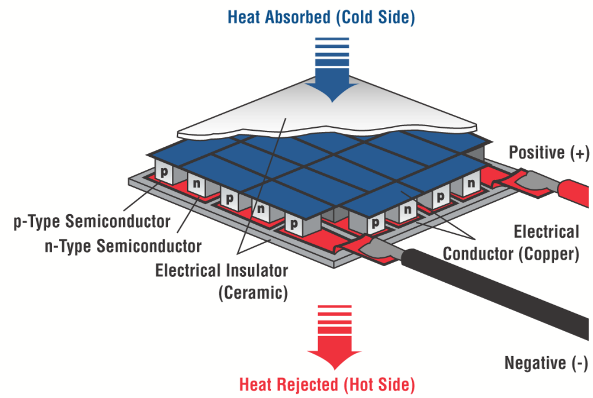
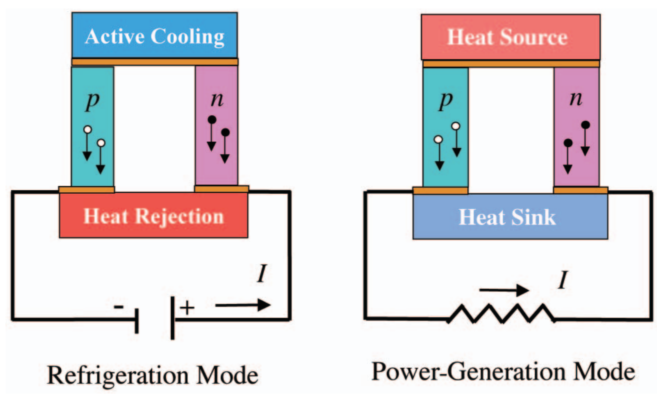
1. Thermoelectric Power and Cooling

1.1. Introduction to Thermoelectrics

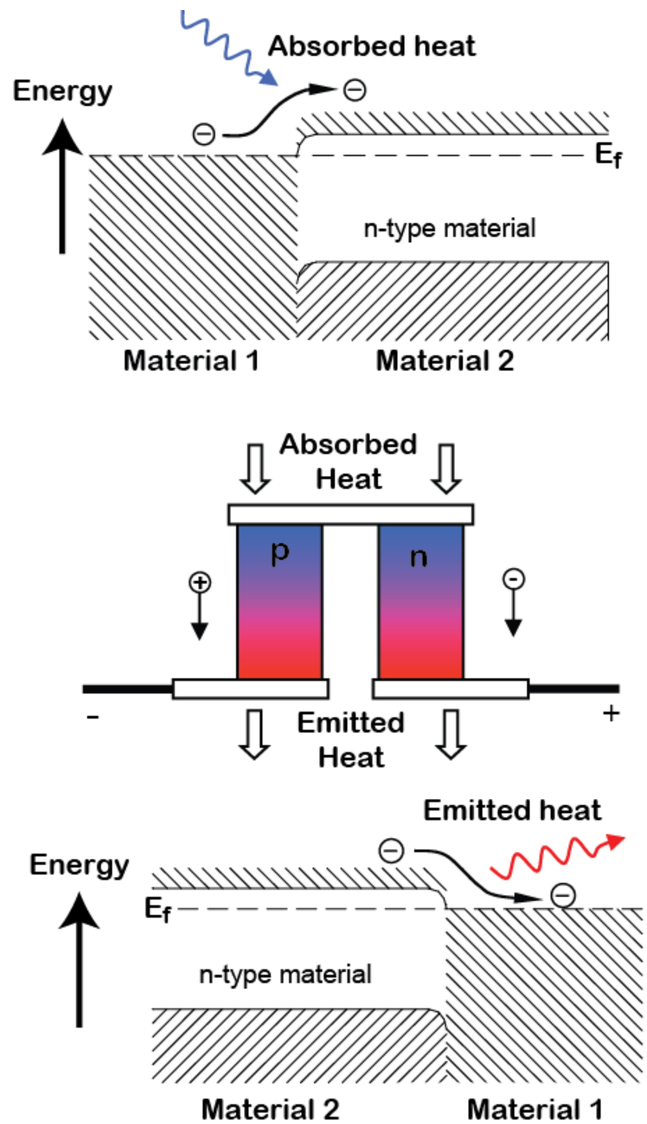




The thermoelectric effect is the direct conversion of temperature differences to electric voltage and vice versa. A thermoelectric device creates voltage when there is a different temperature on each side. Conversely, when a voltage is applied to it, it creates a temperature difference. At the atomic scale, an applied temperature gradient causes charge carriers (e.g. electrons) in the material to diffuse from the hot side to the cold side. This effect can be used to generate electricity, measure temperature or change the temperature of objects. Because the direction of heating and cooling is determined by the polarity of the applied voltage, thermoelectric devices can be used as temperature controllers and coolers. (Source: Wikipedia)

(Adapted from Dr. Hogan, Mich State) In 1822, Seebeck observed that when two electrically conducting materials are connected in a closed loop and a temperature difference exists at the two junctions $T1$ and $T2$, then there was a deflection of the magnetic needle in his measurement apparatus. The deflection was dependent on the temperature difference between junctions and the materials used for the conductors. Many scientists subsequently researched this relationship, and it was discovered that the observation by Seebeck was not caused by a magnetic polarization, but was caused by electrical current flowing in the closed loop circuit. Twelve years after Seebeck's discovery, a watchmaker and scientist named Jean Peltier reported a temperature anomaly at the junction of two dissimilar materials as a current was passed through the junction. It was unclear what caused this anomaly and while Peltier attempted to explain it on the basis of the electrical conductivities and/or hardness of the two materials, Lenz removed all doubt in 1838 with one simple experiment. By placing a droplet of water in a dimple at the junction between rods of bismuth and antimony, Lenz was able to **freeze the water** (!) and subsequently melt the ice by changing the direction of current through the junction. In this way, Lenz had made the first thermoelectric cooler. The rate of heat absorbed (Q) or liberated from the junction was later found to be proportional to the current or, Q = pi*I, where pi is the Peltier coefficient and I is the current.

Physically, what is happening as the charge carriers move through the conductors is complex. To get a relatively simple view of the heat absorption or emission process, we need to consider the charge carrier energy levels in the materials – simplified as energy bands. Electrical engineers often use band diagrams to describe electrical processes in materials. A band diagram showing the changing energy levels of the charge as it moves through a material and the resulting absorption or emission of thermal energy due to this change in energy level is given in the figure to the right.



1.2. Thermoelectric Activity

Who: Group of 5 students
What: This is a solid-state energy conversion demonstration with a thermoelectric device using heat to power a fan, and using power to freeze water. The purpose of this activity is to look at multiple energy conversion processes between heat, electricity, and shaft power.
Where: Classroom
Time: 4 hours

Supplies:

Item	Quantity	Check-out	Check-in	Notes
Peltier Cooler (12 V, 5.5 A)	1			
Aligator clips	2			
Cardboard sheet (4 in x 6 in)	1		NA	
Heat sink fins	2			
DC motor	1			
D-cell batteries	8			
Batter pack	1			
Plastic trays	2			
Plastic cup	1			
Metal tin tray (from Al foil)	1			
Thermal interface grease	1			
1 cup of boiling water	1			

Learning Objectives:

- Hands on experiment exposing students to energy conversion, thermal energy, electric work, and shaft power. Build knowledge in electrical wiring and energy conversion systems.
- Introduce concepts of heat transfer, and conservation of energy
- Introduce concept of power generation and refrigeration

SAFETY NOTES

- **Burn hazard**: Dealing with boiling water that can cause serious burns
- **Electricity**: Electrical wiring and power devices

Activities:

A. Use heat to power a fan

Procedure

1. Construct a fan blade from the cardboard provided and glue it to the shaft of the small DC motor. Allow glue to dry.
2. Apply a thin layer of thermal interface grease to the heat sink fins and attached the thermoelectric device. Connect heat sink fins on both sides of the device.

3. Connect the alligator clips to the electrical leads of the thermoelectric device, and then connect the other side of the alligator clips to the small DC motor.
4. Poor boiling water from kettle into a ceramic mug
5. Poor the hot water into the plastic container filling to a height of approximately 1.5 cm.
6. Place 1 side of the heat sink fins in the hot water. Does the fan rotate?
7. Disconnect the motor from the thermoelectric generator and connect the leads to 1 D-cell battery. Does the fan rotate? Is there a difference in speed? Why?

B. Use power to make a thermoelectric cooler

Procedure

1. Place a heat sink fin on one side of the thermoelectric device using a thin layer of thermal interface grease between the materials.
2. Place cold water in the plastic tray, and place the heat sink fins into the cold water
3. Make a small tray with aluminum foil that will hold a small amount of water, roughly 1 ml of water.
4. Put thermal interface grease on the exposed side of the thermoelectric device and carefully place the aluminum tray on top.
5. Put the D-cell batteries into the battery pack, and use the alligator clips to connect the battery pack to the electric leads of the thermoelectric device.
6. What are your observations?

Additional details will be provided in an additional handout.

OBSERVATIONS AND NOTES