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הטכניון
מכון טכנולוגי לישראל
Technion
Israel Institute of Technology

Physical Sciences: Energy

Learning Unit

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The project was initiated by:
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The project is sponsored by the American Technion Society

PHYSICAL SCIENCES: ENERGY

INTRODUCTION

This learning unit was developed as part of a project entitled: Adapting education in science and technology to the 21st century, a joint venture of the Technion, Israel Institute of Technology and the Abrams Hebrew Academy, a co-educational community Hebrew day school.

The learning materials include short video lectures that incorporate animations and colorful illustrations that explain and demonstrate scientific principles and concepts. They include closed questions and helpful hints for self-examination, and open-ended questions that encourage reflection and classroom discussions. The learning assignments encourage the understanding of scientific concepts represented in different modes such as: equations, graphs and tables. They combine critical thinking, argumentative reasoning, and inquiry-based learning although planning and implementing research-based laboratory activities.

This document contains learning materials for middle school students who are studying the subject of energy. The materials are intended to be used together with the online learning materials found at www.schoology.com. The materials are designed to conform to the Next Generation Science Standards for Middle School Physical Sciences (2013).

This learning unit was developed and written by Mr. Sam Ribnick.

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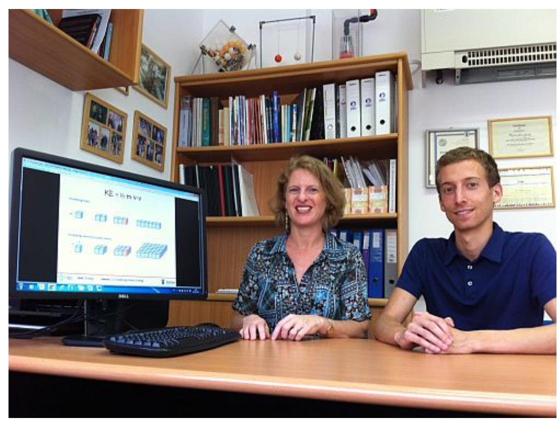


Assistant Professor Miri Barak and Sam Ribnick in the process of developing the learning materials. Photographer: Daniel Shapira

Chapter 1 What is Energy?

In this chapter you will learn about human activities that induce global changes, what fossil fuels are and their different types. You will learn about renewable energy sources. You will also learn about different forms of energy, energy transfer, and the law of energy conservation. We hope ypu will enjoy reading this chapter. For more explanations, go to www.schoology.com. There you can find lecture videos with thorough explanations and a series of questions that will help you test your knowledge.

1.1 Global Warming and Energy

Global warming is one of the most important scientific issues of our time. Understanding the science behind global warming is important to anyone who uses electricity, rides in a car or bus, or buys things in stores – in other words, almost everyone!

Global warming is about how the temperature of the Earth has is changing, and what will happen to the temperature of the Earth in the future. To understand the future, we can start by looking at the temperature of the Earth in the past.

Over the past 500 million years, the temperature of the Earth has fluctuated, meaning that it has gone up and down. There were times when the temperature was higher than today and times when it was lower.

Over the past 150 years, the temperature has started to go up. Nearly all scientists agree that this is because of human activity, and that the temperature will keep going up unless we make some changes (Figure 1.1)

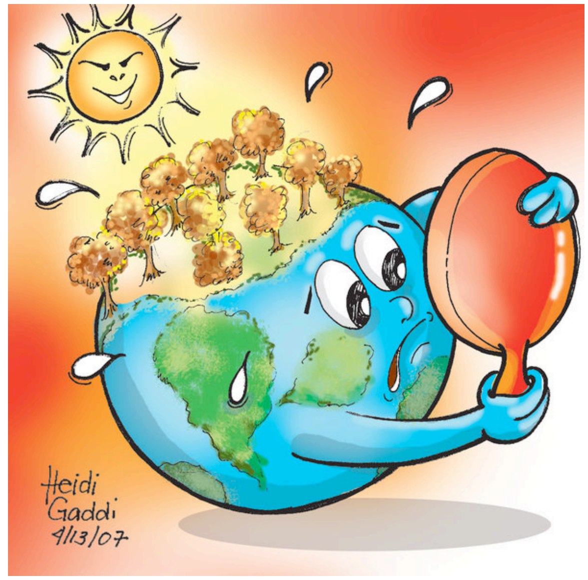


Figure 1.0 Global warming
Taken from http://adi1heidi2gaddi3.deviantart.com/art/the-effects-of-global-warming-53517162 under Creative Commons Attribution 3.0 License

The Industrial Revolution

Human activity only became a major cause of global warming about 200 years ago. Around that time, scientists and inventors in England created the very first engines that burned coal as fuel. This was called the Industrial Revolution, and led to the invention of steam boats, train engines, factory machines and much more. As the Industrial Revolution spread to America and other countries, humans started burning more and more coal, oil and gas as fuel for all these new inventions.

Today we are burning more fuel than ever before, and every year we use even more than we did the last year. We burn fuel in our cars, trucks and airplanes, and also in the power plants that make the electricity we use every day. The factories that make our things are burning huge amounts of fuel.

While some people disagree with scientists about what will happen to the temperature of the Earth, everyone agrees that the amount of fuel we burn will continue to increase in the future. This is because there are millions of people in different countries that are living in poverty today, but are striving to improve their situation. As people start buying more cars, bigger houses, and more things made in factories, the amount of fuel needed will continue to skyrocket.

What can we do about it?

Scientists worry that burning more fuel will make the problem of global warming even worse. To stop the temperature from rising too much, we need to do two things:

1. Use cleaner fuels
2. Use less fuel

Already, many people are trying to make changes to prevent global warming, by driving hybrid cars, using energy-efficient LED light bulbs and putting solar panels on their roof. All of these technologies are connected to the science of energy.

What uses fuel?

Some things require fuel in order to function, and some can function without using fuel. Here are some examples:

Need fuel

- Cars
- Fire
- Phone
- Sports
- Garden

Don't need fuel

- Desk
- Bottle
- Pin
- Window shades
- Blanket

Notice that even those things that can function without using fuel probably needed fuel for their production

Summary points:

- ***Over the past millions of years, the temperature of the Earth has fluctuated. This means that sometimes the temperature was higher, and sometimes it was lower.***
- ***Right now, the temperature is getting higher.***
- ***Scientists believe that this time, the temperature will keep getting higher, because humans are burning way more fuel than ever before. This adds heat and greenhouse gasses to the atmosphere around the Earth.***

1.2 Types of Fuels

We use many different types of fuels ever day, for our most basic needs like transportation and food. The most obvious example is the gasoline we put in our cars. Without the gasoline as fuels, the car cannot run.

Fossil Fuels

Cooking also requires fuel. Cooking in the kitchen usually uses gas, or cooking on a grill might use coal. These common fuels, coal, oil and gas, are called **fossil fuels**. Like fossils, they are found deep underground where they have been for millions of years.

Fossil fuels work very well as fuels, but they have two major problems. First, they create a lot of pollution when they burn. This pollution can make the air dirtier, causing health problems, and also contributes to global warming. Second, we only have a limited amount of fossil fuels. Fossil fuels need to be dug up from the ground, and as we use up all the easy-to-reach fuel, it will become more expensive and more difficult to dig up enough fossil fuels for all of our activities.

Electricity

We use electricity all the time for gadgets like microwaves, toasters, computers and television. Is electricity a fuel?

Think about where electricity comes from. A television needs to be plugged into the wall to get electricity. But where does that electricity come from? Every house must have power lines connecting it to a **power plant.** A power plant is a building where electricity is made using fuel. Most power plants in the US make electricity by burning coal, oil or gas – the fossil fuels.

Electricity is not exactly a fuel, but it is a way of carrying the energy from the power plant to the place where it is needed. When a television is running, it is using electricity that comes from a power plant, and that power plant must be using some sort of fuel. Even though it doesn't look like it, using the television requires burning fossil fuels and polluting the Earth.

Summary points:

- ***Many things that need fuel use fossil fuels, such as gasoline, coal, oil, and gas. These are chemicals that are found deep underground, like fossils.***
- ***Fossil fuels must be burned when you use them, and this releases a lot of pollution.***
- ***Electricity is important for many devices we use every day, but electricity isn't really a fuel. Electricity is made in a power plant that must use another kind of fuel, most likely fossil fuels.***

1.3 Renewable Energy Sources

Fossil fuels are very useful fuels, but they are also a major contributor to global warming. In order to use them, we must burn coal, oil or gas, and this releases a lot of pollution into the atmosphere. Also, we only have a limited amount of fossil fuels, so if we use them up too fast we will find ourselves with no fuels at all.

Fortunately, there are other forms of fuel that are cleaner, and that will never run out. These fuels are called "renewable fuels" or **renewable energy resources.** The most significant renewable energy sources are solar, wind, hydroelectric and geothermal. But before we discuss those, it's helpful to understand how we use the sun to make fuel for our own bodies.

Food Energy

Even if you don't have a house, a car, a phone or any other devices or tools that use fuel, you would still need fuel for your body. Every move we make requires a small amount of fuel, and over the course of a normal day we actually use quite a lot of fuel.

Our bodies use food as fuel. Though we also need air and water to survive, it is the food we eat that actually serves as fuel by providing energy for our body. Most of our food is made of either plants or animals. As other living beings, what do they use as fuel?

Animals get their fuel by eating either plants or other animals. Plants use the sun as a fuel to grow. Plants absorb water and nutrients from the ground, and carbon dioxide from the air, and then use the sun as fuel to process these raw materials.

Plants actually help slow the process of global warming for this reason. First of all, they take carbon dioxide (a polluting greenhouse gas) out of the air; second, their only fuel source is the sun, which adds no pollution to the Earth.

Solar Energy

Fortunately, humans have found many ways to use the sun as a fuel, just as plants do. Whenever we use energy from the sun, we call this **solar energy,** because the word "solar" means "related to the sun."

Solar panels are the most obvious way that use the sun as a fuel. Solar panels use energy from the sun's light to make electricity, which we can then use however we need. Before solar panels, humans would also use sunlight to heat up food or water outside. Even today, in Israel and many other countries, people put their water heater tanks on the roof of their buildings so that the energy from the sun can heat the water.

Photovoltaic cells (the technical name for solar panels) are improving rapidly thanks to engineers and researchers around the world. Still, in the near future, solar panels are not yet cheap or efficient enough to be our main fuel. As technology improves, solar panels could be a promising option for the future.

Is Light a Fuel?

Sun light provides the energy for nearly all living things on Earth. It seems like light should be counted as a fuel.

However, it makes more sense to think of light as a way of carrying energy from place to place, like electricity, and not as a fuel. A fuel should generally be an energy source, a place where the energy comes from. The sun is an energy source, but the light that comes from the sun simply carries the energy from the sun to the Earth.

Some scientists would say that light *is* an energy source, and this isn't completely wrong. It's simply more useful to think of light as carrying energy *from* an energy source.

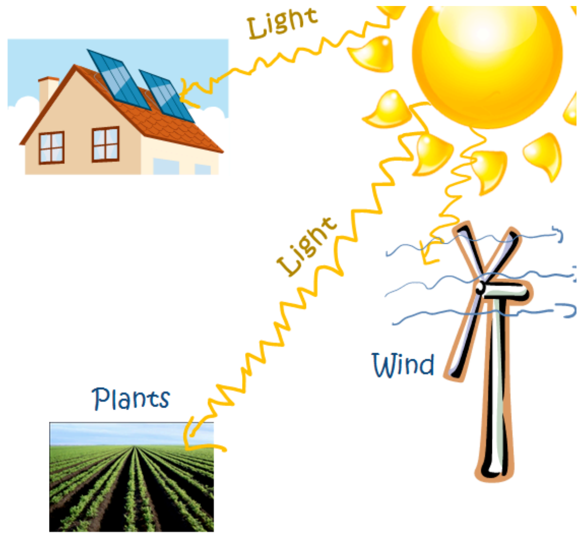


Figure 1.0 Energy from the sun is carried to the Earth by light

Figure 1.2 shows how energy from the sun is carried to the Earth by light, providing energy for plants to grow and for solar panels to heat water. The sun also affects wind power, which you can learn more about in the next chapter.

Wind Energy

Surprisingly, windmills and wind generators also get their energy from the sun. A wind generator is a machine that makes electricity from the wind. But why does wind exist in the first place?

Wind happens because sunlight heats up different areas of the atmosphere in different amounts. As these hot and cool air pockets shift around, we feel this as wind. So even wind energy comes originally from the sun!

As with solar energy, wind energy is still too expensive to be used as our primary energy source. Many people also argue that in order to have enough wind energy, we would need to put many windmills in beautiful natural settings. While they do not pollute, not everyone wants to look at their view and see windmills where there was once only nature.

Hydroelectric Energy

Hydroelectric power plants use the movement of flowing water to turn the wheels of a generator and make electricity. In order for hydroelectric power stations to work, there needs to be a place where water flows downhill, usually either at a human-made dam, or a waterfall. In either case, it requires that water is constantly flowing down from somewhere higher.

The water gets to these higher places because water in lower areas is evaporated by heat from the sun, and this water rises up to form clouds, and eventually rain or snow that can flow downhill again. The sun plays a crucial role in this water cycle, because the water would not be able to evaporate and move back up to the higher areas without the sun as an energy source.

Hydroelectric energy faces some of the same challenges as wind energy. It is still relatively expensive, and also requires building large dams or other structures on rivers. This can spoil the natural view, and also interfere with the ecosystems of animals living in or near the river.

Geothermal Energy

Geothermal energy is the one source of energy that is completely independent from the sun. If we ran out of fossil fuels and the sun stopped providing energy to the Earth (which won't happen for billions of years), geothermal would be our only option.

Geothermal energy is the energy that comes from the natural heat inside the Earth. The word is made up of two parts that represent this: "geo" means rock or ground, as in geography or geology. "Therm" means heat, as in thermometer.

Like the other renewable energy sources, we can use geothermal energy nearly forever without running out. Like the others, it is also a very clean energy source, as it does not require burning anything or polluting.

Figure 1.0 A geothermal power plant
Shared under Creative Commons from http://commons.wikimedia.org/wiki/ ile:NesjavellirPowerPlant_edit2.jpg

Geothermal is a very practical energy source in some areas of the world, where the geology of the Earth means that the heated layers are close to the surface. For example, Iceland has many geothermal "hot spots" where you can even see steam rising from the ground. As a result, Iceland heats about 85% of its homes with geothermal energy. It also uses the geothermal energy for industry. Figure 1.3 shows a geothermal power plant in Iceland that takes advantage of a natural geothermal heat source to provide clean energy. What looks like smoke coming from the stacks is actually clean steam from boiling water.

Unfortunately, most countries do not have such easy access to geothermal energy, so it is not cost-effective as a worldwide solution.

Using Renewable Energy Sources

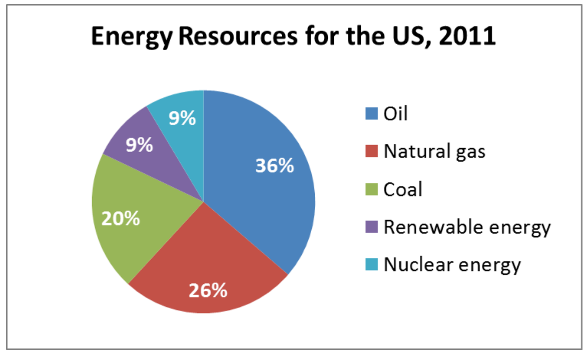


Figure 1.0 Energy sources for the United States
Data from U.S. Energy Information Administration, Annual Energy Review 2011, Tables 1.3, 2.1b-2.1f , 10.3, and 10.4.

The US currently uses fossil fuels (oil, natural gas, and coal) for the vast majority (more than 80%) of its fuel needs (Figure 1.4). Fossil fuels are very cheap and effective energy sources, but they come with many problems. The pollution from fossil fuels not only harms the people and nature around the power plants where the fuels are burned; they also contribute to global warming. Besides the problems of pollution, we also have only a limited amount of fossil fuels that can run out. We probably have enough to last 50 years or more, but sooner or later we will need alternatives.

Renewable energy sources (solar, wind, hydroelectric and geothermal) all hold promise for the future, but none of them is quite ready to become our main energy source today. As people across America acknowledge the risks of global warming, one of the big challenges is finding an energy source that can replace fossil fuels. Fortunately, the more students become energy scientists in the future, the better the chance of developing a technology that can help solve the problem. We hope that in the future, you will be part of a team of scientists and engineers that will find an efficient way for utilizing renewable energy.

SUMMARY POINTS:

- ***Solar panels use the sun as a fuel. They get energy from the sun and make electricity.***
- ***Wind power also gets its energy from the sun, because wind is caused by heat from the sun.***
- ***Geothermal energy uses heat from inside the Earth to create electricity. It's like using the heat from lava deep underground.***
- ***Because the sun will be around for billions of years, and it doesn't make pollution, it is a much better energy source than fossil fuels. However, fossil fuels are still much cheaper than renewable energy sources. In the future, scientists may develop technology to change that.***

1.4 FORMS OF ENERGY

Understanding fuels is all about seeing where energy comes from. The next step is to understand the many places and forms that energy exists in the world around us. Energy can take many different forms, and it's important to be able to recognize them so that you can tell when an object has energy.

In this course, we will focus on five main forms of energy: kinetic energy, gravitational potential energy, elastic potential energy, thermal energy and chemical energy (Figure 1.5). Each form of energy will be presented in a chapter where it will be explained and detailed; for now it is enough to understand just the definition and a few examples of each.

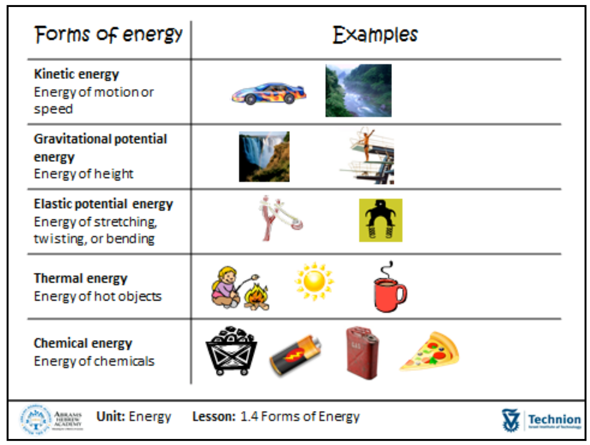


Figure 1.0 A list of five important forms of energy.

Kinetic Energy is the energy of motion or speed. Any object that is moving has kinetic energy. For example, a moving car, a basketball being passed, a flowing river, or even the blowing air in the wind all have kinetic energy.

Gravitational potential energy is the energy related to an object's height. When an object is high off the ground, it has the *potential* to fall and start moving because of gravity, so we say it has gravitational potential energy. For example, a box on a high shelf, a diver on a tall platform, or water at the top of a waterfall all have gravitational potential energy.

Elastic potential energy is the energy of an object that is bent, stretched, squeezed or twisted out of its usual shape that will naturally return to that shape. For example, when you squeeze a spring, stretch a rubber band, or wind up a toy car, those are all cases with elastic potential energy.

Thermal energy is the energy related to the heat of objects. For example, a campfire, the sun or hot coffee all have thermal energy. In fact, even cold objects like an ice cube still have some thermal energy, they just have less (after all, while an ice cube is cold, it is hotter than *some* things, so it must have more thermal energy than zero).

Chemical energy is the energy stored in chemicals. For example, all fossil fuels have chemical energy. Our food that we eat has chemical energy, because even natural food is still made from chemical bonds between carbon, oxygen and other elements.

Identifying when an object has energy

An important part of thinking like an energy scientist is being able to look at the world and see when objects have energy. By understanding where the energy is in a situation, you can make better predictions about what will happen next.

One strategy for identifying energy is to consider each object in a situation and ask yourself if it fits any of the five forms of energy listed here. By going through the list, you can be pretty sure that you'll notice if an object has energy.

You can also use another strategy to help you identify when an object has energy. As a general rule, the more energy an object has, the more harm or damage it can cause. This rule isn't true 100% of the time, but it's a good way to notice when an object has energy and even to tell which object has more or less energy. Generally, the more damage something can cause the more energy it has.

Practice Examples

For the examples below, identify whether the object has energy or not, and if so, what type or form of energy. Use the two strategies above to help.

Example 1: A mousetrap

Figure 1.0 A loaded mousetrap, ready to spring. Does it have energy? If so, what form?
Image shared under Creative Commons from http://commons.wikimedia.org/wiki/File:Victor-Mousetrap.jpg

The mousetrap in Figure 1.6 is loaded and ready to spring on a mouse (or a person, if they aren't careful!). Does the mousetrap have energy? If so, what form?

Answer: First, we can tell that the mousetrap definitely can do some harm or damage, and this is a sign that it does have energy. Next, let's try to identify what form of energy it has.

When it springs, it will be moving so it would have kinetic energy, but it is not moving yet. The best match for this situation is elastic potential energy, because the spring is twisted out of its normal shape, and the reason the mousetrap works is because the spring will snap back into shape if it has the chance.

The mousetrap has energy, and the form is elastic potential energy.

Example 2: A heavy box on the ground

Does a heavy metal box sitting on the ground have energy? If so, what form?

Answer: The first question is whether the box can cause any damage. If it is sitting on the ground, it doesn't seem like it could do much damage at all, so it seems like it does not have energy.

Additionally, if we look through the five forms of energy, we find that the box on the ground does not meet the definition for any of the five forms. It does have some thermal energy because it might be at a normal warm temperature, and it has some chemical energy because, like everything, it is ultimately made out of chemicals. Strictly speaking, you could say it does have thermal and chemical energy, but it doesn't really have a *usable amount* of energy.

This example shows that pretty much everything has at least *some* energy, but we are usually interested in finding objects that have significant amounts of energy because these are the objects that can be used as energy sources to make something happen!

Example 3: A fully charged battery

After you charge up a battery, does it have energy? If so, what form?

Answer: First, we know that a battery has the ability to cause damage. It can be used to power a tool or device that could cause damage, and a battery can even cause harm on its own. Want to test this? Touch a nine-volt battery to your tongue and you will feel a small (but safe) electric shock!

What form of energy? You might be tempted to say electrical energy, but remember that electricity isn't really a fuel or a form of energy, just a way of carrying energy from place to place. To determine the form of energy, think about what is inside a battery that gives it energy. If you have ever seen a battery leak, you know that it has chemicals inside (often called battery acid) that make it work. Thus a battery has chemical energy.

1.5 Energy Transfer

We have seen how to identify when an object has energy. The next step is to learn to identify when energy is being transferred or moved around during an activity. Often when two objects *interact*, the result is that energy is *transferred* or moved from one object to the other.

Thinking Like an Energy Detective

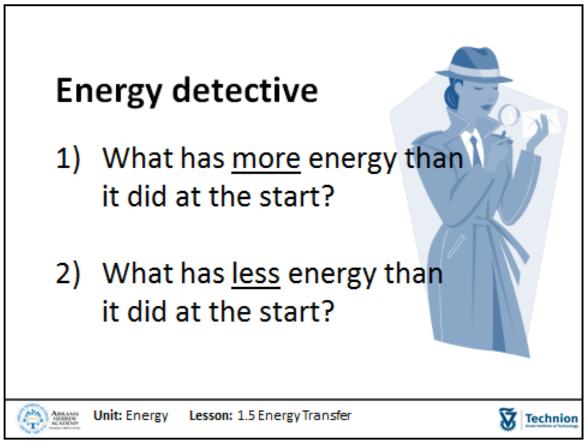


Figure 1.0 Think like an energy detective

To identify energy transfer, you should think like an energy detective. When you see something changing, you should ask yourself two questions that are presented in Figure 1.7. Thinking like an energy detective takes some practice, but it is not much more difficult than identifying objects with energy, as you did in the previous section. An example will help illustrate the thought process.

Example 1: Gas stove heating water

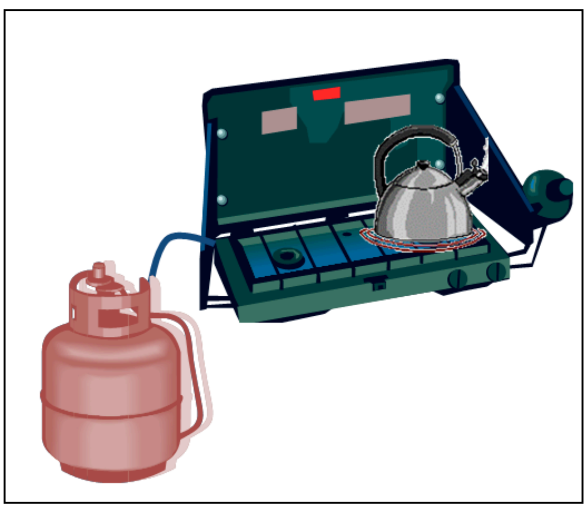


Figure 1.0 A full gas tank acts as fuel for a stove as it heats a pot of water.

Figure 1.8 shows a full tank of natural gas connected to a camping stove that will heat a pot full of water. The water is cool at the start, and after some time on the stove, the water heats up enough to boil.

During this interaction, we want to understand how the energy was moved or *transferred.* We can understand the situation by asking ourselves two questions:

1) **What has <u>more</u> energy than it did at the start?**

   The water in the pot has gained thermal energy, so it has more energy than it had at the start.

2) **What has <u>less</u> energy than it did at the start?**

   The gas tank is not full anymore, so it has less gas. Because the gas has chemical energy, this means the gas tank has less chemical energy than it did at the start.

From these two questions, we can now see that energy was transferred *from* the gas tank *to* the water in the pot. Notice that the energy is in two different forms: it starts as chemical energy and ends as thermal energy. This happens thanks to an in-between step of the process: when the gas is burned in the stove.

The most important thing to see in this situation is that energy has been moved or *transferred* from one object to another as a result of the process.

Example 2: Electric stove heating water

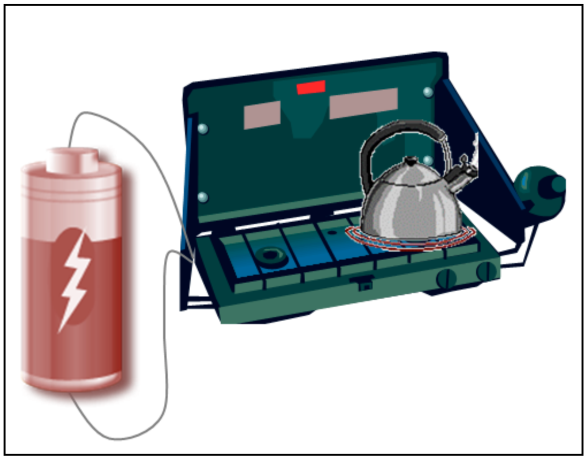


Figure 1.0 A full battery acts as fuel for an electric stove.

Figure 1.9 is very similar to the previous example, only this time we have an electric stove that uses a battery as fuel, rather than a gas tank. The thinking is very similar as well:

1) **What has <u>more</u> energy than it did at the start?**

   The water in the pot has gained thermal energy, so it has more energy than it had at the start.

2) **What has <u>less</u> energy than it did at the start?**

   The battery has less chemical energy than it did at the start.

From these two questions, we can see that energy was transferred *from* the battery *to* the water in the pot.

Example 3: Slingshot shooting a ball

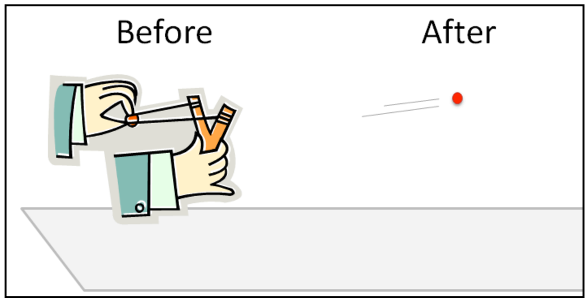


Figure 1.0 A ball held in a loaded slingshot is then launched.

In Figure 1.10 a person places a ball into a slingshot and stretches the rubber back to hold the ball ready to launch. The person releases the ball and it flies straight across the room. How has energy been transferred in this situation?

1) **What has <u>more</u> energy than it did at the start?**

   The ball has gained kinetic energy because it is now moving, when it was not at the start.

2) **What has <u>less</u> energy than it did at the start?**

   The rubber in the slingshot has lost elastic potential energy because it was stretched at the beginning and now it is relaxed.

The energy was transferred from the stretched rubber of the slingshot to the ball. Interestingly, we can also look one step earlier and one step later and see even more energy transfers.

Looking earlier, in order to stretch the rubber of the slingshot in the first place, energy was transferred from your arm to the rubber as your arm did the work to pull it back.

Looking later, when the ball hits its target, the kinetic energy of the ball will be mostly transferred to the target, so the energy is passed on again. Many situations work this way, with a series of energy transfers linked together.

Summary points:

- ***Whenever one object is gaining energy, there must be another object losing energy.***
- ***By looking at the before and after situations, you can see how the energy was transferred to make something happen.***

1.6 Law of Conservation of Energy

As scientists developed their understanding of energy, they noticed an important pattern developing in situations with energy transfer. The amount of energy lost from one object is always equal to the amount of energy gained elsewhere. In other words, while the energy can move around, the total amount stays constant.

This is known as the **Law of Conservation of Energy,** and it can be explained in a few different ways that all say the same thing:

- All energy must come from somewhere, and all energy must go somewhere.
- Energy can never be created, and can never be used up or destroyed.
- When energy moves around or changes forms, the total amount must always stay the same.

In some situations, this conservation can be very obvious. For example, when the energy of natural gas is transferred to the water to heat it, it makes sense that the amount of energy you take from the gas is the same as the amount you add to the water. In other situations, it can be more difficult to see how the total amount of energy is staying the same, such as when your phone's battery runs out. In this case, where has the energy gone? We will answer this question using an analogy.

An analogy between energy and money

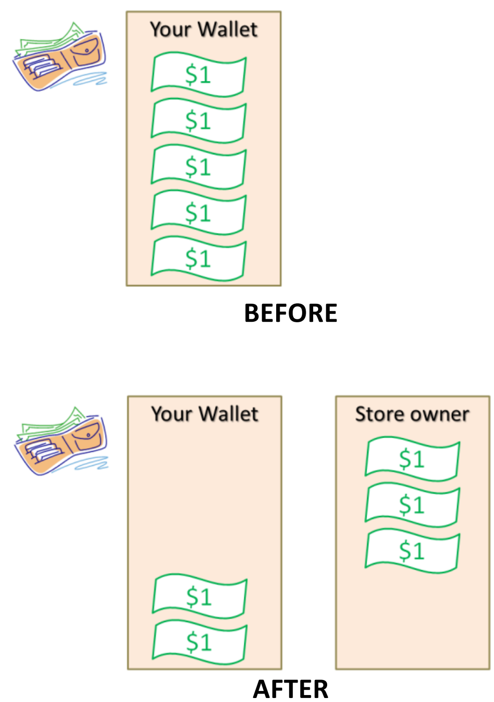


Figure 1.1 Before: You start the day with $5 in your wallet. After: You have spent $3, but the total amount of money between you and the store owner is still $5, so the total is conserved.

Imagine you start the day with five one-dollar bills in your pocket. At lunch time, you decide to spend some money on a slice of pizza and a drink. You pay take three dollars from your wallet to pay. At first glance, it seems like those three dollars have disappeared. You started the day with five dollars and now you have only two (Figure 1.1).

But if we look at the bigger picture, we see that the five dollars still exist after all. If you count the money from both your wallet and the store owner, you will find all five dollar bills, just as at the start. In this case, we can say that the amount of money was *conserved*, meaning kept constant.

In fact, no matter how much these five dollars are moved around or spent or transferred, those five dollars still exist somewhere in the world! This is exactly how it works with energy: no matter how much energy is moved around, the total amount still stays the same. This is the law of conservation of energy.

(By the way, the analogy with money isn't perfect, because it's possible for a government to print more money or for someone to put money through a shredder to destroy it. Energy can never be created or destroyed. The key idea from the analogy is that whenever one object loses energy, that energy must still be somewhere else. You just have to know where to look!)

This also explains why we can say that *fuel* is used up, even when energy can never be used up or disappear. Fuel is like the money in your wallet. Fuel has energy that is useful *for you.* When you burn fuel, you use up the fuel because you no longer have the stuff that is so useful for you. But the energy from the fuel hasn't been used up; it's simply moved to somewhere else.

Summary points:

- ***Scientists have noticed a pattern for any time energy moves around:***
- ***All energy must always <u>come from somewhere</u>***
- ***All energy must always <u>go somewhere</u>***
- ***This means that energy can never be created or used up.***
- ***When it looks like energy is being used up, it is actually just moving to a different place. It's like when you spend money. The money is not used up, it just leaves your wallet and goes to the store - but all the money is still there!***

1.7 Energy Transfer, Transformation and Dissipation

There are three basic ways that energy can move around and change. Fortunately, they all have simple analogies with money so they will be easy to understand.

Energy Transfer

Energy transfer is the movement of energy from one object to another. For example, when a tennis racket hits a ball, energy is *transferred* from the racket to the ball. When a car burns gasoline, energy is transferred from the gasoline to the car.

This is analogous to passing money from one person to another. If you start with $12 and pass $9 to Joe, then you have transferred the money to Joe. He could then transfer some of that money to his friend Sara (Figure 1.12).

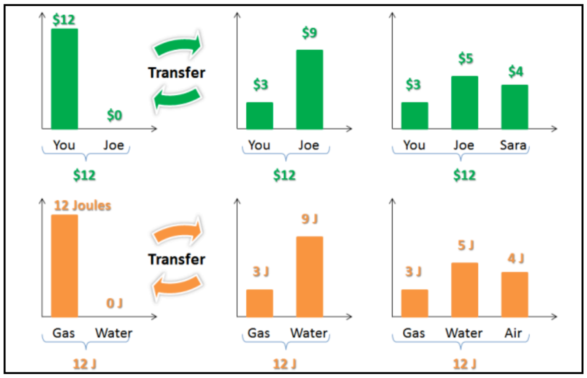


Figure 1.1 Money transfer (green) is an analogy for energy transfer (orange)

Similarly, after the energy was transferred from the racket to the ball, if the ball hits a cup of water some of the energy will be transferred from the ball to the cup. Notice that the *total* amount of energy must always stay the same, even if some of the energy is with one object and some with another object.

Energy Transformation

Energy transformation is when energy changes from one form to another. For example, when water falls from a high cliff, the potential energy of the water is *transformed* into kinetic energy as it speeds up during the fall. Sometimes this is called energy *conversion*; it means the same thing.

Transformation (or conversion) can sometimes happen at the same time as transfer. For example, when a car burns gasoline as fuel, the energy is *transferred* from the gasoline to the car, and it is *transformed* from chemical energy to kinetic energy.

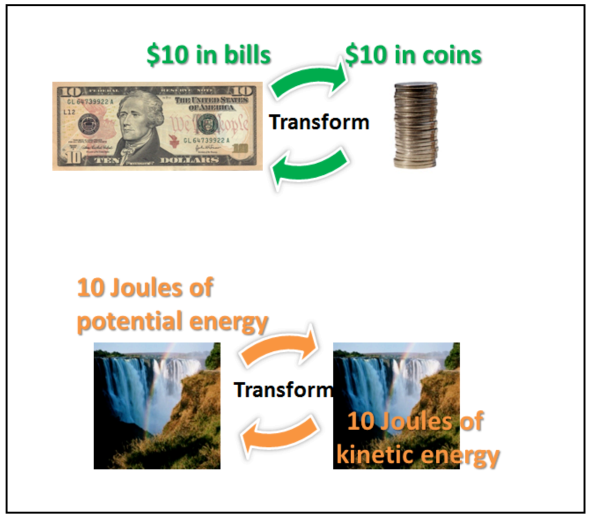


Figure 1.1 Money can be transformed (green) as can energy (orange)

In analogy with money, imagine that you start with a ten-dollar bill and you go to a bank to change it into ten dollars' worth of quarters. You still have ten dollars; it is simply in a different form than before (Figure 1.13).

Similarly, when energy is transformed, even though the form changes, the total amount of energy always stays the same.

Energy Dissipation

To understand conservation of energy in the real world, it is especially important to understand energy dissipation. **Energy dissipation** is the process of energy spreading out to the environment as heat (thermal energy). Ultimately, all energy that we use ends up being dissipated as heat.

When you charge your cell phone, you are transferring energy from a power plant, through the electrical wiring, into the battery of your phone. When the phone runs out of battery charge, the energy in the battery has been *dissipated* into the surroundings as heat. You can actually feel this process. When a phone is working, you can often feel it heat up, especially when it is doing something complicated like playing a video, and using energy from the battery more quickly.

Dissipation comes up almost every time we use energy. When your car burns gasoline, the energy is transformed into kinetic energy, but eventually the car comes to a stop. Where has the energy gone? It has been dissipated as heat that spread out to the environment, which you can observe if you touch the hood of the car after it has been running.

When you have a cup of hot coffee, it has a lot of thermal energy. After it sits on the table for an hour, it has less thermal energy. Where has the energy gone? It has been dissipated into the surroundings, as the heat from the coffee spread out into the air.

In the analogy with money, this is like taking the ten dollars in quarters and giving one quarter to many different friends. After you have passed out all the quarters, the ten dollars still exists, but it is spread out to the environment. It is no longer useful to you or anyone else, because it has been so spread out.

Similarly, when energy is dissipated, the total amount of energy has stayed the same, but the energy is much less useful. A gallon of gasoline can be used to power an engine, but once the energy has been dissipated as heat from the engine, the energy isn't useful for much, even though it does still exist in the environment.

Energy dissipation is a one-way process. It cannot be reversed. Just like you couldn't really collect the ten dollars in quarters from all your friends again, energy that has been dissipated as heat cannot generally be recaptured. This is different from transferring or transforming energy; both of those processes can often be reversed (though not always).

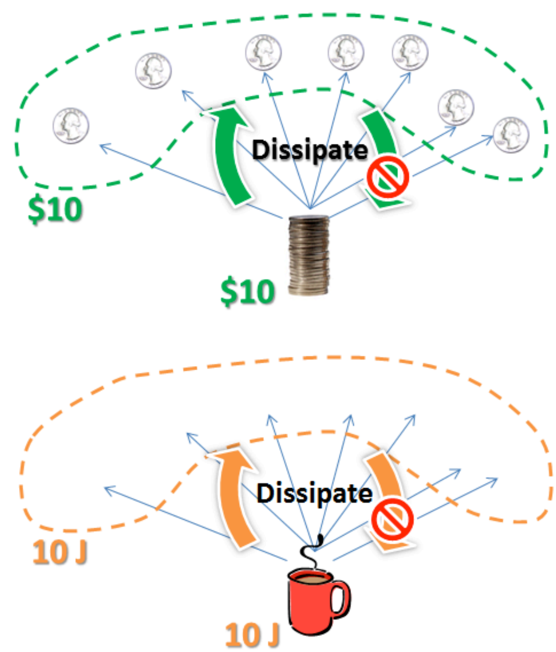


Figure 1.1 Money can be dissipated (green) as can energy (orange)

Energy dissipation is taking place constantly, in nearly every activity that uses energy. Even when energy is being transferred or transformed, some portion of the energy is being dissipated. When your car burns gasoline, only about 30% of the energy from the gasoline is used as kinetic energy for the car (and then eventually dissipated). The other 70% is immediately dissipated without ever doing anything useful at all!

One big way that we can reduce our energy needs is by reducing the useless dissipation from machines and devices that we use, so that a higher percentage of the energy is actually used. This is the reason for the move to new lightbulbs. New compact-fluorescent bulbs are about three times as efficient as old-fashioned bulbs, and LED bulbs can even be five times as efficient. This means more energy is used for lighting and less energy is wastefully dissipated as heat.

Summary Points

- ***Energy can move and change in many ways, but remember that the total amount of energy must always stay the same!***
- ***Energy Transfer:*** *moving energy from one place or object to another place or object. Example: A baseball bat gives some of its kinetic energy to a ball when you hit the ball.*
- ***Energy transformation:*** *Changing energy from one form to another form. Example: A diver starts with gravitational potential energy when she is up high. As she dives and moves faster, the energy is transformed to kinetic energy.*
- ***Energy dissipation:*** *When energy spreads out as heat (thermal energy). Example: A cell phone has chemical energy stored in the battery, but as it runs the phone heats up and the energy is dissipated as heat given to the surrounding air.*
- ***Energy transfer and transformation can sometimes be reversed, but energy dissipation only goes one way. Once the thermal energy spreads out, you can't bring it back. The energy still exists, but it's no longer useful.***

1.8 Energy and Global Warming

With your new knowledge of energy, you are now able to understand much more of the science behind global warming. The story of global warming essentially can be told with two graphs.

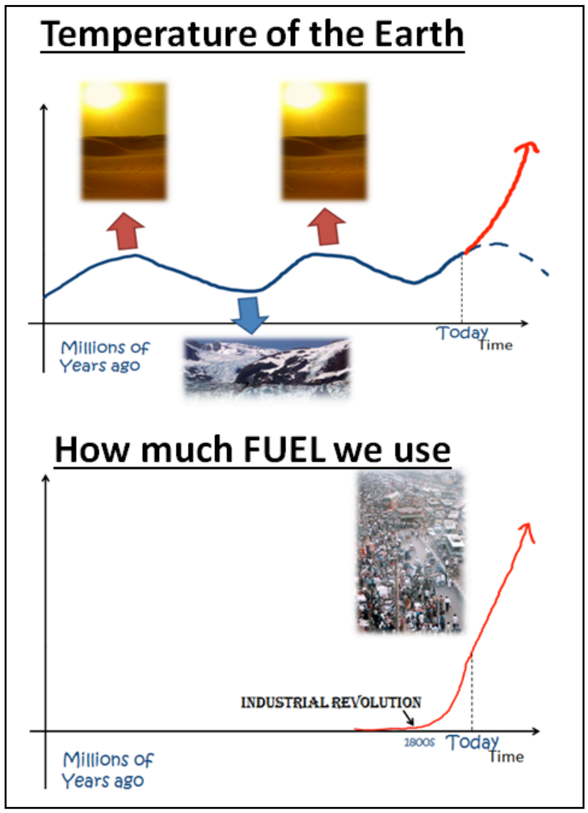


Figure 1.1 The two graphs that explain the story of global warming

The temperature of the Earth has fluctuated up and down throughout millions of years of history, passing through hot eras and ice ages (Figure 1.15). In the last century, we have seen temperatures on the rise, and some indicators that this time the temperature will only keep rising.

The main reason scientists expect temperatures to keep rising is because of the link between temperature and fossil fuels. Burning fossil fuels adds heat to the environment and pollutes the atmosphere with greenhouse gasses such as carbon dioxide, methane and others. Throughout history, scientists have seen that when the temperature of the Earth was higher, the amount of greenhouse gasses in the atmosphere was also higher. This evidence suggests a link between temperature and greenhouse gasses.

Our fuel usage is the second part of the story (Figure 1.15). After the Industrial Revolution, countries like England, the US and others began using enormous amounts of fossil fuels as energy sources for factories, cars, trains and power plants. Burning fossil fuels dissipates thermal energy into the atmosphere and releases greenhouse gasses. If we want to stop global warming, we must reduce the amount of greenhouse gasses and heat. But this will be extremely difficult because billions more people are starting to go through their own Industrial Revolution, and will be soon using as much energy as people in countries like the United States.

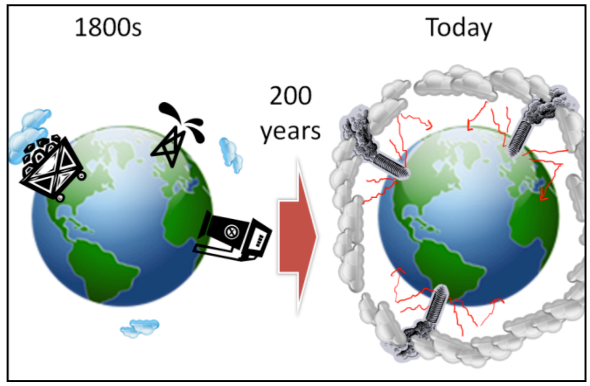


Figure 1.1 Greenhouse gasses act like a blanket that traps in thermal energy

In just two hundred years, we have completely transformed the Earth by burning huge amounts of fossil fuels. The greenhouse gasses in the atmosphere act as a giant blanket (Figure 1.16), trapping in the thermal energy that comes from the sun or dissipated from burning fuels.

To turn things around, we will need many new technologies and strategies to reduce our fuel usage, and especially our reliance on fossil fuels. As you learn more about energy, you can join the ranks of scientists around the world who are working hard to stop global warming and create a better future.

Problems and Questions: What is Energy?

1. Global warming (or climate change) has many effects on the Earth. Which of these is an effect of global warming? There is more than one right answer, so circle all that apply.

   a) More extreme weather
   b) Rising temperatures
   c) Animals or plants becoming extinct
   d) Areas turning into deserts
   e) More asteroids hitting the Earth

2. Which of these activities require fuel? There is more than one right answer, so circle all that apply.

   a) A shelf holding a book
   b) Window shades blocking the sun
   c) Driving in a car
   d) Charging a phone

3. Scientists who study global warming have studied how the temperature of the Earth has changed over the past millions of years. Based on the evidence, scientists believe the temperature...

   a) ...has gone up and down over millions of years
   b) ...has been rising for millions of years
   c) ...has stayed the same for millions of years
   d) ...has been falling for millions of years

4. **Fill in the blanks:** For most of history, humans have used very little ____________. However, starting with the ____________ ______________, we started to build machines and factories, so our use went up. In the future, with billions of people buying cars and houses, humans will be using even more than ever before, so we expect the temperature of the Earth to ____________ .

5. Which statements are true about fossil fuels? There is more than one right answer, so circle all that apply.

   a) They are found deep underground
   b) They are all chemicals
   c) They are good for the environment
   d) They can run out if we use them all up
   e) Some examples are coal, oil and gas

6. **Fill in the blanks from the choices below:** A power plant is a building where you burn ______________, and use the ______________ to make ______________.

Word bank:

Toaster	energy	barbecue	
Electricity	power lines	car	fuel

7. Why isn't electricity considered a fuel?

a) Because all fuels must be dug up from the ground
b) Because only some devices can use electricity, but things like a barbecue or car cannot use electricity
c) Because the only fuels are coal, oil, gas and gasoline
d) Because a fuel is an energy source, and electricity only carries energy from place to place

8. Which is the best explanation for how a microwave uses fuel?

a) You burn coal in your house to run the microwave
b) The microwave uses electricity that is made in your wall
c) Food is the fuel required to run a microwave
d) The microwave uses electricity, and the electricity is made from burning fossil fuels

9. For each item on the list below, decide if it uses fossil fuels or not.
Y = Yes, uses fuel
N = No, does not use fuel

___Running your refrigerator
___Driving a car
___Grilling hamburgers
___Getting a suntan
___Reading a book you already own
___Charging your phone

10. Which of the following can be an energy source (fuel) for animals? Circle all that apply.
a) Animals
b) Plants
c) Sunlight

11. Which of the following is the typical energy source (fuel) for plants? Check only one answer.

a) Animals
b) Plants
c) Sunlight

12. Match each activity to the energy source that would most likely be used by drawing a line between them.

• Growing strawberries	• Fossil fuels in a power plant
• Lighting a room with a lamp	• Gasoline
• Driving a car	• Grass
• Raising a cow	• A giant plate of pasta
• A person swimming across a lake	• The sun

13. What are some advantages of renewable energy sources compared to fossil fuels? There is more than one correct answer so circle all that apply.

a) They pollute less and emit fewer greenhouse gasses
b) They don't add as much heat to the Earth
c) They are more expensive
d) They will last much longer

14. Which of these fuels listed below are examples of renewable energy sources? There is more than one correct answer so check all that apply.

a) Wind
b) Coal
c) Oil
d) Geothermal
e) Gas
f) Solar

15. Who am I? The hints below describe an idea from the videos. Read the hints and write your answer at the end.

- I am not a fuel or a source of energy.
- I am a useful way of carrying energy from one place to another.
- I am made in a power plant, using some kind of fuel.
- You use me when you use a microwave, a computer or a phone.

Who am I? ____________________

16. Match the correct form of energy to each explanation given below.

Forms of energy: Chemical energy, thermal energy, kinetic energy, gravitational potential energy, elastic potential energy.

________________ The energy stored in chemicals

________________ The energy of motion or speed

________________ The energy of hot objects

________________ The energy of something bent, stretched or twisted

________________ The energy of something high up

17. For each example, match it with the main form of energy that it has. (if you think it has more than one kind of energy, pick the form that fits the best)

Forms of energy: Chemical energy, thermal energy, kinetic energy, gravitational potential energy, elastic potential energy.

________________ Gasoline

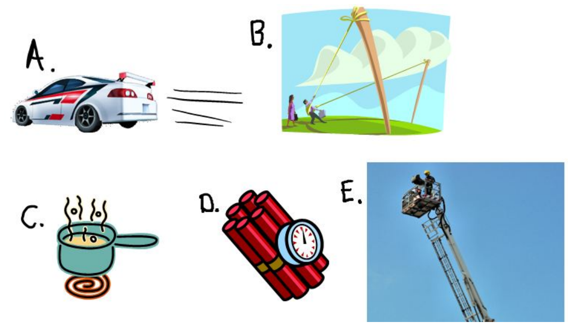
________________ A fast baseball pitch

________________ A stretched rubber band

________________ Hot water

________________ A box on a high shelf

18. For each example, match it with the main form of energy that it has. (if you think it has more than one kind of energy, pick the form that fits the best)



Forms of energy: Chemical energy, thermal energy, kinetic energy, gravitational potential energy, elastic potential energy.

a) ______________________
b) ______________________
c) ______________________
d) ______________________
e) ______________________

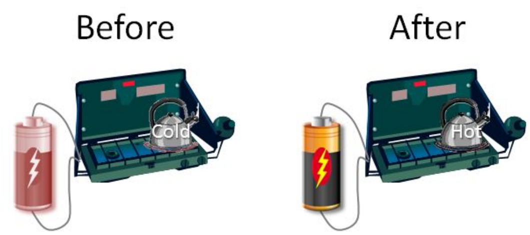
19. A battery's energy is an example of which form of energy?

a) Chemical energy
b) Thermal energy
c) Kinetic energy
d) Electrical energy

20. Which of the following objects have thermal energy? There is more than one right answer, so circle all that apply.

a) A cup of hot coffee
b) A campfire
c) A tub of ice water
d) A person's body

21. The battery is fully charged at the start, and is used to power the stove and heat the water. As an energy detective, you are trying to answer this question:

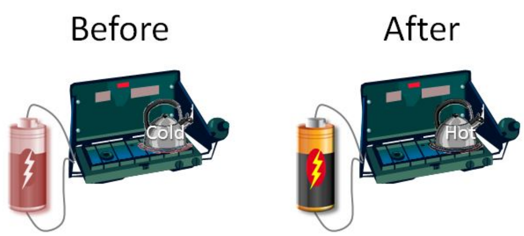


What has **lost** energy during this process?

Which is the best answer:

a) The battery has lost chemical energy
b) The stove has lost electrical energy
c) The water has lost thermal energy
d) The water has lost chemical energy

22. The battery is fully charged at the start, and is used to power the stove and heat the water. As an energy detective, you are trying to answer this question:

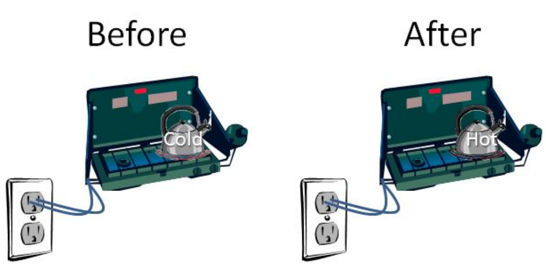


What has **gained** energy during this process?

Which is the best answer:

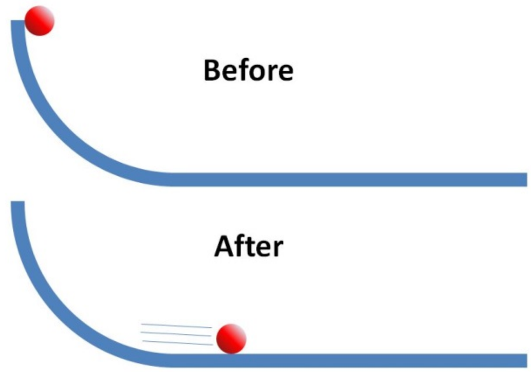
a) The battery has gained chemical energy
b) The water has gained thermal energy
c) The water has gained chemical energy
d) The stove has gained electrical energy

23. In this example, we can see that the water will gain energy during this process. We need to figure out what will lose energy during this process. Pick the best answer from the choices below:



a) The electricity has less thermal energy
b) The fossil fuels at the power plant have less chemical energy
c) The outlet has less electrical energy
d) The power plant has less kinetic energy

24. The diagram shows a ball starting at rest (not moving) at the top of the ramp, then rolling down and gaining speed until it is moving quickly across the flat part of the ramp.



In this case, the ball has energy at the start and energy at the end, but it is only the form of energy that changes. Which statements about the ball's energy are true? There are exactly two correct answers, so circle both.

a) The ball has lost gravitational potential energy
b) The ball has gained gravitational potential energy
c) The ball has gained kinetic energy
d) The ball has lost kinetic energy

25. In a campfire, wood serves as the fuel, or energy source. This means that as the wood is burned up, the energy of the wood decreases. When the wood has burned up completely, what has gained energy from this process?

a) Other wood has gained chemical energy
b) The wood has gained gravitational potential energy during the process

c) The ashes have gained elastic potential energy
d) The environment around the campfire has gained thermal energy

26. Which of these rules is true about energy? There is more than one right answer, so circle all that apply.

a) Energy can never disappear altogether
b) Energy must always come from somewhere
c) Energy can never be moved around
d) When you use energy, that energy is gone forever
e) Energy can be created from nothing
f) Energy must always go somewhere

27. Think about the analogy between spending money and using energy. Match each part of the story about money with the analogous (similar) part of the story about energy.

_____ At first your wallet has five dollars

_____ You spend $3 on pizza and soda

_____ The store owner gains $3

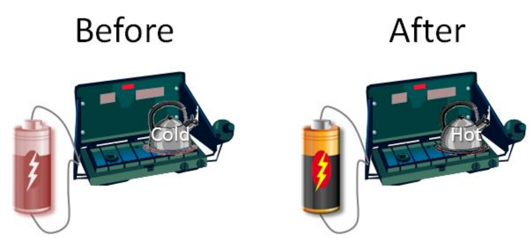
_____ The total amount of money at the end is still five dollars

_____ The $3 weren't used up, they just aren't in your wallet anymore

Match these answers to the blanks above:

a) To start, the battery has a full charge of chemical energy
b) The battery has less energy that you can use, but the energy wasn't destroyed
c) The combined energy of the water and the battery at the end is the same as at the start
d) The water gets energy from the battery and heats up
e) Some of the battery's energy is used to heat the water

28. In this diagram, a battery is connected to a stove in order to heat up the water. Which statement is true about this situation?



a) The stove creates energy as it heats the water
b) The energy flows from the battery to the water
c) The chemicals from the battery flow into the water
d) The battery's energy disappears

29. Imagine that you could add up all the energy everywhere in the universe and write down that amount. Then you wait 1 billion years. Stars are born, planets die, and galaxies change. You add up the all the

energy in the universe again, and write down the number. What would you expect to find?

a) The two numbers are the same
b) The amount of energy has decreased because some energy was used up
c) The amount of energy has increased because some energy was created
d) There is no more energy left in the universe

30. In this example, we have already seen that the battery loses chemical energy and the water gains thermal energy. Based on the law of conservation of energy, which statement would you expect to be true?

a) The amount of chemical energy lost is much less than the amount of thermal energy gained.
b) The battery does not actually lose any chemical energy because of the Law of Conservation of Energy.
c) The amount of chemical energy lost is about the same as the amount of thermal energy gained.
d) The amount of chemical energy lost is much more than the amount of thermal energy gained.

31. Match each term with its definition:

Terms: Joule, transfer, transformation, dissipation

____________ The unit we use to measure amounts of energy

____________ Changing the type of energy

____________ Moving energy from one place or object to another

____________ When energy spreads out as heat

32. **Fill in the blank:** Many people believe that when you burn fossil fuels, that energy is used up. In truth, this is an example of energy _____________ . The energy is not gone, but it has spread out as heat, causing the environment to get warmer.

33. Match each term with its definition:

Terms: transfer, transformation, dissipation

____________ Thermal energy from an electric stove moves to the pot of water, heating it up

____________ A fire burns, and its energy spreads out into the environment.

____________ Chemical energy from a battery in a toy truck changes to kinetic energy when the truck moves forward.

34. A little kid playing T-ball swings a bat and hits a ball that was sitting on a stand. We can look at this event by considering the energy involved.

Match each step of the process to the name of what happened to the energy during this step.

Terms: transfer, transformation, dissipation

_____________ The bat gives kinetic energy to the ball, and starts it moving.

_____________ The ball flies high up into the air, and the kinetic energy changes into gravitational potential energy, then back to kinetic as it falls.

_____________ As the ball rolls through the grass, it slowly loses its energy to the surroundings until it comes to a stop.

35. Your friend says he has found an example that breaks the law of conservation of energy. He explains that when a car starts with a full gas tank in the garage, it has chemical energy stored in the gas. After it drives around for a few days and comes back to the garage, some of the chemical energy has been used up.

"But," you say, "the car gained kinetic energy while it was driving around. That's where the energy went!"

"Maybe..." says your friend.

"But now the car is stopped again, so even the kinetic energy seems to be gone. I think the chemical energy from the gasoline has completely been used up and disappeared."

What is the best response to explain the situation?

a) This is an example that doesn't follow the law of conservation of energy
b) The energy is dissipated into the air around the hot engine.
c) The chemical energy has been transferred to another part of the car.
d) The energy was all transformed into kinetic energy, so the car still has kinetic energy even when stopped.

36. You come back to your friend with another idea that might break the law of conservation of energy.

"When I put a bowl of oatmeal in the microwave, I use energy to heat it up. The energy comes from the chemicals at the powerplant, and goes to the oatmeal. But then, if I leave the oatmeal out on the table for a while, it will be cold. So that energy has disappeared!"

"Wait a minute..." your friend says. "I think that energy still has to be somewhere..."

Where has the energy gone in this situation?

a) The energy has been transferred back into the microwave
b) The energy is still in the oatmeal, even though it is cold
c) The energy has dissipated into the environment, heating the room slightly

d) This is a case where energy has disappeared

37. "OK," says your friend. "I'm starting to believe that this law of conservation of energy always works, but I've got one more example that I can't quite figure out."

"Let's hear it!" you say.

"What about when you drop a ball? It starts with gravitational potential energy, then it falls and gains kinetic energy. But after it bounces a few times, it eventually comes to a stop and has no energy at all. Where did the energy go?"

a) The energy has been dissipated as thermal energy in the ball and environment.
b) The energy was transferred to the floor in the form of kinetic energy.
c) This is an example where the law of conservation of energy does not apply
d) The energy was transformed into chemical energy

38. A slingshot is loaded with a small stone, and the elastic is pulled back until the slingshot has 200 Joules of elastic potential energy. The slingshot is fired, and the stone's speed is measured. Based on the stone's speed, it is calculated to have 190 Joules of kinetic energy. What has most likely happened to the remaining 10 Joules of energy?

a) 10 Joules were destroyed by the slingshot
b) 10 Joules remains in the slingshot
c) 10 Joules has been dissipated into the environment
d) 10 Joules have disappeared

39. In a game of pool, the white ball (called the cue ball) is hit by the player and collides with a red ball and a green ball, both of which are sitting still.

Picture shared by by Flickr user brian.demaio under Creative Commons License http://www.flickr.com/photos/demaiob/4221633260/sizes/m/in/photostream/

The white ball has 36 Joules of energy going into the collision, and 10 Joules coming out of the collision. The red ball has 12 Joules of energy coming out of the collision. According to the Law of Conservation of Energy, how much energy should the green ball have, if no energy was dissipated?

a) 10 Joules
b) 12 Joules
c) 14 Joules
d) 36 Joules

OPEN-ENDED QUESTIONS

Below are 4 choices of topics related to fuel and energy in some way. In each topic, the first part of the question has a "right" answer, based on the scientific ideas you've learned about energy.

The second question has no right answer. State a claim about what you think, then present arguments to support your claim, considering energy, the environment, safety, cost, or other issues that are important to this question.

I. Has the temperature of the Earth been increasing or decreasing in the last 50 years? Do you think we should expect the temperature of the Earth to rise or fall in the coming 50 years? Explain and provide arguments for your claim.

II. What are two ways that driving a gasoline-powered car contributes to global warming? New electric cars use large batteries to store energy instead of gasoline, and the batteries are charged by plugging into the electrical system in your house. Should the government pass laws requiring car companies to make electric cars like this? Explain and provide arguments for your claim.

III. What sorts of fuels are used to make the electricity that powers your computer and other gadgets? When you buy something from a website on the internet, it must be shipped to your house. Do you think it is better to drive to a store yourself to buy something, or to have it shipped by buying it online? Explain and provide arguments for your claim.

IV. In which country does the average person use more fuel today, the United States or China? In the current debate over global warming, countries that are still developing argue that because the people there use much less energy on average, they should not have to reduce their fuel usage right now. Do you think everyone should be required to reduce their fuel use equally, or should countries that use less be allowed to continue increasing their fuel use? Explain and provide arguments for your claim.

SCORING RUBRIC FOR OPEN-ENDED ARGUMENTATION QUESTIONS

	Missing	Partial	Complete	Excellent
Closed-ended question	0 points No answer is given for the closed ended question, or the answer is not connected to scientific principles	1 point There is a correct answer, but no explanation given	2 points The answer is correct, and there is a relevant explanation connected to scientific ideas	3 points The answer is correct, and there is a relevant explanation showing thorough understanding of the scientific ideas
Claim	0 points No claim is made	1 point The student responds to the question but does not make a clear		3 points The student clearly states a claim in response to the question

		claim		
Supports	0 points The student does not present any arguments	1 point The student presents 1 argument to support the claim	2 points The student presents 2-3 arguments to support the claim	3 points The student presents 4-5 arguments to support the claim
Arguments	0 points The student's arguments are not relevant to the claim or based in fact	1 point The student's arguments are relevant to the claim but unclear	2 points The student's arguments are relevant to the claim and persuasive	3 points The student's arguments are relevant, persuasive and address more than one aspect of the claim

A = 11 – 12 points B = 9 – 10 points C = 7 – 8 points F = 6 or less points

