Physics 213 Lab  Work done by a Heat Engine

Object:

To study the work done by a simple heat engine by comparing it to the mechanical work it does.

Apparatus:

Pasco Heat Engine with Reservoir, Pasco Low Pressure Sensor, Pasco Temperature Sensor, Pasco Rotary Motion Sensor, Steam Generator with stoppers and insulating ring, 5 g weight hanger, and weights (10 g, 20 g, 50 g, 100 g, and 200 g), string, small stand and bar, plastic tubing from heat engine set, 1000 ml beaker and ice, water for reservoirs, paper toweling for wiping up spills.
See Figures 1 and 2.

Theory:

The work done by a heat engine in one thermal cycle can be calculated as the area enclosed within a p-V diagram of the thermal cycle. In this case the work done will lift a known mass through a height $\Delta h$, and thus can also be calculated according to the work done by (against) gravity as

$$mg\Delta h. \quad (1)$$
Procedure:

(Refer to Figures 1, 2 and 3 as appropriate)

1. Turn on the Science Workshop interface box and the computer (in this order).
2. Start Data Studio.
3. Connect the low pressure sensor and the working substance (air) can tubes to the pressure sensor and working substance can, respectively. Connect the other tube ends to the output connections on the heat engine.
4. Assemble a string to the heat engine platform, pass it over the rotary motion sensor, and attach a 5 g weight hanger to the other end.
5. Add 30 g to the weight hanger for a total of 35 g. (Note: This mass compensates for the mass of the piston which is 35 g according to the manufacturer.)
6. Insert the temperature sensor into a one hole stopper and place in the steam generator (high temperature reservoir). Turn on the steam generator and set the temperature control to point to the U in MEDIUM. (The goal is a temperature between 60 and 95 C.)
7. Connect the Rotary Motion Sensor, Low Pressure Sensor and Temperature Sensors to the interface. Click and drag the sensor icons to the picture of the interface box on the monitor.
8. Open a Digital Temperature window to monitor the temperature. (Click and drag the Digits icon to the icon of the temperature sensor.)
9. Double click on the rotary motion sensor and select linear position measurement and deselect angular position.
10. Open a graph that plots position horizontally and pressure vertically. (Note: the position of the piston is proportional to the volume.) First click and drag the graph icon to the pressure sensor icon, then click and drag the rotary motion sensor icon.
to the horizontal axis of the graph that is displayed. If necessary select the Graph (icon) menu at the top right of the graph, and select Data Grouping.

11. Disconnect the tube to the working substance can to unseal the system and manually adjust the piston so it is a few cm above the bottom of the cylinder. While keeping the position of the piston where you set it reconnect the tube to the apparatus.

12. Place the working substance can into the ice-water (low temperature) mixture. **BE CERTAIN TO MONITOR THE TEMPERATURE OF THE HIGH TEMPERATURE RESERVOIR THROUGHOUT THE TAKING OF DATA! RECORD ALL VALUES AND WHEN CHANGES OCCURRED (IF ANY).**

13. Collect data for one thermodynamic cycle by clicking on the start button then doing the following:
   a. Add 100 to 200 g to the platform.
   b. Move the working substance can to the high temperature reservoir (steam generator at 6) °C or higher. Allow the gas to reach thermal equilibrium.
   c. Remove the mass (Step 13a) from the platform.
   d. Move the working substance can to the low temperature reservoir.

14. Stop the data collection.

15. Use the smart cursor to find the data points for max and min pressure, and max and min position at each endpoint (the corners of the trapezoid) for the cycle.
   Note: You should turn off the data point gravity feature.

16. Repeat steps 13 through 15 for two more complete cycles using the same mass.

17. Change the mass on the platform to another value (between 100 g and 200 g) and repeat steps 13 through 16 for 3 cycles with the new mass.

18. Shut down and clean up.

**Calculations and Report:**

Refer to Figure 3 while following the instructions below:

Using the data from the smart cursor:
1. Determine the change of height for the piston.
2. Using $W = mg\Delta h$ calculate the work done against gravity in lifting the mass.

To calculate the thermodynamic work done:
3. Calculate the area of the trapezoid on the h - V diagram for each cycle.
4. Calculate the thermodynamic work done lifting the mass on the platform for each cycle by multiplying the area obtained in step 2 by the area of the piston (piston diameter = 32.5 mm). [Note: $W = p\Delta V$ which for this application is $(p\Delta h)A$.]
5. Determine the percent difference for each cycle using step 2 as the “most accurate” value for the work done.
6. Which cycle (if any) was the most accurate? Why?
7. Were the cycles repeatable? Why or why not?
8. What are your sources of experimental error?