Thermodynamics

Pressure-Volume Work Determination

On a P-V diagram, the net work done is equal to the area inside of a closed loop. In this lab you will find that work value and relate it to actual work done.

**Purpose:**
To find the work done by a gas while lifting a weight.

**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
- Aluminum Air Chamber

**Cautions:**
This equipment is delicate. Everything should go together with the lightest of touches. Do not force anything!

You may find that some of the setup procedure has already been done for you. Check each step to make sure that it is done properly. The success of your work depends upon correct setup!

**Procedure to set up the heat engine**
1. Prepare two containers of water, one at room temperature and one with ice.
2. Place the heat engine on the ring stand base.
3. Attach the rotary motion sensor to the ring stand at the top of the rod, extending over the heat engine.
4. Loosen the thumbscrew (black screw at the top of the heat engine) holding the heat engine piston, lift the piston to a point midway in its travel, and retighten the thumbscrew. *Tighten this screw lightly, just enough to hold the piston in position.*
5. Add 30g to the mass hanger.
6. Wrap the string clockwise around the middle pulley of the rotary motion sensor, then bring the hook down and hook it under the tray of the heat engine. There is a small hole in this tray to accept the end of the wire hook. Allow the mass holder to hang freely.
7. Wind the string around the middle pulley until the mass holder is approximately 15cm below the pulley. You may lower the position of the rotary motion sensor on the ring stand a little to get close to the 15cm dimension.
8. Adjust the heat engine so that the string from it to the pulley is vertical.
9. Connect the tube from the aluminum air chamber to one port of the heat engine. Push and twist slightly to lock the tube in place.
10. Connect the Gas Pressure Sensor Adapter from the pressure sensor to the other port of the heat engine. Push and twist slightly to lock the tube in place.
11. Connect the gas pressure sensor to the “CH 1” port of the LabPro interface.
12. Connect the rotary motion sensor to the “DIG/SONIC “1 port of the LabPro interface.
13. Connect the LabPro interface to the iBook computer with the USB cable.
14. Plug the LabPro sensor into a power outlet. After a short pause, it will beep merrily.
15. Plug the i-Book computer in with its power adapter.
16. Turn on the i-Book and wait for it to boot up.
17. Log on to the computer with the username “student” and password “student”.
18. Launch the “Heat Engine” Activity by double-clicking it.
19. A Sensor confirmation window will appear. Click on Connect to activate the Rotary Motion Sensor.

Data Collection:
1. Loosen the thumbscrew on the Heat engine, allowing the piston to move freely. *It should stay pretty much in place as it is counterbalanced by the hanging weight.*
2. Immerse the aluminum air chamber in the ice water bath. *The piston should move down a bit as the water cools the aluminum air chamber.*
3. Wait one minute for the aluminum air chamber to cool down properly.
4. Click on the zero button.
5. Make sure the rotary motion sensor is selected and the gas pressure sensor is not.
6. Click on OK to zero the rotary motion sensor.

**The next few steps must be done with minimum delay for best data.**
7. Start the data collection process by clicking on the Collect button.
8. Once data begins to show on the computer screen in the data table, gently place the 100g mass on the platform of the heat engine and immediately move the aluminum air chamber from the ice water bath to the room temperature water bath.
9. Watch the “Change in Volume value at the bottom left of the screen. It will increase as the air in the aluminum air chamber is warmed.
10. When the “Change in Volume” value stays steady for more than one second, remove the mass from the platform of the heat engine and immediately move the aluminum air chamber from the room temperature bath to the ice water bath.
11. Watch the “Change in Volume” value at the bottom of the screen. It will decrease as the air in the aluminum air chamber is cooled.
12. When the “Change in Volume” value reaches zero, click on the Stop button to end data collection. *Do not allow this value to go negative as this will cause errors in your data analysis.*

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| 8. Add mass & Move Chamber | 9. Wait until ΔV is steady (1 second w/no change) | 10. When ΔV is steady Remove mass & Move Chamber | 11. & 12. When ΔV goes to 0 click stop | P-V, Adler |
Recording your data

1. Click on the Integrate button (just to the right of the STAT button). The area inside the loop will fill and the area data will be displayed (it is labeled as “integral” in the integration box).
2. Record the integral value in the data table below in the “Area Inside…” column. 
   Note that you should record data in the middle row for the 100g mass!
3. Click once in the graph window to select it.
4. To determine the maximum height of the piston ($H_{\text{max}}$), click and drag across the lower right corner of the graph. The corresponding data points will be highlighted in the data table. You may have to scroll within the data table to find the highlighted points. Find the maximum piston height in the distance column of the data table and record that value in the data table below.

Data Table:

<table>
<thead>
<tr>
<th>Mass (kg)</th>
<th>Area inside closed loop (kPa* m$^3$)</th>
<th>$H_{\text{max}}$ (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.05</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.20</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Analyzing your data

1. The area of the loop is given in kPa*m$^3$, but we need it in Pa*m$^3$ (which is the same as Joules). To do this, multiply the work value from above by 1000 Pa/kPa and record the $W_{\text{area of loop}}$ in the calculation table below.

2. Determine the work done in lifting the mass using the following formula:
   $$W = m \cdot g \cdot H_{\text{max}}$$
   (m in kg, H in m)

3. Record the work $W_{\text{lifting mass}}$ in the calculation table below.

4. Calculate the percent difference between the two work values below using the following formula:
   $$\left| \frac{W_{\text{area of loop}} - W_{\text{lifting mass}}}{W_{\text{area of loop}}} \right| \times 100$$

5. Repeat the data collection and data analysis for masses of 50g and 200g. Complete the data table.
Calculation Table:

<table>
<thead>
<tr>
<th>Mass (kg)</th>
<th>Work_{area of loop} (J)</th>
<th>Work_{lifting mass} (J)</th>
<th>% Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.05</td>
<td></td>
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<tr>
<td>0.10</td>
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</table>

Questions:

1. Draw the typical P-V diagram in this space. You do not have to label values; just draw the shape of the diagram you see on the display.

2. Compare the two work values for each mass in your calculation table. Were they the same? If not, how close were they? Should they have been the same? Why or why not?
3. Did the values for the area inside the loop and the value for work go up together as the weight was increased?

4. Name at least two sources of error that were present in the lab and describe how each would have affected the results of the lab? (no human error)

Extension question:

1. Describe what would happen to the graph if the room temperature water were replaced with water at 90°C.