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Grade 5 Lunar Base Science Unit

An Interactive Qualifying Project Report
submitted to the Faculty of
WORCESTER POLYTECHNIC INSTITUTE
in partial fulfillment of the requirements for the
Degree of Bachelor of Science

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We would also like to thank Mr. Mahoney for provide us with the opportunity to experiment with our enriched activities on his classes.

ABSTRACT

The goal was to promote technological literacy, make science education fun, and identify talented students interested in science and foster their efforts starting with 5th grade. Our team was able to create activity kits that included materials, storyline, activities, and concept sheets. These kits go with several key chapters in the 5th grade textbook that is used by the Worcester Public Schools. The theme connecting the units was a story line involving the challenge of building a lunar base out of local lunar materials. One advantage of this theme was that we could show them a picture of a proposed base that won the technical feasibility award in a recent architectural contest to design a 2069 Lunar Base. Much of the work leading up to a finished base 57 years from now would be within the working lives of these 10-year-old 5th grade students.

CHAPTER 1
INTRODUCTION

One hundred years after the launch of Apollo 11, when the first human ever, Neil Armstrong and Edwin "Buzz" Aldrin, Jr. stepped onto the moon, we are now imagining a full scale lunar base that can feed itself, pay for itself and support 60 people at a time. Excited by the reports of more water on the moon than expected, an architectural organization associated with Boston chapter of American Institute of Architects “SHIFTBOSTON” had organized a lunar base design competition. The challenge was to design a second-generation agriculture base, which can handle 60 people at a time on one-year deployment. It was made clear that the base was to be expandable into a lunar city over time. Among all the designs, some have proposed solutions to significant issues such as food and power resources, yet those solutions are still conceptual and further considerations will be needed before we can actually build the base on the Moon. That will be the job of the next generation after those of us getting degrees in the next few years.

Let’s move the time forward, years later, this generation of college students and professionals probably will not be the ones who conduct the construction of the lunar base. It is the 10-year-old or younger kids who will be responsible for building the base our generation plans, after we build the first generation base for 6 – 10 people at a time. Nowadays, the majority of the public still doesn’t know that it is possible to build a base for people to live on the Moon. Also Survey had shown that the percentage of the teenagers in the United States who are interested in math and science is much lower than many other countries. For the purpose of improving students’ interests in deep learning science and technology and more importantly promoting the possibility of building a lunar base, our IQP team designs enrichment activities which are appropriate for use at elementary school level and more importantly relate the lunar base theme in teaching science concepts. Our sponsor, the ones picking up bills for about $50.00 worth of materials every 2 weeks, has been the AIAA, New England Chapter. The AIAA reports that 20 percent of its current memberships will reach retirement age in the next 3-5 years, so it is very interested in on tread to the public schools. Our job was to make science the fun class and use a lot of aerospace examples not in their text.

CHAPTER 2
BACKGROUND

LAST YEARS REPORT

This project is a continuation of last year's "Fifth Grade Lunar-Themed Science Curriculum Unit" team. The team from last year also focused on developing "fun" activities and getting students involved in hand-on activities instead of letting them simply read through concepts and experiments on the book. However, they planned big events while we focused more on the day-to-day classroom. Still the previous team and our team shared the same purpose, which is increasing students' interests in science and technology, especially in the field of aerospace tied to an interdisciplinary effort to build a lunar base. Furthermore, all of us wish the students would potentially improve their MCAS scores by performing the hand-on activities we designed in order to retain the concepts better. Since one quarter of the credit involves a design project we wanted to get them thinking in applied problem solving terms. The team from last year organized three capstone events: MCAS Review Day on the moon at WPI, Dr. Fred Bortz's presentation on our next planet at Elm Park School in the classroom, and a field trip to the McAuliffe Center in Framingham (a Mars Crew Exchange Mission) to enrich the classroom learning. They claim to have taught more science in a day than was covered in a month of classes. However we doubt the curriculum connection was made. What they did was peak their interests in science and technology.

5TH GRADE KEY WORDS IN TEXT BOOK

Using the 5th grade textbook was an important factor during this project. We had to able to tie the lunar base theme to the important key concepts in the students' textbook, and do it day in and day out for weeks. Since these were the terms that they learned in class and were going to be on the MCAS, the teacher was will to cooperate. Below are each of the chapters and key words in those chapters that we used in order to be able to easily explain to the students the concepts and the theme.

Chapter 13: Earth, Moon, and Beyond

Lesson 1:

Sun: The star at the center of our solar system

Rotate: To spin on an axis

Axis: An imaginary line that passes through Earth's center and its North and South Poles

Revolve: To travel in a closed path

Orbit: The path one body takes in space as it revolves around another

Equator: An imaginary line around Earth equally distant from the North and South Poles

Lesson 2:

Moon: Any natural body that revolves around a planet

Crater: A low, bowl-shaped area on the surface of a planet or moon

Moon phase: One of the shapes the moon seems to have as it orbits Earth

Eclipse: An event that occurs when one object in space passes through the shadow of another object in space

Refraction: the bending of light as it moves from one material to another

Lesson 3:

Star: A huge ball of very hot gases in space

Solar system: A star and all the planets and other objects that revolves around it

Universe: everything that exists, including such things as stars, planets, gas, dust, and energy

Galaxy: A grouping of gas, dust, and many stars, plus any objects that orbit those stars

Chapter 14: Properties of Matter

Lesson 1

Volume: The amount of space an object takes up

Atom: The smallest particle that still behaves like the original matter it came from

Molecule: Two or more atoms joined together

Nucleus: A dense area in the center of an atom that contains protons and neutrons

Element: Matter made up of only one kind of atom

Periodic table: A chart that scientists use to organize the elements

Lesson 2

Physical change: A change in which the form of a substance changes, but the substance still has the same chemical makeup

Density: The measure of how closely packed an object's atoms are

Mixture: A combination of two or more different substances

Solution: A mixture in which all the parts are mixed evenly

Lesson 3

Combustibility: A measure of how easily a substance will burn

Reactivity: The ability of a substance to go through a chemical change

Chapter 15: Energy

Lesson 1

Energy: The ability to cause changes in matter

Kinetic energy: The energy of motion

Potential energy: The energy an object has because of its condition or position

Lesson 2

Solar energy: Energy that comes from the sun

Light: Radiation that we can see

Chemical energy: Energy that can be released by a chemical reaction

Mechanical energy: The combination of all the kinetic and potential energy that something has

Electric energy: Energy that comes from an electric current

Lesson 3

Heat: The transfer of thermal energy between objects with different temperatures

System: A group of separate elements that work together to accomplish something

Conduction: The transfer of heat from one object directly to another

Convection: The transfer of heat through the movement of a gas or a liquid

Radiation: The transfer of energy by means of waves that move through mater and pace

Reflection: The bouncing of heat or light off an object

Lesson 4

Fossil: The remains or traces of past life, found in sedimentary rock

Resource: Any material that can be used to satisfy a need

Nonrenewable resource: A resource that, once used, cannot be replaced in a reasonable amount of time

Conservation: The use of less of a resource to make the supply last longer

Renewable resource: A resource that can be replaced within a reasonable amount of time

Pollution: A waste product that harms living things and damages an ecosystem

Chapter 16: Electricity

Lesson 1

Electricity: A form of energy produced by moving electrons

Electromagnet: A magnet made by coiling a wire around a piece of iron and running electric current through the wire

Lesson 2

Static electricity: The buildup of charges on an object

Electric current: The flow of electrons

Current electricity: A kind of kinetic energy that flows as an electric current

Conductor: A material that carries electricity well

Insulator: A material that does not conduct electricity well

Lesson 3

Electric circuit: The path an electric current follows

Series circuit: An electric circuit in which the current has only on path to follow

Parallel circuit: An electric circuit that has more than one path for the current follow

Chapter 17: Sound and Light

Lesson 1

Vibration: A back-and-forth movement of matter

Volume: the loudness of a sound

Pitch: How high or low a sound is

Frequency: the number of vibration per second

Lesson 2

Reflection: The bouncing of heat or light off an object

Opaque: Not allowing light to pass through

Translucent: Allowing only some light to pass through

Refraction: The bending of light as it moves from one material to another

Concave lens: A lens that is thicker at the edges than it is at the center

Convex lens: A lens that is thicker at the center than it is at the edges

Chapter 18: Forces

Lesson 1

Force: A push or pull that causes an object to move, stop, or change direction

Friction: A force that opposes motion

Gravity: The force of attraction between objects

Gravitational force: The pull of all objects in the universe on one another

Magnetic: Having the property of attracting iron objects

Magnetic force: The force produced by a magnet

Lesson 2

Balanced forces: Forces that act on an object but cancel out each other

Unbalanced forces: Forces that act on an object and don't cancel out each other; unbalanced forces cause a change in motion

Net force: The combination of all the forces acting on an object

Buoyant force: The upward force exerted on an object by water

Lesson 3

Work: The use of a force to move an object through a distance

Simple machine: A device that makes a task easier by changing the size or direction of a force or the distance over which the force acts

Lever: A bar that makes it easier to move things

Fulcrum: The balance point on a lever that supports the arm but does not move

Wheel-and-axle: A wheel with a rod, or axle, in the center

Pulley: A wheel with a rope that lets you change the direction in which you move an object

Inclined plane: A ramp or another sloping surface

Chapter 19: Motion

Lesson 1

Position: The location of an object in space

Speed: The distance an object travels in a certain amount of time

Velocity: A measure of an object's speed in a particular direction

Acceleration: The rate at which velocity changes

Lesson 2

Inertia: The property of matter that keeps it at rest or moving in a straight line

CHAPTER 3
METHODOLOGY

LUNAR BASE

Materials and Cost List

- Table top Lunar base model built by a previous group – (The one before the last group)
- Solar panel kit
- Handout (Appendix A)

Method:

Divide all students into several groups. Introduce the lunar base model and provide each group with a list of names of structures on the lunar base model. The main structures are living space; gas gathering unit, power plant (nuclear), Silicon (glass) processing unit and metal processing unit, greenhouse (agriculture unit). Assign each group a specific structure name and let them try to find which structure on the lunar base correspond to the name given and why. Each group choose a leader explain and justify their choices and presenter tells them if it's correct or not, if not, provide the correct choice and also tell students why. Then presenter gives a short demonstration on how solar energy works and why it is important as an energy resource on the Moon. Teacher or Presenter gives a presentation on lava tubes and craters, poles and equators, especially Shackleton crater on the south pole of the moon in order to prepare students for writing assignment on where they would put a lunar base and the coming crater activity. They also provide the students with knowledge on building lunar base and trade-offs in choosing locations of lunar base. Then give them take-home writing assignment on where we should put the lunar base and why.

Structure list for the activity:

Living space – human habitat
Biosphere Theme
 - Exhaust gas gathering unit
 - Greenhouse – Agriculture unit (Provide oxygen)
Astronomy station
Silicon (glass) processing unit and metal processing unit
Power plant (nuclear)
Solar panel (solar energy) unit
Spacecraft station
Ground Transportation facility

EARTH MOON

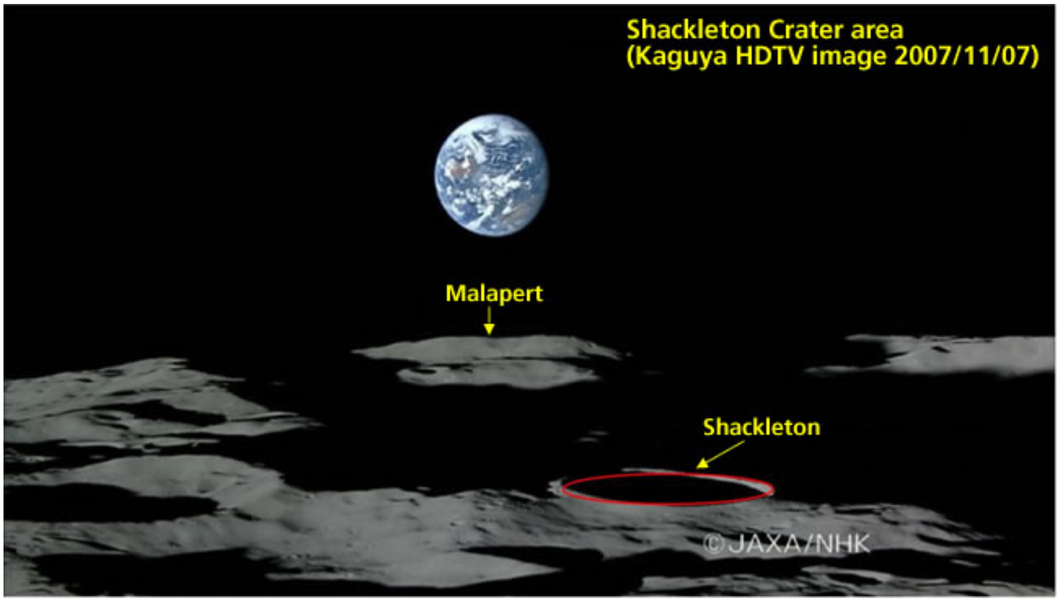
Earth and Moon for the Lunar Base:

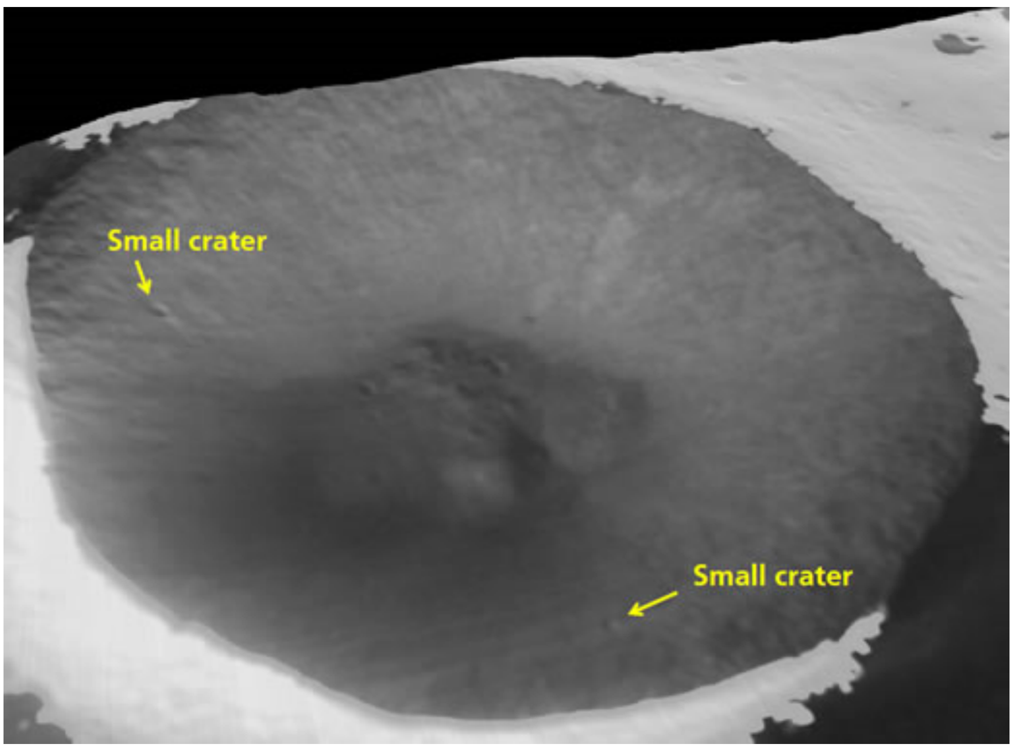
Both the Earth and moon are made of many of the same materials, such as aluminum, oxygen, calcium, silicon, iron, and titanium. The diameter of the Earth is 4 times larger than the diameter of the moon, and the Earth's gravity is 6 times stronger than gravity on the moon. The moon has very little atmosphere. This means two very important things. 1. Temperatures of the moon are much more extreme than on Earth, ranging from over 212 degrees in the day to -247 degrees at night. 2. The moon has no protection from the Sun's radiation or asteroids so it is dried out and covered with craters, while the Earth isn't. Also nothing grows there naturally.

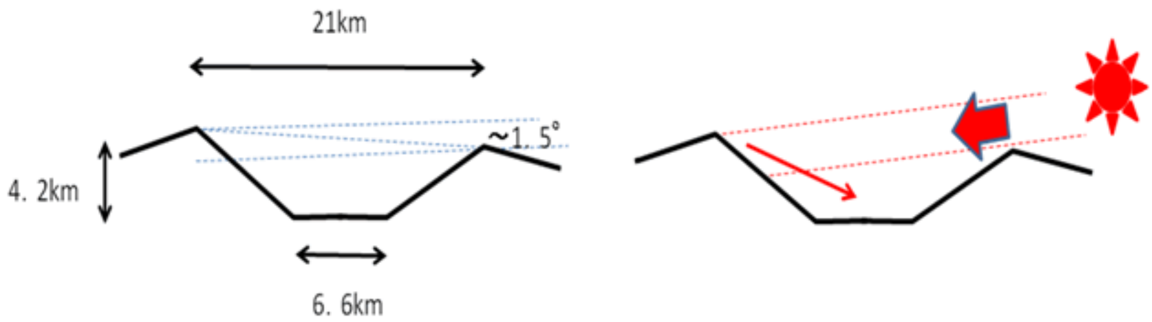
There is no plant or animal life though the moon is made of nearly the same things as the Earth. Plants and animals on Earth need water and breathe gases from the air. The moon can't support that kind of life. The Earth's atmosphere protects the Earth from small comets (ice), asteroids and meteors (stone or iron). They hit the air surrounding the Earth and held to it by gravity and get very hot. The small ones melt or burn up completely and the medium sized ones that are stones explode. So, the Earth's atmosphere allows only the biggest stone (and the Iron ones that are good sized) to actually hit the Earth. More than half of them hit an ocean, make a big wave and cloud of steam as they disappear from sight. Even those craters on the land disappear over time because the Earth has water and air, which are reshaping it all the time. Even the hardest rocks wear down or "weather" over time as wind and rain impact them and water breaks up the rocks when it freezes.

Rain fills the craters and the lakes in them overflow at the lowest point and cut a channel into the side of the crater. So, wind and rain cause erosion, which makes craters harder and harder to recognize on Earth on the moon, every asteroid and meteor hits it, no matter how small, and the craters are not changed by wind and water so they are changed only by other later asteroid craters. So you can see layer upon layer of crater impacts smashing the surface into fine dust.

The picture below is of a famous crater near the south pole of the moon that is considered small- only 19 km diameter across it. Note that there are smaller craters in it, from asteroids that hit later. NASA thinks it Shackleton Crater might be a good place for a lunar base. The sun nearly always shines there, but the bottom of the crater is always dark and cold- so any ice there would not melt and evaporate off into space. Water on the moon of any kind is rare and valuable.


Shackleton Crater area
(Kaguya HDTV image 2007/11/07)
Malapert
Shackleton
©JAXA/NHK


Small crater
Small crater



Earth and Moon Activity:

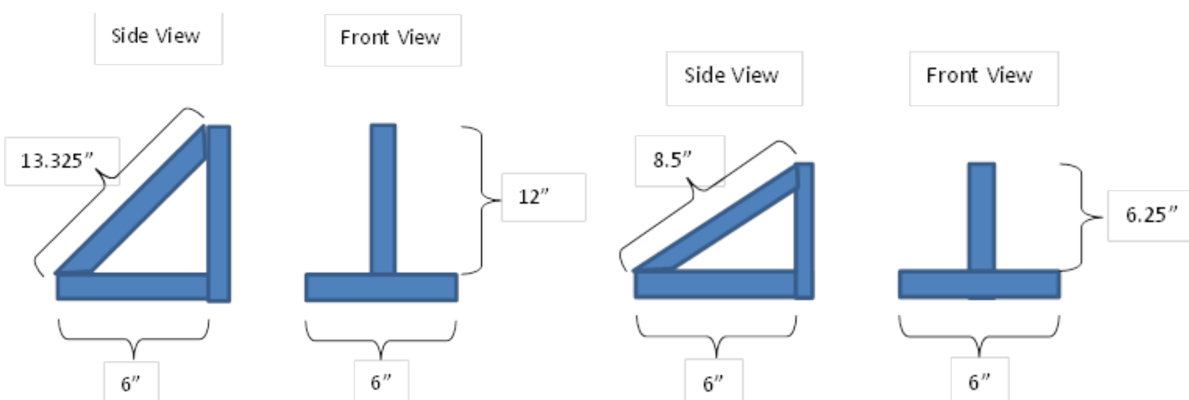
Materials and Cost List

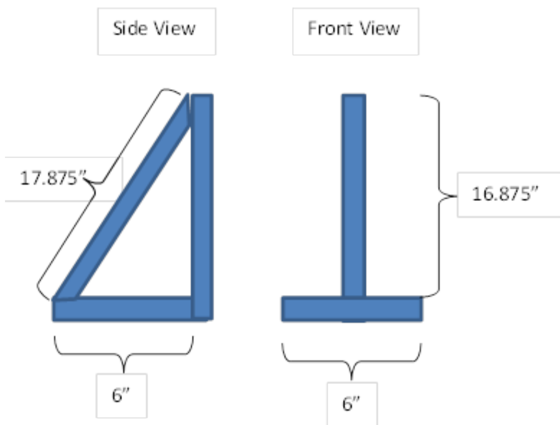
- 2 Lbs. Flour - $4.00 each Lb.
- 1 bag of Black Sand - $5
- 6 ft. long vinyl edging (Ramps) - $6 each
- Ramp Stands (15°,30°,45°,60°) - $10 total
    - 1in square wooden dowel rods
    - Wood screws
- 5 Aluminum Trays - $3 each
- Shooter size Marbles/Ball Bearings (¾ in diameter) - $5 a bag
- Ruler - $1
- Meter Stick – reusable
- In – Class Handout (Appendix D)

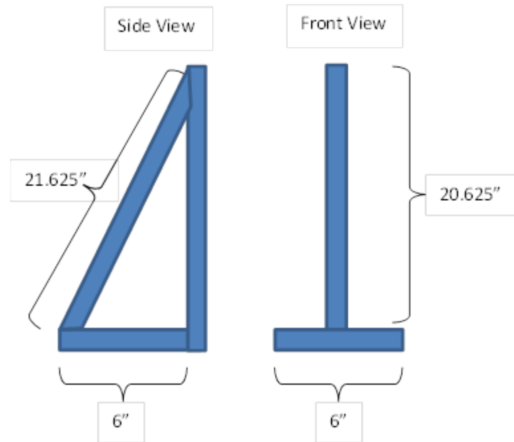
Method:

For the dimensions of constructing the ramp stands, see figure below for the 15° ramp stand, figure below for the 30° ramp stand, in the figure below for the 45° ramp stand, and figure below for the 60 ° ramp stand. These figures are not to scale.

There should be a total of five trays, four with ramps and one with the meter stick. Each tray should be layered with one inch of play-dough (not a necessity) and two inches of flour with a sprinkling of black sand on the very top. This represents the surface of the moon with the sand being the basalt and the flour representing the regolith. The play-dough represents the crust of the moon, anorthosite, but not having the play-dough does not alter the actual experiment. The idea for these layers was found in book (Appendix C). However, the method of experimentation was the same in that the only variable was a change in height for the ball bearings. The ramps should be positioned so that the bottom of the ramp is just at the lip of the tray (see figure below). The class should be split into no more than five groups. Each group is assigned a station where they will drop the ball bearing from the top of the ramp (or the top of the meter stick). Following the instructions on the handout, they record the necessary information before rotating to the next station. Once the data has been collected from each station, assistants should remove the ramps and flour while the teacher finishes the discussion about what they learned and ask the question, "What angle did they think the asteroid that made Shackleton Crater came in at?" Through this activity the Earth and Moon chapter was expanded (Appendix B).







MATTER

Matter Activity:

Materials and Cost List:

- 3 Lbs. Paraffin Wax - $5 each Lb.
- Wax skin treatment heater/Crockpot - $20 total
- Ladle - $2
- 4 Aluminum trays - $3 each
- 1 ½ Lbs. Play dough - $4 total
- Small Tools - $5
- In - Class Handout (Appendix E)

Method:

The assembly and preparation of the Matter Chapter kit was one of the simpler kits in the unit. Preparation before the in class activity is crucial; the wax melts at approximately 100°F and depending on the heating temperature of the skin treatment wax heating unit or crockpot it may take between a few minutes to several hours to fully melt the wax. Once the wax is melted, if necessary, lower the heating temperature to around 110-120°F to keep the wax melted but to prevent injury in case a student accidentally touches the wax.

Each group of students in the classroom will also need their own tray with enough play dough in it to make an impression of whatever tool they are assigned. The key of the activity was for the students to be able to watch a material go from a liquid to a solid right before their eyes. In addition, it helped drive home the point that while freezing only occurs at 32°F for water; other materials freeze at higher (or lower) temperatures. During the class discussion before the actual activity, the class was briefed on the fact that it is extremely expensive to bring materials from Earth to the moon. As a result, it is more economical to make tools and other necessities from materials found on the moon. The students were told that the wax represented metal that was mined on the moon and melted down for processing. The tools were pressed into the play dough to make molds and the wax poured into the mold to make a new tool. It takes the wax between 5-10 minutes to solidify to the point where it can be removed from the mold.

FORCES

BUOYANCY

Buoyancy Activity:

Materials List:

- 15 Liter Plastic container - $2 each
- Water
- 1 - two piece canning lid – (reusable)
- 1 - single piece canning lid – (reusable)
- Pocket change
- Helium balloon- $1.50

Method:

The plastic container should be filled three quarters of the way full with water prior to the in-class discussion. The discussion should focus on the concept of displacement and the relationship of the weight of the water displaced to the weight of the object that is displacing the water. This concept can be difficult for the students to pick up and it will need to be explained more than once. Drawing a diagram on the board of a block partially in the water and a dotted line showing the water that is "missing" does help considerably. The discussion should be led into how boats are able to float when they are made of materials that don't normally float (metal, concrete, etc.). To further drive home the idea first show the two lids. The will see that they are both the same size and made of metal. "Break" up the two-piece lid and show that both pieces will sink in the water. Then put the single piece lid in the water and ask why it floats. You then need to explain that the air in the ship also counts as weight, even though it is next to nothing, but the water weight of the displaced area is still immense. If the first part was explained well this concept is not hard for them to pick up. To increase the wow factor, slowly add pocket change into the lid until it sinks. This entire discussion can be done in five minutes but should not take more than ten in order to have time for the gravity and friction forces.

GRAVITY

The gravity section is suggested to move into math class since it involves multiplication of decimals and fractions.

Gravity for the Lunar Base:

People in good shapes do regular workout, they lift weights and comparatively, people who do not workout have less muscle. In low gravity situation, people experience even less body weight, muscles are stronger than it's necessary. So people don't use or use just a little muscle in lower gravity to walk or do things.

Imagine stand on head your head is filled with more blood than it usually has, it is because of gravity. Gravity prevents human blood from “overflowing” into head. But under low gravity, more blood goes to head and the body reacts by decreasing the blood volume so to avoid the excess blood in head.

On the moon, you will experience only 1/6 of the gravity on Earth. Now we have discussed damages of less gravity on human beings. In order to fight against damage caused by less gravity, the assignment is to find out how much additional weight people have to carry so to maintain their normal muscle strength.

Gravity Activity:

Materials and Cost List:

- Three identical boxes (Labeled) - reusable

30lb mass What you will feel when lifting it on Earth	30lb mass What you will feel when lifting it on Mars	30lb mass What you will feel when lifting it on the Moon

- 24 pack of water bottles – $3 total

(Note: The mass ratios inside the boxes should be 6:2.4:1 (Earth: Mars: Moon). Sample weight to put inside the boxes: 30lb in “Earth” box, 12lb in “Mars” box, and 5lb in “Moon” box)

Method:

Sit all students in order and assistants pass around three boxes. Ask each student to lift the box and feel the weights of the same object on different planets. Also ask them to remember the relative weight and the planets. Then show students the relative size of the planets. (Ordered from large to small: Earth, Mars, and Moon). Ask them to compare the weight and the size of the planets. The conclusion should be the larger the planet is the heavier the weight of the same object will be.

Gravity Math exercise:

Where you at	Description	Weight	Notes and Hints
Earth	Your Weight on Earth		Your muscles normally support this amount of weight on Earth
Moon	Your Weight on the Moon		Now if you go to the moon, your muscle actually support of 1/6 of the weight on Earth
Moon	Additional weight has to be carried?		It's difference between the weight on Earth and on the Moon
Earth	What's the weight you carried on the moon if it's on Earth		Imagine that the weight you carry on the moon is now on Earth

Sample worksheet:

Weight on Earth = 6 * Weight on Moon

Where you at	Description	Weight	Notes and Hints
Earth	Your Weight on Earth	60lb	Your muscle normally support this amount of weight on Earth
Moon	Your Weight on the Moon	10lb	Now if you go to the moon, your muscle actually support of 1/6 of the weight on Earth
Moon	Additional weight has to be carried?	50lb	It's difference between the weight on Earth and on the Moon
Earth	What's the weight you carried on the moon if it's on Earth	300lb	Imagine that the weight you carry on the moon is now on Earth

FRICTION

Reducing Friction on the Earth and moon for Activity:

Materials and Cost List:

- 6 Canned food (soup) cans - $1 or $2 each
- 6 Single piece lids (mason jar size) reusable
- One sheet of sandpaper - $1 a sheet
- Ball bearings- 6-10/ can all the same size
- Tape
- 6 Index cards (2 different colors)

Method:

Before doing this activity in your classroom the cans and lids need to preassemble. Take the index card and tape three of the same color on three different cans. Repeat on the other three sets of cans of the second color. Once the cans are distinguished, set up the lids. You will only take three lids and place sand paper in each one. Make sure that each edge inside the lid is covered.

In the classroom divide your students into 3 different groups. Pass two each group two different cans, one with the sandpaper lid and one without the sandpaper lid. Instruct the students to feel the difference between the two cans and to think which one provided more friction. Once each student has tried to move each lid bring the whole class to attention and discuss how this affects the design of the rotating solar collectors on the South Pole lunar base. They have to track the Sun as it goes around the base on a 28-29 Earth day cycle. Should the lunar design include ball bearings to reduce friction given the surrounding lunar regolith that will get into the tracks is like fine sand? Show the image of the Tom Schmidt version of the lunar base.

MAGNETISM

Magnetism Activity:

Materials and Cost List:

- 12 Bar Magnets - $20 total
- 6 Nails - $3 for a box
- 1 six inch bolt - $2 each
- 1 Box of paperclips - $2 a box
- Pictures – (reusable)
    - Earth's Magnetic field
    - Bar Magnet with iron filings showing magnetic field
    - Electro-Magnet

Method:

The Magnetism activity was done on its own day at the request of the teachers, Francis Mahoney; so more time could be spent on discussing it. He felt gravity had been covered a few times, but not magnetism. Therefore, this plan is designed for an entire lesson block and was not fit into 45 minutes with the buoyancy, gravity, and friction forces. Hence, 90 minutes in all went to covering these 4 forces, half to magnetism.

Minimal preparation is needed before the start of the lesson; only the projector to show the images provided should need to be set up and ready to go. Supplies should not be passed out until they are ready to be used. Begin the class with a brief discussion of what magnets are and where they can be found in the real world. Be sure to mention compasses, Earth, and magnetic fields in the discussion. The students seem to think magnetism passes through the metal rather than having a field extended around a steel or iron object.

At this time, pass out the magnets and ask the students to determine which side is the north side of the magnet and which is the south (they should not be labeled). After a minute or two, recollect the magnets and quickly discuss with the class that the north and south poles of magnets are assigned. If they grasp the concept quickly, a good question to ask is "If a compass is a magnet where the North Pole points north, where is the Earth's magnetic north pole?" They should be able to remember that opposites attract and if the magnetic north of a compass points north, then Earth's magnetic north is in Antarctica. If they are not able to figure it out on their own after a minute, tell them the correct answer and why and move on.

A solid chunk of the discussion should revolve around magnetic fields particularly Earth's magnetic field and implications of the moon's lack of one. Utilize the images and discuss the advantages of having a magnetic field and the difficulties people on the moon would face from cosmic radiation without it.

The last fifteen minutes of class should be reserved for the hands on experiment. Spend the first five minutes to show that magnets can be used to briefly magnetize iron. Another important demo is to show that the metal, the bolt works best, does not need to be in contact with the magnet in order to become magnetized. The final ten minutes should be left to the students to perform their experimentation. Pass out a large and small magnet to each group, a handful of paperclips, and datasheets. Have the student see how many paperclips they can pick up with the large, small, and combined magnets. Be sure to specify they are trying to see how many they can pick up in a chain. The idea is to see whether the physical size of the magnet has an effect on the strength of the magnetic field or not.

ENERGY

Energy for the Lunar Base:

The sun constantly releases solar wind, which carries hydrogen atoms from the sun across space. When the hydrogen from the solar wind hits the moon, it combines with the oxygen atoms in the regolith to form water molecules. On most of the moon, direct sunlight soon evaporates the water and it escapes into space where it cannot be used. However, because the sun stays low in the sky when you are at the north or south poles, the sunlight cannot reach the lower part of the insides of the craters at those parts of the moon. Water forms and accumulates in the form of a dirty ice ball in the dark bottom half of the crater.

Now imagine that a moon base is being constructed on the edge of in Shackleton Crater (South Pole) in 2060. The base was dug into the side of the crater nearly three kilometers above the bottom of the crater. On any given day half of the top third of the crater is lit. Because the inside of the bottom two thirds of this crater never gets any sunlight, miners (robots directed by people on Earth or in the lunar base at the top of the c rater) go to the bottom of the crater to mine ice that has formed there for use at the base.

Shacklton crater is about 19-20 km in diameter at the surface but only 6.6 km of flat area can be found on the crater floor. So the processing center in the middle of the bottom is about 3 km away from the crater walls on all sides. A parabolic mirror at any point along the rim of the crater can thus redirect a concentrated beam of sunlight down into the crater to hit the processing center and warm it to the melting point of ice, which is comfortable for a human with a space suit. People can work in this building, but no one has to be there. Usually one person is on duty observing a crew of ten robots two of which work in the building and 8 of which work outside of it. The human monitor can take control of any of the 10 away from the remote operator on Earth if need to be.

The miner robots carve blocks out of the crater bottom and shaded sides with small lasers that look a bit like light sabers, they bring the raw material to the special heated building at the center of the crater to separate the water from the other materials in the water ice rich regolith. They only want to take uniform sized blocks of pure ice up the ramp. The building is black and the mirrors are polished and coated chromium. This is significant, as we want to reflect a powerful a beam of light as possible down 6 km into the otherwise perpetually dark center. Then we want the light not to reflect off the building but to be absorbed into it as heat rather than light.

One does not want intense direct sunlight to flash the water into steam and have it float off into space. We want controlled heating so the roof can change color and be partly white and reflective if it gets too hot inside. White means we are reflecting all colors of light. Black means it is not reflecting any but it is being absorbed. If you see red (infrared) or blue (ultraviolet) that means that wavelength of light is being reflected and the rest absorbed.

The ice inside melts and pools as heavier solids fail to the bottom of the processing vat due to the moons of gravity. The somewhat salty water is drawn off of the top, and put in cube-sized holders with a metal bar through them. They are then taken out of the building and left in the shade at the bottom of the crater where they rapidly freeze back into solid ice.

Sometimes there are cracks and flaws in the blocks but normally you get a smooth solid block with an iron bar through it to provide a place to tie on a cable to pull it along a smooth fiberglass ramp.

Now, in order to get the ice up to the base, the miners have built a long ramp from fiberglass that was made of silicon taken out of the regolith removed from the dirty ice mined at the moon. This was some of dirty part of the raw material. Some of the rest became the metal iron bar. You have to make it a lot hotter to melt glass and iron then ice, but it can be done. The miners can also drill a hole through the block of ice and place a cable through it if necessary, but at the temperature in the shaded crater ice is as hard as steel, so that take a lot of energy drill and it more likely to crack the brittle ice than to insert the bar before the water freezes. Far Better to put the iron in while it is still a liquid and have it freeze around the metal. In any case the robot operators on Earth can now have the robot pull a cable that drags the block all the way up the ramp to the base at the top of the crater. Indeed, one can rig a system with two ramps so that one is always pulling up one cable and letting out another so the robots just have to move from one ramp to the other to hook up a new ice block.

The ramp is flat for 3 km and then tilts to about 30 degrees for the 4 km trip up the crater side. If the ice cube was flawed it should break and the pulling bar would probably then come loose within the first 3 km. if this happens a robot minor just takes it back to be melted again and refrozen. It is more problematic if it does not break then but starts up the crater side and then breaks. Why?

The problem with this method of transporting the ice to the moon base by dragging it up a ramp it will slide back down the ramp if the ice block breaks free. The higher it is when the breaks the farther and faster it will side. Worse, near the top of the crater, for a short distance, the sunlight is able to hit the ramp and warm up both the ramp and the ice. The ramps were made of fiberglass rather than metal for this reason, metal conducts heat and the whole ramp would be hot and melt the ice if it were metal. Only the area near where the sunlight actually hits heats up when it is glass. When the Sunlight hits it the ice will begin melting especially at the point of the metal pole goes through the ice. The whole bar-even that in the middle of the ice cube will get hot enough to start melting the ice around it since metal conducts heat better then the water. If it gets too hot it will melt the ice holding it in place and the cube will break free right near the top of the ramp. This is a problem only fourteen days every month. The ramp is in the shade the rest of the time all the way to the top.

Although the ice will survive the trip through the sun up into the moon base, there is the possibility of the ice breaking free of the cable and falling back down the ramp to the bottom of the crater, and the risk is much greater when it travels through intense sunlight. During the 14 days the ramp is in the light the middle days 7 and 8 are the hottest. How dangerous is a break free and should we shut down the ice operation for a while each month? We want you to decide.

As a result, we need you and your team to experiment with models of ice breaking free at different heights and sliding down a ramp back into the crater. The main question is, how far will the ice slide on the crater floor and is the icehouse building at the center of the crater in any danger?

Energy Activity:

Materials and Cost List:

- 6 Towels – (reusable)
- 6 Nails – $3 a box
- Paper Towel Rolls - $1 each
- 4”x4” wood squares (1” thick)-
- 6 ft. long vinyl edging (Ramps) - $6 each
- Ice cubes with different shapes
- Small boxes – (reusable)
- 6 Golf Balls - $15 total
- 6 Ping Pong Balls -$4.50 total

Method:

Ice cubes slides down the ramp simulating when the system fails. There is a small plastic tray or box about 4” x 6” and one inch high representing the ground facility in the middle of the crater bottom. The objective is to investigate what the highest distance up the slope of the 30 degree ramp that an ice cube can be raised, before a failure would hit the tray or box, representing damage to the ice making facility. We also want to investigate how the shapes of the ice cube change the distance it will slide. Set up the equipment. Be sure the icebox and the ramp are on a line (when the ice cube slides down, it should be able to hit the box). Slide down the ice cube from one position on the ramp. (Note: No initial push). Observe whether it hits the box on the floor or not. Repeat step 2 and 3 with ice cube of the same shape at different position on the ramp. Repeat step 2 through 4 with a different ice cube. We did this on a tile floor where the tiles were about right to represent one kilometer each from the end of the ramp. This was not the case measuring off that distance would be necessary. The floor gets wet, so we ringed the area on both sides with a rag made of half a regular towel. This confined the ice and water and made clean up easy. It also avoided a hazard since a child could slip on a wet floor.

The last ten minutes of the class should be reserved for a demo on energy transfer. In a location where all of the students can see, set up one ramp on the stand and a second ramp flat on the table (but so they are touching and a ball can roll across both of them). You may need an assistant to set up a box at the very end of the ramp. Before the demonstration, be sure to pose the question to the students, “If the ice were to break free, would the other ice blocks waiting to go up stop it before it hits the building?” Most likely they will all agree and the first demo would be to put one golf ball at the base of the ramp and release the second from the top. After seeing the first ball stopped and the second one go flying, propose the idea to stack more on the bottom of the ramp. If there is time go in increments of two, but if not, just stack all five on the bottom. The same result should occur where the final ball goes shooting off at the box at the end. Repeat the final demo with the ping pong balls to demo what a lighter object does. Quickly discuss the transfer of energy and how it is not a safe method to rely on stopping the sliding ice blocks. A final demo, for excitement purposes only, would be to slide a golf ball down at a row of ping-pong balls.

Work sheet:

Shape of Ice cube	Height of drop	Is it safe? (Does it hit the box?)

LIGHT AND SOUND

Light and Sound for the Lunar Base:

When the competitors for the 2010 Shift Boston lunar base contest read the rules describing a serious lunar base circa 2069, it was clear that about a third of the lunar base would be devoted to growing plants for food and raw materials for building and making textiles, like bamboo, flax and wood from aging fruit trees. The rules called for a large capacity electrical generating plant and about half of it was to be used providing power for grow lights to run an underground greenhouse. However, turning sunlight into electricity and using the electricity to run lights is very inefficient. That means that very little of the energy in original light actually gets to the plants for them to use in photosynthesis, (about 10%). There had to be a better way.

Could one use the sunlight directly? The goal would be to use reflection to deliver about as much as would reach Earth through the atmosphere and cloud cover. Could mirrors alone get sunlight without radiation to the plants in the top level of the lunar base, which would be developed to agriculture? In order to do so the light would have to be made to concentrate into a beam, go around corners and then spread out in the greenhouse (convex and concave lens), or one would have to make the whole roof of the greenhouse a transparent radiation shield. This is not easy to do but the two winners of the contest figured out how to do it, one solving each of these problems. Both also got interested in how to use fiber optic cables to get natural light to the living spaces for humans and minimize the use of electricity. Still, both teams did need to generate electricity.

Since, the base still needs electricity for other things (like cooking and to power motors), so is there a way to provide that via the use of solar energy or is another source of power going to have to be used? On Earth we generate electricity using falling water, steam or wind to power a turbine. On the moon water is too scarce and wind is nonexistent, but we do have enough water to turn into steam. To heat the water to steam on Earth coal or oil is usually what is used, but there are no fossil fuels on the moon. Another possibility is nuclear power. But at the south pole of the moon the sun is always shining. Can one create a solar furnace and get the water as hot as burning coal would get it? Then there is the possibility of using solar voltaic energy - solar cells that directly convert light into electricity- but not very efficiently.

The question before you is to look at the two systems the solar base contestants came up with for lighting up the greenhouse and see if they are actually better ideas than generating electricity to power grow- lights. If so, which system do you consider superior and would you propose be made part of the base to make photosynthesis possible in the underground greenhouse? Then, once you know whether you will need massive or more modest amounts of electricity, which do you think is the best way to generate it: nuclear power plant, photovoltaic cells or solar furnace to boil water.

It is a long shot but some contest contestants thought there would be another way the generate electricity by 2069, nuclear fusion (not fission) reactors. This is a tempting possibility because there is an energy resource on the moon that is not present on Earth. In a fusion reactor one mimics the Sun and burns Helium-3. The fuel of the Sun is naturally delivered to the moon by the solar wind and there is a substantial amount on the moon while on Earth little to none exists naturally, but it can be created (at create cost). It seems that Helium 3 hitting the Top 3 meters or so of the lunar regolith adheres to the oxides, both iron oxide and titanium oxide. If heated it releases again at a specific temperature and dissipates as a gas that is mostly Helium- 4 but a few percent Helium- 3. The lunar gas miners will be after the oxygen to send it to orbiting refueling depots is LOX the liquid form of oxygen. Combine this with hydrogen and one has rocket fuel. The lunar miners will also want the metals, both iron and titanium, anyway, iron for local use in construction and titanium to make spacecraft. In effect they will get the Helium as a free bonus and can use the Helium 4 to inflate surface structures which can then be buried under regolith to provide radiation protection for those working in them The Helium-3 would be separated out and used to generate electricity is special reactors on the moon, on Earth and even on space craft and space stations.

There is one little problem. We do not yet know how to create the temperature and pressure conditions on the Sun elsewhere without using as much or more energy than one gets back in electricity. Will we have mastered that art but 2069? Let's not count on it, but by 2112, in a century, that is likely. If so, the moon will have a major new export product and be to the fusion energy era what the Saudi Arabia is to the oil era, the source of 50% of Earth's main energy resource for generating electricity. By then the burning or coal will probably be banned for environment al reasons and there will be not more oil to burn. What little is left will be too valuable as a petrochemical feed stock, to burn.

However, all that is beyond our time line. We have to grow food to support a human population on the moon before we start planning a new lunar civilization in an area the size of north and South America and functions as the Persian Gulf of the next energy era.

One of the most important parts of a lunar base is its agricultural center. The agricultural center, or garden, is what moon colonists would use to grow their own food and it also balances the biosphere or ecosystem as plants generate the oxygen animals such as humans need to breath. In return, the plants need the carbon dioxide that we exhale into the air. One of the key ingredients a plant needs make carbon dioxide and water into carbohydrates we can eat is sunlight (or an artificial light with the same light color spectrum. Leaves look green, so they are reflecting blue and yellow, and absorbing the red from which they get heat to cook up food in many forms but especially starch and sugar.

There are a few issues that need to be thought out and solved so we can get light to the plants in the base. First problem is that the base is located underground; we need to find a way to get the light into the base. The second problem is that the moon has no magnetic sphere to block incoming radiation; we need to find a way to separate or block the radiation but allow the light to go through. One of the interesting differences between visible light and other forms of radiation is that light can be bounced off of a mirror while radiation passes through. The final issue is we need to find a way to get a lot of light into the base but diffuse the light once it reaches the plants so it isn't too intense and wilts or dries like a brown autumn leaf. At some point they would actually burst into flame.

Light and Sound Activity:

Materials and Cost List:

- 4 Double Convex Lens - $19 total
- 4 Double Concave Lens - $17 total
- 1 Prism - $12
- 4 toy periscopes - $84
- 4 toy look sideways binoculars -$84
- 1 Solar energy kit - $20
- 2 Mirrors - $5

Methods:

After a brief discussion focusing on light vocabulary from the text, each group will be given a concave lens, a convex lens, a set of binoculars that can see sideways at the flip of a switch and a periscope. They will have some time to experiment and "play" around to figure out how each object alters light around them. While this is happening, the instructors will go to each group with the prism and show how white light is composed of all the colors of the rainbow. After the groups have had time to experiment with the materials, and discuss the problem of how to get light to go around corners and focus or diffuse, the assistants will collect them and reorganize the class back into discussion mode.

Then they will ask the groups to settle on a solution that is the majority view and the group spokesman will be asked to present it to the class. We want to know if they think grow lights can be avoided, and if there is a consensus on the best solution. If there is time we also want to know whether they liked the Team Goddard or Team Hong Kong approach better so you need to have both lunar base designs displayed. How they solved the problem of getting light into the agricultural center (concave lens to focus the light into a periscope to isolate the light from the radiation and to get the light into the base from the surface where it is then put through a convex lens to disperse the light throughout the room). If the students are struggling with how to get this result, help lead them along. The last 7 minutes should be reserved for the slinky demo showing the difference between the light and sound waves. Key things to hit would be the fact that sounds needs a medium (air/water/etc.) to travel whereas light does not. Ask how people can talk on the moon.

On another day, the instructors is asked to distribute a set of various musical instruments to the class, drum, wooden flute, triangle, tambourine etc. and each group is asked what is vibrating to make the noise and can they control whether it makes noise and how much, or even change its pitch? We have added to the kit a toy that electronically alters ones voice as you speak into it and change the settings. In on setting you sound like a robot, and we think the kids will want to know what that setting does to the sound waves as is shifts them into electric impulse signals and back again to audible sound. At that point you are ready to talk about a telephone, but it might be better to wait until electromagnets have been discussed in the electricity chapter. Making a telegraph key first might be a nice touch.

Where you are going in the lunar theme is how people will communicate with each other when working in small groups on the moon outside the base, where there is no air to propagate sound so they can just talk normally? They will have microphones in the helmets of their space suits and be sending radio waves, since they will not want to drag wire around to talk by telephone over short distances. Radio waves a travel without a medium like air or water to carry them.

ELECTRICITY

Electricity for the Lunar Base:

Electricity Activity:

Materials and Cost List:

- 4 Electric Bell Kits
- 4 Aluminum Bar
- 1 Steel Bar (cut into four 6in segments)
- 2-4 Titanium clad Drill Bits
- 5 Copper Bar
- 4 Ceramic Plate
- 4 Glass beads like squashed marbles
- Circuit Board
    - 3 Light Bulb and Socket -
    - Wiring

    - 1 Switch
    - 1 Plug
- Steel Cable
- Parallel Wired Christmas Lights
- Clear coated double wire
- Fiberglass
    - Insulation pink cottony fiber-
    - Fabric – from a car body or boat hole patch kit
    - Paper – from an air filter unit

Method:

Preparation of this activity is minor unless the “bell” kits and circuit board have not been pre-assembled. (It should be noted that we got our kits second hand and none of the bells still in them actually worked, but the rest of the kit was useful. They could be used to make a telegraph key, and we adapted that to our use.) The bell kits should be assembled as the instructions that come with the kit describe except a longer section of the wire should be cut so that materials can be put into the circuit to test conductivity. A list of materials that can be made on the moon should be written on the board for the class to see (iron, steel, titanium, aluminum, glass, and probably ceramic). The students should have learned what conductors and insulators are by the time the enrichment activities takes place, but a brief reminder is encouraged before the actual discussion. This also serves to lead into a short discussion on what wires on Earth are made of and why copper is so popular. What materials are available on the moon for astronauts to make wire from? The scenario presented to the students is that they need to experiment with the different materials in order to determine new materials to make wire out of while on the moon for lack of copper, rubber and plastic.

At this point, the bell kits along with one sample of each of the materials and the datasheets should be passed out to each group. With the helpers, each group should wrap the wires (or press in the case of a thick or awkwardly shaped material) onto the material and press the button on the kit. If the electromagnet turns on you hear a click, (our kits lacked a working bell or buzzer) they know that the circuit was closed and the material conducts electricity. If it does not, then the material was an insulator and does not conduct electricity.

It would have been a nice touch to have a meter to show how much current was conducted and assess the metals as conductors relative to one another but we could not find 4 cheap enough to acquire and were determined to get some use out of the kits we had bought. Once all the materials have been tested, the kits should be recollected before continuing the discussion.

The students should have concluded that the metals were conductors and the glass and ceramic insulated. Discuss which metal would be best for wire (steel due to high melting temperature and relative ductility) and how finding an insulator is problematic (glass and ceramic don't bend easily). Displaying the different types of fiberglass will show that glass has many uses and can take many forms and may be able to be used as an insulator after all-especially if you place the wires into the units of the lunar base as you a making them out of wound fiberglass. The last five minutes should be reserved for the circuit board (see figure__) demo. The circuit board is wired in both parallel and series and by unscrewing different light bulbs you can demonstrate how the different circuits work. A question that will be asked is why the lights wired in parallel are dimmer than the one in series. We had a handout of the students to take home on the circuitry as well, since they are not allowed to take their science texts home, and we were going to give them a homework problem.

RESULTS AND ANAYLSIS

TABLE TOP GENERIC LUNAR BASE

This activity covers additional concepts from the requirements of the book. It introduces students to the idea of a resource rich and inhabitable moon that counters the image of the moon provided a desolate, dry and resource poor moon where no one could or would want to live for long that is presented by the text. The text wants to make the Earth look good and worth protecting, which is not hard. By contrast, we wanted to present the moon as a design challenge-maybe the ultimate one- as the human race will perish if it does not leave the Earth before a large asteroid strikes it or the Sun engulfs it. After you have design a lunar base, living on any part of the Earth is an cinch. Bring on an ice age or put me in a desert. No problem.

The lunar base overview is a starting class for all activities we did later on lunar base theme. This activity was taught to two different classes separately.

The preparation for this activity took quite a lot of time for the first time. Since we are not the ones who made the mock up of the lunar base, Professor Wilkes had to remember which part is which and where all the toy models should be. The whole setup process was smooth and we were able to get all the parts to where they should be. The second time we setup the lunar base model, it was a lot easier.

Students from both classes were very excited when they saw the lunar base model. It was the first time ever they saw the base. They had lots of interest in learning about it in part because the whole idea was so out of line with the tone and message of their text. The first time when we taught the class, the home teacher was there and handled dividing them into groups, it was quiet and quick and we had 6 groups. Then we started talking about the team assignments after we explained the lunar base. Each group was given 1 structure to look for. But for the second class, the story is very different since the teacher was away while we were dividing the groups. It was a mess and we ended up with only three groups based on freids and cliques so each group was given 2 or 3 structures to look for. But the explanations of the lunar base and the team assignment were successful. The teacher said he had formed 5 teams of balanced ability earlier but the students would not admit that he had or accept them without him present. Our teams were of greatly varying ability.

While they discussed their assignments, some students showed full confidence that the half-cylinder shaped structure on the surface is the living space because it looks like normal Quonset hut habitat on Earth. But after we explained that the moon's condition is different from the Earth's because there is no atmosphere protecting human from the Sun's radiation, they learnt the idea quickly since they've already learned about atmosphere in previous chapter and had ideas on how important the atmosphere is for people to survive.

Students noticed a transparent tube connecting the surface to the underground and recognize easily that it is for "transporting" light. But they had hard time determining whether it's the greenhouse or the human habitat. Since the human habitat was built differently from what it is on Earth. As the answers for each structure revealed, there were a lot of whys from those kids.

Some students were interested in the design of round shape on the living space. We told them the fact that the gravity on moon is only one sixth of that on earth and people feel much lighter on the moon, however what they can't understand is when you are moving around a circle, it can creates the extra “weight” which is centrifugal force. Since they haven’t covered force chapter yet, this should give them a preview on what forces are.

It seemed easier for the groups looking for gas gathering unit because there is all kinds of tubes connecting it that makes them think those are for transferring gases. But when it came to different types of gases such oxygen, nitrogen, carbon dioxide and etc., they were confused about how we use any of them except oxygen. Even then they were not thinking of oxygen as a critical aspect of rocket fuel.

As for groups looking for the glass and metal processing unit, it’s the easiest to find the glass processing unit because we put some glass there but they hesitated to determine that the metal processing unit is right beside the glass processing unit. With our help, as they found out the metal processing unit, we showed them different tools made of different metals: Iron pan, titanium drill head, magnets, steel, glass and also the simulated lunar regolith. Students were very interested when we demonstrated the magnetic property of different metals. They would like to touch and feel the magnets and metals a lot more than just looking at them. As we were discussing other structures, some students were playing the magnets, which is good because in a later chapter, they will learn more on what magnets are and also electromagnets and experience magnets gives them a head start.

When we let the groups looking for nuclear power plant show their choices, it’s hard because it’s not obvious. The power plant on the lunar base model has a different look than what it is on the earth. Also only a few blocks on the underground of the base build it. So it turned out we told them that that is the nuclear power plant, well actually they got it by default as that was the one left after the other teams found their facilities.

Also we talked students through other structures, which are not assigned to any groups. The spacecraft station, ground transportation facility and the solar panel unit are easy to find out and they all located on the upper level of the lunar base model. As we talked about the solar panel unit, we had a solar panel kit, which converts light into electricity and power a sound box. We demonstrated how it works with fluorescent lamps and covered the solar panel with paper and the sound faded away.

As we went over the structure list, some students noticed we didn't have astronomy station. Then we guided them to the away base that contains the astronomy station and we told them that the astronomy station has to be away from factories so there will be less light and noise then the astronomy equipment will work the best.

After we completed the lunar base tour activity, Professor Wilkes started the presentation about all kinds of locations where we can put our lunar base. Although the students were not paying full attention to the presentation (which is expected), most students still learned the difference of different locations from the presentation. We can tell from their writing assignments.

From their writing assignments, it's easy to tell that they compared two different locations for building the potential lunar base: crater on the lunar South Pole and lava tubes on the equator. Since for the first class, professor focused on talking more about the Shackleton Crater, which is at the south pole of the moon. The writing assignments from the first class showed strong preference to build the base on the South Pole. In the second class, professor put same emphasis on both the crater on the South Pole and the lava tubes on the equator. It turned out there were similar amount of students choosing the crater as those choosing the lava tube. Although NASA has officially claimed that it's more reasonable to build lunar base on the South Pole, the process which the students thought about this issue is much more important than the results. In practice, JAXA, (the Japanese space agency) is advocating a lava tube location for a base and has found a likely one near the equator, so we did not make this up.

Overall, this was a very successful activity. It provided 5th grade students with the first impression of the lunar base. All activities we did for the next 5 chapters would use the overview knowledge they have learned from this class.

EARTH MOON

The activity was done twice: first time by Mr. Mahoney himself and second time by Professor Wilkes and Mr. Mahoney. Due to time conflict, none of the students were able to attend the class section, but according to the feedback from Mr. Mahoney, description and comments from Professor Wilkes and the experience of demonstrating the activity in NEAM (New England Air Museum), we made a successful improvement in the kits.

First time when Mr. Mahoney did it on his own, he asked students to help with the preparation of the play-dough and the flour. He said the activity went ok but may not be as good as we expected since no one was there to help. He shifted more toward demonstration in front of the class than having the teams work in groups due to lack of assistants.

For the second class, Professor Wilkes wanted to get into small groups but with only two people Mr. Mahoney broke the class into two groups and wanted Prof Wilkes to work wit ha small group and generate new data while he worked with the rest of the class working with data generated earlier in math class. Mr. Mahoney liked the angles part of the activity for visualizing math concepts. Wilkes got to prepare the kits and set up for a group of about 7 students and there was a fire drill. This cost him half his time with the group. He reported that students were enjoying rolling the ball bearings down the ramp and were excited to see the flour splash. The low angle impacts making the biggest crater despite the balls not going as fast surprised the students. The activity was a success. But the cleaning up of the flour on the floor was said to be annoying and it was clear that the apparatus was not robust enough for this age group to use. As they tried to hold the delivery end steady they kept moving the top end at launch and the bottom end would sweep back and forth in 4 to 5 inch sweeps. It was clear that the bottom needed to be anchored and the aluminum pans needed to be cut with V shaped notches to hold the lower end still.

Everyone wanted to help hold the angle ramp holders still, but too many holders made it jump around. It needs to be able to be stand-alone with no one touching it. Thus, the parts holding the top to the stand have to be stronger and the bottom better anchored. The top parts can't just be glued. They are going to have to be drilled countersunk and the screw heads covered with a plastic ceramic repair kit goop that hardens smooth. We have the right idea but now need to design for 10-year-old use over time. You can't be using crazy glue after each use to repair half the holding flanges. .

Overall, the enrichment activity clearly illustrates the concepts of formation of craters and simulates the phenomena when an asteroid hit the planet. The guesses as to what angle the hit that formed Shackleton crater was at were not bad. They got the idea of which side it had to have come from and it was not straight down, but at a steep angle. The idea that one could figure that from our evidence left behind made it sort of like a detective story.

MATTER

Professor Wilkes and Jon Rodgers went to Elm Park for a chapter enrichment activity for the matter unit. This enrichment activity differed from our typical activities in that there was no experimentation involved; it was purely designed as an interactive demonstration. The prep work for this activity, while not difficult, consumed a lot of time. We began melting the wax around 10:00AM, but by noon when we returned to set up for the 12:40 event only half of it had melted. So when we arrived at the school for the final preparatory work we also had to find something hotter than 120 degrees. We were fortunate for the school to allow us to use one of their stoves to quickly finish melting the wax. Either more time is needed or investing in a crockpot in order to increase the heating temperature is needed. However, the school does not want hazards around and it was a major selling point that this device was designed for a temperature that you could stick you hand in and not be hurt. It could hold the wax at temperature, but struggled to melt it in the first place. Take a pan with a pouring spout if you are going to use a heater assist as the aluminum pans we had were not ideal for safe handling of wax on a stove and the stuff will burn if you ignite it- think candle. Also bring a label, though a wax paper cup will work in a pinch.

Surprisingly ten minutes was required to place play-dough in the aluminum trays for molds. Much of that time was discussing what object in the classroom to press into it of mimic by hand. You can save a lot of time by handing out small tools with metal parts. Another five minutes was required to write key metal melting points (copper, tin, gold, silver, iron, aluminum, water, and wax) on the whiteboard along with body temperature, air temperature and the moon's temperature Swing. The class was separated into four groups of four and another 5 students had to go finish a test. We had expected to work with 5 teams.

Preparing the play-dough and writing the key metal melting points should be done before the students arrive for class. Another alternative is to bring handouts for each of the students with the various melting temperatures. You want to show the lunar regolith and ask how the various metals in it can be separated out?

The activity began with Professor Wilkes delivering a brief account on the development of metallurgy throughout history, focusing on what melting points of the metals from key ages (Copper, Bronze, and Iron) in history you could reach with a fire, a charcoal fire, and how you needed charcoal and a bellows to get to the temperature needed to work with iron.

Jon Rodgers then took over and led an interactive discussion regarding different melting points of metals. The objective of the discussion was to get the idea that different metals melted at different temperatures and that ore or a solid made of two metals could be heated to separate them. The idea was to get the fifth graders to make that connection themselves and roughly half the class realized it by the time it was directly mentioned. The discussion then moved to the moon and how utilizing melting points can get different gas, glass, and metal materials out of the regolith. What water would look like on the moon at -275 degrees also came up and was discussed. The final topic point before the demonstration was to take metals and melting them down to create different objects. One student had an aluminum ruler and was trying to believe that it could be turning into a puddle of liquid and then shaped into something else. When the answer was yes, they seemed incredulous.

Roughly twenty minutes was left for the students to prepare play dough molds for us to make wax "tools" similar to how you would melt and mold metal on the moon to make tools. After a quick demonstration of making an impression using scissors and then making the molten wax take that form the students were instructed to make their own molds for us to come around and pour the wax it. Ten minutes were required for all the molds to be formed and wax to be poured in them. Soon hinges, hammers, and even a calculator mold were ready. While the students watched the wax harden- or "freeze", Professor Wilkes gave a brief accounting as to what dry ice sublimating directly from solid to gas looked like and why carbon dioxide would be saved and stored on the moon in frozen form and then "fed" to the plants. He had the attention of about half the class. The "water" they saw poured before them turning into something cloudy and hard at room temperature- and they could touch it and feel it harden transfixed the rest. Although watching the wax solidify was a crucial part of the demonstration, only the first minute or so was required as that was when the wax went from a clear color to a chalky white. Once the wax reaches that point, it is advised to remove the tray and place it off to the side in order to continue the discussion and reduce the chance of the students getting distracted.

After the wax had frozen in the molds, Professor Wilkes and Jon Rodgers went around and removed them from the play-dough for the students to examine. By then most of them had scraped up the excess spilled wax and were playing with it in their hands as a warm solid. Discussion turned to what you could do with it- like making candles. They clearly wanted to take some home, but we collected everything "to re-melt" and they were intrigued with the idea of melting it again and how that idea could lead to reusing metals over and over again too. We did not go into recycling.

Clean up took roughly fifteen minutes with the wax and play-dough easily separating from each other. The wax stuck rather firmly to the aluminum trays causing them to get beat up quite a bit in order to get all the wax off. We should have reheated the wax in the aluminum trays or gotten them much colder. It grips rather well at just above room temperature. The recovered wax was left in the tub to freeze overnight before transporting it back. Another way to minimize the amount of wax that collects at the bottom of the tray is to ensure that the mold impression is even and the walls of the play dough at the ends are higher than in the center where you are pouring wit h a ladle.

One of the main changes for next time this activity is run would be to assign the groups different tool mold shapes to make and allot them only five minutes to make it. Half the teams could not decide what to do with their play dough and needed a coach. This delayed the pouring. We ran very close to the end of the allotted time waiting for some of the wax molds to harden. Assigning specific objects for the students to make, as depressions in the play dough would speed up the process. However, once we pour- the attention of the class will not be on the speaker anymore. They do not seem to like multi-tasking. They want to observe.

Another improvement would be having known the temperature of the sun (11000 Fahrenheit), the deposition temperature of carbon dioxide (-69.5 Fahrenheit), and the melting point of bronze (found in table) on the white board. These came up as questions. The students wanted to know if you could mix metals when they were melted- ie, they re-invented bronze.

Finally, several students requested that they be allowed to keep the table of the different metal melting points. Fortunately, enough copies were made for each group and only 5 asked, but next time it would be better to print enough for all the students to take one home.

Mr. Mahoney was extremely pleased with the results of the enrichment activity and saw great potential in it. He could spin off implications and extensions and multiple applications of it for his class with ease. Connections to both social studies and science and math problem solving were all there. He was exceptionally intrigued with the idea of the students making molds and duplicating common objects. He was particularly thrilled with the group that copied a calculator, for some reason. That the students were realizing that many types of matter could be separated, manipulated and changed in shape and state by knowing the melting and gasifying temperatures pleased him a lot. This was useful and applied knowledge that helped one understand history and plan for building things on the moon out of local materials. It also had them thinking just how many common objects that they use were made?

We even got questions about how the plastic handle on the metal scissors got there. The idea of a plastic coating of metals was mentioned but not pursued, though clearly the class did not want to leave and the door was open to rust- oxidation and why you coat or paint many metals. We did not open that door.

They clearly wanted to follow this other logic further and talk about melting other things than metal- glass, plastic, and at some point they were bound to make the connection to cooking and we'd have been off into why cooks consider sugar a liquid though it looks like a granular solid at room temperature.

Even with a few hitches here and there, the enrichment activity went well, was well received and it was clear that we barely scratched the surface of the potential in this line of inquiry. As for the kids, they want to get their hands on the play dough and wax again, and a sorely tempting thought is if we had molds and could let them take home candles shaped like space ships; however, in the interest in maintaining a sustainable kit, it is advised to collect all of the wax at the end of the demonstration.

Next time we should have pictures of glass blowers and foundries and blast furnaces so they could see metal being poured into molds and castings and turned into aluminum, copper, steel, and iron objects. Something that still looks a bit like the sand mold in which it was formed would be a good show and tell too. However, the wax should not be poured into a sand mold for the sand will mix with the wax and render it useless. It separates from the properly made play dough (using our recipe) just fine however.

FORCES

BUOYANCY

The buoyancy demo took just under five minutes to discuss and show. It took some repeated explaining for the students to understand the relationship between the weight of the displaced water and the weight of the displacing object; however, once the concept was understood the lesson proceeded without a hitch. The comparison of the two lids further drove the point home with the students and helped explain to them why boats made out of metals that are heavier than water were able to float. The students were additionally fascinated by the amount of weight, in the form of pocket change, which could be added to the single piece lid before it sank. For the second week's demo (with the second class), we asked Mr. Mahoney if he wanted to take the lead with the class discussion and activity in order to begin to prepare him for the process of taking over the enrichment activities in the future. Mr. Mahoney deferred to Jon on the discussion aspect of the buoyancy force but did take the lead on the demo activity. We recommend that future groups working with the teachers try to remain in the background as support staff and have the teacher remain as the focus of the lesson. One way to do this would be to build a solid lesson plan so the teacher does not feel the need for the supporting college students to teach the lesson. Another reason we were not able to do this is the lack of lead-time for the teacher. We were always working up to the last minute and improving the unit between runs. The situation was not stable this year. Next year it should be a fixed plan that can be reviews 2 weeks in advance.

GRAVITY

During the gravity section we compared the different gravities on Earth, Moon and Mars and showed students the relative size of the planets so as to convey the concept that the larger the planet is, the greater the gravity is. The students were asked to do some “lifting” work. Students passed around the boxes and felt the different weight. It seemed they know what’s inside of the boxes, so it didn’t bring much surprise to them when they tried different boxes. They quickly adopted the idea that gravities on different planet are different. Mr. Mahoney said that the demonstration was interesting but they had gone over the gravity idea before as part of the reading.

Fran suggested moving the gravity section into the math class and thought students already had knowledge about gravity so it would be a good exercise for the students to calculate the weight they will be on different planets. Also then we could devote more time into other forces during their science class such as magnetism and friction, which seemed a lot of fun for students to discover.

We countered that it should be used to set up a homework assignment in which they figure out how much weight they would need to carry on the moon to keep their muscles at Earth gravity strength on return. The activity was received well, but not the idea of doing it as homework, and he considered it a suitable math assignment.

FRICTION

The friction activity was changed from the first demo to the second demo. During the first demo we had 6 different examples to show friction, but we ran out of time because of there was a fire drill and repeated Public address calls from the office. This made it difficult to be able to get the activity done as planned. . Since we didn't have a data collection sheet prepared in advance, it took the students awhile to record the data. One the examples were to use ball bearing, but this caused difficulties. The second time the friction activity went smoother, but we still ran out of time. We had to cut down the examples into using just two different examples. It is not clear that the students connected the design problem on the moon with the hands on activity of feeling for resistance when turning a lid on a soup can. The idea we tried to get across, that a good way to reduce resistance by friction on Earth, using ball bearings, was not suitable or necessary (and was even counterproductive) under lunar conditions. There were so many students and we wanted them to all have a chance to try to turn the lids one right after the other to compare them that logistics dominated the event and we ran out time before we could o discuss the results and relate them to the moon problem on friction.

Though the friction activity is more difficult to relate to the moon it is important. . It is a storyline that needs to be developed by example to the students in a way they could understand what problem you want them to solve it by using just two different examples rather than 5-6 one has more time to explain the scenario to the students.

However, we are told that the approach used last year involving heat from rubbing your hands, then putting a pencil through a plastic bag filled with water and explaining why it did not leak, followed by talk of asteroids blowing up and why space craft returning to

Earth need a heat shield and those landing on the moon do not worked better overall due to the dramatic imagery. On the other hand they did that in 45 minutes and we tried to make the same conceptual points in 15 minutes.   We had to do 3 forces in one day to leave time to do magnetism right in a day devoted to just that force.

MAGNETISM

The magnetism interactive discussion was given its own full day to be taught the lesson and every minute was used. The process of explaining how magnets worked and some applications in real life proceeded quickly. One of the questions that were asked of the students was, "If the Earth is a giant magnet, where is the magnetic north pole located?" A surprising number of students correctly answered that it was located somewhere in Antarctica. The explanation of the magnetic field went well enough with the pictures that were provided, but an excellent demonstration (if the materials could be acquired) would be to place a bar magnet under a piece of paper and sprinkle iron fillings on the paper to show the field. Most of the discussion was on the magnetic field, earth's magnetic field and its benefits, and the lack of a magnetic field around the moon and what hazards result from it.

The final ten to fifteen minutes of the class was reserved for a demo on magnets and hands on experimenting of the magnets we brought along. The class was absolutely fascinated to find out that iron could be briefly magnetized with a weak magnetic field. They were even further surprised to be shown that the iron did not need to be touching the magnet, only in the magnetic field, in order to pick up paperclips of its own. Unfortunately, the experiment with the magnets and paperclips was rushed at the end of the class and the students were not able to make all of the tests that were intended. However, the experiment was still well received by both the students and the teachers. Another recommendation for future assistance for this activity would be to reserve at least twenty minutes for the hands on demonstration and activity at the end.

ENERGY

The Energy chapter experiment was done twice, once with each of the fifth grade classes. Both experiments were virtually identical and this analysis section will discuss what happened on both days. The experiments went well with the students being able to experience and record the linear relationship between the height of the ice cube on the ramp at the time of release and how far across the floor it would skid. One of the differences between the first week and the second was that we did not regularly change out the ice-cubes to the different groups. As a result, they students were baffled as the further up they placed the ice-cube, it would not go as far. We had to explain that the ice-cube was losing mass and that was decreasing the potential energy more than the increase in height was raising it. The second week we regularly changed out the ice-cubes in order to maintain the same mass as the students proceeded with their experimentations that fixed the problem.

The last ten minutes of the class were reserved for a demo to further demonstrate the properties of energy to the students. A ramp was set up in the back of the classroom and all the students were asked to crowd around so that they could see what was going on. We presented the question as to how to stop the ice block should it break free and slide down the ramp. The first suggestion was to put something at the bottom of the ramp in order to stop it. Using golf balls and Ping-Pong balls, Professor Wilkes led a quick discussion as to why that was not a good idea by demonstrating energy transfer. The students were very amazed to see the farthest ball in the line go shooting off when the one that was released from the top of the ramp hit the first ball. That the energy was transmitted though the object was stopped was dramatic and complicated the problem of how to protect the icehouse. Just for fun we put the Ping-Pong balls after the golf balls and did it again. The student standing at the end of the ramp was amazed to find 4 ping-pong balls literally flying at him. He ducked, too late, but ping-pong balls do not hurt. They just look like golf balls when they are flying at you.

LIGHT AND SOUND

The preparation for this activity was simple: once you get all the necessary materials bought, assembled and transported to the school and put up the posters of the two designs of the lunar base.

This activity was done twice with two different classes. For the first time, on March 7th 2012, Ye Lu went there for the enrichment activity. He went through the concepts given on the book and focused on talking about the differences between concave and convex lenses. Still some students were mixing up the two lenses and were not able to identify which one is concave or convex. (So, he developed a formal handout on the subject for them to take home.) Then he talked through two designs of the lunar base and focused on explaining how to get the light into the greenhouse in the underground. Then all the materials were distributed to each group and every student had the opportunity to try each light-reflecting toy. They had a great fun and they also had questions on how the periscope works. Since Ye was the only there, he wasn't able to answer all the questions students had during the discussions, but later on he explained to the whole class about the common questions students had. After everyone tried the toys that were collected afterward, Ye explained again about the design problem they had to solve in group. He provided hints to some groups but weren't able to help with all groups' design.

Overall students were very active during the discussion and they had active imaginations. They knew how to get light into the underground from the idea of a periscope and seemed to get it that the light was coming in low over the horizon and the lunar South Pole. Since they wanted light every day and the suns was going around then in a 28 day cycle the "periscope" would have to follow the Sun rotating a little each day. They also knew that mirrors could reflect light while radiation passes through the mirror to get the sunlight without the radiation. However, most did not get it that one can also use the convex lens or curved mirrors to concentrate the light sent down the "periscope" to the greenhouse. It was equally hard for them to figure out how to disperse the light using a concave lens. Ye talked about the principles of how concave and convex lenses work, but unfortunately, there were no materials to use for visualizing the effects. At last, Mr. Mahoney and Ye did a demonstration using slinky showing the different forms of propagation of the sound wave and light wave. Students were thrilled by that demonstration and asked for more.

For the second week of the class, same materials were taught to the students, but with more helpers. There were three students and Professor Wilkes. Each group had an individual assistant to help discover the secrets inside all the materials being distributed. Jonathan took over the second class and had a great control. He talked through more examples than Ye did for the first class and there were more interactive discussions. Since each group had an assistant, compared with the first class, the designs were also more complete and the reasoning was much better when speakers of each group presented their designs. In addition, Professor Wilkes showed students a concave mirror, which is consistent with one of the lunar base design posters and they finally got the idea of concentrating the light hitting a wide area into a powerful beam that goes into the top of the periscope without any radiation. It is not clear that they understood what needed to happen at the other end to disperse the light or what would happen to the plants if it were not made diffuse enough to be like the ambient light on Earth under the cloud cover.

Students were very interested in the periscopes and enjoyed seeing through them, but this just whet their appetite for how you would use them on Earth to see around corners or over the top of a trench. Then they wanted to bend and reflect light with curved mirrors and looking sideways out of trick binoculars, and were much less interested in the binocular effect of the lens making things look bigger when they are far away.

Overall, the enrichment activity went very well, all students got their hands on the different lenses, periscopes and also binoculars. They got to see a prism. They would love to play with the toys again as expected. Students also did a great job in the design task of how to get light into the underground greenhouse. Their ideas were quite interesting. Although they were not able to consider all the possibilities, but different ideas from groups cover most aspects of the design task. By integrating the ideas from all groups, the purpose of the design task was achieved and the problem solving logic point was made.

ELECTRICITY

The preparation for this activity took us a while, yet we didn't get what we have planned. Assembling the electricity kits was a tedious work, we wanted to get the bell to work but seem to have gotten defective kits from a second hand store that did not have all the parts listed. Hence, we ended up with determining whether there is a circuit through the device by showing the electromagnet property. Although it's not an obvious phenomenon, students were still able to perform the activities with a device designed to be something like a telegraph key.

We did this activity twice with both of Mr. Mahoney's class. For the first time, we had four people going to the class and each took care of one group's activity. At the beginning of class, Jonathan talked about electricity and had interactions with the students about the concepts of the electricity chapter. Then we started the activity. Students tested the conductivity of lots of materials besides the ones listed and provided, such as wood, glass and etc. Since each group had its own assistant, the activity went very smooth. The only one problem is that we didn't inform Professor Wilkes that we had to push the button in order to test the conductivity, so it took them a while to figure out how it works. Besides that, the rest groups had more than enough time to do the activity. The activity took most of the class time. By quickly concluding the conductivity of each material, we came to the end of the first week's class. However, Professor Wilkes was asked to return to explain the homework assignment based on the lesson. The task was to change a drawing of a series circuit into one that is parallel, but we juiced it up with lunar base theme. They got a depiction of a big tank or tube made of wound fiberglass fiber with 4 dorms room in it. Each dorm room had a track light, a screen and communications unit, and a plug from which other devices could be wired.

There were two steel wires (one positive and one negative) built right into the fiberglass that could be tapped, but not moved. A wire went from one to the other tying in all the devices. The students were told if the wire broke anywhere or the light burned out of the screen failed, all the power to the room would be lost. In fact all the power to the room on the other side of that wired wall could also be lost, and in some cases all 4 units would be affected. The idea of being cold in the dark in a hole on the moon was disconcerting. They know that was not good and their job was to fix it some that would not happen. Worst case you lose one device and bring in a replacement that you can power from the still function wall plug.

The challenge in doing this assignment turned out to be the fact that they had never seen perspective drawings and had trouble envisioning what the unit looked like as an object before it was drawn in 3 flat pictures. So, we brought in an oatmeal box stripped down to cardboard and put a slit in the middle into which the "wired wall" serving 4 (one top and one bottom on each side) units would be dropped. Then you could draw the main line on the side that was in the wall, inserted during the fiberglass wrapping process. The circuits could also be built into the inserted wall that was electrified, but for now we told them they had steel wire wrapped in flexible textile fiberglass to run as they wished. It was great help to the class to have Prof Wilkes open one end of the cereal box and say that is what you see from this picture. Then one could turn it to the side and say that is what you see in this picture, and so on. In the end the student's ability to handle the circuit question on the MCAS and the design problem worth 25% of the credit were both enhanced by this one lesson?

In order to improve the activity, for the second class, we decided to do something different. We put less emphasis on the conductivity of materials but focus more on introducing fiberglass, and talking about parallel and series circuit. The goal was to get them ready for the homework in one lesson, but Prof Wilkes ended up coming back the next day to explain the assignment in detail anyway. However, this time they got it faster and were more confident that they could fix the problem that idiot had created by doing a series circuit.

Same as the first time, Jonathan talked through electricity generally and the concepts listed on the book. Then we showed the students parallel and series circuit using light bulbs: two bulbs in parallel and another one in series with the two. So when we unscrew the one in series, whole circuit breaks, whereas when we unscrew one of the two in parallel, the other two still shine. Students kind get the idea that breaking one bulb in series circuit breaks the circuit while breaking one set up in a parallel circuit does not.

Professor. Wilkes then showed the students a wire with transparent insulator around through which students can clear see the two wires inside. This gave them knowledge that typically the wire we use is set up for parallel application, but it is not obvious that that is the case unless you look closely.

After the demonstration of the parallel and series circuit, complete with a string of Christmas light through the class so the students could see that what looked like one wire was really two in another familiar and dramatic case we then started to test the conductivity of materials. This time, we were short one assistant, so Mr. Mahoney had took care of one group. We cut the number of materials to test in order to save time the second time we did this. Each group had just the right time to finish up testing the materials we distributed. For this time, the problem is Mr. Mahoney was not instructed on how to do the testing, so he was just sitting and watching the students do the activity. One of the students ended up helping two groups with the activity. Overall, students were able to identify conductors and insulators after the activity. Even if they were not sure about the conductivity of one material, they should be able to come up with one way to test it.

Just before the end of class, professor. Wilkes showed the kids with an unusual form of glass, fiberglass, which seemed very interesting to them. No one expected to see the glass in cotton-like form. Student showed an amazingly amount of curiosity and they loved it. They were told that if they touched the textile version of the glass they would itch later- and that did not stop any one of the 6 students who wanted to touch it from doing so. This was a new experience of glass, and they wanted to understand what lunar insulation might feel like.

The purpose of the activity was achieved and seemed to be very well received. . Noticing he differences in what we had done in two classes, we surely provided students with a clearer impression of several conductors and insulators with more time and show and tells to spend on it. The students want to test everything in sight. We had to limit them to things that would be available on the moon. However, using the copper, as a baseline would be a good thing is we had a meter and could compare level of resistance and conductivity in the different metals. In terms of experimental purpose, adding the introduction of fiberglass and parallel wire is better than doing the activity of testing conductor and insulator alone. But for general class teaching purposes, the cost of the extra materials would be beyond what a public school could afford for a single use. It would have to be shared by at least 10 classes.

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Overall, as experimental classes, the activity was considered well designed. We related the concepts to the lunar base theme and had an overview on electromagnetism. It was a successful activity.

NEAM

Three experiments were brought along to NEAM to demonstrate to anyone who was interested in our table; the Earth and Moon Chapter (Crater) Activity, the Matter Chapter Activity involving Wax, and the Energy Chapter Activity involving the ice cubes. The Matter Chapter Activity was always kept out while the Earth and Moon Chapter activity and Energy Chapter Activity was rotated every half hour. Surprisingly, the Energy Chapter Activity was the most popular of the three and we received repeated requests to demo it. Many children between 3rd and 8th grade age level stopped by our table and requested to try out our experiments. All children that stopped by our table were interested in learning the science behind the experiment and participating with the hands on experiment and spent a fair deal of time there.

All kids loved to see how the crater was created and the splash of flour made them excited. Trying rolling down ball bearings at various angles, the shapes of the crater created on the flour are quite different. With the black powder on top of the white flour, the hit from ball bearing made perfect illustration of how the white flour came to be on top of the black (volcanic basalt) powder. Those adults who were watching the demonstration showed interests in seeing the crater shapes vary with the angle of attack.

The energy activity was very interesting to all the kids. They loved to push the ice cubes up the ramp and see them sliding down and hit the black plastic tray we called the icehouse. By letting kids changing the height of drop, they noticed the change in distance travelled on the table also. The potential and kinetic energy concepts were very well illustrated. By far the most popular things was trying to block the block in motion- for this we used a golf ball- using 4 other blocks- ie 4 times the mass. They loved to see the first ball in motion stopped and the one at the end of the row of 4 suddenly take off and smash the ice house anyway. Many had ideas about how to stop the energy from being conveyed through the balls at rest. When we compensated for the gravity difference by using ping-pong balls they often decided the icehouse was safe after all. Actually, we never found a suitable ball that was really 1/6th the mass of a golf ball, so that was misleading but the points was made that testing on Earth is complicated due to the different lunar conditions.

Compared with other two activities, the Matter activity didn't bring much attention because only thing they are involved in is making shapes on the play-dough. Then they were just watching us pouring liquid wax into the play-dough and waiting. Since the mold is large, it took quite a lot of time to cool. The kids didn't get to play with the liquid wax so it was less suitable for this setting.

While the children were playing with the experiments, several of the parents asked why we were developing these experiments and how they were relevant to space? We had two tables and set up on the other one was poster displays of the lunar bases from the contest that we had used so often in class. If they went to the posters first Prof. Wilkes roped them in and then passed them to us. If they came to us first it gave us some opportunities to explain exactly what our IQP project was about and also explain the lunar base tie in. Of the parents that asked about us working with fifth graders, most were able to see the value of the experiments and how they could be used to enrich the classroom. We had the textbook being used in Worcester with us. Especially after looking through what the Elm Park students read on a daily basis the parents could easily see why the theme and activities had massively improved the science experience for these classes.

There was a steady flow of people visiting our table with interest in what we were doing, but hardly any science teachers were at the NEAM event. We saw two and both left us their cards and wanted to her more when the project was written up. Although being able to demonstrate our experiments to space enthusiasts both young and old added to the NEAM event, (even the celebrity astronaut checked in with us) this event did not directly help us reach our target audience of fifth grade teachers interested in science. PTA word of mouth is not to be discounted, but we would rather meet with 15 teachers than the 180 members of the public (out of 900 at the event) we spoke to over about 5 hours. As a result, we have come to the conclusion that, although a nice trip, and valuable to our sponsor the AIAA New England Chapter that paid for our materials, it did not do much to promote the application of enriching fifth grade science classes.

COMMENTS FROM THE TEACHER

Did you feel the weekly enrichment activities helped your students understand the material?

Combined with the material covered by the homeroom teacher it was helpful

Were there any activities that did this particularly well? Were there any activities that did not do the job (fun but not educational)?

The crater activity sticks out. The flour left a visual imprint on their minds and I was pleased to use math (angles) with science. The one activity that didn't meet the objective was the friction lesson. I would not use ice in the future; too much cleanup for a teacher after the team left the students questioned the purpose of the activity. Pushing students their intellectual activities is a good thing to a point, but were there any activities that were perhaps a little too far out of reach for at least half of your class? Any activities that were just busy work and not very intellectually challenging? There wasn't any busy work. The main thing is anyone who comes in to the classroom must realize that accommodations must be made to meet Special Education Plans as well as the accommodations for ESL students

With continued WPI support in the form of a few students once a week for crowd control, do you think you could take these activities and experiments and run them yourself 2 years from now?

Next year you will have 2-3 students working directly with you again, doing assessment, supporting you? They will do what you ask, but will probably not initiate much unless you ask them to improve on existing units or create new and better ones. I believe that the units are strong as they are and should be left to the teacher to decide what level to take it

We tried to make Science "the fun class" this year. Do you think we succeeded?

Indeed

How much do you think was lost by not having a field trip this year- like the one to the moon at WPI for the day, or the one to New England Air Museum in the past?

Field trips are beneficial but do not make or break success in learning they are a bonus.

DISCUSSIONS OF RESULTS AND RECOMMENDATION TO THE FUTURE

Through our project we realized that there was a larger need for thematically integrated, hands on science enrichment materials and experiences. We saw a clear need and to link such units together and produce and kits for other grade levels to build on our start. s. Creating a spiral curriculum for grades 5th – 9th with this common theme would help enrich science education in a larger view for the Worcester area. We decided to interview the 6th (biology) and 7th (robotics) grade teams to see what they did and what their final project was. We hoped they would build smoothly onto our 5th grade unit and had used the same concept of a lunar base, but no one had asked for diagrams or pictures such as we had used repeatedly. Further we had not consulted with each other much at all. The odds of a smooth transition were low, but maybe we got lucky.

The 6th grade team (Bailey-Gates, Piccione and Deisadze) was working at Flagg Street School and had developed a curriculum based on the Plant & Biology section of the 6th grade WPS textbook. The team went to the classroom introducing the Lunar Base theme, as they understood it and the 6th graders had no idea what they were talking about not having had the 5th grade unit. . Based on the knowledge of the 6th graders they were working with, the team didn't call in the 5th grade team with its tabletop lunar base for orientation. They minimized the theme and stuck not with the theme when developing their curriculum, instead they focused on teaching plant biology and teaching the basic concepts of the Plants & Biology unit as presented in the text. They were able to develop a well thought-out curriculum for enhancing this unit. It included: the different lesson plans, handouts, activities, assignment, study guides, and a final exam. Their activities weren't hand-on activities, but more of in –class games, such as jeopardy. Their objective was to stress the plants and science and get the students more interested in plants. They were able to meet with three different classrooms and 6 times for each classroom during the whole term. so they too were a near weekly event in the classroom designed to make science the fun class and motivate the science. They were working with a teacher who was strong in science, confident and let the students take their science texts home. Homework was expected. Obviously they played different role in such a classroom than we did at Elm Park School.

The 7th grade robotics design unit team was very different because this team didn't meet with the middle school class at Forest Grove classroom on a weekly basis. They met with the teacher twice through their whole project; first time when they met him and the second time when they showed they showed him what they accomplished. After having meeting with teacher, he instructed them to take a different route. By this it meant that instead of developing a curriculum for the 7th grade classroom they would be developing activities for the Robotics After School Club. Their objective became to teach students how to think about how to engineer a lunar robot. They were able to develop a curriculum that would include: lesson plan, discussion, mind-storm activities, and a capstone robot. When developing their lessons plans this team didn't use the 7th grade WPS text and concepts. Based on the theme they developed a lesson plan that would have four "lessons". The lessons would be: Introduction to the Lunar Base, Moon Environment and Effects, Introduction and Discussion of the Robot, How the Robot is Powered, and The Capstone. The Capstone would involve actually building a model robot from a kit. Though this was designed for an after school club it still could easily be adapted by other teachers for their use in class except that concepts from the book were not integrated with the activities.

After some discussion and research in the 5th grade team, we became concerned that our work would never be used as intended unless helpers could be recruited for the teachers. Mr. Mahoney reverted to demonstration whenever left alone with the kits we had prepared in Quadruple so as to support small group activities and hand's on science. There will not always be a WPI IQP team wanting to do curriculum development in his class. Hence, we have come up with the recommendation for WPI students to start an on-campus service club. This club would support teachers interested in doing this kind of enrichment activity- especially if they wanted to use the kits developed by project students.

A teacher at any school in the area, or at least WPS, would be able to ask for just the kit, training on the activity and a kit or the kit and some assistants to help them run it in class. The more support requested the less control the teacher would have over exactly when a team could assemble at their school to put on the event, but in principle substantial support could be offered. The student club would also develop special field trips and after school club activities as well as other programs for the WPS 5th and 6th grade students who emerge from a talent search process we think should be based on performance in a science fair or an essay contest. They also would take a special interest in coaching students who want to enter a science fair or the robotic contest run by WPS, and help run or judge such events.

Fundraising is expected to be a regular club activity and it is likely that club members would be available to support teachers who want to do special hands on activities of their own design in their classes. However, we would also do workshops on how to use our own hands-on kits. The beginning process of starting this club is underway. After speaking directly speaking with outreach and service coordinator Emily Perlow we realized that we should get started on procedures for starting a club on campus. At a minimum there have to be 4 officers willing to serve and a petition signed by 50 WPI students supporting the idea. We have completed both of those steps, and worked on a mission statement and constitution. A faculty advisor has been found as well. Below in Appendix …… are the forms that go into starting club on-campus. Haven filled out these forms in advance we are hoping that next year this club affiliated with WPI will be launched. Two members of this team will join to provide organizational memory on how to use the kits that already exist, and they will train a pool of volunteers to do outreach.

Exploring the possibilities having a system for surfacing and encouraging or nurturing promising science talent early, we found that something the team did last year at one school should be expanded system wide to at least 10 of the 35 elementary schools. That was their essay contest based on a book by Dr Fred Bortz. It has a lunar theme dealing with the search for water on the moon.

Finding ways to make science the most fun class and broadening the pool of students potentially interested in going to college and majoring in STEM subjects is important, especially to WPI. In order for this thematic spiral curriculum program and the service club to successful two things have to happen. One is that the other teams that will be involved in developing 6th and 7th grade curriculum have to build off of the 5th grade curriculum. The 5th grade curriculum also has to be assessed and disseminated out of the Elm Park School. This means coordinated meetings between the teams working at different levels. Prof Wilkes should be the advisor to all the advisors coordinated their efforts next year and not just doing one level himself if this type of spiral curriculum initiative is to keep progressing. In effect, the curriculum development effort has to keep up with the current 5th graders at Elm Park as they become 6th graders and beyond. Paula Proctor, the principal at Elm Park has committed her 6th grade teacher to this effort next year. The 6th grade team will have to build on our project while adapting what was done at Flagg St School this year.

As you read above, the teams this year did different projects. Meeting with them towards the end when the project was already done and there was no time or possibilities of change was unwise. However, the 5th grade team had to recruit another person in C terms to even consider taking on the coordinating role and even then it was too late. Having the teams together in the beginning and making sure that everyone is on the same page as to where their project is going is what needs to happen in the future. This will help the club and program grow in a coordinated way that will benefit the WPS and seems to be something they would o appreciate having WPI do.

SUMMARY AND CONCLUSIONS

Put in larger perspective, this project is part of a three pronged initiative to produce a science curriculum with a lunar theme, an exhibit representing the interior of a 2069 lunar base that would be the ultimate field trip for students taking such classes in a spiral curriculum, and a paperback children's book that is fiction but scientifically accurate that the students could take home and own for less than $15.00. There is some thought that a play depicting life at a lunar base might also be worth developing for this age group.

The pivot point of the whole thing is the curriculum. The public school teachers like the idea of a thematically integrated science program, and though some would prefer an environmental message them, they seem okay with the lunar base theme on the South Pole. But, they do not want an exhibit if it does not grow out of the curriculum. It must be a review of the curriculum field trip, not a distraction from preparing for the MCAS.

We also found that if the program does not start with a firm foundation that has high educational potential, the teachers will drift from t he theme because they are there to teach science concepts. It is the AIAA that is paying for the kits and materials to do hands on stem that wants to get the space theme back into the science curriculum. It was a common them 50 years ago, but now space is being squeezed out, except for some bland so9lar system and astronomy concepts. The moon was actually depicted as barren rather than resource rich in the textbook used by the WPS.

Against this background we can claim considerable success in making the case for the educational potential in a lunar base theme, and bringing hand's on science to a school that was not doing anything interesting in science class. The way is now paved to build a next step spiral into biology for the 6th graders. It is also paved to start planning the Exhibit art and design work because one can tell them what kind of education and curriculum unit they are supporting. It may be a bit early to plan the book and play, but it is time for essay contests with the space theme and to look for suitable field trips until such time as the exhibit can be created.

We think our idea of sustaining the effort in Worcester with a service club will prove to be important in keeping both the hands' on science effort alive and making the most of the resources to support it that we have collected. There is interest in this pilot project elsewhere, as indicated by the success of the table exhibit at the NEAM Space Expo. The next step is for WPI to figure out how to coordinate the efforts of several IQP teams engaged in a common initiative. We think we pointed to the need for that if not the means for how to do it. We can also claim to have secured the WPI Elm Park School partnership. The Principal there has decided her school will be strong in science and wants to see the kind of thing we have done expanded. WPI students will be on her strategic planning team next year.

All in all good progress has been made toward a model program in Worcester. Even the science coordinator for WPS, Kathy Berube sees considerable promise in the Club idea and wants to address its members next year. She will be pushing the idea of a lively science fair program supported by the club. She also notes that only 1 in 4 of her elementary teachers at the 5^{th} and 6^{th} grade level are really interested in of competent/confident in science. The rest will make science class just another reading class without a push to do things differently that is supported by people knowledgeable and confident in STEM- like the WPI student body. A broad partnership at the system level may be about to emerge and we did our part to set the stage for it.

APPENDIX

APPENDIX A: LUNAR BASE HANDOUT

Your homework assignment is to decide where on the moon you would put a lunar base similar to the one you saw today and then meet in you r group tomorrow and talk over your reasons. You will then have someone in the group present your teams plan with you decision and the reason s you made that decision.

The possibilities for putting it underground to protect it from solar radiation are to find a cave, (probably created by an ancient lava tube in a hilly area), put it in a crater, (probably by digging into the side of the crater), you also can dig a big hole anywhere you want and cover it over or just build it on the lunar surface and then bury it in lunar regolith dust at least 10 feet deep by piling it up.

The things to think about in terms of your base's location are light, water, valuable things to mine and how easy it is to get back and forth to Earth. You are to decide whether to put your base near the equator or at one of the poles of the moon. There are caves near the equator but not at the poles, and there are lots of craters everywhere.

It is easier to land and take off in a spacecraft from the equator of the Earth or the moon. NASA has its launches from Florida, close to the Equator to get an extra push from the spin of the Earth. The moon also spins but much more slowly. A "day" the moon is 28-29 Earth days long. Half of that time (about 2 weeks) is in the dark at the Equator. That is a night 14 Earth days long without seeing the Sun followed by intense light with no night for another 14 Earth days. At the equator it is really hot or really cold and there are no places that escape sunlight, oxygen in it completely evaporates into space every day.

At the poles it is colder on average but never gets as hot as on the equator, so the change in temperature is not as great. This is because the Sun is almost always shining on you, (unless you are in the shade of a hill, mountain or crater) but it is low in the sky and the rays come in at an angle. Further, when you are at the pole the Sun seems to go around you in a big circle for 28-29 Earth days. So, each Earth day shines on you from a different direction during the lunar day. Some places like the bottom of a deep crater never are in sunlight – always dark. That is interesting since any water that formed would be a hard ice and not evaporate into space, like it does where the Sun's rays hit it.

The Sun is a fusion nuclear reactor so the Solar wind also carries the fuel of the Sun, which is Helium-3, through space. The Earth does not get any on the surface of the planet because our atmosphere protects us from solar radiation and also deflects the solar wind. However, the moon has nearly not atmosphere and the radiation hits its surface directly. The solar wind deposits Helium-3 in the lunar regolith as well as the Hydrogen that we already said combines with Oxygen in the rocks and dust to make water. The more direct the sunlight a place on the moon gets, the more Helium-3 will be in the surface regolith, so there is much more Helium-3 (fusion reactor fuel) at the equator than at the poles.

So the equator is easier to get to, has little to no accumulated water but more accumulated helium-3? There are probably lava tube caves, but the temperature extremes are great and the "night" is long.

The poles are harder to land and take off from, but on the top of a hill or mountain there is nearly always sunshine though not as strong light as at the equator. In the bottom of some deep crates that are always dark there will be water ice. There are craters but no known caves. The temperature does not change as much, but on average it is colder at the poles. Where would you put your lunar base?

"At the pole in a crater or on the surface or on the equator in a lava tube cave, crater or on the surface?" Be sure your base has a power source to grow your food, provide electricity and keep you warm.

15 sample writing assignments selected by the home teacher out of 60 students

I think NASA should put the lunar base at the South Pole. I say this because when ice melts it turns into water. The people can drink the water to survive. That's why I chose the South Pole for the lunar base.

If I was to place a lunar base somewhere on the moon it would be on the equator. At the equator it is really hot and really cold and there are no places that escape sunlight. The water forms on the surface when the solar wind hits moon dust or rocks.

If I was to place a lunar base somewhere on the moon I think it would be at the South Pole. I would say this because I don't want it to be too cold or too hot. Also, if you go on a hill it's still not as bright as the equator is. This is why I would pick the South Pole.

I would put the lunar base on the North Pole. I would because there would be a better power source. We would use the power to warm up. The power would come from the Sun. I would produce light for the greenhouse to grow vegetables. That is why I would put the Lunar Base at the North Pole.

I would put the lunar base at the equator for many reasons. My first reason is that it is 14 days of hot and 14 days of cold. I think that is fair. My second reason is that it is easier to take off in a spacecraft from the equator. My last reason is that since it's really hot and cold the water completely evaporates into space. There are my reasons why the people should put the lunar base at the equator.

My lunar base will be in some place hot and with water. In the North Pole because maybe there's water and light, so it might be comfortable. If there's might not be light in the equator of moon then you can't see and sun evaporates all the water.

North pole I pick the north pole because it is always sunny there and if you put the cave there then that means that you can survive and not be cold and stay healthy and without any light then who can you stay awake and eat any food but if you go to the north poles. I would pick the poles because I want to stay alive and I want be able to eat something and you can also stay warm because of the weather there.

I think the lunar base should be at the north part of the moon because the north part gets light for the green house and water to drink and water the plants. The lunar base shouldn't be in the equator because there's no water to water the plant, and there's no light to grow plants. The lunar base also shouldn't be at the South Pole because it may have light. But we predict there's water there. That's why the lunar base should be at the north part of the moon.

I decide to put the lunar base in the South Pole because it is hot there. The hotter the more it got electricity. So it could stay forever. On the equator in a lava tube, cave crater. This is where I'm going to put it.

I think we should put the lunar base at the poles of the moon on the surface because you can get valuable things at the poles. At the poles, the sun is going to be shining. At the equator, the moon spins slowly, so it is very hot or cold. This makes the water evaporate or freeze, but at the poles, water is liquid. Also, solar winds carry Helium-3, or fuel of the sun. Helium, -3 mixes with oxygen and makes water. Water can be found at the poles of the moon.

I would put the lunar base at the South Pole of the moon because it is heard that the south pole where the moon is that there is water on the South Pole on the moon. Also I would put the lunar base at the South Pole because I think it has enough sun for a couple weeks like 2 or 3 or more weeks. Also I would like to put the lunar base on the other side of the moon, which is the South Pole because it probably will have enough things to survive. Some of the stuff to survive is food, water, and soap also shampoo and conditioner.

This is about where on the moon would I put a lunar base. I would put it in the Northeast in an equator. I would put it there because there will be water and heat and I will be able to plant things because there will be heat. Since there will be heat I would be warm. I will be hydrated with the little accumulated water. That's where I choose to put my lunar base.

The place where we should put the lunar base is on the moon because the possibilities for putting it underground to protect it from solar radiation are to find a cave (probably created by an ancient Lava tube). The lunar surface and then bury it in lunar regolith dust at least 10 feet deep by pulling it up. The things to think about in terms of my bases location are light, water, valuable things to mine and how easy it is to get back and forth to earth. I'll decide whether to put the base near the equator or at one of the poles of the moon. It will be easier to land and take off in a spacecraft from the equator of the earth or the moon. NASA has its launches from Florida close to the equator, to get on extra push from the spin of the earth. At the poles it is very cold on average but never gets as hot as on the equator. The sun will almost shine but you are in shade of a hill. The sun is a fusion nuclear reactor. So the lunar base will not be near the solar system because the solar wind also carries the fuel of the sun, which is Helium-3 through space. So the equator is easier to get to, has little to no accumulated Helium-3, combines with the oxygen in the rocks? So my lunar base will be inside the moon and away from the solar systems and it will have light, water and valuable things to mine so that's where I'll put my lunar base.

Where I'll put the lunar base on the equator of the moon because the craters, which we will make homes in them, and there's, ice which we will heat them into water. We can use the sunrays and make Helium-3 to make rocket fuel. On the equator in lava tube will be in the crater. We will have a greenhouse underground and have the solar panels on the surface so the radiation will not harm the plants or food. The solar panels will provide electricity to warm us. That's where I'll put the lunar base.

I would rather put the lunar base on the equator than the lava tube. I would put the lunar base on the equator because of the sunlight to get light to work and the lava tube for which you need to get away for a bit when really hot.

APPENDIX B: EARTH AND MOON CHAPTER

Read and Learn

VOCABULARY
moon p. 482
crater p. 482
moon phase p. 485
eclipse p. 486
refraction p. 486

SCIENCE CONCEPTS
- how the moon and Earth are alike and different
- how the phases of the moon and solar and lunar eclipses happen

COMPARE AND CONTRAST
Look for ways the phases of the moon are alike and different

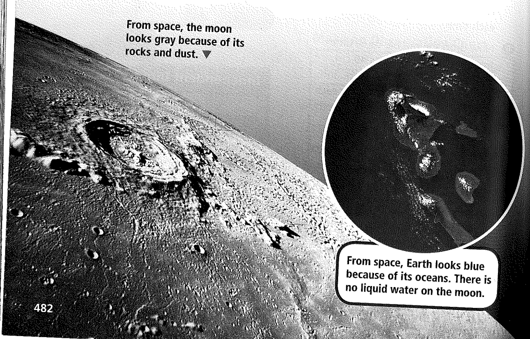
alike — different

The Moon and Earth

If you stare at the moon at night, you may wonder what the surface of this silent, round object is like. A **moon** is any natural body that revolves around a planet. Earth and its moon are similar in several ways. Both are rocky and fairly dense. Both are made of many of the same elements, including aluminum, oxygen, calcium, silicon, and iron. Both the moon and Earth have craters. A **crater** is a low, bowl-shaped area on the surface of a planet or moon.

However, there are also important differences between the moon and Earth. One clear difference is size. The moon's diameter is about 3476 km (2160 mi), only about one-fourth of Earth's diameter.

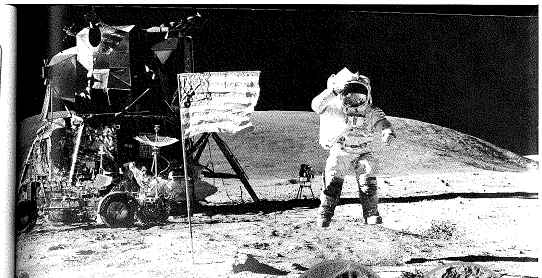
The moon's pull of gravity is only about one-sixth that of Earth. A person who weighs 800 newtons (180 lb) on Earth would only weigh 133 newtons (30 lb) on the moon. The moon, unlike Earth, has almost no atmosphere and no liquid water. Temperatures on the moon can vary.



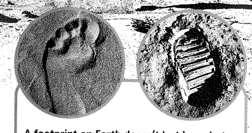
From space, the moon looks gray because of its rocks and dust. ▼

From space, Earth looks blue because of its oceans. There is no liquid water on the moon.

482



▲ Astronauts need spacesuits on the moon to provide air to breathe and to protect them from the extreme temperatures. The heavy suits and other equipment feel much lighter on the moon than on Earth because of the weaker gravitational pull of the moon.



A footprint on Earth doesn't last long, but a footprint on the moon could last millions of years due to lack of erosion.

Temperatures can be more than 100°C (212°F) during the day to –155°C (–247°F) at night. Earth's temperatures are less extreme.

The moon's surface is covered with craters, many more than on Earth. The craters were made by objects falling from space, like the marbles in the Investigate.

Most objects that fall from space toward Earth burn up in the atmosphere before they reach the ground. The craters that do form on Earth are usually worn down by weathering. Objects that fall to the moon, though, do not burn up, because there is hardly any atmosphere. And there is no erosion, because of the lack of atmosphere and lack of water. As a result, craters on the moon last indefinitely.

COMPARE AND CONTRAST **How is the moon's surface different from that of Earth?**

Insta-Lab

Astronaut Moves

To work on the moon or in space, astronauts need to wear spacesuits to protect themselves. Try to thread a nut on a bolt while wearing heavy gloves. How difficult do you think it would be to work on the moon or in space?

483

Phases of the Moon

On some nights, you may notice that the moon seems to have disappeared. On other nights, you see a large, white moon shining brightly. The moon, though, has not changed at all. Instead, the moon and Earth have moved.

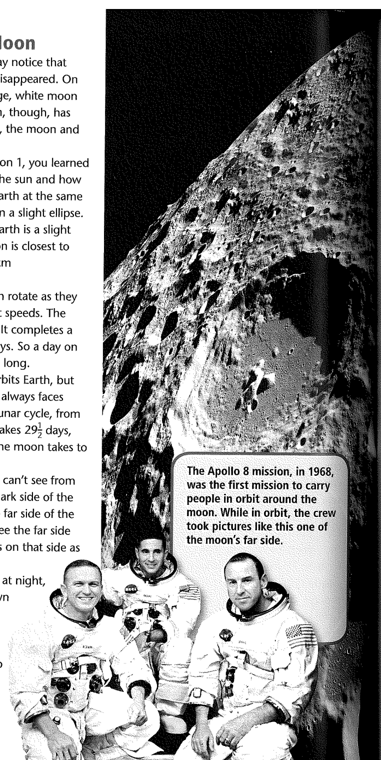
In the Investigate in Lesson 1, you learned how Earth travels around the sun and how the moon travels around Earth at the same time. Earth orbits the sun in a slight ellipse. The moon's orbit around Earth is a slight ellipse, too. When the moon is closest to Earth, it is about 356,400 km (221,000 mi) away.

Both Earth and the moon rotate as they revolve, though at different speeds. The moon rotates more slowly. It completes a rotation every $29\frac{1}{2}$ Earth days. So a day on the moon is $29\frac{1}{2}$ Earth days long.

The moon rotates as it orbits Earth, but the same side of the moon always faces Earth. That's because one lunar cycle, from new moon to new moon, takes $29\frac{1}{2}$ days, the same amount of time the moon takes to complete one rotation.

The side of the moon we can't see from Earth was once called the dark side of the moon. A better name is the far side of the moon. Although we can't see the far side of the moon, the sun shines on that side as often as on the side we see.

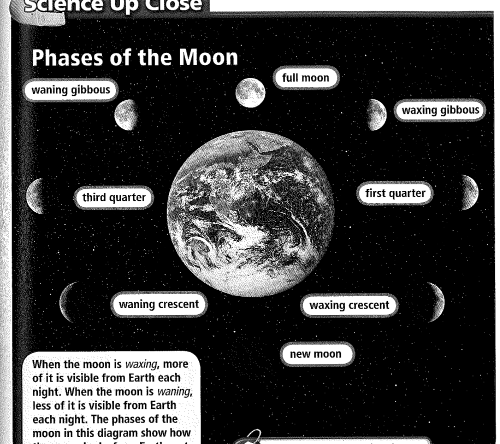
The moon is often bright at night, but it doesn't give off its own light. As the moon orbits Earth, its position in the sky changes. The part of the moon that is exposed to the sun reflects the sun's light.



The Apollo 8 mission, in 1968, was the first mission to carry people in orbit around the moon. While in orbit, the crew took pictures like this one of the moon's far side.

484

Science Up Close



When the moon is *waxing*, more of it is visible from Earth each night. When the moon is *waning*, less of it is visible from Earth each night. The phases of the moon in this diagram show how the moon looks from Earth, not from space.

For more links and animations, go to **www.hspscience.com**

The way the moon looks from Earth changes daily. At any time, half of the moon is lit by the sun. But how much you see depends on the moon's phase. A **moon phase** is one of the shapes the moon seems to have as it orbits Earth. When Earth is between the moon and the sun, you see a full moon. When the moon is between Earth and the sun, you can't see the moon at all. This is called a new moon.

The cycle of phases of the moon takes $29\frac{1}{2}$ days. During the cycle, the visible portion of the moon changes gradually. Starting with a new moon, you see more and more of the moon each day until the full moon. Then you see less and less each day until the next new moon.

COMPARE AND CONTRAST **Contrast the appearance of the moon during a full moon and a new moon.**

485

Eclipses

Objects in space block some of the sun's light, producing shadows. An **eclipse** occurs when one body in space blocks light from reaching another body in space.

Eclipses we see on Earth are solar eclipses and lunar eclipses. They are alike because both occur when Earth, the sun, and the moon line up. However, solar and lunar eclipses also differ.

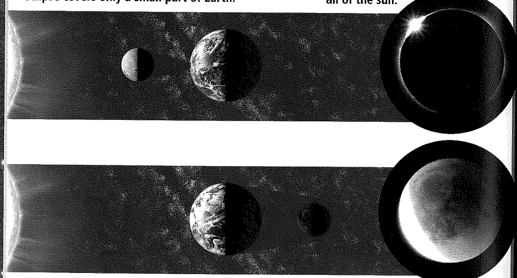
A solar eclipse occurs when the moon—always a new moon—casts a shadow on Earth. In some places the moon seems to cover the sun, and the sky gets dark. Only the outer atmosphere of the sun is visible, as a bright glow around the moon. At other places, only part of the sun is covered.

A lunar eclipse occurs when the moon—always a full moon—passes through the shadow of Earth. Earth blocks the sun's light from reaching the moon, but the moon does not look black. Instead, it looks red. This is because Earth's atmosphere bends red light, which then reflects off the moon. Scientists call this bending of light **refraction**.

You might think that eclipses happen with every new or full moon. But the moon and Earth are not always in the proper alignment. Sometimes only a partial eclipse occurs. Partial solar and lunar eclipses each occur two to four times a year.

Focus Skill COMPARE AND CONTRAST

How do solar and lunar eclipses differ?



A solar eclipse occurs when the moon casts a shadow on Earth. A total solar eclipse covers only a small part of Earth.

During a total solar eclipse, the moon covers all of the sun.

When the moon passes through Earth's shadow, a lunar eclipse occurs.

The moon appears red during a lunar eclipse because gases in Earth's atmosphere bend red light.

Lesson Review

Essential Question

How Do Earth and the Moon Compare?

In this lesson, you learned about the relationship between the moon and Earth. You also learned about the phases of the moon and what happens during an eclipse.

1. Focus Skill COMPARE AND CONTRAST Draw and complete a graphic organizer that compares and contrasts Earth's and the moon's atmosphere, temperatures, and craters.

   alike — different

2. **SUMMARIZE** Write a one-paragraph summary of the phases of the moon.
3. **DRAW CONCLUSIONS** How would the moon be different if it had liquid water?
4. **VOCABULARY** Explain in a sentence what an eclipse is.

Test Prep

5. **CRITICAL THINKING** On a night when you see a full moon, where are the moon, sun, and Earth relative to each other in space?
6. Which of these are on the surfaces of both the moon and Earth?
   - **A.** craters
   - **B.** liquid water
   - **C.** oxygen
   - **D.** windstorms

Make Connections

Writing

Narrative Writing

Think about the differences between the moon and Earth. Then write a **story** that describes the differences. Use as many descriptive words as you can.

Math

Use Fractions

During a full moon, you can see half of the moon's surface. During a first quarter, what fraction of the moon's surface can you see on a clear night?

Physical Education

Running to the Moon

The moon is about 221,000 mi from Earth at its closest point. To get an idea of how far that is, run or walk 221 steps. Each step represents 1000 miles.

APPENDIX C: EARTH AND MOON ACTIVITY IDEA

20

LUNAR LAVA

THE COLOR OF ROCKS will help pioneers to find useful minerals on the moon. The original lunar crust was nearly white—the color of anorthosite. This crust was pounded and scattered by impacts. But it was still white. The "black eyes" of the moon are a different kind of rock.

As the moon cooled, the crust cracked like a cake fresh from the oven. Pressure pushed hot lava up through these weak areas to spew onto the surface off and on between 4.2 and 1.2 billion years ago. The lava was made of basalt, a rock type more dense than anorthosite. Basalt contains iron and magnesium and is nearly black in color. The lava flowed on top of the anorthosite and pooled in the deepest craters. The pools cooled and became the maria, the Latin word for seas. The maria are dark because of the basalt.

"We believe the eruptions on the moon were very similar to something we call flood basalts," geologist Aileen Yingst says. Flood basalts have "lots of volume, lots of stuff coming out at the same time, but [are] very liquid, flowing very rapidly over a great distance." The lava had the consistency of motor oil. "What that means is that we don't have those beautiful volcanoes building up," Yingst says. "They just don't have the time. The lava comes out and flows away." The maria are round because the basins created by impacts were round, not because they are the tops of giant volcanoes.

The lava didn't just bubble out of cracks in the crust. Some of it burst forth in what geologists call fire fountains. "A fire fountain on the moon probably looked like a shimmering mushroom, depending on how constant the eruption was," lunar geologist and astronaut Harrison Schmitt

Fire fountains, such as the one shown here in Hawaii, brought volcanic material from the interior to the surface of the moon in fine sprays of lava about three billion years ago. The moon is no longer volcanically active. INSET: Moon rocks are made of oxygen, silicon, iron, calcium, aluminum, and magnesium. They also contain less than one percent of rare elements such as titanium, potassium, and phosphorus.

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says. "It took sort of a dome shape as the particles spread out and fell back to the ground—a little bit like a water sprinkler."

Dr. Schmitt discovered the remains of a fire fountain during Apollo 17. "There is orange soil! It's all over. It's orange!" he said from the moon. The colored beads produced by fire fountain eruptions are coated with rare volcanic gases. Plants and animals need these elements. So if you go to the moon, keep an eye out for orange soil!

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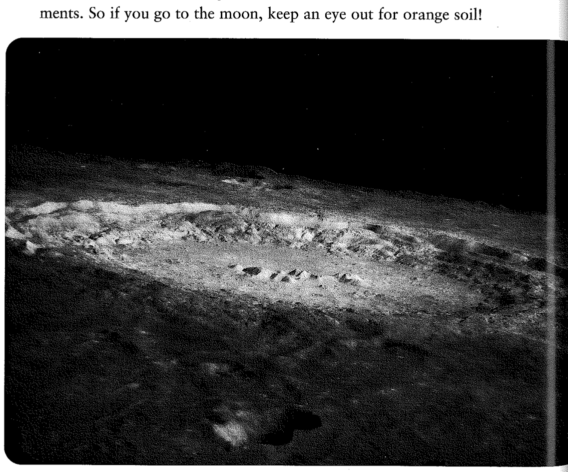


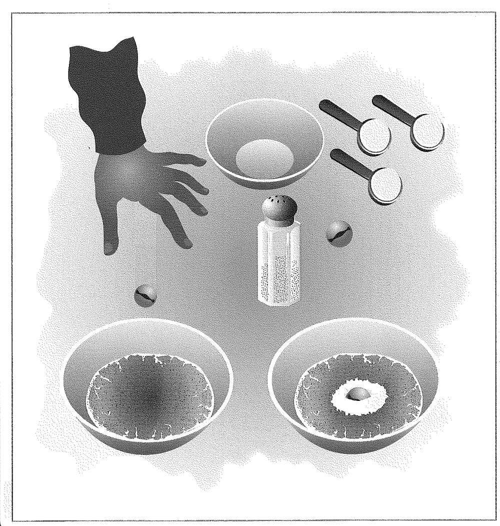
The impact that created the crater Copernicus (shown here in a photo from Apollo 12) blasted through the dark layer of lava that filled the Oceanus Procellarum. Copernicus is one of the youngest craters on the moon at about one billion years old. Scientists think the central peak was uplifted from 9 to 12 miles below the surface and may be part of the original lunar crust.

ACTIVITY
CRATER COLOR EXPERIMENT

SUPPLIES: Small bowl, 3 tablespoons flour "anorthosite," pepper "basalt," and a marble "meteorite."

Directions

1] Put the flour in a bowl and shake pepper over it until the surface is dark. Drop the marble from one foot above the bowl. Remove the marble. Note the white ring around the crater. Only new craters are white on the moon.
2] Try dropping the marble from two feet. It will hit faster. Is the crater bigger?



APPENDIX D: EARTH AND MOON HANDOUT

In – Class

	Angle of Impact	Length of Crater	Width of Crater	Ratio (L/W)	Other Observations
Station 1					
Station 2					
Station 3					
Station 4					
Station5					

APPENDIX E: MATTER HANDOUT

Melting Points of Some Metal and Alloys

Metal	Melting Point	
	(^oC)	*(^oF)*
Admiralty Brass	900 - 940	1650 - 1720
Aluminum	660	1220
Aluminum Bronze	600 - 655	1190 - 1215
Antimony	630	1170
Beryllium	1285	2345
Beryllium Copper	865 - 955	1587 - 1750
Bismuth	271.4	520.5
Brass	930	1710
Cadmium	321	610
Cast Iron, gray	1175 - 1290	2150 - 2360
Chromium	1860	3380
Cobalt	1495	2723
Copper	1084	1983
Cupronickel	1170 - 1240	2140 - 2260
Gold	1063	1945
Hastelloy C	1320 - 1350	2410 - 2460
Inconel	1390 - 1425	2540 - 2600
Incoloy	1390 - 1425	2540 - 2600
Iridium	2450	4440
Iron	1536	2797

Lead	327.5	621
Magnesium	650	1200
Manganese	1244	2271
Manganese bronze	865 - 890	1590 - 1630
Mercury	-38.86	-37.95
Molybdenum	2620	4750
Monel	1300 - 1350	2370 - 2460
Nickel	1453	2647
Niobium (Columbium)	2470	4473
Osmium	3025	5477
Platinum	1770	3220
Plutonium	640	1180
Potassium	63.3	146
Red Brass	990 - 1025	1810 - 1880
Rhodium	1965	3569
Selenium	217	423
Silicon	1411	2572
Silver	961	1760
Sodium	97.83	208
Carbon Steel	1425 - 1540	2600 - 2800
Stainless Steel	1510	2750
Tantalum	2980	5400
Thorium	1750	3180
Tin	232	449.4
Titanium	1670	3040
Tungsten	3400	6150
Uranium	1132	2070
Vanadium	1900	3450
Yellow Brass	905 - 932	1660 - 1710
Zinc	419.5	787
Zirconium	1854	3369

APPENDIX F: ENERGY HANDOUT

Take-home reading & study sheet for energy chapter

Where and how do people get energy?

Forms of energy:

Chemical energy is generally the energy stored in fuel, such as fossil fuels and nuclear fuels.
Mechanical energy: Potential energy and kinetic energy are mechanical energy.

Electrical energy is the energy that comes from an electric current.

- Battery provides electrical energy

Fossil is the remains or traces of past life, often found in sedimentary rock

- Coal, oil and natural gas are fossil fuels and the energy produced by those fuels are called **fossil energy**

Solar energy is the energy that comes from the sun.

Nuclear energy is the use of sustained nuclear reaction to generate energy

- A neutron collides with a Uranium atom and it breaks the atom into two parts and produce massive energy

Forms and conversion of energy:

Energy list:

Use the above forms of in the first column (energy stored column) write the forms of energy stored inside the object and in the second column (energy produced column) write the forms of energy being produced from the object

	Energy stored in	Energy produced
Battery	Chemical energy	Electrical energy
Motor		
Windmill		
Solar panel		
Light Bulb		
Heater		

How is heat transferred?

Conduction: The transfer of heat from one object directly to another.

- Example: Directly touching a hot metal and feels that the heat from the metal.

Convection: The transfer of heat through the movement of a gas or a liquid.

- Example: There is a hot pot with water inside. Start heating the pot and put hands in the water. You will feel the heat that is transferred by water from the pot to hands.

Radiation: The transfer of energy by means of waves that move through matter and space.

- There is no gas or liquid between the Sun and you, it's vacuum. The heat from the sun is transferred by radiation.

Resources: Any material that can be used to satisfy a need

Nonrenewable resource: A resource that, once used, cannot be replaced in a reasonable amount of time

Renewable resource: A resource that can be replaced within a reasonable amount of time

Pollution: A waste product that harms living things and damages an ecosystem

Energy resource	If it is renewable or nonrenewable		Is it harmful to environment
	Yes, renewable	No, nonrenewable	
Coal			
Wind			
Solar			
Water			
Oil			
Nuclear			
Natural gas			

APPENDIX G: LIGHT AND SOUND HANDOUT

Take-home reading & study sheet for Sound and Light chapter

What is Sound?

Sound is a wave that is **vibration** transferred through a solid, liquid, or gas.
Note: Sound must be travelling in medium such as solid, liquid or gas. Without these mediums, sound cannot travel through vacuum. So people cannot hear anything in space because there is no medium.

Vibration: A back-and-forth movement of matter.
Example: Music instruments make sound by the vibration of the strings.

Volume: is the loudness of a sound

Pitch: is a measure of how high or low a sound is

Frequency: The number of vibrations per second.
Note: people can only hear sound with frequency between 20 to 20,000 vibrations per second.

How is the loudness of sound measured?

The decibel (dB) is the unit people use to measure the loudness of sound.

Sustained exposure at 90 – 95 dB may result in hearing loss
Hearing pain begins at 125 dB
Short-term exposure at 140 dB can cause permanent damage

Types of sound (Sources)	Loudness
Whisper in quiet library	30 dB
Normal Conversation	60-65 dB
City traffic	85 dB
Train whistle	90 dB
Hand drill	98 dB
Motorcycle	100 dB
Loud rock concert	115 dB
Jet engine	140 dB
Shotgun blast	165 dB

What is Light?

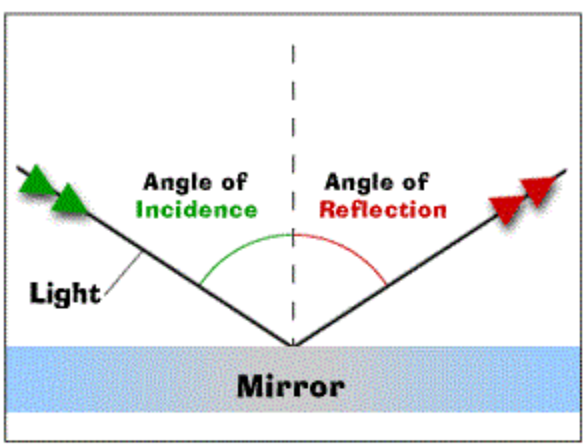
Visible Light is electromagnetic radiation that is visible to the human eye.

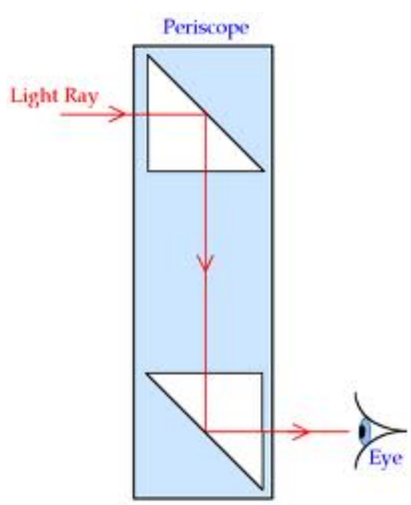
Opaque object: light cannot pass through

Translucent object: only some light can pass through

Transparent object: all light can pass through
Light can be redirected through **reflection** or **refraction**.

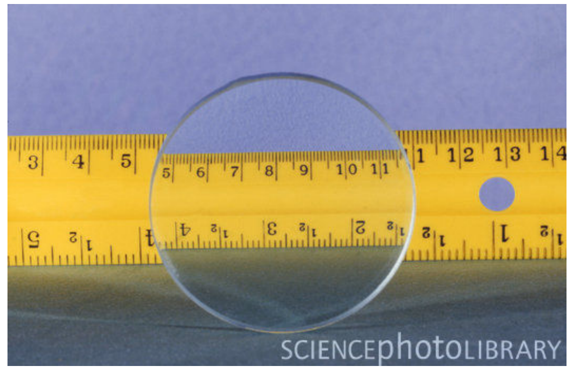
Reflection: the bouncing of light off an object.
Examples: mirror, periscope.

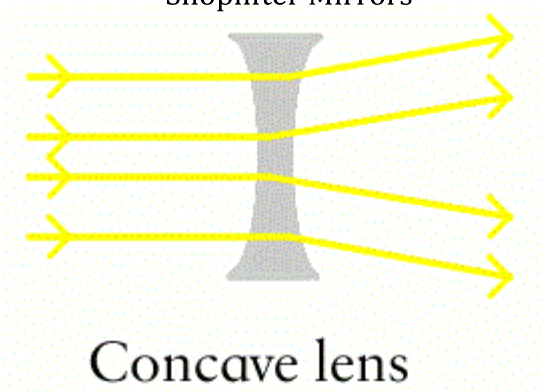




Refraction: The bending of light as it moves from one material to another.
Concave lens: A lens that is thicker at the edges than it is at the center
Uses of concave lens:

- Treat Nearsightedness
- On Door Holes
- Shoplifter Mirrors

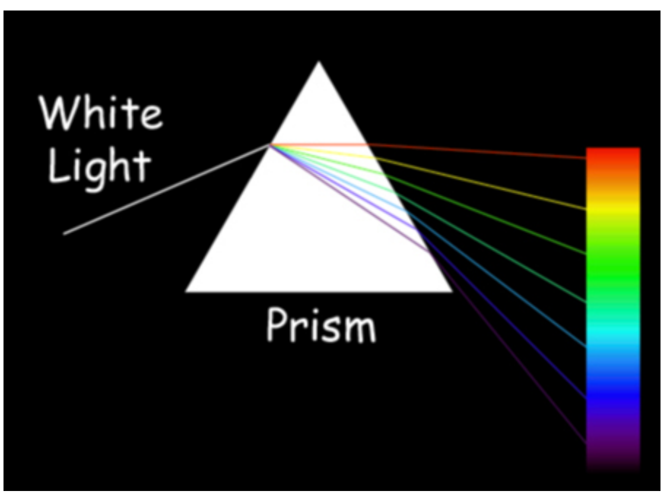


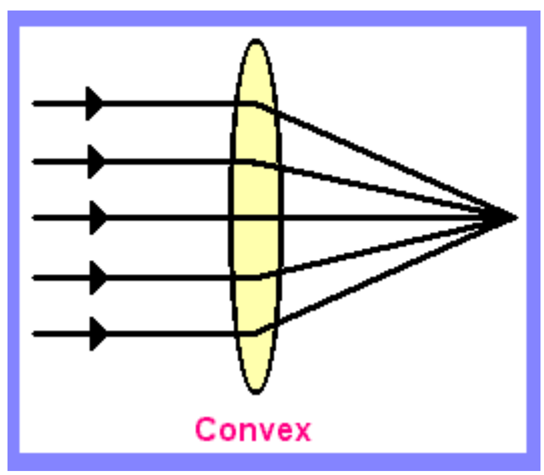


Convex lens: A lens that is thicker at the center than it is at the edges
Uses of convex lens:

- Magnifier
- Treat farsightedness
- Used on microscope to see tiny objects
- Used on cameras
- Human eyes are double convex lens

Prism: (Requires color printer for this)
Usually it's a triangular prism with a triangular base and rectangular sides. It can be used to produce rainbow light.





APPENDIX H: ELECTRICITY HANDOUT

Take-Home Reading & Study Sheet for Electricity Chapter

What is Electricity?

Electricity is a form of energy produced by moving electrons (aka. Electric current)

Recall from energy chapter, **Electrical energy** is the energy that comes from an **electric current**.

Moving electrons produces electricity we use in everyday life. There is also another form of electricity, **static electricity** that involves no moving electrons.

Static electricity is the buildup of charges on an object. (Note: charges are electrons)

Current electricity is a kind of kinetic energy that flows as an electric current.

How does Electricity Work?

Conductor: A type of material that carries electricity well. (The electrons can move freely through the material)

Insulator: A type of material that does not conduct electricity well. (The moving of electrons is constrained through the material, in other words, no electrons can pass through.)

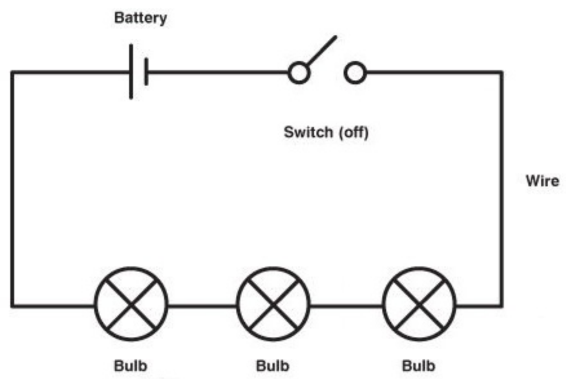
How to Use Electricity?

Electric circuit: The path an electric current follows

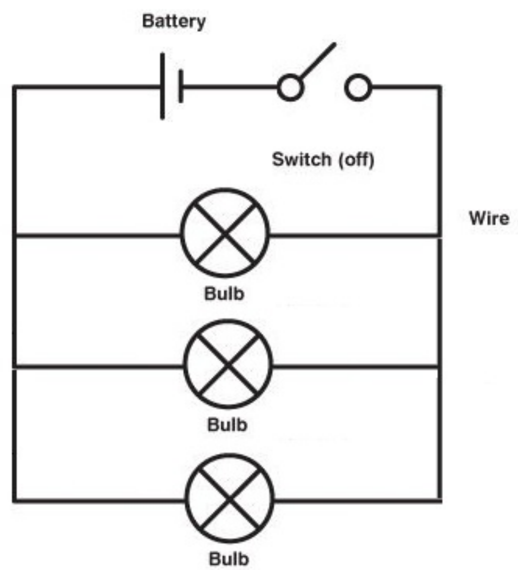
Series circuit: An electric circuit in which the current has only one path to follow.

Parallel circuit: An electric circuit that has more than one path for the current to follow.

Example of series circuit:



Example of parallel circuit:



Disadvantages and advantages of both series and parallel circuit:

Connecting three bulbs in series circuit uses less wire than in parallel circuit

If any one of the three bulbs in series circuit breaks, other two bulbs will not be working simply because there is one way the electric current can flow and the only way is broken.

If any one of the three bulbs in parallel circuit breaks, the other two bulbs will still be working because the electric current has three ways to go in parallel circuit. One bulb breaks meaning only one of the ways in which the electric current can follow breaks and the other two ways are still working.

What does Electricity do?

Turning electricity into magnetism

Electromagnet: A magnet made by coiling a wire around a piece of iron and running electric current through the wire.

Note: The piece of iron itself is not magnetic, but by coiling a wire around it and running electric current through it will make it magnetic.

APPENDIX I: NEAM HANDOUT

LUNAR BASE (5th Grade) Curriculum kit Overview

We are a team of students from Worcester Polytechnic Institute who are sponsored by the New England Chapter of the American Institute of Aeronautics and Astronautics to do an outreach curriculum project to the public schools. We were asked to explore a few ways that one could enrich science education in nearby public schools at low or no cost so that it is sustainable with local resources. The general goal was to promote technological literacy, make science education fun, and identify talented students interested in science and foster their efforts starting with 5th grade. We decided to create activity kits (materials, storyline, activities, concept sheets) to go with several key chapters in the text used by the Worcester Public Schools. The goal was thematically integrated hands on science experiences and link such units and kits created for grades 5-9 into a spiral curriculum with a common theme.

The theme connecting the units was a story line involving the challenge of building a lunar base out of local lunar materials. One advantage of this theme was that we could show them a picture of a proposed base that won the technical feasibility award in a recent architectural contest. Our advisor John Wilkes of WPI headed the team that designed it; hence we had access to an extraordinarily detailed illustration of a second-generation base circa 2069. That would be within the working lives of these 10-year-old 5th grade students. The 5th grade text chapters we prepared activities and kits for follow the one comparing the Earth and moon. These were:

Matter: Demonstration of something changing states with temperature. We melted wax using a paraffin bath heater and made shapes out of the liquid wax with play dough molds made by the students. They liked to make things shaped like tools. We talked about the melting points of different metals and how you could separate the aluminum from the iron and titanium in the lunar regolith.

Forces: The study of friction, gravity, buoyancy and magnetism, each with different demonstrations or hands-on activities associated with a lunar base challenge. The big one is what to do about the lack of a magnetosphere to protect the moon (and hence the base) from cosmic radiation. But even the problem of getting sand in the gears that rotate the solar voltaic unit that follows the Sun was of interest to the 5th graders. The idea of 1/6th gravity- or being 6 times as strong on the moon absolutely intrigued them.

Energy: Ice harvesting from the bottom of a perpetually dark crater- how would you do it? Once you have formed massive ice cubes and are transporting them up a 4km ramp on a 30-degree incline up to the base, what is the hazard level if one broke free? In order to find out, we have them slide ice cubes down a 30-degree ramp and observe how potential energy can turn into kinetic energy. By changing the height up the ramp of release one can model at what point an ice block that broke free would crash into the ice making apparatus that produced it and destroy the system.

Electricity: There are lots of conductors on the moon, though regretfully not much copper, silver or gold. Still, the students find out that iron, steel and aluminum work fine as would chromium and titanium. However, when it comes to insulators one has only inconvenient glass. There is nothing to make rubber or plastic from and no wood. How to generate electricity is also discussed, but the key things the teacher's need covered are generating electromagnetism with coils and designing circuitry. So the students wire models of some habitat units of the base, decide what to do about insulators and consider the case for series or parallel wiring of the base dorm rooms.

Sound and Light: It would take a lot of electricity to grow food underground using grow lights, so is there another way? Only if you can get light to turn corners and concentrate and diffuse on command. The students observe convex and concave lenses and experience a periscope. They then form design teams and suggest feasible ways to get light to the greenhouse in and underground lunar base- massively reducing the base's electricity requirements.

If you would like to receive more information about the kits (and how to access them) contact one of the people below. Contact Information: Jon Rodgers jnrodgers@wpi.edu Yadira Hilario yhilario@wpi.edu; Ye Lu harryluchn@wpi.edu; Professor John Wilkes jmwilkes@wpi.edu.