Curriculum Units by Fellows of the Yale-New Haven Teachers Institute
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Energy and Work: Transformation through Engines

Curriculum Unit 04.04.06
by Crystal P. LaVoie

Rationale

The goal of every unit I teach is to have students use the scientific method to design and conduct experiments and to communicate scientific information in writing. I have discovered that my students stumble with how to organize information in a logical fashion. My students also need help with their reading and writing skills, especially vocabulary. Students come into contact with as many new words and definitions in my class as they would in any English or World Language classroom. For all of these reasons, it is important to emphasize strategies that address these issues throughout the course of the school year. The objectives addressed in this unit will focus on the physical science concepts of energy and work, but I will continue to return to my bigger goals as I proceed through the content.

This unit is aimed at ninth graders taking the Integrated Science course. It could be adapted to a sixth grade class when they cover these concepts, and could also be modified for use in a senior level physics class. Energy is defined in most physics texts as “the ability to do work”. You will often hear students speak of energy when they do not have any. The dilemma that I am faced with in planning the physical sciences curriculum is how to get students to understand the concept of energy more in a scientific sense. Thermodynamics, the study of conversions between heat and other types of energy, is not something that comes easy to young people and might rank near to a root canal on a list of their priorities. It is my goal to make this topic more interesting and accessible to ninth graders as it relates to their every day lives.

New Haven Academy, a member of the Coalition of Essential Schools, is an interdistrict magnet school whose mission it is “to provide a rigorous education that prepares all students to succeed in college and become active citizens able to make informed decisions about their lives and their communities.” By definition, an interdistrict magnet school is a public school of choice designed to reduce racial, ethnic and economic isolation. We are committed to small class sizes and assessment by exhibition. All students are required to complete and present projects in each of the classes at all grade levels. While following district guidelines, it is our goal to personalize our instruction for our students. Our school is our personal construction based upon teacher, student, parent and administrator expertise and input.

New Haven Academy ninth graders will participate in the Integrated Science Curriculum consisting of a triad of physical science, earth and space sciences and life science. Considering the topic of “Energy, Engines and the

Environment" seemed to me a great way to bridge the gap between two of the physical science and earth science sections in this curriculum.

Our classrooms consist of a variety of students, from fully included special education students with very specific educational needs to students of outstanding potential but with low skill sets to highly functioning, self-motivated students all of whom may be in the same class together. This necessitates differentiation of instruction such that you keep the top level interested while not losing those students at the lower end. Another challenge in managing the classroom at New Haven Academy is that we meet in 85 minute blocks. Many times it is necessary to have that amount of time if we are to really delve into and complete an activity. However, this also requires careful lesson planning and thought given to exactly how the time will be divided between direct instruction, hands-on activities and assessments. It is my goal to have the student-as-worker and the teacher-as-guide for as much of the class as possible.

The lessons that focus on Energy will be covered during the physical sciences segment. It will be particularly important to "chunk" the time of the class into manageable segments because this topic can be formidable. I hope to limit my direct instruction time to the first and last 15-20 minutes of class and have the students involved in activities during the rest of the class. During this time they teach themselves and each other and master just a couple of the fundamental concepts during one class period.

Unit Overall Goals

This unit is to be used during the Integrated Science curricula, typically for ninth graders. The overall goal is to have students design and conduct experiments, to communicate scientific information and data in writing and to use standard scientific methodology. The objectives of this unit are aimed at achieving those goals during a traditional examination of energy and work. It is assumed that the majority of students will have little to no background in the physical concepts of work and energy (while these concepts are covered in sixth grade, it is my experience that students will remember little of this by ninth grade), so this unit will be designed as an introduction to those topics. The unit is to be used amidst the physical science section of the Integrated Science curriculum. It is important that students understand what energy is and how it relates to achieving work; I want them to have a clear understanding of the relationship between these two concepts and how they relate to the natural world. Students will learn where the energy they use every day comes from and how some of the things that produce work for them function. Students will learn about the different types of energy, and how energy is conserved by transformation from one form to another. To do this, students must be introduced to and master a fundamental understanding of the first law of thermodynamics. Students will examine the transformation of energy through a variety of hands-on activities and labs, including constructing a model car and an online dissection of a combustion engine. This leads into an examination of energy resources by comparing different energy sources and ways to conserve energy. This is detailed in the unit co-published herein, "Fossil Fuel Sources, Usage and Alternatives: What Are the Options?" by S. Van Biersel (Resource Teacher at NHA and Institute Fellow, 2004).

Unit Measurable Objectives

Students will be able to:

- Define and conduct experiments to illustrate: energy, work, heat, heat conduction, thermodynamics, potential energy, kinetic energy, chemical energy, mechanical energy, thermal energy, combustion, electrical energy, reactants, products, transformation, conversion, conservation, temperature, mass, speed, gravity, motor, engine.
- Explain the 1st and 2nd laws of thermodynamics.
- Illustrate the conversion of potential energy to kinetic energy.
- Diagram a combustion engine and define the steps of a 4 stroke combustion cycle.
- Research and design a model, conduct experiments, and present a Science Fair poster.

Content Standards (8)

Scientific Reasoning and Communication Strand:

- SRC9-10.1 Scientific inquiry is a thoughtful and coordinated attempt to search out, describe and explain our world.
- SRC9-10.2 Literacy in science education includes speaking, listening, presenting, interpreting, reading and writing about science.
- SRC9-10.3 Mathematics provides useful tools for the description, analysis and presentation of scientific data and ideas.

High School Science Strand 1: Alternative Energy Resources:

HSI.1

Energy: How is it transferred and transformed? The total matter and energy of the universe is constant. Energy cannot be createdor destroyed, but it can be changed from one form to another.

1a . Describe the transformation of kinetic and potential energy in mechanical, chemical and electrical systems and the conservations of potential energy.

High School Science Strand 2: A Balanced Environment:

HSII.2

Chemical reactions: How are New Materials Formed? Atoms react with one another to form molecules, and the configuration of atoms and molecules determines the properties of the new materials.

2d . Explore reactants and products (e.g., CO, NOx, SO2, Ozone, particulates) in combustion reactions.

High School Science Strand 5: The Physics of Modern Technologies:

HSV.1

1c . Explore and explain how heat can be transferred through materials and across space.

Overview

Students will be asked:

- What is energy? Where does your energy come from? How is energy different from power?
- What does it mean to do work?
- What is heat?
- What is an engine?

Energy Work and Power

Energy can be a confusing topic because it seems familiar to us, and our students, but as we begin to delve into it, what *IS* energy, really? If you look up the definition of energy in a dictionary you will find "potential forces; inherent power; capacity for vigorous action" (5) and if you look in the glossary of your college physics text you will find "the ability to do work". Work is similarly difficult to talk about because we are also familiar with the concept of work, but again have some difficulty in explaining what work is from a scientific perspective.

I ask the question, as you read this document, are you doing any work? The answer is no, not because you are reading in an effortless process, but because in a strictly physical sense you are not doing any work. In order to be doing work you must be moving an object some distance by applying a force on that object. Work is done anytime there is force on and motion of an object. If there is force, but no motion (as when a table is holding up a bag of groceries) then there is no work. If there is motion, but no force (as with a moving hockey puck after it has been struck in the absence of friction **),** then no work is done. Additionally, the force must be applied in the direction of the motion in order for there to be work done. Consider another example: moving a barbell from the floor over your head requires work, however, once the barbell is overhead and is no longer moving, you are no longer doing any work.

So then, is work being done as an object falls freely? Your instinctive answer might be no, and you could be right, but it depends on how you define your system. If the system that you define includes something attached to the freely falling object, say through a pulley and the falling object actually pulls something else up at the end of their tether. Imagine an anvil falling as a piano attached to the end of a connecting rope is being lifted, using a fulcrum pulley. In this case, work is certainly being done as the piano is raised.

Defining the system then becomes an important aspect of our discussion of energy and work. Defining the system is simply indicating precisely which objects or "bodies" you are talking about and what is the environment those bodies are confined within. While I say that it is simple to make this indication, it may not be as easy as you would think. It is important that you give an unambiguous description of what you include in the system. When defining a system we talk about quantities that are in either the whole system or some well-defined portion thereof. Depending on how you define it, the quantities will change. In thermodynamics the quantities that we use are energy, heat, work and entropy.

Energy is the ability to do work. Work is any interaction between bodies that is not heat and is represented by the equation:

W = FL

where W = work, F = force and L = length, and is measure in Newton-meters, also called a Joule. Again, within the system we define, an object must be moved by a force if we are to conclude that work has been done. Doing work transfers energy. An example would be when you hammer a nail into a piece of wood. The force that you apply on the hammer is transferred first to the nail, and then to the piece of wood. Some energy is transferred to the environment in a form that cannot be harnessed. This is discussed further later.

It is necessary to distinguish between the concepts of energy and power, as students will often think of these as the same thing. Power is defined as the rate at which energy is converted from one form to another or transferred from one place to another and is given by the formula

P = W/t

where W is work and t is time (8). The **watt** is a unit of power and is defined as one Joule/second.

Activities for the above discussions:

Students will conduct activities that will connect with the above discussions from class. I would expect to spend about 3 days discussing the above topics and integrating hands-on and technological resources into those lessons. Students will be asked to write short essays nightly on what was done in class and how it relates back to the discussion and notes from the beginning of the class. An activity will be necessary to work on the units of energy and work. Students should conduct the matter and energy activity and the online energy activity detailed at the end of this unit. Other activities done during class include numbers 1-3 and 7 from the detailed activities section at the end of this unit. A field trip opportunity would be to visit the local power company.

Forms of energy

Most types of energy fall into two categories: potential energy (the energy from location) and kinetic energy (the energy from movement). Potential energy (specifically gravitational potential energy) is given to an object by moving it against an opposing force, like lifting a book against gravity to the top of a shelf. The book energy has energy that is “stored” as a result of position. The book has no kinetic energy as it sits on top of the shelf, but when you push it off the shelf, it accelerates to the floor, having a maximum kinetic energy just before it hits the floor. The stored energy the book had just before it was pushed was the potential energy given to it by the work you did in lifting it to the shelf. The equation used to calculate the amount of potential energy an object has is given:

PE = mgh

where m=the object mass, g=acceleration due to gravity (9.8 m/sec2), and h=the height above earth at which the object lay.

Kinetic energy is energy of motion and depends on an object’s mass and speed. The faster the object moves and the more mass it has, the more kinetic energy it will have. Kinetic energy is given by the formula

KE = 1/2mv2

where m=mass and v=speed. Kinetic energy can either increase or decrease by transformation either from or to potential energy, friction or heat. A moving object can transfer its kinetic energy to a stationary one, causing it to move. However, what happens when a moving object hits something soft, like sand. Where does that energy go? Is it lost in the sand? The energy of that motion is not, in fact, lost, but is transformed into a different form of energy, like heat. There are many forms of energy, but all of them can be classified as either potential or kinetic.

Internal energy is due to the kinetic energy associated with the movement of particles in matter. Thermal energy, also called heat, occurs as objects warm up and is related to an increase in the kinetic energy of a material’s atoms and molecules. We said that work is an interaction that is not HEAT. Consider dragging a heavy box across a wooden floor. Where does your work go? Or when you rub your hands briskly together, where does your work go? The answer is thermal energy and is a part of where most energy ends up. Any form of energy can be changed entirely into heat, but when heat is changed into other forms (like in the automobile engine when you convert the chemical energy of fuel into heat which is then converted into mechanical energy to make the car move), the change is not complete, and some always remains as heat. The energy converted to heat is no longer available as potential or kinetic energy, but it was not destroyed. Thus, the energy exchange of a system satisfies the following:

/\E = Q-W

where /\E is the change in energy, Q is heat (the energy exchanged between the system and the environment due to temperature changes) and W is work (the energy exchanged between the system and the environment other than heat). The total energy of a system includes the potential energy, kinetic energy and internal energy. This total energy remains constant so long as there is no exchange with the environment of heat or work.

Heat flows spontaneously from hot objects to cold objects in contact with each other (3). This transfer of heat between objects of matter is called heat conduction. In order to test how hot or cold something is, you might use a thermometer to measure its temperature. Temperature is a function of the energy in an object as a result of the random motions of its particles (3). Atoms and molecules of all matter are in motion; changes in their average energy of motion result in changes in the temperature of the matter.

It becomes clear from this discussion that energy can change forms. In fact, as long as there is no exchange with the environment of heat or work, the total energy of a system always remains constant. However, the forms of energy that are present in the system will change. This is the law of conservation of energy (the 1st Law of Thermodynamics) which states that energy cannot be created or destroyed (it does not just appear and disappear), but it CAN be converted from one form to another. This process of energy conversion is taking place all of the time, and allows for everything to balance. An example is in a wind-up toy, which stores potential energy in a compressed spring. That potential energy is converted into kinetic energy when the spring unwinds. If we could ignore the energy that is lost to the environment (due to the force of friction, for example), then the total energy of the system would remain unchanged, only the *form* of energy present would change. Some different forms of energy include: thermal energy, chemical energy, mechanical energy, electromagnetic (radiant) energy, nuclear energy, and electric energy.

Consider the following examples of the 1st law of thermodynamics:

> - In a pendulum, kinetic energy and potential energy are constantly converted back and forth as the pendulum swings. At the highest point of the swing, the pendulum has maximum potential energy and no kinetic energy. As the pendulum swings down the potential energy is converted to kinetic energy. At the bottom of the swing the pendulum has maximum kinetic energy and zero potential energy. This energy can also be transferred if you have two pendulums next to each other, their energy will be transferred back and forth as they collide.
> - In a roller coaster, the coaster climbs to the first hill where it has maximum potential energy. That is converted into kinetic energy, the energy of motion. That kinetic energy is later converted back into potential energy as the speed of the coaster decreases as it climbs the next hill. Over the course of the ride the roller coaster's total energy decreases due to friction from the rails and the air, until all of the potential energy from the original lift is completely lost.

The 2nd Law of Thermodynamics says that some energy always degrades into forms that cannot be exploited (heat), for example, frictional effects. Friction is a force that results form relative motion between objects, like the wheel an axle of a car (4). These frictional forces work against the motion that made them. Friction comes from two surfaces that move against each other. The smoother the surfaces are, the less will be the frictional forces between them. Even seemingly very smooth surfaces have microscopic "hills" and "valleys" that contribute to friction. Air also will cause friction. In machines, axles and ball bearings are inventions that help to reduce friction.

Activities for the above discussions:

Students will conduct activities to connect the above discussions with real-life scenarios. I would expect to spend at least 8 days discussing the above topics and integrating hands-on and technological resources into those lessons. Students will be asked to write short essays nightly on what was done in class and how it relates back to the discussion and notes from the beginning of the class. The heat activities detailed at the end of this unit will be used during this section. Other activities conducted during class include numbers 4-6 and 8-9 from the detailed activities section at the end of this unit. Students must also complete the CAPT performance task **"Craters"** during this section and are required to write up their lab using the standard CAPT format (see rubric Appendix B).

Engines

We will now turn to an examination of one way that energy is transformed. A motor is one type of machine that produces motion or power for doing work at the expense of some other form of energy. An engine is a work machine that converts energy in a chemical form to mechanical energy for the performance of work. A combustion engine takes the potential energy in fuel (chemical energy) and converts it into motion so that something can move, your car for instance. The efficiency of an engine is the amount of work you get out of it versus the amount of energy that was put into it. Efficiency can never be 100% because the conversion of heat into mechanical energy is involved. Heat can never be converted completely into mechanical or electrical energy, as discussed above in the second law of thermodynamics.

One example of an engine that is capable of producing work was the first practical steam engine, designed by Thomas Newcomen. This engine worked on the principle that as steam condenses into water, it occupies a much smaller space. If you put a piston between the condensing steam and the air, that piston will move as the air pushes down to fill space. By attaching a pump to the piston, you have created a machine capable of doing work. James Watt later improved the steam engine by separating the heating and cooling units, making the engines more efficient and able to drive many other machines than pumps. This is from the fundamental concept from Carnot that you can take heat from a high temperature reservoir and put it into a cool temperature reservoir, and get work out of that temperature difference. The higher the heat difference, the more work you can get, and the more efficient your engine is.

The four-stroke spark ignition engine, also known as the Otto Engine (named for is inventor Nikolaus Otto) works on a cycle originally proposed by Alphonse Beau de Rochas. This sequence of events is what runs most of our cars today (2):

1) An *intake stroke* , when the piston lowers in the chamber to allow fuel mix to enter through open intake valve.
2) A *compression stroke* , when both intake and exhaust valves are closed and the piston rises to compress the fuel mixture. The temperature and the pressure both go up.
3) A *power stroke* , where the hot high-pressure gasresulting from the combustion by spark that occurs right at the end of the compression strokepushes the piston down and does work on the crankshaft.t.
4) An *exhaust stroke* when the piston pushes the spent gas out through the exhaust valve.

In combustion, a substance (wood, natural gas, e.g.) combines with oxygen to release energy in the form of light or heat (4). The general formula for combustion is given:

Fuel (carbon compound) + O_2 (Oxygen) -> CO_2 (Carbon Dioxide) + H_2O (Water).

The reaction rate increase as the temperature rises, so in that way combustion is a self accelerating process, at least until one of the reactants runs out.

There are two common modes of combustion: 1) that with a premixed combustion source, where the fuel and the oxygen are mixed prior to the combustion initiation (e.g. a Bunsen burner) and 2) that which results as the fuel and the oxidizer diffuse toward each other and flame results at the front at which they meet (like in a candle). Our four-stroke engines are premixed combustion, while the diesel engine is non-mixed or diffusion regulated.

The energy sources that we primary use in our society are hydrocarbons, also known as, fossil fuels. They are called fossil fuels because they were formed underground from the remains of once-living organisms. Fossil fuels are a non-renewable resource, which means that they exists in limited quantities and cannot be replaced. It is necessary to conserve use of these non-renewable resources by finding ways to use less energy or by using energy more efficiently. This is known as energy conservation and is discussed in the unit enclosed in this publication titled, “Fossil Fuel Sources, Usage and Alternatives: What Are the Options?” by S. Van Biersel (Resource Teacher at NHA and Institute Fellow, 2004).

Also at issue with combustion sources of energy, is the pollution that results from that process. Primary products of the combustion reaction include: CO_2 (a greenhouse gas), CO, NO_x, particulate (soot), ozone (O_3), PAN, and photo oxidants. Adverse health effects of this pollution include but are not limited to bronchitis, vomiting, nausea, headache, coma, and death. These also contribute to acid rain, which damaging buildings, plants and animals. All of this is beyond the discussion of this particular unit, but will be followed up during the earth science section.

Activities for the above discussions:

Students will conduct activities that will connect with the above discussions had in class. I would expect to spend approximately 5 days discussing the above topics and integrating hands-on and technological resources into those lessons. Students will be asked to write short essays nightly on what was done in class and how it relates back to the discussion and notes from the beginning of the class. Students will need to discuss the relationship between volume and pressure. Then they can examine the Vipratech website (http://techni.tachemie.uni-leipzig.de/otto/index_e.html) where they can view the cycles of the four-stroke combustion engine with the corresponding Pressure: Volume graphic. The hyper physics website is also a must see for this section (http://hyperphysics.phy-astr.gsu.edu/hbase/hframe.html). Students will also view Matt Keveney’s personal web page (http://www.keveney.com). Students will diagram the four-stroke engine and will graph the changes in pressure versus volume as the engine progresses through the cycle. Students will conduct an in-depth research project on an engine of their choice following the given rubric (Appendix C). A definite field trip opportunity would be the Eli Whitney Museum on 915 Whitney Avenue in Hamden, CT (http://www.eliwhitney.org/index.html).

Vocabulary Strategies

Vocabulary is by far one of the most common stumbling blocks that students have in my classes. I will try to drill constantly using many different learning styles in order for students to really get a handle on the primary vocabulary. Two strategies will be employed to tackle the vocabulary that will be required initially in order for the students to handle the complicated concepts that are coming up. Students will be given the list of vocabulary words on the board and will have to copy them into their notebooks. We will then divide the list up such that each student is responsible for two words. It is alright if a word is assigned to more than one student, as it is always advantageous to compare different students' answers.

- **Energy:**
- the ability to do work. Any object that has energy has the ability to create force.
- **Work:**
- the force times the distance moved in the direction of the force. Only the part of the force in the direction of motion does work.
- **Efficiency:**
- the ratio of the work output to the energy input
- **Power:**
- rate at which work is done, i.e. work divided by time.
- **Heat:**
- a flow of thermal energy from one object to another object due to a temperature difference.
- **Thermodynamics** : the branch of physics concerned with the conversion of different forms of energy.
- **Potential energy:** energy of position; stored energy that is capable of being active, but is not at that particular time.
- **Kinetic energy:** energy of motion; depends on mass and speed.
- **Transformation:** when energy is changed from one form into another.
- **Conversion:**
- energy is changed from one form to another.
- **Conservation:** energy is neither created nor destroyed, but is converted from one form to another
- **Chemical energy:** the type of energy stored in molecules. Examples are the food we eat, and the fossil fuels we burn.
- **Mechanical energy:** the type of energy possessed by an object due to its motion or its stored energy of position (thus, can be either kinetic or potential energy). An object that has mechanical energy can do work.
- **Electrical energy:** a type of energy that we usually take for granted and is actually provided by other sources of energy, like fossil fuels.
- **Nuclear energy:** a type of energy that comes from splitting an atom, or fusing two atoms together. This is often used in power plants to make electricity, but not in CT.
- **Electromagnetic energy (or radiant energy):**

is light energy that is made up of waves;

heat from the sun is one form of radiant energy.

- **Temperature:** a measurement used to quantify hot and cold; related to the

- average motion of molecules in an object.
- **Combustion reaction:** a reaction in which a carbon-containing substance combines with oxygen to release a large amount of energy in the form of heat and light.
- **Reactants:**
- substances that enter into and are altered during a chemical reaction
- **Products:**
- substances that are produced in a chemical reaction from reactants.
- **Conduction:**
- transfer of thermal energy by the direct contact of two bodies of different temperatures.
- **Mass:**
- the amount of matter an object has (measured in grams).
- **Speed:**
- movement from one place to another over time (measured in distance/time, e.g., meters/sec).
- **Gravity:**
- the attractive force that exists between any two objects that have mass. Earth’s gravity results mostly from the force between us and our sun.
- **Motor:**
- a machine that produces motion or power for doing work at
- the expense of some other form of energy.
- **Engine:**
- a work machine that converts energy in a chemical form to mechanical force and motion for the performance of work.

Many other strategies will be employed to drill home the vocabulary while we cover the unit. We will design a "word wall" where student assignments related to the vocabulary will be posted on a growing display directly related to the unit. Students will not only reproduce the definitions of the words for display, but will also be required to submit entries where they are required to use the words in context. Students will also be required to make a set of flashcards that they will use to study from for weekly quizzes, that lead up to the unit exam. We will also use a Jeopardy style game for review prior to the quiz. Teams of two will be formed, and the definitions will be read aloud by me, and the students must come up with the question. Point values are assigned based on level of difficulty, and will be tallied and used to reward bonus points on the unit exam. Homework and review will include word puzzles (see Appendix D).

Performance Tasks

Students will:

- Perform daily lab activities (outlined below) and homework will consist of answering questions and writing interpretations of those daily activities.
- Take notes, construct webbing diagrams and concept maps in their journals daily.
- Construct graphs to represent data.
- Do a 5 minute pre-class warm-up in order to make connections from the previous days lectures.
- Conduct research on a type of engine, its inventor, and its pros and cons.
- Debate over which engine type is best.
- Design, conduct and write-up a practice CAPT performance task ("Craters"); see rubric, Appendix B.
- Conduct research and design a science fair poster for the city-wide fair held in February. Models will be made of a steam engine, a car, or a steam turbine.

Detailed Activities (9):

1. What is speed and how is it measured? Students will calculate speed of a car traveling down a ramp. They will compare speed in different units. (p 8)
2. Can you predict the speed of the car at any point on the ramp? Students will determine the speed of the car at different points as it rolls down the ramp. Students will make a speed versus position graph with their data, and predict speed at any point using their graph. (p 10).
3. What is the relationship between force, mass, and acceleration? Students will: 1. measure the force on a car as it starts to roll down the ramp; 2. compare the force on the car as the angle of the ramp is changed; 3. calculate the acceleration of the car as the angle of the ramp is changed; and, 4. explore the relationship between force and acceleration. (p 16).
4. What happens when you multiply forces in a machine? Students will explore how simple machines are able to multiply forces and will be able to calculate work. (p 30).
5. What is energy and how does it behave? Students will discover the relationship between speed and height on a roller coaster and describe how energy is conserved. (p 34).
6. Where did the energy go? Students will describe energy transformations in several scenarios including identifying mechanical, radiant, electrical, chemical and nuclear forms of energy. (p 38).
7. How much does it cost to use the electrical appliances in your home? Students will read appliance labels to determine their power rating. They will calculate the number of kilowatt-hours each appliance uses in a month and then calculate the approximate cost of running each electrical appliance using their electric company rates. (p 52).
8. How is temperature measured? Students will accurately measure changes in temperature and will develop a way to convert between Fahrenheit and Celsius temperature scales. (p 186).
9. How efficient is an immersion heater? Students will calculate an increase in thermal energy, work output, work input and efficiency. They will then analyze the efficiency of a household appliance. (p 188).

Matter and Energy Activity (http://www.utm.edu/departments/ed/cece/seventh/7C1.shtml)

In conducting this activity, students will define and demonstrate an understanding of mass by correctly measuring various objects using a balance. They will also define the terms energy, potential energy and kinetic energy and will give examples of each. Divide the class into groups of two and let them measure the mass of several objects. Use heavy objects such as a glass or beaker, eraser, scissors, and small objects such as a pencil, pen, or graduated cylinder. After all groups have measured the objects, have them compare their findings. Help them to see that larger objects generally have more mass while smaller objects have less mass, depending upon their densities. (You might also point out that it requires more energy to move the larger objects than it does to move the smaller objects.) Give students a worksheet of problems to solve for potential and kinetic energy using the formulas PE = mgh (where g is the acceleration due to gravity = 9.8 m/s2) and KE = 1/2mv2 (Appendix E). For closure, ask students to turn to their neighbor and tell him how to measure an object's mass and how its mass is related to energy. Also review the two types of energy and the definition of each type.

Energy Activity

Have students perform this online task to determine how much energy their homes use.
http://www.omsi.edu/teachers/psd/2002/eq/

The activity takes about 10 minutes and is available in English and Spanish.

Heat Activities

What is heat? (http://www.utm.edu/departments/ed/cece/sixth/6C4.shtml)

The objective of this is activity is for students to describe the scientific meaning of heat. Using simple materials (Pieces of sheet metal and coat hanger wire, beakers, food coloring, droppers, candle or hotplate), students will bend a piece of sheet metal and feel the increase in temperature at the bend caused by increased molecular motion; they will do the same experiment with the coat hanger. Next they will place equal amounts of food coloring, drop by drop, into two beakers of cold water. The water should not be stirred after adding the food coloring. Students should then heat one of the beakers and compare the results. Have students write the reason for the sheet metal and wire becoming warm after being bent back and forth and draw a diagram of what happened to the food coloring in the two beakers of water during their experiment. Write the following questions on the board:

- Define heat.
- Compare the movement of molecules in a gas to a solid.
- What causes the increase in heat where the wire hanger is bent?

Have students copy the questions into their notebooks and answer the questions for homework. Use the answers in a "do now" the following day.

Heat transfer activity

Students will be given the opportunity to research heat transfer as demonstrated by a potholder, or a trivet or a thermos. Students will design their own trivets and then write an expository essay about why it works to prevent the counter from being burned by a pot. Another possibility is to do an experiment where you put ice into hot water and measure the changes. Again, an expository essay should be written explaining why the ice melts, but the water does not freeze.

Combustion engine activity

Activity: Illustrate and explain the four stroke engine (use Keveney.com, Brainpop.com and Challoner's, Energy). Graph the pressure versus volume changes as the cycle proceeds.

Energy Web quest

Using the Energy Information Administration's Website (www.wia.doe.gov), students will conduct a web quest where they are asked to choose an energy source and describe where it is most often used, how does it work, what is the efficiency of that source and what are the environmental impacts of this energy source. This will be a lead-in activity to the earth science section and discussion of global impacts of energy consumption.

Culminating activities

CAPT Performance Task: "Craters"

Students are given the following materials, and are asked to design and conduct their own experiment.

Colored sand

cafeteria tray

meter stick

stopwatch

Balance

balls of differing mass and size

Students should design an experiment aimed at discovering that the more potential energy an object is given by its height, the greater the kinetic energy it will have upon impact, i.e., the bigger crater it will make. This kinetic energy is not only dependent upon its height (or speed), but also its mass. The students will be assessed on their write up according to the CAPT rubric (Appendix B).

Science Fair participation

Poster

Models (steam engine, steam turbine or car)

Research paper and oral presentation as mid-year project grade

Lesson Plans

Lessons One-Three

The following lessons will include discussions on energy, work and power. Brainstorming and note taking (15 minutes) will precede the laboratory activities (60 minutes) which will then be followed by journal reflection (5 minutes). Lessons 2 and 3 should begin with a 5 minute journal connections writing prompted by one or two questions written on the board.

Objectives:

Students will be able to:

- Take measurements in units of grams, (milli)meters, seconds.

- Calculate speed and use photogates to measure speed. Evaluate the effect of different variables on speed.

- Construct a speed versus distance graph. Use the graph to make a prediction.

- Explain power. Rank the amount of power used by various household appliances.

Materials:

Balance, random objects to “weigh”, timer with photogates, physics stand, car and ramp set, three weights, tape measure, calculator, ruler, graph paper, a few small appliances.

Procedures:

Lesson one

1. Ask students to define energy. Brainstorm ideas on board.

2. Brief lecture (10 min) on energy work and power.

3. Conduct measurement activity; assign worksheet for homework.

4. Conduct speed activity.

5. Journal reflection.

Lesson Two

1. Do connections journal writing: What is energy? How does the lab begin to answer that question?

2. Review notes of energy, work and power.

3. Conduct speed prediction activity.

4. Assign lab report (3 days).

5. Ask students to go home and find the ratings on various appliances.

6. Journal reflection.

Lesson Three

1. Connections journal writing. What variables affect speed? What are work and power?

2. Review lab; make sure everyone has data to use for their lab report.

3. Students should read the section from their text on work, energy and power.

4. Students should take out their appliance ratings list from last night (have one of your own to provide students that do not have one).

5. Conduct work, energy and power activity.

6. Journal reflection.

Assessments:

1. Complete metric system worksheet for graded homework.

2. Lab report for quiz grades.

3. Journal check at end of unit for test grade.

Lessons Four-Seven

The following lessons will include discussions on forms of energy. Brainstorming and note taking (15 minutes) will precede the laboratory activities (60 minutes) which will then be followed by journal reflection (5 minutes). All lessons should begin with a 5 minute journal connections writing which will be prompted by one or two questions that are written on the board.

Objectives:

Students will be able to:

- Calculate the amount of work done by a simple machine.
- Use units of joules to measure the amount of work done.
- Analyze the effects of changing force or distance in a simple machine.
- Identify the relationship between speed and height on a roller coaster.
- Describe the marble's motion in terms of energy and conservation of energy.
- Identify and describe different types of energy.
- Distinguish between kinetic and potential energy.
- Discuss the energy transformations in a real-life situation.
- Measure temperature and convert between temperature scales.
- Measure how the temperature of water increases by adding heat.
- Discuss the relationship of heat and energy.
- Calculate efficiency of a heating system.

Materials:

Ropes, pulleys, physics stand, spring scale, meter stick, weights, roller coaster, timer and photogate, steel marble, calculator, poster paper, markers, Celsius and Fahrenheit thermometers, beakers, graph paper, water, immersion heater, timer, food coloring, hotplate, colored sand, cafeteria tray, stopwatch, balance, balls of differing mass and size, goggles, apron.

Procedure:

Lesson four

1. Connections writing: how many different types of energy can you name?
2. Begin brain storming on board about types of energy.
3. Conduct 15 minute lecture on potential versus kinetic energy. Talk about different types of energy with special emphasis on thermal energy, or heat.
4. Do simple machine activity. Assign calculations for homework.

5. Journal reflection.

Lesson five

1. Connections writing: what is a machine?
2. Review notes from yesterday especially potential and kinetic energy.
3. Conduct the roller coaster activities.
4. Construct a graph of speed versus height for homework.
5. Analyze real-life scenarios and decide what type of energy is involved in each scenario.
6. Journal reflection.

Lesson six

1. Connections writing: what is thermal energy?
2. Review notes on heat.
3. Do demo of heat activity using the dispersion of food coloring in a beaker of cold water versus hot water.
4. Conduct heat activities (measuring heat using a thermometer, immersion heater).
5. Assign homework: read CAPT lab and write a problem statement.
6. Journal reflection.

Lesson seven

1. Connections writing: What is the difference between kinetic and potential energy? What does

the law of conservation of energy tell us?
2. Review notes of types of energy.
3. Review problem statements. Ask for volunteers to share their statements.
4. Conduct “Craters” lab (see above).
5. Assign lab write up for homework.
6. Journal reflection.

Assessments:

1. Work calculations worksheet.
2. Speed versus height graph.
3. CAPT lab write up for exam grade.
4. Journal check at end of unit for test grade.

Lesson Eight

The next lesson will focus on engines. The four stroke engine is discussed in greatest detail. Students will do a research paper on an engine. We will visit the Eli Whitney Museum.

Objectives:

- Students will be able to:
- Diagram an Otto engine cycle.
- Graph the pressure versus volume in an Otto cycle.
- Complete a research paper on an engine of their choice.

Materials:

Laptop computers with internet access, graph paper, art paper.

Procedure:

1. Introduce students to the four stroke engine cycle.
2. Direct student to appropriate websites for engine animations. Have them work in pair to draw their own illustration.
3. Give students pressure and volume data for each stroke of the cycle and have them graph the data.
4. Assign the research paper and review the rubric for the paper (7 days).

Assessments:

1. Illustrations and graphs for a quiz grade.
2. Research paper for an exam grade.

Resources

Books for teachers:

1. Jack Challoner; *Energy* (Dorling Kindersley)

2. J. B. Fenn, *Engines, Energy and Entropy* (Freeman)

3. Wysession, et al, *Physical Science: Concepts in Action* (Prentice Hall)

4. Tom Hsu; *Foundations of Physical Science with Earth and Space Science* ; (CPO Science)

5. Webster's New World Dictionary; Third College Edition

6. Frederick J. Bueche (5th Ed) *Principles of Physics* ; (McGraw Hill Book Company)

7. Godfrey Boyle; *Renewable Energy: Power for a Sustainable* Future (Oxford)

8. Content Standards and Expected Performances for High School Science Grades 9-10"by the New Haven Science Teachers' Curriculum Development Team, November 2003

9. Tom Hsu; *Investigations in Foundations of Physical Science*

Books for students:

Tom Hsu; Investigations in Foundations of Physical Science
Jack Challoner; *Energy* (Dorling Kindersley)

Websites for teachers:

http://www.keveney.com

Matt Keveney's personal web page, home of the Animated Engines

http://science.howstuffworks.com

Search "Under the Hood"

http://www.educationcoffeehouse.com/voc/automotive.htm

Link to: http://techni.tachemie.uni-leipzig.de/otto/index_e.htmlThis is an animation of a 4-stroke, complemented with a pressure: volume graph; students could describe the 4 parts of this cycle and refer to what is happening in the cylinder using the color changes (blue=cold, red=hot)

www.teachersfirst.com

(Virtual roller coaster lessons)

http://www.eduref.org/cgi-bin/printlessons.cgi/Virtual/Lessons/Science/Physics

Potential & Kinetic Energy lesson from: "An Educator's Reference Desk Lesson Plan"; Submitted by: Ben Pflugrad, Caldwell S.D.A. Elementary School; Caldwell, ID

http://www-istp.gsfc.nasa.gov/stargaze/Lenergy.htm

Part of a high school course on astronomy, Newtonian mechanics and spaceflight by David P. Stern, Code 695, Goddard Space Flight Center, Greenbelt, MD 20771 u5dpslepvax.gsfc.nasa.gov or audavsternerols.com

http://www.eliwhitney.org/index.html

The Eli Whitney Museum website. A good resource for research and you can also get booking information for field trips.

http://www.cloudnet.com/~edrbsass/edsci.htm

(an online science lesson planning resource. This page provides links to lesson plans and resources for all grade levels and all science areas typically taught in K-12 schools. This lesson plan is for: Kinetic Energy and Work http://hyperphysics.phy-astr.gsu.edu/hbase/hframe.html

Students MUST visit this site. The web diagram will lead them to many valuable lessons. You can create your own online lesson using the links in this website.

http://www.secondlaw.com/two.html#time

A conversation about the second law of thermodynamics. Would be helpful to refer students to. Perhaps ask them to read it and their textbook and then describe the second law in their own words.

http://my.unidata.ucar.edu/content/staff/blynds/tmp.html

Sections include:

What is Temperature?

The Development of Thermometers and Temperature Scales

Heat and Thermodynamics

The Kinetic Theory

Thermal Radiation

3 K - The Temperature of the Universe

http://www.nsta.org/energy/find/primer/

This is the National Science Teacher Association website's information on Energy. There are some very good examples here that can be used to initiate discussion in class and get kids thinking about their world and how the topics in class apply.

http://www.eia.doe.gov/kids/whatsenergy.html

This defines energy in basic terms and gives many active link to different conceptual ideas. An online lesson could be designed in a treasure hunt format where kids are given some prompts and must find the answers themselves.

http://www.brainpop.com/

This website describes how science works using simple explanations and animations. It is a very good resource for lower-functioning students to make real connections.

http://www.utm.edu/departments/ed/cece/samco68.shtml

This is the University of Tennessee at Martin's website containing a manual of activities for K-8 science teachers. The lesson plans are really thorough, complete with written objectives, and suggested hooks, openers, discussions, activities and closings. I used activities 7C1 and 6C4.

http://www.omsi.edu/explore/whatzit/

Science Whatzit is an online science learning project of the Oregon Museum of Science & Industry and you can type in questions and get answers, or you can search their database of lesson plans and resources. Students can also take a quiz to determine their home's energy quotient (this is available in either English or Spanish). This looks like a great resource for many different science units.

www.doscience.com

This is a website that has many links to numerous science activities that can be done with simple materials (many are things that you would have at home). The activities include but are not limited to earth and space science, biology, and physics.

/curriculum/units/1986/6/86.06.06.x.html

Motivational Techniques and Materials for Teaching High School Science in the City of New Haven by Roche A. Samy.

One lesson is: Activity on Greenhouse affect is included in these lessons, also acid rain and water pollution

/curriculum/guides/1986/6/86.06.05.x.html

Atmospheric Changes and Energy Loss Due to Industrial and Residential Combustion of Hydrocarbon Fuels by Susan M. Burke.

One lesson is: The Anthropogenic Effects of Air Pollution Upon Soil, Terrestrial Vegetation and Materials and Building Facades

/curriculum/units/1981/5/81.05.09.x.html

Energy Alternatives by Thelma Stepan.

This includes a short description of energy and work. Not much detail, but accurate.

/curriculum/units/2003/4/03.04.09.x.html

Physics- “24”by Gwendolyn Robinson.

This is a really creative unit that can be used in its entirety or picked from to supplement your physics lessons.

/curriculum/units/1986/6/86.06.02.x.html

Oil and Gas As A Source of Energy by Grayce P. Storey.

This is more of a geology unit on where oil and gas come from. Some cool activities that teachers might use. This would probably be best for a lower level group.

Websites for students:

Matt Keveney’s personal web page, home of the

http://science.howstuffworks.com

Search “Under the Hood”

http://www.educationcoffeehouse.com/voc/automotive.htm

Link to: http://techni.tachemie.uni-leipzig.de/otto/index_e.html

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http://hyperphysics.phy-astr.gsu.edu/hbase/hframe.html

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www.doscience.com

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Appendix A: Standards

Content Standards

Scientific Reasoning and Communication Strand:

SRC9-10.1 Scientific inquiry is a thoughtful and coordinated attempt to search out, describe and explain our world.

SRC9-10.2 Literacy in science education includes speaking, listening, presenting, interpreting, reading and writing about science.

SRC9-10.3 Mathematics provides useful tools for the description, analysis and presentation of scientific data and ideas.

High School Science Strand I: Alternative Energy Resources:

HSI.1

Energy: How is it transferred and transformed? The total matter and energy of the universe is constant. Energy cannot be created or destroyed, but it can be changed from one form to another.

1a . Describe the transformation and conservation of kinetic and potential in mechanical, chemical and electrical systems.

1b . Explore and describe how electricity is generated, transferred and used in modern technologies.

High School Science Strand 2: A Balanced Environment:

HSII.2

Chemical reactions: How are New Materials Formed? Atoms react with each other to form molecules, and the configuration of atoms and molecules determines the properties of the new materials.

2d .Explore reactants and products (e.g., CO, NOx, SO2, Ozone, particulates) in combustion reactions.

High School Science Strand 5: The Physics of Modern Technologies:

HSV.1

Electromagnetic Spectrum: What are the properties of waves? Waves have energy and can transfer energy when they interact with matter.

1c . Explore and explain how heat can be transferred through materials and across space.

Appendix B

Lab Report Rubric

(Table available in print form)

Appendix C

Research Paper Rubric Points

Title Page

5

Present

Correct format

Table of Contents 5

Present

Correct format

Introduction

25

Identification of engine type

Reason for choosing this engine

Research

35

Inventor

Basic mechanic principle

(show diagram)

Energy source

Efficiency of engine

(show graph)

Discussion

20

Benefits

Dangers

Potential improvements

Bibliography

10

Present

Correct format

Appendix D

(image available in print form)

Across

3. rate at which work is done

5. the amount of matter an object has

10. energy is neither created nor destroyed, but is converted from one form to another

11. a measurement used to quantify hot and cold; related to the average motion of particles of an object

12. a reaction in which a carbon-containing substance combines with oxygen to release a large amount of energy in the form of heat and light

13. the attractive force that exists between any two objects that have mass

14. energy of position

15. movement from one place to another over time

16. the force times the distance moved in the direction of the force Down

Appendix D (page 2 of 3)

1. the branch of physics concerned with the conversion of different forms of energy

2. when energy is changed from one form into another

4. the ratio of the work output to the energy input

5. a machine that produces motion or power for doing work at the expense of some other form of energy

6. a work machine that converts energy in a chemical form to mechanical force and motion for the performance of work

7. a flow of thermal energy from one object to another object due to a temperature difference

8. energy of motion

9. the ability to do work

Appendix D (page 3 of 3)

w f y a p i z z y a y a c b r r a u c y s a u q y

f s g d v o d l a w r t r n g o v p g u y u l h w

i c m q c b g r z q p y p w n l p r n p d z f g i

i m x l c g s u t i k c g j a d e w c y b d k g w

x z z k f l t b w w m n w n w n v e y r g m o s x

k c f l g t d b g j o e b r e a y i w q w k j f b

k u x o q j q c a h n i v l y f u n t n w k u l d

p k h v f t z c o i o c a p i c s d t g u m k r w

q t b i l d y w g n i i b a k z o t x c d w b r o

i v d f r y i n t d t f m n b j b m b u p o f p l

f u m e e w e l a n a f o v x q j u b h e f d r t

k r e r u t a r e p m e t p j o w o e u d e w v u

s a i r a f r t h e r m o d y n a m i c s f e c n

r a t b t c o y a k o n r g n z v k p t q t w u m

y t w n d p o w e r f j r s e b l h e v v d i z x

s s u z z l g n v w s e r d s v a j m u a f p o h

u a y l j s b o s r n z o k o n y p d l h g g g n

y u p o h e i q d e a h a v f n m g p q k w z c q

t r d g q c v m c p r q m c s c h f z i e d z q u

x w w d h v x i x p t v b s b d a o l m u e w o s

f s g o e a t k e d u b a o j l o y r k d b w f r

n o i s r e v n o c o m f t v b f l a k r p d d h r j j x n k p p f k g r a v i t y u h m w a b z z

y u u i y a t s n h u g s n u o l t z b d p a n f

c k k y f k y b v t j t h h l r n g j l e p a r g

combustion temperature

conservation speed

conversion work

efficiency transformation

energy power

engine potential energy

gravity thermodynamics

heat motor

kinetic energy mass

Puzzles are courtesy of PuzzleMaker.com.

Appendix F (3) (page 1 of 2)

1. A 60.0 kg person walks from the ground to the roof of a 74.8 meter tall building. How much gravitational potential energy does she have at the top of the building?
2. A pitcher throws a 0.145 kg baseball at a velocity of 30.0 m/s. How much kinetic energy does the ball have?
3. A 0.15 kg ball is thrown into the air and rises to a height of 20.0 meters. How much kinetic energy did the ball initially have?
4. A 125 g steel ball with a kinetic energy of 0.25 Joules rolls along a horizontal track. How high up an inclined track will the ball roll if friction is ignored?
5. At a construction site, a 1.50 kg brick is dropped from rest and hits the ground at a speed of 26.0 m/s. Assuming air resistance can be ignored, calculate the gravitational potential energy of the brick before it was dropped.
6. A soccer ball is kicked from the ground into the air. Describe two graphs that show how the PE and KE change between the time the ball is kicked and when it lands. (hint: make time the x axis).
7. When a falling object reaches a speed called terminal velocity, its speed not longer increases. The object is losing gravitational potential energy but not gaining kinetic energy. Since energy must be conserved, where must the gravitational potential energys be going?
8. Suppose a 200.0 kg dolphin is lifted in the air to be placed into an aquarium tank. How much energy is needed to lift the dolphin 3.0 meters into the air?
9. A small meteoric is approaching earth. It has a mss of 100.0 kg and a speed of 10.0 km.s. How

much kinetic energy does the meteoroid have? (hint: 1km=1000m)

10. A 0.15 kg ball is dropped from the top of a 150 m building. What is the kinetic energy of the ball when it passes the 16th floor at a height of 63 m?

11. Using mass in kg, velocity in m/s, and height in m, show that the formulas for kinetic energy and gravitational potential energy result in energy values with the same units. What is the energy unit called.

Appendix F (page 2 of 2)

Questions 12-14 refer to the following table

Object Mass (kg) Initial upward speed (m/s) Initial height above ground (m)

Ball 1 1.00 8.00 15.00

Ball 2 2.00 1.00 10.00

Ball 3 3.00 4.00 5.00

12. How much kinetic energy does each ball have when it is thrown?

13. Which ball has the greatest gravitational potential energy when it reaches its maximum

height? (hint: find the total energy for each ball.)

14. Which ball hits the ground with the most kinetic energy?