Experiment 3:
A Model Refrigerator

Equipment Required	Part Number
Thermoelectric circuit board	part of ET-8782
Foam insulator	part of ET-8782
Heat sink and thumbscrew	part of ET-8782
Banana patch cords (qty. 4)	part of ET-8782
Temperature cables (qty. 2)	part of ET-8782
Fast Response Temperature Probes (qty. 2)	PS-2135 (3-pack)
DC Power Supply (10 V, 1 A minimum)	SE-9720A or equivalent
PASPORT Voltage/Current Sensor	PS-2115
PASPORT Quad Temperature Sensor	PS-2143
PASPORT interface(s)	PS-2001 or equivalent
DataStudio software	See PASCO catalog
“Refrigerator” configuration file for DataStudio	part of ET-8782

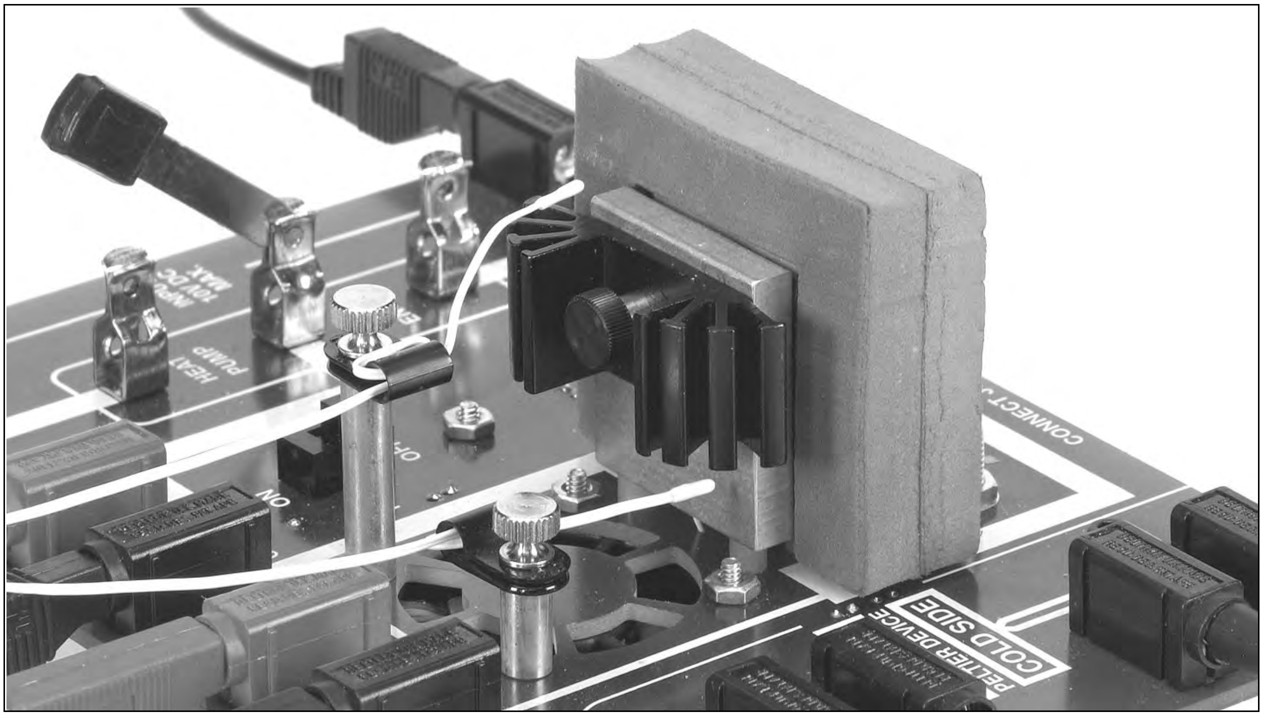
Introduction

In this activity you will use the peltier device to model a refrigerator. As you run your model refrigerator, DataStudio will display the voltage and current supplied to the peltier, the temperature of both blocks, and the temperature of the air flowing past the heat sink. You will use these measurements to investigate some of the factors that affect the temperature of a refrigerator

Set-Up

1. *Input Power:* Set the Heat Pump/Heat Engine switch to the neutral position (straight up). Connect the power supply using banana patch cords to the input power terminals on the circuit board. Note the polarity.
2. *Insulator:* Place a foam insulator on the aluminum block on the Cold Side of the peltier.
3. *Block Temperature:* Connect the cables from the temperature ports on the circuit board to the Quad Temperature Sensor. Connect the Cold Side to Channel 1 of the sensor and the Hot Side to Channel 2.
4. *Air Temperature:* Set up two Fast Response Temperature Probes to measure the temperature of the air before and after it flows through the heat sink. Use the temperature clamps to position the probes below and above the heat sink (as shown in the picture). The probes should not touch the

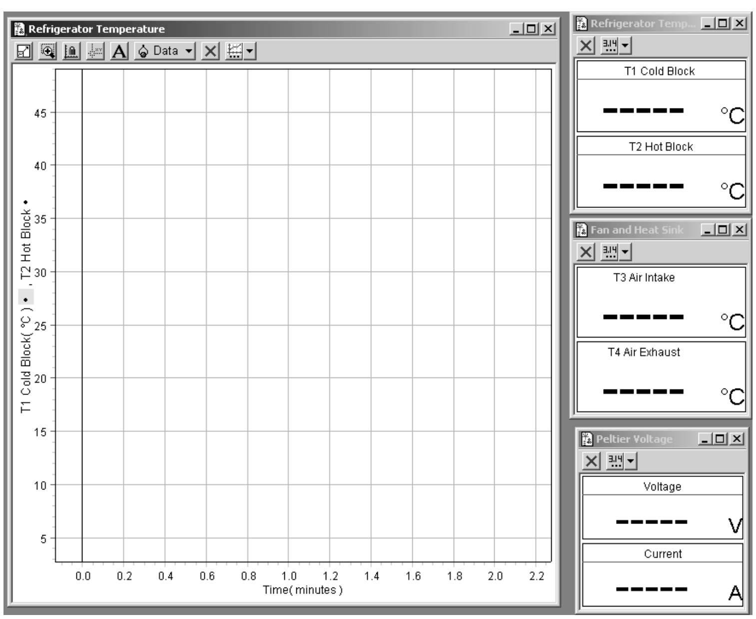
heat sink or the aluminum block. Connect the probe below the heat sink to Channel 3 of the Quad Temperature Sensor; connect the other probe to Channel 4.



5. *Voltage:* Connect the voltage leads of the Voltage/Current Sensor to the Voltage Ports on the board. Note the polarity.

6. *Current:* Connect separate red and black banana patch cords from the current input of the Voltage/Current sensor to the Current Ports on the board. Note the polarity.

7. *Computer:* Connect the sensors to the computer through the PASPORT interface. Open the pre-configured DataStudio file “Refrigerator”. The display should look as shown below.



Procedure

As you follow this procedure take notes of your observations and write down the answers to the questions.

1. Put the knife switch in the neutral position (straight up). Set the DC Voltage to about 6 volts.

2. Turn on the fan.

3. Start data recording. Set switch to Heat Pump mode. (Check that the current is not more than 1 amp; if it is, the sensor will beep and you should open the switch, decrease the applied voltage, then close the switch again.)

4. Observe the temperatures of the hot and cold sides of the peltier device. Which side has the bigger temperature difference from room temperature? Why are they not the same?

5. Let the refrigerator run in this mode for at least 5 minutes while the temperatures reach equilibrium. Meanwhile, continue on to the next section.

Air Flow and Heat Transfer

6. Observe the air temperatures below and above the heat sink. By how much does the air temperature increase when it passes through the heat sink? This increase in temperature is caused by the heat flowing from the heat sink to the air.

You will now estimate the rate of heat transfer from the heat sink to the air. For a gas, we can write

$$Q = nc\Delta T$$

where, in this experiment:

Q = heat transferred from the heat sink to the air (in joules),
n = number of moles of air (not the mass),
ΔT = change in temperature of the air,
c = specific heat of air.

The specific heat of a gas depends on whether it is heated at constant volume or constant pressure. In this case the air is heated at constant pressure, so the specific heat is c_{air} = 29.1 J/(mol·°C).

The manufacturer's specification for the air flow generated by the fan is about 2 liters per second. At room temperature, one mole of gas occupies about 24.3 liters, so in one second the quantity of gas is

$$n = \frac{2\text{ L}}{24.3\text{ L/mol}} = 0.082\text{ mol}$$

7. *After the temperatures of the hot and cold blocks have stabilized*, calculate the heat, Q, transferred to the air every second. Is your estimate likely too high or too low? Explain your reasoning.

The power supplied to the heat pump is

$$P = IV$$

where:

P = power (in watts = joules/second),
I = current (in amps),
V = voltage (in volts).

8. From the measured values of applied voltage and current, calculate the energy used to run the heat pump for one second. How does the energy supplied to the peltier every second compare to your estimate of the heat transferred from the heat sink to the air every second? Which is bigger? Explain your observations in terms of conservation of energy.

Insulator, Fan and Heat Sink

9. When the hot and cold blocks have reached equilibrium, write down the temperatures. Did you make a good refrigerator?

10. Remove the foam insulator (continue recording data). Can you see a change in the cold temperature? Put the foam insulator back on. Why did the temperature change?

11. Turn off the fan (continue recording data). Observe the effect on the temperatures for a few minutes. How have the temperatures of both sides changed? How has the temperature difference between the hot and cold sides changed? Can you explain why?

12. Observe the air temperatures. Have they changed from when the fan was on? Do you think that the rate of heat transferred from the heat sink to the air has increased, decreased, or stayed the same? Explain your reasoning.

13. If the blocks were allowed to reach equilibrium with the fan off, what do you think the final temperature of the “cold” block would be? Would that represent a good refrigerator?

14. *Before the hot side reaches 80 °C* open the knife switch or turn the fan back on.

15. What part of a real refrigerator is represented by the cold block on your model?

16. In general terms, what does a refrigerator do to make the inside cold? Why does it need insulation? Why does it need a heat sink?

Further Investigation

1. Let the refrigerator run for several minutes with the insulator removed and the fan switched on. What is the equilibrium temperature of the cold block in this mode?

2. Without increasing the power supplied to the peltier, can you make the cold side colder? Propose a modification to your model refrigerator and do an experiment to test it.