3.5-7

LA.A.1.3.1-4, 2.3.1-8, LA.C.1.3.1-4, 2.3.1-2, LA.E.1.3.1-5, 2.3.5-8

Have students read "The Shot From the Moon" by Arthur C. Clarke (found in Science Fiction Stories chosen by Edward Blishen, Kingfisher Books, ISBN 1-85697-889-3). This science fiction story contains mention of a magnetic launcher in use on the moon. (In the 1970s, Arthur C. Clarke came up with this idea that was then heavily promoted for a short period of time.) Transporting people and goods to and from the moon if a moon colony were established is a problem that theoretically could be alleviated by using a magnetic launcher. Ask students to draw their idea of what a magnetic launcher would look like and answer the following questions: Why would a magnetic launcher be appropriate for use on the moon? [The moon's gravity is one-sixth that of Earth; it is fuel efficient; the moon has no atmosphere.] Drawings should portray the concept of opposites attracting and like poles repelling like poles.

SC.C.2.3.1-7, SC.D.2.3.1-2, SC.E.1.3.1, SC.G.2.3.3-4, SC.H.3.3.4-7

LA.A.1.3.1-4, 2.3.1-8, LA.B.1.3.1-3, LA.E.1.3.1-5

The use of fossil fuels is an issue that is discussed frequently on television news programs, newspapers, and magazines. By middle school, students should be able to identify the fossil fuels and the reasons why we should be conserving them. Have students research the use of fossil fuels using print media, videotapes,

or worldwide web sites. This information will be used in Expedition 16. Each group should identify this as an area of worldwide concern.

SC.D.2.3.1-2, SC.F.2.3.4, SC.G.2.3.1-4, SC.H.1.3.1, 3.3.4-7

LA.A.1.3.1-4,2.3.1-8,LA.B.1.3.1-3, LA.D.2.3.3-7

One of the reasons that the United States has cut back on fossil fuel use is that they pollute the atmosphere. This could be tied into increasing levels of carbon dioxide in the atmosphere. Have students research the issue and present their findings at a poster session. Students may want to invite others to participate to share their information as scientists do in actual laboratory situations.

SC.D.2.3.1-2, SC.F.2.3.4, SC.G.2.3.1-4, SC.H.1.3.1, 3.3.4-7

LA.A.1.3.1-4, 2.3.1-8, LA.B.1.3.1-3, 2.3.1-4, LA.D.2.3.3-7

FOR YOUR PLANBOOK: Build A MagLev Train Model

Suggested time: 1-3 hours

Gear: small square magnets (20-30 per group), foam board or cardboard, masking tape, grease pencil

National Science Content Standards: A, B, E, F, G

Sunshine State Standards Benchmarks: SC.B.2.3.2, SC.C.1.3.1, SC.C.2.3.1, SC.C.2.3.2, SC.C.2.3.3, SC.C.2.3.6, SC.D.2.3.1, SC.D.2.3.2, SC.G.2.3.3, SC.G.2.3.4, SC.H.1.3.1, SC.H.1.3.2, SC.H.1.3.3, SC.H.1.3.4, SC.H.1.3.5, SC.H.1.3.7, SC.H.3.3.4, SC.H.3.3.6

Sunshine State Standards Benchmarks -- Language Arts: LA.A.1.3.1-4, 2.3.1-8, LA.B.1.3.1-3, 2.3.1-4, LA.C.1.3.1, 3-4

Sunshine State Standards Benchmarks -- Social Studies: SS.A.1.3.1-3, 2.3.1-8, 4.3.1, 6.3.2, 6.3.3-5, SS.B.1.3.1-7, SS.C.1.3.2,5-6, 2.3.1-7, SS.D.2.3.1-3

Homework: This works best if assigned before completing the activity. Allow students several days to complete the assignment. Have students interview a grandparent, great-grandparent, or other adult over 50 (the older the better). The interviewer will ask two questions about changes in transportation: (1) What kinds of transportation did you use when you were middle school age? and (2) How has transportation changed since that time? Instruct students to note the name, date, and place of the interview as well as the age of the interviewee. Answers should be recorded in the Alpha Log.

Homework Assessment: Encourage students to consider all types of transportation when conducting their interviews, for example, not just cars or planes, but scooters, roller skates, skis, walking as a mode of transportation, horseback riding, or tractor. Interviewing is another way of gathering data. If students come to class with answers to the two questions as well as the name, date, and place of the interview, they have successfully completed the assignment.

Assessment: Use data gathered from interview questions assigned for homework to conduct a class discussion. From this discussion, students generate a list of modes of transportation and then add to it how each has

changed over a time. Students develop an understanding of the historical place of science in society. This would be a good place to distinguish between innovation and invention.

Have students create a Venn diagram (three concentric circles) based on the information from interviews and follow-up discussions. One circle could represent transportation in the past; another, transportation in the future; and the third, transportation at present. The intersection of the three would be a place to list those modes of transportation are common to all three.

Instead of the Venn diagram (above), have students create a concept map based on the same information. It serves the same purpose: students view science as a human endeavor with lasting influence upon society. A concept map is a way for students to present, in visual form, their conception of certain information. To create a concept map, students first clarify how new knowledge is related to other ideas that they have encountered. Concept maps present interrelated knowledge rather than isolated facts.

Models created should indicate that students understand enough of the technology to know that the MagLev trains are created by magnets that repel and attract, that all magnets must be placed in a certain configuration in order for these forces to work, and that the nature of science is such that trial and error create opportunities for new development.

Check Alpha Logs for record-keeping. Students realize quickly the need for accurate and detailed records. In this activity, particularly, it will be to the students' advantage to write down each time they have a problem and how they solve it. If Logs contain this type of information, students have been successful in their record keeping. Remind students that replication is important in science. Other scientists have to be able to reproduce what another scientist has done in order to validate the results.

BUILD A MAGLEV TRAIN MODEL

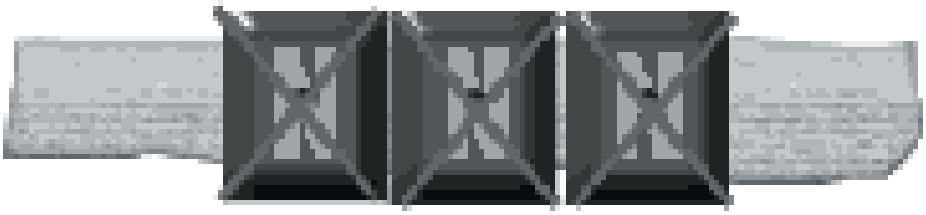
Itinerary

It is possible to build a simple levitating train using some of the principles that you have learned about magnets. Although a MagLev train is a very complex device, you should be able to build a mock-up of a simple train that levitates along a 1-foot (approximately) track using permanent magnets and common materials.

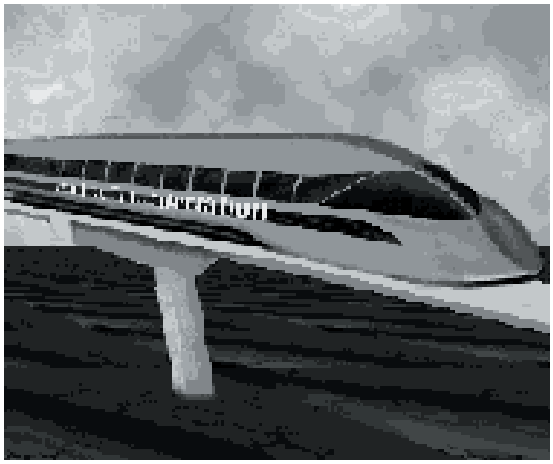
Fossil fuels are becoming less and less abundant. They are also a source of pollution that is threatening our atmosphere. A magnetic levitation system consists of safe, quiet, nonpolluting vehicles. Worldwide there are two types of magnetic levitation trains: those that use superconducting magnets and those that use conventional magnets. Both systems can travel at very high speeds; both systems are nonpolluting.

The German system relies on attraction; the Japanese system on repulsion. In both systems propulsion is similar in that the train rides on an electromagnetic wave. The German Transrapid has no wheels; electromagnets on board are attracted to a magnetic surface on top of the track. This lifts the train about 3/8 inch off the ground. The Japanese system rests on a set of wheels. When it reaches 100 mph it levitates 4 inches above the rails. Both systems rely on a lateral guidance system to keep the train in the middle of the track.

1. The Materials Manager should collect all necessary materials: foamboard, poster board, or cardboard, a marker, 20-30 square magnets, and masking tape. Be creative. If there is other material that you believe you need, ask your teacher .
2. Construct a track for your MagLev train. This is a little more complicated than it seems at first, so be patient. Keep a record in your Alpha Log of any problems you may have .
3. If you get to a point in your design or construction stage where you cannot overcome difficulties that you are having, consult another group, or your teacher.



4. Once your track is in place, make a "train" that will float above the rails. Weight and shape are important; try several different designs before deciding on the final one.
5. In your Alpha Log, draw a plan of the train, listing materials and directions. Remember, other scientists will need to replicate (repeat exactly) your work.
6. Decorate your model. Design a logo based on a team name or nickname.
7. Demonstrate your model for the other groups.
8. In your Log, list some ways that you could improve your design.



MAGLEV MODEL TRAIN COMPETITION

PLANNING YOUR EXPEDITION

Students use models created for Expedition #15 "Build a MagLev Train." You will need to refer to the group descriptions on the Student Group Worksheets.

Students will be divided into role playing groups to decide whether or not MagLev transportation should be adopted in Florida. They will also be deciding which of four MagLev designs to implement should the decision be reached to have this type of system in Florida. In this activity, students will answer the question, "Should Florida, whose population will grow to over 15.5 million by the year 2000, develop and build the Florida High Speed Transportation System?" by modeling the decision-making process that goes into high-stakes financial commitment to new technology.

Each group will have a predetermined role to play so this activity has five different Itineraries instead of one. Divide the class into 9 groups as follows: a design group**,** builders (4 groups), the public, a consortium to market the transportation system, state legislators, and the Department of Transportation. Here is where you may wish to take a look at the talents of individual students to preselect the groups. It is a good opportunity for students to work with other groups. You can study each group description and determine who best suits each category.

[If you have not yet completed the activity on superconductors, you may wish to refer to it at this point or you may wish to refer students to the CD-ROM for vocabulary help.]

There will be one Itinerary for each role. It will describe the role that students are to play, some tasks that the group will be performing, and reasons why certain steps must be done before other groups can get their work done. Be sure to set a deadline for the public presentation of the MagLev models and the town meeting.

1. Remind students that they will need the models created for "Build a Model MagLev Train."
2. Hand out the Itineraries for the Design Group, Builders (4), The Public, Consortium to Market the Transportation System, State Legislators, and The Department of Transportation. Give each group a chance to look them over and then discuss the worksheets with each group before they begin the activity.
3. Either set up a schedule to meet with each group or walk around visiting with each group on a regular basis for the duration of the Expedition.
4. Once you are comfortable that groups know what to do, you serve in an advisory capacity.
5. Once the public meeting is organized by "The Public", you will need to make a poster or put on the board the two questions that will be answered in the meeting: Which model should we recommend for Florida? Should we support a MagLev system of transportation in Florida?

BACKGROUND

Fossil fuels are dwindling. They are also a source of pollution that is threatening our atmosphere. A magnetic levitation system consists of safe, quiet, nonpolluting vehicles. Worldwide there are two types of magnetic levitation trains: those that use superconducting magnets and those that use conventional magnets. Both systems can travel at very high speeds; both systems are nonpolluting. The German system relies on attraction; the Japanese system on repulsion. In both systems propulsion is similar in that the train rides on an electromagnetic wave. The German Transrapid has no wheels; electromagnets on board are attracted to a magnetic surface on top of the track. This lifts the train about 3/8 inch off the ground. The Japanese system rests on a set of wheels. When it reaches 100 mph it levitates 4 inches above the rails. Both systems rely on a lateral guidance system to keep the train in the middle of the track.

The Florida Maglev Consortium, Inc. (FMLC) is a public-private partnership of private high-tech companies, local governments, and the Florida Department of Transportation that proposed building a high speed transportation system based on magnetic levitation technology. The high speed vehicles were to run from Miami to Orlando to St. Petersburg. FMLC made the following claims: environmental impacts are minor; the system will attract business; and the system will provide safe, fast, and affordable mass transportation.

The Florida proposal uses the superconducting magnet system. The vehicle itself becomes a superconducting magnet that rides in a magnetic field on a "guideway." The magnetic field shifts (controlled from a substation) and the wheelless train is propelled at great speeds along the guideway. The Florida Maglev system was intended to be inexpensive, fast, and frequent; one feature was to link the high speed train system with airlines, buses, local railway lines, and cruise ships to become part of an overall statewide transportation system.

EXCURSIONS

Have students read "Buy Jupiter" by Isaac Asimov (found in Fantastic Reading: Stories and Activities Grades 5-8, Scott, Foresman, & Co., 1984, ISBN 0-673-15936-1) or you can read it aloud to them. Negotiating is an important skill in deciding what scientific innovations or inventions to market to the public. In the story, the Minister of Science is the one who is in charge of negotiations. Clearly, the government thought the negotiations involved a scientific discovery of some importance. Students will model the relationship between scientific invention and the real-life skills necessary to bring that invention to the public.

LA.A.1.3.1-4, 2.3.1-8, LA.B.1.3.1-3, LA.E.1.3.1-5

FOR YOUR PLANBOOK: MagLev Model Train Competition

Suggested time: 2-3 hours

Gear: MagLev train models (from "Build a Simple MagLev Train Model"), materials to make new train models (see "Build a Simple MagLev Train Model")

National Science Content Standards: A, E, F, G

Sunshine State Standards Benchmarks: SC.B.2.3.2, SC.C.2.3.1, SC.C.2.3.2, SC.G.2.3.4, SC.H.1.3.1, SC.H.1.3.3, SC.H.1.3.4, SC.H.3.3.4, SC.H.3.3.5, SC.H.3.3.6, SC.H.3.3.7

Homework: Assign this task before beginning the activity. Each student will consider his or her role for this activity and write a paragraph or two identifying what they think their job will be, what kinds of tasks they will have to do, and who they will be dealing with. For example, if the student is assigned the role of member of the design group, they will probably imagine that their group must prepare a materials list, approximate costs of materials, make a plan from which the builders group will work, etc.

Homework Assessment: Not only will students be better prepared to work with their groups on this activity, but they will organize their ideas about how people in these positions really work. Encourage students to seek out friends, relatives, or neighbors who might be in these positions. They could call the Department of Transportation, for instance, or a design office that creates plans for others to follow. Students will be translating their classwork to real world experiences. Any description that closely approximates the job is acceptable.

Assessment: One way to assess whether or not your students have successfully completed this activity is to devise a checklist. For example, with each group, list characteristics of a successful group experience: all members participated, group defined their task, wrote letters of support, interacted with other groups, defended their position, and participated in public debate, and so forth. If all criteria are met, then the group earns an A; if 5 out of 6 are complete, then they have earned an A-, etc. In this way, students are aware of grading criteria ahead of time and have a shared vision of how to be successful.

Students research, using the worldwide web, specifications of present magnetic levitation train systems. Then have them compare and contrast the systems.

MODEL TRAIN COMPETITION

Itinerary: State Legislators

Each legislator represents a different district, so depending upon whether you represent a district that is impacted by the new transportation system or not, you must take a stand: Will you support the effort to develop and build a MagLev transportation system in the State of Florida?

1. Determine which of you will be representing a district that will be impacted by the train system and which of you is representing a district that is NOT affected by the train system (you will have to get with the Department of Transportation).
2. Anticipate questions that your constituents will ask you. For example, is the system environmentally safe? Will it bring jobs to our area? What kinds of jobs? Will tourists like this system? Will we get more tourist dollars? What will we get out of this? Is there an alternative to the MagLev technology that other groups have not considered?
3. Decide whether your group will support the effort for a MagLev train system or not. Be prepared to defend your position at the public meeting.
4. Meet with the other groups to gather as much information as you can and then write an editorial for the local newspaper on your position. You could call a local legislator and ask him or her about the kinds of research done to learn about issues and the kinds of questions that they ask.
5. Be prepared to argue pro (support) or con (nonsupport) for the MagLev train system at the public meeting.

MODEL TRAIN COMPETITION

Itinerary: Department of Transportation

Your group has two main jobs: (1) to determine if MagLev technology is in the best interest of the State of Florida; and (2) to provide guidelines for the Builder Groups to follow.

1. Decide on proposed route(s) for the train and identify the political districts that will be affected by the train system.
2. Develop specifications that the train system must meet; that is, decide what features you think Florida's system needs. Do you need the train to carry large numbers of people long distances? Do you wish the train to be fast, moving people quickly from place to place? Are your concerns environmental? Where in the state do you believe this system would be best utilized? Are you imagining a small train or a large train?
3. Meet with the design group to explain to them the conditions that must be met before the State will approve a design.
4. Write a letter to the members of the State legislators group telling them what kind of system you are supporting and why.
5. If you decide to make changes in the design of the system or in the model itself, let the Design Group know so they can inform the Builders Group.

MODEL TRAIN COMPETITION

Itinerary: The Public

You will be planning and hosting a public meeting of all concerned groups: the design group, the four builders groups, the group marketing the system, State legislators, and the Department of Transportation. This involves data gathering so that you will know the questions to ask and information to look for.

1. Begin gathering information that will enable you to be effective decision-makers. Look up MagLev train technology; call the Department of Transportation in Tallahassee; or find magazine articles written about Europe's rapid transit system.
2. Visit the Design Group and the Department of Transportation in the classroom to study what they are doing. Take notes so that you are able to back up your opinions at the public meeting.
3. Plan a day and time for the meeting, checking with all groups to make sure that they will be ready. Then design an advertisement for the local newspaper announcing the meeting.
4. Organize the agenda for the meeting and distribute a copy to each group.
5. Develop a list of questions and/or topics for discussion at the public meeting that you will be hosting.
6. Decide who will moderate (ask the questions and make sure everyone has a chance to speak). If all four people are going to participate, divide up the responsibilities.

MODEL TRAIN COMPETITION

Itinerary: Builders

Your job is to build one of the the MagLev train models based upon the plan given to you by the Design Group. There may be specific guidelines developed by the Department of Transportation group that you may need to follow. There is a certain date that this model must be ready to be presented at a public meeting.

1. Before you are given the design plan, you must discuss among yourselves the best materials to gather in anticipation of the actual work.
2. Get information on MagLev technology by using web sites, phone calls, or print media. You can also interact with the Design group to gather the most data about how your train would be used.
3. After receiving both the design plan and specifications from the Design Group, construct the model. If you need help with this, consult the Design Group. If you are unsure of why specifications are written in a certain way, consult the Department of Transportation.
4. Have your model ready for the public meeting.

MODEL TRAIN COMPETITION

Itinerary: Design Group

Your job is to choose four MagLev train model designs that will be built and presented to the general public, a marketing group, state legislators, and representatives of the Department of Transportation. This group, including you and the model builders, will be involved in the final discussion as to whether this technology should be used in Florida.

1. Gather all of the designs done for Expedition #15 "Build a MagLev Train Model".
2. Before choosing the designs to support, meet with the Department of Transportation to get specifications of what features they think are necessary for the State of Florida to approve the plan.
3. Choose the four designs that you think are best suited for public presentation to diverse groups. You may suggest changes or modifications to the existing designs. Each Builder Group will be responsible for building one of the models.
4. Write a letter of support to each Builder Group stating why you support that design.
5. Give each of the four groups one of the design plans that you have approved, accompanied by the letter of support.
6. One person needs to work with each of the four builder groups to oversee the work being done.

MODEL TRAIN COMPETITION

Itinerary: Marketing Group

In anticipation of approval by the State of Florida, your group is designing a marketing campaign to make the public aware of this technology and informing their decisions.

1. First, discuss ways to anticipate what people will want to know about MagLev train technology.
2. From all the information that you gather from other groups, choose the information that you believe is the most important to transfer to the public (this also includes State legislators who represent the public).
3. Design a logo for the new Florida system of transportation and go to each of the four builders groups to see if they will put your logo on their design. If they want to know what is in it for them, you must have an answer ready. If you wish to try four logos (one for each model that will be presented) do so.
4. Come up with a plan (film, video, radio or tv spots, print advertising, etc.) to market the new trains. How will you educate the public? How will you publicize the new technology? What are the good things about it that you can write about? What are the bad things about it that you can anticipate and explain?
5. Create an example of at least one of your planned marketing techniques to present at the public meeting.

UNDERSTANDING A COMPASS

PLANNING YOUR EXPEDITION

Check that your compasses have been stored properly. Magnets close to the compasses will affect their accuracy. Also, be aware of metal objects near, in, or under the desks or work tables that could affect students' results.

Most students are aware that compasses are used to determine direction in some way. They may have experience through scouts or camping. However, where do compasses come from and how are they used? Do they really point north? How do magnets affect a compass? These are some of the questions that students will ask and answer by completing this activity. This Expedition is used in conjunction with others, and compasses will be used in a practical application in Expedition # 19 "Making a Map Using a Compass."

The invention of the compass in its present form transformed travel and exploration. Many times students believe that an invention has to be "big" to be important. It is possible that they miss the tremendous effect that "smaller" inventions have on the development of culture and society. Certainly the compass is one of these that is easily overlooked by middle school students. The intention is to introduce compasses as measurement instruments, to begin to articulate how magnetic fields affect a compass, and to discuss compasses in relation to the development of culture.

This activity can be used in a number of places according to your preference. You may wish to use this before Expedition #7, which focuses on the difference between magnetic north and geographic north.

1. Have students write in their Alpha Logs what they know about compasses. Pass out compasses to each student and allow them to observe and investigate their behavior, characteristics, and properties. By encouraging individual, unstructured observation, students begin to articulate their own ideas about compasses and take a look at preconceived ideas about what they think a compass is and what they think it does.
2. Allow students to begin their work investigating how the bar magnet affects the compass. They may, at this point, go beyond noticing that geographic north and magnetic north are different, to noticing the tilt of the compass needle. (You may wish to refer to the CD-ROM and the work of Robert Norman who first noticed this tilt.)
3. As students work they will write observations, draw conclusions, and state explanations about what they are experiencing in their Alpha Logs.
4. Groups share with one another or with the class as a whole, their findings. At this point, students could share their homework ideas. This activity may change their ideas about early explorers and adventurers. It is important that they articulate ideas before

BACKGROUND

For a detailed history of lodestones and the development of compasses, see Hidden Attraction: The Mystery and History of Magnetism by Gerrit L. Verschuur (Oxford University Press, 1993).

Early scientists and travelers noticed a particular quality of a rock found in Magnesia in northern Greece. This rock became known as a lodestone and was observed to attract iron and repel like stones. The observation of magnetic properties led to the further discovery hat the lodestone always pointed toward the mine in which it was found. However, on closer examination, it appeared all lodestones actually pointed in the same direction, not just to the area in which they were found. Using the North Star (Polaris) as a point of reference, it became clear that there was a definite north-south orientation to the lodestone.

Finding a way to measure and study this phenomenon resulted in early attempts at manufacturing compasses. Once sailors started using compasses, they realized that there was a distinction between magnetic north and geographic north. Manufacturing compass needles became important as did the directions that went with them enabling sailors to remagnetize the needles with a lodestone when necessary. So, sailors still carried with them the original compass, the lodestone, as well as the new technology.

EXCURSIONS

Either read to students or have them read "How We Were Tracked By A Tripod" by John Christopher, in Science Fiction Stories edited by Edward Blishen (see Appendix C). Students can create an explanation of how the Tripods are tracking the main characters. Are they using compasses? If not, could they have used compasses? How does the metal enable the Tripod to track the boys? By answering these questions (and any others either you or the students formulate), students are encouraged to find a relationship between the activity they did and a fictional adaptation of that information.

SC.C.2.3.1-3

LA.A.1.3.1-4, 2.3.1-8, LA.E.2.3.8

Lodestones were the basis not only for scientific advancement and the evolution of science but for myths and legends that sought to explain the magnetic phenomena. Early investigators had little science knowledge with which to explain their observations, so they resorted to using what they did know--the natural world. Early on, observers thought that lodestones all pointed toward Polaris because of a celestial connection. Have students create their own explanations with reference to natural phenomena to explain lodestones. This will prepare students for predicting outcomes and explaining results.

SC.C.2.3.1-3, SC.H.1.3.1-7, 3.3.5-7

SS.A.1.3.1-3, 3.3.1-3

Gulliver's Travels by Jonathan Swift contains a section about a magnetic island that can be rotated. The island is made of lodestone and the magnetic qualities of lodestone are used as the basis for explaining how the island was moved and why. Reading this aloud and basing class discussions upon Swift's explanations for natural phenomena serves as a vehicle for students to clarify their own ideas about magnetism (see Annotated Bibliography, Appendix C).

SC.C.2.3.1-3

LA.A.1.3.1-4, 2.3.1-8, LA.C.1.3.1-4, LA.E.2.3.8

Design a bulletin board that indicates the north-south orientation of the bulletin board and presents information on compasses, their history and characteristics, influences on modern technology (for instance, navigational devices). Translating what students have learned into language that makes it clear to others is a way for students to gain a deeper understanding of the subject matter.

SC.C.2.3.1-3

Serendipity is a word that is used in reference to scientific discovery and innovation. One cannot help but notice that some events appear to happen in a random fashion. Students might ask "what if?" type questions. "What if Christopher Columbus had not said three days but had said two?" "What if the crew asked a week before they did?" [See "Homework."] "What if Clyde Tombaugh was on vacation the week he was able to detect Pluto?" This type of questioning can get students started thinking about the way scientists ask and answer questions. Questioning is a way to model behavior that is done in real-world situations. A good source of serendipitous scientific discoveries is Odyssey magazine, Cobblestone Publishing, 7 School Street, Peterborough, NH 03458.

SC.H.1.3.1-7, 3.3.5-7

SS.A.1.3.1-3, 3.3.1-3

Notes:

FOR YOUR PLANBOOK: Understanding A Compass

Suggested time: 1 hour

Gear: bar magnet, compass, drawing paper

National Science Content Standards: A, B, E, F, G

Sunshine State Standards Benchmarks: SC.C.1.3.1, SC.C.2.3.1, SC.C.2.3.2, SC.C.2.3.3, SC.H.1.3.1, SC.H.1.3.2, SC.H.1.3.4, SC.H.1.3.5, SC.H.1.3.7, SC.H.3.3.5, SC.H.3.3.6

Sunshine State Standards Benchmarks -- Language Arts: LA.B.1.3.1-3, 2.3.1-4

Sunshine State Standards Benchmarks -- Social Studies: SS.A.1.3.1-3, 2.3.1-5, 3.3.3, SS.B.1.3.1

Homework: Allow students one week to complete this assignment. According to information found in Hidden Attraction (see Appendix C), Christopher Columbus carried on his voyage to the new world a lodestone with which to magnetize compass needles. The tale goes that as his crewmen grew more and more impatient he made a deal with them: They would sail west (according to his compass) for a specified time after which, if they did not see land, they would turn around and sail home. Have students speculate in writing where Christopher Columbus might have landed if he had the ability to determine geographic north rather than magnetic north. To accomplish this task, students will be required to research Christopher Columbus' voyages, where he first landed and subsequent landings. They will determine, by measuring the angle of declination (see "The Earth's Magnetosphere"), where Columbus might have landed or *if* he would have reached land at all.

Homework Assessment: Look for a synthesis of ideas from the students as to how far-reaching one incident in history can be. The papers that are turned in should ask questions such as, What if the sailors had made their demands a day (or week) earlier? What if the lodestone was not closely guarded? Research papers should include indication of the difference between magnetic and geographic north in a way that connects with historical events. The most important lesson to be learned from this assignment is the relationship between scientific discovery or invention and how we view things now.

Assessment: Check Alpha Logs for preconceived ideas about compasses. The Logs should demonstrate that students have moved beyond the basic idea of a compass pointing north to the fact that it is a measuring device. Beyond that, the Logs should indicate a realization that there are misconceptions about compasses (they always point north) that the students can now explain.

Students organize a panel to debate old versus new technological developments. The discussion should indicate a knowledge of the layering of scientific innovations; students recognize that each new technology that is advanced is done so after a period of refinement based on earlier discoveries. The compass is an excellent example of this. The debate format will assist some of the students who are still having trouble envisioning a compass as technology.

Have students write a fiction story that includes a homemade compass as the device that either helps someone in the story or is the focus of the story. For instance, soldiers in World War II had compasses in their buttons in case they were taken prisoner; or a magnetized needle could be included in a package to a prisoner who would then use it to make a compass to find his way home. In order to do this effectively, students will be asking critical questions and analyzing them. Look for clear answers to well-articulated questions.

Have students create compass art to be displayed around the room or around the school. Classes could compare the work developed and discuss in large or small groups the relationship of artwork to science and math (if students made the leap from the compass to geometric shapes). This assignment demonstrates the link between art and technology, science and art, and creativity in science.

UNDERSTANDING A COMPASS

Early scientists and travelers noticed a particular quality of a rock found in Magnesia in northern Greece. This rock became known as a lodestone and was observed to attract iron and repel like stones. The observation of magnetic properties led to the further discovery that the lodestone always pointed toward the mine in which it was found. However, on closer examination, it appeared all lodestones actually pointed in the same direction, not just to the area in which they were found. Using the North Star (Polaris) as a point of reference, it became clear that there was a definite north-south orientation to the lodestone.

Finding a way to measure and study this phenomenon resulted in early attempts at manufacturing compasses. Once sailors started using compasses, they realized that there was a distinction that needed to be made between magnetic north and geographic north.

Manufacturing compass needles became important, as did the directions that went with them enabling sailors to remagnetize the needles with a lodestone when necessary. So, sailors still carried with them the original compass and the lodestone, as well as the new technology.

1. Write in your Alpha Log everything that you know about compasses. Do not worry about whether you are "right" or "wrong."
2. The Materials Manager should collect your equipment: a compass for each group member, bar magnet, and drawing paper.
3. Now, make another list in your Log of characteristics and properties of a compass. If there is anything that makes you believe that you were incorrect in your first list, cross out those items.

4. Place the bar magnet on your desk with the north pole pointing away from you. Place the compass on the magnet so that the north-seeking end of the needle points to the north pole of the magnet. Observe what happens to the compass needle and draw a picture in your Alpha Log. Discuss the following questions with your group and answer them in your Log:

   1) Is the needle of the compass still pointing to the north pole?

   2) Is this what you expected to happen?

   3) Why do you think this happened?

   4) What do you think will happen if you move the compass around the magnet?

   5) Explain your answer.

5. Before you test the theory that you have just expressed, make a group decision as to how you want to record your further investigation. Do you want to write your findings in sentence form? Do you want to draw a diagram each time you move the magnet? Do you want to make a model? Can you think of any other way to display your information? You will be sharing your findings with other groups, so be creative!

6. Test the theory that you set forth in answer to the questions above. Move the compass around the magnet. Since each time you move the compass you introduce another variable, you might want to measure the distance you move the compass so that you are consistent. Record the results of each trial in the manner you and the group decided in Step 5.

7. Share your results with another group. In your Log write several paragraphs about what you shared, what you learned from the other group, and this activity in general.

BUILD A COMPASS

BEFORE YOU BEGIN

Be sure that the styrofoam pieces you use do not dissolve in water!

You will need to assemble a large number of items. Most of these are found around the home, but you will probably need a little time to accumulate enough for five classes to make compasses. You may wish to put a list of household items (for example, small plastic containers like the ones margarine comes in) on the chalkboard or ask students to copy them down in Alpha Logs and to supply them. Send a letter home indicating that these items are necessary disposables with which the children are going to work.

Students will be keeping their compasses for use in another activity.

Make sure that all magnets are put away. Compasses are affected by magnets!

PLANNING YOUR EXPEDITION

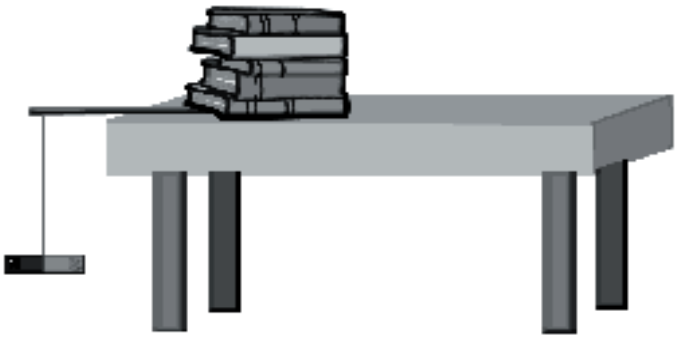
Recreating the work of early scientists and scholars will help students discover that the simplest solution is often the best. Today's compasses are made in much the same way that they were imagined in the 13th century. Some innovation has been made in their manufacture such as adding degrees to the cardinal points to help determine the difference between geographic north and magnetic north, replacing the lodestone with a magnetized needle, or putting the needle on a pivot. However, the basic technology is the same.

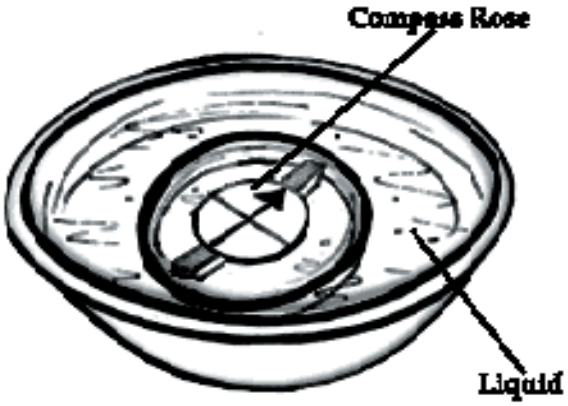
Because students must make a compass without specific directions or a model from which to copy, they will have to ask themselves certain questions before trying each design. Discussing with one another the possibilities for success or failure models what scientists do in the real world. Before scientists undertake a major design or implementation of a design, they anticipate points at which they might run into trouble.

You will be giving your students materials from which they will be asked to build a working compass. Encourage students to bring in other supplies if they need to and, if you are comfortable, devote another class period to refining original designs. Design sketches should be included in the Log since each group will give handwritten instructionsto another group to replicate (repeat exactly) the design. One important lesson taken from this activity is that it is very difficult to write clear instructions for another person (see Excursions).

If students would like to research the "first compass" or early compasses for ideas on how to proceed, encourage them to do so. However, what you want to avoid is your students building a compass from instructions provided for them. The experience of trial and error, putting together different materials, is important.

1. Inform students that they can use any and all of the materials at their disposal to create compasses.
2. Students first discuss in their group which of the group's plans (done for homework) they will adapt for use in this activity. This will require a good deal of discussion.
3. Each group will build their compass and test it to be sure it does what they expect it to do.
4. Each student should draw a labeled diagram in his or her Alpha Log with observations and comments.
5. The group writes a step-by-step instruction sheet for another group to use.
6. Groups exchange written instructions and proceed to build and test another compass.
7. In the Alpha Log students compare and contrast the two compasses.
8. Groups choose one compass to use in the next activity.





BACKGROUND INFORMATION

In the 13th century, Peter Peregrinus, a crusader in Italy, attempted to write down all he knew about lodestones. As he tried to explain the phenomenon that he observed, he devised a compass by shaping a piece of lodestone into a circle and floating it. Not for another 300 years did sailors try to use this idea and manufacture magnetic compasses. (See Hidden Attraction by Gerrit L. Vershuur for a detailed history.) Early explorers took with them compass needles and lodestones (to keep the needles magnetized). Compasses as we know them, encased and easy to carry around, still did not exist.

EXCURSIONS

For more advanced students: Have students react to the following quotation that is credited to contemporaries of Galileo. If your students keep journals, this would be an appropriate place to make such an entry. "Jupiter's moons are invisible to the naked eye, and therefore can have no influence on the earth, and therefore would be useless, and therefore do not exist." Student responses, at this point, might mention magnetic fields, but should include some synthesis of the idea that we are able to investigate that which we cannot see, that many great scientific theories are developed about things we cannot see. This connection will indicate that students have a grasp of what theory is as opposed to practice and that we can attempt to explain what we cannot see.

SC.H.1.3.1-7, 3.3.5-7

LA.B.1.3.1-3, 2.3.1-4

Instruct students to brainstorm (with another student or a parent) common phrases that include the words magnet, magnetism, or magnetic. For example, magnetic personality, animal magnetism. Students will then draw their interpretation of one of these phrases to share with the class. Drawings will reflect the meaning of the phrase as yet another way for students to demonstrate their fluency with the vocabulary of this unit.

If you are unsure whether or not your students understand how to write directions, you could start with something like: Pretend you are hosting a person from another planet who is unfamiliar with what hamburgers are. Write a description that would enable them, when they return to the home planet, to recreate the hamburger. Or, write out instructions for someone to do a chore like putting dishes in the dishwasher or setting

the dinner table. This exercise requires describing steps and refining instructions by restating those steps.

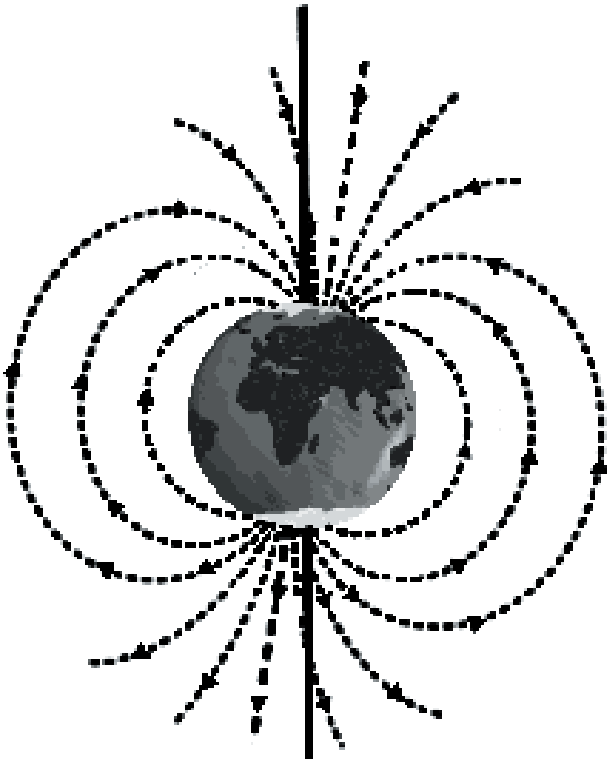
SC.H.3.3.5-7

LA.B.1.3.1-3, 2.3.1-4

On a recent episode of "Star Trek: Deep Space Nine," the chief engineer was asked to find a ship that had crashed. The planet it crashed on was surrounded by satellites that disrupted all instruments. A magnet would detect metal from the downed ship. He created a magnet, found the ship, and all was well. What if it was not a magnet that he needed but a compass? Would this storyline work? Rewrite the story to reflect this idea. Stories should indicate some knowledge that a compass (such as the ones the students made in this activity) would not work in space as a directional device, unless the ship were made of a magnet-attracting material, and the planet did not have a magnetic field. Student stories should explain this and demonstrate that compasses work as they do because of Earth's magnetic north and south pole.

SC.H.1.3.1-7, 2.3.1, 3.3.5-7

LA.B.1.3.1-3, 2.3.1-4



FOR YOUR PLANBOOK: Build A Compass

Suggested Time: 2 hours

Gear: paper clips, pins, needles, paper, masking tape, petri dishes (or other small containers), aluminum foil, pie plates, corks, pieces of wood, jars, cardboard, mineral oil (if possible), styrofoam, water, bottle caps, permanent marker, thread, a variety of magnets

National Science Content Standards: A, B, D, E, G

Sunshine State Standards Benchmarks: SC.C.1.3.1, SC.C.2.3.1, SC.C.2.3.2, SC.E.1.3.1, SC.E.1.3.2, SC.E.2.3.1, SC.H.1.3.1, SC.H.1.3.2, SC.H.1.3.3, SC.H.1.3.4, SC.H.1.3.5, SC.H.1.3.6, SC.H.1.3.7, SC.H.3.3.4, SC.H.3.3.5, SC.H.3.3.6

Sunshine State Standards Benchmarks -- Language Arts: LA.B.1.3.1-3, 2.3.1,4

Homework: This homework assignment must be done before the activity. Have each student create a plan for building a compass. Tell students that they must include only materials that will be available in the classroom, and the plan must include a labeled drawing, with step-by-step instructions.

Homework Assessment: The assignment should include a list of materials, a labeled diagram, and step-by-step instructions. If all are included, then the student has successfully completed the assignment. Whether the plan is actually one that will work will be determined during the Expedition and should not be part of the homework assessment.

Assessment: Students have built a compass that consistently indicates a north-south orientation. Look for clear, easy to understand step-by-step directions that were followed by another group of students to replicate the original model. Completion of these two steps demonstrates that students are able to state explanations for why the compass points north-south and can communicate their observations through a clearly written set of instructions.

Students successfully construct a second compass using another group's set of instructions. By doing so, students demonstrate the ability to apply what they have learned to a new set of ideas. Then they will list similarities and differences between the two compasses. Identifying the relationship between the two methods requires analysis of how compasses work. Students determine which compass is the "better" of the two and explain the choice, predicting which compass will work best in a practical application.

Have students find a way to communicate answers to the following questions: How did the group decide which model to make? How did they test their compass? What problems did they have replicating someone else's model? If there were no problems, why was the plan a successful one? What are the features of a good model drawing and set of instructions? By answering these questions (and any others that you believe are pertinent), students articulate beliefs about tools they needed to successfully complete an activity. Students identify alternate ways to be successful with a task (drawing, writing instructions, verbally communicating information).

Have students create a concept map or other visual tool to explain what a compass is, how it is made, and how it is used. Visual tools allow students to construct their own meaning because they design a personal way of organizing information. Be flexible about grading this product since it represents the student's ideas, not yours or anyone else's. It should contain the basic vocabulary that you think is necessary for understanding the idea of compasses as directional tools related to the Earth's magnetic field. For example, if the visual tool is one that you can interpret (or another student can interpret) without help, then it will receive the highest grade (A); if it has all the right words, but you need the student to show you how they relate to one another, then it would get a B; if the student has clustered words without any connections, then it receives a C; and, if the student has put only some of the words and no connections, it would receive a D; not completing the assignment would be the only way to fail.

BUILD A COMPASS

Itinerary

In the 13th century, Peter Peregrinus, a crusader in Italy, attempted to write down all he knew about lodestones. As he tried to explain the phenomenon that he observed, he devised a compass by shaping a piece of lodestone into a circle and floating it. Not for another 300 years did sailors try to use this idea and manufacture magnetic compasses. Early explorers took with them compass needles and lodestones (to keep the needles magnetized). Compasses as we know them, encased and easy to carry around, still did not exist.

This activity will allow you to construct your own compass based on what you know about magnetism. You will be using your homework design in this activity as a model from which to work. Remember to write down all observations and comments in your Alpha Log. This will help you reconstruct your design and construction process at the end of the activity.

1. Discuss the compass designs that you created for homework. Talk about the advantages and disadvantages of each, making a list of the most desirable features of each in your Alpha Log. Decide which plan your group will use.
2. The Materials Manager should now pick up all necessary supplies to create and test your compass.
3. Build your compass. When you have finished, use your knowledge of magnetism and geography to test it. Write the results in your Log and include a labeled diagram of your compass.
4. As a group, write up instructions for another group so that they can replicate your model. Keep in mind the characteristics of easy to follow instructions that you have had experience with. Assume that the group assembling this compass knows nothing!

5. When you have completed your **written** (not drawn) instructions, exchange them with another group and build and test the second compass.
6. In your Logs, compare and contrast the two compasses, listing advantages and disadvantages of each one.
7. Choose the compass that you will use for Expedition #19 " Make a Map Using a Compass".

MAKE A MAP USING A COMPASS

PLANNING YOUR EXPEDITION

Students will use the compass constructed in Expedition # 18 to complete this activity and should complete the homework assignment before attempting mapmaking.

This activity is designed for students to use the compass they built for a practical purpose. In this case, that purpose is to make up directions, follow directions to reach a predetermined point, and to make a map. Because you are giving students a reason for having constructed their compasses in the previous activity, it becomes more meaningful. Real-world orienting experience allows students to appreciate the compass as a navigational device.

Students learn to be precise in their measurements so that others can follow their directions and create a map from them since they will be evaluating one another's maps. Maps could take various forms, any of which should be acceptable, if the information is usable. Sharing and discussing maps made for homework lets you see what students consider usable maps and allows you to maintain control over the kinds of maps that are acceptable for this activity. Checking with the geography teacher provides added information of maps students are already familiar with.

There are several ways to complete this activity. Students develop their own directions for another group to follow or you supply the directions leading to a certain location or several locations. This depends upon how much time you wish to devote to this Expedition. If you decide to make up directions ahead of time, you will want to create several sets so that all of your students are not moving in the same direction at the same time. Let other teachers around the school know that your students will be outside doing this activity, in case they are testing or planning a quiet activity. You can require students to create their maps in groups or individually, or you could give them the choice. Two Itineraries are included here to accommodate either option.

If you are having students create their own directions to a place of their choice, proceed as follows:

1. Instruct students (in pairs or groups) to take their compasses and make up a set of directions leading to a predetermined place. For instance, "walk 3 feet west, 2 feet north, 5 feet northwest." Students can then add clues if they wish such as "walk 3 feet west, 2 feet north, you should see a sign. . . ."
2. Also instruct students to map their route as they are making up the directions so that they have both written instructions and a graphic representation.
3. Students exchange directions and try to follow the new ones, again mapping their route as they follow a new set of directions. When finished, each group will have two sets of directions and two maps.

4. When all students have finished, the groups that exchanged sets of directions should sit down together and compare maps, noting similarities and differences, and difficulties they might have had following each other's directions.
5. The Itinerary instructs students to make notes and answer questions in their Alpha Logs.

If you are giving students directions that you have made up leading to a certain destination, proceed as follows:

1. Instruct students (in pairs or groups) to take their compasses and follow your directions, mapping the route as they go.
2. When students complete the route, have them sit in groups and compare maps, discussing similarities and differences and difficulties they had in following the directions.
3. The Itinerary instructs students to make notes and answer questions in their Alpha Logs.

BACKGROUND INFORMATION

Compasses as navigational tools have been used since the 13th century. They are used for a variety of purposes by sailors, campers, cartographers, and explorers. Although early compasses took a different form than ones we use today, the technology is the same: a magnetized needle that points north/south because of the Earth's magnetic field.

EXCURSIONS

Read an excerpt from Treasure Island (Part VI -- Captain Silver, The Treasure Hunt -- Flint's Pointer) by Robert Louis Stevenson that describes the treasure map. As a class discuss the problems that are encountered when using a map of this kind. What types of changes could take place over time that would affect a treasure map? (Students will probably note that trees and plants grow, weathering or erosion might change physical features, etc.) Point out that each person's "pace" is different depending upon their height, how quickly or slowly they are walking, whether they are walking uphill or downhill, etc. Students will determine that maps of this sort are unreliable at best and unusable at worst.

SC.D.1.3.1,4, SC.G.2.3.4

LA.C.1.3.1-4, 2.3.1, 3.3.2, LA.E.1.3.1-5, 1.3.2-8

Early cartographers sometimes could not see what they were mapping. Have students imagine that they were asked to map a country for which they have limited information. It is across the sea, is many months' journey, has a beach that leads to mountains which then becomes plains interrupted by yet another mountain range. Eventually another sea is reached after crossing two rivers. You can make up any description you wish that could represent a real place. Ask students to create a map from your description and compare it to an actual map. Students explain how they made their maps and the difficulties they encountered.

They will evaluate their own work by determining how close they came to the actual map.

SC.H.3.3.5-7

SS.A.6.3.2, SS.B.1.3.1

Ask students to brainstorm kinds of maps. Offer a prize for the group that comes up with the most types of maps. This exercise helps students articulate different ways that maps are used, including concept maps.

SS.A.6.3.2, SS.B.1.3.1

If you are still reading aloud, either about the race to the North Pole or about Dilly McBean's magnetic hands, have students write about how information on compasses as navigational tools could help the characters avoid a potentially dangerous or risky situation.

SC.C.2.3.1

LA.C.1.3.1-4, 2.3.1, 3.3.2, LA.E.1.3.1-5, 1.3.2-8

Have students research early maps of Florida on the worldwide web, CD-ROM, or using print media. Because Lake Okeechobee is so large, early cartographers did not imagine that it could be a lake. Instead they thought it was the ocean. This belief affected maps of Florida and thus exploration and settlement. Reports will bring historical mapmaking information to a local level enabling students to better visualize some problems associated with the making of maps.

SC.H.1.3.1-7, 3.3.5-7

SS.A.6.3.2, SS.B.1.3.1

Notes:

FOR YOUR PLANBOOK: Make A Map Using a Compass

Suggested time: 1 hour

Gear: student-made compass, paper

National Content Standards: A, B, E

Sunshine State Standards Benchmarks: SC.C.2.3.1, SC.C.2.3.2, SC.H.1.3.1, SC.H.1.3.4, SC.H.1.3.7, SC.H.3.3.6

Sunshine State Standards Benchmarks -- Language Arts: LA.B.1.3.1-3, 2.3.1-4, LA.C.1.3.1-4. 3.3.3

Sunshine State Standards Benchmarks -- Social Studies: SS.A.6.3.2, SS.B.1.3.1

Homework: Have students make a map from their home to the school. Assure them that you do not intend for this to be a map to scale, but one they would give to someone as directions to their home. Encourage those students who are worried about this assignment to use graph paper if that makes them more comfortable and remind them to use landmarks. One of the comments frequently made after Hurricane Andrew devastated Homestead, Florida, was that when all buildings, homes, and trees were flattened, it was difficult (if not impossible) for people to figure out where their homes were. There were no landmarks!

Homework Assessment: Accept any reasonable map as successful completion of this assignment. Maps should include major landmarks, ordinal directions, and approximate distances. This exercise will start students thinking about maps and, if they share them as a group completing the Expedition, they might eliminate difficulties.

Assessment: As part of the activity, students create a set of directions that can be followed by another group. The successful completion of the pre-set route demonstrates that the directions were usable and that the first group made the transition from prior activities to practical usage of a compass.

Students successfully follow your directions to a predetermined location. Completion of this part of the activity demonstrates that students are able to apply the information from other activities in a practical manner.

Students create a map using the given set of directions. Doing so indicates that students can transfer one type of information into a graphic representation of that same information. The map can be to scale or not (your choice depending upon the level of students). This is a good opportunity to discuss map scales in general. Because they are working in groups, students will need to state explanations about maps, how to make maps, and the use of maps before they decide what type of map to make.

MAKE A MAP USING A COMPASS

Itinerary

Using the compass that you constructed in "Building a Compass," you will be making up a set of directions for another group to follow using their compass. At the same time, you will be mapping the route, so you must determine a destination before you begin. You are applying in a practical way what you learned from previous activities. You will use a compass to find a particular location.

Part I

1. With your group or partner choose a place somewhere on school grounds. Once you have decided on a place, start at the classroom door and describe that route using points on a compass. For instance, "Begin at the classroom door and proceed 15 feet west. Then go 5 feet north." You can put in hints if you think your route is particularly difficult, such as "Begin at the classroom door and proceed 15 feet west. You should see the office door." Try to make this a challenge.
2. Write the directions on a separatre sheet of paper and also make a map of your route in your Alpha Log. Then return to the classroom.
3. In your Alpha Log, write your observations of any difficulties you had either with the directions or with the map.

Part II

4. Exchange your written directions (not your map!) with another group.
5. Try to follow the new set of directions mapping the route as you go much as you did in the first part of the this activity. Take into consideration problems you had in making your map and use them to help you. When you are finished, return to the classroom.
6. Sit down as a group and discuss your map fixing anything that you believe is incorrect or unclear. In your Log, write down any observations that you made about your trip.

Part III

7. When the group with whom you exchanged directions returns, compare maps and answer the following questions in your Log. How do the maps compare with the original maps made by the group creating the directions? Compare and contrast the maps. What suggestions do you have for people giving directions? What would you do differently if you were to repeat this experience?
8. Make a list in your Log of occasions you might have to give directions to another person. Have you changed your idea of how to do this? What are some important elements of giving directions that you had not thought of before this activity?

MAKE A MAP USING A COMPASS

Itinerary

Using the compass you made for "Build a Compass," you will be following a set of directions that leads you to a certain place. You use your compass as a navigational device as you would for camping. As you find your way, you will also be mapping the route. When you reach your destination, return to the classroom.

1. Take your compass and follow the directions, making a map of your route as you go.

2. When you return to the classroom sit down with another group, discuss the directions, and compare and contrast your maps.

3. Answer the following questions in your Alpha Log: How do the maps compare? Are they the same or different? What suggestions would you give to people writing directions? What would you do differently if you were to repeat this experience?

4. Make a list in your Log of occasions you might have to give directions to another person. Have you changed your view of how you would do this? What are some important elements of giving directions that you had not thought of before this activity?

BUILD A TRASH SEPARATOR

PLANNING THE EXPEDITION

You will need to get foam board, posterboard, or cardboard for this expedition. One large corrugated cardboard box cut with a mat knife into 12" square pieces will be enough for several classes.

Assign the homework (if you decide to use it) in advance of doing the activity. Allowing the students to think about design issues before they begin building their models will facilitate the activity.

This is a good opportunity to call in a guest speaker. There are several possibilities: a county recycling official, a state recycling official, a landfill administrator, or a representative from a private waste disposal company.

In advance of completing this expedition, you will either be collecting dry trash yourself or assigning students to this task. Since students are going to be designing and building a model trash separator, you will need to get dry trash for them and have it accessible. One method of facilitating this is to distribute small trash bags to other teachers and asking them to have students place **dry** trash items in it, seal it up, and return it to you at the end of the day. If you have five classes and six groups per class, you will need help in accumulating enough trash. Be sure to include soda cans, however. If your school recycles, this will be an easy matter; otherwise, ask students to bring clean, dry cans from home.

Students will build a model trash separator. Before beginning this expedition you may wish to show your classes a short video on a trash separator already in use that uses magnetism to separate certain types of recyclables. After viewing the video, discuss it as a class, and identify the ways that magnets were used. Then, allow groups to brainstorm ways to adapt their design plans. Students will be modeling decision-making and prototype-building. Previous experiences with building a model from a design will help students make decisions regarding what will and will not be feasible with the supplies available to them.

1. Using either the design plans that students completed for homework or design plans that they create in groups in class, students will be attempting to construct a model of a trash separator. Allow students to consult other groups as they modify their designs.

2. Students record answers to questions in their Alpha Logs as well as draw a design

BACKGROUND INFORMATION

Landfills are currently an issue of great concern to many people. Land is scarce for such use and there is much publicity about building landfills and whether this is the best method for trash disposal. Scientists who study landfills (garbologists) claim that relatively little garbage is actually decomposing. In fact, some organic material that one would expect to be disintegrated exists for decades. An example is a package of hot dogs that dated back 20 years found in a landfill.

Recycling and reusing trash is a subject so much in the news that there are very few students who have not heard of the terms or who do not have an opinion. You will want to define the difference between recycling and reusing and discuss the merits of each one. Students will have many examples of wastefulness. If they shop with their parents, they should be reminded of how much cardboard is thrown out when the groceries are being put away, for example.

Discuss with students the advantages of trash recycling, the progress that has been made in your area, and ways that students can contribute to the overall effort. Depending upon the level of sophistication of your students, you could compare the United States with other countries. For instance, Japan recycles over 50% of its garbage. Students could research the percentage for other countries.

EXCURSIONS

Students call or visit a local landfill to see firsthand how trash is disposed. Comparing this method of disposal to recycling, students report on which is more desirable and why. Have students brainstorm ways to increase recycling in their community and design a plan for publicizing their ideas. Some students may wish to send their ideas directly to the county landfill administrators or to the local recycling companies.

SC.B.2.3.2, SC.D.1.3.1-4, 2.3.1-4, 3.3.4

LA.A.1.3.1, LA.C.1.3.4, 3.3.2

In an old aquarium or plexiglas box, have students create a mini-landfill. Students place representative items in the landfill, cover them with soil, occasionally adding to the landfill and putting new layers of dirt on it. On graph paper, students will identify what they placed and where so that in a predetermined amount of time, students can check to see how their garbage did. Did it decompose? If so, why? If the items did not decompose, have students make an educated guess why not. Students should keep track of their graph paper evidence in Alpha Logs and periodically check the landfill and record their observations. Then, students can consult either print resources or call a recycling company to check their predictions. This activity is adapted from the 4Rs Project materials (Florida Department of Education, 1990).

SC.B.2.3.2, SC.D.1.3.1-4, 2.3.1-2, SC.G.1.3.4, 2.3.3-4, SC.H.1.3.1-7, 3.3.4

"The Shot From The Moon," by Arthur C. Clarke, in Science Fiction Stories edited by Edward Blishen (ISBN 1-85697-889-3)

is a short story that includes a magnetic launcher from a moon colony. Have students draw an illustration to go along with the story that you have either read aloud or they have read themselves.

SC.E.1.3.1-4

LA.A.1.3.1-4

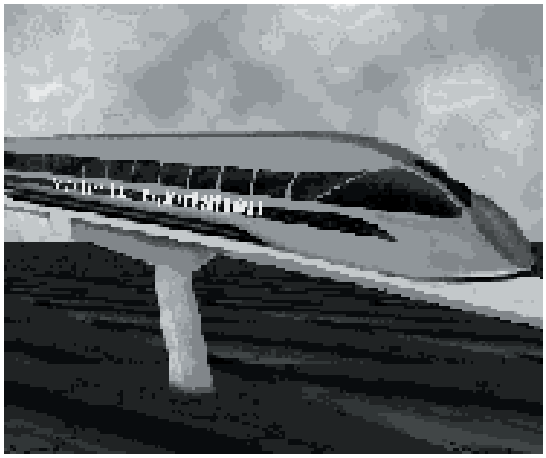
Have students investigate Arthur C. Clarke's scientific discoveries as well as his contribution to the body of science fiction literature by producing a biographical sketch. Clarke's science fiction novels and short stories have been made into highly successful films, not the least of which is "2001". He has also been involved in a number of environmental issues. The varied experiences that all contribute to his success will point out to students that science is done by different types of people from very different backgrounds. The biographical report could be presented in poster and photograph form, a written report, or a computer presentation.

SC.H.1.3.1-7, 3.3.4-7

LA.A.1.3.1-4, 2.3.1-8, LA.B.1.3.1-3, 2.3.1-4

Have students research the use of permanent magnets in industry by conducting phone or letter interviews with American Maglev Technology Inc. (AMT), Edgewater, Florida. Obtaining information on research being done that relates directly to classroom activities will help students understand the background information and theory necessary to facilitate technological design. Practical application of concepts addressed in the classroom justifies why the activity is being done.

SC.B.2.3.2, SC.C.2.3.1-5, SC.G.2.3.1, SC.H.3.3.4



Notes:

FOR YOUR PLANBOOK: Build A Trash Separator

Suggested time: 1-3 hrs.

Gear: variety of magnets, cardboard, posterboard, scissors, glue, markers

National Content Standards: A, B, E, F, G

Sunshine State Standards Benchmarks: SC.B.2.3.2, SC.C.1.3.1, SC.C.2.3.1, SC.C.2.3.2, SC.C.2.3.3, SC.C.2.3.4, SC.C.2.3.5, SC.C.2.3.6, SC.C.2.3.7, SC.D.2.3.1, SC.D.2.3.2, SC.G.2.3.1, SC.G.2.3.3, SC.G.2.3.4, SC.H.1.3.1, SC.H.1.3.2, SC.H.1.3.3, SC.H.1.3.4, SC.H.1.3.5, SC.H.1.3.6, SC.H.1.3.7, SC.H.3.3.1, SC.H.3.3.4, SC.H.3.3.5, SC.H.3.3.6, SC.H.3.3.7

Sunshine State Standards Benchmarks -- Language Arts: LA.A.2.3.1-8, LA.B.2.3.1-4, LA.C.1.3.1, 1.3.4, 3.3.2

Homework: You will need to present some information on trash separators before assigning this homework. Explain to students that they will be making a model of a trash separator. Before they can do this, they need a plan. Have students design a plan for a trash separator that includes how they will accomplish their goal of removing certain objects from dry trash. Diagrams should include a materials list. The plan should be on paper only (no models, yet).

Homework Assessment: Students will think through the entire process of designing a model: defining a goal, determining how they can accomplish that goal, and deciding on the materials necessary. Appreciating the complexity of technological design moves students into a sophisticated level of classroom science. Any design possibilities are acceptable. For example, the following rubric can be used: if the student has a design with materials listed and a diagram of how it will look, it has fulfilled all requirements and receives an "A"; if there is a plan and a materials list

but no diagram, it earns a "B"; a materials list and diagram but no plan, a "C", a plan with no diagram or materials list, a "D."

Assessment: Have students demonstrate for you the trash separator. If it works, students have successfully completed this task. The separator should follow a plan or diagram that was predetermined by the group. Modifications to the design should be indicated on the original design plan or will be written below it. The fact that students are using a predesigned plan to complete their work models the way that technological design is done in the real world.

Alpha Logs will reflect a number of things. First, all revised design diagrams and materials lists should be included in the Log. Logs will also reflect that students are manipulating one variable at a time, holding certain conditions constant as they try to refine their designs. This provides you with evidence that your students are able to provide explanations for cause and effect and identify criteria by which they will judge their models.

After researching public and private recycling companies in your area, have students contact these sources directly for information on using magnets and other technologies to separate trash. Students can conduct personal or phone interviews, request that information be sent by mail, or conduct on-site visits to observe the technology in operation. After writing up findings, those students that chose to complete this assessment task will report to the rest of the class. Verbalizing and/or writing down the information that they obtain will provide a reusable resource for future classes. Look for clarity of information and thought, depth of research, and a method of presentation (poster, written report, overheads, or photographs) that could be shared with other classes.

BUILD A TRASH SEPARATOR

Itinerary

You will be constructing a model of a trash separator based upon the design plan that you completed for homework. In this activity you perform many of the same tasks that real-world research and development professionals do as they take a product from the design stages to a working model.

1. As a group, discuss your design plans and decide which plan or combination of plans you wish to construct. A Recorder should keep notes in the Alpha Log on the group conversation so that there is a record of all ideas and important information. If, after your discussion, you decide as a group that you wish to design a new trash separator, do so.
2. Enter your decision in your Alpha Log along with any design modifications that you have made.
3. Redo the materials list based upon the changes you made in the design and have the Materials Manager gather everything you will need to build the separator.
4. Construct your model based on your design.
5. Test the trash separator. If it does not work, make modifications to your design. If you are still unable to get it to work, check with another group that has one working and find out what they did to get results. Be sure to write all changes in your Alpha Log so that you can retrace your steps if you have to.
6. Refine your model and test it several times to be sure it is reliable. Record the results of all tests in your Log.

COW MAGNETS

PLANNING THE EXPLORATION

Many people are not aware of cow magnets and how they are used. Comparing a cow's anatomy with that of humans (or any other animal that you are studying) can serve to link the study of magnetism with other areas of science.

Students use information about cow magnets that they acquire to complete a product of their choosing based upon their individual learning style. Any one of the "Assessments," or a combination, can be completed for this assignment. Background Information is provided for your use to guide the students. It is expected that students will perform their own research using the CD-ROM or print media. Contacting an Agricultural Extension Office, the Department of Agriculture, a farmer, or a university or college is another way of gathering data.

Pass the cow magnet around for everyone to observe and handle. Keep the magnet accessible so that students can continue to touch it and use it to inspire their work.

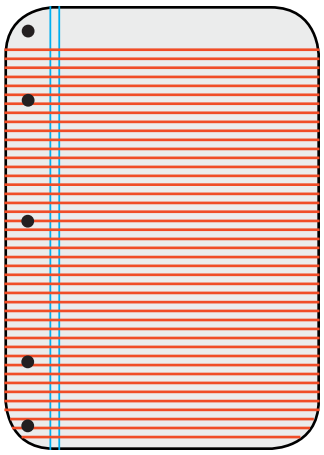
BACKGROUND INFORMATION

Ruminants have a 4-chambered stomach consisting of the rumen, reticulum, omasum, and abomasum. As a cow feeds, grass is passed to the rumen where it is broken down and turned into cud (small balls). The cud is returned to the cow's mouth where it is rechewed and passed to the reticulum. Then it passes on to the omasum and lastly to the abomasum where enzymes facilitate final digestion. The abomasum is sometimes called a "true stomach," because this is where real digestion occurs.

Dairy farmers realized that they had a problem related to digestion as cows ingested pieces of wire used to bale hay or from fences. The wire would pass along into the cow's second stomach and could puncture the animal's heart or other vital organs nearby. This condition was called "hardware disease" and before farmers used cow magnets, they lost many animals.

Cow magnets are put into the cow's throat, swallowed and are lodged in the reticulum, although they can sometimes stay in the first stomach. They do not harm the animal. The magnet attracts the pieces of metal wire (and any other metal objects) that they swallow and keep them from doing any damage. If the magnets get totally covered by debris and can no longer attract metals, the farmer must make a decision as to whether or not it is worthwhile to operate. If the animal is valuable, the farmer may decide to have the magnet removed and replaced. If, however, the animal is not valuable, the cow is simply replaced. Once the cow dies or is slaughtered, the cow magnet can be retrieved and reused.

FOR YOUR PLANBOOK



Suggested time: 1+ hours

Gear: CD-ROM, cow magnet, supplies for projects

National Science Content Standards: A, C, E, F, G

Sunshine State Standards Benchmarks: SC.C.2.3.1-3, SC.D.2.3.1-2, SC.F.1.3.1, 1.3.7, SC.G.1.3.4-5. 2.3.4, SC.H.1.3.1-7, 3.3.1-4, 3.3.5-7

Sunshine State Standards Benchmarks -- Language Arts: LA.A.1.3.1-4, 2.3.1-8, LA.B.1.3.1-3, 2.3.1-4, LA.C.1.3.1-3, 2.3.1-2, 3.3.3, LA.D.2.3.1-7, LA.E.1.3.1-5, 2.3.1-8

Sunshine State Standards Benchmarks -- Social Studies: SS.A.1.3.1-3, 2.3.3, 4.3.3, 5.3.2, SS.D.2.3.1-3

Homework: It is intended that students will work on their chosen projects at home over a designated period of time based on the complexity of the project or the amount of time that you wish to devote to the Explorations.

Assessment: Listed below are areas to explore that relate to cow magnets. Ideally students will

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generate ideas, plans for carrying out their ideas, and ways to present their findings to the class. All explorations require presentation to the class which could be done as a poster session, an oral report, role-playing "skit," musical composition, artwork, computer-assisted presentation, or multimedia presentation.

Technological design: The word "technology" for middle school students usually means computers or computer-like machines. However, technology is any development used for a practical purpose that makes a task more efficient or more effective. The cow magnet can be considered a technological advance because it saves farmers a great deal of money, saves the lives of cows, and solves a problem.

Have students research historical technological innovations and inventions that are sometimes overlooked when they study the cotton gin, the steamboat, electricity, etc. Brainstorm as a whole class seemingly simple technological designs that have made a difference in our lives. Students could start with cow magnets if they wish. Interviewing farmers who use them, agricultural extension workers who have information about them, farm bureaus and farm agents could provide information not available in textbooks or reference material.

Other examples of "small" but important discoveries are the mechanical pen, the zipper, velcro, the compass, teflon, or tissues. Encourage students to look around and investigate something about which they are curious. Whether the students pursue the cow magnet as a technological invention or choose another invention or innovation, the research should reflect a variety of sources: web sites, print media, videos, etc. Students are only limited by their imaginations for these explorations!

Allow students to choose their method of research and presentation as well as whether they work individually or in groups. This is a chance to address all **learning styles** in your classroom by encouraging choice and

allowing students to design their own method of presentation.

Stomach stones: Cow magnets serve another purpose -- aiding digestion. Other animals, such as birds, swallow stones which lodge in their gizzards and further grind food into digestible pieces. Most middle schoolers are not aware of this phenomena. This is a natural connection to life science, comparative anatomy and animal behavior.

Additionally, there is some evidence that points to the fact that dinosaurs also ingested rocks to aid in digestion. This is another area for exploration that students may choose to pursue that would lead to research on geological time, connections of dinosaurs to modern birds, or fact versus fiction in movies and books.

Economic issues: The farmer must make a choice when a cow magnet "fills up." Is it sound business practice to have a veterinarian perform a costly operation on the cow or is it a better decision to have the cow slaughtered? This type of decision is one that is made daily in the business world; a decision that requires determining how much something is "worth." The concept of worth is one that will require discussion because it is different for each person. An animal lover will say that sacrificing the cow because of monetary reasons is inhumane; on the other hand, a practical businessman will say that the cow is no longer a good investment, so it is time to cut the losses.

Students could **debate** this issue in front of the class and bring in other topics of this sort. For example, should developers be forced to give up building plans because of a bird's nest? Whose rights are violated when boaters are fined when they hit a manatee? Is the "cost" of technological development too great to bear (e.g., space junk or toxic waste)?

Careers: Farmers, veterinarians, Department of Agriculture employees, or farm bureau agents would be the most obvious career connections for students to make.

Interviewing is one technique for students to use to collect information. First students will design an interview instrument by developing a set of questions. Then students will decide on a method to record the responses, for example, chart or graph, in writing, audiotape, or videotape.

Creative writing: Have students write a story dealing specifically with cow magnets. The story could be in the form of a cartoon or short story format that deals with the adventure of a cow with a magnet inside. It could be a science fiction story (tells a good story; deals with human nature; considers strange and unusual occurrences; and has science facts). Encourage students to present their stories in creative ways: as a play, cartoon, or computer presentation, for example.

Reading: James Herriot wrote a number of books about the experiences of a country veterinarian. The most famous of his collections are: All Creatures Great and Small, Every Living Thing, and All Things Bright and Beautiful. His stories are the basis for a long-running PBS series, All Creatures Great and Small that is available at local libraries.

"How We Were Tracked By A Tripod," by John Christopher (found in Science Fiction Stories, edited by Edward Blishen, ISBN 1-85697-889-3) tells about boys followed by machines that tracked them by following metal plates that had been implanted in their heads.

Encourage students to find their own fiction and nonfiction reading material. Now that they know how magnets are used with other animals, they may wish to research how magnets are used in human medicine. For example, magnets are used by orthopedic surgeons to stimulate bone growth.

Notes:

POLE REVERSAL

PLANNING THE EXPLORATION

This exploration lends itself well to making connections with Earth Science: in particular, the study of oceanography, plate tectonics, and continental drift. You can make this connection for the students or simply propose it as a topic for further research. The reversal of present-day pole positions is a difficult concept, one that students may or may not be able to comprehend depending upon their level of sophistication. Since students are designing their own projects, however, they will relate this information to what they already understand in a way that makes sense to each one of them.

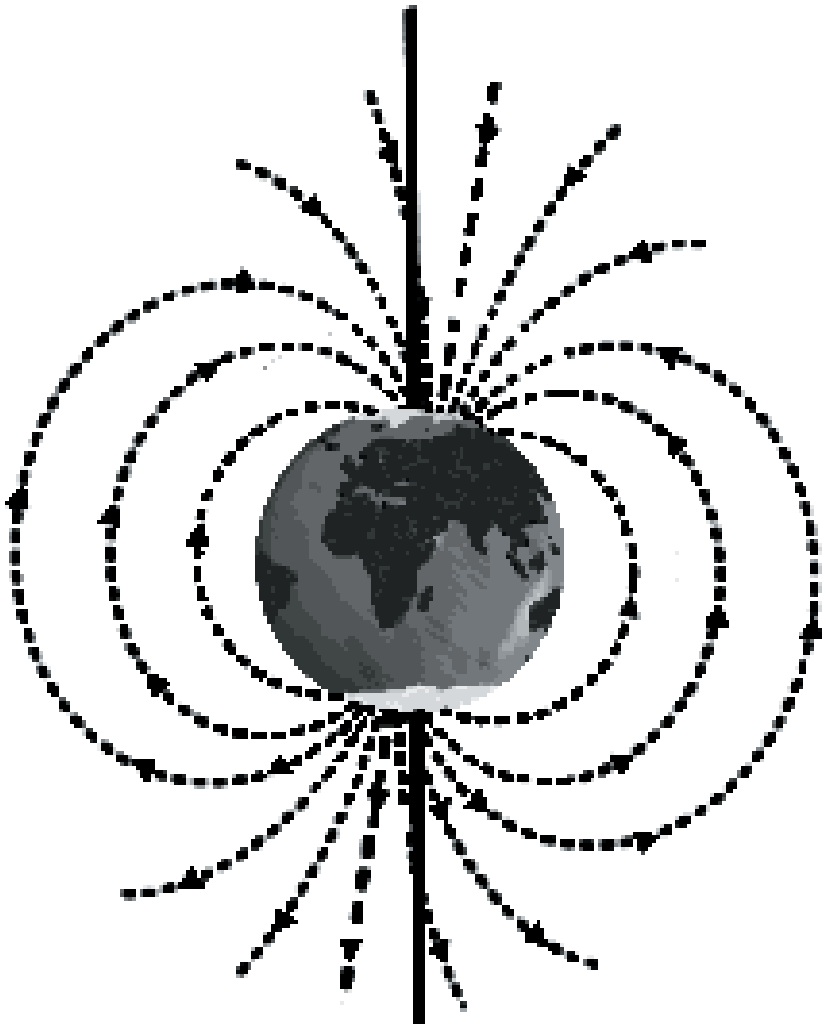
It is important that students design their own research project. Rather than choosing what they perceive as the easiest task, students should be encouraged to tap into their strengths (writing, art, music, computer graphics, or computer usage, for example). Depending upon your particular class, you may wish to contract with each student about their project; or, you may be at a point where you can just assign a project and give guidance only where necessary. Projects can be done individually, in pairs, or in groups. This allows students who are uncomfortable with group work a chance to demonstrate their individual strengths as well as to pursue a subject of personal interest.

This is a good time to revisit your discussion of models and how they are used in science. A model does not have to be what we traditionally think of when we hear that word: car or ship models with pieces that are glued together or papier mache representations. A model can be anything that allows students to look at or demonstrate an idea that is too large (or small) or too complex to observe directly.

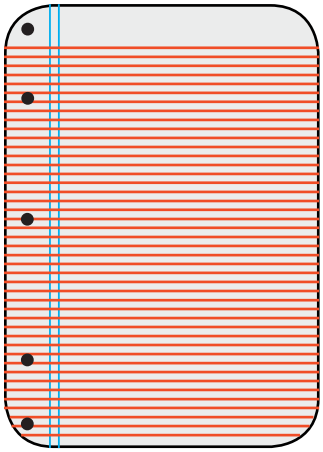
BACKGROUND INFORMATION

Although most of us are familiar with the North Pole and South Pole, the Earth's magnetic poles have switched several times throughout geologic history as is evidenced by magnetic stripes on the ocean floor. Magnetic stripes are indicators of polar wandering because of the iron content in basalt -- the most common rock on the ocean floor. Basalts have a high iron content, and as they are deposited on the ocean floor by volcanic eruptions they cool and freeze and leave a magnetic "fingerprint." Each time there is an eruption new layers of basalts are laid down on the ocean floor resulting in stripes that represent the direction of the magnetic field lines at the time of the eruption.

The actual reversal takes place relatively quickly (1000 years) once the process begins, although the entire process can take on the average of 500,000 years. The study of paleomagnetism investigates polar wandering by counting back from mid-ocean ridges to determine the relative age of the stripes. Absolute dating can be done using potassium-40/argon-40 . When scientists looked at rocks 1,000,000 years old, they found that the magnetic field at that time was close to today's position but when other rocks were tested, it was apparent that the north and south poles had switched positions. This disparity in rock layers is just one piece of evidence to support Alfred Wegener's theory of continental drift. He proposed that continents moved around on the Earth's surface after observing similar fossil evidence in rock layers from different locations (specifically Africa and South America). This led to the later theory of plate tectonics and the supercontinent of Pangaea which supported Wegener's continental drift (5-10 cm per year) and is confirmed by magnetic rock layers.



FOR YOUR PLANBOOK



Suggested time: 1+ hours

Gear: CD-ROM for reference

National Science Content Standards: A, B, C, D, F, G

Sunshine State Standards Benchmarks: SC.B.2.3.1, SC.C.1.3.1, SC.C.1.4.1, SC.C.2.3.1, SC.C.2.3.2, SC.C.2.3.3, SC.F.2.3.4, SC.H.1.3.1, SC.H.1.3.2, SC.H.1.3.4, SC.H.2.3.1, SC.H.3.3.6, SC.H.3.3.7

Sunshine State Standards Benchmarks -- Language Arts: LA.A.1.3.4, LA.A.2.3.5, LA.A.2.3.7, LA.A.2.3.8 (if Reading and Writing assessment pieces are completed) , LA.B.1.3.1, LA.B.1.3.2, LA.B.1.3.3 (if research report is done), LA.B.2.3.1, LA.B.2.3.3, LA.B.2.3.4, LA.C.3.3.3 (Booktalk and oral presentation), LA.D.2.3.4, LA.D.2.3.5, LA.E.2.3.5, LA.E.2.3.6, LA.E.2.3.7, LA.E.2.3.8

Homework: Have students work on projects at home.

Assessment:

Have students design **a model, map, or other visual aid** that demonstrates how scientists made the connection between magnetic stripes on the ocean floor and the theory of continental drift. The model could compare the fossil evidence with magnetic rock layer evidence that supports Alfred Wegener's theory. Products should show the relationship between magnetic material on the ocean floor and how the continents have moved over the past 400,000,000 years. Encourage students to look for additional information using the CD-ROM, web sites, print material, videos, etc.

The theory of plate tectonics differs somewhat from continental drift theory in that it is not just the continents that are moving but, in fact, the entire tectonic plate floating on the upper part of the mantle. Have students come up with a way to present the difference between continental drift and plate tectonics to the class. Encourage students to use **computer graphics** (quicktime movies from the worldwide web, for example) as a means to present information to a large group. This assessment lends itself well to **artwork** (clay models or other media) that represents continents and the plates upon which they rest. Students may choose to write a **research report** and present it orally.

Have more advanced science students with a chemistry background research and report on the difference between relative and absolute dating: specifically, the difference between carbon-14 dating and the dating done using potassium-40 argon-40. Students will design a **model or activity** that presents the information. The product, in order to be successful, will clarify this information for the class. Encourage the students to include with their product an **evaluation** of some sort so that they can determine whether or not they were successful in explaining the topic to others. This could be in the form of a quiz or short

essay question(s) or a survey that has several student-oriented questions.

Creative writing. Assign a fiction story about how the magnetic stripes on the ocean floor affect an animal that uses magnetoreceptors (see Exploration D: Animal Magnetism) to migrate. This might take the form of an animal that has adventures because he goes off course because of the stripes or animals that exhibit special characteristics because the magnetic fields interfere with one another. In order for this assessment to be completed successfully, students must include information on magnetic fields and magnetic stripes.

Reading and writing. Have students research articles on whales (and other mammals) beaching themselves and ask themselves if there could be some connection between Earth's magnetic field and this phenomenon. Could there be a tie-in with magnetic stripes? Probably the evidence will be inconclusive but this is an area of great interest among marine biologists at this time. An extensive print and website search will yield a great deal of information.

MYTHS AND MAGNETISM

PLANNING THE EXPLORATION

All science disciplines have their share of myths and misconceptions. Magnetism is no exception; in fact, because the study of magnets and magnetic fields requires understanding a force that we cannot see as well as other scientific concepts to explain that force, it is particularly prone to misunderstandings. Similar to studying works of science fiction, exploring various myths and the cultures that created those myths requires that students distinguish fact from fiction. To really understand myths about the natural world, students must have a deep knowledge of the subject in question.

This Exploration requires that students analyze both expository pieces and fiction, distinguishing between explanation and evidence. Although myths, stories, and seemingly scholarly articles may appear to state an explanation that makes sense to the reader, students must be looking for evidence to support the explanations. How far you choose to go with this Exploration depends on the time available to you as well as the level of sophistication of your classes. If your students are studying World Cultures, for example, there is a possible connection investigating myths of certain cultures and identifying how myths are a representation of beliefs and rituals.

Listed below are several areas that students could explore. Any other ideas that students develop themselves should be encouraged. If students identify a misconception that they held before working through this series of Expeditions, that could be a good place to start. Several assessment activities appeared previously as Excursions; other Excursions could be used as well.

BACKGROUND INFORMATION

It is advisable here to differentiate between myths and misconceptions if only to clarify them for students so that they are successful in completing their tasks. According to The New Merriam-Webster Dictionary, a myth is a "legendary narrative that presents part of the beliefs of a people or explains a practice or natural phenomenon." A misconception, on the other hand, although similar, is not necessarily an attempt to explain natural phenomena but is a misunderstanding or misinterpretation based upon prior understanding. It is only when students present their work that misconceptions can be identified. As students display their work, not only do they get to clarify it for themselves but for the teacher as well. An outstanding example of a student's misconception and the teacher's attempt to correct it is found in the short video, "A Private Universe," available from The Astronomical Society of the Pacific, 390 Ashton Avenue, San Francisco, CA 94112.

Health issues. Living in or near an area where high magnetic fields are generated is a concern to some people who believe that there is a connection between these fields and incidences of cancer. It remains to be seen as to whether or not this is a misconception; **however, recent medical research indicates no correlation between health problems and high voltage wires.** Any time electric current runs through a wire a magnetic field is generated. The implication is that all household appliances, lights, and home wiring could affect our health.

There are many health-oriented businesses that make unsubstantiated claims about using magnets to improve pre-existing conditions and prevent others. Because our bodies produce a low intensity biomagnetic field, some researchers believe that we could be affected by exposure to stronger electromagnetic fields. Taking advantage of people who do not fully understand the concept of magnetic fields, there are products on the market today that claim to use magnets to solve myriad health problems. Driving Force (cited below) is a good source for claims of those who believe magnets can be used to cure disease. Some examples that you may wish to share with the students are listed below.

Magnetic field therapy explores the relationship between the magnetic energy in the human body and magnetic fields in homes, offices, etc. Magnetic field therapy claims to be able to use magnets to kill cancer cells, treat arthritis, glaucoma, infertility, and diseases that are associated with aging. Proponents of magnetic field therapy claim that magnets can have a calming effect and help make a patient sleepy; they can reduce stress, and magnetic fields can act as an antibiotic. You may wish to point out here that there is some danger in believing too strongly that magnets can act against viral and bacterial infections.

Biomagnetism is touted as treatment for a wide variety of ills. Using magnets, companies that produce health-related magnets for sale claim that cancer cells cannot exist in magnetic fields, magnets relieve pain and inflammation, and in general, bring a sick body back to health.

One company claims that magnetic foot strips can reduce and, in some cases, eliminate pain throughout all areas of the body. Biomagnetics uses a technique similar to acupuncture since the belief is that different areas of the foot are directly related to all organs of the body, the company claims. For instance, the tip of the big toe connects directly with the sinuses. By using magnetic foot strips a person could, in theory, cure any and all aches, pains, and illnesses. In addition, by wearing a magnetic bracelet, which generates its own magnetic field and electric current, circulation will be improved and fatigue eliminated.

Franz Anton Mesmer. An Austrian doctor and contemporary of Mozart, Mesmer used permanent magnets developed by Father Maximilian Hell, who believed that diseases could be "pulled" from the body by shaping magnets to match the body part in question. Mesmer supported his ideas by reporting cures of seizures, deafness, and chest pains. He called his philosophy "animal magnetism" and as he influenced more and more people in Europe, they were known to be "mesmerized." Mesmer's assistants, known as magnetizers, later branched off into the study of hypnotism which explains why some people use the words hypnotism and mesmerism as synonyms. This is fertile ground for research on early medicine since the modern practice of chiropracty developed from an interest in magnetic healing. Driving Force by James D. Livingston (ISBN 0-674-21645-8) is an excellent source for early medical uses for magnets.

Native American myths. Indigenous people from all over the world traditionally utilize storytelling to communicate and pass on information. Often these stories are myths that have

developed over the years by individual tribes as they attempt to explain and understand the natural world. As important as it is to identify and clarify students' thinking before teaching a new concept, it is also important to do the same for other cultures. Investigating cultures other than their own helps students look at their own world in a different way and realize that there are many perspectives through which to view the natural world. Native Americans do not see themselves as apart from nature but, rather, as a part of the natural world. Rather than observing and attempting to control nature, they view themselves as an integral part of it which provides a different way of looking at relationships among people.___

FOR YOUR PLANBOOK

Suggested time: 1+ hours

Gear: CD-ROM for reference, books, articles, project supplies

National Science Content Standards: A, B, C, E, F, G

Sunshine State Standards Benchmarks:

SC.B.2.3.2, SC.C.2.3.1-2, SC.D.2.3.2, SC.G.2.3.1, SC.H.1.3.1-.2,6, SC.H.3.3.1-2,6, SC.H.3.3.4-6

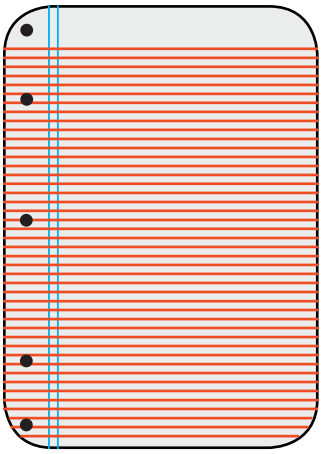
Sunshine State Standards Benchmarks -- Language Arts:

LA.A.1.3.1-4, 2.3.1-4, LA.B.1.3.1-3,2.3.1-4, LA.C.1.3.1-3, LA.D.1.3.1-4, 2.3.1-7, LA.E.2.3.1

Sunshine State Standards Benchmarks -- Social Studies:

SS.B.2.3.6-9, SS.C.2.3.6-7, SS.D.1.3.1-3

Assessment:



Conduct **a class discussion or debate** about health concerns of people living near high-power lines. Some people believe that the magnetic fields created by these high-power electrical lines are harmful. A worldwide web search or print media search could turn up many articles on this subject. Choose four class members for each side and the rest of the class becomes the audience at a town meeting called by concerned citizens. At the end of the debate the audience helps decide whether or not to pay to evacuate citizens that live in the affected area. This exercise takes a real-world concern/current issue and allows students to use their knowledge of magnetic fields learned in the classroom. They will be modeling a process that is widely used by communities to discuss issues of mutual concern. The New York Times Book of Science Literacy (ISBN 0-06-097455-9) has a short article on this subject.

A **search of worldwide web** sites about

magnetism will reveal a large number of products for sale designed to aid certain health conditions using magnets. Have students research these -- let each group choose one -- and then report back to the class as a whole why it would be a waste of money to buy each of the items. Becoming educated, responsible consumers is important especially when the students realize that they control a large percentage of dollars spent on consumer goods.

Encourage students to **write their own myths** about magnetism. For example, myths could deal with auroras (see "Auroras, Moon Rocks, and Magnetism"). Magnetite (lodestone) as a compass could be the subject of a myth about Native Americans migrating. Students must find a way to present their myth to the class. Storytelling, role-playing, drawings, dancing and singing are some options for class presentations that would be true to Native American culture.

Have students **create a chart** of myths and misconceptions about magnetism that they have discovered over the course of completing the Expeditions and Explorations, that they find on the worldwide web, or that are found in newspapers, magazines, stories, television, films, etc. One column of the chart will be to list the myths and/or misconceptions and the second column will list the science fact that disputes or repudiates them.

Have students **create cave drawings** to explain the phenomenon of magnetism. Early inhabitants often recorded natural occurrences that later became part of Earth's history. Students can recreate this way of communicating using drawing paper or papier mache, cardboard, or other media. Cave drawings were used in much the same way that Native Americans used their stories: to explain the natural world.

Students **organize a poster session** that educates other classes about myths and misconceptions regarding magnetism and magnetic fields. Each group of students creates a poster that combines written explanation with graphics as well as a short oral presentation. The posters could be transported to an elementary school as part of a plan to educate elementary students about magnetism. **Myths** could also be a part of an outreach program to elementary schools in which middle school students read original works to classes and extend this further to explain the writing process.

ANIMAL MAGNETISM

PLANNING THE EXPLORATION

Many animals often travel great distances for a variety of reasons. Ducks migrate in formation, often to the same nesting places. Whales, butterflies, and turtles are believed to use the earth's magnetic field to orient themselves when migrating. The idea that animals may have internal compasses that enable them to complete the same route time after time is one that scientists have been exploring for a very long time.

Students are required to complete a project on the subject of animals and magnetism that is suitable to be presented to the entire class. How this is accomplished is up to you. Below are some suggestions that you may wish to share with your students. However, introducing them to the subject and letting each student, or each group of students, design their own project would be the ideal. The due date that you assign plus the level of your students will determine the complexity of the projects.

BACKGROUND INFORMATION

One way that animals are believed to travel great distances is called directional orientation. This implies the ability to travel in a certain direction without using landmarks of any sort. Scientists believe that animals are able to use the sun, the stars, and the earth's magnetic field as compasses. Birds are the most often used example of this phenomenon. They travel thousands of miles in a particular direction and stop when they have flown a prescribed distance.

Recently, there have been articles written on the monarch butterfly (see The Washington Post, May 5, 1997, among others). One study demonstrated that in conjunction with its own internal clock, the monarch uses the sun as a compass to navigate. Monarchs fly 2400 miles across North America each spring. Such a long passage led scientists to study the circumstances necessary for the monarch to make this journey. Although scientists have purported that the monarchs use the sun as a compass, they have also demonstrated that monarchs are able to continue their journey even when it is cloudy. They believe this is due to an internal backup compass. This study has led to an increased interest in the way in which other animals navigate over long distances.

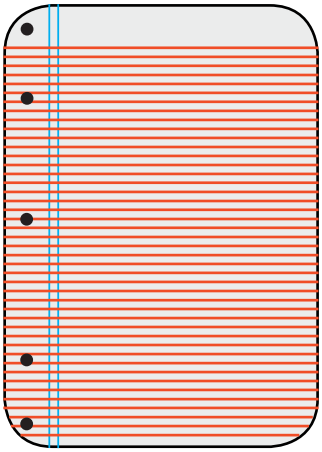
Animals other than birds that exhibit this ability are turtles, whales, and dolphins. Bees are thought to be influenced by some kind of magnetoreception, as are some types of bacteria. Salmon, sharks, rays, and other fish are also thought to be influenced by the earth's magnetic field either alone or in conjunction with other influences such as magnetite deposits, light, or electricity. It is also thought that some animals are sensitive to polarity: the fish swims in a

certain direction because the field is becoming stronger or weaker.

Some animals actually have magnetite in their bodies, usually in the skull. This could enable them to carry internally a permanent magnet that acts as a compass when they migrate. The magnetite might align with the earth's magnetic field and stimulate some other receptor so that the animal is aware of the direction and strength of the magnetic field. Some bacteria navigate in this manner. The permanent magnets in these cells act like a compass needle. The bacteria then swim in the direction toward magnetic north (in the northern hemisphere).

A good source for information on magnetoreception is Perspectives on Animal Behavior by Judith Goodenough, Betty McGuire, and Robert Wallace (John Wiley & Sons, 1993, ISBN 0-471-53623-7).

FOR YOUR PLANBOOK



Suggested time: 1+ hours

Gear: CD-ROM for background information, project supplies

National Science Content Standards: A, B, C, D, G.

Sunshine State Standards Benchmarks: SC.C.2.3.1, SC.C.2.3.2, SC.C.2.3.3, SC.F.1.3.1, SC.F.1.3.2, SC.F.1.3.7, SC.F.2.3.2, SC.G.1.3.2, SC.H.1.3.1, SC.H.1.3.3, SC.H.1.3.4, SC.H. 2.3.1, SC.H.3.3.7.

Sunshine State Standards Benchmarks -- Language Arts (if "Reading and Writing" assessment pieces are completed): LA.A.1.3.4, LA.A.2.3.1, LA.A.2.3.2, LA.A.2.3.5, LA.A.2.3.6, LA.A.2.3.7, LA.A.2.3.8, LA.B.1.3.1, LA.B.1.3.2, LA.B.1.3.3, LA.C.3.3.3. If computer options are completed: LA.D.2.3.4, LA.D.2.3.5. If Prince of Whales is used: LA.E.1.3.2, LA.E.2.3.1, LA.E.2.3.2, LA.E.2.3.5, LA.E.2.3.6, LA.E.2.3.7.

Homework: Students work on their projects at home.

Assessment:

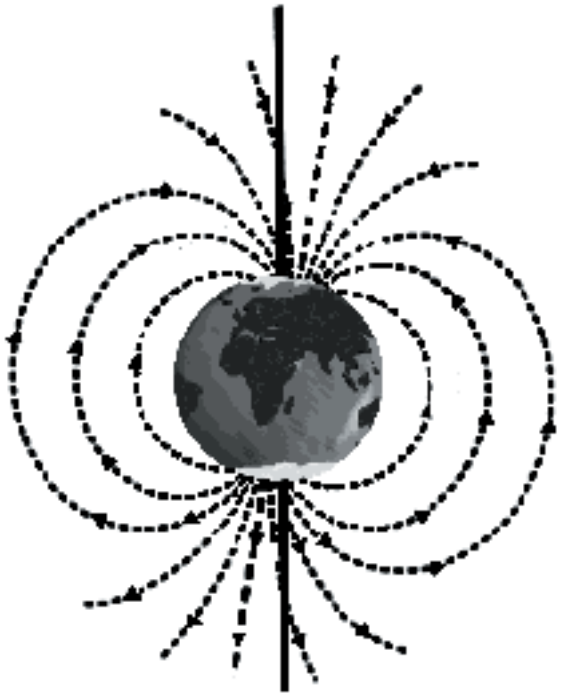
Although the method of presentation is up to each student based on his or her learning style, each student or group of students should have a presentation for the whole class. The presentation includes information on how the earth's magnetic field influences animal behavior to indicate that students have determined the relationship between migratory patterns and magnetism. There should be some discussion of an internal compass to show that students can think critically about information on magnetism. Students will demonstrate that they have designed a project and executed that design.

Regardless of how students decide to present findings, this subject requires research in scientific journals (for example, Nature or Scientific American). Web sites could be explored, as could textbooks, encyclopedias, or the CD-ROM supplied with this book. Explain to students that looking up information on CD-ROM or web sites and printing the information is not creating a report and would be unacceptable.

Reading and Writing. Using CD-ROM reference material, web sites, or print media, students explore information about animals

that use the earth's magnetic field to guide their migratory journeys. There are many outstanding science magazines that can be accessed through school, public, or university libraries. Using LUIS, students can access sources by subject and find out where to obtain them. Expository reading in science is an important skill for students to develop. Information can be presented in ways that encourage analysis of information and the relationship between that information and the subject being studied.

Have students highlight the articles as they read, then summarize, and present a **poster** summarizing the articles. By focusing on the most important information, students will be forced to identify what is closely related to the study of magnetism. Students will be critical readers as well as demonstrate that they can paraphrase and summarize pertinent information.



Some students could create an **annotated bibliography** for other students to use in the future. In doing so, the student will list sources as well as a short explanation of what can be found at that source. Students will have to distinguish between articles and books that delve into the subject and those that just mention it.

The Prince of Whales by R.L. Fisher (ISBN 0-812-56635-1) is a clever story of a young whale that sets out by himself as he is forced to leave his pod. The pod leaves for their annual migration,and Toby must proceed alone. Although this fantasy does not deal with magnetic reception specifically, students could make the connection. A possible product could be **a diorama, drawing, or a book talk** that states the relationship between Toby's journey and the study of magnetism used to support migratory patterns of whales.

Have students create a **science fiction** or creative writing story that involves an animal that uses the earth's magnetic field to find its way. Stories should include all characteristics of science fiction (tells a good story, deals with human nature, includes science fact, and presents something strange or unusual).

Students can create an **illustrated booklet** for younger children that deals with this subject. This would require that students be able to explain to others how animals use the earth's magnetic field to navigate. Stating explanations and then finding a way to present them to another person will force students to clarify their own ideas.

Art. Have students create a **diorama** of insects, birds, or mammals that use the earth's magnetic field to find direction. The relationship between magnetism and animals' ability to find direction must be clearly displayed plus students will orally explain their project to the rest of the class. Explanations should include why they chose that particular animal, how that animal differs from others, and how it uses either an internal or external compass.

Computer presentation. A **multimedia presentation** could include quicktime movies, video clips, a slide show, or any combination of these with text. This could be viewed on individual computers, through a monitor for large-group viewing, or in any other way that the students design themselves. Once they have collected information, students individually or in groups should design a plan for implementing the presentation of the information. Have students present the plan to you for approval, making sure that the task can be completed in the time allotted. Students with computers at home may be more inclined to choose this option.

A computer version of **an annotated bibliography** could be accomplished through a detailed search of web sites that provide information on "animal magnetism." Using the technique of listing the site and then critiquing the site for usefulness, complexity, readability, and accuracy requires that students analyze what they are reading and compare sites. Many websites contain similar information; how well that information is presented (spelling, grammar, etc.) and how sources are presented so that students have confidence that the information is accurate are important skills for middle school students to learn.

PRACTICAL APPLICATIONS

PLANNING THE EXPLORATION

These areas of recommended further study address three important issues: first, they are an attempt to bridge the gap between classroom science and real-world science research and development; second, they introduce students to the many and varied careers associated with magnet research; third, they encourage students to become responsible consumers of information. Scientific advances bring both problems and advantages which require that informed citizens understand how these advances impact their lives. Today's citizens must make decisions based on social issues; for example, genetic engineering, reduction of sources for fossil fuels, environmental issues, health concerns, or ethical issues in science research. This Exploration provides opportunities for students to analyze the impact of science and technology on society, to determine their costs and benefits, and to apply classroom work to real-world situations.

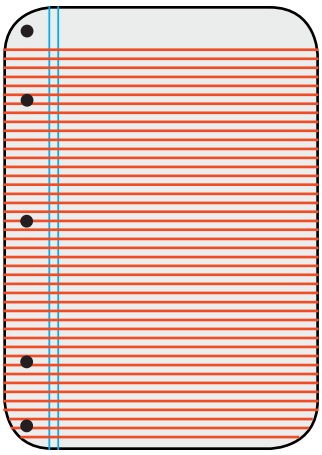
BACKGROUND INFORMATION

Information on the practical applications of magnet science can be found in a variety of sources. Since this Exploration addresses a number of different subjects, the best place to start is with the Alpha Interface. The Alpha Interface (CD-ROM) provides basic information on these issues as does "Build a Simple MagLev Train" and "Build a Magnetic Trash Separator Model." An excellent source for information on some of the topics being covered is the web site at the National High Magnetic Field Laboratory (www.magnet.fsu.edu).

Additional sources of information can be found in a variety of print media: encyclopedias, science encyclopedias, Odyssey Magazine, Earth magazine, Discover magazine, videos (available from the public library), personal interviews, visiting government agencies, writing letters to the editor or to private companies, etc.

MagLab: Alpha

FOR YOUR PLANBOOK



Suggested time: 1+ hours

Gear: CD-ROM for reference

National Science Content Standards: (Depends on whether students complete an assignment on one particular application or whether they look at all seven listed here.) A, B, C (if students take an in-depth look at MRI technology), E, F, G

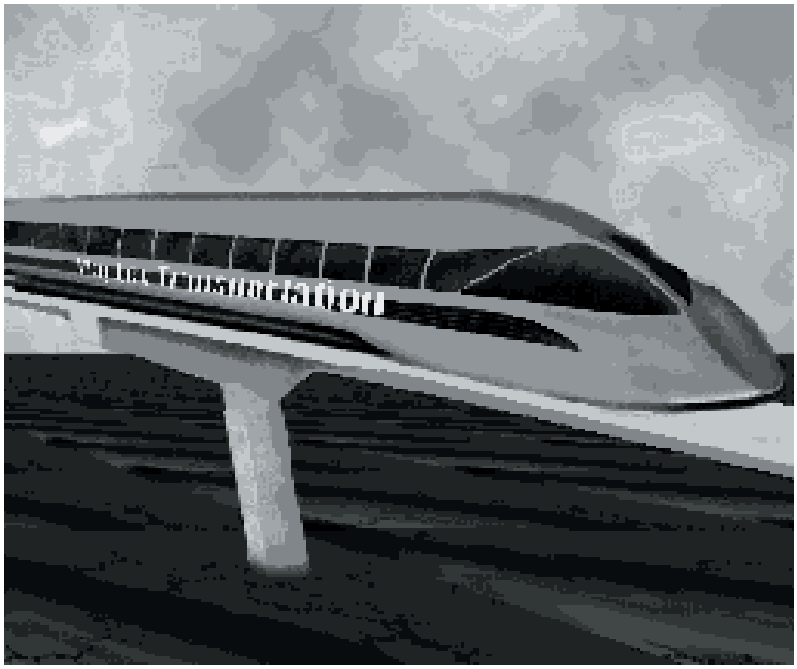
Sunshine State Standards Benchmarks: (Depends on whether students complete one particular assignment or whether they research all seven.)SC.B.1.3.1, SC.C.2.3.1, SC.C.2.3.2, SC.C.2.3.3, SC.C.2.3.4, SC.C.2.3.6, SC.C.2.3.7, SC.D.2.3.1, SC.D.2.3.2, SC.G.2.3.1, SC.H.1.3.1, SC.H.1.3.2, SC.H.1.3.3, SC.H.1.3.4, SC.H.1.3.6, SC.H.3.3.4, SC.H.3.3.6

Sunshine State Standards Benchmarks -- Language Arts: LA.A.1.3.1-4, 2.3.1-8, LA.B.1.3.1-2, 2.3.1-4, LA.C.1.3.1-4, 2.3.1-2, 3.3.1-3, LA.D.2.3.1-7, LA.E.2.3.4-8

Homework: Students will be working on their individual research projects on their own time.

Assessment: Each of the topics could be explored in a number of ways to accommodate individual learning styles. Examples of ways to integrate reading and writing in the science curriculum are given as well as ways to tap into each student's talent.

Some areas for further exploration into the practical applications of magnet science are: *MRI, lithotripsy, MagLev trains, magnetic mining, energy storage, trash separators, magnetic launchers, and the development of superconductors.*



Presentations. Each student, pair of students, or group of students could create a presentation of one of the topics of interest. The purpose of the presentation would be to share what they have learned with the rest of the class members. Completing the task in this manner would yield the most information in the shortest period of time. Students come to class with expertise in one area but leave the class knowing about all seven.

Presentations could be done in a number of formats. Multimedia sharing, perhaps a listing of web sites, or visiting web sites and keeping a diary of sites visited that discuss practical applications of high field magnet science. Role playing (particularly in the case of MRI technology) and models would be appropriate.

Debates could be organized by students to bring to the class issues that are involved in controversy or which have the potential to become controversial. For example, students could debate the use of magnetic mining techniques as a safe, efficient way to remove certain materials from mines. However, the other side of the issue deals with people being put out of jobs that have been traditionally held either in that geographical area or by that particular group of people. Students will be forced to answer the question "What happens to people who know only one skill or business? How will they find work?" If a large number of people are put out of work, what implications does this have for the economy of the area?

Encourage students to channel their natural tendency to take sides to inform a large number of people about the issue in which they believe. If the debate is set up as a town meeting format, other students could represent the voting public and actually take a vote at the end of the debate. Winning and losing is not the issue; informing the greatest number of people of both sides of an issue is.

Write letters to the editor of a local newspaper in support of one of the areas of practical application, e.g., MagLev trains, magnetic mining, energy storage, trash separators, etc. By formulating a way to express themselves, students will be articulating their opinions on issues that affect the environment. Analyzing each of the issues for its potential to improve the quality of life on the planet encourages students to become competent, responsible consumers of information presented by mass media.

Have students create their own *science fiction* based upon one of the practical applications of magnet science. By including a great deal of science fact, students demonstrate that they can distinguish between science fact and fiction. They will be describing and explaining whichever of the technological developments they choose to fictionalize. Students can choose another *genre* with which to work: fantasy, nonfiction, fiction, biography, reporting, etc. as a vehicle for presenting what they have learned.

Students can create *games* that trace the development or use of a particular invention or innovation or that illustrate one or more of the technologies that are being explored. If they are more comfortable adapting a game with which they are already familiar, rather than creating an entirely new game, encourage this as a worthwhile way of modifying work that others have done. This is typical of real-world science discoveries which are often modified as new work is being tested and new theories are proposed.

A *research report* which meets predetermined

requirements on one or all of the practical applications will allow students to discover that, although the disciplines appear to be very different, often the purpose is the same (e.g., to create jobs, provide a more efficient transportation system, advance medical research, or improve the environment). Reports could be created on the computer and include graphics that are shared with the rest of the class.

Students who are talented at creating works of *art* should be encouraged to design a project or piece of artwork that would portray technological advances. Artists are only limited by their imaginations as to the media that they use to express themselves. Creating a piece of art that the student can explain as representative of one or more of the practical applications (MRI, for instance) models how artwork sometimes reflects the time in which it was created.

Those who are interested in art but do not want to create a piece of artwork should be encouraged to investigate and then explain to the class how the Industrial Revolution was reflected in artwork; how WPA-backed art portrayed middle America in the Depression; or how computers have changed how some art is done. *Science in art* and the *art in science* would be challenging topics for more sophisticated or gifted students.

APPENDIXES

Appendix A - Standards

Appendix B - Directions

Appendix C - Annotated Bibliography

Appendix D - Blackline Masters

Appendixes

	EXPEDITION #1 What is a Magnet?	EXCURSIONS for Expedition #1
National Science Education Standards	**A.** scientific inquiry and understandings about scientific inquiry **B.** properties and changes of properties in matter, motions and forces, and transfer of energy **G.** science as a human endeavor, nature of science, history of science	**A.** scientific inquiry and understandings about scientific inquiry **B.** properties and changes of properties in matter, motions and forces, and transfer of energy **G.** science as a human endeavor, nature of science, history of science
Sunshine State Standards - Science	**C.2.** understands the types of force that act on an object and the effect of that force can be described, measured, and predicted **H.1.** uses the scientific processes and habits of mind to solve problems **H.2.** understands that most natural events occur in comprehensible, consistent patterns **H.3.** understands that science, technology, and society are interwoven and interdependent	**B.2.** understands the interaction of matter and energy **C.2.** understands that the types of force that act on an object and the effect of that force can be described, measured, and predicted **D.2.** understands the need for protection of the natural systems on Earth **F.2.** understands the process and importance of genetic diversity **H.1.** uses the scientific processes and habits of mind to solve problems **H.3.** understands that science, technology, and society are interwoven and interdependent
Sunshine State Standards - Mathematics		
Sunshine State Standards - Language Arts	**A.1.** uses the reading process effectively **A.2.** constructs meaning from a wide range of texts **B.1** uses writing processes effectively **C.3.** uses speaking strategies effectively **E.1.** understands the common features of a variety of literary forms	**A.2.** constructs meaning from a wide range of texts **B.1.** uses writing processes effectively **B.2.** writes to communicate ideas and information effectively **D.2.** understands the nature of language **E.1.** understands the common features of a variety of literary forms **E.2.** responds critically to fiction, nonfiction, poetry, and drama
Sunshine State Standards - Social Studies		**A.2.** the world from its beginnings to the time of the Renaissance **A.3.** Western and Eastern civilization since the Renaissance **A.4.** U.S. history to 1880

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	EXPEDITION #2 What Objects do Magnets Attract?	EXCURSIONS for Expedition #2
National Science Education Standards	**A.** scientific inquiry and understandings about scientific inquiry **B.** properties and changes of properties in matter, motions and forces, and transfer of energy **G.** science as a human endeavor, nature of science, history of science	**A.** scientific inquiry and understandings about scientific inquiry **B.** properties and changes of properties in matter, motions and forces, and transfer of energy **G.** science as a human endeavor, nature of science, history of science
Sunshine State Standards - Science	**A.1.** understands that all matter has observable, measurable properties **A.2.** understands the basic principles of atomic theory **C.2.** understands that the types of force that act on an object and the effect of that force can be described, measured, and predicted **H.1.** uses the scientific processes and habits of mind to solve problems **H.3.** understands that science, technology, and society are interwoven and interdependent	**C.2.** understands that the types of force that act on an object and the effect of that force can be described, measured, and predicted **H.1.** uses the scientific processes and habits of mind to solve problems **H.2.** understands that most natural events occur in comprehensible, consistent patterns **H.3.** understands that science, technology, and society are interwoven and interdependent
Sunshine State Standards - Mathematics	**A.1.** different ways numbers are represented and used in the real world **B.1.** measures quantities in the real world and uses the measures to solve problems **B.4.** selects and uses appropriate units an instrumetns for measurement to achieve the degree of precision and accuracy required in real-world situations **C.3.** uses coordinate geometry to locate objects in both two and three dimensions and to describe objects algebraically **D.1.** describes, analyzes, and generalizes a wide variety of patterns, relations, and functions **E.1.** uses the tools of data analysis for managing information **E.3.** uses statistical methods to make inferences and valid arguments about real-world situations	
Sunshine State Standards - Language Arts	**A.1.** uses the reading process effectively **B.1.** uses writing processes effectively **B.2.** writes to communicate ideas and information effectively **C.1.** uses listening strategies effectively **C.3.** uses speaking strategies effectively **D.2.** understands the power of language	**A.2.** constructs meaning from a wide range of texts **B.1.** uses writing processes effectively **B.2.** writes to communicate ideas and information effectively **C.1.** uses listening strategies effectively **D.1.** understands the nature of language **D.2.** understands the power of language **E.1.** understands the common features of a variety of literary forms **E.2.** responds critically to fiction, nonfiction, poetry, and drama
Sunshine State Standards - Social Studies		

	EXPEDITION #3 Viewing a Magnetic Field	EXCURSIONS for Expedition #3
National Science Education Standards	**A.** scientific inquiry and understandings about scientific inquiry **D.** structure of the earth system, Earth's history, Earth in the solar system **E.** abilities of technological design, understandings about science and technology **F.** personal health, populations, resources, and environments, natural hazards, risks and benefits, science and technology in society **G.** science as a human endeavor, nature of science, history of science	**A.** scientific inquiry and understandings about scientific inquiry **D.** structure of the earth system, Earth's history, Earth in the solar system **E.** abilities of technological design, understandings about science and technology **F.** personal health, populations, resources, and environments, natural hazards, risks and benefits, science and technology in society **G.** science as a human endeavor, nature of science, history of science
Sunshine State Standards - Science	**A.2.** understands the basic principles of atomic theory **B.1.** recognizes that energy may be changed in form with varying efficiency **B.2.** understands the interaction of matter and energy **C.2.** understands that the types of force that act on an object and the effect of that force can be described, measured, and predicted **E.1.** understands the interaction and organization in the Solar System and the universe and how this affects life on Earth **E.2.** recognizes the vastness of the universe and the Earth's place in it **H.1.** uses the scientific processes and habits of mind to solve problems **H.2.** understands that most natural events occur in comprehensible, consistent patterns **H.3.** understands that science, technology, and society are interwoven and interdependent	**C.1.** understands that types of motion may be described, measured, and predicted **C.2.** understands that the types of force that act on an object and the effect of that force can be described, measured, and predicted **E.2.** recognizes the vastness of the universe and the Earth's place in it **H.1.** uses the scientific processes and habits of mind to solve problems **H.2.** understands that most natural events occur in comprehensible, consistent patterns **H.3.** understands that science, technology, and society are interwoven and interdependent
Sunshine State Standards - Mathematics		
Sunshine State Standards - Language Arts	**A.1.** uses the reading process effectively **B.2.** writes to communicate ideas and information effectively **C.1.** uses listening strategies effectively **C.3.** uses speaking strategies effectively	**A.1.** uses the reading process effectively **A.2.** constructs meaning from a wide range of texts **B.2.** writes to communicate ideas and information effectively **C.1.** uses listening strategies effectively **E.2.** responds critically to fiction, nonfiction, poetry, and drama
Sunshine State Standards - Social Studies		

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	EXPEDITION #4 Visualizing Magnetic Field Lines	EXCURSIONS for Expedition #4
National Science Education Standards	**A.** scientific inquiry and understandings about scientific inquiry **B.** properties and changes in matter, motions and forces, transfer of energy **E.** abilities of technological design, understandings about science and technology **F.** personal health, populations, resources, and environments, natural hazards, risks and benefits, science and technology in society **G.** science as a human endeavor, nature of science, history of science	**A.** scientific inquiry and understandings about scientific inquiry **B.** properties and changes in matter, motions and forces, transfer of energy **E.** abilities of technological design, understandings about science and technology **F.** personal health, populations, resources, and environments, natural hazards, risks and benefits, science and technology in society **G.** science as a human endeavor, nature of science, history of science
Sunshine State Standards - Science	**C.1.** understands that types of motion may be described, measured, and predicted **C.2.** understands that the types of force that act on an object and the effect of that force can be described, measured, and predicted **D.2.** understands the need for protection of the natural systems on Earth **E.1.** understands the interaction and organization in the Solar System and the universe and how this affects life on Earth **H.1.** uses the scientific processes and habits of mind to solve problems **H.2.** understands that most natural events occur in comprehensible, consistent patterns **H.3.** understands that science, technology, and society are interwoven and interdependent	**C.2.** understands that the types of force that act on an object and the effect of that force can be described, measured, and predicted **H.1.** uses the scientific processes and habits of mind to solve problems **H.3.** understands that science, technology, and society are interwoven and interdependent
Sunshine State Standards - Mathematics		
Sunshine State Standards - Language Arts	**A.1.** uses the reading process effectively **A.2.** constructs meaning from a wide range of texts	**A.1.** uses the reading process effectively **A.2.** constructs meaning from a wide range of texts **C.3.** uses speaking strategies effectively
Sunshine State Standards - Social Studies		**C.2.** understands the role of the citizen in American democracy **D.1.** understands how scarcity requires individuals and institutions to make choices about how to use resources **D.2.** understands the characteristics of different economic systems and institutions

	EXPEDITION #5 Drawing Magnetic Field Lines	EXCURSIONS for Expedition #5
National Science Education Standards	**A.** scientific inquiry and understandings about scientific inquiry **B.** properties and changes of properties in matter, motions and forces, and transfer of energy **D.** structure of the earth system, Earth's history, Earth in the solar system	**A.** scientific inquiry and understandings about scientific inquiry **B.** properties and changes of properties in matter, motions and forces, and transfer of energy **D.** structure of the earth system, Earth's history, Earth in the solar system
Sunshine State Standards - Science	**C.2.** understands that the types of force that act on an object and the effect of that force can be described, measured, and predicted **H.1.** uses the scientific processes and habits of mind to solve problems **H.2.** understands that most natural events occur in comprehensible, consistent patterns	**C.2.** understands that the types of force that act on an object and the effect of that force can be described, measured, and predicted **H.1.** uses the scientific processes and habits of mind to solve problems **H.3.** understands that science, technology, and society are interwoven and interdependent
Sunshine State Standards - Mathematics		
Sunshine State Standards - Language Arts	**A.2.** constructs meaning from a wide range of texts	**A.2.** constructs meaning from a wide range of texts
Sunshine State Standards - Social Studies	**A.2.** the world from its beginnings to the time of the Renaissance **A.3.** Western and Eastern civilization since the Renaissance	**A.2.** the world from its beginnings to the time of the Renaissance **A.3.** Western and Eastern civilization since the Renaissance

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	EXPEDITION #6 North and South Poles-Not Just Polar Bears and Penguins	EXCURSIONS for Expedition #6
National Science Education Standards	**A.** scientific inquiry and understandings about scientific inquiry **B.** properties and changes in matter, motions and forces, transfer of energy **G.** science as a human endeavor, nature of science, history of science	**A.** scientific inquiry and understandings about scientific inquiry **B.** properties and changes in matter, motions and forces, transfer of energy **G.** science as a human endeavor, nature of science, history of science
Sunshine State Standards - Science	**C.2.** understands that the types of force that act on an object and the effect of that force can be described, measured, and predicted **H.1.** uses the scientific processes and habits of mind to solve problems	**B.1.** recognizes that energy may be changed in form with varying efficiency **B.2.** understands the interaction of matter and energy **C.2.** understands that the types of force that act on an object and the effect of that force can be described, measured, and predicted **D.2.** understands the need for protection of the natural systems on Earth **E.1.** understands the interaction and organization in the Solar System and the universe and how this affects life on Earth **G.2.** understands the consequences of using limited natural resources **H.1.** uses the scientific processes and habits of mind to solve problems **H.2.** understands that most natural events occur in comprehensible, consistent patterns **H.3.** understands that science, technology, and society are interwoven and interdependent
Sunshine State Standards - Mathematics		
Sunshine State Standards - Language Arts	**B.1.** writes to communicate ideas and information effectively **B.2.** writes to communicate ideas and information effectively **D.2.** understands the power of language **E.1.** understands the common features of a variety of literary forms	**A.1.** uses the reading process effectively **A.2.** constructs meaning from a wide range of texts **B.1.** writes to communicate ideas and information effectively **B.2.** writes to communicate ideas and information effectively **D.1.** understands the nature of language **D.2.** understands the power of language **E.1.** understands the common features of a variety of literary forms
Sunshine State Standards - Social Studies		**A.1.** understands historical chronology and the historical perspective

	EXPEDITION #7 Earth's Magnetosphere	EXCURSIONS for Expedition #7
National Science Education Standards	**A.** scientific inquiry and understandings about scientific inquiry **E.** abilities of technological design, understandings about science and technology **G.** science as a human endeavor, nature of science, history of science	**A.** scientific inquiry and understandings about scientific inquiry **E.** abilities of technological design, understandings about science and technology **G.** science as a human endeavor, nature of science, history of science
Sunshine State Standards - Science	**A.2.** understands the basic principles of atomic theory **B.1.** recognizes that energy may be changed in form with varying efficiency **C.1.** understands that types of motion may be described, measured, and predicted **C.2.** understands that the types of force that act on an object and the effect of that force can be described, measured, and predicted **G.1.** understands the competitive, interdependent, cyclic nature of living things in the environment **H.1.** uses the scientific processes and habits of mind to solve problems	**C.1.** understands that types of motion may be described, measured, and predicted **D.1.** recognizes that processes in the lithosphere, atmosphere, hydrosphere, and biosphere interact to shape the Earth **H.1.** uses the scientific processes and habits of mind to solve problems **H.2.** understands that most natural events occur in comprehensible, consistent patterns **H.3.** understands that science, technology, and society are interwoven and interdependent
Sunshine State Standards - Mathematics	**A.4.** estimation in problem solving and computation **B.1.** measures quantities in the real world and uses the measures to solve problems **B.4.** selects and uses appropriate units an instrumetns for measurement to achieve the degree of precision and accuracy required in real-world situations	
Sunshine State Standards - Language Arts	**A.2.** constructs meaning from a wide range of texts **C.1.** uses listening strategies effectively **C.2.** uses viewing strategies effectively **C.3.** uses speaking strategies effectively **D.1.** understands the nature of language **E.2.** responds critically to fiction, nonfiction, poetry, and drama	**A.1.** uses the reading process effectively **A.2.** constructs meaning from a wide range of texts **B.2.** writes to communicate ideas and information effectively **D.2.** understands the power of language
Sunshine State Standards - Social Studies	**A.1.** understands historical chronology and the historical perspective **B.1.** understands the world in spatial terms	

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	EXPEDITION #8 Blocking the Field	EXCURSIONS for Expedition #8
National Science Education Standards	**A.** scientific inquiry and understandings about scientific inquiry **B.** properties and changes of properties in matter, motions and forces, and transfer of energy **D.** structure of the earth system, Earth's history, Earth in the solar system **E.** abilities of technological design, understandings about science and technology **G.** science as a human endeavor, nature of science, history of science	**A.** scientific inquiry and understandings about scientific inquiry **B.** properties and changes of properties in matter, motions and forces, and transfer of energy **D.** structure of the earth system, Earth's history, Earth in the solar system **E.** abilities of technological design, understandings about science and technology **G.** science as a human endeavor, nature of science, history of science
Sunshine State Standards - Science	**A.2.** understands the basic principles of atomic theory **B.1.** recognizes that energy may be changed in form with varying efficiency **B.2.** understands the interaction of matter and energy **C.1.** understands that types of motion may be described, measured, and predicted **C.2.** understands that the types of force that act on an object and the effect of that force can be described, measured, and predicted **H.1.** uses the scientific processes and habits of mind to solve problems **H.3.** understands that science, technology, and society are interwoven and interdependent	**C.2.** understands that the types of force that act on an object and the effect of that force can be described, measured, and predicted **D.2.** understands the need for protection of the natural systems on Earth **H.1.** uses the scientific processes and habits of mind to solve problems **H.2.** understands that most natural events occur in comprehensible, consistent patterns **H.3.** understands that science, technology, and society are interwoven and interdependent
Sunshine State Standards - Mathematics	**A.3.** effects of operations on numbers and the relationships among these operations, selects appropriate operations, and computes for problem solving **B.4.** selects and uses appropriate units an instrumetns for measurement to achieve the degree of precision and accuracy required in real-world situations **E.1.** uses the tools of data analysis for managing information	**A.1.** different ways numbers are represented and used in the real world **C.1.** describes, draws, identifies, and analyzes two- and three-dimensional shapes **D.2.** uses expressions, equations, inequalities, graphs, and formulas to represent and interpret situtations **E.1.** uses the tools of data analysis for managing information
Sunshine State Standards - Language Arts	**A.2.** constructs meaning from a wide range of texts **B.1.** uses writing processes effectively **B.2.** writes to communicate ideas and information effectively **E.2.** responds critically to fiction, nonfiction, poetry, and drama	**A.2.** constructs meaning from a wide range of texts **B.1.** uses writing processes effectively **B.2.** writes to communicate ideas and information effectively **D.2.** understands the power of language
Sunshine State Standards - Social Studies	**B.1.** understands the world in spatial terms	**A.1.** understands historical chronology and the historical perspective **B.1.** understands the world in spatial terms

	EXPEDITION #9 Use Electricity to Make a Magnet	EXCURSIONS for Expedition #9
National Science Education Standards	**A.** scientific inquiry and understandings about scientific inquiry **B.** properties and changes of properties in matter, motions and forces, and transfer of energy **E.** abilities of technological design, understandings about science and technology **F.** personal health, populations, resources, and environments, natural hazards, risks and benefits, science and technology in society **G.** science as a human endeavor, nature of science, history of science	**A.** scientific inquiry and understandings about scientific inquiry **B.** properties and changes of properties in matter, motions and forces, and transfer of energy **E.** abilities of technological design, understandings about science and technology **F.** personal health, populations, resources, and environments, natural hazards, risks and benefits, science and technology in society **G.** science as a human endeavor, nature of science, history of science
Sunshine State Standards - Science	**A.1.** understands that all matter has observable, measurable properties **A.2.** understands the basic principles of atomic theory **B.1.** recognizes that energy may be changed in form with varying efficiency **C.2.** understands that the types of force that act on an object and the effect of that force can be described, measured, and predicted **H.1.** uses the scientific processes and habits of mind to solve problems **H.3.** understands that science, technology, and society are interwoven and interdependent	**A.2.** understands the basic principles of atomic theory **B.1.** recognizes that energy may be changed in form with varying efficiency **C.2.** understands that the types of force that act on an object and the effect of that force can be described, measured, and predicted **D.2.** understands the need for protection of the natural systems on Earth **G.2.** understands the consequences of using limited natural resources **H.1.** uses the scientific processes and habits of mind to solve problems **H.3.** understands that science, technology, and society are interwoven and interdependent
Sunshine State Standards - Mathematics		
Sunshine State Standards - Language Arts	**A.1.** uses the reading process effectively **A.2.** constructs meaning from a wide range of texts **B.1.** uses writing processes effectively **B.2.** writes to communicate ideas and information effectively **C.1.** uses listening strategies effectively **D.2.** understands the power of language **E.1.** understands the common features of a variety of literary forms **E.2.** responds critically to fiction, nonfiction, poetry, and drama	**A.1.** uses the reading process effectively **A.2.** constructs meaning from a wide range of texts **B.1.** uses writing processes effectively **B.2.** writes to communicate ideas and information effectively **D.1.** understands the nature of language **D.2.** understands the power of language **E.1.** understands the common features of a variety of literary forms **E.2.** responds critically to fiction, nonfiction, poetry, and drama
Sunshine State Standards - Social Studies		**A.1.** understands historical chronology and the historical perspective **A.2.** understands the world from its beginnings to the time of the Renaissance **C.2.** understands the role of the citizen in American democracy

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	EXPEDITION #10 Build a Stronger Electromagnet	EXCURSIONS for Expedition #10
National Science Education Standards	**A.** scientific inquiry and understandings about scientific inquiry **B.** properties and changes of properties in matter, motions and forces, and transfer of energy **C.** structure and function in living systems, reproduction and heredity, regulation and behavior, populations and ecosystems, diversity and adaptations of organisms **D.** structure of the earth system, Earth's history, earth in the solar system **E.** abilities of technological design, understandings about science and technology **F.** personal health, populations, resources, and environments, natural hazards, risks and benefits, science and technology in society **G.** science as a human endeavor, nature of science, history of science	**A.** scientific inquiry and understandings about scientific inquiry **B.** properties and changes of properties in matter, motions and forces, and transfer of energy **C.** structure and function in living systems, reproduction and heredity, regulation and behavior, populations and ecosystems, diversity and adaptations of organisms **D.** structure of the earth system, Earth's history, earth in the solar system **E.** abilities of technological design, understandings about science and technology **F.** personal health, populations, resources, and environments, natural hazards, risks and benefits, science and technology in society **G.** science as a human endeavor, nature of science, history of science
Sunshine State Standards - Science	**B.1.** recognizes that energy may be changed in form with varying efficiency **C.2.** understands that the types of force that act on an object and the effect of that force can be described, measured, and predicted **D.1.** recognizes that processes in the lithosphere, atmosphere, hydrosphere, and biosphere interact to shape the Earth **D.2.** understands the need for protection of the natural systems on Earth **G.1.** understands the competitive, interdependent, cyclic nature of living things in the environment **G.2.** understands the consequences of using limited natural resources **H.1.** uses the scientific processes and habits of mind to solve problems	**C.2.** understands that the types of force that act on an object and the effect of that force can be described, measured, and predicted **H.1.** uses the scientific processes and habits of mind to solve problems **H.3.** understands that science, technology, and society are interwoven and interdependent
Sunshine State Standards - Mathematics	**A.4.** estimation in problem solving and computation **B.3.** estimates measurements in real-world problem situations **B.4.** selects and uses appropriate units an instrumetns for measurement to achieve the degree of precision and accuracy required in real-world situations **D.1.** describes, analyzes, and generalizes a wide variety of patterns, relations, and functions **E.1.** uses the tools of data analysis for managing information **E.3.** uses statistical methods to make inferences and valid arguments about real-world situations	**A.4.** estimation in problem solving and computation **B.1.** measures quantities in the real world and uses the measures to solve problems **B.3.** estimates measurements in real-world problem situations **B.4.** selects and uses appropriate units an instrumetns for measurement to achieve the degree of precision and accuracy required in real-world situations
Sunshine State Standards - Language Arts	**A.1.** uses the reading process effectively **A.2.** constructs meaning from a wide range of texts **C.3.** uses speaking strategies effectively **D.1** understands the nature of language **D.2.** understands the power of language	**A.1.** uses the reading process effectively **A.2.** constructs meaning from a wide range of texts **B.1.** uses writing processes effectively **B.2.** writes to communicate ideas and information effectively **D.2.** understands the power of language
Sunshine State Standards - Social Studies		**A.1.** understands historical chronology and the historical perspective **A.2.** understands the world from its beginnings to the time of the Renaissance **A.3.** understands Western and Eastern civilization since the Renaissance

	EXPEDITION #11 Auroras, Moon Rocks, and Magnetism	EXCURSIONS for Expedition #11
National Science Education Standards	**A.** scientific inquiry and understandings about scientific inquiry **D.** structure of the earth system, Earth's history, Earth in the solar system **E.** abilities of technological design, understandings about science and technology **F.** personal health, populations, resources, and environments, natural hazards, risks and benefits, science and technology in society **G.** science as a human endeavor, nature of science, history of science	**A.** scientific inquiry and understandings about scientific inquiry **D.** structure of the earth system, Earth's history, Earth in the solar system **E.** abilities of technological design, understandings about science and technology **F.** personal health, populations, resources, and environments, natural hazards, risks and benefits, science and technology in society **G.** science as a human endeavor, nature of science, history of science
Sunshine State Standards - Science	**B.1.** recognizes that energy may be changed in form with varying efficiency **C.2.** understands that the types of force that act on an object and the effect of that force can be described, measured, and predicted **E.1.** understands the interaction and organization in the Solar System and the universe and how this affects life on Earth **H.1.** uses the scientific processes and habits of mind to solve problems **H.3.** understands that science, technology, and society are interwoven and interdependent	**A.2.** understands the basic principles of atomic theory **B.1.** recognizes that energy may be changed in form with varying efficiency **B.2.** understands the interaction of matter and energy **C.2.** understands that the types of force that act on an object and the effect of that force can be described, measured, and predicted **D.1.** recognizes that processes in the lithosphere, atmosphere, hydrosphere, and biosphere interact to shape the Earth **E.1.** understands the interaction and organization in the Solar System and the universe and how this affects life on Earth **E.2.** recognizes the vastness of the universe and the Earth's place in it **H.1.** uses the scientific processes and habits of mind to solve problems **H.2.** understands that most natural events occur in comprehensible, consistent patterns **H.3.** understands that science, technology, and society are interwoven and interdependent
Sunshine State Standards - Mathematics		**C.1.** describes, draws, identifies, and analyzes two- and three-dimensional shapes
Sunshine State Standards - Language Arts	**A.2.** constructs meaning from a wide range of texts **B.2.** writes to communicate ideas and information effectively	**A.1.** uses the reading process effectively **A.2.** constructs meaning from a wide range of texts **B.1.** uses writing processes effectively **B.2.** writes to communicate ideas and information effectively **D.2.** understands the power of language **E.1.** understands the common features of a variety of literary forms **E.2.** responds critically to fiction, nonfiction, poetry, and drama
Sunshine State Standards - Social Studies		

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	EXPEDITION #12 Magnetism in Space	EXCURSIONS for Expedition #12
National Science Education Standards	**A.** scientific inquiry and understandings about scientific inquiry **G.** science as a human endeavor, nature of science, history of science	**A.** scientific inquiry and understandings about scientific inquiry **G.** science as a human endeavor, nature of science, history of science
Sunshine State Standards - Science	**A.2.** understands the basic principles of atomic theory **B.1.** recognizes that energy may be changed in form with varying efficiency **C.2.** understands that the types of force that act on an object and the effect of that force can be described, measured, and predicted **E.1.** understands the interaction and organization in the Solar System and the universe and how this affects life on Earth **H.1.** uses the scientific processes and habits of mind to solve problems	**A.2.** understands the basic principles of atomic theory **B.1.** recognizes that energy may be changed in form with varying efficiency **B.2.** understands the interaction of matter and energy **C.2.** understands that the types of force that act on an object and the effect of that force can be described, measured, and predicted **D.1.** recognizes that processes in the lithosphere, atmosphere, hydrosphere, and biosphere interact to shape the Earth **E.1.** understands the interaction and organization in the Solar System and the universe and how this affects life on Earth **E.2.** recognizes the vastness of the universe and the Earth's place in it **H.1.** uses the scientific processes and habits of mind to solve problems **H.2.** understands that most natural events occur in comprehensible, consistent patterns **H.3.** understands that science, technology, and society are interwoven and interdependent
Sunshine State Standards - Mathematics		**C.1.** describes, draws, identifies, and analyzes two- and three-dimensional shapes
Sunshine State Standards - Language Arts	**A.2.** constructs meaning from a wide range of texts **B.2.** writes to communicate ideas and information effectively	**A.1.** uses the reading process effectively **A.2.** constructs meaning from a wide range of texts **B.1.** uses writing processes effectively **B.2.** writes to communicate ideas and information effectively **D.2.** understands the power of language **E.1.** understands the common features of a variety of literary forms **E.2.** responds critically to fiction, nonfiction, poetry, and drama
Sunshine State Standards - Social Studies		

	EXPEDITION #13 Magnets and Work	EXCURSIONS for Expedition #13
National Science Education Standards	**A.** scientific inquiry and understandings about scientific inquiry **B.** properties and changes in matter, motions and forces, transfer of energy **E.** abilities of technological design, understandings about science and technology	**A.** scientific inquiry and understandings about scientific inquiry **B.** properties and changes in matter, motions and forces, transfer of energy **E.** abilities of technological design, understandings about science and technology
Sunshine State Standards - Science	**A.1.** understands that all matter has observable, measurable properties **C.2.** understands that the types of force that act on an object and the effect of that force can be described, measured, and predicted **H.1.** uses the scientific processes and habits of mind to solve problems **H.3.** understands that science, technology, and society are interwoven and interdependent	**A.1.** understands that all matter has observable, measurable properties **C.2.** understands that the types of force that act on an object and the effect of that force can be described, measured, and predicted **D.2.** understands the need for protection of the natural systems on Earth **H.1.** uses the scientific processes and habits of mind to solve problems **H.3.** understands that science, technology, and society are interwoven and interdependent
Sunshine State Standards - Mathematics		
Sunshine State Standards - Language Arts		
Sunshine State Standards - Social Studies		

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	EXPEDITION #14 Magnetism and Temperature	EXCURSIONS for Expedition #14
National Science Education Standards	**A.** scientific inquiry and understandings about scientific inquiry **B.** properties and changes in matter, motions and forces, transfer of energy **E.** abilities of technological design, understandings about science and technology **F.** personal health, populations, resources, and environments, natural hazards, risks and benefits, science and technology in society **G.** science as a human endeavor, nature of science, history of science	**A.** scientific inquiry and understandings about scientific inquiry **B.** properties and changes in matter, motions and forces, transfer of energy **E.** abilities of technological design, understandings about science and technology **F.** personal health, populations, resources, and environments, natural hazards, risks and benefits, science and technology in society **G.** science as a human endeavor, nature of science, history of science
Sunshine State Standards - Science	**A.1.** understands that all matter has observable, measurable properties **A.2.** understands the basic principles of atomic theory **B.1.** recognizes that energy may be changed in form with varying efficiency **H.1.** uses the scientific processes and habits of mind to solve problems **H.3.** understands that science, technology, and society are interwoven and interdependent	**A.1.** understands that all matter has observable, measurable properties **A.2.** understands the basic principles of atomic theory **B.1.** recognizes that energy may be changed in form with varying efficiency **C.1.** understands that types of motion may be described, measured, and predicted **C.2.** understands that the types of force that act on an object and the effect of that force can be described, measured, and predicted **H.1.** uses the scientific processes and habits of mind to solve problems **H.3.** understands that science, technology, and society are interwoven and interdependent
Sunshine State Standards - Mathematics	**A.1.** different ways numbers are represented and used in the real world **B.1.** measures quantities in the real world and uses the measures to solve problems **B.2.** compares, contrasts, and converts within systems of measurement (both standard/nonstandard and metric/customary) **B.3.** estimates measurements in real-world problem situations **B.4.** selects and uses appropriate units an instrumetns for measurement to achieve the degree of precision and accuracy required in real-world situations **C.3.** uses coordinate geometry to locate objects in both two and three dimensions and to describe objects algebraically **D.1** describes, analyzes, and generalizes a wide variety of patterns, relations, and functions **E.1.** uses the tools of data analysis for managing information **E.2.** identifies patterns and makes predictions from an orderly display of data using concepts of probablility and statistics **E.3.** uses statistical methods to make inferences and valid arguments about real-world situations	**A.1.** different ways numbers are represented and used in the real world
Sunshine State Standards - Language Arts		**A.1.** uses the reading process effectively **A.2.** constructs meaning from a wide range of texts **B.1.** uses writing processes effectively **B.2.** writes to communicate ideas and information effectively **C.3.** uses speaking strategies effectively **D.2.** understands the power of language
Sunshine State Standards - Social Studies		**A.1.** understands historical chronology and the historical perspective **A.2.** understands the world from its beginnings to the time of the Renaissance

	EXPEDITION #15 Build a Maglev Train Model	EXCURSIONS for Expedition #15
National Science Education Standards	**A.** scientific inquiry and understandings about scientific inquiry **B.** properties and changes in matter, motions and forces, transfer of energy **E.** abilities of technological design, understandings about science and technology **F.** personal health, populations, resources, and environments, natural hazards, risks and benefits, science and technology in society **G.** science as a human endeavor, nature of science, history of science	**A.** scientific inquiry and understandings about scientific inquiry **B.** properties and changes in matter, motions and forces, transfer of energy **E.** abilities of technological design, understandings about science and technology **F.** personal health, populations, resources, and environments, natural hazards, risks and benefits, science and technology in society **G.** science as a human endeavor, nature of science, history of science
Sunshine State Standards - Science	**B.2.** understands the interaction of matter and energy **C.1.** understands that types of motion may be described, measured, and predicted **C.2.** understands that the types of force that act on an object and the effect of that force can be described, measured, and predicted **D.2.** understands the need for protection of the natural systems on Earth **G.2.** understands the consequences of using limited natural resources **H.1.** uses the scientific processes and habits of mind to solve problems **H.3.** understands that science, technology, and society are interwoven and interdependent	**C.2.** understands that the types of force that act on an object and the effect of that force can be described, measured, and predicted **D.2.** understands the need for protection of the natural systems on Earth **E.1.** understands the interaction and organization in the Solar System and the universe and how this affects life on Earth **F.2.** understands the process and importance of genetic diversity **G.2.** understands the consequences of using limited natural resources **H.3.** understands that science, technology, and society are interwoven and interdependent
Sunshine State Standards - Mathematics		
Sunshine State Standards - Language Arts	**A.1.** uses the reading process effectively **A.2.** constructs meaning from a wide range of texts **B.1.** uses writing processes effectively **B.2.** writes to communicate ideas and information effectively **C.1.** uses listening strategies effectively **C.2.** uses viewing strategies effectively	**A.1.** uses the reading process effectively **A.2.** constructs meaning from a wide range of texts **B.1.** uses writing processes effectively **B.2.** writes to communicate ideas and information effectively **C.1.** uses listening strategies effectively **C.2.** uses viewing strategies effectively **D.2.** understands the power of language **E.1.** understands the common features of a variety of literary forms **E.2.** responds critically to fiction, nonfiction, poetry, and drama
Sunshine State Standards - Social Studies	**A.1.** understands historical chronology and the historical perspective **A.2.** understands the world from its beginnings to the time of the Renaissance **B.1.** understands the world in spatial terms **C.1.** understands the structure, functions, and purposes of government and how the principles and values of American democracy are reflected in American constitutional government **C.2.** understands the role of the citizen in American democracy **D.2.** understands the characteristics of different economic systems and institutions	

Appendix A - Standards

	EXPEDITION #16 Model Train Competition	EXCURSIONS for Expedition #16
National Science Education Standards	**A.** scientific inquiry and understandings about scientific inquiry **E.** abilities of technological design, understandings about science and technology **F.** personal health, populations, resources, and environments, natural hazards, risks and benefits, science and technology in society **G.** science as a human endeavor, nature of science, history of science	**A.** scientific inquiry and understandings about scientific inquiry **E.** abilities of technological design, understandings about science and technology **F.** personal health, populations, resources, and environments, natural hazards, risks and benefits, science and technology in society **G.** science as a human endeavor, nature of science, history of science
Sunshine State Standards - Science	**B.2.** understands the interaction of matter and energy **C.2.** understands that the types of force that act on an object and the effect of that force can be described, measured, and predicted **G.2.** understands the consequences of using limited natural resources **H.1.** uses the scientific processes and habits of mind to solve problems **H.3.** understands that science, technology, and society are interwoven and interdependent	
Sunshine State Standards - Mathematics		
Sunshine State Standards - Language Arts		**A.1.** uses the reading process effectively **A.2.** constructs meaning from a wide range of texts **B.1.** uses writing processes effectively **E.1.** understands the common features of a variety of literary forms
Sunshine State Standards - Social Studies		

	EXPEDITION #17 Understanding a Compass	EXCURSIONS for Expedition #17
National Science Education Standards	**A.** scientific inquiry and understandings about scientific inquiry **B.** properties and changes in matter, motions and forces, transfer of energy **E.** abilities of technological design, understandings about science and technology **F.** personal health, populations, resources, and environments, natural hazards, risks and benefits, science and technology in society **G.** science as a human endeavor, nature of science, history of science	**A.** scientific inquiry and understandings about scientific inquiry **B.** properties and changes in matter, motions and forces, transfer of energy **E.** abilities of technological design, understandings about science and technology **F.** personal health, populations, resources, and environments, natural hazards, risks and benefits, science and technology in society **G.** science as a human endeavor, nature of science, history of science
Sunshine State Standards - Science	**C.1.** understands that types of motion may be described, measured, and predicted **C.2.** understands that the types of force that act on an object and the effect of that force can be described, measured, and predicted **H.1.** uses the scientific processes and habits of mind to solve problems **H.3.** understands that science, technology, and society are interwoven and interdependent	**C.2.** understands that the types of force that act on an object and the effect of that force can be described, measured, and predicted **H.1.** uses the scientific processes and habits of mind to solve problems **H.3.** understands that science, technology, and society are interwoven and interdependent
Sunshine State Standards - Mathematics		
Sunshine State Standards - Language Arts	**B.1.** uses writing processes effectively **B.2.** writes to communicate ideas and information effectively	**A.1.** uses the reading process effectively **A.2.** constructs meaning from a wide range of texts **C.1.** uses listening strategies effectively **E.2.** responds critically to fiction, nonfiction, poetry, and drama
Sunshine State Standards - Social Studies	**A.1.** understands historical chronology and the historical perspective **A.2.** understands the world from its beginnings to the time of the Renaissance **A.3.** understands Western and Eastern civilization since the Renaissance **B.1.** understands the world in spatial terms	**A.1.** understands historical chronology and the historical perspective **A.3.** understands Western and Eastern civilization since the Renaissance

APPENDIX A - STANDARDS

	EXPEDITION #18 Build a Compass	EXCURSIONS for Expedition #18
National Science Education Standards	**A.** scientific inquiry and understandings about scientific inquiry **B.** properties and changes in matter, motions and forces, transfer of energy **D.** structure of the earth system, Earth's history, Earth in the solar system **E.** abilities of technological design, understandings about science and technology **G.** science as a human endeavor, nature of science, history of science	**A.** scientific inquiry and understandings about scientific inquiry **B.** properties and changes in matter, motions and forces, transfer of energy **D.** structure of the earth system, Earth's history, Earth in the solar system **E.** abilities of technological design, understandings about science and technology **G.** science as a human endeavor, nature of science, history of science
Sunshine State Standards - Science	**C.1.** understands that types of motion may be described, measured, and predicted **C.2.** understands that the types of force that act on an object and the effect of that force can be described, measured, and predicted **E.1.** understands the interaction and organization in the Solar System and the universe and how this affects life on Earth **E.2.** recognizes the vastness of the universe and the Earth's place in it **H.1.** uses the scientific processes and habits of mind to solve problems **H.3.** understands that science, technology, and society are interwoven and interdependent	**H.1.** uses the scientific processes and habits of mind to solve problems **H.2.** understands that most natural events occur in comprehensible, consistent patterns **H.3.** understands that science, technology, and society are interwoven and interdependent
Sunshine State Standards - Mathematics		
Sunshine State Standards - Language Arts	**B.1.** uses writing processes effectively **B.2.** writes to communicate ideas and information effectively	**B.1.** uses writing processes effectively **B.2.** writes to communicate ideas and information effectively
Sunshine State Standards - Social Studies		

	EXPEDITION #19 Make a Map Using a Compass	EXCURSIONS for Expedition #19
National Science Education Standards	**A.** scientific inquiry and understandings about scientific inquiry **B.** properties and changes in matter, motions and forces, transfer of energy **E.** abilities of technological design, understandings about science and technology	**A.** scientific inquiry and understandings about scientific inquiry **B.** properties and changes in matter, motions and forces, transfer of energy **E.** abilities of technological design, understandings about science and technology
Sunshine State Standards - Science	**C.2.** understands that the types of force that act on an object and the effect of that force can be described, measured, and predicted **H.1.** uses the scientific processes and habits of mind to solve problems **H.3.** understands that science, technology, and society are interwoven and interdependent	**C.2.** understands that the types of force that act on an object and the effect of that force can be described, measured, and predicted **D.1.** recognizes that processes in the lithosphere, atmosphere, hydrosphere, and biosphere interact to shape the Earth **G.2.** understands the consequences of using limited natural resources **H.1.** uses the scientific processes and habits of mind to solve problems **H.3.** understands that science, technology, and society are interwoven and interdependent
Sunshine State Standards - Mathematics		
Sunshine State Standards - Language Arts	**B.1.** uses writing processes effectively **B.2.** writes to communicate ideas and information effectively **C.1.**uses listening strategies effectively **C.3.**uses speaking strategies effectively	**C.1.** uses listening strategies effectively **C.2.** uses viewing strategies effectively **C.3.** uses speaking strategies effectively **E.1.** understands the common features of a variety of literary forms
Sunshine State Standards - Social Studies	**A.6.** understands the history of Florida and its people **B.1.** understands the world in spatial terms	**A.6.** understands the history of Florida and its people **B.1.** understands the world in spatial terms

APPENDIX A - STANDARDS

	EXPEDITION #20 Build a Trash Separator Model	EXCURSIONS for Expedition #20
National Science Education Standards	**A.** scientific inquiry and understandings about scientific inquiry **B.** properties and changes in matter, motions and forces, transfer of energy **E.** abilities of technological design, understandings about science and technology **F.** personal health, populations, resources, and environments, natural hazards, risks and benefits, science and technology in society **G.** science as a human endeavor, nature of science, history of science	**A.** scientific inquiry and understandings about scientific inquiry **B.** properties and changes in matter, motions and forces, transfer of energy **E.** abilities of technological design, understandings about science and technology **F.** personal health, populations, resources, and environments, natural hazards, risks and benefits, science and technology in society **G.** science as a human endeavor, nature of science, history of science
Sunshine State Standards - Science	**B.2.** understands the interaction of matter and energy **C.1.** understands that types of motion may be described, measured, and predicted **C.2.** understands that the types of force that act on an object and the effect of that force can be described, measured, and predicted **D.2.** understands the need for protection of the natural systems on Earth **G.2.** understands the consequences of using limited natural resources **H.1.** uses the scientific processes and habits of mind to solve problems **H.3.** understands that science, technology, and society are interwoven and interdependent	**B.2.** understands the interaction of matter and energy **C.2.** understands that the types of force that act on an object and the effect of that force can be described, measured, and predicted **D.1.** recognizes that processes in the lithosphere, atmosphere, hydrosphere, and biosphere interact to shape the Earth **D.2.** understands the need for protection of the natural systems on Earth **E.1.** understands the interaction and organization in the Solar System and the universe and how this affects life on Earth **G.1.** understands the competitive, interdependent, cyclic nature of living things in the environment **G.2.** understands the consequences of using limited natural resources **H.1.** uses the scientific processes and habits of mind to solve problems **H.3.** understands that science, technology, and society are interwoven and interdependent
Sunshine State Standards - Mathematics		
Sunshine State Standards - Language Arts	**A.2.** constructs meaning from a wide range of texts **B.2.** writes to communicate ideas and information effectively **C.1.** uses listening strategies effectively **C.3.** uses speaking strategies effectively	**A.1.** uses the reading process effectively **A.2.** constructs meaning from a wide range of texts **B.1.** uses writing processes effectively **B.2.** writes to communicate ideas and information effectively **C.1.** uses listening strategies effectively **C.3.** uses speaking strategies effectively
Sunshine State Standards - Social Studies		

	EXPLORATION A Cow Magnets
National Science Education Standards	**A.** scientific inquiry and understandings about scientific inquiry **C.** structure and function in living systems, reproduction and heredity, regulation and behavior, populations and ecosystems, diversity and adaptations of organisms **E.** abilities of technological design, understandings about science and technology **F.** personal health, populations, resources, and environments, natural hazards, risks and benefits, science and technology in society **G.** science as a human endeavor, nature of science, history of science
Sunshine State Standards - Science	**C.2.** understands that the types of force that act on an object and the effect of that force can be described, measured, and predicted **D.2.** understands the need for protection of the natural systems on Earth **F.1.** describes patterns of structure and function in living things **G.1.** understands the competitive, interdependent, cyclic nature of living things in the environment **G.2.** understands the consequences of using limited natural resources **H.1.** uses the scientific processes and habits of mind to solve problems **H.3.** understands that science, technology, and society are interwoven and interdependent
Sunshine State Standards - Mathematics	
Sunshine State Standards - Language Arts	**A.1.** uses the reading process effectively **A.2.** constructs meaning from a wide range of texts **B.1.** uses writing processes effectively **B.2.** writes to communicate ideas and information effectively **C.1.** uses listening strategies effectively **C.2.** uses viewing strategies effectively **C.3.** uses speaking strategies effectively **D2.** understands the power of language **E.1.** understands the common features of a variety of literary forms **E.2.** responds critically to fiction, nonfiction, poetry, and drama
Sunshine State Standards - Social Studies	**A.1.** understands historical chronology and the historical perspective **A.2.** understands the world from its beginnings to the time of the Renaissance **A.4.** understands U.S. history to 1880 **A.5.** understands U.S. history from 1880 to the present day **D.2.** understands the characteristics of different economic systems and institutions

	EXPLORATION B Pole Reversal
National Science Education Standards	**A.** scientific inquiry and understandings about scientific inquiry **B.** properties and changes in matter, motions and forces, transfer of energy **C.** structure and function in living systems, reproduction and heredity, regulation and behavior, populations and ecosystems, diversity and adaptations of organisms **D.** structure of the earth system, Earth's history, earth in the solar system **F.** personal health, populations, resources, and environments, natural hazards, risks and benefits, science and technology in society **G.** science as a human endeavor, nature of science, history of science
Sunshine State Standards - Science	**B.1.** recognizes that energy may be changed in form with varying efficiency **C.1.** understands that types of motion may be described, measured, and predicted **C.2.** understands that the types of force that act on an object and the effect of that force can be described, measured, and predicted **F.2.** understands the process and importance of genetic diversity **H.1.** uses the scientific processes and habits of mind to solve problems **H.3.** understands that science, technology, and society are interwoven and interdependent
Sunshine State Standards - Mathematics	
Sunshine State Standards - Language Arts	**A.1.** uses the reading process effectively **A.2.** constructs meaning from a wide range of texts **B.1.** uses writing processes effectively **B.2.** writes to communicate ideas and information effectively **C.3.** uses speaking strategies effectively **D.2** understands the power of language **E.2.** responds critically to fiction, nonfiction, poetry, and drama
Sunshine State Standards - Social Studies	

	EXPLORATION C Myths and Magnetism
National Science Education Standards	**A.** scientific inquiry and understandings about scientific inquiry **B.** properties and changes in matter, motions and forces, transfer of energy **C.** structure and function in living systems, reproduction and heredity, regulation and behavior, populations and ecosystems, diversity and adaptations of organisms **E.** abilities of technological design, understandings about science and technology **F.** personal health, populations, resources, and environments, natural hazards, risks and benefits, science and technology in society **G.** science as a human endeavor, nature of science, history of science
Sunshine State Standards - Science	**B.2.** understands the interaction of matter and energy **C.2.** understands that the types of force that act on an object and the effect of that force can be described, measured, and predicted **D.2.** understands the need for protection of the natural systems on Earth **G.2.** understands the consequences of using limited natural resources **H.1.** uses the scientific processes and habits of mind to solve problems **H.3.** understands that science, technology, and society are interwoven and interdependent
Sunshine State Standards - Mathematics	
Sunshine State Standards - Language Arts	**A.1.** uses the reading process effectively **A.2.** constructs meaning from a wide range of texts **B.1.** uses writing processes effectively **B.2.** writes to communicate ideas and information effectively **C.1.** uses listening strategies effectively **D.1.** understands the nature of language **D.2.** understands the power of language **E.2.** responds critically to fiction, nonfiction, poetry, and drama
Sunshine State Standards - Social Studies	

	EXPLORATION D Animal Magnetism
National Science Education Standards	**A.** scientific inquiry and understandings about scientific inquiry **B.** properties and changes in matter, motions and forces, transfer of energy **C.** structure and function in living systems, reproduction and heredity, regulation and behavior, populations and ecosystems, diversity and adaptations of organisms **D.** structure of the earth system, Earth's history, earth in the solar system **G.** science as a human endeavor, nature of science, history of science
Sunshine State Standards - Science	**C.2.** understands that the types of force that act on an object and the effect of that force can be described, measured, and predicted **F.1.** describes patterns of structure and function in living things **F.2.** understands the process and importance of genetic diversity **G.1.** understands the competitive, interdependent, cyclic nature of living things in the environment **H.1.** uses the scientific processes and habits of mind to solve problems **H.3.** understands that science, technology, and society are interwoven and interdependent
Sunshine State Standards - Mathematics	
Sunshine State Standards - Language Arts	**A.1.** uses the reading process effectively **A.2.** constructs meaning from a wide range of texts **B.1.** uses writing processes effectively **C.3.** uses speaking strategies effectively **D.2.** understands the power of language **E.1.** understands the common features of a variety of literary forms **E.2.** responds critically to fiction, nonfiction, poetry, and drama
Sunshine State Standards - Social Studies	

	EXPLORATION E Practical Applications
National Science Education Standards	**A.** scientific inquiry and understandings about scientific inquiry **B.** properties and changes in matter, motions and forces, transfer of energy **C.** structure and function in living systems, reproduction and heredity, regulation and behavior, populations and ecosystems, diversity and adaptations of organisms **E.** abilities of technological design, understandings about science and technology **F.** personal health, populations, resources, and environments, natural hazards, risks and benefits, science and technology in society **G.** science as a human endeavor, nature of science, history of science
Sunshine State Standards - Science	**B.1.** recognizes that energy may be changed in form with varying efficiency **C.2.** understands that the types of force that act on an object and the effect of that force can be described, measured, and predicted **D.2.** understands the need for protection of the natural systems on Earth **G.2.** understands the consequences of using limited natural resources **H.1.** uses the scientific processes and habits of mind to solve problems **H.3.** understands that science, technology, and society are interwoven and interdependent
Sunshine State Standards - Mathematics	
Sunshine State Standards - Language Arts	**A.1.** uses the reading process effectively **A.2.** constructs meaning from a wide range of texts **B.1.** uses writing processes effectively **B.2.** writes to communicate ideas and information effectively **C.1.** uses listening strategies effectively **C.2.** uses viewing strategies effectively **C.3.** uses speaking strategies effectively **D.2.** understands the power of language **E.2.** responds critically to fiction, nonfiction, poetry, and drama
Sunshine State Standards - Social Studies	

Appendix A - Standards

Directions for Assembling the Magnetic Field Viewers

Assemble the Magnetic Field Viewers (MFV) well in advance of beginning Expeditions #3 & #4

You will need the following materials (all contained in your Alpha Pack) for each of the 9 MFVs that you assemble:

15 g (1 teaspoon) iron filings
1 plastic box
1 plastic sheet
glue

1. Measure the iron filings. This is important, because too many iron filings in the viewer will reduce the clarity of the images formed. If you use a spoon, make sure that it is an actual measuring spoon; other spoons vary greatly in their capacities.

2. Pour the iron filings into the frame. Apply a thin bead of glue along the open edge of the box. Place the plastic sheet over the opening of the frame, making sure that there are no gaps along the edges. Press gently together and let dry overnight.

Appendix B - Directions

Coloring the Blocks

In Expedition #8, the students will use wooden blocks to help them determine the position of the north and south poles of the wand magnet. **You will need to color the wood blocks prior to beginning the Expedition.** You have two choices to make regarding the colors of the blocks: all of the blocks can be colored the same color; or, all of the blocks in each group can be colored the same color, but each group can be a different color. Working alone, you can expect this task to take you 1-2 hours to complete.

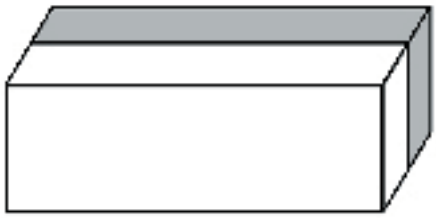
You will need the folowing materials:

54 wood blocks
permanent magic marker(s) or paint(s)
ruler

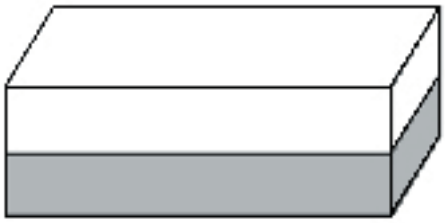
1. Separate the blocks into 3 groups of 18 blocks. You will color each group with a different pattern.

2. For the first group of blocks, use a ruler to draw lines dividing the blocks into two regions and then color in one half of the block, as shown below. All of the blocks in this group should be colored the same color.

3. For the next group of blocks, use a ruler to draw lines dividing the blocks into two regions and then color in one half of the block, as shown below. All of the blocks in this group should be colored the same color, although the color may be different from the first group.

4. For the last group o  ividing the blocks into two regions and then color in one All of the blocks in this group

should be colored the same color, although the color may be different from the other groups.



USE OF MAGNETS AND CARE OF ALPHA PACK MATERIALS

Magnets can cause problems if not handled and stored properly. You can prevent inconvenient and costly damage to computer equipment, TV's, VCR's, computer disks, compasses, videotapes, audio tapes, video cameras, and credit/debit cards by keeping all magnets at least 2 feet from these objects. Be especially careful not to carry magnets in a briefcase or tote if you are also carrying computer disks or credit cards -- the information on the disks and cards can be destroyed or distorted by the magnetic field.

To help you safeguard sensitive equipment in your classroom, a blackline master of a "Magnet Free Zone" warning has been included for you to copy and post on or near any object that you need to protect from a magnetic field. It is strongly recommended that you keep these signs posted for as long as you are using magnets in your classroom.

The magnets can affect the compasses included in the Alpha Pack. It would be best to store the compasses in a different location than the Alpha Pack (at least 2 feet away); if this is not possible, be sure to store all of the magnets on one side of the Pack, and the compasses on the other side.

Take care to keep the iron filings off the magnets -- they are very difficult to remove! If you find that you need to use the magnets and the iron filings at the same time, wrap the magnets in plastic wrap or baggies to keep the filings off the magnets.

APPENDIX C

ANNOTATED BIBLIOGRAPHY

"Anti-Matters." Earth, August 1995 (excerpt taken from Naked Earth: The New Geophysics by Shawna Vogel).

An eight-page article in a magazine devoted to earth science-related issues and research, it is an in-depth look at the earth's interior. Vogel suggests an upside-down version of mountains as a boundary between the outer core and mantle. How scientists work, the latest information about how geophysicists are exploring "inner space," and detailed data from latest seismic readings are included to support recent discoveries.

Asimov, I. "Buy Jupiter." In Fantastic Reading: Stories and Activities Grades 5-8. (1984). New York: Scott, Foresman, & Co. (ISBN 0-673-15936-1)

A short-short story in a collection of short science fiction, fantasy and horror stories that are accompanied by activities, the premise is that interplanetary exploration has taken a more economic turn. The planets are for sale and valued for position in the solar system as it relates to trade routes. Decision-making and the consequences of those decisions are explored.

Berton, P. (1993). Dr. Kane of the Arctic Seas. Toronto, Canada: McClelland & Stewart Inc. (ISBN 0-7710-1446-5)

This short nonfiction work written for teenage readers is an ideal one or two-sitting book to accompany the study of the Earth's magnetic and geographic poles. Kane was a self-promoter whose stories were read by both Amundsen and Peary, two later polar explorers.

Billings, C. W. (1991). Superconductivity: From Discovery to Breakthrough. New York: Cobblehill Books. (ISBN 0-525-65048-2)

Filled with photographs, this concise book on superconductivity traces the history of development of superconductors and describes some of their applications. Also included is information on how superconductors are made. Nobel Prize winners are mentioned and pictured.

Blishen, E. (Ed.). (1988). Science Fiction Stories. New York: Kingfisher Books. (ISBN 1-85697-889-3)

Twenty science fiction stories by well-known authors and written for young adult readers, this collection combines excerpts and adaptations from well-known works and stories originally printed elsewhere. Authors included are Jules Verne, H. G. Wells, Ursula LeGuin, Arthur C. Clarke, Isaac Asimov, and Ray Bradbury.

Bradbury, R. "A Sound of Thunder." In Bradbury: Classic Stories 1. (1990). New York: Bantam Books. (ISBN 0-553-28637-4) Also found in R is For Rocket.

An excellent example of four characteristics of science fiction (includes science fact, deals with human nature, tells a good story, and presents something strange and unusual), the story presents a look at the future and the past. Man's interference with matters he does not understand lead to a surprising future. Some students may be disturbed by the ending and may wish to discuss the story with others. This is an excellent lead-in for H. G. Wells' The Time Machine since it is a look at possible time travel.

Brennan, R. P. (1990). Levitating Trains and Kamikaze Genes. New York: John Wiley & Sons. (ISBN 0-471-07902-2)

A look at nine areas of technological development that have been, and will continue to be, areas of concern for the general public, not just scientists and students of science. This collection contains short essays on areas from genetic engineering to superconductivity. Controversial matters are clarified in easy-to-understand explanations.

Costello, M. J. (1992). How To Write Science Fiction. New York: Paragon House. (ISBN 1-55778-473-6)

Readable guide to writing the specific genre of science fiction that could be used for both adults and young adult readers. This is a step-by-step set of instructions with examples as experienced by a published science fiction writer. Costello looks at genres that relate to science fiction and are sometimes confused with it.

"Does the Sun Trigger Outbursts From Earth's Magnetosphere?" Science, Vol. 271, March 15, 1996.

An excellent resource to understand auroras, magnetic storms, and Earth's magnetosphere, this article is for sophisticated readers only. Students will need guidance to interpret and apply the information contained here.

Fisher, R. L. (1985). The Prince of Whales. New York: Tom Doherty Associates, Inc. (ISBN 0-812-56635-1)

A combination of fantasy and real-world application of environmental concerns, this

novel for young adult readers uses humor and drama to tell the story of an adolescent whale, Toby. His journey to find himself and to understand human whale hunters considers migratory patterns and different types of whales.

Flaste, R. (Ed.). (1991). The New York Times Book of Science Literacy. New York: Harper Perennial. (ISBN 0-06-097455-9)

New York Times editors and reporters deal with science issues ranging from astronomy to nuclear waste. Serious science and technology issues are discussed in ways that are easily understandable. This is the first of a two-volume set designed for nonscientists and based on articles published in "Science Times."

4 Rs Project. (1990). A Solid Waste Management Curriculum for Florida Schools. Tallahassee, FL: Florida Department of Education.

A set of materials representing interdisciplinary activities that span the K-12 levels. Activities are designed to increase awareness of the problem of solid waste worldwide but with specific references to the State of Florida. Consequences of not recycling and reusing are approached as well as solutions for the future.

Goodenough, J., McGuire, B., & Wallace, R. (1993). Perspectives on Animal Behavior. New York: John Wiley & Sons. (ISBN 0-471-53623-7)

A very detailed, comprehensive college text on animal behavior, this volume includes a good deal of animal physiology as well. It is recommended as a resource for life science links and was used to determine the ways in which various species use magnetism for migration, breeding, and navigation.

Haas, D. (1986). The Secret Life of Dilly McBean. New York: Bradbury Press. (ISBN 0-02-738200-1)

Dilly McBean was born with special powers: his hands are magnetic. The magnetism concepts used to support this young adult fiction novel are sound and may help some students to clarify what they are learning about magnets in the classroom. This is a lot of fun, includes mystery and suspense, and would be a perfect read-aloud book to generate class discussions.

Hemingway, E. (1964). "A Day's Wait" in The Snows of Kilimanjaro and Other Stories. New York: Charles Scribners' Sons. (ISBN 0-684-71807-3)

A young boy believes he is dying because he has not yet learned the difference between

body temperature expressed as degrees Fahrenheit and degrees Celsius. The story introduces students to one of America's most famous literary personalities through an age-appropriate short story. As students struggle with the concept of different temperature scales, this would be a relevant link between their science classroom and classic literature.

Herriot, J. (1972). All Creatures Great and Small. New York: Bantam Books. (ISBN 0-553-26812-0)

Herriot, J. (1973). All Things Bright and Beautiful. New York: Bantam Books. (ISBN 0-553-26970-4)

Herriot, J. (1976). All Things Wise and Wonderful. New York: Bantam Books. (ISBN 0-553-26605-5)

Herriot, J. (1992). Every Living Thing. New York: St. Martin's Press. (ISBN 0-312-95058-6)

Herriot, J. (1981). The Lord God Made Them All. New York: Bantam Books. (ISBN 0-553-26958-5)

James Herriot was an English country veterinarian who chronicled life for both human and other animals in his touching and humorous novels. His first book, All Creatures Great and Small is also the name of a long-running BBC series.

Hyerle, D. (1996). Visual Tools for Constructing Knowledge. Alexandria, VA: Association for Supervision and Curriculum Development. (ISBN 0-87120-266-2)

An excellent guide to different ways of organizing information. Brainstorming, webs, concept maps, organizers, thinking maps, and circle diagrams are described, illustrated, and examples of ways they can be used in a science classroom are provided. Rationale is giving for the use of visual tools in general and for the specific types contained in this ASCD-produced book.

Konigsberg, E. L. (1967). From the Mixed-up Files of Mrs. Basil E. Frankweiler. New York: Aladdin Paperbacks. (ISBN 0-689-71181-6)

This classic young reader novel is the story of two runaways that hide in the Metropolitan Museum of Art and solve a mystery involving a precious statue. The method the children use to research the statue, make and substantiate their hypothesis, and present their findings are similar to the ways in which we investigate phenomena in the science classroom.

Krauss, L. M. (1995). The Physics in Star Trek. New York: BasicBooks. (ISBN 0-465-00559-4)

For "Star Trek" fans, this book attempts to explain which scientific inventions and innovations are defensible based on the modern physics and which are pure fiction. Written not for students but for adults, parts of the book could be used with sophisticated readers but would be more suitable as a teacher resource. Phasers, beaming, warp speed, wormholes, and holodecks are explained in terms of physics as we know it today and possibilities for the future.

Langley, A. (1994). The great polar adventure: The journeys of Roald Amundsen. New York: Chelsea House Publishers. (ISBN 0-7910-2820-8)

This nicely-illustrated picture book provides visual as well as textual descriptions of exploration of the South Pole while including information about auroras, the Inuit, Robert Peary, the North Pole glaciers, and Antarctic wildlife. Although this appears elementary at first glance, it is suitable for middle school students either for reading aloud or keeping on the bookshelf.

Livingston, J. D. (1996.) Driving Force. Cambridge, MA: Harvard University Press. (ISBN 0-674-21645-8)

A comprehensive reference on magnets, magnetism, and related ideas, this book can be used to understand the basics or go beyond to an explanation of quantum electrodynamics. This resource links magnetism with all science disciplines as well as current issues related to magnetism such as health concerns and high voltage wires. Practical applications of magnetism are explained, as are the historical experiments upon which current magnet science is based.

Masters, A. (Ed.). (1994). Heroic Stories. New York: Kingfisher. (ISBN 1-85697-983-0)

A collection of true stories about a variety of people who exhibited courage under difficult circumstances. Tales range from Charles Lindbergh to Anne Frank and are told in various ways from autobiographical sketches to diary entries. Twenty-three stories are written for young adult readers including ones about Marie Curie and Captain Robert F. Scott, which are particularly suitable for this unit of study.

McAleer, N. (1992). Arthur C. Clarke: The Authorized Biography. Chicago, IL: Contemporary Books, Inc. (ISBN 0-8092-3720-2)

This excellent teacher resource could be used to introduce students to science fiction

writers in general and how Arthur C. Clarke specifically used real science in his writing. Although this is not written for young readers, excerpts could be read aloud as an example of a contemporary scientist and author's contributions to society.

Morpurgo, M. (1985). When the Whales Came. New York: Scholastic Inc. (ISBN 0-590-42912-4)

A fictional account of living on an island off Great Britain around World War I. Of particular interest will be the way the islanders deal with whale beaching. This relates particularly to the discussion of animal magnetism.

Odyssey Magazine. Cobblestone Publishing, 7 School Street, Peterborough, NH 03458.

Science-based, this is a publication with middle school students as its focus. The monthly magazine contains regular features as well as reporting on current science issues and research.

"Reinventing the Wheel." Autoweek, March 3, 1997.

This article deals with alternative energy sources for powering automobiles as well as scientific endeavor with real-world applications.

"Solar Cloud Hits Earth's Magnetosphere." Science News, Vol. 151, February 1, 1997.

Scholarly article on the most recent and most visible magnetic cloud activity. Explains how a solar cloud influences the earth's magnetosphere, how scientists gather this information, and what practical value this information has.

Stevenson, R. L. (1964). Treasure Island. New York: F. Watts.

The classic story of a boy's adventure with pirates searching for buried treasure can be used with Extensions dealing with measurement as well as geography.

Swift, J. (1996). Gulliver's Travels. New York: Pocket Books. (ISBN 0-671-00174-4)

Gulliver's account of a magnetic island and how it is manipulated by its inhabitants is an amusing way to discuss how magnetism affected early explorers and adventurers. Part III of the novel, published in 1726, tells in detail about the floating island Laputa.

Tesla, N. (1995). My Inventions. New York: Barnes and Noble Books. (ISBN 0-7607-

0085-0)

This is an edited collection of autobiographical magazine articles written by Tesla that clearly describe his inventions, how he thought of the idea for each invention, how he implemented his ideas. Tesla details his education and what it is like to be an inventor. Illustrations, photographs, and detailed diagrams of some inventions are included.

Vaughn, N. (1990). With Byrd at the Bottom of the World. New York: Macmillan/ McGraw-Hill. (ISBN 0-02-274969-1)

A first-person account of a young man who accompanied Admiral Byrd on the 1928-1930 expedition to the South Pole, this autobiographical work is written for young adult readers. Actual photographs lend to its appeal as entertaining nonfiction. This is a survival story as well as a firsthand look at a well-known explorer.

Verne, J. (1996). Paris in the Twentieth Century. New York: Random House. (ISBN 0-679-44434-3)

A recently discovered manuscript, this novel was first published in 1996, and reveals what Verne believed cities of the future would be like. It is a good accompaniment to his more well-known works such as Twenty Thousand Leagues Under the Sea or Journey to the Center of the Earth.

Verne, J. (1993). From the Earth to the Moon. New York: Bantam Books. (ISBN 0-553-21420-9)

Set in the Tampa, Florida area, this is an amusing novel that deals with Verne's vision of what space vehicles and space travel would be like in the future. The parallels between Verne's vision and actual rocket development are striking.

Verschuur, G. L. (1993). Hidden Attraction: The Mystery and History of Magnetism. Oxford University Press. (ISBN 0-19-510655-5)

An invaluable teacher resource on the history of magnetism, this volume also includes practical applications of magnets and magnetism as well as information on magnet science in general. It is a comprehensive reference guide for any teacher or student of magnetism.

Wells, H. G. (1995). The Time Machine. London: J. M. Dent. (ISBN 0-460-87735-6)

The classic story of a scientist who creates a time machine that enables him to visit both the past and the future.

Wells, H. G. "The Truth About Pyecraft." In Knight, D. F. (Ed.) (1973), The Golden

Road: Great Tales of Fantasy and the Supernatural. New York: Simon and Schuster.

A bizarre story about magic and mysticism that portrays a man who gets what he asks for but does not know the difference between mass and volume.

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