Forms of Energy: Multiple Transformations : Teacher Notes

Introduction

The focus of the investigation is to further define energy and realize that chains of energy transformations can occur. The VoltageCurrent, Light and Temperature probes enable students to investigate quantitatively and measure the conversion of one form of energy into another. This investigation encourages students to question and test their models of understanding about energy conversions and suggest alternative explanations for their observations.

In addition, students will gain experience with inquiry skills, including:

- realizing that heat (energy) moves in predictable ways, flowing from warmer objects to cooler ones, until both reach the same temperature;
- knowing that electrical circuits provide a means of transferring electrical energy when heat, light, sound, and chemical changes are produced;
- identifying variables that can affect the outcome of an experiment;
- understanding that energy is a property of many substances and is associated with heat, light, electricity, mechanical motion, sound, nuclei, and the nature of a chemical. Energy is transferred in many ways;
- knowing that scientific investigations involve asking and answering a question;
- planning and conducting simple investigations (e.g., formulating hypotheses, designing and executing investigations, interprets data, synthesizing evidence into explanations, proposing alternative explanations for observations, critiquing explanations and procedures);
- establishing relationships based on evidence and logical argument (e.g., provides causes for effects);
- knowing that scientific inquiry includes evaluating results of scientific investigations, experiments, observations, theoretical and mathematical models, and explanations proposed by other scientists (e.g., reviewing experimental procedures, examining evidence, identifying faulty reasoning, identifying statements that go beyond the evidence, suggesting alternative explanations).

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Discussion Guide

Using this Guide

This guide is designed to help you convert the investigations your students experience into solid learning. The "Overview" section mentions some of the learning issues raised by this content. These issues might come up in conversations with students anytime. The "Setting the Stage" section provides ideas for a discussion you might hold before beginning the investigations. This discussion is important to motivate and alert students to observations that might answer their questions. The "Wrap Up" section can be used after the investigations to help student reflect on what they have done. Taking time to reflect while the investigations are fresh in students' minds has been shown to substantially increase learning.

Overview

The diagrams students made in the previous investigation suggest that there could be chains of energy transformations, where energy goes from form A to B to C and so on. Students will investigate such multiple transformations in this investigation.

Most energy we encounter has gone through multiple transformations. Here are some examples.

The light from a flashlight comes from thermal energy of a filament, which can be traced back through electrical energy to the chemical energy of the battery. The battery required energy inputs to purify the zinc or other metal it uses. The energy to get a bike moving comes from muscles that burn sugars made from food. The energy in food can be traced back to sunlight that green plants converted to sugars. In the sun, the fusion of hydrogen releases thermal energy that causes the gasses to glow, releasing electromagnetic energy in the form of light. This light travels across space and a tiny amount makes sugar in green plants. This provides all the energy in our food and long ago initiated a chain of reactions that resulted in coal, gas fuel, and oil.

Setting the Stage

Have students look at their circle-arrow diagrams of energy transformations. Up to now, they have focussed on only one transformation. It should be clear from these diagrams that energy could be transformed many times.

Ask students:

Suggest common situations that involve two energy transformations. Suggest situations that involve three or more energy transformations. "Why does it make sense to heat your house (increase its heat energy) using electricity (electrical energy) that was derived from coal (chemical energy)? Why not heat with coal?" [Electricity is more convenient. The power plant can be far away.]

Have students pretend to be the patent office. What would they think of an inventor who claims that he can transform one form of energy into MORE energy of a different form? For instance, For instance, suppose someone had an invention for converting a certain amount of heat energy into more electrical energy.

The answer is that this invention is impossible. If it were possible, you could use it

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to make unlimited amounts of electrical energy. Here is how you could do this. Start with some electrical energy and use a resistor to the same amount of heat energy. This invention could then produce more electricity, and so on. Cycling the energy back and forth between heat and electricity would result in unlimited amounts of energy. This is impossible.

Wrap Up

Have students identify the forms of energy in each of the three trials as well as the way energy was transformed. Ask: [Kinetic energy] [The propeller pushing on air.] [Electrical energy] [The solar cell.] [Light.] [light --> electrical energy --> kinetic energy.]

Repeat this kind of detailed review of the other two trials. The second trail is interesting because it is almost the opposite of the first trail. The third trail is interesting because the hand crank is used to transform the energy two different ways, to and from electrical energy.

These multiple transformations can stimulate a discussion of efficiency. Can you get energy out of heat? Yes, but not with 100% efficiency. Think of a steam engine. The modern equivalent is a turbine. High-pressure steam expands against a cylinder or fan-like blades. The steam expands, cools, and looses its energy. This is how energy is extracted from a nuclear energy.

The final discussion should refer back to the discussion about global energy consumption that preceded the first investigation in Energy Conversions. Now, that students understand how energy is transformed, they should be able to think more deeply about global energy issues. The major uses of energy are for transportation, heading, and industry. Most of that energy comes from the fossil fuels: oil, coal, and natural gas. Some comes from nuclear energy and a tiny fraction from water dams.

Each one of these forms of energy can be transformed into electricity and electricity can be converted to almost any form of energy we need. This is why different kinds of energy conversions are so important. Electricity is not efficient because some energy is lost when it is made and lots of its energy is lost in transmission. This is why it costs less to heat a house with fossil fuels than with electricity that was generated from fossil fuels.

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Additional Teacher Background

This investigation explores how many common devices involve a whole chain of energy transformations that we hardly notice because we take them for granted. It includes the use of solar cells, generators, lights, motors, and falling weights. The amount of energy doesn't change through all of these transformations, although it may be lost to the environment, usually as heat. The efficiency of the transformation is extremely important in everyday life. For instance, only about 30% of the electrical energy generated at a power plant arrives at our houses. A gasoline-driven car is even less efficient. The wasted energy means more pollution and consumption of natural resources.

Solar cells use thin silicone wafers to convert sunlight directly into electrical current. Students will discover that it takes a lot of area to obtain very much power. To run an air cart, the sunlight is changed into electric current, then into mechanical energy with a motor. In a real solar car, there would be the additional step of storing the energy chemically in a battery. Energy is lost in each step. At best, solar cells are about 15% efficient in changing light energy to electrical energy. If they were 90% efficient, we could probably all live in solar-powered houses and drive solar-powered cars.

Using a generator to light a bulb is the reverse process of the solar cell in that mechanical power produces light. But the process is an indirect one. The mini light filament radiates light by being heated "white-hot" by the electrical current that passes through it. It gives off non-visible radiation as well, which heats up the surroundings. Quite a bit of the energy is lost as heat. It is monitored with the Light probe, which uses a photodiode to measure light intensity.

Note that fluorescent light is not effective in powering the solar cell. The light emitted from the fluorescent light has the wrong wavelengths. Incandescent light has similar wavelengths to the Sun. Fluorescent lights are much more efficient, however, in converting electrical current into visible light. Incandescent lights get very hot, and all of that energy is wasted.

Hooking two Genecon generators together is an illustration of a great use for electricity. Suppose there was a source of mechanical power in one place (e.g. a water wheel) and a need for power in another (e.g. a flour grinding mill). Before electricity, the source of power needed to be mechanically connected to the power, with shafts and gears. Indeed, early industrial processes were often located near the source of power.

However, by using an electric generator in one place and an electric motor in the other, the two can be connected by wires. Electric current flowing in the wires transmits the power. This provides enormous flexibility. A large hydroelectric dam can supply electricity to small motors doing many different things in many places, far from the power plant.

This investigation also illustrates the idea that a generator is a motor in reverse. When a current is run through the coils of the Genecon, a force is exerted on each wire. This makes the handle spin. In a generator, spinning creates a current. In a motor, current creates spinning. Motors and generators of varying sizes work on this same principle.

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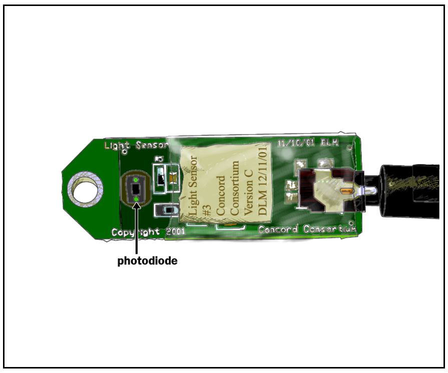
A pulley wheel attached to a Genecon offers a way to quantify the amount of energy put into a motor. The change in gravitational potential energy of an object is its weight times its change in height. For instance, a 1kg mass has a weight of 9.8N. If it falls 2m, it gives up energy in the amount of 9.8 newtons * 2 meters = 19.6 joules.

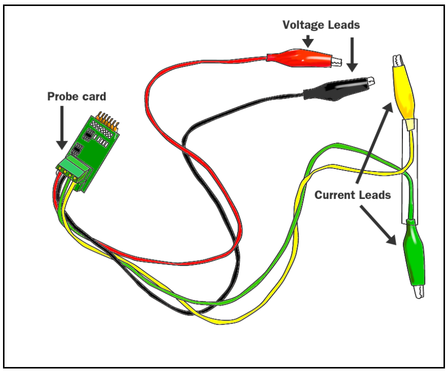
The "Rube Goldberg" chain of energy-transforming devices is more common in everyday life than we may realize. Here are two examples:

Refrigerator run by a hydroelectric dam: gravitational PE (water behind dam) -> KE (falling water) -> whirling turbine blades -> electric power (in wires) -> mechanical power (compressor) -> thermodynamic energy (compressed refrigerant) -> coldness (heat energy) Internal combustion engine: gasoline (energy in chemical bonds) -> thermodynamic energy (heat and pressure of burning fuel) -> mechanical (pistons moving) -> motion of gears and wheels -> moving car

But Rube Goldberg didn't worry about efficiency, and we need to keep it constantly in mind in order to make the best possible use of our limited natural resources.



The Light Probe has a photodiode that responds mainly to visible light, which is also the light needed for photosynthesis by plants. It produces a voltage depending on the light level. There are two ranges, one that can measure bright sunlight, and the other for indoor light.



The Voltage/Current Probe measures either voltage or current. It can also measure both at the same time. The CCProbe software can use these readings to calculate and display power (watts) and energy (joules).

Voltage is like potential energy, The voltage between points A and B is a measure of the energy each electron could release as it moves from point A to point B in a wire. Voltage at one place is always measured relative to some other place. Therefore the probe requires two leads, and the voltage can be measured just by touching the two leads to two places. Voltage difference is measured in volts (V). The

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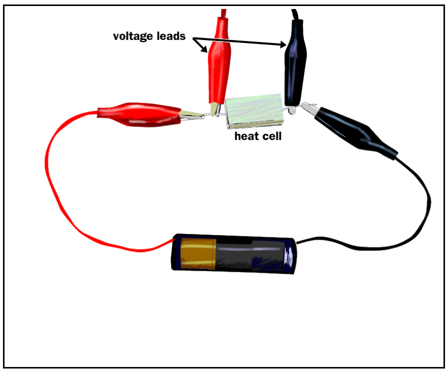
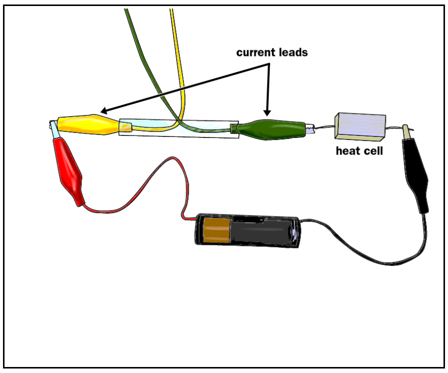
red clip lead goes to the greater, or positive (+) location, and the black clip lead goes to the smaller, or negative (-) location. To measure voltage across a heat cell , the clips are placed on the two ends of the heat cell as shown.



Current is the amount of electricity flowing, a bit like the current in a stream. Current can be pictured as the total number of electrons flowing per second through a wire or other substance. You can imagine measuring current by setting up a tollbooth in a wire and simply counting how many electrons went by each second. Current is measured in amperes (A).

To measure the current in a wire, you have to set up a tollbooth by breaking the wire and forcing the current to go through your current probe. The convention is that current is positive when it flows from a positive to a negative voltage, that is, from red to black. For the current through the probe to be positive, it should flow into the yellow clip lead and out of the green clip lead. Here is how to measure current going through a heat cell attached to a battery. Note: positioning of the probe is different while measuring current then it when measuring voltage.



Electrical power, the rate of using energy, is the voltage difference times current. It can be pictured as the number of electrons flowing per second, multiplied by the energy each one loses (P=IV). Power is measured in watts (W).

To measure the power going into a heat cell from a battery, you must measure both voltage and current. The CCProbeware will calculate and display the power from these measurements.

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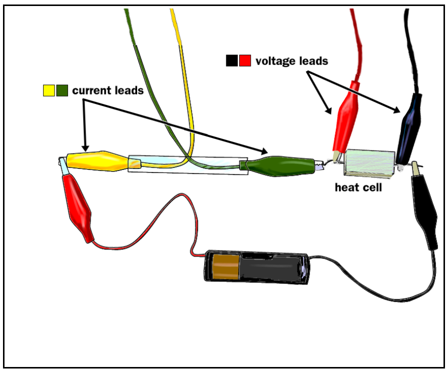

Electrical energy is the power accumulated over time. It can be pictured as the total number of electrons that flow, multiplied by the energy that each one gains (or loses). Energy is measured in joules (J). To measure the energy transferred into a heat cell from a battery, you must measure both voltage and current (see diagram above). The CCProbeware will calculate and display the energy from these measurements.

Depending on your needs, the Voltage/Current probe can be a volt meter, an ammeter, a power meter, or a joule meter!

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Suggested Timeline

The amount of time you spend on introductory discussions, data collection, and analysis, will determine your overall timeline. The following represents a possible timeline.

One class period - "Setting Up" discussion

One class period - Trial I: Electricity from the sun

One class period - Trial II: Cranking up the lights

One class period - Trial III: Remote lifting

One class period - Analysis and "Wrap Up" discussion

Additional days can be used for Further Investigations.

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