Materials and Manufacturing

Madness in March

Grade Level(s): 9th – 12th

Academic Content Areas: Math, Science and Technology

Topics: Physical Science, Scientific Inquiry, Technology, Patterns, Function, and Algebra, Data Analysis and Probability, Measurement

Recommended area of co-teaching for an AFRL Engineer or Scientist

Main Problem / Essential Question

What affects the performance of a basketball?

Summary

March Madness is an exciting time of year when the best college basketball teams square off for a final tournament. Many students are enthralled by the games and become energized by basketball. This lesson begins by having student view a short video clip, “One Shining Moment” from the men’s NCAA basketball tournament. Students will then research information about basketballs through exploring the internet and conducting experiments. Students will also learn about energy conservation as they use energy equations to solve problems.

This lesson connects to the state standards and coincides with the madness of the game. Basketballs are made from a variety of materials and multiple sizes depending upon the gender, players and league. In the game of basketball, the referee checks the bounce of a basketball prior to the start of the game. The questions presented to the students in this inquiry based lesson include: How does temperature and pressure affect the bounce of the ball; and does the composition of the ball and floor affect the bounce of the ball?

Big Ideas / Focus

The Materials and Manufacturing Directorate researches, processes and characterizes new and novel materials. In this lesson the students will investigate the effect of variables on basketball performance. Through lesson activities, students will discover how properties of the ball affect the game, what properties can be changed for optimum performance and how energy changes forms as a basketball bounces.

Prerequisite Knowledge

Students should be familiar with data collection, conversions between different metric systems, have basic computer skills (including Internet research skills) and an understanding of the design process.

Standards Connections

Content Area: Science

Physical Science Standard

Students demonstrate an understanding of the composition of physical systems and the concepts and principles that describe and predict physical interactions and events in the natural world. This includes demonstrating an understanding of the structure and properties of matter, the properties of materials and objects, chemical reactions and the conservation of matter. In addition, it includes understanding the nature, transfer and conservation of energy; motion and the forces affecting motion; and the nature of waves and interactions of matter and energy. Students demonstrate an understanding of the historical perspectives, scientific approaches and emerging scientific issues associated with the physical sciences.

Grade 9 Benchmark D: Explain the movement of objects by applying Newton's three laws of motion.	21. Demonstrate that motion is a measurable quantity that depends on the observer's frame of reference and describe the object's motion in terms of position, velocity, acceleration and time. 22. Demonstrate that any object does not accelerate (remains at rest or maintains a constant speed and direction of motion) unless an unbalanced (net) force acts on it. 24. Demonstrate that whenever one object exerts a force on another, an equal amount of force is exerted back on the first object. 25. Demonstrate the ways in which frictional forces constrain the motion of objects (e.g., a car traveling around a curve, a block on an inclined plane, a person running, an airplane in flight).
Grade 9 Benchmark F: Explain how energy may change form or be redistributed but the total quantity of energy is conserved.	15. Trace the transformations of energy within a system (e.g., chemical to electrical to mechanical) and recognize that energy is conserved. Show that these transformations involve the release of some thermal energy.
Grade 12 Benchmark D: Apply principles of forces and motion to mathematically analyze, describe and predict the net effects on objects or systems.	3. Describe real world examples showing that all energy transformations tend toward disorganized states (e.g., fossil fuel combustion, food pyramids and electrical use). 5. Use and apply the laws of motion to analyze,

	describe and predict the effects of forces on the motions of objects mathematically.

Scientific Inquiry Standard

Students develop scientific habits of mind as they use the processes of scientific inquiry to ask valid questions and to gather and analyze information. They understand how to develop hypotheses and make predictions. They are able to reflect on scientific practices as they develop plans of action to create and evaluate a variety of conclusions. Students are also able to demonstrate the ability to communicate their findings to others.

Grade 9 Benchmark A: Participate in and apply the processes of scientific investigation to create models and to design, conduct, evaluate and communicate the results of these investigations.	2. Research and apply appropriate safety precautions when designing and conducting scientific investigations (e.g., OSHA, Material Safety Data Sheets [MSDS], eyewash, goggles and ventilation). 3. Construct, interpret and apply physical and conceptual models that represent or explain systems, objects, events or concepts. 4. Decide what degree of precision based on the data is adequate and round off the results of calculator operations to the proper number of significant figures to reasonably reflect those of the inputs. 5. Develop oral and written presentations using clear language, accurate data, appropriate graphs, tables, maps and available technology. 6. Draw logical conclusions based on scientific knowledge and evidence from investigations.
Grade 11 Benchmark A: Make appropriate choices when designing and participating in scientific investigations by using cognitive and manipulative skills when collecting data and formulating conclusions from the data.	1. Formulate testable hypotheses. Develop and explain the appropriate procedures, controls and variables (dependent and independent) in scientific experimentation. 2. Evaluate assumptions that have been used in reaching scientific conclusions. 3. Design and carry out scientific inquiry (investigation), communicate and critique results through peer review. 4. Explain why the methods of an investigation are based on the questions being asked. 5. Summarize data and construct a reasonable argument based on those data and other known information.

Grade 12 Benchmark A: Make appropriate choices when designing and participating in scientific investigations by using cognitive and manipulative skills when collecting data and formulating conclusions from the data.	1. Formulate testable hypotheses. Develop and explain the appropriate procedures, controls and variables (dependent and independent) in scientific experimentation. 2. Derive simple mathematical relationships that have predictive power from experimental data (e.g., derive an equation from a graph and vice versa, determine whether a linear or exponential relationship exists among the data in a table). 3. Research and apply appropriate safety precautions when designing and/or conducting scientific investigations (e.g., OSHA, MSDS, eyewash, goggles and ventilation). 4. Create and clarify the method, procedures, controls and variables in complex scientific investigations.

Content Area: Mathematics

Measurement Standard
Students estimate and measure to a required degree of accuracy and precision by selecting and using appropriate units, tools and technologies.

Grade 9 Benchmark D: Use proportional reasoning and apply indirect measurement techniques, including right triangle trigonometry and properties of similar triangles, to solve problems involving measurements and rates.	5. Solve problems involving unit conversion for situations involving distances, areas, volumes and rates within the same measurement system.
Grade 12 Benchmark D: Solve problem situations involving derived measurements; e.g., density, acceleration.	1. Solve problems involving derived measurements; e.g., acceleration and pressure.

Patterns, Functions and Algebra Standard
Students use patterns, relations and functions to model, represent and analyze problem situations that involve variable quantities. Students analyze, model and solve problems using various representations such as tables, graphs and equations.

Grade 9 Benchmark B: Identify and classify functions as linear or nonlinear, and contrast their properties using tables, graphs or equations.	3. Describe problem situations (linear, quadratic and exponential) by using tabular, graphical and symbolic representations.

Grade 9 Benchmark I: Model and solve problem situations involving direct and inverse variation.	13. Model and solve problems involving direct and inverse variation using proportional reasoning.
Grade 10 Benchmark D: Use algebraic representations such as tables, graphs, expressions & inequalities to model and solve problem situations.	3. Solve equations and formulas for a specified variable; e.g., express the base of a triangle in terms of the area and height.
Grade 12 Benchmark A: Analyze functions by investigating rates of change, intercepts, zeros, asymptotes, and local and global behavior.	6. Make arguments about mathematical properties using mathematical induction.

Data Analysis and Probability Standard
Students pose questions and collect, organize, represent, interpret and analyze data to answer those questions. Students develop and evaluate inferences, predictions and arguments that are based on data.

Grade 9 Benchmark A: Create, interpret, and use graphical displays and statistical measures to describe data.	2. Create a scatterplot for a set of bivariate data, sketch the line of best fit, and interpret the slope of the line of best fit.
Grade 10 Benchmark A: Create, interpret, and use graphical displays and statistical measures to describe data	2. Represent and analyze bivariate data using appropriate graphical displays (scatterplots, parallel box-and-whisker plots, histograms with more than one set of data, tables, charts, spreadsheets) with and without technology. 6. Interpret the relationship between two variables using multiple graphical displays and statistical measures; e.g., scatterplots, parallel box-and-whisker plots, and measures of center and spread.
Grade 11 Benchmark A: Create and analyze tabular and graphical displays of data using appropriate tools, including spreadsheets and graphing calculators.	4. Create a scatter plot of bivariate data, identify trends, and find a function to model the data. 8. Analyze and interpret univariate and bivariate data to identify patterns, note trends, draw conclusions, and make predictions.

Grade 11 Benchmark C: Design and perform a statistical experiment, simulation or study; collect and interpret data; and use descriptive statistics to communicate and support predictions and conclusions.	1. Design a statistical experiment, survey or study for a problem; collect data for the problem; and interpret the data with appropriate graphical displays, descriptive statistics, concepts of variability, causation, correlation and standard deviation.

Content Area: *Technology*

Standard 3: Technology for Productivity Applications
Students learn the operations of technology through the usage of technology and productivity tools. Students use computer and multimedia resources to support their learning. Students understand terminology, communicate technically and select the appropriate technology tool based on their needs. They use technology tools to collaborate, plan and produce a sample product to enhance their learning and solve problems by investigating, troubleshooting and experimenting using technical resources.

Grade 11 Benchmark A: Integrate conceptual knowledge of technology systems in determining practical applications for learning and technical problem-solving.	1. Make informed choices among technology systems, resources and services.

Standard 5: Technology and Information Literacy
Students engage in information literacy strategies, use the Internet, technology tools and resources, and apply information-management skills to answer questions and expand knowledge.

Students become information-literate learners by utilizing a research process model. They recognize the need for information and define the problem, need or task. Students understand the structure of information systems and apply these concepts in acquiring and managing information. Using technology tools, a variety of resources are identified, accessed and evaluated. Relevant information is selected, analyzed and synthesized to generate a finished product. Students evaluate their information process and product.

Grade 9 Benchmark B: Apply a research process model to conduct research and meet information needs.	2. Select and evaluate appropriateness of information from a variety of resources, including online research databases and Web sites to answer the essential questions.
Grade 10 Benchmark A: Determine and apply an evaluative process to all information sources chosen for a project.	1. Examine information for its accuracy and relevance to an information need (e.g., for a report on pollution, find information from sources that have correct and current information related to the topic).

	2. Identify relevant facts, check facts for accuracy and record appropriate information (e.g., follow a standard procedure to check information sources used in a paper).
Grade 10 Benchmark A: Determine and apply an evaluative process to all information sources chosen for a project.	3. Determine and apply an evaluative process to all information sources chosen for a project.
Grade 12 Benchmark D: Evaluate choices of electronic resources and determine their strengths and limitations.	4. Select an appropriate tool, online resource or Web-site based on the information need.

Standard 6: Design
Students apply a number of problem-solving strategies demonstrating the nature of design, the role of engineering and the role of assessment.

Students recognize the attributes of design; that it is purposeful, based on requirements, systematic, iterative, creative, and provides solution and alternatives. Students explain critical design factors and/or processes in the development, application and utilization of technology as a key process in problem- solving. Students describe inventors and their inventions, multiple inventions that solve the same problem, and how design has affected their community. They apply and explain the contribution of thinking and procedural steps to create an appropriate design and the process skills required to build a product or system. They critically evaluate a design to address a problem of personal, societal and environmental interests. Students systematically solve a variety of problems using different design approaches including troubleshooting, research and development, innovation, invention and experimentation.

Grade 10 Benchmark C: Understand and apply research, development and experimentation to problem-solving.	5. Use computers, calculators, instruments and devices to access, retrieve, organize, process, maintain, interpret, and evaluate data and information in order to communicate to group members (e.g., CAD-computer aided design, software, library resources, the Internet, word processing, CBLs-calculator based labs, laser measuring tools and spreadsheet software).

Standard 7: Designed World
Students understand how the physical, informational and bio-related technological systems of the designed world are brought about by the design process. Critical to this will be students' understanding of their role in the designed world: its processes, products, standards, services, history, future, impact, issues and career connections.

Students learn that the designed world consists of technological systems* reflecting the modifications that humans have made to the natural world to satisfy their own needs and wants. Students understand how, through the design process, the resources: materials, tools and machines, information, energy, capital, time and people are used in the development of useful products and systems. Students develop a foundation of knowledge and skills through participation in technically oriented activities for the application of technological systems. Students demonstrate understanding, skills and proficient use of technological tools, machines, instruments, materials and processes across technological systems in unique and/or new contexts. Students identify and assess the historical, cultural, environmental, governmental and economic impacts of technological systems in the designed world.

*The technological systems areas include energy and power technologies, transportation technologies, manufacturing technologies, construction technologies, information and communication technologies, medical technologies and agricultural and related biotechnologies.

Grade 11 Benchmark C: Classify, demonstrate, examine and appraise manufacturing technologies.	1. Document processes and procedures using appropriate oral and written techniques (e.g., flow charts, drawings, graphics, symbols, spreadsheets, graphs, Gantt charts and World Wide Web pages).

Preparation for activity

Photocopy all necessary worksheets
Arrange for class access to Internet enabled computers
Gather all necessary lab materials and equipment

Critical Vocabulary

Atmospheric Pressure – The force per unit area exerted on the surface of the earth based on the amount of atmospheric mass above the surface. The following are some unit conversions for atmospheric pressure: 1 atmosphere = 101.325kPa = 760mmHg = 39.92 inHg = 14.696 psi

Basketball – Spherical sports ball used to play the game called basketball. The basketball is produced in different sizes, depending on the type of game that is being played.

Bivariate data – Data having two values for each observation. One value is the dependent variable the other is the independent variable.

Bladder – The inside part of the basketball that contains the air. Similar to the innertube on a bicycle tire.

Bounce – In physics, the event where an object collides with a plane surface and changes direction.

CBL – Calculator Based Laboratory. A Texas Instrument device used with a TI calculator and a sensing device, to record data; for example, temperature, pressure, ph, light intensity, etc.

CBR – Calculator Based Recorder. A Texas Instrument device used to record the motions of objects in its viewing range. Also referred to as a Sonic Ranger.

Conservation of Energy – A law in physics which states that the total amount of energy in an isolated system remains constant over time; energy can neither be created nor destroyed.

Elastic Collision - The sum of the kinetic energy of two objects before a collision is equal to the sum of the kinetic energy of the objects after a collision *(*Encyclopædia Britannica 2011)

Force – An influence, such as a push or pull, which causes an object with mass to change its velocity.

Friction – A force restricting the motion of solid surfaces. For example the friction between a car tire and the road surface.

Harmonic Motion – The motion caused by a force on an object, where the force is directly proportional to the displacement of the object from the equilibrium position, and acts in the opposite direction of the displacement.

Inelastic Collision – The sum of the kinetic energy of two objects before a collision is not equal to the sum of the kinetic energy of the objects after a collision *(*Encyclopædia Britannica 2011)

Kinetic Energy – A form of energy that an object has due to its motion *(*Encyclopædia Britannica 2011)

Leather – The material created by tanning animal rawhide, or cattle hide.

NCAA – National Collegiate Athletic Association – The governing body of collegiate athletics

Potential Energy – Stored energy that is dependent on the position of an object or parts of a system *(*Encyclopædia Britannica 2011)

Pressurized – The act of maintaining a set pressure. For example, the ball was inflated with air to a pressure of 10psi, therefore the ball was pressurized.

Pressure – "The perpendicular force per unit area" *(*Encyclopædia Britannica 2011)

Pressure Gauges – A device that is used to measure pressure.

psi – Pounds per Square Inch. A particular unit or measure of pressure. (See also atmospheric pressure above).

Ribs - The small nibs or extrusions on a basketball (or other sports balls) for the purpose of gripping the ball.

Rubber – A material made of an elastic polymer that is used to produce the inside bladder of a basketball or the outside surface of a basketball.

Sonic Ranger – (see CBR above).

Synthetic – A material made from purified natural rubber used to make the outside surface of some basketballs.

Variable – A quantity that may assume any one of a set of values. (Math Glossary of Terms n.d.)

Timeframe

The timeframe outlined below is based on 50 minute periods and one period a day. The schedule may be adjusted to fit the needs of the student and/or instructor.

Day	***Activities***
1:One Shining Moment	Administer pretest (Appendix G) Watch video "One Shining Moment" (available online) Class discussion
2: Guided Internet Research	Guided Internet Research for baseline industry standard (use worksheet "Some questions that need to be answered…" from Appendix A)
3: Baseline Activity	Guided baseline activity (use the activity "How High Does it Bounce?" from Appendix C)
4: Baseline Activity Continued	Continue Guided baseline activity (use the activity "How High Does it Bounce?" from Appendix C)
5: New Variable Research	Students will choose a variable to study and perform independent research of the variable. Examples of variables students may choose are: pressure, temperature, ball and floor material, and size. (Note that students are not limited to these variables).
6: Experimentation	Students design and conduct their experiments based on their variable research from above.
7: Data Analysis	Students will finish conducting their experiments and begin data analysis.
8: Data Analysis	Students will finish analyzing their data.
9: Energy Conversion	Students will learn about energy conversion and practice using energy equations. (Appendix E)
10: Assessment	Administer the post test (Appendix G) Post activity discussion Optional: student presentations

Materials & Equipment

Video or DVD of "One Shining Moment", NCAA Basketball tournaments ~3 minutes
  To view video online type "One Shining Moment" into an internet search engine and select the most recent version (use Zamzar (http://www.zamzar.com/) or another program to convert video if necessary)
DVD player and 1 TV (or computer with DVD player and projector or computer and interactive white board)
6 Deflated regulation basketballs
6 Girls' or boys' regulation high school basketball
6 Rubber basketballs
6 Synthetic basketballs
6 Air pumps
6 Tire pump with pressure gauges
6 Pressure gauges that read at least 10 psi
6 Inflation needles and needle valves
6-12 meter sticks or metric system tape measures
2-6 Step ladders

The following materials are optional:
30 Student computers with internet connection
  (Computers are needed if students will be conducting their research in class) and Microsoft Excel, Fathom and/or access to Google Docs Computer projection basketball scoreboard such as the Bailey vision scoreboard found at http://www.bellsouthpwp2.net/b/a/baileyvision/scoreboard/
Pressure gauges for TI 83/84 calculators
Video cameras, tripods, and tapes
  (A video camera on a tripod can be used to record the drop. The video can be played back on a monitor and the bounce height can be found by frame-by-frame play back.)
Sonic rangers and TI 83/84 calculators (A sonic ranger can be mounted above the basketball to determine the bounce height.)
Referee shirt and whistle
Various amount of basketball decorations

Safety & Disposal

Using a hand held air pump in itself is not hazardous. However in the event shop air is utilized shop air safety procedures must be followed including the use of eye protection. Never place the air nozzle on the skin because this could cause damage to the blood vessels and break the skin.

Ensure students use proper step ladders or safety rails when performing the basketball drop. (Chairs are not made for standing on and are extremely unsafe).

Pre-Activity Discussion

The pre-activity discussion is covered during the class discussion on Day 1.

Teacher Instructions

DAY 1: One Shining Moment

Objective: Students will discuss what affects the way a basketball behaves and formulate ideas to measure these affects.

1. Give the pretest. See Appendix G.

2. Watch the video for "One Shining Moment", NCAA Basketball. (Available as DVD or online by typing "One Shining Moment" into an internet search engine and selecting the most recent version.)

3. Class discussion questions include:

- What are basketballs made of? Why are these materials used?

- Are official NCAA basketballs the same or different from official high school basketballs?

- If the basketballs are made of the same materials and the same size, why are they? Is that important? If different, how are they different? How do you know? Is the difference important? What factors might be considered in the selection of materials used for basketballs for home use, high school, NCAA, professional?

  Teachers Note: These open questions may naturally lead to a discussion about materials, pressure, and temperature. However, if needed, here are some follow-up questions:

- What affects the way a basketball behaves?
  Possible Answers: The material the basketball is made of; its surface texture, its internal pressure, and its temperature affect the way a basketball behaves. The floor surface, dirt, and moisture all affect the ball's behavior. The force applied to the ball and spin given to the ball also affect how it behaves.

- What affects how high the basketball bounces?
  Possible Answers: The ball's pressure and temperature affect how high it bounces. The floor surface, the material the ball is made of, and the force applied also affect how high a basketball bounces.

- What affects the friction between a basketball and the floor?
  Possible Answers: The material the basketball is made of and its surface texture affect the friction between the ball and the floor. Moisture, dust, and the composition of the floor also affect the friction between the ball and the floor.

- Is there a difference between leather, synthetic, and rubber basketballs?

Possible Answers: There is a difference between leather, synthetic, and rubber basketballs. Leather is usually considered the favorite ball for indoor use although it is expensive. It maintains its shape well, feels soft, absorbs moisture from the players sweat without becoming slick, and has a good coefficient of friction. Rubber balls hold up best for outside use on rough surfaces such as concrete and asphalt. They are cheaper than leather, harder, don't hold their shape as well, and become slicker when wet. Synthetic balls feel more like leather and can be as expensive as leather. They have a higher coefficient of friction than leather when dry, but become slick when wet. They tend to have less bounce than leather balls and hold up better on rough surfaces.

- Is there a standard for high school basketballs?
  Possible Answers: Boys' High School basketballs should be 0.7493 meters (29.5 inches) in circumference, weigh from 0.56 - 0.616 kilograms (20-22 ounces), and bounce 1.2446 – 1.3716 meters (49-54 inches) when dropped from a height of 19.6848 meters (6 feet). Girls' High School basketballs should be 0.7239 – 0.7366 meters (28.5-29.0 inches) in circumference, weigh from 0.504 - 0.56 kilograms (18-20 ounces).

- Do referees check the ball before a game begins? How? Why?
  Possible Answers: To check the basketball before a game, a referee drops the ball to check that it bounces 1.2446 – 1.3716 meters (49-54 inches) when dropped from a height of 19.6848 meters (6 feet). This done to ensure that players will know what to expect from the ball and that the home team will not have an advantage since they provide the game ball.

- Does a basketball change during a game? (i.e. Does its pressure change? Does its temperature change?) If the basketball changes, does that affect the way it behaves? Could it affect the outcome of a game?
  Possible Answers: As a basketball game is played, bouncing the ball causes its temperature to increase. This causes the air pressure in the ball to increase and generally will cause it to bounce higher. During the course of the game, the players' sweat gets on the ball. Moisture causes rubber and synthetic balls to become slick, but leather balls absorb moisture and become stickier. Changes in the basketball over the course of the game can affect the outcome so manufacturers try to get the balls to behave the same throughout the course of the game.

4. Student's research objectives should be set based on today's class discussion.

   Teacher's Note: Create a list of research objectives based on today's discussion.

5. Ask students to continue thinking about these questions.

An AFRL Engineer or Scientist could come speak to the students about the engineering design process, experimental techniques as well as how different materials could be analyzed and why this is important to materials and manufacturing industry.

Teachers Note: If students routinely do their homework and if they all have access to the internet at home, Day 2's work may be assigned as homework on Day 1. (See "Additional Resources" for website suggestions).

DAY 2: Guided Internet Research

Objective: Students will conduct internet research to determine what industry standards are used in manufacturing and testing a basketball.

Teacher's Note: Student's research objectives should be set based on Day 1's class discussion. The teacher should create a list of research objectives and students should record their research in a predetermined fashion. It is recommended that teachers reference this research as a formative assessment. Make sure students know that they will be assessed on the information recorded as it pertains to stated goals.

1. An example teacher script for this day's activity could be:

   "In the previous lesson we discussed basketballs. Our goal now is to find out:

   a. How are basketballs made?

   b. Are they all standardized; if so who or what organization determines these standards? Are basketballs for high school manufactured differently (and in different places) than those for college basketball?

   c. How are basketballs tested to ensure that they meet any necessary standards? Is this done at the factory? By coaches? By the referees at the beginning of games?"

2. Distribute Appendix A. Students should complete worksheet entitled "Some questions that need to be answered…"

3. Have students complete this investigation via internet enabled computers.

   Teachers Note: Students should work at their own computer, if possible, so that they have the opportunity to investigate many different websites.

DAY(s) 3-4: Baseline Activity

Objective: Students will apply the standards from Day 2 and test various air pressure changes to the basketball and determine what affect the air pressure in a basketball

has on the bounce of the basketball. Students will record data for comparison in their STEM notebooks.

1. Have each student create a STEM notebook (See Appendix K).

2. Assign research groups. Each group should contain 3 students.

3. Conduct activity "How High Does it Bounce?"
   Teacher instructions are below and the accompanying student worksheet can be found in Appendix C.

   <u>"How High Does it Bounce?</u>

   Each year people around the world are captivated by the NCAA National Basketball Tournament often called March Madness. The game of basketball is filled with physics and this lesson focuses on what factors influence the behavior of a basketball. Have students use the internet to research what the standard bounce height is for NCAA men's and women's basketballs. Students can also gather information regarding the standard size and weight as well as tests run on basketballs by manufacturers.

   This particular introductory lab asks the question, "Does the air pressure in a basketball affect how high it bounces?" Students will drop a flat basketball (Zero psi above atmospheric pressure) from a height of 19.6848 meters (6 feet) to the floor. The height the ball bounces off the floor will be recorded in a data table and repeated two more times. Students will add air to the ball and repeat the process for different pressures and graph the results."

   Teacher's Note: To promote the basketball theme the teacher could dress up as a referee and students can be encouraged to wear their favorite college team's apparel. The classroom could also be decorated with basketball décor. A scoreboard can be projected onto a projection screen or wall using a computer and projector. The scoreboard can be run showing the students the time they have left in the period to complete the activity. A free computer projection scoreboard can be found at http://www.bellsouthpwp2.net/b/a/baileyvision/scoreboard/.

   Necessary Materials:
   6 Deflated regulation basketballs (possibly obtained from the high school coach)
   6 Air pressure gauge
   6 Air pumps
   6 Meter sticks or metric system tape measures

   Materials Options: Low Tech. Method
   6 girl's or boy's basketballs
   6 Tire pump with pressure gauge
   6 Basketball inflation needles
   6 Meter sticks or metric system tape measures

Materials Options: High Tech. Method
A sonic ranger can be mounted above the basketball to determine the bounce height. A video camera on a tripod can be used to record the drop. The video can be played back on a monitor and the bounce height can be found by frame-by-frame play back.

Example Data Table
(Note: Use data from all groups to increase the number of data points for analysis)

Air Pressure (psi) The amount of pressure above standard pressure as measured by a tire gauge.	Bounce Height (meters)				
	Trial 1	Trial 2	Trial 3	Mean (or $\bar{x}$)	Range
0					
2					
4					
6					
8					
10					
12					

The following questions are included in the student worksheet:

1. What did you discover about the pressure in a basketball and how high it bounces?
2. When might it be an advantage to have a ball that bounces high? One that doesn't bounce high?
3. What is the NCAA standard bounce height for men's basketballs when dropped from a height of 19.6848 meters (6 feet)?
4. What is the NCAA standard bounce height for women's basketballs when dropped from a height of 19.6848 meters (6 feet)?
5. Which pressure(s) reproduced the standard bounce for the men's ball?
6. Which pressure(s) reproduced the standard bounce for the women's ball?
7. List several things, other than pressure, that might affect the bounce height of a basketball?
8. Come to a group consensus of which one of the things listed above that you would like to test.
9. Discuss with your group how you would test this. Have your ideas approved by your teacher before proceeding to test them.

DAY 5: New Variable Research

Objective: Students, working in small groups, will develop their own experiment with a different variable based upon further internet research.

1. Having studied the effects that different air pressures have on the way a basketball behaves, students will spend the class determining what variable their group will study

and how that variable affects the behavior of the basketball. Before the end of the class period, each group should submit a brief written proposal about the variable they plan to study.

The proposal must include what data that they plan to collect, a table that will be used to record the data (both qualitative and quantitative), the equipment needed and why they have chosen the particular variable. (Note: Students must make their own data tables)

Teacher's Note: Students should incorporate the proposal into their STEM Notebook. The proposal should serve as a formative assessment.

AFRL engineer or scientist can aid students in their research methodology and data collection. This individual can emphasize the importance of scientific skills students are utilizing as well as share real-world application to materials testing and research.

DAYS 6 - 8: Experimentation and Data Analysis

Objective: Students will conduct experiments based on their new variable. Students will record and analyze data in their STEM notebook.

1. Groups will perform experiments to collect and analyze relevant data. As students work, the teacher will interact with the groups to ensure that each group is on task.

   Teacher's Note: Use student's progress or lack thereof as a sign of how much additional verbal guidance you should be providing them with. Failed experiments or trials are not bad. Students can learn just as much from a failed experiment as a fruitful one. Do not derail this process of learning but instead scaffold an understanding of what said variable do or do not mean/affect.

   AFRL engineer or scientist can aid students in their research methodology and data collection as well as help students interpret their findings. This individual can emphasize the importance of scientific skills students are utilizing as well as share real-world application to materials testing and research.

DAY 9: Energy Conversion

Objective: Students will demonstrate an ability to use energy equations.

1. Class Discussion

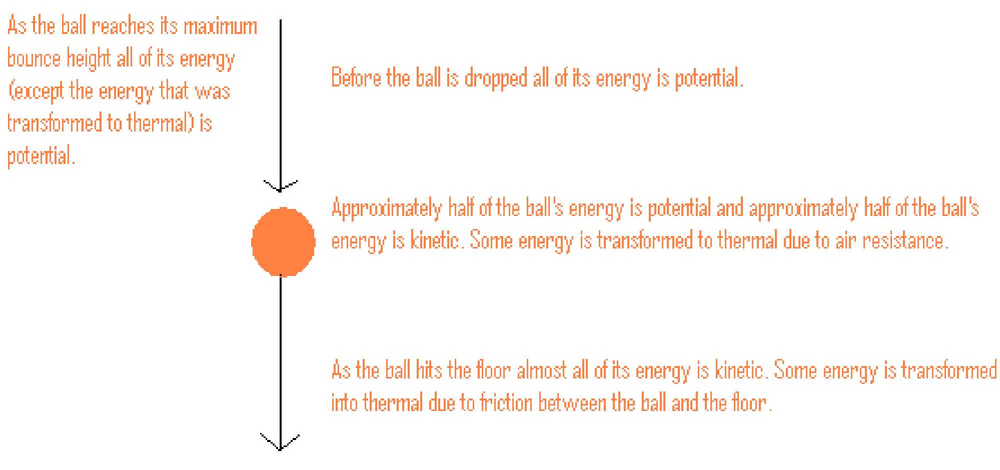
   - Ask students what they know about energy.

     Possible Answers: Students may share what they know about potential, kinetic, or thermal energy. Students may also discuss the conservation of energy, energy equations, or units used when measuring energy.

- Important information to cover during today's class discussion is included in the same teacher script below:

  "The total amount of mechanical energy in a system is the sum of the potential and kinetic energy (ME = KE + PE). Potential energy equals the mass of the ball multiplied by the gravity of the ball multiplied by the height the ball was dropped from (PE = m · g · h). Recall that weight equals mass times gravity (w = m · g). Kinetic energy equals one half of an object's mass multiplied by velocity squared (KE = ½ · m · v^2). Before you dropped your basketball all of the ball's energy was potential. As you released the ball and it reached the half-way point between the height you dropped it from and the floor approximately half of the ball's energy was potential and approximately half was kinetic. Some of the ball's energy was also transformed into thermal energy due to air resistance. Once energy has been transformed to thermal it cannot be transformed back to potential or kinetic. As the ball hit the floor almost all of its energy was kinetic with some being transformed to thermal due to the friction between the ball and the floor. As the ball bounced back up some of its energy was again transformed into thermal due to air resistance and as the ball reached its maximum bounce height all of its energy (except that transformed into thermal due to air resistance) was transformed back to potential. As the ball traveled through the air, hitting the floor, and bouncing back up the total amount of energy in the system was conserved (remained the same). The energy changed forms from potential to kinetic and thermal and from kinetic back to potential, but during all of these changes the total amount of energy remained the same as energy cannot be created or destroyed."

Teacher's Note: A diagram such as the one below may be helpful for students to view during the class discussion.



2. Students will complete Energy Conversion Worksheet in Appendix E.

DAY 10: Assessment

Objective: Students will present their findings from both experiments. Teachers will assess student knowledge and understanding in a post-test.

1. Administer Post Test (Appendix G)
2. Lead post activity discussion
3. Optional: student presentations of their findings (this may range from: formal presentations to informal discussion). See "Instructional Tips" for ideas on student presentations.

Background Information

Basketballs come in a range of sizes. A standard basketball has a circumference of 0.7493 meters (29.5 inches). An official basketball is considered a size 7 while a women's ball is a size 6 and a youth ball a size 5. Basketballs have inflatable inner rubber bladders wrapped in fiber and with leather, rubber or a synthetic composite outer covering. The ball is equipped with a small opening to allow the air pressure to be increased or decreased within the bladder. The surface of a basketball has indented ribs around the ball to assist the ball handler in moving and bouncing the ball. Basketballs come in a variety of colors but most balls are orange. A basketball is 0.7493 to .762 meters (29.5 - 30.0 inches) in circumference and weighs .56 to .616 kilograms (20 - 22 ounces) when fully inflated. When a basketball is dropped 19.6848 meters (6 feet) to a solid wood floor it should bounce 1.2446 to 1.3716 meters (49 - 54 inches).

"The more air pressure a basketball has inside it, the less its surface will bend or deform during a bounce, and the more its original energy will be stored in the compressed air inside. If the ball is underinflated, some of its energy is wasted in deforming the ball as it bounces, and the ball will not rebound very high. For the most elastic collision possible between the ball and the floor, you want a highly pressurized ball. The material you bounce the ball on is also very important. Think about how high it would bounce on a carpeted floor. A soft floor material will flex when the ball hits it, and this will steal some of the ball's energy. The harder the surface, the better the ball will bounce." (Worsley School 2011)

An AFRL engineer or scientist could be contacted to help explain the physics and math involved with this scientific investigation.

Instructional tips

This activity can be noisy with basketballs bouncing all around. Ensure that a suitable area is utilized to conduct this activity to minimize the distractions or disturbances to other teachers and students.

When forming student groups, it is helpful to place students in groups investigating issues they thought were interesting based upon their initial research. An easy method is to have each student complete an index card with the top two variables they would like to test. Place the students in groups of three based on what they wrote on their index cards.

Students should keep STEM Notebooks documenting their research, brainstorming, testing methodology and data, data reduction, and conclusions.

For instructions on creating a STEM notebook from graph paper see Appendix K.

Assignment of Student Roles and Responsibilities:

Students will share the responsibility of performing experimental tests. Additionally, students will assume the following roles:

(Note: If the team is expanded to three or more, additional members will function as assistants to the "Lead Engineer").

Member	*Role Name*	*Brief Description*
1	Lead Engineer	Responsible for organizing team and keeping team on task to meet goals and deadlines Serve as team spokesperson, if one is required Responsible for guiding all activities within the team Report directly to the instructor Partakes in design of experiment and implementation Partakes in collection measurements and pertinent data
2	Data Recorder	Responsible for ensuring that all group members record all data from the activity. This includes, but not limited to: filing in data tables, preparing spreadsheets or graphing data. Reports directly to the Lead Engineer. Partakes in design of experiment and implementation Partakes in collection measurements and pertinent data
As needed	Research Team Engineer	Will assist the Lead Engineer in the activity. Duties will include, but not limited to: assisting with the set up of the activity, running tests and experiments or helping to collect data. Reports directly to the Lead Engineer Partakes in design of experiment and implementation. Partakes in collection measurements and pertinent data

Student Instructions

See Appendix A for the guided research handout "Some questions to be answered…".

See Appendix C for student instructions for the base line activity "How high does it bounce?".

See Appendix E for "Energy Conversion" worksheet

Formative Assessments

See Appendix J for Formative Assessment Rubric.

Post-Activity Discussion

The post activity discussion can include student presentations of their findings (from formal presentations to informal discussion).

See extension section for ideas on student presentations and other activities.

Using 5 sheets of graph paper will give the student a cover sheet, a one page index and 18 pages for notes.   Students should be instructed to:

- Number all pages.
- Date all entries.
- Completely fill each page before starting the next.
- Record method for testing, references, test results, and calculations.
- Sign each page and have you partner witness that the page is complete.
- Do not remove any pages.
- Do not erase mistakes. Simply draw a line through them and initial.

Students could present their findings to an AFRL Engineer or Scientist who could offer encouragement and feedback. The Engineer or Scientist could also bring samples of materials they are working with and demonstrate some of the properties of these materials.

Technology Connection

Use the **ADISC** Model created by ITEL to plan the use of technology in this lesson/activity.

Integration Model	***Application Description***
Technology that supports students and teachers in **dealing effectively with data**, including data management, manipulation, and display	TI 83/84 Calculator Microsoft Excel Calculator Based Lab (CBL2) Calculator Based Ranger (CBR2) Vernier Pressure Sensor
Technology that supports students and teachers in conducting **inquiry**, including the effective use of Internet research methods	TI 83/84 Calculator Computer Internet Calculator Based Lab (CBL2) Calculator Based Ranger (CBR2) Vernier Pressure Sensor
Technology that supports students and teachers in **communicating and collaborating** including the effective use of multimedia tools and online collaboration	TI 83/84 Calculator Microsoft Excel PowerPoint Projector & screen

Interdisciplinary Connection

English Language Arts Connection:

A research paper based on any of the topics covered in this activity could be incorporated with a student's English class.

The presentation at the end of the activity could be incorporated with the student's English class or a multimedia design course.

Home Connection

Students can interview members of their family who played a sport utilizing a ball. Questions should include how the ball reacted to different environments. Responses should be written and turned into the teacher. These can be used to supplement the end of activity discussions.

Students may want to continue their investigation by having family members help conduct experiments at home. Examples of home experiments are:

- How high dose a ball bounce on different surfaces? (Hardwood, carpet, etc.)
- How do balls from different sports behave and how does this affect how the sport is played? (For example baseballs, tennis balls, golf balls, footballs, racket balls, etc.)
- What happens when you use the wrong type ball for a sport? For example what happens when you try to use a golf ball to play ping pong or a basketball to play kick ball?

Students could collaborate with their families to create their own games centered around a type of ball. Have the students teach the game to the class and discuss why their selection of ball type is important.

Students could visit a sporting goods store and see if there are any product specifications, standards organization or other things that provide more information on basketballs. At the same time students could write down the price of the balls, the store where they found the balls, manufacturers, NCAA or high school or other specifications. Students could generate a data sheet to keep track of their information. Hopefully students will discover that cost is a consideration in material selection and perhaps also determine that there are some commonalities among all the different types of basketballs (ASTM Standards, etc.).

Differentiated Instruction

Process: Use grouping and regrouping based on content, project, and assessments.

Product: Vary the expectations and requirements of individual students based on ability.

Content: The teacher can address the same concepts with all students but adjust the degree of complexity based on the range of student abilities.

Extension

<u>Additional Student Activities</u>

- Students could attend a basketball game and compare what they observe to what was learned from the lesson.
- Students could check the bounce and pressure of the basketball, play a scrimmage and at intervals, and recheck the ball for changes in pressure.
- Students could use this lesson and apply it to any type of ball used in sports.

- Students could visit a manufacturing company or view a DVD on the manufacture of basketballs and determine how the company's manufacturing and quality testing relates to this lesson.

Possible Guest Speaker

- Arrange for a speaker from Goodrich to discuss the air pressures and testing of aircraft tires and have the students compare the information to this lesson.

Examples of post lesson activities

Post lesson activities and discussions can be implemented based on the amount of time available to dedicate to them and the level of information desired.

- Each team can create and deliver a Power Point presentation of their experiment, data, and conclusions. (Allow two days for this activity).
- Teams can make poster boards showing their test results and conclusions. Have each team give a short description of their poster board in class. (Allow one day for this activity).
- Each team can write a formal point paper. (See Appendix I for recommended format) Have each team give a 2 minute brief of their results using the point paper for notes. Collect point papers after discussions. (Allow one day for this activity).

  All activities should include information on:
  - Variable being researched and tested
  - Test procedures and set up
  - Problems encountered during testing
  - Data and conclusions

An AFRL Engineer or Scientist from the Materials Directorate could come speak to the students about the engineering design process, experimental techniques as well as how different materials could be analyzed. The Engineer or Scientist could also bring samples of materials they are working with and demonstrate some of the properties of these materials.

Career Connection

This activity is related to materials engineering and materials science degrees and careers. Engineers experiment and/or characterize new and novel materials. Manufacturing these new materials is also a related career field.

Materials engineers develop technologies, systems, and structures to advance manufacturing and research. This can include anything from electrical components, exhaust manifolds, combustion engines, fire retardant clothing, to sterile containers. These professionals rely on technical understanding of scientific, mathematical, and engineering concepts to innovate new solutions to cutting edge problems.

Additional Resources

Resource:	***Purpose and Application:***
http://www.sizes.com/sports/basketball.htm	Basketball Specifications

http://www.sciencebuddies.org/science-fair-projects/project_ideas/Sports_p007.shtml http://www.physics.ucsb.edu/~circus/energy demo.htm	The Physics of basketballs
http://www.answers.com/topic/basketball http://www.madehow.com/Volume-6/Basketball.html	Manufacture and facts about basketballs
http://www.dailytrader.com/ss-basketball/manufacturers.html	Basketball Manufacturers
http://www.ncaa.org/	NCAA

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Amy Lamb – Author and Editor

Dr. Susann Mathews – Author

Clif Martin – Author

Dr. Margaret Pinnell – Editor

Sandra Preiss - Editor

Michael O'Shaughnessy – Author

Dr. Richard Warren – Author

Teacher Reflections

Were students focused and on task throughout the lesson? *Insert answer here.*

If not, what improvements could be made the next time this lesson is used? *Insert answer here.*

Were the students led too much in the lesson or did they need more guidance? *Insert answer here.*

Did the students learn what they were supposed to learn? *Insert answer here.*

How do you know? *Insert answer here.*

How did students demonstrate that they were actively learning? *Insert answer here.*

Did you find it necessary to make any adjustments during the lesson? *Insert answer here.*

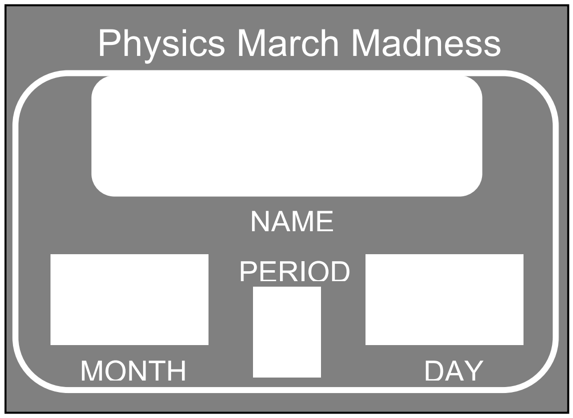
What were they? *Insert answer here.*

Did the materials that the students were using affect classroom behavior or management? *Insert answer here.*

What were some of the problems students encountered when using the …? *Insert answer here.*

Are there better items that can be used next time? *Insert answer here.*

Appendix A: Guided Research Student Worksheet



Some questions that need to be answered.....

Each year, people around the world are captivated by the NCAA National Basketball Tournament often called March Madness. How much do you know about the tournament? When did the tournament start? Who won the men's tournament and the women's tournament last year? Who is the favorite in the men's tournament and the women's tournament this year? Who do you think will win each this year? Does the way that the ball bounces affect how the teams play?

Research the questions above on the internet and find what the standard bounce height is for NCAA men's and women's basketballs. What are the standard size and weight of the men's and women's basketballs? What tests do manufacturers run on to insure the uniformity of their basketballs?

Measurement Conversions

12 inches = 1 foot
1 foot = .3048 meters
1 ounce = 28 grams
1 gram = 0.001 kilograms

Round your answers to the nearest tenth.

1. The NCAA tournament was first held in 19 ____.

2. Last year, the men's tournament was won by ______________________________.

3. Last year, the women's tournament was won by ___________________________.

4. I think the men's champion will be ______________________________ this year.

5. I think the women's champion will be ___________________________ this year.

6. When dropped from 6 feet, the men's ball should bounce _____ to _____ inches.
   When dropped from 19.6848 meters, the men's ball should bounce _____ to _____ meters.

7. When dropped from 6 feet, the women's ball should bounce ____ to ____ inches.
   When dropped from 19.6848 meters, the women's ball should bounce _____ to _____ meters.

8. The standard circumference of the men's basketball is _______ inches.
   The standard circumference of the men's basketball is _______ meters.

9. The standard circumference of the women's basketball is _______ inches.
   The standard circumference of the women's basketball is _______ meters.

10. The standard weight of the men's basketball is ________ ounces.
    The standard weight of the men's basketball is _______ kilograms.

11. The standard weight of the women’s basketball is ________ ounces.
The standard weight of the women’s basketball is _______ kilograms.

12. What materials are used today to make a basketball?

13. Describe one test that a basketball manufacturer performs on its basketballs.

Appendix B: Guided Research Student Worksheet Answer Key

1. *1939*

2. *Answers will change as time progresses. Men's tournament winners can be check on the NCAA website at http://www.ncaa.com/history/basketball-men/d1*

3. *Answers will change as time progresses. Women's tournament winners can be check on the NCAA website at http://www.ncaa.com/history/basketball-women/d1*

4. *Answers will vary based on students' opinions.*

5. *Answers will vary based on students' opinions.*

6. *Bounce of Men's Ball: 9 – 54 inches, 1.2446 – 1.3716 meters (Bilik & Williamson 2009)*

7. *Bounce of Women's Ball: 51-56 inches, 1.2954 – 1.4224 meters (Bilik & Williamson 2009)*

8. *Circumference of Men's Ball: 29.5 to 30 inches, 0.7493 - 0.762 meters (Bilik & Williamson 2009)*

9. *Circumference of Women's Ball: 28.5-29 inches, 0.7239 – 0.7366 meters (Bilik & Williamson 2009)*

10. *Weight of Men's Ball: 20-22 ounces,0.56 - 0.616 kilograms (Bilik & Williamson 2009)*

11. *Weight of Women's Ball: 18-20 ounces, 0.504 – 0.56 kilograms (Bilik & Williamson 2009)*

12. *Answers will vary as manufacturing creates new materials.*

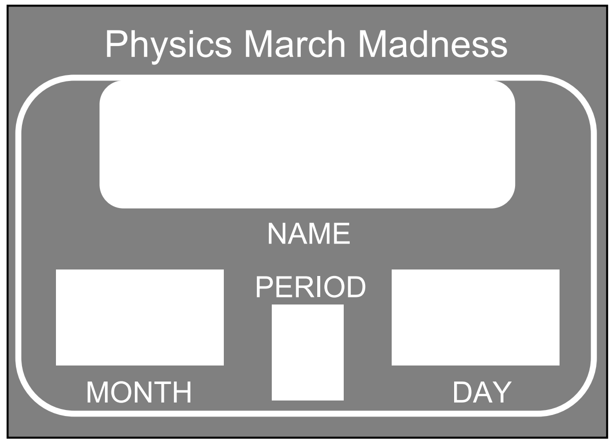
13. *Answers will vary as there are a variety of tests and the testing process continues to change and evolve.*

Information for # 6-11 was obtained from the NCAA 2010 and 2011 men's and women's rules.

Bilik, E & Williamson, D. (2009). *NCAA 2010 and 2011 men's and women's rules.* Indianapolis, IN: NCAA. Retrieved from: http://www.ncaapublications.com/productdownloads/BR11.pdf

Appendix C: How High Does it Bounce Student Worksheet

How High Does It Bounce?



In this activity, you should experiment to find out if the air pressure in a basketball affects how high it bounces? Start by dropping a flat basketball (zero psi above atmospheric pressure) from a height of 19.6848 meters (6 feet) to the floor. Record the height it bounces off the floor in a data table. Repeat this two more times. Add air to the ball and repeat the process for different pressures and use a scatter plot to graph the results. Then answer the following questions. Convert all units to metric and round your answers to the nearest tenth.

1. What did you discover about the pressure in a basketball and how high it bounces?

2. When might it be an advantage to have a ball that bounces high? One that doesn't bounce high?

3. What is the NCAA standard bounce height for men's basketballs when dropped from a height of19.6848 meters (6 feet)?

4. What is the NCAA standard bounce height for women's basketballs when dropped from a height of 19.6848 meters (6 feet)?

5. Which pressure(s) reproduced the standard bounce for the men's ball?

6. Which pressure(s) reproduced the standard bounce for the women's ball?

7. List several things, other than pressure, that might affect the bounce height of a basketball?

8. Come to a group consensus of which one of the things listed above that you would like to test.

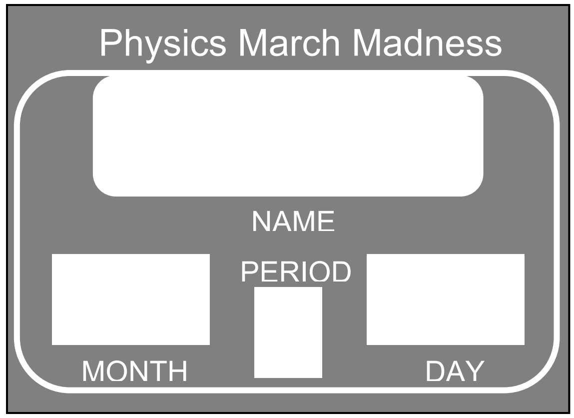
9. Discuss with your group how you would test this. Have your ideas approved by your teacher before proceeding to test them.

Appendix D: How High Does it Bounce Student Worksheet Answer Key

1. *As the pressure in a ball increases so will its bounce height.*
2. *Answers will vary. Check for logical reasoning.*
3. *Bounce of Men's Ball: 9 – 54 inches, 1.2446 – 1.3716 meters*
4. *Bounce of Women's Ball: 51-56 inches, 1.2954 – 1.4224 meters*
5. *Answers will vary.*
6. *Answers will vary.*
7. *Answers could include: Temperature, circumference, weight, texture, and material composition of basketball. The force applied to ball. Amount of moisture on the outside of ball. Material composition of and moisture on the floor.*
8. *Answers will vary.*
9. *Check students' ideas for testing their variable from number 8.*

Appendix E: Energy Conversion Worksheet

Energy Conversion!



Solve the problems below using what you have learned about basketballs and energy this week. Round your answer to the nearest tenth.

Formulas

ME = PE + KE
PE = m · g · h
KE = ½ · m · v^2
g = 9.8 meters/$second^2$

Recall that potential, kinetic, and mechanical energy are measured in joules. Mass is measured in kilograms, gravity in meters per second squared, and velocity in meters per second.

1. You are getting ready to drop a .616 kg ball from a height of 2 meters. How much potential energy does your ball have?

2. Your ball has 14 joules of potential energy and a mass of .504 kg. What height did you drop your ball from?

3. A ball has 7.35 joules of kinetic energy and a mass of .588 kg. At what velocity is the ball traveling?

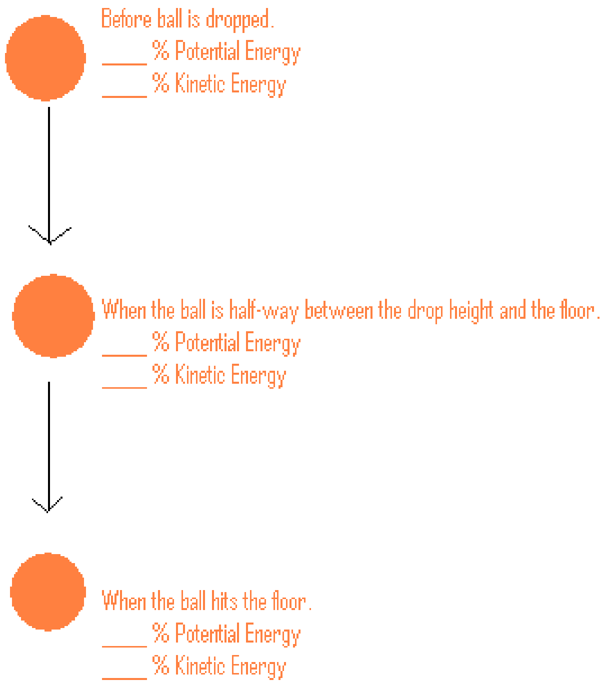
4. A ball with a mass of .56 kg traveled at a velocity of 3 meters per second. How much kinetic energy does the ball have?

5. A ball has 10 joules of potential energy and 23 joules of mechanical energy. How much kinetic energy does the ball have?

6. A ball has 14.6832 joules of mechanical energy, a mass of .532 kg, and was dropped from a height of 2 meters. How much kinetic energy does the ball have?

7. A ball has 32.956 joules of mechanical energy, a mass of .616 kg, and traveled at 3 meters per second. From what height was the ball dropped from?

8. Label the diagram below with the approximate percentages of potential and kinetic energy.



9. What form is energy transformed into due to air resistance and friction? Can energy be transformed back into potential or kinetic from this form of energy?

Appendix F: Energy Conversion Worksheet Answer Key

1. You are getting ready to drop a .616 kg ball from a height of 2 meters. How much potential energy does your ball have?

$PE = m \cdot g \cdot h = (.616\ kg)\ (9.8 m/s^2)\ (2\ m) = 12.0736 = 12.1$ joules
The ball has 12.1 joules of potential energy.

2. Your ball has 14 joules of potential energy and a mass of .504 kg. What height did you drop your ball from?

$PE = m \cdot g \cdot h$
$14\ joules = (.504\ kg)\ (9.8 m/s^2)(h)$

$$\frac{14\ joules}{(.504\ kg)(9.8 m/s^2)} = h$$

$2.8\ m = h$
I dropped the ball from a height of 2.8 meters.

3. A ball has 7.35 joules of kinetic energy and a mass of .588 kg. At what velocity is the ball traveling?

$KE = ½ \cdot m \cdot v^2$
$7.35\ joules = ½\ (.588\ kg)\ (v)^2$

$$\frac{7.35\ joules}{½\ (.588\ kg)} = (v)^2$$

$25 = (v)^2$
$5\ m/s = v$
The ball is traveling at a velocity of 5 m/s.

4. A ball with a mass of .56 kg traveled at a velocity of 3 meters per second. How much kinetic energy does the ball have?

$KE = ½ \cdot m \cdot v^2$
$KE = ½\ (.56\ kg)\ (3m/s) = 0.84$ joules
The ball has 0.84 joules of kinetic energy.

5. A ball has 10 joules of potential energy and 23 joules of mechanical energy. How much kinetic energy does the ball have?

$ME = PE + KE$
23 joules = 10 joules + KE
13 joules = KE
The ball has 20 joules of kinetic energy.

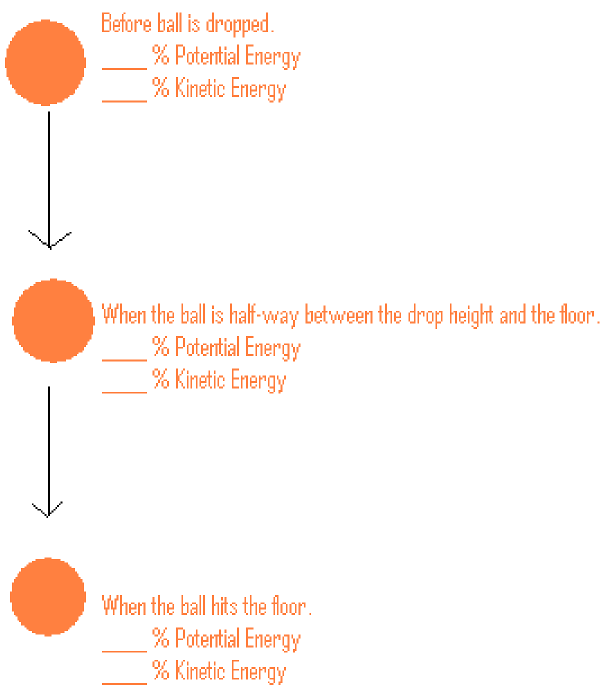
6. A ball has 14.6832 joules of mechanical energy, a mass of .532 kg, and was dropped from a height of 2 meters. How much kinetic energy does the ball have?

ME = PE + KE
14.6832 joules = [(.532 kg) (9.8 m/s^2) (2 m)] + KE
14.6832 joules = 10.4274 joules + KE
4.2558 joules = KE
The ball has 4.3 joules of kinetic energy.

7. A ball has 32.956 joules of mechanical energy, a mass of .616 kg, and traveled at 3 meters per second. From what height was the ball dropped from?

ME = PE + KE
ME = m · g · h + ½ · m · v^2
32.956 joules = (.616 kg) (9.8m/s) (h) + ½ (.616 kg) (3m/s)^2
32.956 joules = 6.0368 h + 2.772
30.184 joules =6.0368 h
5 m = h
The ball was dropped from a height of 5 meters.

8. Label the diagram below with the approximate percentages of potential and kinetic energy.



Before the ball is dropped 100% of its energy is potential and 0% is kinetic. As the ball is half-way between the drop height and the floor approximately 50% of its energy is potential and approximately 50% of its energy is kinetic. As the ball hits the floor 0% of its energy is *potential and 100% is kinetic. (Note that in reality some energy is transformed to thermal energy as the ball travels.)*

9. What form is energy transformed into due to air resistance and friction? Can energy be transformed back into potential or kinetic from this form of energy?

Air resistance and friction transform some of the energy into thermal energy. Once energy is transformed into thermal energy it cannot be transformed back into potential or kinetic energy.

Appendix G: Pre/Post-Test

Name______________________________

Madness in March Assessment

1. List variables that affect the height that a basketball bounces.

2. Identify the components and materials used to manufacture a basketball.

3. Describe the process and standards a referee uses to test the bounce of a ball before a game.

4. Answer the following questions about energy.

   A. You are getting ready to drop a .504 kg basketball from a height of 2 meters. How much potential energy does the ball have? (Recall that Potential Energy = mass * gravity * height and gravity = 9.8 m/s)

   B. What form is energy transformed into due to air resistance and friction? Can energy be transformed back into potential or kinetic from this form of energy?

5. Below is a table comparing the first bounce heights of two different basketballs. Using the graph provided, plot the data, draw a line of best fit, and write an equation for each balls performance.

Drop Height	First Bounce Mean	
	Ball A	Ball B
2 ft	12 in	16 in
4 ft	25 in	32 in

5 ft	30 in	40 in
6 ft	37 in	49 in
7 ft	41 in	55 in

After you have graphed the data, answer the following questions:

6. How high would each ball bounce if it rolls off the rim at a height of 10 feet during a game?

7. Which ball would be the best ball to use in this week's game against our school rival? Explain your answer.

8. Explain the meaning of the slope and y-intercept of a balls equation.

9. As a consultant, you are given the following set of data. Your job is to make a report to the regional basketball sales team, first using descriptive statistics and followed by creating a graph which best displays that data.

   A. For your report, calculate the mean and median as the measure of central tendency. Choose one of these to use in your report and explain your choice.

   B. Do you need to include the range in your report? If so, why? If not, why not?

Appendix H: Pre/Post-Test Answer Key

1. *Air pressure in the ball, texture of surface the ball is bounced off of, the amount of force applied to the ball when bounced, the height the ball is bounced from, the material composition of the ball, the diameter or circumference of the ball, the weight of the ball, the amount of moisture on the outside of the ball.*

	4	3	2	1
List variables that affect the height that a basketball bounces.	*Student lists 7-8 variables that affect the height that a basketball bounces.* *Variables that affect the height that a ball bounces are air pressure in the ball, texture of surface the ball is bounced off of, the amount of force applied to the ball when bounced, the height the ball is bounced from, the material composition of the ball, the diameter or circumference of the ball, the weight of the ball, the amount of moisture on the outside of the ball.*	*Student lists 5-6 variables that affect the height that a basketball bounces.* *Variables that affect the height that a ball bounces are air pressure in the ball, texture of surface the ball is bounced off of, the amount of force applied to the ball when bounced, the height the ball is bounced from, the material composition of the ball, the diameter or circumference of the ball, the weight of the ball, the amount of moisture on the outside of the ball.*	*Student lists 3-4 variables that affect the height that a basketball bounces.* *Variables that affect the height that a ball bounces are air pressure in the ball, texture of surface the ball is bounced off of, the amount of force applied to the ball when bounced, the height the ball is bounced from, the material composition of the ball, the diameter or circumference of the ball, the weight of the ball, the amount of moisture on the outside of the ball.*	*Student lists 1-2 variables that affect the height that a basketball bounces.* *Variables that affect the height that a ball bounces are air pressure in the ball, texture of surface the ball is bounced off of, the amount of force applied to the ball when bounced, the height the ball is bounced from, the material composition of the ball, the diameter or circumference of the ball, the weight of the ball, the amount of moisture on the outside of the ball.*

2. The outside covering of a basketball is made of synthetic rubber, rubber, composition, or leather. The inside consists of a bladder and the carcass. The bladder is wrapped in fiber and made of butyl rubber, and the carcass consists of threads of nylon or polyester.

	4	*3*	*2*	*1*
Identify Components	*Student can correctly identify 7-8 components of a basketball.*	*Student can correctly identify 5-6 components of a basketball.*	*Student can correctly identify 3-4 components of a basketball.*	*Student can correctly identify 1-2 components of a basketball.*

3.

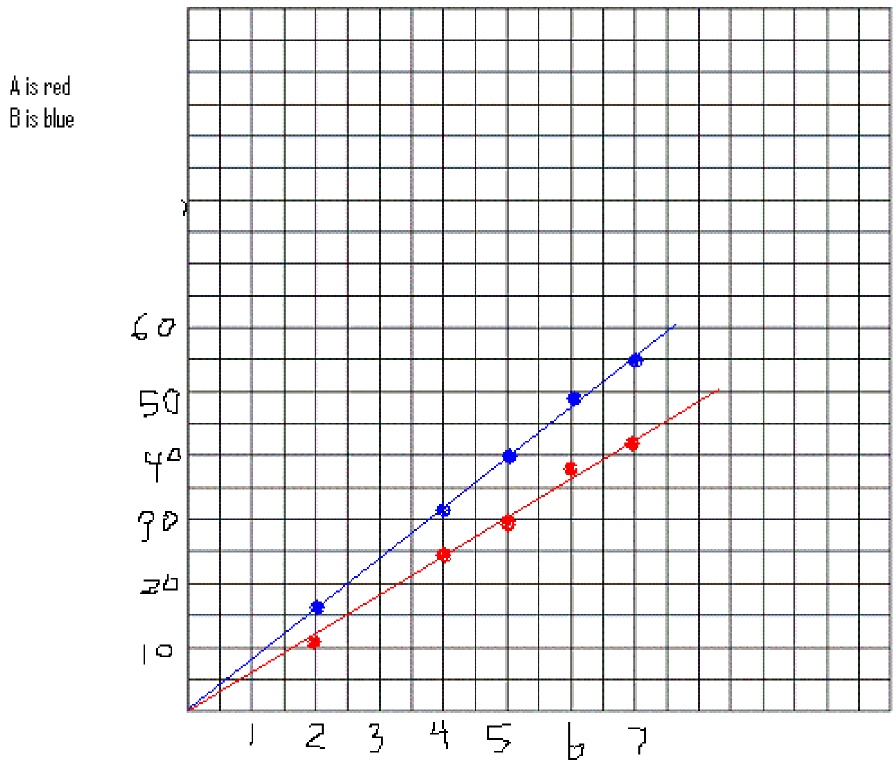
	4	*3*	*2*	*1*
Describe the process and standards a referee uses to test the bounce of a ball before a game.	*The student clearly indicates that the ball should be dropped from a height of 6 feet (1.829 m) and should rebound to a height of 49-54 inches (1.245-1.372 meters).*	*The student indicates that the ball should be dropped from a certain height and that it should rebound to a certain height. The student also indicates either the proper drop height of 6 feet (1.829 m) OR the proper rebound height of 49-54 inches (1.245-1.372 meters).*	*The student indicates that the ball should be dropped from a certain height AND that it should rebound to a certain height, but does not indicate what the accepted heights are.*	*The student indicates that the ball should be dropped from a certain height OR that it should rebound to a certain height, but does not indicate what the accepted heights are.*

4. *Answer the following questions about energy.*

A. *PE = m g h*
PE = (.504 kg) (9.8 m/s) (2 m)
PE = 9.8784 joules

B. *Air resistance and friction transform some of the energy into thermal energy. Once energy is transformed into thermal energy it cannot be transformed back into potential or kinetic energy.*

5. A sample graph is shown below. The y-axis represents the first bounce mean and each horizontal line signifies an interval of 5 inches. The x-axis represents the drop height and each vertical line signifies an interval of 6 inches. Data for ball A is red and data for ball B is blue. (Note that student may create different intervals than those shown in the sample graph.)



Equations:

slope = change in bounce mean/change in drop height
d = drop height
Ball A: y = 6in/ft * d
Ball B: y = 7.5in/ft * d

6. Ball A: y = 6d

y = 6(10) = 60 inches

Ball A would bounce 60 inches if it fell off a rim at a height of 10 feet.

Ball B: y = 7.5d

y = 7.5(10) = 75 inches

Ball B would bounce 75 inches if it fell off a rim at a height of 10 feet.

7. Answers will vary. Check for logical reasoning.

Ball A: I would choose ball A because it has less bounce height than ball B making it easier to control.

Ball B: I would choose ball B because it has a greater bounce height than ball A. This means that the players would need to apply less force to ball B in order to get it to bounce at the same height as ball A. Less force implies less effort by the players.

8. The slope of the line is the change in the bounce mean divided by the drop height. The slope of the graph describes how many inches the ball bounces per foot it is dropped. The y-intercept is zero because the ball would not bounce if it was not dropped.

9.

A. Mean = 9.68 psi, Median = 8 psi

The median should be included in the report because the several outliers at the upper values shift the mean so much that it is unrepresentative of all of the data.

B. The range is 9.4 psi and should be included in the report because it represents the large variability in the data. This might inform the sales representatives that they need to do a better job of quality control.

Appendix I: Formal Point Paper Format

Point Paper On

Formal Point Paper Format

PROBLEM
Statement or description of topic. Type “PROBLEM” three lines from title.

BACKGROUND
A summary of what has transpired to date. Block paragraphs(s)

DISCUSSION

A summary of what remains to be done. Use indented, numbered paragraphs.

1. Formats are not universal, but this is a typical format used by many companies for formal point papers. All point papers for this class will use this format.
2. Prepare on 8.5 x 11 inch plain white paper. The length should be between 2-4 pages.
3. Center the subject in underscored capital letters Approximately 1 inch from the top of the page. Use the same five underlined sections of this paper.
4. Use 1 inch margins on top, right and bottom. 1 ¼ inch margin on left. Use 1.5 spacing for all lines. Type in Times New Roman font size 12.

CONCLUSION
Concisely state the facts.

RECOMMENDATIONS
Point out areas of disagreement. Include areas of agreement. Give your own opinion of the subject.

Appendix J: Formative Assessment Rubric

Formative Assessment: Lab Pedagogy Rubric

CATEGORY	4	3	2	1
Contributions/ Team Work **(Days 1-9)**	*The student or group is observed being on-task and working with their group 95-100% of the time.* *Behaviors observed may include:* *The discussion is about the project, the students are listening to other members of the group, and all members are recording the data or are doing their assigned job for the day.*	*The student or group is observed being on-task and working with their group 80-94% of the time.* *Behaviors observed may include:* *The discussion is about the project, the students are listening to other members of the group, and all members are recording the data or are doing their assigned job for the day.* *At this level the teacher may observe a few minor instances where the students are off task but quickly get back on task when asked to do so or refocused by the teacher.*	*The student or group is observed being on-task and working with their group 70-79% of the time.* *Behaviors observed may include:* *The discussion is about the project 2 out of 4 times the teacher observes the group.* *2 out of 4 times the members of the group are listening to other members of the group.* *The teacher observes members recording the data or they are doing their assigned job for the day 2 out 4 times.* *At this level the teacher may observe instances where the students are off-task 2 out of 4 times that they observe the group. The group requires time by the teacher to get back on-task when asked to do so.*	*The student or group is observed being on-task and working with their group 50-69% of the time.* *Behaviors observed may include:* *The discussion is about the project 1 out of 4 times the teacher observes the group.* *1 out of 4 times the members of the group are listening to other members of the group.* *The teacher observes members recording the data or they are doing their assigned job for the day 1out 4 times.* *At this level the teacher may observe instances where the students are off-task 1 out of 4 times that they observe the group. The group requires time by the teacher to get back on-task when asked to do so.*

Scientific Knowledge ***(Days 1-9)***	*Student/Group shows evidence of understanding specific scientific knowledge 95 - 100% of the time when asked by the instructor. Each scientific principle is documented in the STEM Notebook with a definition and any related research notes.*	*Student/Group shows evidence of understanding specific scientific knowledge 80-94% of the time when asked by the instructor. Each scientific principle is documented in the STEM Notebook with a definition and any related research notes.*	*Student/Group shows evidence of understanding specific scientific knowledge 70-79% of the time when asked by the instructor. Each scientific principle is documented in the STEM Notebook with a definition and any related research notes.*	*Student/Group shows evidence of understanding specific scientific knowledge 50-69% of the time when asked by the instructor. Each scientific principle is documented in the STEM Notebook with a definition and any related research notes.*
Preparedness ***(Days 1-9)***	*Student/group will bring all required materials to class each day 100% of the time. Student/group will start work every day when asked and have all materials put away at the end of each day 100% of the time. All needed materials will be requested 1 day in advanced (in writing) 100% of the time. All assigned with will be turned in and complete on required date 100% of the time.*	*Student/group will bring all required materials to class each day 90% of the time. Student/group will start work every day when asked and have all materials put away at the end of each day 90% of the time. All needed materials will be requested 1 day in advanced (in writing) 90% of the time. All assigned with will be turned in and complete on required date 90% of the time.*	*Student/group will bring all required materials to class each day 80% of the time. Student/group will start work every day when asked and have all materials put away at the end of each day 80% of the time. All needed materials will be requested 1 day in advanced (in writing) 80% of the time. All assigned with will be turned in and complete on required date 80% of the time.*	*Student/group will bring all required materials to class each day 70% of the time. Student/group will start work every day when asked and have all materials put away at the end of each day 70% of the time. All needed materials will be requested 1 day in advanced (in writing) 70% of the time. All assigned with will be turned in and complete on required date 70% of the time.*
Concept Inquiry – Internet research ***(Days 2 and 5)***	*The student has gathered information from at least 5 websites or other resources (books, magazines, Notebook articles). All research material is organized and cited in the student's STEM Notebook per instructions.*	*The student has gathered information from at least 3-4 websites or other resources (books, magazines, Notebook articles). All research material is organized and cited in the student's STEM workbook per instructions.*	*The student has gathered information from at least 2 websites or other resources (books, magazines, Notebook articles). Most research material is organized and cited in the student's STEM workbook per instructions.*	*The student has gathered information from at least 1 website or other resource (books, magazines, Notebook articles). Research material is organized and cited in the student's STEM workbook per instructions.*

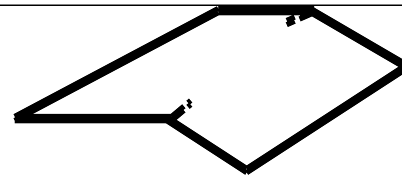
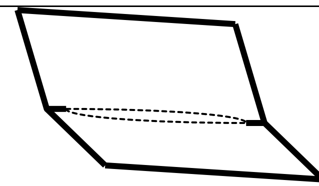
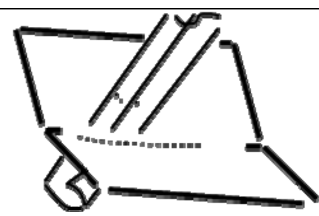
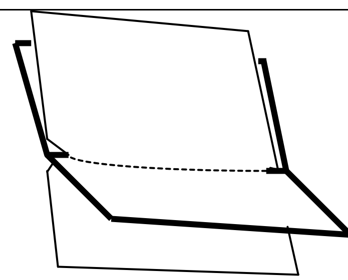
Data Collection, Analysis & Measurement - both directed and individual research ***(Days 3-4)*** ***(Days 6-8)***	*Student/group will include 95-100% of all data collected into the proper table/spreadsheet format. All tabulated data will show the formula used to derive data. 100% of the data fields will have a label. Any use of a unit of measure will be properly notated with the full unit name or approved abbreviation. All conversions will show the used formula.*	*Student/group will include 80-94% of all data collected into the proper table/spreadsheet format. All tabulated data will show the formula used to derive data. 90% of the data fields will have a label. Any use of a unit of measure will be properly notated with the full unit name or approved abbreviation. All conversions will show the used formula.*	*Student/group will include 70-79% of all data collected into the proper table/spreadsheet format. All tabulated data will show the formula used to derive data. 80% of the data fields will have a label. Any use of a unit of measure will be properly notated with the full unit name or approved abbreviation. All conversions will show the used formula.*	*Student/group will include 60-69% of all data collected into the proper table/spreadsheet format. All tabulated data will show the formula used to derive data. 70% of the data fields will have a label. Any use of a unit of measure will be properly notated with the full unit name or approved abbreviation. All conversions will show the used formula.*
Data Collection, Analysis & Measurement - both directed and individual research ***(Days 3-4)***	*Student/group will include 95-100% of all data collected into the proper table/spreadsheet format. All tabulated data will show the formula used to derive data. 100% of the data fields will have a label. Any use of a unit of measure will be properly notated with the full unit name or approved abbreviation. All conversions will show the used formula.*	*Student/group will include 80-94% of all data collected into the proper table/spreadsheet format. All tabulated data will show the formula used to derive data. 90% of the data fields will have a label. Any use of a unit of measure will be properly notated with the full unit name or approved abbreviation. All conversions will show the used formula.*	*Student/group will include 70-79% of all data collected into the proper table/spreadsheet format. All tabulated data will show the formula used to derive data. 80% of the data fields will have a label. Any use of a unit of measure will be properly notated with the full unit name or approved abbreviation. All conversions will show the used formula.*	*Student/group will include 60-69% of all data collected into the proper table/spreadsheet format. All tabulated data will show the formula used to derive data. 70% of the data fields will have a label. Any use of a unit of measure will be properly notated with the full unit name or approved abbreviation. All conversions will show the used formula.*
Plan ***(Day 5)***	*Student/group plan for conducting research for the new variable will be clear and concise with 95 - 100% of experimental*	*Student/group plan for conducting research for the new variable will be clear and concise with 80-94% of experimental*	*Student/group plan for conducting research for the new variable will be clear and concise with 70-79% of experimental*	*Student/group plan for conducting research for the new variable will be clear and concise with 50-69% of experimental*

	components properly labeled (this can be in the form of a table or spreadsheet). The timeline and sequence of operations will be in a logical order and followed during the experiment 100% of the time. All modifications will be documented with a date and time to show when a deviation from the plan occurred.	*components properly labeled (this can be in the form of a table or spreadsheet). The timeline and sequence of operations will be in order and followed during the experiment 80-94% of the time. All modifications will be documented to show when a deviation from the plan occurred.*	*components properly labeled (this can be in the form of a table or spreadsheet). The timeline and sequence of operations will be in order and followed during the experiment 70-79% of the time. All modifications will be documented to show when a deviation from the plan occurred.*	*components properly labeled (this can be in the form of a table or spreadsheet). The timeline and sequence of operations will be in order and followed during the experiment 50-69% of the time. All modifications will be documented to show when a deviation from the plan occurred.*
Focus on the design challenge – introduction of new variable to experiment. ***(Days 6-8)***	*The student/group has met all 8 requirements for the introduction of testing a new variable. At least 5 research sources were properly cited and documented in the STEM Notebook per instructions.*	*The student/group has met all 6-7 requirements for the introduction of testing a new variable. 3- 4 research sources were properly cited and documented in the STEM Notebook per instructions.*	*The student/group has met all 4-5 requirements for the introduction of testing a new variable. A minimum of 3 research sources were properly cited and documented in the STEM Notebook per instructions.*	*The student/group has met all 2-3 requirements for the introduction of testing a new variable. At least 1 research source was properly cited and documented in the STEM Notebook per instructions.*

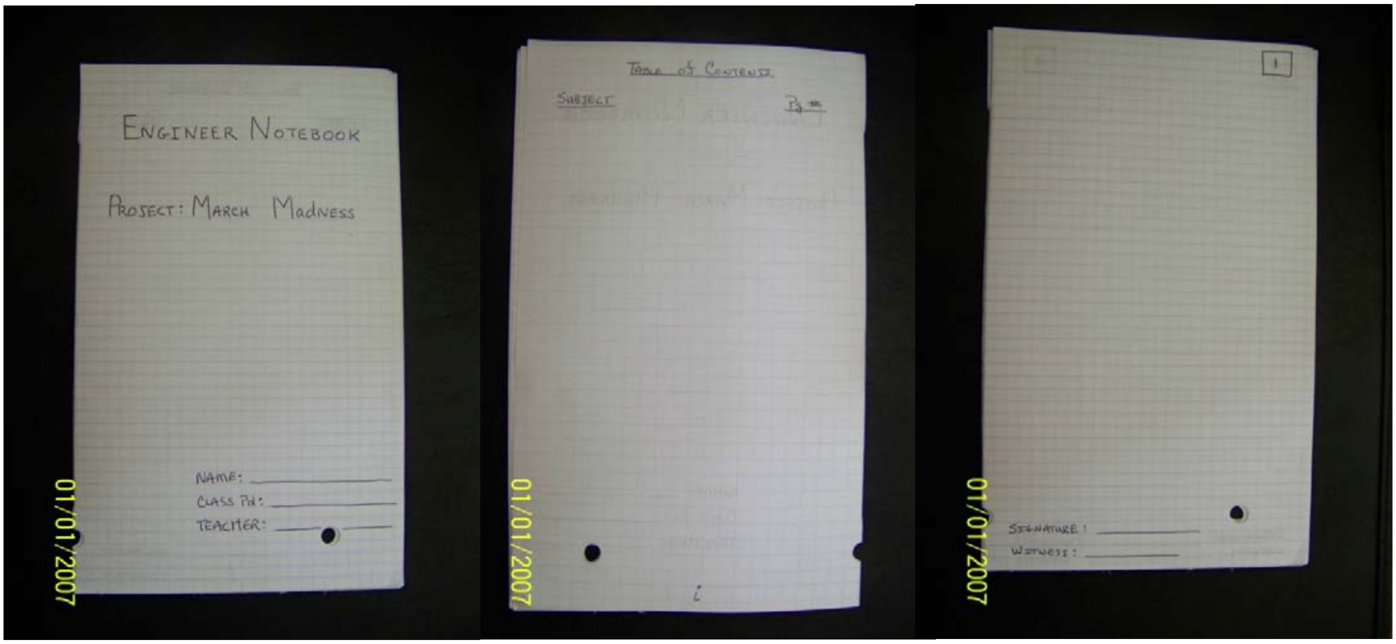
Appendix K

How to make a STEM Notebook

A simple and easy construction method using graph paper is:

1. Take five sheets of double sided graph paper and fold them in half lengthwise. (hamburger fold)	
2. Set aside one sheet of graph paper. On the other sheets cut along the fold about 1¼ inch in from each side.	
3. On the sheet you set aside, mark 1 inch in on the fold from each side. Cut away the fold between the two marks.	
4. Fold but do not crease the first set of sheets width wise and insert them through the hole.	
5. Open the folded papers so the slits extend past the edge of the hole from step 3.	

For the last step, fold the book in half and label as in the picture below:



Using 5 sheets of graph paper will give the student a cover sheet, a one page index and 18 pages for notes. Students should be instructed to:

- Number all pages.
- Date all entries.
- Completely fill each page before starting the next.
- Record method for testing, references, test results, and calculations.
- Sign each page and have you partner witness that the page is complete.
- Do not remove any pages.
- Do not erase mistakes. Simply draw a line through them and initial.