Introduction:
A heat engine works by absorbing heat from a warm source and rejecting heat to a colder sink. It requires both of these to operate continuously. This experiment makes this clear to students because they have to work both with a warm source and a cold sink, without which the engine cannot be made to operate. Also demonstrated is Carnot efficiency as the difference between source and sink temperatures is varied.

Experimental goals:
After completing this experiment, students will be able to describe the need for both a heat source and a heat sink for a heat engine. They will be able to describe the operation of the simple heat engine. They will be able to describe the effect of varying temperature difference on efficiency.

California Science Standards addressed in this laboratory activity:
3(a) Students know heat flow and work are two forms of energy transfer between systems.
3(b) Students know that the work done by a heat engine that is working in a cycle is the difference between the heat flow into the engine at high temperature and the heat flow out at a lower temperature (first law of thermodynamics) and that this is an example of the law of conservation of energy.
3(g) Students know how to solve problems involving heat flow, work, and efficiency in a heat engine and know that all real engines lose some heat to their surroundings.

Investigation & Experimentation:
1(a) Select and use appropriate tools and technology (such as computer-linked probes, spreadsheets, and graphing calculators) to perform tests, collect data, analyze relationships, and display data.
1(c) Identify possible reasons for inconsistent results, such as sources of error or uncontrolled conditions.
1(d) Formulate explanations by using logic and evidence.
1(l) Analyze situations and solve problems that require combining and applying concepts from more than one area of science.
**Equipment:**
Pasco Heat Engine  
Ice and water containers

**Key words:** work, pressure, volume, heat, check valve

**Procedure notes:**
Each lab group needs a minimum of 2 students.  
Warm water bath should be 25-30°C and hot water bath should be 40-50°C.

**Answers to questions:**

**General Questions:**
1. Compare the number of warm water exposures needed to lift the 100g mass to the number needed to lift the 50g mass.

   *Lifting the 100g mass required more warm water exposures. (but it will not be doubled the amount of exposures, remember, the 35g piston is also being raised.)*

2. What was the effect of using hot water in place of warm water to raise the 100g mass?

   *The weight was raised much faster*

**Detailed Questions:**

1. When you moved the aluminum air chamber from the ice water to the warmer water, what happened to the temperature of the air inside the aluminum air chamber?

   *The temperature increased*

2. Did heat flow into or out of the aluminum air chamber?

   *Heat flowed into the aluminum air chamber*

3. What happened to the volume of the air?

   *The volume of air increased*

4. Did the aluminum air chamber get visibly larger when it was heated?

   *No*

5. Where did the extra air volume go and what did it do?  *Hint: Look at the arrangement of the check valves in the tubing!*

   *The extra air went out the tube, through the in-line check valve and into the bottom of*
the cylinder. It did not go out of the “T” because the check valve in the “T” prevented it.

6. When you moved the aluminum air chamber from the warm water to the ice water what happened to the temperature of the air inside the aluminum air chamber?

*The temperature decreased*

7. Did heat flow into or out of the aluminum air chamber?

*Out*

8. What happened to the volume of the air?

*It decreased*

9. Did the aluminum air chamber get visibly smaller when it was cooled?

*No*

10. Where did the extra air come from? *Hint: Look at the arrangement of the check valves in the tubing!*

*The extra air came in through the check valve in the “T”. Air could not come in via the in-line check valve because that valve only allows air to flow toward the cylinder.*

11. Considering an entire cycle, did all the heat energy absorbed from the warm water get turned into mechanical work? If not, where did the “wasted” energy go?

*Not all the energy went to work. Some energy was lost as heat to the ice water.*

12. Could you make an engine that works without a place for the heat to leave (a cold reservoir)? Why or why not?

*No. If you do not reject some heat, the working gas cannot be replenished and the engine will simply stop.*

13. Which water temperature caused the engine to lift the weight faster? How does this relate to the Carnot efficiency equation?

*The hot water lifted the weight faster. The carnot equation is \((T_{\text{hot}}-T_{\text{cold}})/T_{\text{hot}}\). The greater the difference between the hot and cold temperatures, the greater the efficiency and the faster the weight is raised.*

**References**

Pasco equipment guide
California Science Standards