SEE WHAT PHYSICAL SCIENCE IS ALL ABOUT™

4-6

MATTER - Section I:

Safety

* **Good safety practices:** [lesson]

1. Use a lab coat when necessary. These can be found in thrift stores and really have value in the classroom (role playing, etc.).
2. Discuss safety. Tasting, touching, smelling unknown chemicals; unauthorized experiments.
3. Show safety goggles. Discuss their many uses.

* **An unauthorized experiment:** [demonstration]

clean test tube
test tube holder
wood splints (or popcicle stick)
¼ teaspoon (aluminum)
test tube brush
propane torch (or bunsen burner)
safety goggles
potassium chlorate ($KClO_3$) (labeled "Mystery Powder")
metal pan

Caution: Before attempting this yourself, check local fire regulations. This demonstration will set off smoke detectors. Elementary teachers may prefer to borrow (from the junior or senior high) only enough chemical to use that day. Store only small quantities (30gms or 1 oz. is sufficient for 20 demonstrations). Store in a locked cabinet. Do not grind this chemical in a motar and pestle. Potassium Chlorate is stable under ordinary conditions of use and storage. It is not combustible but, when heated it releases oxygen (it is an "oxidizer"). Oxygen, in turn, promotes rapid combustion of flammable materials. Skin contact may cause redness, irritation and pain. If exposed, wash with soap and water.

1. a. Read caution label to class, ". . . This chemical should not come in contact with anything organic." Discuss "organic" and "inorganic."
   b. "Is it okay to put some in a glass test tube? Can we use an aluminum spoon? (Have you heard of an aluminum tree? Where does aluminum come from?)"
2. Place ¼ teaspoon or 1½ grams of $KClO_3$ in a tube. Move the rest of the $KClO_3$ sufficiently away.
3. Put on safety goggles and gently heat chemical over the burner.
   Note: Test tube is always pointed away from people.
4. The powder will quickly melt to a liquid. Do not boil. Once it has melted, remove test tube from flame and drop in two wood splints or popcicle stick (present this as a mischevious student doing an unauthorized experiment).
5. Hold test tube upright over a metal pan for safety. The hot chemical will oxidize the wood. This also dramatically demonstrates a chemical change.
6. Once cooled, the test tube can be cleaned with water and a test tube brush.

The atom

* **Structure of the atom:** [lesson]

1. Proton: in nucleus, has a plus electric charge.
   Neutron: in nucleus, has no electric charge
   Electron: orbits around the outside, has a negative electric charge.
2. Each atom has equal numbers of protons (+) and electrons (-) so that the net charge on the atom is zero ("+'s" and "-'s" cancel).

Reading the periodic table

* **Determining the number of protons, neutrons and electrons:** [lesson]

1. Using carbon (C) as an example:

   Top number is called "atomic number" (6) and is number of protons (and, also electrons, of course).
   Lower number is called "atomic weight". Atomic weight is the **sum of protons plus neutrons.** Therefore, if atomic weight is 12 (we round off this number to nearest whole number), it must have 6 neutrons and 6 protons.

2. Aluminum (Al): atomic number = 13 Therefore, has: 13 protons
   atomic weight = 27 13 electrons, and
   27 minus 13 or 14 neutrons.

   (Note: most aluminum atoms have 14 neutrons but every now and then you'll find one with 13 neutrons. The atomic weight is the **average** weight of all aluminum atoms. Since most weigh "27" and a few weigh "26", this **average** weight will be expressed as a decimal fraction (i.e., 26.98). Atoms with different numbers of neutrons are called "Isotopes" (this is a junior high concept).

* **Common elements and symbols:** [lesson]

H - Hydrogen
He - Helium
C - Carbon
N - Nitrogen
O - Oxygen
Ne - Neon
Na - Sodium
Mg - Magnesium
Al - Aluminum
Si - Silicon

P - Phosphorus
S - Sulfur
Cl - Chlorine
K - Potassium
Ca - Calcium
Mn - Manganese
Fe - Iron
Co - Cobalt
Ni - Nickel

Cu - Copper
Zn - Zinc
Ag - Silver
Sn - Tin
I - Iodine
Au - Gold
Hg - Mercury
Pb - Lead
U - Uranium

Elements, compounds, mixtures

* **Three general categories of matter:** [lesson]

1. Elements: the simplest forms of matter that still retain physical and chemical properties.
   Elements cannot be broken down into simpler substances by ordinary means.

2. Compounds are combinations of two or more elements in specific proportions that are bound together (electrically). Properties of compounds are usually different than the properties of the elements that make them.
   Example: Sodium - reacts violently with water
   Chlorine - poisonous green gas
   Compound sodium chloride (NaCl) is common salt.

3. Mixtures are two or more substances put together (proportions can vary). The properties of the mixture are a combination of the properties of the items in the mixture.
   Example: Water boils at 100°C
   Alcohol boils at 65°C.
   A mixture of alcohol and water will boil somewhere in between (depending on relative proportions).

Filtering and using indicators

* **How can the starch be separated from a starch/water mixture?** [observational experiment]

3 test tubes (20 X 150 mm)
test tube holder
cornstarch
tincture of iodine
funnel
filter paper (#6 coffee filters cut into 7 cm. radius circles)

1. Hypothetical separations: big rocks/little rocks
   salt/sand
   iron filings/wood shavings
2. Define "indicator": A chemical that changes color to tell you something (show iodine on a piece of bread or potato).
3. Mix up starch and water (2 c. water, ¼ t. starch), stir before use.
4. Pour mixture into test tubes #1 and #2.
5. Test for presence of starch in #1 with a few drops of iodine.
6. Pour test tube #2 mixture through filter paper (in funnel) into test tube #3.
7. Test filtered liquid with iodine.
8. Conclusion: We can separate a simple mixture with filtration.

* **Can sugar be separated easily from a sugar/water solution?** [observational experiment]

Tes-tape (indicator)
sugar solution - must be glucose (corn syrup). Can use Karo syrup or pancake syrup
½ t. + 1 qt. water

1. Perform experiment as above using sugar water and Tes-tape.
2. Conclusion: Sugar goes through filter paper. It is very small and somehow attached to water particles (a solution is a special type of mixture). To separate this special mixture, we must resort to distillation.

* **Compounds:** [lesson]

1. Sugar (C,H and O — C&H Sugar box as memory aid)
   a. Cane or beet sugar (sucrose): $C_{12}H_{22}O_{11}$
   b. Grape sugar or blood sugar (glucose): $C_6H_{12}O_6$ - a simple sugar
   c. Other sugars: milk sugar (lactose)
      fruit sugar (fructose) the sweetest sugar of all
2. Compounds are grouped according to their chemical formulas.
   Examples: carbohydrates (C,H,O compounds), alcohols, salts, acids, bases

Model for combing atoms

* **How elements combine to make compounds** (this is a very important lesson)!

different paper cutouts representing "ions"

1. Atoms can gain or lose electrons (they are then called "ions" not atoms).
   Example: 8 protons and 8 electrons = no charge (atom)
   8 protons and 9 electrons = -1 (ion)
   8 protons and 7 electrons = +1 (ion)

2. Oxygen has 8 protons and 8 electrons. It tends to get 2 more electrons (for a total of 10) so the ion is "-2".
   Make a paper Oxygen cutout with 2 indentations, write a "-1" at each indentation.

3. Hydrogen tends to lose its one electron when it "ionizes" (net charge = +1).
   Make 2 paper Hydrogen cutouts each with one point marked "+1".

4. Show how 2 Hydrogen ions (+1) fit into one Oxygen ion (-2) to make water.

5. Like Hydrogen, Sodium also tends to lose 1 electron (ion is +1).
   Chlorine is a -1 ion (one indentation).
   Show how Na and Cl combine to make NaCl (salt).

6. Note on periodic table that elements on left-hand side tend to be + ions (lose electrons). Those on right-hand side tend to be - ions (gain electrons). We list compounds with the + ion first, i.e., Sodium Chloride (NaCl) not Chloride Sodium (ClNa).

7. Use cutouts to form other compounds:

   Na_2O - Sodium Oxide
   HCl - Hydrogen Chloride

8. Explain "inert" elements (i.e., He, Ne, Ar, Kr):
   They "like the way they are" and do not gain or lose electrons (they don't ionize). As a result, they don't easily combine with any other elements (don't form compounds). Make a round paper cutout to demonstrate these.

Acids, bases and indicators

* **Acids and bases:** [lesson]

1. Acid: HCl in water breaks apart. Many H^{+1} ions "swimming" around. The more H^{+1} ions, the stronger the acid. All acids have H^{+1} in them and their chemical formula begins with an "H" (i.e., HCl, H_2SO_4, HNO_3).

2. Base: Opposite of an acid (+1), so must be -1. Show that O^{-2} combining with H^{+1} makes OH^{-1}.
   Sodium Hydroxide (NaOH), when in water, $(OH)^{-1}$ ions "swim around". The more $(OH)^{-1}$ ions, the stronger the base. The chemical formula of all bases end in an "OH" -- they are called "Hydroxides" (i.e., NaOH, KOH, NH_4OH).

3. Mixing an acid and a base H^{+1} combines with $(OH)^{-1}$ to make H_2O (this is called neutralization).
   Use HCl + NaOH paper cutouts to make (a) HOH (water) and (b) NaCl (salt).
   Try HCl + KOH to make HOH (water) and KCl (potassium chloride - a different "salt").
   Note: "K" cutout looks like "Na" with one "point".

* **Testing for acids and bases:** [experiment]

1. pH: a measurement from 1-14 of the relative strength of acids and bases (1 is acid, 14 is base, 7 is neutral).
   Use memory aid: "A" comes before "B"
   "1" comes before "14"

2. Using wide range Accutint, student groups test materials at various stations, record pH value and then identify as "strong", "weak", "acid" or "base".
   Samples: vinegar, ammonia, pickle juice, Draino (in water), soap,, shampoo, egg white, 7-up, sauerkraut juice, lemon juice, dissolved Rolaid tablet, etc.
   Variation: Test various "mystery liquids" (make ahead using varying concentrations of vinegar + water or ammonia + water). This makes a good safety lesson!

3. Bromothymol Blue (narrow range indicator: 6.2 to 7.4).
   a. Test distilled water and tap water.
   b. Blow breath through water with indicator in it. CO_2 from breath makes a mild acid (H_2CO_3) - changes color.
   c. Test 7-UP or tonic water (Note: Same weak acid called "carbonic acid").
   d. Test and record tap water (monitor weekly). Test water from various sources, i.e., pools, hot tubs, ponds.

      Note: With Bromothymol Blue, pH could be well below 6.2 and it will still be yellow or well above 7.4 and it will be blue.

4. Demonstrate neutralization with Phenolphthalein (range 8.3 to 10).
   a. Demonstrate color (clear to fushia pink) when put in a base (ammonia).
   b. Neutralize ammonia (containing indicator) with vinegar. Goes clear.
   c. Add more ammonia, turns pink again.

5. Every indicator has a specific pH range over which it works. Red cabbage juice works great (if you can stand the smell)!

MATTER - Section II:

Weight of a gas

* **How much does the gas weigh that's given off from an Alka Seltzer tablet?** [experiment]

balance	Alka Seltzer tablet
glass of water	(Note: You can cut into halves or quarters to save material)

1. Given materials above, how would we determine the weight of the gas? Let students "brainstorm" the solution . Test incorrect answers (guided inquiry). It may take 15 minutes of discussion to reach an acceptable answer. Some solutions may have unnecessary measurements. Problem can be solved with two weighings (for advanced class you can add distractors, i.e., a balloon, a graduated cylinder, request the simplest solution).

2. Weigh all together. Record weight. Drop tablet in, let it fizz away. Weigh again and subtract second value from first (answer .4 to .5 gram).

3. Variations: Test different variables: [experiment]
   a. How does temperature of water affect the amount of gas given off?
   b. How does age or temperature of tablet affect the amount of gas given off?
   c. How does type of liquid (i.e., vinegar) affect the amount of gas given off?

4. Demonstrates a chemical change -- gas (CO_2) given off.

Physical and chemical properties

* **Physical/chemical properties and physical/chemical changes:** [lesson]

1. Review physical properties (K-3 concept) -- shape, size, color, texture, density, etc.

2. Identify some chemical properties — flammability, solubility, how something reacts with other chemicals, boiling point, freezing point, etc.

3. a. Using a piece of chalk, identify its physical properties -- white, cylindrical, solid, etc.

   b. Crush the chalk. Identify its physical properties again.

   c. Is it still chalk? (yes) The chemical has not changed, only the physical appearance. This is a physical change.

4. a. Physical change — car crash (with no fire). All pieces can be swept into a pile. It is still a car, it just looks different.

   b. Chemical change: Car catches on fire. Some parts of car (i.e. gasoline, seats, tires) combine with oxygen in air (burn) and make new chemicals (CO_2, H_2O, CO, etc.).

* **Indications of a chemical change:** [lesson]

1. Heat or light given off.
2. Gas produced.
3. Color change.
4. Precipitate formed from two liquids or gases.

* **Chemical change activity #1:** [observational experiment]

test tube rack
5 test tubes (numbered 1-5)
sodium carbonate
vinegar
phenolphthalein solution
calcium chloride
household ammonia
water

1. Mix up five stock solutions in advance (exact measurements are not critical):

   a. Phenolphthalein -- Dissolve ½ gm (1/8 t.) phenolphthalein powder in 350 ml (1½c.) of ethyl alcohol. Add water and dilute to 1 liter (1 qt.) -- you can substitute 500 ml of isopropyl (rubbing) alcohol and dilute to 1 liter with water.

   b. Ammonium hydroxide (NH_4OH) -- Mix 600 ml (2½ c.) distilled water and 8 ml (2 t.) household ammonia — or 5 drops ammonia per ½ test tube of water.

   c. Acetic acid (vinegar) -- Mix 250 ml (1 c.) of household vinegar with 500 ml (2c.) of water

   d. Calcium chloride ($CaCl_2$) -- Mix 600 ml (2½ c.) distilled water to 6 grams (1½t.) $CaCl_2$.

   e. Sodium carbonate (Na_2CO_3) — Mix 600 ml (2½ c.) distilled water to 9 grams (1½t.) Na_2CO_3.

2. Fill each test tube (#1-#5) half full of the corresponding stock solutions.
3. Describe each solution (color, clarity, odor). Hypothesize what will happen when Solution #1 is poured into Solution #2. Mix them.
4. Next, hypothesize then pour Solution #2 into Solution #3 (fill #3 to the top, notice that the pink color disappears).
5. Now, pour some of Solution #3 back into test tube #2 (hypothesize first, then pour slowly). Notice that the pink color in test tube #2 will eventually clear.
6. Explanation: Phenolphthalein can be represented as a weak acid "HIn," which is colorless. When a base is added, the OH^{-1} combines with the H^+ to form water (HOH) and the "anion" (an ion with a minus charge) "In," which is red. The greater the amount of OH^- added, the redder it gets (more "In"). Then when the vinegar (acid) is added, the H^+ recombines with the In to reform HIn and make the red color disappear.
7. Now pour Solution #4 into #5 (the two clear liquids turn to a milky color).
   Explanation: $CaCl_2 + Na_2CO_3$ --> $CaCO_3$ (chalk) + 2NaCl (salt)
   $CaCO_3$ (calcium carbonate) is the precipitate.

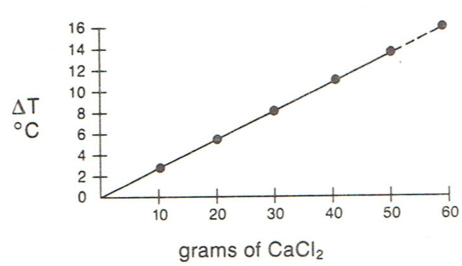
*** Extra activity:**
Mix vinegar and baking soda ($NaHCO_3$ or sodium bicarbonate) to illustrate a gas being produced -or- drop an Alka-Seltzer tablet in water.

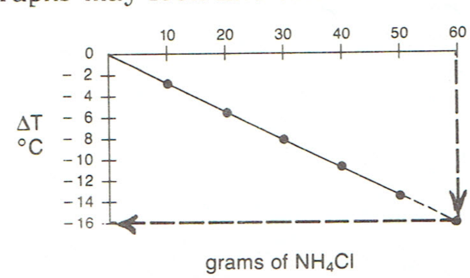
*** Chemical change activity #2 - Exothermic and endothermic reactions:** [observational experiment]

plastic cups
water
thermometer
Calcium chloride ($CaCl_2$)
balance (or teaspoon)
graduated cylinder (or 1 c. measure)
Ammonium chloride (NH_4Cl)

1. Use varying amounts of $CaCl_2$ (gets hotter, exothermic) and NH_4Cl (gets colder, endothermic) with water. All groups must use the same amount of water.

   Groups use between 5-50 grams of chemical in 150 ml (½ c.) water. One teaspoon is approximately 5 grams (groups could use 2 t. (10 grams), 4 t. (20 grams), 6 t., etc.
2. Measure the temperature of water. Record this value. Stir in $CaCl_2$, wait one minute and record the temperature again. Calculate the temperature change (ΔT) by subtracting.
3. Rinse out the plastic cup and repeat Step #2 with NH_4Cl (Ammonium chloride).
4. Graph the results of all groups. Typical graphs may look like this:





5. Follow-up questions:
   a. What would happen if we used the same amount of chemical and more (or less) water?
   b. Interpolate or extrapolate a point in your graph that wasn't used (i.e., 25 gms or 60 gms - see graph). Predict what the temperature rise (or fall) should be, then try that amount. How close are your actual results?
   c. Explanation: Most solids dissolve in water by an exothermic process (NH_4Cl is an exception). Energy is released when the chemical dissolves. This is called "hydration energy."

* **Chemical change activity #3:** [demonstration]

Magnesium ribbon	metal pan	pliers
Bunsen burner or torch	safety goggles	

1. Observe Magnesium ribbon (an element, Mg). Record observations.
2. Break off a 3 cm (1") strip. Wearing safety goggles and using pliers, burn the strip over a metal pan. After it has burned, observe and record the characteristics of the residue. Did a chemical change take place? Why? Will it burn again? (a new chemical was formed, Magnesium oxide, MgO, a compound).

* **Chemical change activity #4:** [observational experiment]

plastic cups	steel wool	candle
vinegar	tongs or pliers	metal plate
bleach	funnel	water
aluminum spoon (non-magnetic)	filter paper	butter knife
paper towel	magnet	graduated cylinder

1. Mix Hypochlorous acid (HClO) solution in advance:

1 station:	100 ml (½ c.) water 20 ml (4 t.) bleach 10 ml (2 t.) vinegar	10 stations:	1 liter (5 c.) water 200 ml (1 c.) bleach 100 ml (½ c.) vinegar

2. Each group gets 100 ml (½ c.) of stock solution and pours it into a plastic cup.
3. Submerge the steel wool into the liquid with a butter knife. Let it settle for 5 minutes (record observations).
4. Did a chemical change take place? Why? Remove the steel wool. Let the red liquid settle for 3-4 minutes. Pour off the clear liquid. Add about 200 ml (1 c.) water to dilute the acid. Let it settle again for 3 minutes. Finally, pour off the clear liquid again.
5. Filter the red mixture with filter paper and a funnel.
6. Observe the red solid material in the filter paper. Observe the liquid that dripped through. Allow the filter paper to dry on a paper towel (5-10 minutes).
7. Test the red "paste" with a magnet (record results). Note: Even though it is non-magnetic, some paste may adhere to the magnet because it is sticky.
8. Scrape some of the red paste off of the filter paper with the butter knife and place it on the spoon. Heat it over a candle flame for 3-4 minutes (caution, the spoon will get hot!). Observe a color change and a chemical reaction.
9. Cool the spoon down and observe the new chemical. Test this with a magnet. Did another chemical change occur? (the new material is now magnetic).
10. Explanation:
    a. Vinegar + bleach + water = Hypochlorous acid (HClO).
    b. HClO + Fe (iron) = $Fe_2O_3 \cdot H_2O$ (Hydrated ferric oxide or rust which is non-magnetic)
    c. $Fe_2O_3 \cdot H_2O$ was then heated and changed to Fe_3O_4 which is magnetic (a black magnetic compound).

    Students will try this one at home. Help them with a 1-station hand-out sheet. Request that they do it under adult supervision. Include chemical formulas, etc., so that they can explain it to their parents.

Paper chromatography

* **Theory:** [lesson]

Black ink is composed of different pigments (i.e., red, yellow, blue). A chemical property of each of these pigments is solubility . . . how well or how quickly that particular color dissolves in water (or some other solvent, like alcohol).

* **Separating black inks into their components:** [observational experiment]

strips of coffee filter paper	different inks
test tubes	water or alcohol (solvents)

Place a dot of ink on paper. Lower into a test tube (with solvent). Ink should be above liquid level. Observe in about 10 minutes. Note color separations.

* **Advanced (rainbow) separations:** [observational experiment]

Use round coffee filter with "tongue" cut out in middle. Tape onto a plate. Pour solvent (alcohol) into plate. Cover with another plate to prevent evaporation.

* **Identify the ink:** [observational experiment]

4 different black inks	4 test tubes
alcohol	filter strips

1. Run all 4 inks before class. Place results on index cards with the name of pen next to it (do not include its corresponding letter).

2. Cut paper strips. Label one strip with an "A" (and a "dot" from Pen A)
   one strip with a "B" (and a dot from Pen B), etc.

3. Student groups run samples A through D in test tubes. Take results to front of room and decide which pen Sample A came from by looking at index cards and comparing results (this experiment is good for developing "Inferring" skills).

Density of solids, liquids and gases

* **Introduction:** [lesson/observational activity]

  2 pieces of clay, one large and one small (with fishing weight inside)

1. Allow a student to "heft" both pieces of clay and note that small one is seemingly heavier.
   Conclude: Small one must have something heavy inside or large one must have something light inside (or is hollow).

2. Define density as more than weight. It also includes the amount of space taken up. Note: It is difficult to compare density of a large rock and a small rock (large one is obviously heavier, but small one may be denser). If both rocks were the same size, it would be easy to determine which is denser (by weighing both).

3. Hypothetically cut a "cube" out of each rock (use sugar cubes as model).
   1 cm. X 1 cm. X 1 cm. = 1 cubic centimeter (equals 1 ml. of liquid volume).
   Densest rock will be the one who's "cube" weighs the most.

* **Calculating density:** [observational activity]

overflow can | balance | assorted materials

1. Use overflow can to determine volume of object (refer to K-3 Physical Science, "Matter").
2. Use a balance to find the weight of a object.
3. Density = $\frac{\text{weight}}{\text{volume}}$ example: $\frac{205 \text{ grams}}{82 \text{ ml}} = 2.5 \frac{\text{grams}}{\text{ml}}$
   (we are finding the weight of one "cube" or one mililiter. Since 1 ml = 1 cm^3, we can also say, for example, that there are 2.5 grams per cubic centimeter.)
   Note: We're actually finding the "mass" of objects rather than the "weight" (see PS(I)-11 for the difference between weight and mass).

* **Journey to a foreign planet:** [observational activity]

Students must find the foreign name for common objects (i.e., lead, rock, wax, clay, steel). To do this, they (a) find the density of each, and (b) look on the blackboard to cross reference the density to the foreign word. (teacher must calculate densities in advance and put the values on the board -- i.e., "Zorp" = 1.5 grams/ml -- distractors like "Bleem" = 1.8 grams/ml add to the fun!)

* **Density of liquids:** [observational experiment]

very salty water (red)
fresh water (blue)
alcohol (green)
graduated cylinder (graduate)
balance

1. weight the empty graduate. Record the weight.
2. Fill it with liquid exactly to the 100 ml mark.
3. Weigh it again.
4. Subtract #1 value from #3 value. This is the mass of 100 ml of liquid. If 100 ml weights 86.0 grams, then 1 ml will weigh .86 grams or D = .86 grams/ml.
5. This experiment can be handled like the last one. Students find densities and identify mystery liquids from a list on the blackboard (use real names this time).

* **Different density layers of liquids:** [observational activity]

#1 water (green)
#2 corn oil (clear)
#3 alcohol (red)
#4 baby oil (clear)
graduated cylinder
piece of wax crayon

Carefully pour each liquid into the graduated cylinder (#1 first). Students predict where the crayon piece will float. Drop it in and see.

* **Density of a gas (CO_2):** [observational experiment]

Alka Seltzer tablet
tank of water
graduated cylinder
drinking glass

1. Collect gas in an inverted glass in the tank filled with water.
2. Remove the drinking glass from the tank without losing the contents. Use the graduated cylinder to measure the amount of space the gas occupies.
3. Density = $\frac{.4 \text{ grams (from earlier experiment)}}{130 \text{ ml (from \#2 above)}} = .003$ grams/ml

   This means that one "cube" of CO_2 weighs 3 thousandths of one gram -- not very dense, is it?

Preparing hydrogen: [observational activity]

magnesium ribbon (1-3 cm. lengths)
vinegar
test tube
crayon
small cup (or bowl)
safety goggles
tape (to seal off test tube)
matches
graduated cylinder

1. Invert test tube full of vinegar into bowl of vinegar.
2. Carefully slip magnesium piece inside test tube. Chemical reaction occurs -- gas produced.
3. Collect gas until magnesium is all gone (about 10 min.). Mark level with crayon.
4. Put goggles on. Tape top of inverted test tube while still in bowl and remove. Hold upright. Light match and quickly slip it under tape (should pop). This is a chemical property of hydrogen.
   Note: H_2 is less dense than air. It will quickly escape from an upright test tube.
5. Measure volume of hydrogen collected. Refill to top or empty the test tube and fill to crayon mark.
6. Use data from class to plot magnesium size (cm) vs. volume of hydrogen produced. Should be a straight line.
   Note that chemicals combine in certain proportions (i.e., a certain amount of magnesium will always make the same amount of hydrogen).
7. Extrapolate graph for a piece of magnesium that was not tested. Try it (remember that test tubes only hold 35 ml of volume).

Preparing and testing Carbon Dioxide:

* **Prepare and test CO_2:** [demonstration]

vinegar
baking soda ($NaHCO_3$ contains CO_2)
tank
matches
bubble soap
candle
wood splints
cardboard trough

1. Test area above baking soda with match. Match burns.
2. Test area above vinegar with match. Match burns.
3. Pour vinegar into tank of baking soda. Note gas bubbles (chemical change).
4. Light wood splint, lower into tank. Note point where fire goes out.
5. "Color" CO_2 with a match.
   a. Rock tank back and forth.
   b. Pour some gas over the side.
   c. Blow bubbles into the tank (CO_2 is denser than air, bubbles float on CO_2).
6. Pour CO_2 down the cardboard trough to extinguish a candle flame.
7. Discuss properties of CO_2:

   Physical: Colorless, odorless, denser than air.
   Chemical: non-flammable (unlike hydrogen).
8. **Note: Never mix the two chemicals in a closed container!**

*** - Develop process skills by involving students as much as possible in these activities.**

MECHANICS:

Forms of energy

* **Identify and discuss different forms of energy:** [lesson]

1. Forms: Heat, light, sound, electrical, motion, chemical, nuclear, etc.
2. Sources: Differentiate between **sources** of energy (i.e., wind, falling water, campfire, radio speaker, match).

Energy conversions

* **Trace energy conversions:** [lesson]

1. Follow energy as it changes from one form to another (i.e., chemicals in battery make electricity -- electricity turns on light bulb, light shines on photo cell, photo cell makes electricity, electricity is used to drive a motor).
2. List "energy conversion" devices. Students explain forms of conversion (i.e., toasters, hair dryers, televisions, matches).
3. Discuss efficiency and how energy gets lost (from one pile to the next) whenever there is an energy transformation.

Work/friction

* **What is work?** [lesson]

1. "Work" is defined as force times distance. An object must move for work to be performed (you can push all day, if it doesn't move, you've done no work).

* **How much work does it take?** [experiment]

wood block
eyelet screw
tacks
sandpaper
ruler
2 rubberbands
cardboard scale (cm)
wood board (1" X 6" X 24")
book (to elevate board)

1. Connect rubber bands and cardboard scale to wood block. Pull up the ramp. Read location of the "knot" between the two rubber bands. Record this value.
2. Measure distance object moves (ramp length). Calculate work. $W = Fd$ (arbitrary units).
   Note: Because your cardboard scale is not calibrated in actual units of force (only "centimeters of stretch"), your value for work can have a homemade unit like "centimeter-power".
3. Measure force required to lift object straight up. Measure vertical distance. Calculate value for work when object is lifted straight up.
   Note: (a) advantage of inclined plane (b) more work (but less force) required when using inclined plane.
4. Using same materials, study (a) effects of adding sandpaper to the block (or ramp) (b) effects of raising or lowering the ramp (c) using a longer ramp (same height).
5. Challenge students to reduce friction and devise the most energy-efficient plan to get the block up the ramp.

* **Lazy susan/rolling friction:** [demonstration]

coffee can with lid | marbles

Gravity, mass and weight

* **How does gravity cause a mass to have weight?** [lesson]

bathroom scale | large rock | ruler

1. Explain how the attraction (gravitational force) acts on objects. This can be measured in pounds (or "dynes", in metric units).

2. When the object moves, work is being done. "Foot-pounds" ("joules" in metric).

3. Power: amount of work done per time. Typical units -- foot-pounds per second (one horsepower equals 550 ft-lbs/sec). In metric units, power is measured in watts. One watt equals 1 joule/sec (we use this to measure power output from light bulbs, etc. In most foreign countries, the power of automobiles is measured in watts)!

* **Weight and mass:** [lesson]

1. Mass is independent of gravity -- "how much stuff is in an object".

2. Weight is the force exerted on an object by the influence of gravity. This force increases as mass increases resulting in more massive objects having more weight.

3. On the moon, objects will weigh 1/6th as much but still retain the same amount of mass.

* **What is gravity?** [lesson]

1. Gravity is a mysterious force that, unlike other forces, only attracts.

2. This force of attraction is between **all** masses, however big or small. The amount of force is dependent on three factors:
(a) the size of mass A
(b) the size of mass B, and
(c) the distance between mass A and B
Mass A and/or mass B must be very large to get a measurable value, although a force does exist between you and this piece of paper!

3. Hypothesize: On a journey to the center of the earth, which way would the forces be pulling on you? (at center of earth you would be weightless)

4. Journey to the moon -- escape velocity from earth orbit = 25,000 mph. Gravity from Earth continuously slows ship down until, at approximately 215,000 miles away, space craft is traveling at only 2,000 mph. Moon then attracts the space craft and it begins to speed up again.

5. Weightlessness by falling: Objects fall to earth unless they have a very high velocity (as they fall, the earth curves away from them).

Laws of motion

* **Demonstrate that forces are necessary to keep objects going in circular paths:** [observational activity]

1. Roll of masking tape with spinning marble inside.

2. Swing an object on an string in a circle over your head -- cut the string.

Conclusion: Objects tend to move in straight lines unless forces act upon them.

* **Newton's 1st law:** [activities]

1. Inertia: tendency to resist the change in motion.

    a. glass, playing card, quarter.

        (1) push card lightly, quarter stays on top.

        (2) Flick card, it flys away, quarter doesn't.

    b. Stack of 4 checkers:

        (1) Flick one checker into the stack.

        (2) Bottom one moves, top ones don't.

    c. Ball-point pen cap on piece of paper hanging over edge of table.

        (1) Challenge to students: How would you get paper out from under the pen without touching the pen?

        (2) Wet finger, snap down on paper.

        (3) Pen cap stays still.

2. Newton's 1st law (part 2): Moving objects tend to continue moving in a straight line unless an outside force acts on them.

    a. Discuss this effect on a moving car when (1) braking (2) accelerating, and (3) turning.
    b. Demonstrate with a rubber ball and milk carton (model of a car and person not wearing a seat belt.

    c. Swing a bucket of water around your head.

* **Newton's 2nd law:** [lesson]

A heavy object requires more force to accelerate (or decelerate) than a light object.
Example: push a compact car, push a truck.

* **Newton's 3rd law — action/reaction:** [lesson/demonstration]

1. Demonstrate rocket engine with a balloon.

Potential and kinetic energy

* **Which marble has more energy?** [experiment]

inclined plane
bottom of milk carton
2 marbles (one large, one small)
ruler

1. Explain potential (stored) and kinetic (motion) energy. When an object is raised up its stored energy is increased.

2. Which marble would require more work to raise to the top of the ramp? Are we storing more energy in the large one? (yes)

3. Roll large marble down ramp. Let it hit milk carton (marble must stay inside). Measure distance milk carton moves (cm). Repeat ten times. Average the results.

4. Do same with small marble.

5. Conclusion: The larger the mass, the greater the energy transferred into the milk carton.

6. Variations: Experiment with other variables (i.e., ramp height, size of milk carton).

Speed

* **Definition of speed:** [lesson]

Distance covered per unit time. If we know total distance covered in total time, we can divide distance by time to find average distance covered per unit time (the units for the answer to this depend on the units of distance and time, i.e., miles per hour, meters per second).

* **How high is a bridge?** [activity]

1. Drop an object off a bridge. Record number of seconds to impact.

2. Distance covered = 16tt (ft.) (or $16t^2$)

   Example: t = 3 sec, d = 16(3)(3)ft.
   [in metric units, $d = 4.9t^2$ meters]

* **– Develop process skills by involving students as much as possible in these activities.**

HEAT:

Expansion of solids, liquids and gases

* **Review:** [lesson]

1. Express the concept of heat as motion of particles (K-3 Earth Science, "Meteorology").
   Solid: atoms bound together -- vibrate faster when heated.
   Liquid and gas: particles moving freely, when heated move faster.
2. Sense of touch as a heat sensor / safety (K-3 Physical Science, "Matter").
3. Reading thermometers, sources of heat, conduction (K-3 Physical Science, "Heat").

* **Heat producing machines:** [activity]

1. Students list machines that (a) produce heat as a by-product, and (b) are designed to produce heat.
2. a. Heat used to do work:
      (1) hot air balloon
      (2) steam engine
      (3) power plant - burns oil, makes steam to drive turbines.
   b. Model of a steam engine (hot plate, tea kettle with potato plug on spout, water balloon).

* **Gases expand when heated:** [observational activity]

(refer to K-3 Earth Science, "Meteorology")

coke bottle with cold air inside balloon

Balloon inflates when bottle is placed in hot water.

Model thermometer

* **Liquids expand when heated:** [observational activity]

1. Explain operation of a thermometer.
2. Make a model thermometer:
   10" piece (25 cm) of 6 mm O.D. (1 mm wall thickness) glass tube (cut with triangular file
   test tube
   single hole #1 rubber stopper
   red water
   a. Prepare glass tubes in corks in advance (wet tube before inserting)
   b. Student groups make model thermometers, tape a plain white card to back of tube, mark level of liquid.
   c. Heat in hands or hold under hot water tap. Observe liquid expand when heated.
   d. Calibrate with a real thermometer using samples of ice water, hot water, etc.

Thermostat, heat devices

* **Solids expand when heated:** [demonstrations]

1. Show ring and ball apparatus. Heat ball with torch, won't fit through ring when heated.

2. Compound bar (or unequal expansion bar) -- two metals bonded together, one expands more than the other when heated making it bend.

   Use guided inquiry to help students explain the operation of this item (relate to running around a track — you must go further in an outside lane). This also demonstrates how a thermostat works.

3. Expansion of wire:

   2 blocks (or chairs)
   uninsulated copper wire (18 ga.)
   weight (i.e., fishing weight)

   a. Connect wire from one block to the other. Suspend weight from the middle (doesn't touch floor). Measure and record distance from floor to weight.

   b. Heat wire with torch. Encourage students to hypothesize.

   c. Measure new distance from weight to floor (we recorded 1 cm closer). When wire cools, what will happen? Test this idea.

   d. Variation: Try wire of a different material (i.e., picture frame wire). Discuss variables (i.e., keep length, amount of heating and weight all the same). See if this wire expands as much.

4. Practical applications: [lesson]

   a. Removing top from a jar (place only top in hot water).

   b. Expansion joints on bridges. Cracks in sidewalks.

Heat and temperature

* **Difference between heat and temperature:** [lesson]

1. Heat is a form of energy — measured in BTU's (British thermal units - English) or calories (metric).

2. Temperature is a measurement of the relative activity of particles within a material.

   Measured in degrees Celsius (centigrade) or Fahrenheit [both units are named after people: Anders Celsius - 1742, and Gabriel Fahrenheit - 1714]

* **Model of heat transfer:** [lesson]

1. One object is on top of a "temperature hill", another is below it on bottom of hill. As water only flows downhill, so does heat from hot to cooler object. Cooler object absorbs heat, gets hotter. Hotter object loses heat, cools down. Both reach equilibrium, somewhere in between (temperature difference between objects determines steepness of hill).

2. Evaluate heat flow. Examples: a. hot metal cup in a cold hand
   b. cold metal cup in a warm hand

   (use model above to explain what happens)

Transfer - conduction, convection, radiation

* **Conduction:** [review lesson] (K-3 Physical Science, "Heat", and K-3 Earth Science, "Meteorology")

  1. Movement of heat through a solid. Energy of vibrating atoms passed down the line through the solid (atoms don't move). Model: clay "atoms" connected by a popsicle stick.

* **Convection:** [lesson]

  1. Particles actually moving and bringing energy of motion from one point to another (happens in liquids and gases).

* **Radiation:** [lesson]

  1. Invisible (infrared) rays, like radio waves, transfer heat from a source to an object. All matter emits this radiation (even you). Our sense of touch can detect infrared rays (hold your hand near a light bulb).

* **How does radiation affect different materials?** [observational experiment]

  light bulb
  different materials (i.e., aluminum foil, black card, glass, wax paper, plastic)

  1. Use hand as sensor. Does radiation pass through some objects? List them.
  2. Does radiation heat up the surface of other objects? Make observations and formulate conclusions (i.e., dark absorbs, shiny or light materials reflect).

Applications

* **Practical applications:** [demonstration/observational experiment]

  1. Styrofoam cups are white (to maximize insulating properties). Heat from a hot liquid inside reflects back into the liquid. White outside helps keep cold liquids cold.
  2. Thermos bottles are shiny inside and out for same reasons. Note also, inner bottle and outer bottle with no air between (vacuum). There is no heat transfer (convection) between the two bottles.
  3. Can a magnifying glass be used to focus infrared rays? (use dark paper because dark absorbs infrared best).

* **Which container heats up/cools down first?** [experiment]

  3 small cans
  aluminum foil
  black paint
  thermometer
  water

  1. Cover one can with foil, paint the other two black on outside. Paint one of these black on inside, too.
  2. Put equal amounts (i.e., 100 ml) of cool water in each can. Record temperature. Place in sun. Students guess what will happen (and why). Record temperature as water heats up (15 - 30 min.).
  3. Use hot water. Let it cool down. Do similar operations as in #2 above (graph results: temperature on vertical axis, time on horizontal axis).

* **Observing convection:** [demonstration] (refer to page ES(P)-16 for spiral)

1. Air convection using paper spiral - less dense (hot) air rises taking heat with it.
2. Convection currents in liquids.

   fish tank with cold water (use ice cubes)
   2 thermometers (one near surface, one at bottom)
   baby food jar with shallow straw on one side, deep straw on other (sealed with wax)
   hot water in jar (green color added)

   a. Lower small jar into tank -- observe convection. Note density difference as hot (green) water floats on cold water.

   b. Record temperatures of each thermometer (typical 4°C difference).

   c. Try reverse experiment: Use hot water in fish tank, add colored ice cubes. Observe cold water sinking. Wavy lines ("heat waves") are caused by light being bent as it travels through the two different densities of liquid (similar to hot air rising off a road in summer).

Insulators (materials that restrict the flow of heat)

* **Which coffee cups hold heat best?** [experiment]

porcelain, metal and plastic cups
hot water
thermometer

1. Hypothesize first before trying the experiment.
2. For easy comparison, temperature can be graphed.

* **Does thickness of styrofoam keep water warmer?** [experiment]

Sample A - one cup
Sample B - 2 cups stacked one inside the other
Sample C - 3 cups stacked one inside the other

1. Perform experiment similar to one above.
2. Discuss usefulness of "dead air" as an insulator (no convection). Applications: dual pane glass windows, double door entryways.

* **How well do different clothing materials insulate?** [experiment]

3 jars
cotton
wool
rubber bands
hot water

1. One jar is a "control" -- it gets no material and is used for comparison. One jar is wrapped in wool, a third, in cotton.
2. With equal amounts of hot water in each, record temperatures as they cool down.

* **Observe heat transfer in a beaker of water being heated on a hot plate:** [observational activity]

1. Conduction: coils to glass
   Convection: in liquid
   Radiation: from all hot items.
2. Encourage students to be aware of heat transfer elsewhere.
3. Heat is similar to light in many respects, only our eyes cannot detect it (it is just below red in the spectrum).

* - **Develop process skills by involving students as much as possible in these activities.**

LIGHT:

Reflection

* **Does the angle of incidence equal the angle of reflection?** [observational experiment]

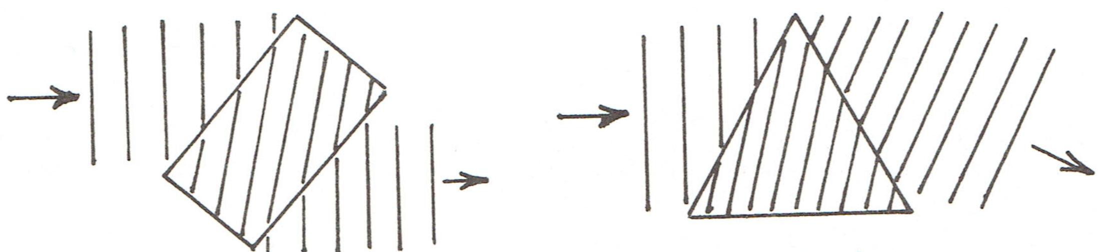
protractor
mirror
2 pencils
paper
clay

1. Draw a large "T" on paper using ruler.
2. Using clay, line up mirror along top of "T".
3. With pencils, test different angles -- set one pencil as angle in, set 2nd pencil on the reflection of the first pencil. Mark points and measure angles with protractor (with respect to center line).

Refraction

* **Explaining refraction:** [lesson]

1. In a vacuum, light travels at 186,000 mps (or 3×10^8 meters per second). Slows down when it travels through denser materials.
2. Model: soldiers marching through mud (explain refraction on blackboard).



soldiers come out going in same direction

soldiers bend even more

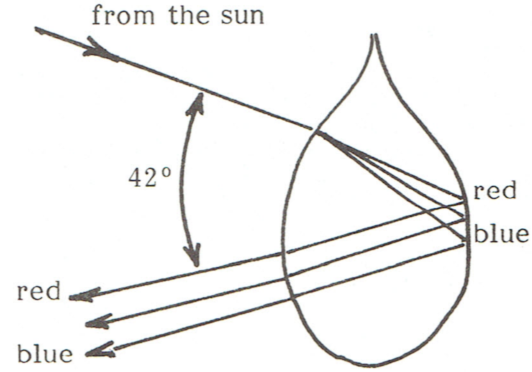
Prisms, rainbows and the spectrum

* **Operation of a prism:** [lesson]

1. White light is made of all colors.
2. When it gets "bent" some colors bend more than others (violet bends most, red least).
3. Use model (above right) to help explain this. In the mud "blue" soldiers slow down most, "red" the least.

* **Rainbows:** [lesson]

1. Water drops act like tiny prisms.
2. To see a rainbow sun must be at your back.



Note: raindrops are round, not tear-shaped.

3. Note: At angles other than 42° light will pass through drop (not reflect on the back side).

* **Observing the spectrum with a prism:** [observational activity]

One student outside with back to sun, projects sunlight through prism into classroom.

* **Learning the colors of the spectrum:** [lesson]

ROY G. BIV (red, orange, yellow, green, blue, indigo, violet)

* **Homemade prism:** [activity]

pan of water
flat mirror
white paper (screen)
flashlight (optional)

1. Place mirror in water at approximately a 45° angle (fasten to pan with tape).
2. Darken room, shine flashlight (almost parallel to water) at mirror. Observe spectrum on paper or use outside with sunlight.
SAFETY: Caution students not to look at reflection of the sun.

Pinhole camera

* **Investigate a pinhole camera:** [demonstration]

coffee can (tiny hole punched in bottom)
plastic lid with wax paper screen

1. Can use outside but observer must be covered with a blanket (like old-time cameras).
2. Darken your room and use a single light source (i.e., candle or 25 watt bulb).
3. Observations: Image is inverted. As you get closer image gets bigger. Explain to students how it works by taking light rays from top and bottom of light source.
4. Hypothesize what would happen if "pinhole" was larger (Answer: Light rays, i.e., from top of bulb, hit screen at many different places — distorts image).

* **Refraction:** [lesson/demonstration]

1. Two factors that affect amount of refraction: (a) density difference between two materials (i.e., air to water is great), and (b) angle of incidence of light beam. If light beam hits perpendicular to surface, no refraction. Greater angles (to perpendicular) cause more refraction.
2. Demonstrate with fish tank, "milky" water and a strong flashlight (4-5 cell lights work best). Use construction paper with a slit in it to make a clean beam of light. Project beam in from one end -- move it up and down. Note refraction.

Lenses - concave and convex

* **What is a lens?** [lesson]

1. Use 2 prisms (base of one on base of the other) to demonstrate convex lens. Beams bend toward each other (always bend from thin to thick part of lens).
2. Use same prisms (point to point) to demonstrate concave lens. Beams bend away (thin to thick rule).
3. Focus is where rays cross in a convex lens (light information crosses and projects a larger image further out).

* **What are magnifiers?** [observational activity]

magnifier wax paper

1. Look closely at magnifier. Is it concave or convex?
   a. Feel shape or note that it brings light rays to a point (converges), therefore, it must be convex.

2. Use lens and make observations.
   a. When object is close, image is right side up and larger.
   b. When object is far, image is upside down and smaller (with concave lens, image is always smaller).

3. Hold magnifier to window. Place wax paper between magnifier and eye. Note image on wax paper (discuss similarities to pinhole camera -- the "pinhole" is actually the focus point of the magnifier).

* **Do all lenses have the same focal length?** [experiment]

magnifier ruler (cm)

1. Record distance from lens to point of light. Are all lenses the same? (try various lenses, if possible).

* **Water drop magnifier:** [observational activity]

water eyedropper
3 wire loops (5, 10 and 15 mm diameters)

1. a. 5 mm holder, when dipped in water, makes a concave lens (check with newsprint). Image smaller and right side up.
   b. Add 1 drop to this holder with eyedropper. Now it is a convex lens.

2. Allow students to experiment on their own with other loops and record findings (i.e., large loop doesn't magnify well because water is too thin).

3. Try activities above with a drop of dish detergent in water (breaks up surface tension -- water doesn't "bow" as much).

Mirrors - concave and convex

* **Mirrors:** [lesson]

1. General observations: Raise right hand, image raises left hand -- there's something backward about mirrors (remember this because properties of mirrors are opposite those of lenses)!

* **Does a concave mirror have properties similar to those of a convex lens?** [observational activity]

shaving mirror

1. How would we test this? Review properties of convex lenses, if necessary. Answer: See if light rays are convergent (come together at a focus).

2. If object is close image should be magnified and right side up. If far away, image is smaller and upside down.

* **How does a concave (parabolic) mirror reflect light from a flashlight?** [lesson]

Bulb is at focus point, all light rays go off in straight lines (to produce a "beam").

* **Use of mirrors and lenses in telescopes:** [lesson]

1. Concave mirrors are used in reflecting telescopes.
2. Convex lenses are used in refracting telescopes.

* **What are the properties of the convex mirror?** [observational activity]

convex mirror (from auto parts store) spoon

1. Observe image: It is smaller and right side up. Note that amount of curvature affects magnifying (or reducing) properties.
2. Hypothesize what image will look like on either side of a spoon.
   Note: concave (side) magnifies if you are close enough. Compare amount of curvature in spoon to shaving mirror.

* **Backward writing:** [activity]

1. Make a message that can only be seen in a mirror.
   a. Write a message in pencil. Flip it over. Rub pencil over back side. Note image that transfers. Darken it by tracing.
2. Looking into a mirror, try and print your name (a) so it can be read in mirror, and (b) so it can be read without mirror.

* **Other forms of radiant energy:** [lesson]

1. Beyond violet light, waves get shorter, pass through more material (i.e., x-rays).
2. Beyond infrared we find longer waves (microwaves, television and radio waves).

<u>Safety</u>

Discuss wavelength (color) and intensity (brightness). Lasers are very intense lights of a single wavelength (color). Intense lights can harm our eyes. Discuss safety.

<u>Speed of light</u>

1. Takes 8 minutes to travel 93,000,000 miles (150,000,000 km) from sun to earth.
2. To nearest star (Alpha Centauri) takes four years.
3. Define "light year". A measurement of distance (how far light travels in one year = 25,000,000,000,000 miles or 4×10^{13} km). Rigel (in Orion, lower right star) is 500 L.Y. away (light you see is 500 years old — interesting prospect — you are seeing what that star looked like 500 years ago. Who knows if some stars we see at night still really exist)!

* – **Develop process skills by involving students as much as possible in these activities.**

SOUND:

* **Review of primary concepts:** [lesson] (refer to K-3, Physical Science, "Sound")

Sources of sound.
Radiates outward in all directions.
"Push" wave (compression, expansion). Demonstrate with Slinky.
Words to describe sound: pitch (frequency), intensity (loudness).
Travels through matter.
Relationship of pitch to length, tension and mass.
Ear and vocal chords -- how they work.

<u>Quality - harmonics</u>

* **What is "quality"?** [lesson]

1. Banjo and violin both play a middle "C".
2. Frequency is the same (i.e., 256 cycles per second). Why do we hear different sounds from each?
3. String vibrates not only at its fundamental frequency (256 cps), but also multiples of that frequency (with different intensities).
   Example: 2 X 256 = 512 cps (vibrates around midpoint)
   3 X 256 = 768 cps (3 little waves, 3rd harmonic)

The sound you hear is the combination of all harmonics (by **plucking** the banjo, more of the higher frequency harmonics are excited. It's these high frequencies that give it its "twangy" quality).

<u>Speed of sound</u>

* **Fun with helium:** [demonstration]

helium balloon

1. Is it safe? Divers mix it with oxygen and breathe it when they go deep because it doesn't dissolve in the blood like nitrogen does. Because it's an inert gas, it doesn't ionize (4-6 Physical Science, "Matter", part 1) so it doesn't easily combine with any other chemical.
   This lesson on safety should be done to encourage students to think twice before inhaling, ingesting or touching any chemicals.
2. Because our bodies can't use it, we would get dizzy, blackout and die (lack of O_2) if we breathe it too long.
3. Helium is much less dense than air. Sound travels faster in helium than in air. Your mouth is like a box that makes different sounds according to its shape and size. If you change the gas in the "box" you change the frequency of the sounds it makes. Since the speed of sound is greater in helium than in air, your voice will have a higher pitch (advanced topic).

* **Observing the speed of sound:** [observational activity]

garden hose

1. Speed = 750 mph; 1,100 feet per second; 340 meters per second.
2. Goes one mile in five seconds.
3. Examples: Lightning - thunder (every 5 seconds = 1 mile away), baseball, fireworks.
4. 50-foot garden hose will delay sound by about 1/20th second -- enough to notice.
   Note: This demonstrates a "sound tube", used on ships (sound is directed along a narrow path, goes further).

Vibrations and frequency

* **Frequency:** [lesson]

Waves per second or cycles per second or Hertz (Hz). (all equal units)
Our hearing range is 20 to 20,000 Hz (ultrasonic is beyond 20,000 Hz).
Dogs can hear to 25,000 Hz.
Piano: low key = 27 Hz, high key = 4,000 Hz
Violin: to 10,000 Hz.
Household electricity is 60 Hz. You can hear this low humming sound on an AM radio (plugged into the wall).

Sound devices

* **Demonstrate frequency and intensity:** [observational activity]

1. Paper towel tube with balloon stretched over one end, paper cone to other. Hold near a candle flame and make noise toward balloon diaphram.

2. Cut both ends out of a short can. Stretch a balloon over one end. Put paper "collar" (barrier) around edge. Put popcorn kernels on balloon and place can on tape recorder - dancing popcorn! Note amount of movement as you vary the volume.

* **Sound amplifiers:** [observational experiment]

tissue tube
balloon half (as above)
rubber band
tape
tiny mirror square (see K-3, Physical Science, "Light", for cutting instructions)

1. a. Balloon held on tube with rubber band, mirror taped to center of balloon (from underside).
   b. Reflect light from sun to a wall. Make noises into the tube.
   c. Students search for tone (fundamental frequency) that makes circular image. Ask them to remember that tone for discussion later in class.
   d. Let students do independent studies and record results. What can they find out with this device?
2. Homemade phonograph using paper tube, straight pin, turntable and old record. Ask students to explain what is happening.

Miscellaneous ideas

1. Sound insulators -- test materials. How can you reduce echoes in a room?
2. Triangulation with two ears (to locate the source of a sound).

Safety

Be sure to cover safety and proper protection of our sense of hearing.

*** - Develop process skills by involving students as much as possible in these activities.**

ELECTRICITY/MAGNETISM

Static electricity

* **Review relevant concepts in chemistry:** [lesson]

Atomic structure: Protons are + and in the nucleus and can't move, but electrons (outer part of atom) can move from one atom to another to create an imbalance of charge.

Static electricity: Rubbing electrons on one object and off another.

Two major concepts: (1) All matter has electricity associated with it.

(2) Static electricity has properties similar to magnetism (like particles repel, unlike particles attract) but **it is not** magnetism.

* **Investigating static electricity:** [observational experiment]

Plastic ruler   wool/rough paper towel   various lightweight materials

1. Charge up ruler with wool and test materials at different stations. Record results.

   Conclusion: Each item responds to charged ruler, therefore, all matter has electric charges associated with it.

2. Explain why some pieces stick and some repel (charge transference).

3. Test charged ruler on thin stream of water/liquid.

4. Plastic box with tissue paper bits and wool -- "dancing paper" [demo]

5. Use balloon and hair to test materials above.

   Note what happens to your hair when charged balloon is close (attraction). Solicit explanations.

6. Scotch tape on table top [demo]. Pull off quickly, hold near your hand, it attracts. Why?

   Pull two pieces off quickly, ask students what they think will happen when you bring them close together (and why).

   Answer: They have similar charges, so they repel.

Current electricity

* **Battery analogy:** [lesson]

1. Two containers of water -- liquid height in both is the same but one holds more water than the other.

   a. Relate liquid height to potential difference (or voltage).

   b. Which one holds more liquid? Develop idea of capacity.

   c. "Current-carrying capacity", using cardboard ramp -- elevated to water height (1.5 volts). How much current (water) would flow from big (1.5 volt) battery vs. small (1.5 volt) battery?

   d. Two big (1.5 volt) batteries, one on top of the other -- ramp now twice as high (3 volts). Would liquid go faster down the ramp? (Yes, the greater the voltage, the greater the current).

e. Show actual 1.5 volt batteries -- one "D" cell and one "AA" cell.

Note: Batteries are not the same height. Remind students that this is only an analogy. Potential difference can be related to static electricity balloon experiment. Light rubbing produces low voltage difference and a great deal of rubbing produces high voltage difference.

Discuss current-carrying capacity and voltage difference between two ends of the battery.

* **Investigate different battery packs and arrays to calculate total voltage:** [activity]

Series vs. parallel combinations of batteries (parallel array does not increase voltage but does increase current-carrying capacity. Series array is additive -- does not increase current-carrying capacity but does increase voltage).

* **Resistance (load):** [lesson]

1. Resistance tends to slow down current.

   Use analogy, put objects on ramp to slow down flow or change width of ramp (narrow) to slow down flow rate (or propose a ramp made of different materials, i.e., carpet).

2. Introduce idea that when an object is on the ramp, it will heat up.

   This is a conversion of energy of motion (water or electrons flowing) into heat energy.

   Would objects get hotter with 1.5-volt ramp or 3-volt ramp? (3-volt, faster current)

3. Light bulb analogy:

   Wire in bulb is narrow (ramp narrows down at a point). Electrons are pushed closer together, hit each other more and heat up. Eventually, the wire gets so hot it gives off light.

<u>Series and parallel circuits</u>

1.5 volt "D" cells — GE-14 (2.5 volt) bulbs — wire

* **Simple complete circuit:** [activity]

one battery — 2 wires — 1 bulb

1. Make the bulb light using 2 wires.

2. Make bulb light using only one wire.

* **Series/Parallel circuit:** [activities]

2 batteries plus holder (red = +, black = -)
2 bulbs plus sockets (can be made with wood and tacks)
18 gauge stranded wire

1. Hypothesize: Using two batteries and one bulb -- would bulb be brighter or dimmer? Use ramp model to support your hypothesis. Students test hypothesis (one bulb).

2. Series circuit (2 bulbs in series):
   Ramp analogy -- two objects on the ramp slowing down the current. Bulbs are dim. Students use two batteries and 2 bulbs (series) to test hypothesis.

3. Parallel circuit:
   Similar to two separate ramps for current to flow down with only one object on each ramp (battery uses twice as much current, bulbs are both bright). Students test this idea.

4. Short circuit:
   Electricity will flow (like water) along the path of least resistance.
   Note: If there were two objects on ramp "B" and only one on ramp "A", electricity would flow down both, but more would flow down ramp "A".

Switches

* **Make a simple switch:** [activity]

wood
piece of aluminum (pie pan)
tacks
wire

* **Design circuits (on paper):** [activity]

Given: 3-volt battery, 2 switches, 2 bulbs, wire.

Design and evaluate different circuits and decide which bulbs will light when combinations of switches are turned on.

Resistance

* **How does pencil lead restrict the flow of current (series array)?** [observational experiment]

3-volt battery
alligator clip wires
pencil lead (split pencils)
1 bulb
wire

By observing brightness of bulb students make inferences about how the length of the pencil lead slows down the flow of current.

* **A resistor -- show one and explain what it does:** [lesson]

Symbol of a resistor: 

Variable resistor (volume control). 

* **Units of measurement:** [lesson]

Voltage = volts
Current = amps
Resistance = ohms

* **What length of pencil lead has the same resistance as a light bulb?** [observational experiment]

1. Make a series circuit with 2 bulbs. Note brightness of bulbs.
2. Replace one bulb with pencil lead and set alligator clips at corresponding distance to make the remaining bulb light up as bright as it did in #1 above (measure and record distance between alligator clips). Compare values as a class.

* **How does pencil lead restrict the flow of current in a parallel array?** [observational experiment]

Similar setup, but with two pencil leads in parallel. Hypothesize before doing experiment.

1. Will the light bulb be brighter or dimmer? (brighter, because current now has two paths to flow through). If we continue to add more pencil leads in parallel, the bulb will get even brighter -- the resistance of the array approaches zero, similar to a straight wire).

* **Troubleshooting:** [lesson]

Go through a circuit (i.e., battery, switch, horn) and follow the path of electricity starting with the battery. Check each component in circuit (by-pass components to test each. Don't forget to test a faulty wire by by-passing it with another). Note: Heed all warnings on car batteries.

Electromagnetic fields

* **Is a magnetic field found whenever electricity flows through wires?** [observational experiment]

How would we test this? Solicit ideas (use a compass, battery and wire).

1. Place compass under the wire (lined up). Connect the battery, needle deflects.

* **How does number of turns around a compass affect the amount of needle deflection?** [experiment]

1. Wrap wire around compass. Try different numbers of turns. Record amount of deflection and number of turns. Formulate conclusion.

* **How does varying the current (use pencil lead) affect deflection of the needle?** [observational experiment]

Do an experiment similar to one above, but put resistors (pencil lead or light bulbs) in line to reduce the current. Note amount of deflection.

* **How does reversing the battery terminals (and current direction) affect deflection of the needle?** [observational experiment]

* **Understanding magnets:** [observational activity]

To make a magnet, electrons in atoms are spinning in the same direction.

1. Use a steel bar, line up in a north-to-south direction, hit on end with hammer. Atoms will "line up" and make a weak magnet.

   To destroy magnet, line up in east-to-west direction, strike again.

* **Experimenting with electromagnets:** [observational experiment]

1. Vary number of turns around the nail, test magnetic strength.
2. Vary amount of voltage (keeping number of turns constant), test magnetic strength.

Conclusion: The more electrons that circle the nail the stronger the electromagnet (this conclusion can be drawn from a variety of the experiments above).

Generating electricity

* **Can we make electricity by moving a magnet across a wire?** [observational experiment]

1. Small current, need sensitive detector (compass with 40 turns of #20 gauge wire. Strip varnish off wire ends with sandpaper). Coil and needle line up.
2. Tissue tube with about 30 turns of #18 gauge wire connected to the detector (1 to 2 feet away).
3. Move a bar magnet inside the tube. Record amount of deflection on current detector (compass).

Study effects of:

4. Adding more turns to the cardboard tube (greater deflection)
5. Using a more powerful magnet (greater deflection)
6. Reversing the poles of the magnet (compass deflects in other direction — current now flowing in opposite direction).

Magnetic strength

* **Review field lines:** [observational experiment]

Use solargraphic or sunprint paper. (Refer to K-3, Physical Science, "Magnetism")

* **Strength of a magnet vs. distance from the magnet:** [observational experiment]

ring magnet
magnetic objects (different weights)
paper scale (milimeters)
books
tape
balance
ruler
thread

1. Record results: (a) distance where object falls, and (b) weight of object
2. Graph weight (grams) vs. distance (cm.).
   Results: curved line. What does this mean? (The magnetic field is very strong near the magnet but decreases very quickly as you move away from the pole).
3. Interpreting an unknown:
   a. Weigh the large paper clip. Find where its weight and the curve line meet. Read off the expected distance at which it will fall.
   b. Test the unknown with the magnet to see how close our approximation was (compare the two results in a lab report).
   c. Which group had the most powerful magnet? Compare graphs of different groups.

Writing a lab report

* **Assign a lab report as a follow-up activity to selected experiments:** [activity]

Three parts:

What I did	What happened	What I found out
State the problem	Observations	Look at data
Make drawings	Data tables	Make conclusions
List materials and procedures	Graphs	

Good lab reports are brief (especially in "procedure" section). Most can be done in 1-3 pages (graphs, extra).

*** - Develop process skills by involving students as much as possible in these activities.**