FOURTEEN K-12 OUTREACH ACTIVITIES FOR MATERIALS SCIENTISTS AND ENGINEERS

Foreward

The activities described in this document were performed by volunteers from ASM International chapters as part of our volunteer leader training in 2007. The event took place in an elegant room with carpet, drapes, and wallpaper so heat treating was done in advance. A similar approach could be used to make the "heat treating" activities safe for younger students.

Please take the utmost care to consider safety aspects as you plan your outreach event. Safety glasses that fit over corrective lenses are needed for many of these activities, and you may have trouble finding them small enough to fit young students.

Many of the activities were gleaned from the ASM Materials Education Foundation's "Teachers Camp" curriculum and have been proven in classrooms. I'm particularly grateful to Debbie Goodwin (Master Teacher) and Matt Perricone for their contributions to this compilation, and to Dr. Kathy Hayrynen of the Detroit Chapter of ASM International for her ongoing contributions to ASM's outreach projects at many levels.

All of the experimental descriptions in this compilation are either free of copyright protection, or have been used in accordance with the use restrictions of the original source. Original sources for each activity have been noted in the appendices. Commercial sources for some supplies have been mentioned as a convenience, and are not an endorsement of the particular company by ASM International, The ASM Foundation, or me.

I hope you'll have as much fun sharing our profession with students and teachers as I do. We would like to gather additional activities to share with our colleagues—please send your ideas to the ASM Foundation. Foundation contact information can be found at www.asminternational.org

Peggy E. Jones, Ph.D.
Volunteer, ASM International

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TABLE 1: LIST OF ACTIVITIES AND SAFETY CONSIDERATIONS

APPENDICES: EXPERIMENTAL PROCEDURES

Table 1: List of Activities and Safety Considerations

APPENDIX	**TOPIC**	**SAFETY**
1	Crystal Structures Different Materials/Same Purpose Giving and Receiving Directions	No issues—toothpicks and marshmallows No issues—coffee cups are one way to demonstrate this concept Paper
2	Properties of Composites: fracture behavior of ice vs. newspaper reinforced ice	Safety glasses. Flying ice chips---may wish to do the hammering outside for easier cleanup.
3	"Who Stole My Dog?"—Middle school outreach activity at Sandia	Safety glasses
4	Oxidation: making handwarmers	Safety glasses. Reaction in sealed plastic bags with 25g of iron powder mixed with water, table salt, carbon, & vermiculite.
5	Heat Treating: comparing properties of bobby pins after various heat treating processes	Safety glasses are needed if you do the heat treating ahead of time. To do the entire experiment you need to account for use of a Bunsen burner or propane torch.

APPENDIX	**TOPIC**	**SAFETY**
6	Instant Snow—No law of "Conservation of Volume"	Can be slippery if spilled on the floor, same MSDS as the polymer in disposable diapers.
7	Shrink To Fit: Thermal stability of polymers	Toaster oven at 250F-need pot holders, tongs, supervision.
8	Work Hardening: Bending copper wires	Safety glasses for hammering wires.
9	Yield strength test for metals	None—measure weight needed to bend a wire so it stays deformed.
10	Thixotropy: Observe effect of shearing on flow properties by stirring catsup (applications to semisolid forming and forming plastics and ceramics)	None. Place small weights into a jar of catsup and measure how long it takes them to sink to the bottom before and after stirring. **VERY MESSY!**
11	Shape Memory	Hot water. Need hot water supply such as a good thermos or coffee pot.
12	Slime/Silly Putty	Wash hands after the experiment. Use Elmer's glue & borax option. Alt: Polyvinyl Alcohol (PVA) & borax kit from Fisher Scientific that's used in schools. PVA is the plastic bag around dishwasher tablets, and is used for laundry bags in hospitals.
13	Half Lives	None—M&M's in a box.
14	Microstructure-process-property relationships: Backpack Survivability Index of Snacks	Be sure your 3 point bending fixture is firmly anchored to the table, keep feet away from the "drop zone" under the specimen, don't burn yourself when making the specimens (rice crispy treats)

APPENDIX 1: Crystal Structures, Giving and Receiving Directions, and Different Materials for the Same Purpose—Why?

Bev Aikin, Los Alamos

Source: Bev Aikin

I have over 20 demos. A favorite with children (of all ages or with a sweet tooth) is Crystal Structures out of toothpicks & marshmallows. You can use colored mini-marshmallows to represent different atoms.

One of my favorites is the Balloon Rocket Pinwheel to study Newton's Laws of Motion (balloons, straight pins, pencils, tape, scissors).

Another favorite of mine is Giving/Receiving Directions, however this requires at least 4 participants and is best in front of a group (paper with trifold brochure design).

I also like doing one about Different Materials / Same Purpose, Why? (cups made out of different materials, materials property map poster).

I leverage other resources in the community (other technical societies, scout groups, high school AP courses, school teachers) to make a successful event.

Examples of Materials Property Maps (ASM Handbooks, Vol. 20—originally devised by Michael Ashby, Cambridge University. See for example: M.F. Ashby, *Material Selection in Mechanical Design*, Pergamon Press, 1992.)

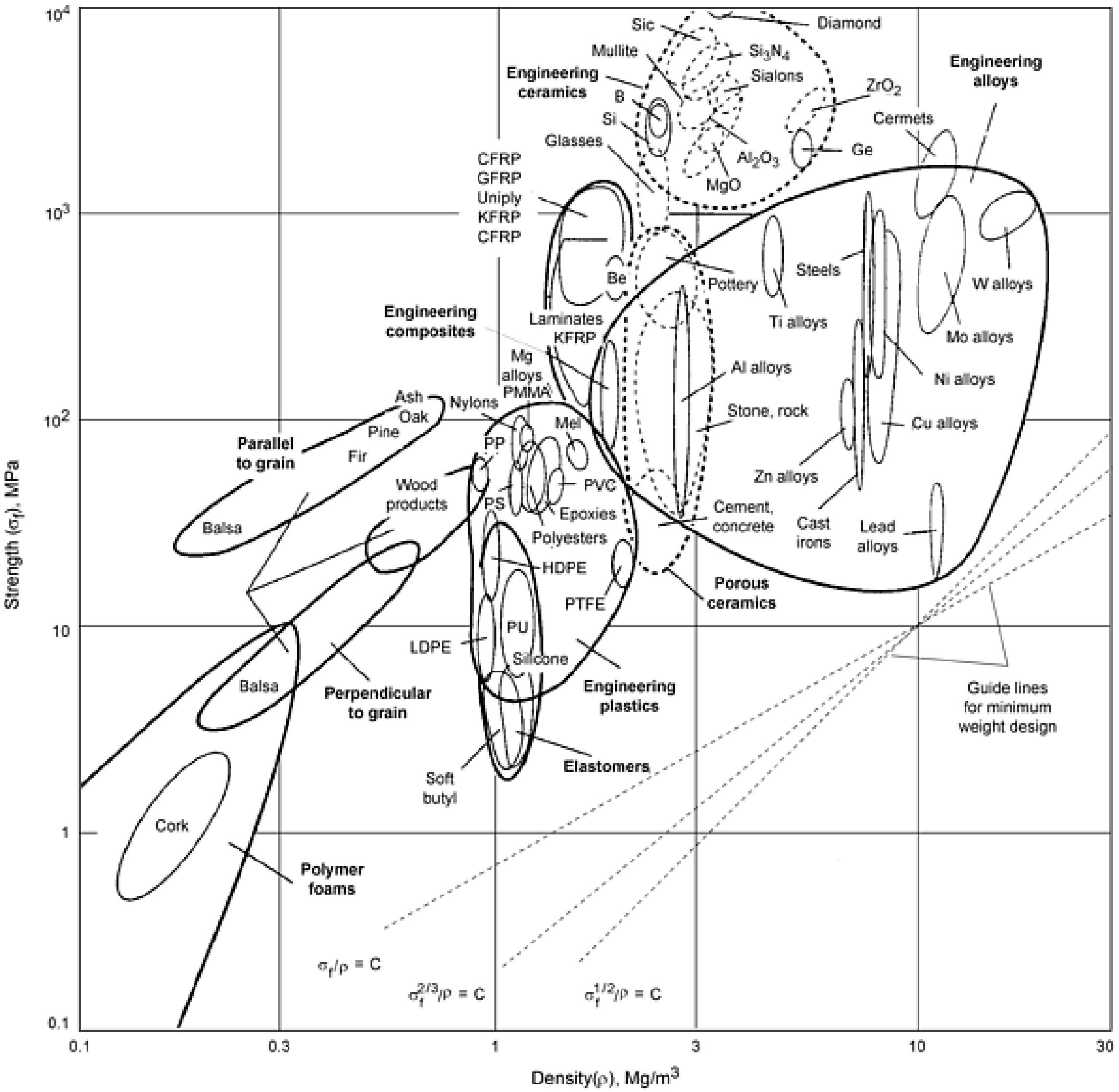


Figure 1: A "Material Property Map" showing how materials compare on the basis of their strength and density. Students may be interested in where sports equipment materials lie on the chart—lightweight bike frames, or new skis vs. their grandparents' skis. (Metals Handbook, Vol. 20, Materials Selection and Design, Material Property Charts, products.asminternational.org/hbk/do/section/content/V20/D00/A00/index.html.

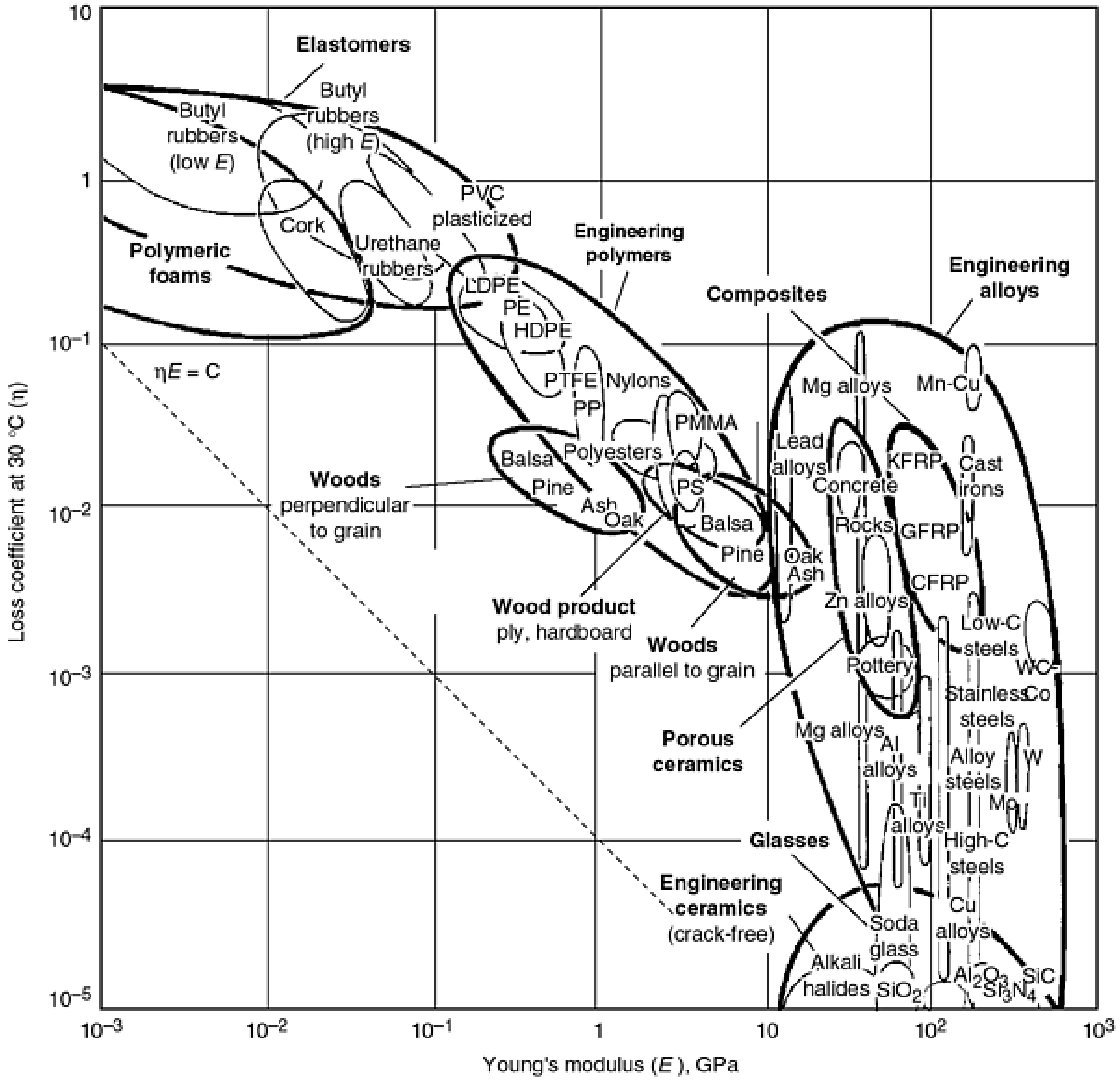


Figure 2: A material property map showing how the sound damping capability of materials goes down as their stiffness increases. Bells are often made from copper alloys because they ring for a long time. However, if you wanted to stop a noise quickly, you'd touch the bell to a piece of cork or rubber to absorb the sound energy. (Metals Handbook, Vol. 20, Materials Selection and Design, Material Property Charts, http://products.asminternational.org/hbk/do/section/content/V20/D00/A00/index.html)

APPENDIX 2:
PROPERTIES OF COMPOSITES

Composite Materials – Ice and Newspaper

Created by Matt Perricone while in the Lehigh Valley Chapter, ASM International
for student-run Materials Camp at Lehigh University
mperricone@rjlg.com

NOTE: A smaller scale version of this was offered by Debbie Goodwin from Chillicothe High School—freeze water, water with sawdust, and water with individually wet newspaper layers in small margarine tubs. Pop the samples out of the tubs and smash them against a wall with a hockey stick. Compare & contrast the fracture behaviors.

Objectives:

1. Demonstrate the concept of how composites can be made to behave differently than each material alone
2. Observe the force required to break each set of materials.
3. Observe is what manner the composites break.
4. Explain why each behaved differently.

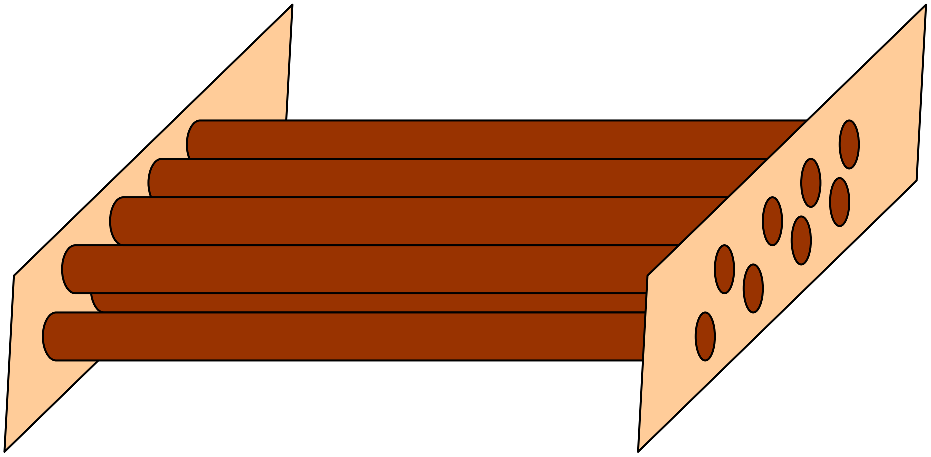
Supplies:

1. Minimum of 3 identically sized trays (minimum 2”-3” deep, minimum 8” x 10” size). Double this number if you want to go through the demo twice.
2. Wooden dowels cut to lengths equal to the mold length. Smallest diameter you can find (1/4” or less). If they aren’t easy to break by hand, they will be too strong for this demo. Plastic or PVC material is NOT an acceptable alternative due to differences in water interaction / load transfer.
3. Piece of cardboard adequate to cover the ends of 2 of the molds.
4. Screwdriver or knife
5. 2 copies of the local city newspaper (e.g., New York Times, Washington Post, etc.)
6. Scissors
7. Water
8. Freezer
9. Safety glasses for EVERYONE INCLUDING STUDENTS

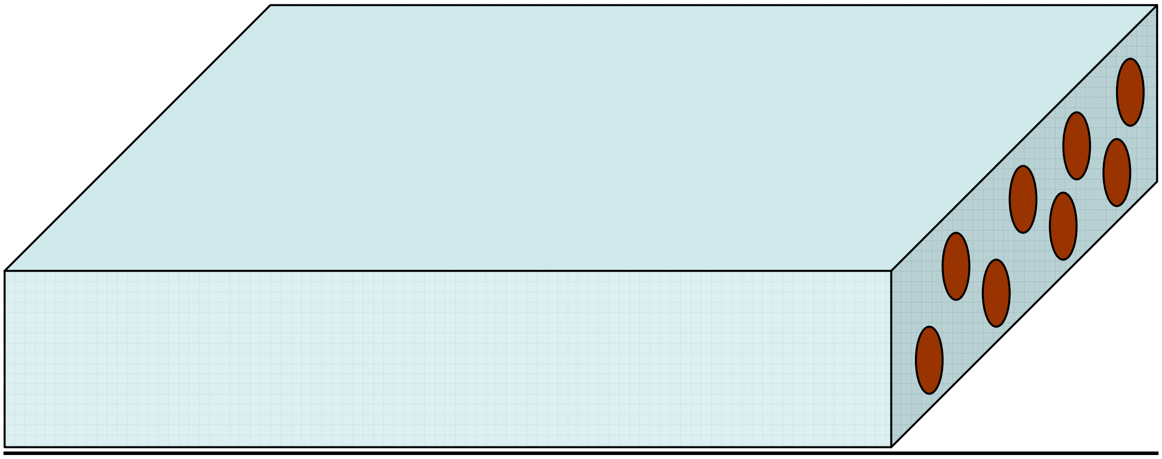
10. Thermally insulated gloves
11. Stand of some kind to set up testing station. (Think boards sitting on cement blocks to be split by karate chop)
12. Hammer (not a rubber mallet)
13. Towels, trash can, etc. Ice will fly everywhere and cleanup/dry-up will be necessary.

Set Up:

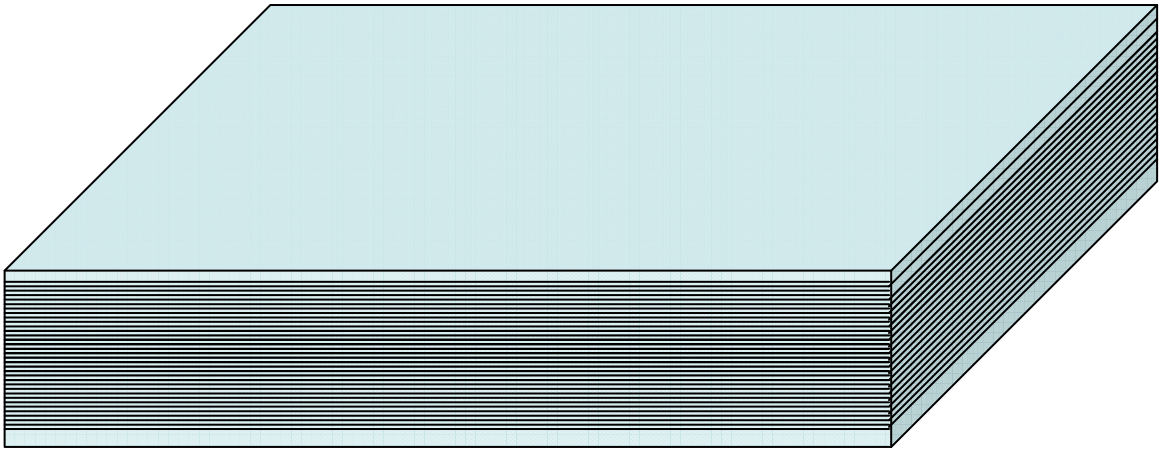
A total of 3 different ice castings will be made (6 if you want to do each twice). Fill one mold with water. Set aside. Cut cardboard to size such that one piece can be set at each end of the mold. Punch holes into the cardboard equal to the number of dowel sections available (use a minimum of 7 or 8) with relatively uniform spacing. Make sure the holes match up on each end of the mold. Insert dowels in holes as shown:



Place this assembly into the mold and fill with water. It should look like this:



Set aside. Take newspaper and cut into sheets of the length and width of the molds being used. You cannot add too much newspaper in this. A minumum of 50 sheets should be used. Add a little water to the bottom of the third mold. Start adding newspaper 1 SHEET AT A TIME. Make sure each piece gets wet. Gradually add water as needed until all 50 sheets have been placed into the mold and are covered in water. It should look something like this:



Take all three molds and place them in a freezer A MINIMUM OF 12 HOURS BEFORE DOING THE DEMONSTRATION. It does take this long and there is no good way to speed it up. Flash freezing through immersion in liquid nitrogen does not work. Be careful about burning out residential freezers by placing all three in at once. The thermal mass is significant enough to cause compressor issues. An industrial freezer should be acceptable. Don’t remove the cardboard on the dowel composite until after freezing.

Ice, Newspaper, Wooden Dowels:

Have the students break or tear each of these materials. For the ice, place the ice on the sample stand (2 concrete cinder blocks) and have students try to break it with a hammer. After 1 good hit, the ice should shatter. Which material is brittle? Which material is flexible? What can each material be used for?

Ice with Wooden Dowels:

Have a student try to break the ice/wooden dowel mixture. Have them note the difference in behavior. (More difficult to break, and when it does, the ice will generally break from around the dowels rather than shattering.) **REAL WORLD PARALLEL = Steel Reinforced Concrete**

Ice with Newspaper:

Have a student try to break the ice/newspaper mixture. Have them note the difference in behavior. (Extremely difficult to break, and when it does, it won't break completely but only where it is being struck with a hammer) **REAL WORLD PARALLEL = Circuit board materials**

OBSERVATIONS:

Specimen ID	**Condition Before Testing**	**Relative Effort Needed for Fracture**	**Fracture Characteristics**
Ice			
Ice + Wood			
Ice + Newspaper			

APPENDIX 3: Who Stole My Dog?

Source: Bernadette Hernandez-Sanchez, Albuquerque (Sandia), Extracted from Sandia Lab News, Vol. 59(4), Feb. 16, 2007, Sandia National Lab.

Hey, kid! You stole my dog!

How do you get kids excited about science? Tim Boyle and his team have perfected one way: Get the kids together in a lab and accuse them of stealing your dog. Then, using techniques you might see on a "CSI" TV program, lead the kids through a series of experiments using the scientific method to figure out who really stole the mutt. Read all about the program in Neal Singer's story on **page 12.**

AH, THE MAGIC OF SCIENCE — Liquid nitrogen freezes milk products into ice cream, its vapors providing excitement otherwise experienced only through Hollywood films and "haunted" houses on Halloween. The students here, from Bellehaven Elementary School, are participating in a "CSI"-type science lesson. (Photos by Randy Montoya)

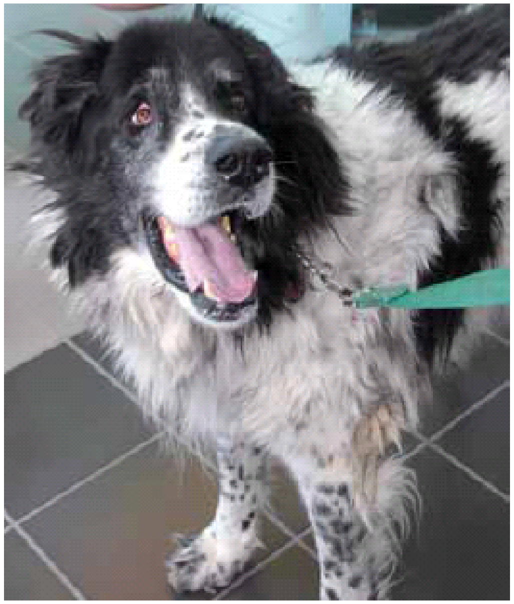
Workshop on stolen dog interests students in science

'CSI' — or its techniques — comes to Sandia, thanks to a team of dedicated volunteers

By Neal Singer

Adults wonder how to get kids interested in science. One way, Tim Boyle (1815) and his volunteers have found, is to collect them in a room and accuse them of stealing your dog. You have their immediate, undivided attention. Then teach the students to use science to find who really did the deed.

While the approach is not systematic teaching but merely the arousal of interest in scientific techniques, it is still somewhat stunning to experience the effect achieved by Boyle's group, one classroom at a time. There's nothing grandiose about it. They won't save the world and certainly won't get rich. But Thursday morning two weeks ago, 25 fifth graders from Bellehaven Elementary School came into an impromptu classroom — the meeting room in the Advanced Materials Laboratory on University Blvd. — sat down on the wall-to-wall rug, and learned that Tim's dog Beaux — yes, Beaux the Magic Chemistry Dog — had been dognapped. And that Tim thinks one of the kids sitting in front of him took his pet. And Tim isn't going to do the purported chemistry magic show until his dog is found.



"I'M SOOO GLAD TO BE BACK" — Beaux, the Magic Chemistry Dog, ready for action after being released by his dognapper.

Who'd do such a thing?

Of course it's all in fun. The kids laugh and protest. They have their teacher Ms. Jewell and a few parents in the room for backup; they're not scared.

Tim says he can't believe any of the adults who work in the building would do such a thing. But wait, he says: He has a fingerprint he believes was left by the perpetrator. He challenges the kids to take a fingerprint test. Interested, they agree. Led by Tim's assistant and event manager, postdoc Bernadette Hernandez-Sanchez (1815), the volunteer staff provide each kid a pencil to blacken a square on a piece of paper. The kids press their finger on the blackness, place a piece of Scotch tape over their fingertips, and press that tape onto another piece of paper. Presto, each child has created a fingerprint.

The game is afoot.

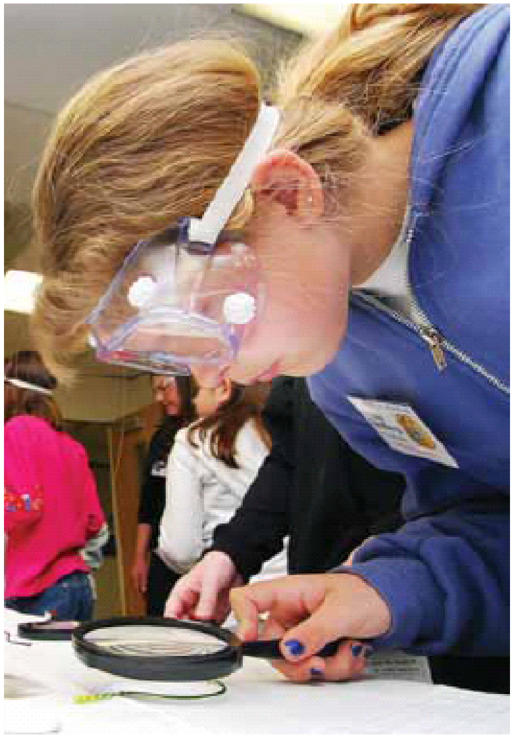
Tim and his assistants — drawn from a pool of more than 60 willing volunteers internal and external to Sandia — project images on a screen to show how to match one set to another — the whorls, the dips, and other patterns. Do any of the students' prints resemble that of the perpetrator? No? Then who stole the dog?

And now the kids are off, involved in a game in which there is no competition to be best of show, as in science fairs, or the best at solving problems in a particular field for a competition. What they are going to experience — fully — and only — is using science to find the answer to a problem that interests them.

Why? "Fourth grade, fifth grade is where kids make their career choices," Tim tells the *Lab News.* "They say, 'Oh, I can't do math or chemistry,' and they're gone forever. Here, at a crucial moment in their lives, they get a chance to see that science is useful and fun. And that they're good at it."

For Galileo, it was inclined planes. For James Clerk Maxwell, it was wires, electricity, and magnetism. For Tim, it was fireworks and how they produced the varied colors of their displays. For these kids, still very young, Tim and his staff create an artificial interest, a la the TV program "CSI," which uses intensive scientific investigation to solve crimes. Tim credits Bernadette, along with Sandia student intern Christina Baros (1815) and Saskia King (2701), for first creating a "CSI"-type program used by Sandia's outreach MANOS program for middle school students, and then helping modify the program for elementary grades.

(Continued on page 9)



SHERLOCK HOLMES, STEP ASIDE — This young sleuth examines nylon fiber evidence left at the crime scene.

Stolen dog

(Continued from page 12)

Tim shows pictures of four adults on a wall screen. These are the only people who were in the building at the time of the 'nap. One was the elementary school principal, Ms. Hamilton.

"That's her!" the kids say excitedly. "She's guilty!" It didn't help Hamilton's credibility to be the only suspect portrayed with a skeleton standing behind her.

RIVETED BY THE EMERGING TRUTH, but not blinded by the light or chemicals, because safety goggles were provided by the Sandia team, two young girls enjoy watching another clue analyzed in tracking Beaux's nefarious kidnapper.

"So, you think you can tell from a picture who's guilty?" says Tim.

Energetic but indecisive

Now he shows a description of the habits of the four suspects. Some like dogs, some don't. Some like ice cream, some lemonade. Some wear lab coats, some do not. The kids vote for guilt by a show of hands. They are energetic but, as a group, now indecisive.

Tim, sitting in the back of the room, raises his hand for each suspect, and Bernadette calls him on it.

"To me, everyone's guilty," he says, "until we prove otherwise." Dressed in jeans and running shoes, a Spy-vs.-Spy T-shirt visible under his black corduroy jacket, with dark shades and thick dark hair combed forward over his forehead, he could be a walk-on scientist on the mathematically oriented "Numb3rs" TV crime show.

"So, from habits and appearances, you can't tell?" says Tim. "Okay, let's do some science."

The kids, aided by Bernadette and other volunteers, inspect the "crime scene" — a collection of objects that seem to have nothing visually to do with each other, side by side: purple-colored water, the ransom note — "I have your dog! If you want to see him again, then you have to take Beaux out of the chemistry magic show" — a white spilled liquid, other oddities. "What do you see that's strange, that's a little unusual?" Tim asks.

"Purple water, right? What is that and why is it there? Is there anything that could lead us to the dognapper?" He points out other tiny bits of material that look as though they weren't part of the original décor of the office.

Now the kids are broken up into groups. Each goes to a table where they watch or perform a particular kind of analysis. A pH test determines that one liquid found in a cup was acid-based, suggesting a drink enjoyed by two of the suspects. A chromatological ink analysis finds the ransom note was written by a gel pen. "Who uses a gel pen?" A nanotechnology lab (which takes some explaining) finds that nanoparticles of gold, treated with certain solvents, becomes purple in the water. "Who among the suspects do we know was working with gold nanoparticles?"

At the end of the analysis, the kids file back into the conference room, sit back on the floor, and line up suspects and attributes with analysis of the clues.

"We match the evidence to the suspects," says Tim.

The guilty party, as portrayed unassailably or at least most probably by science was big, ostensibly friendly and even fatherly-appearing manager Bill Hammetter (1815).

"Give it up, Bill," says one kid's voice.

"Why'd you do it, Bill?" the others shout.

"I wanted Beaux to be my dog and I wanted my cat to be used in the show," Bill confesses as he returns Beaux to the room.

The kids go off to celebrate the successful solution of the case by creating liquid-nitrogen-cooled ice cream.

Having fun, learning about science

The show has hidden costs. Someone needs to pay for a school bus to transport the kids and substitute teachers to stay with the kids who, for one reason or another, can't come. There are supplies.

Tim and Co. figure they can handle the fourth and fifth graders from two schools in a week during winter break, and the same in spring. That means the team can excite kids in four schools a year. Tim tells the kids they can use science in jobs like engineering and chemistry and even firefighting. He keeps statistics on many positive results arising from the three-hour event — more students turned on to science; teachers, administrators, parents all happy with the project and more aware of Sandia; the possibility of a larger student base for Sandia among local students over the years.

But Tim needs a grant to continue this effective program.

Can he get it? He doesn't have the buzzwords; he doesn't mention "strengthening the syllabus" or "fortifying the science experience."

The kids are just having fun learning about science. And, oh, yes, finding Beaux, the Magic Chemistry Dog.

MILK OR GLUE? Forbidden to touch or smell a white liquid found at the crime scene, two students use plastic pipettes to add soap to their samples. Soap separates milk fat to form a mobile rainbow; glue does not react. The criminal apparently likes ice cream.

Who helped find Tim's dog?

All individuals are in Dept. 1815 unless otherwise noted.

- **NanoRoom:** Bernadette Hernandez-Sanchez (postdoc), Marlene Chavez
- **Spill Analysis — pH of Spill:** Diane Dickey (UNM postdoc), Malynda Aragon (6316)
- **Spill Analysis-Indicators:** Troy Russell*, Eric Branson
- **Ink Analysis:** Leigh Anna Ottley*, Rebecca Raymond*
- **Fiber Analysis:** Christina Baros*, Geoffery Brenneca (1816, postdoc)
- **Secret Messages:** Timothy Lambert, Sean Winters (1820)
- **Ceramics Engineering-Robocasting:** John Stuecker
- **Liquid Nitrogen Ice Cream:** Scarlet

Sandia singers enliven the Pit

APPENDIX 4: OXIDATION OF METALS (HANDWARMERS)

Source: http://matse1.mse.uiuc.edu/metals/e.html

Chemical Hand Warmer

Oxidation of a Metal

Objective:

The objective of this lab is to observe the heat energy that is given off during the oxidation of iron.

Review of Scientific Principles:

When a reaction is endothermic (absorbs energy - heat) in one direction, such as the reduction of iron oxide to elemental iron, it will be exothermic (give off energy) in the reverse direction, the oxidation of elemental iron back to iron oxide.

Applications:

Converting iron ore (iron oxide) to iron in the blast furnace requires tremendous amounts of heat energy. When iron spontaneously oxidizes back to iron oxide (rust) in the air the heat released is not noticeable. When this reaction is sped up, the amount of heat is noticeable and usable in the form of a hand-warmer.

Time: 20 minutes

Materials and Supplies:

25 g Iron powder

1 g sodium chloride (table salt)

1 Tbs. small vermiculite (might try sand)

1 Tbs. Pulverized activated charcoal—used for fish aquarium filters.

5 ml Water

Plastic bag with a seal

General Safety Guidelines:

- Avoid burns from the warm chemicals.
- Use normal precautions for a laboratory experiment.

Procedure:

1. Mass 25 g of iron powder or very fine iron filings and 1 g of sodium chloride. Place these in a small plastic bag. Shake the bag to mix.
2. Add about a tablespoon of vermiculite and a tablespoon of charcoal to the bag and shake well.
3. Add 5 ml of water, and seal the bag with plenty of air in it. Shake it. The reaction will start after about a minute.

Questions:

1. The individual commercial sporting goods store hand warmers are purchased in a plastic bag. Inside the plastic bag is a cloth-like polypropylene bag. The directions state that the plastic bags should not be removed until you are ready to activate the hand warmer. Why should the plastic bag not be removed?

2. In this reaction, iron metal was oxidized to form iron (III) oxide and heat was released. Mills that reduce ores to metals take a large amount of energy to form metals. Explain why the second process requires so much energy.

Teacher Notes:

- You might want to bring in a commercial hand warmer to show the students.

Answers to Questions:

1. The plastic bag keeps humidity (moisture) away from the chemicals until they are ready to be activated.

2. The reaction to form elemental iron from iron (III) oxide is very endothermic.

APPENDIX 5: Effect of heat treatment on bobby pins

Source: http://matse1.mse.uiuc.edu/metals/e.html, Experiment #3 Part II in the Metals module.

Objective:

The objective of this lab is to demonstrate the effect of cold-working (strain-hardening) and annealing on the ability of wires of the same metal to support a load.

Review of Scientific Principles:

Because plastic deformation results from the movement of dislocations, metals can be strengthened by preventing this motion. When a metal is deformed, new dislocations are produced. As dislocations are generated and move, the metal can be bent or shaped without cracking. As the number of dislocations in the crystal increases, they will get tangled or pinned and will not be able to move. This will strengthen the metal, making it harder to deform. When this is done at or near room temperature, the process is known as cold-working. When cold-worked metals are annealed (heated gently), new grains form from the cold worked structure and grow until they replace it with new, soft crystals. Steels (alloys of iron with up to 1% carbon) can also be hardened by heating and quenching. At high temperatures (red hot), iron has an FCC structure which can dissolve carbon. At low temperature, the iron changes to BCC which cannot dissolve carbon, so it precipitates as an iron-carbon compound. If quenched, this compound does not have time to form, the carbon is trapped and distorts the BCC crystal structure to create a new, hard and brittle structure called Martensite. If Martensite is gently heated, the carbon can precipitate giving a strong, tough structure.

Applications:

The properties of metals can be altered by processing. Since the properties of a material are dependent upon its structure on the atomic level, altering its structure should alter its properties. Common treatments include cold-working and heat treating.

Time: 50 minutes, part II

Materials and Supplies:

Bunsen burner and tongs

high carbon steel wire or bobby pins

Wire gauze

Safety Glasses

General Safety Guidelines:

- Take precautions to avoid burns when using the Bunsen burner to heat the metal.
- Wear safety glasses.

Procedure (Part II):

1. Obtain 7 samples each of high carbon steel wire (bobby-pins)
2. Bend one of the wires until it breaks. Count and record the number of bends needed to break the wire.
3. Heat the second and third steel wires in the middle until they are red hot. Let them cool slowly in air.
4. When the wires are cool, bend one of them back and forth as before. Count and record the number of bends needed to break this heat treated wire. Label and save the other wire for later.
5. Fill the beaker with cold water.
6. Heat the fourth and fifth wires in the flame until they are red hot and immediately plunge it into the water in the beaker.
7. When the wires are cool, bend one of them as before and record the number of bends needed to break it. Label and save the other.
8. Heat and quench the last two wires as in procedure 6. Heat them again but cool them slowly in air. *(Will do in advance.)* This process is called tempering. As before, note the properties of the tempered wire. Label and save one.

Questions:

1. In Part II, procedure 2, how many bends were required to break the wire? Did it break easily? Briefly describe the mechanical properties for this sample.

2. What term describes the heat treating method used in Part II, procedure 3 (heating, slow cooling)?

3. In Part II, procedure 4, how many bends were required to break the wire? Did it break easily? Briefly describe the mechanical properties for this sample.

4. What is cooling the hot metal rapidly as in Part II, procedure 6 called?

5. In Part II, procedure 7, how many bends were required to break the wire? Did it break easily? Briefly describe the mechanical properties for this sample.

6. In Part II, procedure 8, what were the properties of the tempered wire?

Teacher Notes:

- Processing metals with heat followed by quenching and cold-working should harden them. However, strong heating and quenching will only affect steel. Some aluminum is precipitation hardened with small amounts of copper. Heating these alloys strongly will soften them by causing the copper to form large precipitate particles which have little hardening effect. Most aluminum wire, however, is soft.

Answers to Questions:

1. Answers will vary. The unworked wires should be easier to bend and bend more times before breaking.

2. Annealing.

3. Annealing the wires should soften the metal allowing it to bend more easily and more times before breaking.

4. Quenching.

5. The quenched wires should be harder and bend fewer times before breaking.

6. The tempered wire should bend more times than the quenched wire did before breaking.

Appendix 6: Instant Snow

Source: ASM Foundation Teachers Camp notebook, www.teachersource.com

Instant Snow Polymer – put food coloring in the water to see if it's absorbed into the polymer or not.

> When this granular white powder is added to water, it instantly expands to 40 times its original volume, producing a snow-like material. Great for showing that there is No Law of Conservation of Volume! This artificial "snow" is fluffy and can be readily poured. When wet, it adheres well to boots and is very slippery. It was used in Steven Spielberg's mini-series, Band of Brothers and is becoming popular as an artificial base for skiers. It even can be used to turn white wine into snow ... hmmm! You can carry almost two cubic meters of snow in your briefcase; just add water! Its MSDS is the same as for sodium polyacrylate, the 'diaper' polymer! This is a great demonstration of interest to students and educators of ALL ages and abilities. *We reserve the right to limit quantities.*

GB-300 Instant Snow Polymer 100g (1/5 lb) - **$8.95** - Add ☐ to cart.

GB-315 Instant Snow Polymer 454 g (1 lb) - **$24.95** - Add ☐ to cart.
GB-320 Instant Snow Polymer 2270 g (5 lb package) (We reserve the right to limit quantities) - **$99.95** - Add ☐ to cart.

Appendix 7: Shrink To Fit

Source: ASM Foundation Teachers Camp notebook

Thermal stability of polymers

Objective:

The primary objective of this lab is to observe the effect of heat on thermoplastic polymers. It is also useful for reinforcing math concepts, and demonstrating polymer forming. By varying the types of polymers you expose to heat, you can see differences in behavior of thermoset and thermoplastic materials, as well as differences between various thermoplastics.

Review of Scientific Principles:

Exposing a polymer to heat allows the molecules to realign, and can increase cross linking.

Applications:

Shrink wrap, shrink fit tubes, reverse engineering perform shapes from final product, detecting texture in molded materials.

Time: 10 minutes for the quick version, two class periods for the deluxe Teachers Camp version.

Materials and Supplies:

(Clean) Plastic food containers such as water bottles, salad bar containers, and small polystyrene plastic cups.

Scissors

Charpy Markers

Ruler

Toaster Oven with cookie sheet, set for <250F.

Aluminum Foil

Tongs or spatula to handle the specimens.

General Safety Guidelines:

- Avoid burns from the oven and hot samples.
- Use normal precautions for a laboratory experiment.

Procedure:

1. Cover the cookie sheet with Al foil for easy cleanup.
2. Cut samples out of the food containers, or use whole plastic cups. Samples cut longitudinally, diagonally, and along the circumference of the water bottles are interesting.
3. Measure the starting dimensions of your samples. You may want to mark a 1 or 2 cm. distance on a sample and measure it after shrinking. If you have different polymers (recycling code numbers), cut samples of equal size and mark them with the recycling code using the Charpy marker. Save a control sample from each type of polymer.
4. Place the samples in the toaster and observe their response to heat for 2-5 minutes.
5. Remove from the oven and cool.
6. Compare the size and flexibility of the heated samples to the control sample. If you tested two different types of polymers, did they have the same response to the heat?

Deluxe: Calculate the starting dimensions for a key chain you make by decorating a thermoplastic with Charpy markers, punching a hole in the center, and shrinking it. The students determine the shrink factor on the first day, cut and decorate their key chain at home, then bring it for the shrinking treatment on the second day.

Appendix 8: Work Hardening Copper Wires

Source: http://matse1.mse.uiuc.edu/metals/e.html, Experiment 3, Part I in the Metals Module

Objective:

The objective of this lab is to demonstrate the effect of cold-working (strain-hardening) and annealing on the ability of wires of the same metal to support a load.

Review of Scientific Principles:

Because plastic deformation results from the movement of dislocations, metals can be strengthened by preventing this motion. When a metal is deformed, new dislocations are produced. As dislocations are generated and move, the metal can be bent or shaped without cracking. As the number of dislocations in the crystal increases, they will get tangled or pinned and will not be able to move. This will strengthen the metal, making it harder to deform. When this is done at or near room temperature, the process is known as cold-working. When cold-worked metals are annealed (heated gently), new grains form from the cold worked structure and grow until they replace it with new, soft crystals. Steels (alloys of iron with up to 1% carbon) can also be hardened by heating and quenching. At high temperatures (red hot), iron has an FCC structure which can dissolve carbon. At low temperature, the iron changes to BCC which cannot dissolve carbon, so it precipitates as an iron-carbon compound. If quenched, this compound does not have time to form, the carbon is trapped and distorts the BCC crystal structure to create a new, hard and brittle structure called Martensite. If Martensite is gently heated, the carbon can precipitate giving a strong, tough structure.

Applications:

The properties of metals can be altered by processing. Since the properties of a material are dependent upon its structure on the atomic level, altering its structure should alter its properties. Common treatments include cold-working and heat treating.

Time: 50 minutes, part I;

Materials and Supplies:

Hammer

Bunsen burner and tongs

16 or 18 gauge solid wire of copper (or aluminum)

16 or 18 gauge solid wire of other metals

high carbon steel wire or bobby pins

Pair of 3" C-clamps (or other size if 3" not available)

Wire gauze

Safety glasses

General Safety Guidelines:

- Take precautions to avoid burns when using the Bunsen burner to heat the metal.
- Make sure all fingers are out of the way when hammering the wires.

Procedure (Part I):

1. Hammer one of the pieces of copper wire until it is about half its original thickness.
2. Bend it and the other piece of wire back and forth several times. Observe.
3. Heat the flattened (work hardened) piece of copper in the burner flame until red hot.
4. Let it cool slowly on the wire gauze.
5. Label and save for experiment 4.
6. Repeat procedures 1 - 5 for the other wires.
7. Label and save the wires for later.

Procedure (Part III):

1. Using a pair of 3" C-clamps attached to the ends of the wire stretch a section of annealed copper wire by 5% and another by 10%.
2. Repeat for the other metal wires.
3. Save these wires also for Experiment 4.

Questions:

1. What is the hammering in Part I, procedure 1 called?

2. In Part I, procedure 2, what did you observe about the ease of bending for each wire? Why were they different?

Teacher Notes:

- You might have good success in stretching the wire if you wrap the ends of the wire around the treads of the C-clamp and then tighten the clamp on the ends of the wire.
- A convenient way to stretch the right amount is to mark a 10 cm section of wire with a dark colored marker. Then you can easily measure the amount of stretch between the marks (1 cm increase = 10%). Make sure the students understand that this is another way to cold-work metals.
- Processing metals with heat followed by quenching and cold-working should harden them. However, strong heating and quenching will only affect steel. Some aluminum is precipitate hardened with small amounts of copper. Heating these alloys strongly will soften them by causing the copper to form large precipitate particles which have little hardening effect. Most aluminum wire, however, is soft.

Answers to Questions:

1. Cold-working.

2. The hammered wire was harder to bend, but broke more easily. The hammering produced many dislocations which became tangled, inhibiting the sliding of planes of atoms.

Appendix 9: Yield Strength Tests

Source: http://matse1.mse.uiuc.edu/metals/e.htm, Experiment 4 in the Metals Module

Stretching Wires

Tensile Yield Strength Test for Various Metals

Objective:

The objective of this experiment is to demonstrate the elastic and plastic properties of metals.

Time: 50 minutes

Review of Scientific Principles:

Wires of the same gauge, but made of different metals typically support different loads (masses) before going through the point at which they change from being elastic to being plastic. Elastic deformation is recoverable after the load is removed. Plastic deformation is not recoverable.

Applications:

In order to use metals in particular applications, it is sometimes necessary to know their tensile strength. To avoid failure, the right metal must be used.

Materials and Supplies:

15 to 20 cm long pieces of 16 or 18 gauge wire of copper, aluminum, steel, etc.

wires saved from experiment 3

ring stand

adjustable single-burette clamp

meter stick

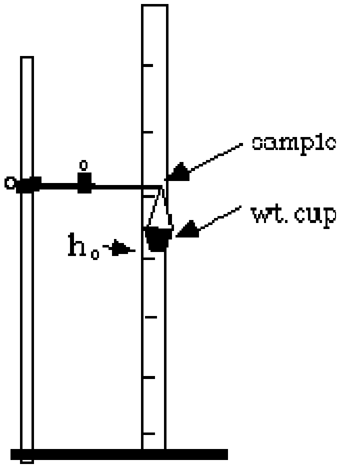
small paper cup (a 1-oz) paper cup works well)

variable masses (lead shot or small ring-washers)

Procedure:

1. Clamp the solid copper wire in the clamp and attach the small cup to the end of the metal wire. See diagram of setup.
2. Adjust the wire so it extends horizontally about 8 to 10 cm beyond the edge of the clamp.
3. Measure the height of the end of the wire above the surface of the work area. This height, ho, will be your reference height.
4. Carefully place 3 small washers (approximately 3 g) into the cup and again measure the height of the end of the metal wire above the surface of the work area. Record this mass and the new height.
5. Using your hand, gently support the cup and show the students how to check to see that the wire returns to approximately its original height, ho.
6. Continue increasing the mass in the cup by 3 washers at a time, recording both the mass in the cup and the height of the end of the wire above the surface of the work area, until the wire no longer returns to approximately ho. Record this value of mass. We shall refer to this maximum number of washers (mass) that the wire can elasticity support as its critical number, Wc.
7. Now take 3 or 4 more sets of data on this wire after straightening it.
8. Replace the original copper wire with annealed copper wire of the same gauge.
9. Replace the annealed copper wire with the piece of copper wire that has been annealed and then stretched (cold-worked) by 10%.
10. Repeat procedures 1-8 above for the other wires, time permitting. Be sure the distance from the clamp to the point where the weights are attached is the same for the annealed wire as it was for the original wire.

Diagram of Set-up:

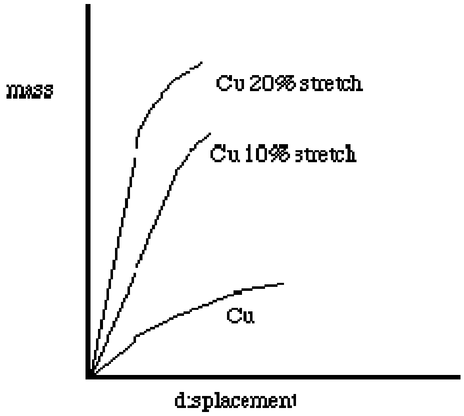


Data:

Sample table

mass	ht.	disp.

Sample Graph:



Analysis:

1. From your data collected in Part III, generate a data table for each wire; including the values for mass, height, and displacement (height - ho).

2. Plot a graph of mass (on vertical axis) versus displacement for each of the different types of wires. Note that the slope of the curve represents the relative stiffness of the wire represented by the curve. See sample graph.

3. For each of the types of metal wires, find the maximum mass for which the curve remained basically a straight line (the slope was constant). This defines the yield strengths of the metal.

Questions:

1. What is happening to the bonded metal atoms during elastic deformation?

2. What is happening to the bonded metal atoms during plastic deformation?

3. Give the maximum mass placed on each wire before permanent deformation occurred.

4. Why would an engineer be interested in the yield strength of a metal for a particular application?

Teacher Notes:

- It is advisable to test this experiment beforehand to be sure the particular gauge wire that you have chosen undergoes sufficient deformation with the masses you are making available to the students.
- One way to save time on this lab is to have different groups do different metals.

Answers to Questions:

1. The bonds between the atoms are stretching.

2. Metal atoms are sliding past each other.

3. Student answers.

4. In most applications, it is not desirable to exceed the yield strength of the product. If the yield strength is exceeded the object will be permanently deformed and likely will no longer be useful.

Appendix 10: Thixotropy

Source: ASM Teachers Camp notebooks, and also at http://www.seed.slb.com/en/scictr/lab/ketchup/ketchup.pdf

Application: Suspending rocks during oil drilling, magnesium semisolid forming for cell phone housings, slurry processing of ceramics.

NOTE: This is a good example of a BAD experiment.

1. ***Messy.***
2. ***We had to thin the catsup with water so our marbles (weights) would sink—you MUST test drive all your experiments before doing them with the students.***
3. ***It was very hard to see the marbles when they got to the bottom of the beaker.***

NOTE—See caution on prior page

Ketchup: a Thixotropic Liquid

In Drilling Fluid: The Lifeblood of the Well you can read about the interesting properties of Visplex*. This fluid is a liquid while in motion, but when at rest it turns into a thick gel. This makes it useful because when the circulation of the drilling fluid stops, the gel suspends the rock cuttings and prevents them from sinking to the bottom of the borehole.

Fluids, like Visplex, that become more viscous when standing still are called thixotropic. Another thixotropic liquid is ketchup. Have you ever had trouble getting ketchup to come out of the bottle? You shake and shake but it's stuck. Then, once it gets going it flows quite freely. Ketchup that has been sitting still becomes thick. When it's shaken or stirred it becomes thinner. Here's a way to explore the thixotropic property of ketchup by seeing how rapidly weights fall through it.

* Mark of Schlumberger

You will need:

- A beaker full of ketchup. Let it stand for an hour or so.
- A ring stand
- A mirror
- Several weights or steel balls. We used 10 gram brass weights that came with our balance scale.
- A spoon
- A stopwatch

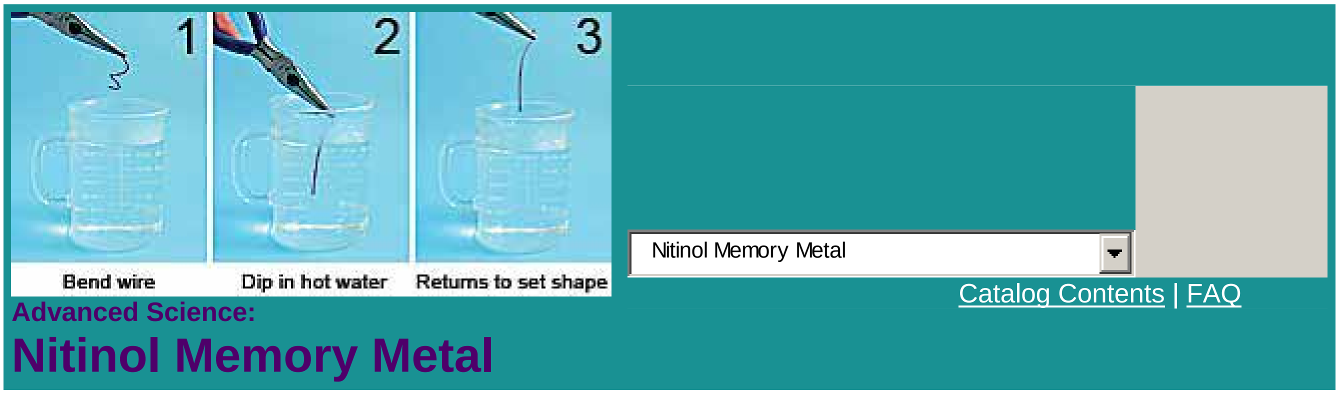
What to do:

1. Put the beaker on the ring stand with the mirror underneath as pictured to the right. The mirror is there so you can see when the weights reach the bottom without twisting your neck.
2. Drop a weight into the ketchup from just above the surface. Time how long it takes to reach the bottom.
3. Drop and time four more weights the same way. Be careful not to drop a weight in the same spot where you previously put one. You want each weight to fall through undisturbed ketchup.
4. Retrieve the weights with the spoon.
5. Stir the ketchup thoroughly
6. Repeat steps 1 through 3.

Use the chart on the next page to record your results.

Appendix 11: Shape Memory Wire

Source: Popular demo in Teachers Camp materials. This summary is from www.teachersource.com



Advanced Science:

Nitinol Memory Metal

Nitinol Shape Memory metal is an alloy of nickel and titanium which bends quite easily at room temperature. When heated above a certain transition temperature, however, it undergoes a phase change, becomes hard and assumes a previously set shape. Nitinol Shape Memory metal can be deformed easily when below its transition temperature and the metal crystal boundaries shift but do not suffer permanent damage. Heating the alloy to above its transition temperature causes the metal crystal to undergo a phase change and return to its original shape; it does so with a large force -- several times greater than the force needed to deform the crystal in the first place. When again cooled below its transition temperature, the phase change reverses and the metal can be easily deformed once more. By heating the metal significantly higher than the transition temperature, the metal can be re-set into different shapes.

Nitinol Memory Wire

This crystalline metal changes phase around 50°C. Bend it, then drop it into hot water and watch it return to its original shape! Can be set into different shapes by heating with a candle flame. (.0297 inches)

Quantity Discount	
per foot (~.3 meters)	**Cost**
1-5	$5.00
6 & up	$4.50

HS-6 Nitinol Memory Wire (by the foot)- Add ☐ to cart.

HS-610 *SPECIAL* Nitinol Memory Wire (10 ft pack) - **$24.95** - Add ☐ to cart.

View Cart

Memory Wire Samples

These 3" (~7.6 cm) samples of memory wire can be wound around a pencil to form a coil. When immersed in hot water, the wire returns to its original shape. The wires can be "set" into other shapes, using a candle flame. These wires have a smaller diameter than our memory wire sold above by the foot. (10 wires per package)

Quantity Discount	
Per Pack of 10 pieces	**Cost**
1-10	$6.50
11 & up	$5.50

HS-9 Memory Wire Samples (pk of 10)- Add ☐ to cart.

View Cart

Appendix 12: Slime/Silly Putty

Source: http://matse1.mse.uiuc.edu/metals/e.htm, Experiment 3 in the Polymers Module

A Silly Polymer

Cross-Linking a Polymer to Create Everyone's Favorite Childhood Toy, Silly Putty

Objective: The objective of this experiment is to cross-link a polymer and observe the changes in the physical properties as a result of this cross-linking. The changes in physical properties of a cross-linked polymer are also studied as the temperature is varied.

Review of Scientific Principles:

If a substance springs back to its original shape after being twisted, pulled, or compressed, it is most likely a type of polymer called an elastomer. The elastomer has elastic properties (i.e., it will recover its original size and shape after being deformed). An example of an elastomer is a rubber band or a car tire.

The liquid latex (Elmer's glue) which you use contains small globules of hydrocarbons suspended in water. The silly putty is formed by joining the globules using sodium borate (a cross-linker). The silly putty is held together by very weak intermolecular bonds that provide flexibility around the bond and rotation about the chain of the cross-linked polymer. If the cross-linked bonds in a polymer are permanent, it is a thermosetting plastic, even if above the glass-transition temperature (T_g). If the bonds are non-permanent, it can be considered either thermoplastic or an elastomer.

Time: A 20-25 minute period is required to perform the mixing/making of the silly putty.

Materials and Supplies:

- 50 % Elmer's glue solution in water
- 4 % borax solution (sodium borate) (8g borax/100g water -- not 4g-- due to waters of hydration in the sodium borate.)
- Styrofoam cups
- Plastic bags with “zipper” closures – snack size are large enough
- food colors

General Safety Guidelines:

- Since borax solid (a bleaching agent) and solution will burn the eyes, goggles and aprons should be worn.
- Hands should always be washed after kneading the silly putty and finishing the experiment.

Procedure:

1. Wear goggles and lab aprons.
2. Pour 20 ml of the Elmer's glue solution into a Styrofoam cup.
3. Add 10 ml of the cross-linker (borax solution) to each cup.
4. Immediately begin stirring the solutions together using the wooden stick.
5. After a couple of minutes of mixing, the silly putty should be taken out of the cup and kneaded in the hands. Don't worry about the material sticking to your gloves as these pieces will soon mix with the larger quantity with which you are working. Continue to knead until the desired consistency is reached.
6. Using a ruler to measure, drop the ball from a height of 30 centimeters. To what height does it rebound?
7. Stretch the silly putty slowly from each side.
8. Compress the silly putty back into a ball.
9. Pull the silly putty quickly from each side and compare the results.
10. Place the silly putty on some regular news print and press down firmly.
11. Remove the silly putty from the news print and make observations.
12. Repeat the same procedure on a comic section of the newspaper. The silly putty is non-toxic and safe to handle so you can put it in a zip-lock bag and take it home.
13. Follow good laboratory procedure and wash your hands with soap and water when you have finished the experiment.

Video Clip

Data and Analysis:

Height of the rebound __________ cm.

Observations of pulling the silly putty slowly:

Observations of pulling the silly putty quickly:

Observations of the silly putty on newsprint:

Observations of the silly putty on the comic's section of the newspaper:

Questions:

1. How do the physical properties of the glue, water mixture change as a result of adding the sodium borate?
2. What would be the effect (your thoughts) of adding more sodium borate solution?
3. What is the ratio of the height of the drop to that of the rebound distance?
4. Who in the class had the ball with the most elasticity?
5. How did you come to the conclusion of whose ball was most elastic?
   At Home:
   -Place your ball in the refrigerator for 10 minutes. Recheck the bouncing portion of this experiment.
6. What are your observations?
7. Why do you think this was observed?
   -Now place your ball about 6 inches from a light bulb for about 5 minutes and again recheck the bouncing portion of this experiment.
8. What are your observations?
9. Why do you think this happened?

Explain the Following:

1. Why does a car tire appear to be flat in the summer even though the gas inside is hotter than in the winter.
2. Why does a basketball bounce differently inside a gym than it does outside on a cold wintry day.
3. Why will a tire sometimes bump during the winter as a car is moving, only to smooth out its ride after the car has been traveling for a distance.

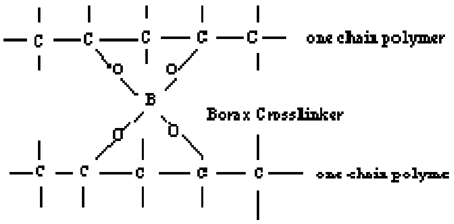
Teacher Notes:

Objective: The objective of this experiment is to investigate cross-linking using a similar technique as was used in the making of slime. The same parameters are worked again with a formal and a quantitative measurement used to describe elasticity. The added home investigation of the effect of temperature on the elasticity also includes concepts of molecular motion and intermolecular bond strength.

Review of Scientific Principles:

If a substance springs back to its original shape after being twisted, pulled, or compressed it is a type of polymer called an elastomer. The elastomer has elastic properties. It will recover its original size and shape after being deformed.

The liquid latex used contains small globules of hydrocarbons suspended in water. Joining these globules forms the mass with which the students will be working. The covalent bonds along the chain are strong, but the bonds between chains are normally weak. However, additives such as borax allow the formation of strong "cross-links" between chains, such as C-B-C. As the number of cross-links increases, the material becomes more rigid and strong.



crosslinker with two chains of polymer

If the rigidity of a polymer is noticed to decrease when a critical temperature is reached, the polymer is called a thermoplastic. If the bonds between polymer molecules are very strong, the material decomposes before any softening occurs. Such a material is called a thermoset plastic.

Natural sources of this liquid latex are milkweed, rubber trees, pine trees, aloe plants, and many desert plants. This latex is used to quickly mend and repair any damage to the outer covering of the plant.

General Safety Guidelines:

- The materials used in this experiment are all non toxic. It is a good idea always to exhibit good laboratory technique when working with the students.

Experimental:

There are many variations of this experiment.

1. The original silly putty was prepared using sodium silicate and mixing this with borax.
2. A variation also exists using laundry starch and mixing it with borax.
3. Similar variations also exist by sprinkling the borax evenly and gently over the solution of latex then working it with the hands. This does not require as much kneading to dehydrate the sample.
4. 3 variants can be made to contrast the properties as a function of the amount of available merrs and crosslinker: a) 10 ml. each—glue, water, 4% borax solution; b) 10 ml. glue, 10 ml. water, 20 ml 4% borax solution (2X cross linkers vs. mixture a); c) 20 ml. glue, 20 ml. 4% borax solution. (2X mers vs. mixture b)

Time: - About 15 minutes are required to ready solutions, cups and tongue depressors. 10-15 minutes will be required in lab for testing and clean up. The students will require 10-15 minutes of work at home in order to finish all of the experimental work on this laboratory and the write up.

Answers to Questions:

1. The liquid type of starting material should jell and become more viscous as cross-linking occurs.
2. The material will become more solid or rigid.
3. Student answer. This is only a method of measuring elasticity of the polymer. Stretching gives a similar means of comparison.
4. Student answer.
5. Greatest rebound to drop height ratio.
6. Here the student will be studying the effect of temperature variation on elasticity. Students are sometimes surprised if they place their sample into a freezer rather than a refrigerator. The results are that the ball will shatter rather than bounce.
7. The ball should be more elastic.
8. Contrary to what some students will predict, should the ball become too warm, the resulting ball will deform rather than continue to increase in elasticity.
9. The ball deformed rather than rebounding.
10. -All of the answers to the questions in the EXPLAIN THE FOLLOWING section involve the use of principles previously presented in this laboratory.

Appendix 13: Half Life of M&M's

Source: http://matse1.mse.uiuc.edu/energy/f.html

Half-Life: The Energizer Bunny$^{\text{reg.}}$ Effect

Objective: This experiment will illustrate the principles of a half-life.

Review of Scientific Principles:

The **half-life** of a radioactive substance is the amount of time it takes for one half of a substance to change into something else. After each half-life only half of the original substance remains. During that change some type of "radiation," either alpha (a helium nucleus), beta (an electron), or gamma (high-energy light), is emitted. A substance which undergoes this type of decay is called radioactive. Radioactivity is all around you--from the food you eat to the bricks in the buildings surrounding you. Radioactive elements that occur naturally are considered part of **background radiation.** Background radiation comes from anything that is part of the natural world that is around *all of the time.* Because of this, you can easily conclude that *all* radioactivity is not deadly. Rather, your body is bombarded with radiation every minute of every day, especially if you get lots of exposure to the sun. Several every day ordinary objects are slightly radioactive, including table salt substitute and bananas!

Nuclear power plants do not emit radioactivity. The radioactive material used in nuclear power facilities is contained in the fuel rods inside the core of the reactor. In some reactors the water coolant also becomes slightly radioactive, but has a short half life and is contained inside the plant.

Fortunately, very little high level waste is made per reactor per year. Unlike a coal plant which produces about 15 tons of carbon dioxide, 200 pounds of sulfur dioxide, and about 1,000 tons of solid ash per *minute*, the high level waste from one *year* of nuclear power plant operation produces about 1.5 tons and would occupy a volume of about half a cubic yard, which could easily fit under your coffee table! The amount of high level radioactive waste produced per person from nuclear power for a 70 year life span is about the size of a soda can.

Other things become radioactive in the process of operating a nuclear power plant, however. Objects like water and air filters for trapping radioactive material, rags, gloves, lab equipment, pipes, and mops are considered low-level radioactive waste. They have been used near or in the reactor and were exposed to neutrons. About 25% of all low-level waste comes from hospitals, research labs, and industry. Although the radioactivity in low-level waste is about a million times lower than that in high level waste, it occupies about 1,000 times the volume of high-level waste. Because the radioactivity is so low, low-level waste is buried at about 20 feet underground in controlled areas and allowed to decay.

Practical Applications: How long do we need to store nuclear waste?

Time: 20 minutes

Materials and Supplies:

- 80 M & M's (or 80 Pennies) per lab group
- one box per lab group (the boxes copier paper comes in work well)
- 1 meter stick
- graph paper
- tape
- red pencil

Procedure:

1. Put 80 M & M's "M's up" in a box.
2. Put the lid on the box and shake.
3. Open the box; leave all the "M's up" M & M's in the box, remove all the blank M & M's.
4. Record the number of removed M & M's in the data table.
5. Repeat steps 2-4 more times
6. Write your results on a large table on the board.
7. Plot on graph paper the number of half-lives on the x-axis and the number of **non-decayed** atoms on the y-axis in red pencil.
8. Average the class data on the board.
9. Plot the class data in normal pencil color on your graph in the same manner described above, and be sure to label each of the graphed lines clearly .

Video Clip

Data and Calculations

Number of half-lives	Number of "non decayed" atoms
0	80
1	
2	
3	
4	
5	

Questions:

1. Treat the M & M's as radioactive units. Using your data, how many half-lives does it take to have an inconsequential amount of radioactive material left? Is it ever really gone (HINT: think about the Energizer Bunny$^{reg.}$--it keeps going and going and going...)?
2. Suppose you were given $1,000,000. How long would it take to have less than five dollars left if you spent half of it every day?
3. Uranium-238 has a long half life. If 450,000 people live to be 70, how many "soda can" size pieces of nuclear waste will we have to store? How much room would that take up is stacked together?
4. Suppose a material emits 25 rem/year (which causes radiation sickness if felt in a single dose), and has a half-life of 5 years. How many years before it emits only 200 millirem/year, which is approximately the amount of background radiation you receive every year. HINT: 1 rem = 1,000 millirem.

Teacher's Notes

Half-Life: The Energizer Bunny$^{reg.}$ Effect

Objective: This experiment will illustrate the principles of a half-life.

Practical Applications: How long do we need to store nuclear waste?

Prep time: 10 minutes

Time: 30 minutes

Sample Data and Calculations (One example) :

Number of half-lives	Number of "non decayed" atoms
0	80
1	44
2	22
3	9
4	4
5	1

Questions:

1. Treat the M & M's as radioactive units. Using your data, how many half-lives does it take to have an inconsequential amount of radioactive material left? Is it ever really gone? **Five half-lives. No; there is always half of the amount left.**
2. Suppose you were given $1,000,000. How long would it take to have less than five dollars left if you spent half of it every day? **17 days.**
3. Uranium-238 has a long half life. If 450,000 people live to be 70, how many "soda can" size pieces of nuclear waste will we have to store? **450,000 * 1 = 450,000**

   450,000*(~18 in^2) = 8,100,000 in^2 = 56,250 ft^2 = 6250 yd^2

4. Suppose a material emits 25 rem/year (which causes radiation sickness if felt in a single dose), and has a half-life of 5 years. How many years before it emits only 200 millirem/year, which is the amount of background radiation you receive every year.

   HINT: 1 rem = 1,000 millirem.

   The easiest way to do this is to divide the amount by 2 for every 5 years.
   25,000 mrem / 2 = 12,500 mrem after 5 years
   10 years: 6,250 mrem 15 years: 3,125 mrem
   20 years: 1,562.5 mrem25 years: 781.25 mrem
   30 years: 390.6 mrem35 years: 195.31 mrem
   The material will decay to background level after 35 years!

BACKPACK SURVIVABILITY INDEX OF PORTABLE SNACKS

Created by Peg Jones, Saginaw Valley Chapter, ASM International for 5th Grade Girls
peggy.jones@gm.com

Objectives:

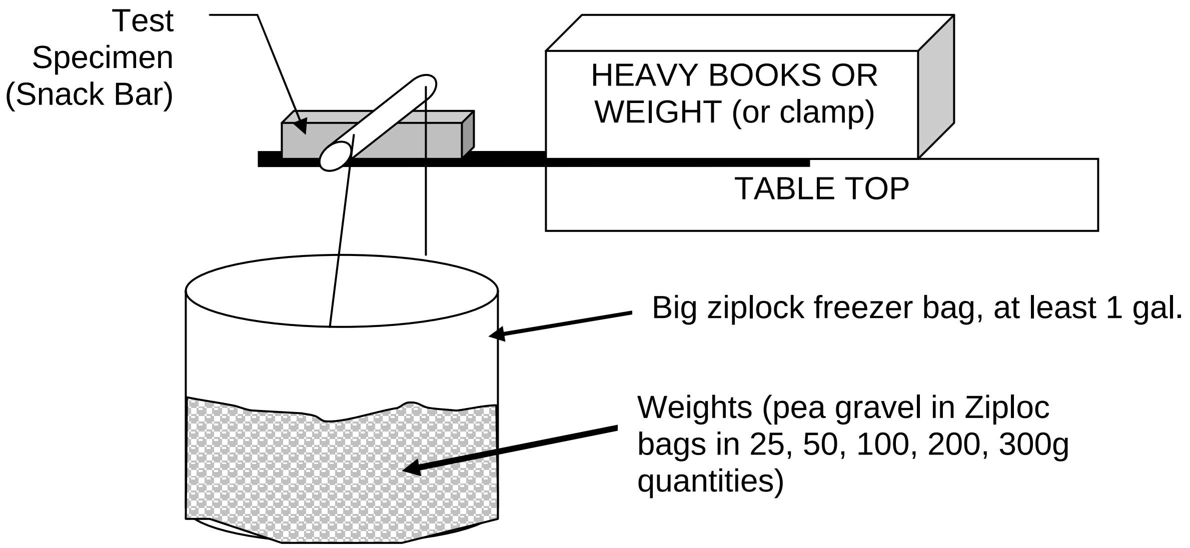
1. Define desired properties for portable snacks.
2. Measure the fracture load for several kinds of portable snacks.
3. Observe how the snacks break.
4. Recommend which snacks might be best to carry in your backpack.

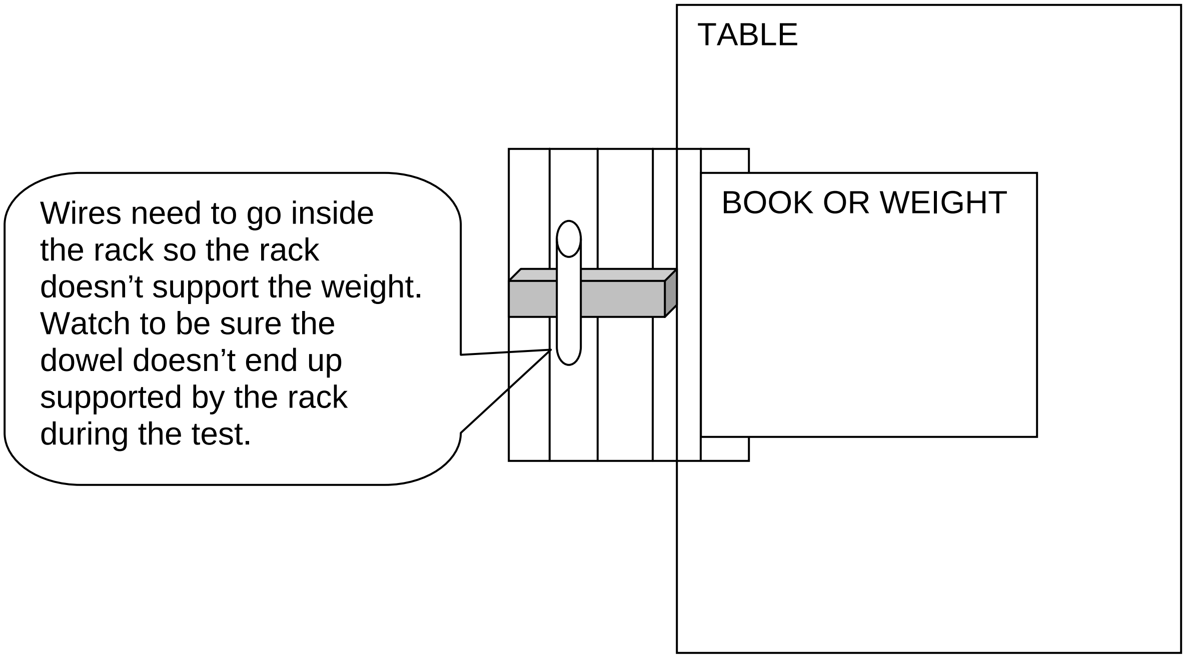
Supplies: (for each station)

1. 1 or 2 gallon ziplock freezer bag to hold weights with holes below the closure, about ¼ of the width from the edges. (Need a big enough opening in the middle to put weights in the bag.) Experimental supplies can be stored in the bags for next year.
2. String or pipe cleaners or wire to attach the freezer bag to the loading dowel. I used 2 pipe cleaners.
3. 15-20 cm. long pieces of ½" diameter wooden dowel rod with a string or pipe cleaner attached to both ends.
4. Weights (various weights of clean pea gravel in Ziploc bags) Steel shot would also work, but is harder to clean up if it spills. Do not use "copper shot" for making bullets or shot gun shells – this can be copper coated lead shot. Marbles wouldn't pack densely enough. You need at least 4 kg. total weight.
5. Bucket or box to "catch" the weights and keep kids' feet from ending up right under the bag of weights. *We didn't have this and it was the biggest safety problem with the activity.*
6. Cooling rack or oven shelf
7. Very heavy books to hold the cooling rack or shelf on a table, or C-clamps. Clamps would be better.
8. Snacks to break (rice crispy treats, granola bars, graham crackers, celery sticks….)
9. Data recording sheet
10. Paper plates to collect the broken snacks for "Fractographic Evaluation"
11. Pencils or pens to label the plates & take notes
12. Magnifying glass to examine fracture surfaces
13. Scale (can be shared), or a calculator to add up the weights required for fracture.

Set Up:

We will put the snack in 3 point bending by placing it on a cooling rack or oven shelf, perpendicular (crosswise) to the metal wires that make up the rack. Put the dowel rod on top of the snack and hook the wires on the ends of the dowel rod to the big ziploc freezer bag that will hold the weights. We need to be sure there's enough weight on the back end of the rack so it won't flip off the table during the test. (Clamps could also be used to hold the rack on the table.) See the sketches below.





Candidate Specimens:

Commercially produced rice crispy treats & granola bars

Celery sticks

Twinkies, Graham Crackers, Jerky, String Cheese, Apple Slices, Laffy Taffy…..

Homemade "rice crispy treats" with different additions (coconut, peanuts, peanut butter)

Homemade "rice cripy treats" bound together with popcorn ball syrup instead of marshmallows to make them harder.

Replace rice crispy cereal with bran flakes or oatmeal and the two binders to see how that affects the strength and fracture appearance

Freeze the cheese or laffy taffy and compare to room temperature specimens

Starting Point: Regular Gooey vs. Hard & Brittle Rice Crispy Treats

This combination demonstrates that by changing the "process" applied to essentially the same ingredients, we can change the "properties" of the material. The "Regular" rice crispy treats are sticky and soft. They gradually fracture between the grains of cereal and we can observe little tendrils of marshmallow glue stretching between the grains. The "hard and brittle" version fractures suddenly and makes crumbs. It tends to break across the cereal instead of between them. In our tests the regular ones fractured between 1.5 and 2 kg., and we couldn't break the hard ones with 4 kg. of weight. (We ran out of weights.) We ended up breaking the hard ones by hand to observe the fracture characteristics. The regular ones can also be "reassembled"—they'll stick back together but the hard ones can't be easily repaired.

Regular:

3 T. margarine
10 oz. Regular marshmallows or 4 C. mini marshmallows
½ t vanilla (optional)
6 C puffed rice

Line a 9x13 pan or cookie sheet with waxed paper, and grease the wax paper with cooking spray or margarine. Grease a spatula for stirring and handling the treats.

In a big heavy pan or big microwave safe bowl, melt the marshmallows & margarine. Stir in the vanilla and puffed rice. Dump onto the wax paper and press out to as uniform a thickness as possible. Cut into 1x3" bars with a greased knife or pizza cutter.

Hard Rice Crispy Treats:

- 1 C Light Corn Syrup
- 3/4 C White Sugar
- 1 T Margarine
- 1/2 t Vanilla (optional)
- 6 C Puffed Rice

Spray a spatula with cooking spray and line a 13x9 baking pan or cookie sheet with waxed paper. Heavily grease the waxed paper with cooking spray.

Heat the corn syrup, sugar, and margarine over med-med/low heat in a heavy pan. Stir until the sugar dissolves and the mixture is clear. Boil it for about 5 minutes until it just starts to caramelize and forms a brittle thread when dripped into ice water. (Cook it to the "hard crack stage". A cookbook will give the right temperature for this--I think it's about 385F, but you need a candy thermometer to measure it.)

Take it off the heat and stir in the vanilla, then the puffed rice.

Using your greased spatula, scrape the sticky glob onto the waxed paper and spritz the top of it with cooking spray. Working quickly and trying not to burn yourself---because the sugar is really hot!--- press it into as uniform a thickness as you can. Press it with the greased spatula and NOT your hands. (Next time I might grease the bottom of a cookie sheet and see if I can use that to quickly press the glob into a more uniform thickness.) The sugar hardens fast so you don't get a lot of time to pursue uniform thickness samples. It is very easy to get a bad burn when you are working with this....just like when you build gingerbread houses glued together with sugar syrup.

Let it cool and lift it out of the pan so you can cut it.

Using a long serrated knife for cutting bread, or perhaps even a clean hacksaw blade, try to saw it into approx. 1x3" pieces. Mine wanted to break. Try not to let the end of the knife batter the crispies, and try to saw all the way through. I ended up sawing a little from one side, then from the other so I wasn't impacting the treats with the end of the knife.

They are edible, but not nearly as good as the originals. (1/3 the fat...)

DESIRED PORTABLE SNACK PROPERTIES

The perfect portable snack would be:

1. Delicious chocolate with no calories, lots of fiber, and plenty of vitamins and minerals.
2. Hard to smash
3. Not messy if it breaks
4. Lasts for months without refrigeration
5. Light weight
6. Not really sticky
7. Doesn't melt on a hot day, floats, ….

So the "properties" we'd like our snack to have are:

1. Strong—takes a lot of force to break it
2. Tough—doesn't fracture into lots of pieces
3. No refrigeration needed
4. High strength to weight ratio
5. High melting or softening point ("glass transition temp")
6.
7.

OBSERVATIONS:

Specimen ID	As Received Condition	Fracture Load (grams)	Fracture Characteristics
Example: Rice Crispy Bar	Sticky Round Rice Crispies One piece Low odor Mostly white	900	Marshmallow glue stretched while it was breaking 3 pieces Took a long time to break Some rice crispies are broken, but most of them are whole where it broke
Rice Crispy “Group A” (Regular)			
Rice Crispy “Group B” (Hard)			

Specimen ID	**As Received Condition**	**Fracture Load (grams)**	**Fracture Characteristics**
Rice Crispy “Group C”			
Celery	(Longitudinal or transverse? Concave up or down?)		
Other			

RECOMMENDATIONS: The snack with the best chance to survive 6 months in your backpack is _____________________ because
____

IDEAS FOR FURTHER INVESTIGATION:

Strain rate sensitivity can be explored with taffy candy, or by pulling the gooey rice crispy samples fast vs. slowly. If you smash a taffy, such as “Laffy Taffy” which comes in a flat form, against the corner of a table it fractures with little deformation. If you stretch it slowly it deforms a lot before fracturing.

Temperature dependence of properties can be demonstrated by freezing the string cheese or taffy before testing—but work fast.