It's a Material World
A Project for First-Year Chemistry Class

Summer draft
Linda Ford, RET 2004

Teacher's Introduction

Recent advances in material science such as optical fibers, semiconductors, composite materials, and polymers and their impact on our lifestyles are provocative to the high school student and rich in connections to fundamental concepts within the first-year chemistry curriculum. Materials science is also multidisciplinary – bringing together chemistry, physics, engineering, medicine, and biology. It melds the four PR's: processing, principles, properties, and products. Details of the microstructure of these new materials that chemists find delightful lead to macroscopic properties that thrill the physicist and propel engineering breakthroughs forward. This project can be used in any high school physical science classroom in which the teacher wishes to open the door to new materials, nanotechnology, and technological advancement to her students. Materials science is really the study of solids and their properties. Technological advances (e.g. faster computers, better cell phones, smaller MP3 players) generally come about because of new materials. New material development relies on the understanding and exploration of properties, especially those involving nano- or microstructures. Magnetism is one of those properties. Recent advancements in magnetic materials are the focus of this project.

Why magnets? Before chemistry and physical science teachers dismiss this project as "for physics teachers only", please consider these points:

- Magnets have a long and colorful history that will hook students.
- Magnets have widespread usage in modern technological advancements. Devices important to students from personal computers to MP3 players to MRIs are loaded with a great variety of magnets.
- The improvement in magnets has skyrocketed since 1900 and is still on the fast track. These improvements involve important chemical concepts of atomic structure, classification of matter, crystals, the connection between chemical composition/ structure and properties, and the collaboration among scientific disciplines.
- Magnets are not intimidating to the students. They have played with magnetic toys since an early age and already are familiar with several basic magnetic facts from elementary school lessons. This familiarity invites further investigation.
- The power of magnetic fields that was once deeply hidden and often considered mysterious or magical can now be understood by the high school student.

Objectives

- Explore the ways in which processes of technological design respond to the needs of society.
- Establish the interdependence of science and technology; each drives the other.
- Trace the historical development of scientific ideas and emerging issues in materials science.

- Explain how variations in the arrangement and motion of atoms and molecules form the basis of a variety of physical properties.
- Improve students' Internet-based research capabilities.
- Strengthen students' organizational skills in reaching long-term goals.

This project makes heavy use of the material presented by James Livingston in his book, Driving Force. Although this material can be found in many other places, Livingston is an excellent read and will provide the teacher with a wonderful background before she begins this class project. As you look over the student group assignments, you might notice some overlap of topics. This is intentional. During the class presentations, overlapping discussion will help to reinforce important concepts and maximize understanding. Nine student group (2 to 3 students per group) assignments are presented. For a smaller class size, you might eliminate group 4 assignment. For larger class sizes, you could split group 9 into 2 groups. The groups should be given six weeks to accomplish the project. They should be kept on a well defined course of action.

Project Calendar

Week 1:

(a) Introduce material science and microstructure. Check "Exploring the Nanoworld" at http://mrsec.wisc.edu/edetc/ for good background. They have a short movie, "The Next Big Thing (Only Smaller)", that discusses what nanotechnology is as described by several scientists in the field. Be careful; it does give a pitch for study at the University of Wisconsin at the end.

(b) Explain the reasons for choosing magnetic materials as the project focus. Show a photo of a WWII vintage speaker (http://www.audioheritage.org/html/readers-photos/) as compared to the small speaker from a modern audio or computer system. Compare the magnetic field of a 1930's Alnico magnet to that of a 1983 neodymium magnet by picking up a string of stainless steel paperclips.

(c) Give group assignments. Be careful here! As you look over the assignments, you can see that they demand different talents and skills. For example, give assignment #1 to students who enjoy experimentation and have the patience and persistence to enjoy the assignment. Give assignment #3 to students who enjoy history and assignment #4 to artistically creative students. Assignments #2, 6, and 8 are more scientifically demanding; the students must be able to deal with new terms and concepts to feel successful. Assignments #5, 7, and 9 can be handled by students of varying capabilities.

(d) Explain clearly how you want them to report their resource list to you but definitely insist on this report. There is a lot of scientific junk on the Internet that you want them to avoid.

(e) Since many of the groups will be producing a Powerpoint presentation, it is important to know if they have knowledge of this software. This is a great time to establish collaboration with your technology instructors so that students can improve their computer skills as they learn about material science.

(f) Give the students a schedule for the project. It should include a weekly consultation with the teacher on the progress the group is making and the questions that they

have. Please see the teacher notes for the individual groups for additional ideas to incorporate into these weekly meetings.

Week 3:

(a) Require a halfway point accounting of progress. Make this a part (perhaps 20%) of your final grade assessment. This assessment should include the extent of the body of research as well as the generation of the finished project (video clips, art work, Powerpoint slides). You should plan to give both verbal and written comments on the work and suggestions for goals during the last 3 weeks of the project.

(b) Check the resources that have been used by the group. Redirect them to better resources if necessary.

Week 6:

(a) Plan a special day(s) for their presentations. If you are on the block schedule, the presentations can be completed on one day. If you are on a regular six to eight bell day, you will need two successive days for presentations. Consider serving simple refreshments such as juice and popcorn. Require the student audience to evaluate each project by providing an evaluation form of your design. The student evaluation should represent part (30%) of the final grade.

(b) Have an evaluation form for your own use. The rubric that you use for grading should be shared with the students early in the project. I suggest that you should show it to them during your first weekly meeting during week 2 of the project. Your evaluation should count for 50% of the final grade.

Teacher Notes for Individual Groups:

Group 1: The ten facts are listed on page 119 of the Livingston book. There are several magnet books available at the library; the Vecchione book is only a suggestion. You will need to have 2 good Alnico bar magnets, some neodymium magnets, a horseshoe magnet, refrigerator magnets, copper wire, iron nails, jumbo paper clips, batteries (or DC power supply), compass, steel needles, and iron filings available. The reason for videotaping the demos rather than presenting them “live” is that the audience will be able to view the video more clearly than a tabletop presentation. They can also replay a demo to help with questions.

Group 2: All of these terms are clearly explained in the Livingston book. Give the students the handouts on demonstrations of diamagnetism, eddy currents, and Curie temperature. They can photograph these demonstrations and incorporate the photos into their glossary. There are also several glossaries on the recommended websites.

Group 3: Some of the recommended websites include timelines. They could also use the book, Hidden Attraction, by Gerrit Verschuur for extensive historical background. Ask your school librarian to commit some budget money to enlarge the collection of magnetic resources.

Group 4: You may want to discuss copyright law with your school librarian so that you can advise the students on what they can and can not do with regard to creative property. There is great value in incorporating this group assignment into the project. It requires talents not often used in the science classroom, yet validates their importance to the whole experience. It encourages students to look at the use of science in the popular culture and encourages them to evaluate its accurate use.

Group 5: This is the "trivial pursuit" assignment. Perhaps you will have additional questions to add to the list. The answers to the nine questions presented are in the Livingston book but encourage students to search the Net for a deeper analysis and experience.

Group 6: Livingston gives a thorough and clear description of the microstructure and property differences between permanent and temporary magnetic materials in chapter 6. Give your students copies of this chapter to begin their work. Show them examples of different types of magnetic materials from your science department's collection. Give them devices and products purchased at the Goodwill Store or donated (they do not have to work!) and have them open them up and find the magnetic material. This is a challenging assignment; this group will need significant support and encouragement from you.

Group 7: Depending on class size, this group could be merged into group 6 because soft and hard materials are used in electromagnet design. Allow this group the opportunity to build electromagnets so that they have the tactile experience with the concepts that they are reading about. Encourage them to open up a device such as an electric bell or motor and find the electromagnet.

Group 8: Use your superconductivity kit to demonstrate the Meissner effect to your class. Allow this group to photograph the demonstration to use in their Powerpoint presentation. This assignment is also challenging but absolutely fascinating. The MRI connection is a great hook for students who have had the procedure done on them or a family member.

Group 9: Help the students to limit their focus. The number of uses is too vast to cover completely so they will have to select representative ones. Encourage them to explore how the use is directly connected to the development and properties of the various magnetic materials. Have them open up broken and discarded devices to find the magnets inside.

Student Group Assignment 1: Principles of Magnetism

You have been given a list of ten facts about magnetic behavior and a copy of Magnet Magic by Glen Vecchione. Your group task is to find and perform illustrative demonstrations for these ten facts. You should plan to videotape your demonstrations and then edited them into a short movie. To make your movie more interesting, you should consider using familiar materials and equipment such as refrigerator magnets (Why do they stick to the frig?) and incorporating some magic tricks that depend upon a magnetic field. Investigate historically important experiments such as the one performed by Hans Christian Oersted in 1820 and try to recreate it. Your teacher will provide your group with a nice selection of different size and type magnets as well as other materials. Become familiar with any safety precautions and material handling issues before you begin your experimental work.

Student Group Assignment 2: Magnetic Properties

Consider this list of properties and terms:

1. Saturation magnetization
2. Coercivity
3. Maximum energy product
4. Magnetic domains
5. Permeability
6. Hysteresis Loop
7. Eddy Currents
8. Ferromagnetism and Ferrimagnetism
9. Diamagnetism and paramagnetism
10. Magnetic anisotropy (isotropic vs. anisotropic)
11. Curie temperature

Your group task is to create a Powerpoint glossary that includes helpful photos, graphs, diagrams and dialogue.

Student Group Assignment 3: Timeline

Your group will create visually accurate and interesting timeline for either classroom or hallway display to show the long and colorful history of magnets. This timeline should include the important scientists, inventors, and engineers as well as the important discoveries, products, and applications. Include important related events as well. Plan to include these people, places, and things:
Robert Norman, William Gilbert, Captain James Cook, Carl Friedrich Gauss, Torben Bergman, Michael Faraday, James Clark Ross, Nikola Tesla, Pierre Curie, Heike Kamerlingh Onnes, Francis Bitter, Ernest Lawrence, Bell Laboratories, J. Georg Bednorz, Alex Muller, and the National High Magnetic Field Laboratory in Tallahassee, MRI, Maglev

You will be surprised how many entries can be included on your timeline! Notice the explosion of entries from 1900 forward. Include pictures and images! For example, how did developments in magnetic materials change the size and appearance of audio speakers, telephone receivers, and lawnmowers?

Student Group Assignment 4: Magnets in the Arts

Knowledge of magnetic interaction is documented in ancient Chinese, Greek and Roman literature. Your group task is to research the appearance of magnets in literature, film, music and stage performance through time and share your findings with your classmates. Here are some suggestions to help you begin:
The James Bond movie, “The Spy Who Loved Me”
A play by Ben Jonson, “The Magnetic Lady”
An operetta by Gilbert and Sullivan, “Patience” (Act II)
Jonathan Swift’s isle of Laputa in Gulliver’s Travels
Magneto in Marvel Comic’s X-Men
Chester Gould’s comic strip, “Dick Tracy”

Your group task is to bring these artistic and magnetic moments to life for your classmates. Be ready to explain the scientific principles behind the artistic references. In fact, concentrate on finding good examples of good science among the choices you make. Video and live performance and readings can be intermixed.

Student Group Assignment 5: Ferromagnetic Behavior

Here is a series of questions that you must research:

1. What are the nature, stability, and abundance of iron?
2. What do the units, gauss and tesla, measure?
3. What elements are ferromagnetic beside iron?
4. How strong is the Earth's magnetic field? How is it measure?
5. How can the Earth's magnetic field switch directions and how do we know that this change of direction has taken place?
6. What is the composition of lodestone? Where is it found? What were its early uses?
7. Are their other cosmic magnetic fields? How do they compare with the strength of the earth's magnetic field?
8. What is the origin of the word, magnet?
9. What is the origin of the word, mesmerize? (Check out Franz Anton Mesmer, 1774)

Your group task is to create an imaginative and informative Powerpoint presentation that reveals the answers to these questions. Feel free to shuffle the order of the questions to fit a logical sequence that you like.

Student Group Assignment 6: Permanent and Temporary Magnets

Your group will first want to research the differences in composition, structure, and properties between permanent and temporary magnets. You will want to read about the history of the development of various types of "hard" and "soft" materials used to make permanent and temporary magnets. You will read about cobalt-chromium steels, Alnico magnets, ferrites, neodymium-iron-boron magnets, permalloys, and amorphous alloys. Think about whether they are homogeneous or heterogeneous materials? Do they have large or small crystalline structure? How have the advances in processing new materials improved their usefulness and applications to new functions? This assignment is rich in all four areas of material science: processing, principles, properties, and products. You will also want to ask your teacher to show you some examples of the types included among the science department materials.

Your task will be to present your findings to your classmates in a well-organized and enlightening Powerpoint presentation.

Student Group Assignment 7: Electromagnets

What are the special features of an electromagnet? Investigate the history of the electromagnet and the relationship between electric and magnetic fields. You will want to explore these keywords: Bitter magnet, pulsed magnet, implosion technique, and hybrid magnet. You will also want to research some of the important uses of electromagnets. Where are they found in out modern day products? Check out linear motors used on new roller coasters such as the "Superman" at Six Flags Magic Mountain in Louisiana. Ask your teacher for the materials to build a simple electromagnet and explore the ways that you can create stronger magnetic fields.

Your task will be to present your findings to your classmates in a fascinating and accurate Powerpoint presentation.

Student Group Assignment 8: Superconductivity

Here are some questions to consider:

1. What is superconductivity? When you research the answer, pay attention to the history of the field.
2. What is the Meissner Effect?
3. What are the special properties of critical temperature, critical field, and critical current?
4. How does diamagnetism enter into the discussion of superconduction?
5. Investigate type I and type II superconductors. How are they different in microstructure? Which type is best for magnet applications and why?
6. What are the advantages and disadvantages of superconducting magnets when compared to other electromagnets like Bitter magnets?
7. What are some of the current applications of superconducting magnets? (Definitely check out NMR/MRI.)
8. What are some future applications for superconducting magnets?
9. What is the "hybrid" magnet?
10. How are fullerenes, nanotubes and other organics entering the discussion on superconduction?

Your group task is to demonstrate your expertise in this special field of magnets by creating an eyecatching and informative Powerpoint presentation for your classmates. The website http://superconductors.org/ is your place to start. The site is rich with information and links you to many other beneficial sites.

Student Group Assignment 9: Uses of Magnets

The uses of magnets are extensive in our modern technologies and processes as indicated by the lists below You will have to be selective in order to limit the scope of your final presentation to a reasonable size.

Products that contain magnets:

1. Motors/ generators
2. Speakers
3. Transformers
4. Magnetic tape for audio, video, and backup data storage and magnetic strips on ATM/credit cards
5. Picture tubes
6. Magnetic ball bearings in Ultracentrifuges
7. CD-ROM
8. Metal detectors

Investigate how the size, quality and function of these products have changed over time due to the improvements in the magnetic materials upon which they depend. You might try to answer the questions, "How many magnets are found in one automobile and what are their functions?" and "What is the magnetic strip on my ATM card actually doing?" The answers may surprise you!

Processes that depend on magnets:

1. Electronic article surveillance (EAS)
2. Magnetic prospecting using magnetic anomaly detector (MAD)
3. Study of sea floor spreading and continental drift (paleomagnetism)
4. High energy atomic particle collisions in the Large Hadron Collider at CERN
5. Maglev transportation
6. Magnetic resonance imaging (MRI)

Future Uses

1. Tokamak nuclear fusion reactors
2. Petaflop computers
3. High temperature superconducting (HTS) cables for electrical power grids
4. Magnetic launch systems for space probes
5. Smaller motors to power navy ships

As you develop your Powerpoint presentation, you will have to convey the wide scope of applications but then explore in depth only a few of greatest interest to you. Do not become overwhelmed! What you are experiencing as you explore this vast scope of application is the motivating factor for choosing magnetic materials for this class project.

Annotated Website List

http://superconductors.org/

This site is rich and provides great links to other important sites. When looking at superconducting materials, start here!

http://science.howstuffworks.com

This site does a wonderful job explaining the basics of magnets and electromagnets as well as many products that contain magnets from motors to MRI,s.

http://my.execpc.com/~hoadley/magindex.htm

Magnet Man (Rick Hoadley) is a great initial site to visit. He links you to sites on history, timeline information, glossary definitions, background concepts, magnet demonstrations, and magnet uses.

http://scitoys.com

This site will show several great demonstrations in hopes of selling you the materials needed for the demonstration. But it also explains the principles behind the demonstrations.

http://micro.magnet.fsu.edu/electromag/java/

Those of you working on magnetic principles, types of magnets, and magnet uses will find this a great site. It has wonderful graphics and explanation for the pulsed magnet, magnetic fields, speakers, transformers, NMR, and metal detectors, et al.

http://www.phy6.org/prospect.htm

Dr. David Stern, an emeritus physicist at Goddard Space Flight Center, has a wealth of information on the history, the Earth's magnetic field, and the principles of magnetism.

http://www.designchambers.com/electra/

View pictures of electric lawnmowers from the 1920's. Look at the size of the motors!

http://www.fancollectors.org/

View pictures of vintage electric fans and notice the change in motor size over the years.

http://www.hfml.sci.kun.nl/

The High Field Magnetic Laboratory at the University of Nijmegen has an extensive website that shows eyepopping images of magnetic levitation.

http://www.o-keating.com/hsr/mlx01.htm

Enjoy an excellent discussion of Maglev trains.

http://physicsweb.org/

This site provides articles on superconductors including new advances in the field.

http://capital2.capital.edu/admin-staff/dalthoff/lim.html

http://www.me.utexas.edu/~uer/roller/tech.html

http://www.sixflags.com/parks/magicmountain/Rides/superman.html

http://www.dcacentral.com/dca/california_adventure/paradise_pier/california_screamin.php

http://www.ultimaterollercoaster.com/coasters/yellowpages/coasters/cascream_dca.shtml

The five sites listed above discuss induction linear motors used on roller coasters.