Reversible Thermoelectric Demonstrator

P6-2700

INSTRUCTIONAL GUIDE

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- Thermoelectric Demonstrator
- Banana plug leads
- Instructional Guide

Recommended for activity:

- Digital Multimeter with Thermocouple (P6-8017)
- Beakers
- Power Supply: 12V Max Battery Eliminator (94-3200)
- Digital Thermometer (68-6300)

Background

The Thermoelectric Effect is the direct conversion of thermal energy moving down a temperature gradient to electrical potential, and vice-versa. Although thermoelectricity can be used to generate electric current or temperature differences, it is almost exclusively used for cooling in applications such as portable refrigerators. Do not confuse the Thermoelectric Effect with the ordinary heating that occurs in all electric circuits. Thermoelectric heating is reversible, while the ordinary heating is not. Thermoelectricity refers collectively to the Seebeck effect, Peltier effect, and the Thomson effect. The temperature difference causes charge carriers (such as electrons) to move from the hot side to the cold side, thus creating an electric current. Conversely, the energy transferred into the material by applying an electric current can cause differential heating. One of the most common thermoelectric materials is Bismuth telluride (Bi^2Te^3), a chemical compound of Bismuth and Tellurium.

Introduction

The demonstrator consists of a pair of thick aluminum strips that act as heat sinks and supports, a semiconductor block sandwiched tightly between the aluminum strips, a small electric motor and fan connected to the semiconductor through a switch, and a pair of banana sockets for attaching a meter or power supply.

Troubleshooting:
If the fan will not spin, pull fan away from the motor. The motor may need to be pushed towards the front of the housing to give the fan more room.

Activities

Thermal gradient generating electricity:
Placing the heat sinks into water baths which are at different temperatures (ice water and hot water) generates a current that can be shown by the attached motor (a mechanical conversion) or measured as a voltage by a user-supplied meter. Switching the hot and cold reservoirs causes the current to flow in the opposite direction—indicated by the direction of motion of the propeller.

- Place one heat sink leg in a cup of ice water and the other in a cup of near-boiling water (about 90°C).
- It will take about 30 seconds for the necessary temperature difference to drive the electric motor to be established between the two heat sinks.
- If the motor does not start to run, check the position of the switch (the switch connects the semiconductor either to the motor or to the banana sockets)
- Carefully lift the device out of the cups (one leg will be HOT!), interchange the cups, and replace the device. The propeller will stop after about 30seconds and then reverse direction after about another 15 seconds.
- Connect a voltmeter that can measure 1V DC and turn the switch to measure the voltage produced by the device.

The generation of electrical potential from a temperature differential is called the Seebeck Effect. If an electric current is drawn (such as by the electric motor) and work is done, then heat flows from the hot side of the device to the cold side to supply the necessary energy. The demonstration also shows that the direction of the heat flow through the device determines the polarity of the potential difference generated, but in both cases the energy conversion is from heat to electrical energy.

Electricity generating a thermal gradient:
Attaching a DC power supply to the device and passing an electric current through it causes the two heat sinks to change temperature—one gets warmer and the other colder. Once more, switching the direction of the current switches the hot and cold heat sinks. (6V/approx. 2A required)

- You will need a DC power supply capable of producing 2A at 6V and at least one thermometer. If your power supply does not have built-in meters, you will also need a DC ammeter with a range that includes 2A.
- Set up the equipment with the same amount of water in each cup, and show that the temperature is the same in both cups (if necessary, include the ammeter in your circuit).
- Turn on the power supply and set it to deliver 2A. Make sure the switch is in the correct position to allow a current to flow to the device).
- After about a minute, you should be able to observe the water temperature begin to rise in one cup and fall in the other. Allow the process to continue until the temperature difference between the two cups is being continuously increased as the current flows.
- Now turn off the power supply, interchange the connections to the device, and turn the power supply on again. After a few minutes, it will become clear that the established temperature difference is being reduced and an opposite one is being built up.

The generation of a temperature gradient from an electric current is called the *Peltier Effect*. It is used commercially in solid state heating and cooling devices. Notice that this is not the same as generating heat by driving an electric current through a resistor.

The demonstration also shows that the direction of heat flow through the device is determined by current direction, but in both cases the energy conversion is from electrical to heat energy. Because the conversion between electrical energy and heat can be made in both directions (heat to electricity and electricity to heat) the process in the semiconductor is said to be *thermally reversible*.

Related Products

Electromagnetic Flashlight (P6-6052) Shake the Electromagnetic Flashlight 40 times and see it light up an ultra-bright LED bulb. The flashlight is perfect for backpacking, emergency kits, the kitchen drawer or just to shed some light on how magnets can be used to produce electricity.

Ice Melting Blocks (P6-7060) Cool experiment kit! Touch these two black blocks, and one feels cooler. This discrepant event introduces many concepts, including heat transfer, change of state, and thermal conductivity.