Introduction of Thermoelectric Generators

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Learning Objectives

1. This MINT high school course introduces the concepts and key terms of thermoelectric generators.

2. The hands-on experiment allows students to visualize the fundamental process behind the energy conversion from a heat flux into an electrical current.

3. By demonstrating a power generation with the thermoelectric module, students will appreciate the fundamentals of the Seebeck effect and the Peltier effect.
Solid-State Thermoelectric Generator

Seebeck Effect

\[ S = - \lim_{\Delta T \to 0} \frac{\Delta V}{\Delta T} = - \frac{dV}{dT} \]

Peltier Effect

\[ \Pi = S \cdot T \]

Kerosene Lamp Generator

Motivation ★ Fundamental ★ Concept ★ Synthesis & Fabrication ★ Characterization ★ Conclusion

http://www.neazoi.com/technology/thermocouple.htm
General Purpose Heat Source Radioisotope Thermoelectric Generator

Cassini Orbiter (Saturn)

Image Credit: NASA
General Purpose Heat Source Radioisotope Thermoelectric Generator

Radioisotope TEG (800°C)

one-way ticket to Mars

Mars mission. Image Credit: NASA
**Figure of Merit - ZT**

\[ ZT = \frac{S^2 \sigma T}{K} \]

\[ \eta = \frac{\text{power supplied to load}}{\text{heat absorbed at hot junction}} \]

\[ \eta = \frac{I^2 R_L}{S IT_H + \kappa (T_H - T_C) - \frac{1}{2} I^2 R} \]

\[ \eta_{\text{max}} = \frac{T_H - T_C}{T_H} \frac{\sqrt{1 + Z T} - 1}{\sqrt{1 + Z T} + (T_C / T_H)} \]

Here,

\[ \bar{T} = (T_H + T_C)/2 \quad \text{and} \quad Z = S^2 \sigma / \kappa \]


**Pros:**
1. Silent, simple, reliable and scalable.
2. Power generation/refrigeration.
3. Suitable for high/low grade thermal energy.
4. It’s green!

**Cons:**
1. Inefficient.
2. High material cost.
**Demonstration: Seebeck effect**

**Seebeck effect**: The Seebeck effect is the conversion of a temperature difference directly into electricity.

1. Immerse one leg in hot water and the other leg in cold water. (switch is at “OFF”)
2. Measure the voltage difference (ΔV) and temperature (ΔT).
3. After getting a high voltage, turn the switch to “on” position. The propeller of the motor will begin to rotate.
4. Remove the module out of the water baths.
**Peltier effect**: Passing a current through the device causes one leg to become warm and the other cold.

1. Immerse one leg in cups of water at the same temperature.
2. Connect the unit to a DC power supply with a 5V, 3A output.
3. Turn the switch to “on” position.
4. Turn “off” the power within two minutes and measure the temperature change ($\Delta T$).
Personal Protective Equipment (PPE): Eye protection.

Reference:
3. Water heat capacity (at 25°C), $C_p = 4.1813$ J/g K; 75.327 J/mol K.