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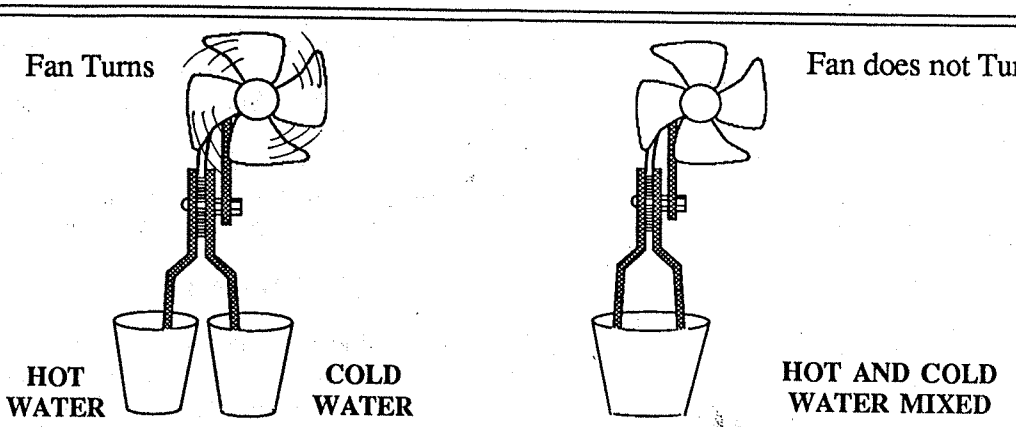
MODEL TD-8550
THERMOELECTRIC CONVERTER



A transformation whose only final result is to transform into work heat extracted from a source which is at the same temperature throughout is impossible.

Lord Kelvin

This was Kelvin's statement of the Second Law of Thermodynamics. The second law has been stated in many, seemingly unrelated ways; but in the end, all have been shown to be different ways of expressing the same basic principle. In its most general form, the Second Law tells us that no physical process will occur if it decreases the disorder—or *entropy*—of the universe. Conservation of energy, as expressed in the First Law of Thermodynamics, holds for every physical process. But many processes which would conserve energy can not occur because they violate the Second Law.

USING THE CONVERTER

The PASCO scientific **Thermoelectric Converter** (Model TD-8550) is designed to demonstrate this relationship between the First and Second Laws of Thermodynamics. The procedure used directly illustrates Kelvin's statement of the Second Law. The Converter is used as shown above. One leg of the unit is placed in a cup of cold water and one in a cup of hot water. (Boiling water and ice water give the best results.) Some of the thermal energy from the hot water is converted into work by the Converter, and the fan turns. Then the hot and cold water are mixed together in a larger container. Both legs of the unit are placed into the container. Now the fan does not turn.

The total internal energy of the water is not changed by mixing the hot and cold together, so there must still be sufficient energy in the water to turn the fan. But this would violate the Second Law of Thermodynamics, as stated by Kelvin.

NOTE: As a further demonstration, place one leg in the mixed water (or in ice water) and one in a container of dry ice to demonstrate that there is energy available in the mixed water (and even in ice water).

This violation of the Second Law can also be explained in terms of entropy, using the expression $\Delta S = Q/T$, where ΔS is the change in entropy, Q is the heat transferred, and T is the temperature at which the heat is transferred. Considering only the heat transfer taking place in the cups of water, the following holds:

1. The change in entropy of the hot water, $\Delta S_h = Q_h/T_h$, is negative, because heat is leaving the water and going into the Converter.
2. The change in entropy of the cold water, $\Delta S_c = Q_c/T_c$, is positive, because heat is going into the water from the Converter.
3. According to the second law, the total change in entropy, $\Delta S_T = \Delta S_c + \Delta S_h$, must be positive. Therefore, the process will only take place if $Q_c/T_c > Q_h/T_h$.
4. In order for the fan to be turned, some of the heat transferred from the hot water must be converted into work and will therefore not be available to be transferred back into the cold water. Therefore, whenever the fan turns, $Q_h > Q_c$.
5. The equations in steps 3 and 4 can only both be true if $T_h > T_c$. Once the water is mixed, however, $T_h = T_c$. Therefore, if the fan were to turn, it would violate the Second Law of Thermodynamics.

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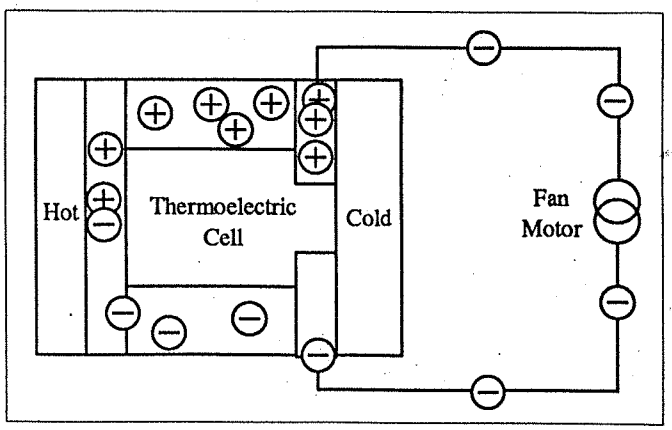
HOW THE THERMOELECTRIC CONVERTER WORKS



Simplified Diagram of Thermoelectric Converter Cell

The Thermoelectric Converter uses a series of thermoelectric cells to convert thermal energy into electrical energy that will drive the fan. Each cell is a semiconductor device. A simplified diagram of one cell is shown above.

The heat entering the cell raises the energy level of some of the electrons in the cell. At the higher energy level, the electrons are no longer bound in the crystal structure of the semiconductor and are free to move. When they do so, they leave a vacant place, or hole, in the crystal. Lower energy electrons, though they can't move freely within the material, can jump from hole to hole. In this way, the holes can also migrate through the semiconductor material.

The electrons migrate, as shown, through the N-type semiconductor material and the holes migrate through the P-type material. (N and P type materials are merely silicon that is "doped" with special impurities that enhance electron and hole migration.) The electrons flow through the external circuit and drive the fan motor. At the other end of the circuit they reenter the cell and encounter the holes of the P-type semiconductor. This occurs near the cold end of the cell. The electrons can therefore drop back into holes, giving up any excess energy they still retain as heat.

As long as the temperature differential is maintained between the two sides of the cell, the electrons and holes continue to migrate, and the fan continues to turn. However, if there is no temperature differential, the electrons can not recombine with the holes because there is no place to give up their excess energy. In this way, the thermoelectric cell is constrained by the Second Law of Thermodynamics.

LIMITED WARRANTY

PASCO scientific warrants this product to be free from defects in materials and workmanship for a period of one year from the date of shipment to the customer. PASCO will repair or replace, at its option, any part of the product which is deemed to be defective in material or workmanship. This warranty does not cover damage to the product caused by abuse or improper use. Determination of whether a product failure is the result of a manufacturing defect or improper use by the customer shall be made solely by PASCO scientific. Responsibility for the return of equipment for warranty repair belongs to the customer. Equipment must be properly packed to prevent damage and shipped postage or freight prepaid. (Damage caused by improper packing of the equipment for return shipment will not be covered by the warranty.) Shipping costs for returning the equipment, after repair, will be paid by PASCO scientific.

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