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Simple Machines, Engines and the Environment

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Introduction

As a Media Center Assistant, my primary focus for the first half of the school year is to work with students in grades 5-8 on their Science Fair project. Science Fair rules dictate that no more than 3 students in grades 5 & 6 and no more than 2 students in grades 7 & 8 may work on a project together. This rule makes it necessary to provide a variety of resources in support of their varied interest and the different directions they may choose to take with the same project. Flexibility (within reason) with his/her investigations is necessary for the student to have an input and a greater interest in their project.

The focus of this unit is on small group instruction and contains a variety of resources where a student can research background information for his/her topic. This background material will provide the student an opportunity to look at his/her project in a variety of ways and help them decide on the focus of their project.

In most cases, the student involvement with physical science has been very limited. This lack of background is a reason why we will rely on computer animated programs and hopefully find a mentor qualified to help them in their area of interest.

The computer activities will allow the student to work at home and/or in school to introduce and reinforce the scientific principles that will enable them to better understand the necessary information about the subject and complete a meaningful project.

Before we begin discussing simple machines and engines, we should have an understanding of work and energy. The definition of work is “exerting a force through a distance.” After giving them six to ten examples of work being done or not being done with several different systems, have them use the equation W= F X D to answer some questions. Questions and examples can be found in most Physical Science textbooks.

Once you are satisfied that the student can distinguish work from exerting a force, begin a discussion on energy. Energy is the ability to do work. The Brainpop website:

http://www.brainpop.com is a good starting point. It has short movies and a quiz about several different forms of energy. The quiz gives the student immediate feedback to determine his/her understanding of the topic.

The available topics are Energy Sources, Forms of Energy, Heat, Kinetic Energy, Potential Energy and Nuclear Energy. You may look at two movies/day without having to pay for this service.

Before we leave this introductory section about energy, we should stress the differences between renewable and nonrenewable sources of energy. This will give them a better understanding why certain sources of energy production are being studied more aggressively than others for future uses. A good website is: http://www.eia.doe.gov/kids/whatsenergy.htm. With this website, you may have the student just list the different forms of renewable and nonrenewable sources of energy or they may “click” on a form for a more in-depth explanation about each form.

At this time, you may want to distinguish between heat and temperature.

Again there is a movie about temperature and another on heat available at Brainpop. Multiple choice questions are used at the end of the movie. These questions will allow you to evaluate their basic understanding of the topics.

I have found that allowing them to do an investigation “Heat and State Changes” helps them to distinguish between heat and temperature. In this investigation, the student and/ or teacher heats a beaker of ice until it boils. A data table (temperature vs. time) will be used to construct a graph when all the data are collected and recorded. The time scale you use will depend upon your heat source. Constructing a graph from the data helps them to visualize what happens when you discuss what is happening during the change of state.

If students have trouble with the concept of molecular motion during the changes of state, I have found using the example of students in a classroom helps clarify this concept.

Solid - Definite shape, definite space.

Analogy:

The students are in the classroom all sitting at their assigned seats.

As the period goes on, they begin to get “antsy” in their seats.

Liquid - No definite shape, definite space.

Analogy:

The students begin to move around the room but do not leave the room.

Gas - No definite shape, No definite space.

Analogy:

Finally the bell rings and the students leave the classroom going out different doors and proceeding to different classrooms.

Another activity that sometimes helps them to understand molecular expansion is to cover a beaker with a balloon. Explain to the student that you are creating a closed system with this set-up. In a closed system, no mass gets in or out of the system. Mass the balloon and beaker. Heat the air in the beaker and watch the balloon expand. Mass the balloon and beaker again. There will be no noticeable difference in mass. They will observe that it in this closed system, with no air getting in or out of the system and the mass remaining fairly constant, the only logical explanation at this point is that the molecules are moving faster and further apart.

To show how the construction industry uses the principle that most materials expand when heated and contract when cooled, ask the student why there are expansion joints between spans in a bridge or in the walls of some large buildings. Hopefully, they will remember that most materials expand when heated and contract when cooled.

As this unit will deal with engines & work, we should touch on horsepower. James Watt is credited with inventing this term by working with ponies lifting coal at a coal mine. Go to the website http://auto.howstuffworks.com/horsepower1.htm to get this information. This site explains how a dynamometer is used to determine the horsepower of an engine. The chart below how horsepower impacts the price of an automobile.

This chart is found at the same site and would be of interest to most students.

Horsepower Weight (lbs) Power:Weight 0-60 mph (seconds) Price

Dodge Viper 450 3,320 0.136 4.1 $66,000

Ferrari 355 F1 375 2,975 0.126 4.6 $134,000

Shelby Series 1 320 2,650 0.121 4.4 $108,000

Lotus Esprit V8 350 3,045 0.115 4.4 $83,000

Chevrolet Corvette 345 3,245 0.106 4.8 $42,000

Porsche Carrera 300 2,900 0.103 5.0 $70,000

Mitsubishi 3000GT bi-turbo 320 3,740 0.086 5.8 $45,000

Ford Escort 110 2,470 0.045 10.9 $12,000

How far you go with the study of horsepower will depend on the age of the student and purpose of his/her project.

Background

Man has always tried to use less effort when doing work. The earliest method of using less energy to perform a task was the use of the simple machines. These 6 simple machines, the lever, inclined plane, pulley, wedge, screw and wheel & axle can also be used together and make what we call a compound machine. But lets not get ahead of ourselves and begin by learning about these simple machines. This section will satisfy Performance Standards 5.1a and 5.1 f. for grades K-4 science.

Remember, a simple machine does not “save” work. What we get is a mechanical advantage (how much a machine multiples the effort force). There is an ideal mechanical advantage (IMA), that we can predict mathematically, and the actual mechanical advantage (AMA) we receive when we perform the task. If you are asking why there is a difference between the IMA and AMA, it is that friction is not involved in the IMA. When we compare the actual mechanical advantage (AMA) to the ideal mechanical advantage (IMA), we can calculate the efficiency of the machine.

These are the formulas we will use for our work with simple machines:

d= distance e= effort r= resistance f = force

IMA =de/dr AMA = fr/fe Efficiency = AMA/IMA X 100%

The type and extent of the investigations you perform will depend on your objectives.

(image available in print form)

The Lever

The lever consists of an effort arm, fulcrum and the resistance arm. The positioning of the three components determine whether the simple machine will allow you to use less effort, gain speed and distance or change the direction of the applied force. Before we begin some hands-on activities let’s look at the movie on brainpop. This movie can be found at http://www.brainpop.com.

The lever consists of a rigid bar, fulcrum, resistance arm, and an effort arm. The positioning of the load in relation to the fulcrum and the effort arm determines the class of lever we are using.

1st class lever - Force Arm (effort) - Fulcrum - Load Arm (resistance)

Uses- Change direction of a force - Multiply force - Gain speed and distance

2nd Class lever - Fulcrum - Load Arm(resistance) - Force Arm (effort)

Use - Multiply force

3rd Class lever - Fulcrum - Force Arm (effort) - Load Arm (resistance)

Use - Gain distance

Demonstrate and/or have students perform the IMA and AMA of the three classes of levers.

(image available in print form)

The Inclined Plane

The inclined plane is a slanted surface over which the load is moved. Again, let’s take a look at the Brainpop movie about the inclined plane. http://www.brainpop.com. You decide how you can best use the questions for this movie.

It is now time to do a demonstration or preferably a hands-on activity.

Do the actual activity using the formula, Work = Force X Distance without using the inclined plane.

Now have them set-up an investigation moving a load up the same height (vertical distance) but using an inclined plane.

Have them determine the IMA of the inclined plane.

(IMA = Length of incline/Height of incline.)

Use the formula AMA = Resistance Force/ Effort Force to find the actual advantage gained doing this task.

You may want to repeat this investigation but use an inclined plane of a different length but keeping the same height.

Pulley

A pulley is a simple machine that uses grooved wheels and a rope to move a load.

Types/Uses - Fixed - Change direction of a force.

Moveable - Multiply Force

Block & Tackle - Multiple Force & Change Direction of a Force

To determine the mechanical advantage of a pulley, you count the number of strands supporting the load, do not count the stand that allows you to change the direction of the force.

(image available in print form)

No Mechanical Advantage

(image available in print form)

Mechanical Advantage =2

If you do not have access to pulleys, have them work on a worksheet so they can distinguish between strands that support the load and strands that only change the direction of the force when determining the mechanical advantage.

With the last three simple machines we may want to just give the definition and examples.

(image available in print form)

The Wedge

A wedge is a pair of inclined planes that move through and object when a force is applied.

Example: An axe, knife

(image available in print form)

The Screw

An inclined plane wrapped around a cylinder. The width of the threads determines the mechanical advantage. The closer the threads, the easier to turn but the number of rotations increase to get to the desired depth.

Examples: Spiral Staircase, Bolts

The Wheel & Axle

A wheel & axle is made of to circular objects that are connected. The larger object is called the wheel and the smaller the axle.

Examples; Screwdriver - Doorknob

Compound Machines

The next step in the evolution of making work easier is the development of compound machines. Compound machines are combinations of two or more simple machines. For this topic, you may ask the student to give examples of compound machines. They will probably come up with answers like a doorknob, automobile tires, wheelbarrow and an axe.

Engines

The main part of an automobile is the engine. This device allows mechanical power to move the vehicle by using what is called a drivetrain. In general, we say forms of energy can be transformed to mechanical energy, such as heat, chemical, electrical, solar and nuclear.

As we study engines, we will learn how the various forms of energy are transformed from one form to another to supply this mechanical power. We will also have the student recognize how the different parts of the system (automobile) work to make the total system operate effectively and efficiently.

This section can satisfy Performance Objectives 5.2d, 2.3, 2.4, and 2.5 for grades 9 -12.

The development of engines has produced both positive and negative results. On the positive side, it has allowed us to do work faster with less effort on our part. We know that without the engines, our quality of life would not be the same. On the negative side, pollution from some of these devices has damaged our environment. We realize the need for these types of machines and we are now trying to make them become more environmentally friendly.

Before we start dealing with environmental concerns, we should investigate the development of engines and the impact they have had on our way of life. The engines we will discuss are referred to as heat engines. They burn various types of fuel to produce a type of heat energy in a process we call combustion. Theses engines are differentiated by where the combustion occurs.

If the combustion occurs outside the engine, we refer to it as an external combustion engine. If the combustion occurs inside the engine, we call it an internal combustion engine.

If a teacher would like to collaborate with a social studies teacher, this would be a great opportunity to discuss the Industrial Revolution starting with the invention of the steam engine.

The Steam Engine is an external combustion type of engine. In earlier times, this was a source of energy for steamboats, trains and factories that were primarily responsible for the start of the Industrial Revolution.

The steam engine changes thermal energy to mechanical energy causing the engine to perform the intended task. One way to show how steam can make an object move is to do

an investigation called the “steam rocket engine.” This can be found online by asking “how to make a steam powered rocket.”

This investigation shows that when heated, water changes to steam and like the earlier investigation with the flask and the balloon, it will expand. However, this time the steam has an opening to escape and move the object. Explain that in a steam engine, the steam causes a piston to move and do mechanical work.

Let’s take a closer look at the steam engine. We know that it uses some of the simple machines such as the wheel and axle as part of the total system (train). But, an engine is used to do most of the work. Just how does this work? We saw from the demonstration with the steam rocket, that heating water causes it to change phase. (liquid to gas) In the gaseous state, the pressure is increased. The steam escaped through the opening causing the “rocket” to move in the opposite direction. In the steam engine, as the gas increases in pressure and volume, it is directed to a piston by the use of valves. We can then make it do useful work.

(image available in print form)

What happens during this operation is that the steam alternates coming into the cylinder. This causes the piston to move back and forth. You may then connect the piston to a device to do work.

The boiler is a very important component of the steam engine. This is where the water is heated and changed to steam. If you have looked at old western movies and a train was involved, you saw water towers at the train stations. These were necessary to replace the water that was used by the train to produce steam.

The website http://www.geocites.com/Athens/Acropolis/6914/thermod3e/htm shows the theoretical cycle of a double-acting steam engine. This animation shows what is happening during the cycle of the steam engine.

If you plan to do a Science Fair Project on the steam engine, there are some web sites that show you how to make a simple steam engine. I would suggest this be done only with the supervision of an adult.

There is a lot of flexibility with your research paper. The focus of the paper will depend upon your purpose/problem and hypothesis.

The next type of engine we should investigate is the internal combustion engine. A good way to start this investigation is to have the student(s) put together a model car. Remember, if you are doing this as a project, no more the two students (grades 7&8) or three students(grades 5&6) are allowed to work together on a project.

This activity will allow them to see where some of the parts are located in the automobile in relation to the engine. You can then direct your attention to what and why most of these objects move. The internal combustion engine.

As stated earlier, the combustion takes place within a cylinder. For our purposes, we will discuss the four-stroke cycle engine. Each up and down movement of the piston inside the cylinder is called a stroke. The cylinder has at least two opening, one for the intake of air and fuel and the other to rid the cylinder of the exhaust. To start a discussion and get a better overview of this process, have the students look at the brief movie called “engines” at http://www.brainpop.com if you have access to computers,

The cylinder is where the action takes places in the internal combustion engine as we have just seen from the “Brainpop” presentation. Let’s revisit what happens during each stroke of this engine at a slower more controlled pace. Again, if you have access to computers, visit the website of “How Stuff Works.” This section takes you through the steps of what happens in the cylinder during the four-stroke cycle. I think we all realize that students learn and retain more if they are actively involved in the learning process. By using this website, we can work at our own pace and visually observe an animation of what is happening in the cylinder.

This is basically what happens during this four-stroke cycle:

- Intake - A premixed fuel in introduced into the cylinder from the fuel-injection system.

- Compression - A piston compresses the fuel and air mixture.

- Power - A spark plug ignites the fuel mixture.

- Exhaust - The exhausted fuel is pushed out of the cylinder to a catalytic converter, muffler, and tailpipe and enters the atmosphere.

Most automobiles in the United States have 4, 6, or 8 cylinder engines. The bigger the engine and the more cylinders it has, the more fuel it will use and the more pollution it adds to the atmosphere.

A research paper on “The History of the Automobile” could be done for social studies.

Diesel Engines

The inefficiency and resource consumption of the steam engine prompted Rudolph

Diesel to develop the diesel engine. This engine uses the high temperature of compressed air to ignite the fuel when it is introduced into the cylinder instead of a spark.

The diesel engine is much more efficient when it comes to changing the potential energy to mechanical energy. The gasoline engine has a compression ratio of 8:1 to 12:1 while the efficiency rating of the diesel engine is 14:1 up to 25:1. The higher ratio means better efficiency for the diesel engine.

Again, go to “How Stuff Works” to see the working of the diesel engine.

During the oil crisis in the United States (1970’s) Americans began buying diesel powered automobiles. Records show that 85% of Peugeot's, 70% of Mercedes Benz, 58% of Isuzu's and 50 % of Volkswagen's sales were diesel-powered vehicles.

What caused us to turn away from diesel fueled engines? The main reason was that prices stabilized and the need for conservation was lessened and the other reason was that the diesel engines did not stand up well due to the higher compression needed for their operation. They were also very sluggish. However, the diesel engine has been improved and many of the initial drawbacks have been reduced or eliminated.

Again we are faced with unstable fuel prices but because of new technology we may not revert back to the use of diesel powered engines no matter what benefit the diesel can do to help the environment.

Automobiles And Environmental concerns

Automobiles affect the environment from their production to the acquisition of petroleum products. We will just concern ourselves with the by-products of combustion.

Pollution from exhaust is the major concern for impacting the environment. As the combustion process is not perfect, pollutants are added to our environment.

The pollutants of concern and their effects are:

- Carbon Dioxide (CO_2) - Emitted from automobile exhaust, contributes to global warming.
- Particulate Matter - Respiratory and cardiovascular disease, lung disease and cancer.
- Nitrogen Oxides (NO & NO_2) - Respiratory problems, reacts in air to cause "bad" ozone (smog), acid rain, and nitrification of wetlands leading to algae growth and the death of fish.
- Sulfur Dioxide (SO_2) - Secondary particulate formation, lung irritant, and acid rain. Interferes with the operation of catalytic converters.
- Hydrocarbons (HC) - Various forms of air pollution, can cause cancer and birth defects, and "bad" ozone.
- Carbon Monoxide (CO) - Impairs the flow of blood to the brain and other parts of our body. May cause death.

In December of 1997, an agreement to control emissions of greenhouse gases that cause global warming was held in Kyoto, Japan. This agreement called for wealthier nations to significantly reduce their greenhouse gas emissions by 2008-2012. However, the United States did not ratify this treaty.

We must hope that the automobile industry will keep experimenting with environmentally friendly vehicles and during this same period of time, produce more fuel efficient vehicles instead of SUVs.

Lesson 1: The Inclined Plane

Purpose: To determine the use of the Simple Machine called the Inclined Plane.

Objective: Upon completion of this lesson, the student will be able to calculate the

IMA (ideal mechanical advantage) and the AMA (actual mechanical

advantage) of using an inclined plane.

Materials:

Spring scale - metric ruler- 30 cm board - a load - string

Procedure:

1. Using your spring scale, mass the object your teacher has given you.
2. How much work would you do if you were to raise this mass 10 centimeters?

Work = Force X Distance

3. If you were to use an inclined plane 30 centimeters long to lift this same object 10 centimeters high, what would be your IMA?

IMA = Length of plane/height of plane

4. How much effort should it take to actually perform this task?

5. Perform this task using your inclined planed.

Length = 30 cm.Height = 10 cm.

6. How much work did you do perform doing this task?

7. What was your actual mechanical advantage using the inclined plane?

AMA = Resistance Force/Effort Force

8. Did this Simple Machine Save you work?

Observations:

1. Mass =64 grams
2. Work =640g/cm
3. IMA= 3
4. Effort = +21g
5. Effort = 22g
6. Work = 660g/cm
7. AMA = 2.9
8. No

Conclusion:

Simple Machines do not save work but allow you to use less effort.

* Student answers may vary due to their spring scale calibration and scale.

Lesson Plan 2: Efficiency

Purpose:

To determine the efficiency of the inclined plane.

Objective:

The student will use the data from lesson one to determine the efficiency of the inclined plane.

Materials:

Data from lesson one.

Procedure:

Efficiency = resistance force x resistance distance/ effort force x effort distance x 100%

Observation:

Efficiency = 64g x 10cm/22gx30cm x 100%

Conclusion:

The efficiency for this simple machine is -97%

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