Teacher Reference Pages

**Introduction:**
On a P-V diagram, the area inside of a closed loop describes the net work done by a system. In this experiment, a heat engine will be used to lift masses while recording data for pressure and piston position. The piston position data is used to determine the change in volume within the cylinder as well as the distance that the mass was lifted. Students will determine the area inside the P-V loop as well as the work done on the mass and then compare the two values. If the experiment is done properly the two values should be within 5 percent of each other.

**Experimental goals:**
After completing this experiment, students will be able to describe the relationship between the area within a loop of a P-V diagram and the work done by the system. They will be able to compute the work done on a mass being lifted. They will be able to evaluate the accuracy of their measurements and cite possible sources of errors in the experiment.

**California Science Standards addressed in this laboratory activity:**
2(b) Students know how to calculate changes in gravitational potential energy near Earth by using the formula (change in potential energy) = mgh (h is the change in the elevation).
3(a) Students know that 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(b) Identify and communicate sources of unavoidable experimental error.
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
- Vernier Gas Pressure Sensor
- Vernier LabPro Interface
- Pasco Rotary Motion Sensor
- Ring Stand
- String with attached Mass Hanger
- Slotted masses
- i-Book computer
- Ruler

**Key words:** work, pressure, volume, gravitational potential energy

**Procedure notes:**
Each lab group needs a minimum of 2 students.

There are two different adapters for the pressure sensor. They are clearly labeled. Make sure to use the correct adapter or the connectors won’t mate!

Students must complete the experiment in a timely fashion. Waiting too long for any part of the experiment will result in degraded results.

**Answers to questions:**

1. The drawing should look like this:

   ![P-V Diagram](image)

2. The values should be within 5% if the experiment was done carefully. It is nearly impossible to get identical values, but they SHOULD have been the same because we were measuring the same thing two ways.

3. Area should increase when mass increases and decrease when mass decreases.

4. Sources of error may include leaking by the piston, errors in the sensors, friction in the piston, mistakes made in the performance of the experiment, etc.

**Extension Question**
1. Using hotter water will extend right side of the P-V diagram.

**References**
- Pasco equipment guide
- Vernier equipment guide
- California Science Standards