SUPERCHARGED SCIENCE

Unit 4: Energy (Part 1)

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Appropriate for Grades:
Lesson 1 (K-12), Lesson 2 (K-12)
Duration: 6-15 hours, depending on how many activities you do!

Energy is the mover and shaker of the universe. Heat from the sun, sounds from your radio, riding a bike, and watching a movie are all expressions of different forms of energy. As you sit there reading this, there is energy flowing all around you in the form of light waves, sound waves, radio waves, heat, and more. You are constantly being bombarded by energy. Energy is everywhere all the time. We're going to focus on pulleys, levers, and simple machines. Are you ready to get started?

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Key Vocabulary

Energy is the ability to do work.

Force is a push or a pull, like pulling a wagon or pushing a car.

Mechanical advantage is simply how many times easier it is to lift an object using a simple machine. Officially, mechanical advantage is the factor by which a mechanism multiplies the force put into it. A simple machine with a mechanical advantage of 100 could lift a 100 pound load with the effort of one pound.

Power measures how quickly work can be done. Mathematically, power is work divided by time. Power can be measured in horsepower or Watts.

Pulleys, like all simple machines, sacrifice distance for force. The more distance the effort moves, the less force is needed to lift the load. The **pulley** is a very powerful **simple machine**.

Simple machines give you mechanical advantage. A major job of simple machines is to decrease the force needed to move something. The more pulleys that are rigged together, the more effective a pulley system can be.

Work is moving something against a force over a distance. Mathematically, work = force x distance. Work can be measured in Joules or calories.

Unit Description

Energy is the mover and shaker of the universe. Heat from the sun, sounds from your radio, riding a bike, and watching a movie are all expressions of different forms of energy. As you sit there reading this, there is energy flowing all around you in the form of light waves, sound waves, radio waves, heat, and more. You are constantly being bombarded by energy. Energy is everywhere all the time. We're going to focus on pulleys, levers, and simple machines. Are you ready to get started?

Objectives

Lesson 1: Levers

We're beginning a unit on energy, and I'm not going to lie to you—this stuff is tough, at least at first. Many of these concepts are quite abstract and it takes a while for them to sink in.

The first bit will focus on some of the major definitions of energy so that you can get a feel for what energy is and what it does. Then we will begin to learn about some of the many forms of energy (sound, thermal, light, heat, electrical) and what they do. Are you ready? Let's get going.

Highlights

- Energy is the ability to do work.
- Work is moving something against a force over a distance.
- Mathematically, work = force x distance.
- Work can be measured in Joules or calories.
- Power measures how quickly work can be done.
- Mathematically, power is work divided by time.
- Power can be measured in horsepower or Watts.
- In the next lesson we will deepen our study of energy by investigating the two main categories of energy—potential and kinetic.

Objectives

Lesson 2: Pulleys

When we played with levers we could see that, by using a simple machine, we were able to use less force to move a heavy object than we would have had to use if we didn't use a simple machine. We also saw that with that lessening of force came an increase in distance.

Obviously, you can only make a lever so long. After a while it gets kind of ridiculous. Imagine lifting a concrete block or a car with a lever. That's a big lever and you probably still wouldn't be able to lift the car very high. This is where pulleys come in. Are you ready? Let's get going.

Highlights for Solids

- The pulley is a very powerful simple machine.
- A major job of simple machines is to decrease the force needed to move something.
- Flag poles, fishing rods, cranes, window blinds, and wishing wells all have pulleys.
- The more pulleys that are rigged together, the more effective a pulley system can be.
- Pulleys, like all simple machines, sacrifice distance for force. The more distance the effort moves, the less force is needed to lift the load.
- Simple machines give you mechanical advantage.
- Mechanical advantage is simply how many times easier it is to lift an object using a simple machine. Officially, mechanical advantage is the factor by which a mechanism multiplies the force put into it. A simple machine with a mechanical advantage of 100 could lift a 100 pound load with the effort of one pound.

Textbook Reading

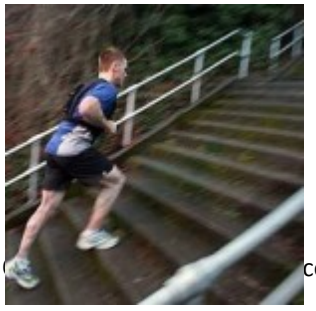
Everything in the entire universe can be categorized into two things—matter and energy. As a matter of fact, according to Einstein and some relatively new physics theories (string theory) even matter is actually energy incarnate. Energy can become matter and matter can become energy. Makes your head spin, right? So what *is* energy?

What Is Energy?

Energy has a number of different forms—kinetic, potential, thermal, chemical, electrical, electrochemical, electromagnetic, sound, and nuclear, all of which measure the ability of an object or system to do work on another object or system. In the physics books, **energy is the ability to do work**.

What Is Work?

Work is the exertion of force over a distance. In our mechanics unit, we defined force as a push or a pull. So work is when something gets pushed or pulled over a distance against a force. Mathematically it's *work = force x distance* or *W = fd*.



Let me give you a few examples. If I was to lift an apple up a flight of stairs, I would be doing work. I would be moving the apple against the force of gravity over a distance. However, if I were to push against a wall with all my might and if the wall never moved, I would be doing no work because the wall never moved. (There was a force, but no distance.)

Another way to look at this is to say that **work is done if energy is changed**. By pushing on the non-moving wall, no energy is changed in the wall. If I lift the apple up a flight of stairs however, the apple now has more potential energy then it had when it started. The apple's energy has changed so work has been done. (We'll define potential energy more in another lesson.)

How Is Energy Measured?

If we wish to talk about energy further, we need to have a unit of measurement. For energy, a couple of units used to express its measurement are the *Joule* and the *calorie*. A Joule is the energy needed to lift one Newton one meter. A *Newton* is a unit of force. One Newton is about the amount of force it takes to lift 100 grams which is

equivalent to about 4 ounces, or an apple.

It takes about 66 Newtons to lift a 15 pound bowling ball and it would take a 250 pound linebacker about 1000 Newtons to lift himself up the stairs! So if you lifted an apple one meter (about 3 feet) into the air you would have exerted one *Joule* of energy to do it.

The *calorie* is generally used to talk about heat energy. You may be familiar with it due to its use to describe the energy in food and energy burned in exercise. A calorie is the amount of energy it takes to heat one gram of water one degree Celsius. Four Joules are about one calorie. (Note: When most people talk about calories, they refer to calories with a capital C as they are really talking about kilo-calories (kCal), which is 1,000 calories. When it is used like this and someone says, for example, that a soda has 160 Calories, it actually has 160,000 calories!

Who Cares?!

We spent a lot of time on this strange concept called work. Work happens when something moves a distance against a force. Swell...*who cares*?!? Well, believe it or not, this is truly one of the most useful concepts in physics. I'm willing to bet you spend a lot of your time moving things over a distance against a force.

Do you ever climb stairs, walk, ride a bicycle, or lift a fork to your mouth to eat? Of course you do. Each one of those things requires you to move something a distance against a force. You're using energy and you're doing work. And really, doing work is not that hard...it's force that can be difficult. Imagine getting up a ten step flight of stairs without a set of stairs. Your legs don't have the strength/force for you to jump up. You'd have to climb up or find a ladder or a rope. The stairs allow you to, slowly but surely, lift yourself from the bottom to the top of the incline.

Now imagine you are riding your bike and a friend of yours is running beside you. *Who's got the tougher job?* Your friend, right? You could go for many miles on your bike but your friend will tire out after only a few miles. The bike makes it easier to do as much work (that is, it requires less force) as the runner has to do.

Now here's an important point—you and your friend do about the same amount of work. You also do the same amount of work when you go up the stairs *versus* climbing up a rope. The work is the same, but the force needed to make it happen is much different. Don't worry if that doesn't make

sense now. As we move forward, it will become clearer.

Highlights for Energy

Energy is the ability to do work.

Work is moving something against a force over a distance.

Mathematically, work = force x distance.

Work can be measured in Joules or calories.

Power measures how quickly work can be done.

Mathematically, power is work divided by time.

Power can be measured in horsepower or Watts.

In the next lesson, we will deepen our study of energy by investigating the two main categories of energy—potential and kinetic.

Simple Machines

This "making the force less" thing is where simple machines come in. Way back when, long before there were cranes and bulldozers, folks needed to move stuff. They needed to move heavy stuff like rocks, boulders, logs, boats, etc. These clever folks discovered machines. **A machine, in science language, is any device that transmits or modifies energy.** In other words, energy is put in to the machine and comes out of the machine but along the way the energy does work, changes direction, changes form, or all of the above.

We're going to focus on the fact that machines can allow you to use less force to do work. Most folks say that there are six simple machines—the inclined plane, wheel and axle, lever, pulley, wedge, and screw. Every machine with moving parts, from a tape player to a car to a computer to a freight train is made up of simple machines, making them *compound machines*.

We are going to spend time with two simple machines. By learning how they work, you will get a nice picture of all the simple machines and what they do. In this lesson, we will be spending some quality time with levers while in the next lesson we will spend time with pulleys.

The Power of Simple Machines

Archimedes (286 to 212 B.C.) said "Give me a place to stand and I can move the Earth." As you can see, Archimedes was quite fond of simple machines. In fact, he was a master

of all the simple machines. He did not invent them but he did put them to some amazing uses.

For example, a story goes that the Greek king Hiero had a problem. He had had a boat made that was so large no number of men could get it into the water. What good is a boat that is stuck on land? The king told Archimedes his problem and Archimedes said, “Pfffft, I can launch that boat with one hand!” Sure enough, after several days Archimedes created a system of levers and pulleys that allowed him to move the boat by himself...with one hand.

According to one version of the story, the king did not believe that Archimedes was doing it on his own and that there must be some trick. Archimedes said, “Okay, you do it.” The king hesitantly gave it a try and sure enough, in front of a huge crowd, the king moved the ship. At that point, the king shouted out, “From this day forth, Archimedes is to be believed in everything that he may say.”

Archimedes was an unbelievable scientist and mathematician, and there are many terrific stories surrounding his life and discoveries. I would highly recommend taking the time to look into him a bit further.

The Lever

So what is this lever thing anyway? Well, at its most basic level, it’s a stick and a rock. Pretty simple machine, huh? The lever is made up of two parts—the lever (the stick part) and the fulcrum (the rock part). Believe it or not, using this very simple machine you can lift hundreds of pounds with your bare hands and very little effort.

Highlights for Simple Machines

Most folks say there are six simple machines. They are the inclined plane, wheel and axle, lever, pulley, wedge, and screw.

All machines with moving parts are made up of simple machines.

A machine made up of multiple simple machines is called a *compound machine*.

A machine is any device that transmits or modifies energy.

Simple machines are often used to reduce the amount of force it takes to move something.

Work in equals work out although, as you’ll see later, work out is always less due to some work being lost to heat and sound.

Simple machines usually sacrifice distance for force. The amount the effort moves is much more than the amount the load moves. However, the force the effort needs to push with to move the load is much less.

Levers have three different parts—the lever, the load, and the effort.

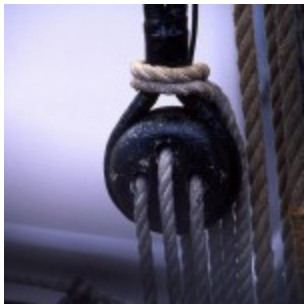
There are three different kinds of levers.

A first-class lever is a lever in which the fulcrum is located in between the effort and the load.

In a second-class lever, the load is between the fulcrum and the effort.

The third-class lever has the effort between the load and the fulcrum.

The Pulley



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Obviously, you can only make a lever so long. After a while it gets kind of ridiculous. Imagine lifting a concrete block or a car with a lever. That's a big lever and you probably still wouldn't be able to lift the car very high. This is where pulleys come in.

By the use of a pulley (otherwise known as a block and tackle), car mechanics lift 600 lb. car engines with one hand! Cranes that lift steel girders and thousand pound air conditioning units are basically pulleys! (By the way, Archimedes is credited with inventing the crane. He actually used a crane as a weapon to defend Syracuse from Rome. When the Roman ships got close to the Syracuse walls, Archimedes' crane would grab them and turn them over! Go science!)

Mechanical Advantage

The other thing I'd like to add here is the concept of mechanical advantage. The definition of mechanical advantage is that it is the factor by which a mechanism multiplies the force put into it. The whole idea behind simple machines is that they give you an advantage. In other words, they help you do things more easily.

The nice thing about pulleys is that it is very easy to see the mechanical advantage. You noticed when you used one pulley that it took about the same amount of effort to lift the load. That would be a mechanical advantage of one. However, when you used two pulleys, half the effort lifted the load. You only had to pull half as hard to lift the load. The pulleys doubled your strength. In this case, the mechanical advantage is two.

Can you guess what the mechanical advantage was of three pulleys? Yup, three. The pulleys tripled your strength. Who needs exercise when you have pulleys?

So, are you ready to do some weight lifting? The best way to learn about this is to actually try it out. Let's start on your experiments right now!

Highlights for Pulleys

The pulley is a very powerful simple machine.

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Flag poles, fishing rods, cranes, window blinds, and wishing wells all have pulleys.

The more pulleys that are rigged together, the more effective a pulley system can be.

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