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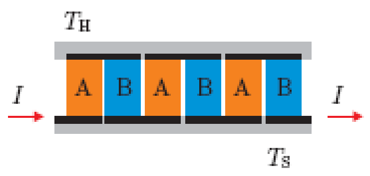
# PELTIER CELL

## OBJECT

Your task is to get acquainted with the Peltier cell behavior in the ThermoElectric Generator mode (TEG) and in the ThermoElectric Cooler mode (TEC)

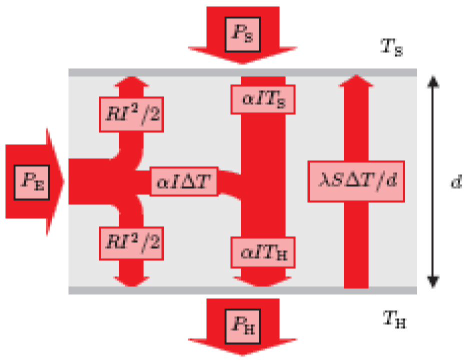
1. Measure the dependence between the thermoelectric voltage and temperature. Plot it in the graph.
2. Calculate Seebeck's coefficient from the measured dependence.
3. Calculate the efficiency of the Peltier cell in the TEG mode and compare it to the efficiency of the ideal thermal machine.
4. Measure the time dependence of the temperature on both sides of the Peltier cell and plot it in the graph

## THEORY




Peltier cell is a thermoelectric device working on the Peltier phenomenon principle. It is mostly used for the active cooling since the cell allows us transfer of heat from the colder place the warmer one, which means in the opposite direction than the heat flows naturally. Peltier cells are commonly constructed of larger amount of semiconductor elements, which are connected in series from the electrical point of view and in parallel from the point of view of the heat transfer.

**Energy balance of the Peltier cell in the TEC mode**




The heat generated or absorbed per time unit by the electric current *I* through the junction of two various conductors can be evaluated

$$\frac{\Delta Q_P}{\Delta t} = P_P = \alpha T I,$$

where $\alpha$ is Seebeck's coefficient and *T* is thermodynamic temperature of the junction. Passing of the current I through the resistance R creates Joule's heat, which can be evaluated

$$\frac{\Delta Q_J}{\Delta t} = P_J = RI^2.$$

The heat passing through the cell per time unit from the hot side of temperature $T_H$ to the colder side of temperature $T_S$ can be obtained from the Fourier's law

$$\frac{\Delta Q_F}{\Delta t} = P_F = \lambda S \frac{T_H - T_S}{d} = \Lambda \Delta T,$$

Where $\Delta T = T_H - T_S$, $\lambda$ is coefficient of thermal conductivity, *S* is cross-section area, *d* is thickness of the material and $\Lambda = \lambda S/d$ .

Thermal power entering the cell on the colder side can be evaluated

$$P_S = \alpha I T_S - \frac{RI^2}{2} - \Lambda \Delta T, \tag{1.1}$$

Thermal power leaving the cell on the hot side can be evaluated

$$P_H = \alpha I T_H + \frac{RI^2}{2} - \Lambda \Delta T. \tag{1.2}$$

After achieving the stable state the electric power flowing into the cell can be evaluated

$$P_E = UI = P_H - P_S = \alpha I \Delta T + RI^2. \tag{1.3}$$

Cooling efficiency of the Peltier cell can be defined like the ratio between that what we want (to take heat from the colder side) and that what we pay (electric power), so

$$\eta_{TEC} = \frac{P_S}{P_E} = \frac{\alpha I T_S - \frac{RI^2}{2} - \Lambda \Delta T}{\alpha I \Delta T + RI^2}. \tag{1.4}$$

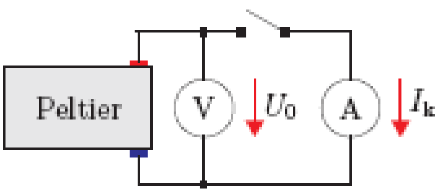
We can see that there are two factors lowering the efficiency. The first one is Joule's heat, which is created in resistance of the cell and the second one is thermal conductivity, which allows to carry part of the heat in the opposite direction than the Peltier cell does. If these factors could be eliminated (Λ=0, R=0), then the cooling efficiency could be evaluated

$$\eta'_{TEC} = \frac{T_S}{T_H - T_S},$$

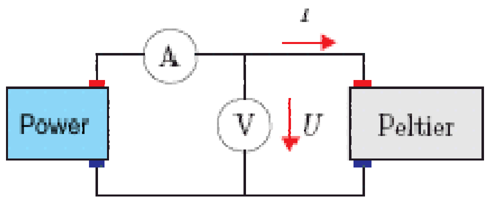
which is efficiency of the ideal thermal machine.

## PROCEDURE

**IMPORTANT NOTE!** Never exceed the maximum values for the Peltier cell. The maximum current is $I$= 4A and the highest temperature of the hot side is $T_H$= 100°C.




**Configuration A**




**Configuration B**

### A) Peltier cell in the TEG mode

1. Connect the Peltier cell with voltmeter and ammeter (range 10A or 20A) according to the configuration A. Plug into the power a pump, which pumps water form the outer reservoir into the thermal exchanger on one side of the Peltier cell. Fill the small vessel on the other side with water heated in the kettle 1 mm below the upper edge. If there is water from the previous measurement suck it out by the syringe. Cover the vessel by the cap.
2. Wait a moment for equalizing of temperatures between the hot water vessel and the Peltier cell (about 30 s) until the temperature on the hot side begins to drop. Measure the dependence between the thermoelectric voltage $U_0$ and temperatures $T_H$ and $T_S$ in time. Short-circuit the voltmeter by the ammeter after each reading and measure the short-circuit current $I_k$.
3. Plot the graph of the values from the point 2 assuming linear dependence. Calculate the Seebeck's coefficient α. Use the method of least squares.

4. Estimate efficiency of the Peltier cell, which is defined as $\eta_{TEG} = \frac{P_E}{P_H}$,

where $P_E$ is theoretical maximum power supplied by the cell to the load

$$P_E = \frac{1}{4}U_0 I_k$$

and $P_H$ is thermal power flowing through the hot side of the cell.

$$P_H \approx \frac{\Delta Q_H}{\Delta t} = \frac{C_{celk}(T_{H1} - T_{H2})}{t_1 - t_2},$$

Where $C_{celk}$ is the total thermal capacity of the vessel on the hot side (and is equal to 1121 J/K), $T_{H1}$ and $T_{H2}$ are temperatures on the hot side in moments $t_1$ and $t_2$. Prefer the values from the beginning of the measurement, when the temperature difference is high.

5. Compare the calculated efficiency with the efficiency of the ideal thermal machine.

$$\eta'_{TEC} = \frac{T_S}{T_H - T_S},$$

**B) Peltier cell in the TEC mode**

1. Fill the vessel on the side of the Peltier cell about 1 mm below the upper edge by the tap water. Wait about 3 minutes so the temperatures on both sides of the cell could equalize. Cover the vessel by the cap.
2. Switch on the power source, the current can be set by the current limiter on the source and should not exceed 4 A.
3. Measure temperatures $T_H$ and $T_S$ on both sides of the cell in one minute intervals. Check the current value and correct it if necessary.
4. Plot the graph of $T_H$ and $T_S$ depending on time.
5. What was your lowest temperature?

## SEMESTER WORK INSTRUCTIONS

Create a program, which will simulate the time dependence of temperatures on both sides of the device in the TEC mode. Take into account the thermal transfer between the upper parts of water reservoirs. Changeable parameters: voltage, current and initial water temperature in both reservoirs. Additional task: examine, whether is possible to achieve the freezing point temperature in the cooler reservoir using standard laboratory devices and parameters. If not, suggest which parameters should be dramatically changed and how.

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