Goals

1. To become familiar with the thermodynamics of a heat engine.
2. To compare the thermodynamic work to the mechanical work done in one cycle.

Equipment:

Pasco Heat Engine Apparatus, metal air chamber, stopper, tubing with connectors, hot plate, water, ice, beakers, pressure sensor, motion sensor, computer with LabPro interface, note card, tape, syringe, 200-g mass.

Reading:

- Review chapter T9

Pre-Lab Problems (answer 1-4 in WebAssign *and* record all, 1-5, in your notebook for reference during the lab**):**

The heat engine (shown on the next page) will cycle through states *A*, *B*, *C*, and *D* as follows:

- Transition *A* → *B*: The air chamber starts in the cold reservoir and a mass is added to the platform above the piston.
- Transition *B* → *C*: The air chamber is moved to the hot reservoir.
- Transition *C* → *D*: The air chamber remains in the hot reservoir and the mass is removed from the platform.
- Transition *D* → *A*: The air chamber is moved to the cold reservoir.

1. Consider the transition from state *A* to state *B*. What should happen to the height of the platform when you add the mass? What should happen to the volume of the gas? What should happen to the pressure? If the change happens quickly, approximately what kind of transition is this (isobaric, isothermal, adiabatic, or isochoric)?
2. Consider the transition from state *B* to state *C*. What should happen to the height of the platform when you move the air chamber from the cold reservoir to the hot reservoir? What should happen to the volume of the gas? What should happen to the pressure? What kind of transition is this (isobaric, isothermal, adiabatic, or isochoric)?
3. Consider the transition from state *C* to state *D*. What should happen to the height of the platform when you remove the mass? What should happen to the volume of the gas? What should happen to the pressure? If the change happens quickly, approximately what kind of transition is this (isobaric, isothermal, adiabatic, or isochoric)?
4. Consider the transition from state *D* to state *A*. What should happen to the height of the platform when you move the air chamber from the hot reservoir to the cold reservoir? What should happen to the volume of the gas? What should happen to the pressure? What kind of transition is this (isobaric, isothermal, adiabatic, isochoric, or none of those)?
5. How can you calculate the thermodynamic work done during one cycle?

Lab Procedure:

1. Be sure that the piston is attached to a post so that it cannot tip over.
2. Prepare boiling water for the hot reservoir and ice water for the cold reservoir.

3. Set up the equipment as shown below. Make sure the lock near the top of the heat engine is loose so the piston can move. Also, check that the two clamps (underneath the piston) on the tubing are open. Record the diameter of the piston, which is written on the base.
4. Plug the motion sensor into LabPro's "DIG/SONIC 1" port and the gas pressure sensor into "CH 1". Open the file "HeatEngine.cmbl" with the *LoggerPro* program.
5. Tape a piece of note card to the top of the piston and aim the motion detector at it. With the piston all the way down, zero the motion sensor by selecting "Zero…" from the "Experiment" menu and choosing that sensor. After this, the motion sensor will measure the height of the piston relative to the bottom of the piston.
6. Calibrate the pressure sensor by selecting "Calibrate" from the "Experiment" menu and selecting that sensor. To use two points for calibration, unselect "one point calibration". For the first point, attach the syringe and pull it all the way back to get a pressure of approximately zero (to the accuracy of the sensor). For the second point, remove the syringe to get atmospheric pressure (101 kPa).
7. With the pressure sensor disconnected from the piston, place the air chamber in the cold bath and let it cool. Put the 200-g mass on the piston. Manually raise the piston slightly and attach the pressure sensor to the piston. When you let go of the piston, it should lower, but not quite touch bottom. You may have to try this a few times to get it right.
8. Go through the entire cycle slowly. Compare what happens to what you expect.
9. Press "Collect" in *LoggerPro* to record the pressure and height. Move through the cycle fairly rapidly to avoid significant air leakage. Place and remove the mass right after a data point is taken. Repeat the cycle at least once to be sure it can be approximately reproduced.

Post-Lab Assignment:

1. Make a graph of pressure vs. volume in the piston. The total volume of the gas is larger, but it changes in the same way as the volume in the piston. Label points on the graph corresponding to states *A*, *B*, *C*, and *D*. Indicate the nature of each of the transitions.
2. For one cycle, calculate the net thermodynamic work. Explain any approximations that you make. You do *not* have to find the uncertainty.
3. For one cycle, calculate the net mechanical work on the mass. You do *not* have to find the uncertainty. In a complete cycle, the piston returns to its original height so no net work is done on it.
4. Compare the works calculated in the two previous steps.