

STIRLING ENGINES

Experiment 4

Time : 3 hours



Figure 1. The low temperature Stirling engine.

Equipment

Low temperature Stirling engine
5V power supply
Gas pressure sensor
Voltage sensor
LabQuest Mini
Foam brake
Insulated water container
Digital thermometer
Stirling.cmb1 file

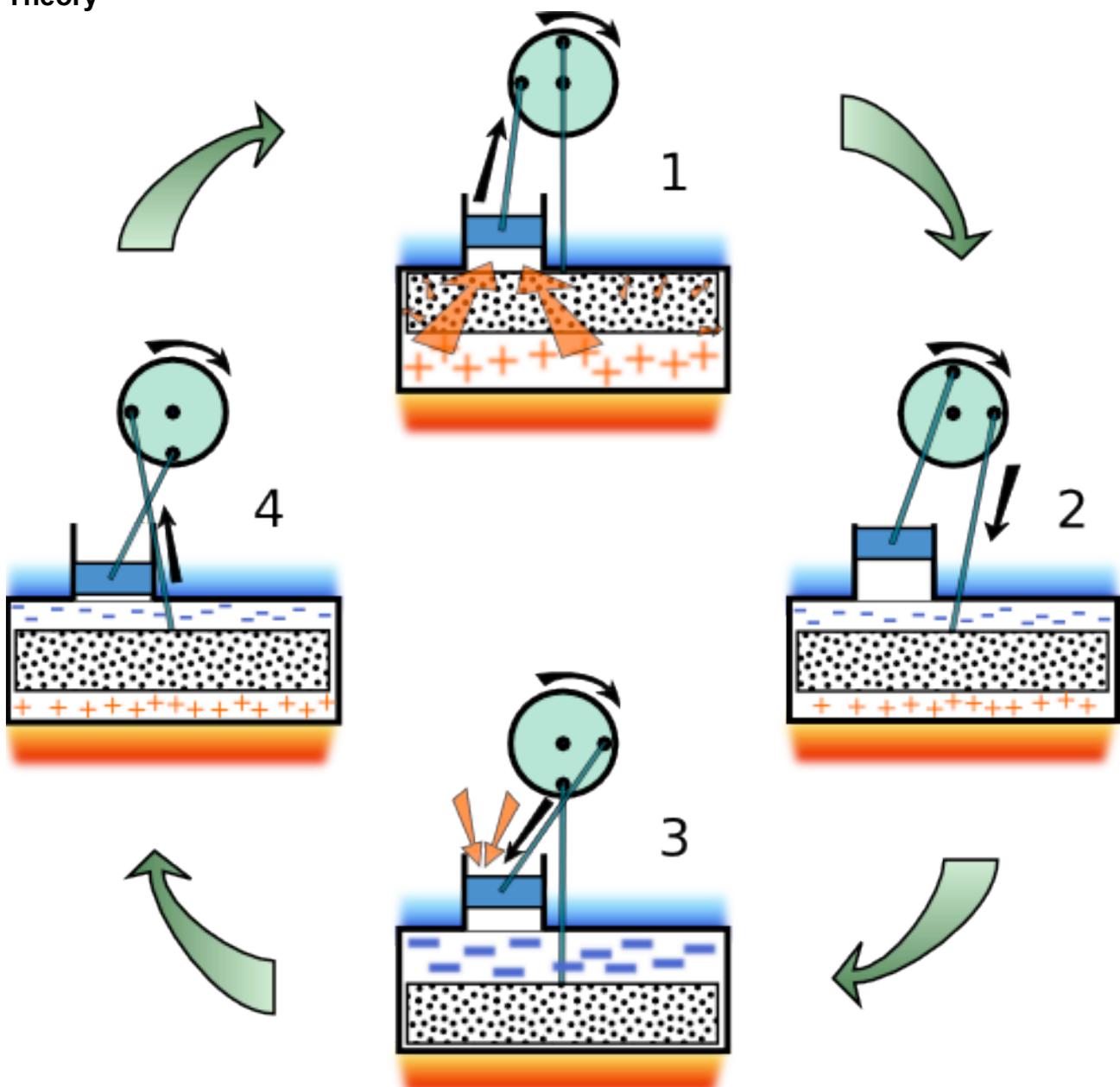
Introduction

In this experiment a low temperature displacer type Stirling engine will be used to explore the harvesting of heat into mechanical energy. This engine is intended to clearly demonstrate the operation of a Stirling engine rather than be powerful or highly efficient. PV graphs will be generated to examine the work being done in the Stirling cycle of this engine.

Warning: The model Stirling engine has some delicate components. Please treat this fine machine with the care it deserves.

Warning: You will be using hot water in this experiment. Please ensure you do not burn yourself, or spill water on electrical equipment.

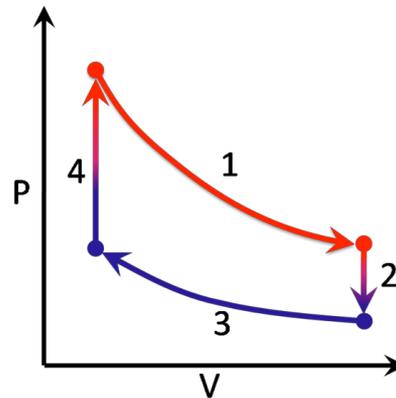
Theory



<http://janneinosaka.blogspot.com.au/2008/05/stirling.html>

Figure 2. The displacer type Stirling engine cycle.

Figure 2 shows four stages in the cycle of the displacer type Stirling engine. The top plate of the large cylinder is the 'cold' plate (shown blue). The plate on the bottom is the 'hot' plate (shown red). Also note that the large displacer piston is a loose fit in the cylinder which can allow air to pass around the piston.



http://en.wikipedia.org/wiki/File:Stirling_Cycle_color.png

Figure 3. The 4 stages of pressure and volume in a stirling cycle.

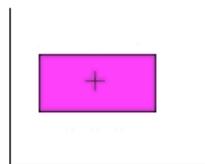
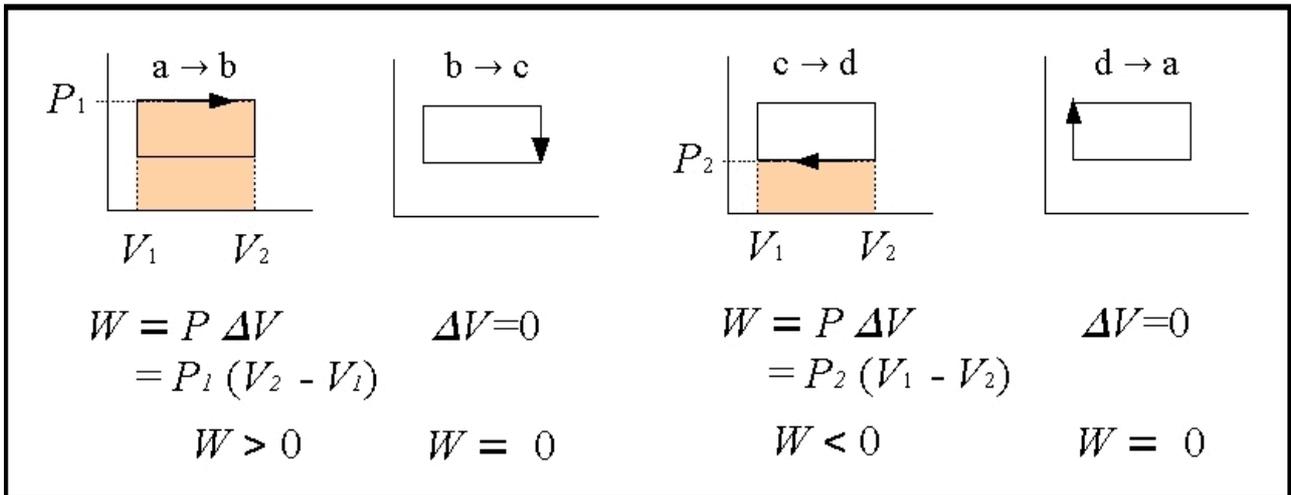
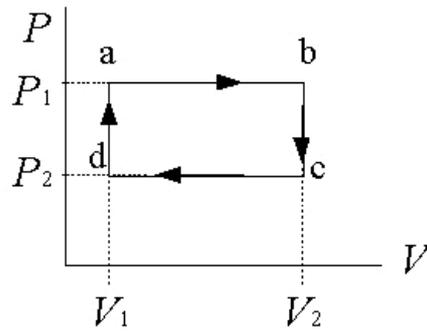
A thermodynamic cycle exists for an engine like this which describes the phases occurring in each cycle. Phase 1 in the above cycle is the isothermal expansion. This is where the gas in the engine is heated solely due to application of an external heat source. Phase 2 is the isovolumetric (or isochoric) phase. This is constant volume heat removal. Phase 3 is isothermal compression, ie. the gas compresses due to cooling. Finally phase 4 is the isovolumetric (or isochoric) phase. This is constant volume heat addition.

The total work done can be calculated as

$$W = \oint P dV$$

In this case to calculate the work done one needs to integrate the four phases. Figure 4 shows the process. Obviously the integration of phases 2 and 4 give zero work. Integrating phases 1 and 3 will reveal positive and negative work, and the difference between these two will give the work done in the total cycle. This is the area contained by the loop.

It should be noted that in a real machine the Stirling cycle will not be as square sided as shown in these figures. Thermal and mechanical inertia will make the cycle into a rounded loop. Appropriate methods to calculate the area of the loop will reveal the total work. The total work divided by the period of the cycle will give the power of the engine.



$$W_{\text{NET}} > 0$$

<https://people.ok.ubc.ca/jbobowski/Stirling/which.html>

Figure 4. Calculation of work from the Stirling cycle.

Q1. Examine the stirling engine, and figure 2, and write a full description on how the engine operates. Relate the operation to the phases of the PV cycle.

EXPERIMENT

PV plots

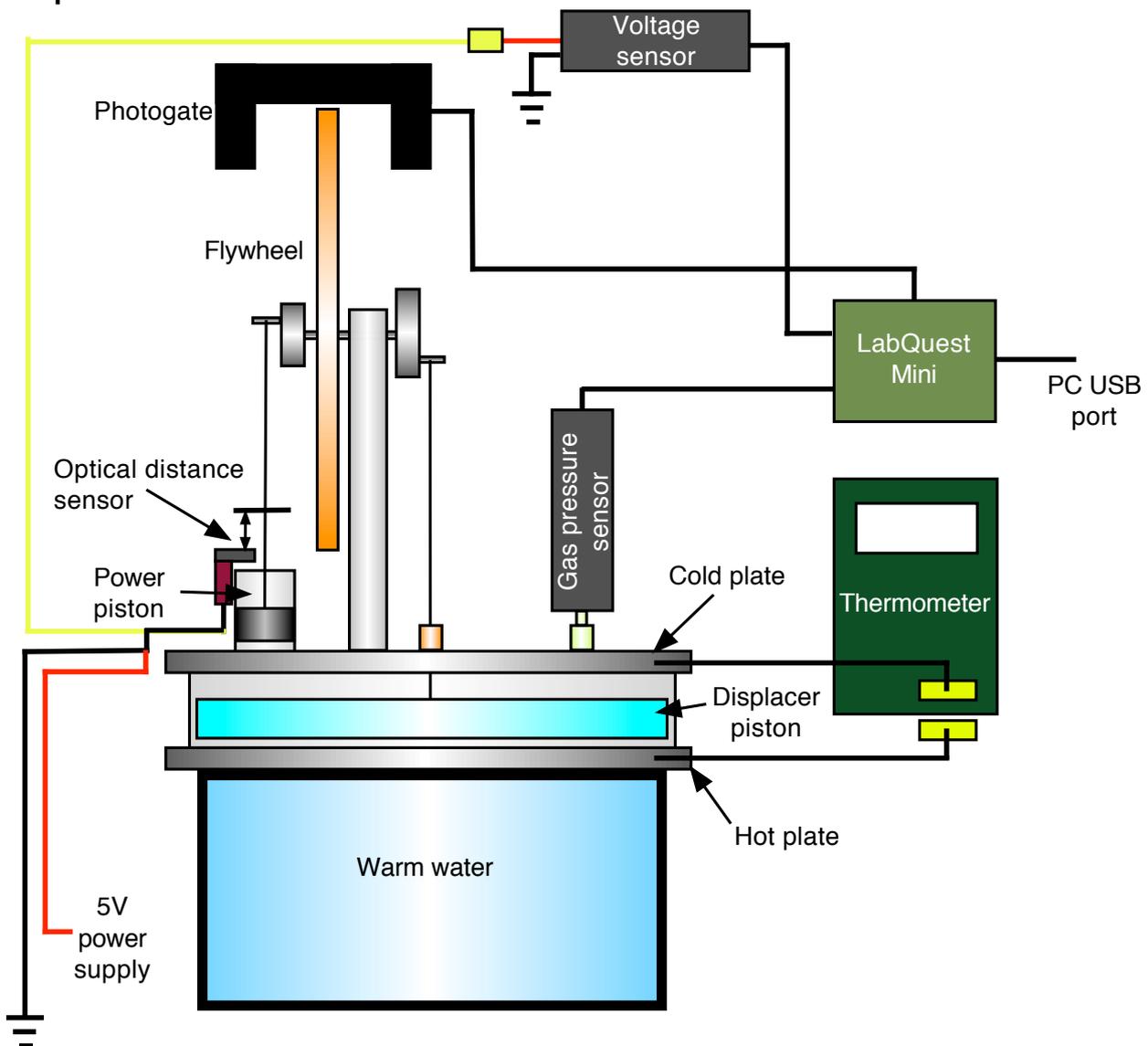


Figure 5. The experimental Stirling engine setup.

1. Ensure the engine and instrumentation is set up as shown in figure 5.
2. Run the 'stirling' cml file on the PC
3. Dilute the hot water supplied until it is approximately 75°C. A separate temperature probe is available for measuring the water temperature.
4. Carefully place the hot water under the engine.



Figure 6. The direction of rotation.

5.Wait approximately 15 seconds then gently start the flywheel spinning in clockwise direction as shown above.

6.Press the start button on the loggerpro software (green play symbol).



7.Observe the readings on the PC screen. When the engine speed stabilises stop the recording when a full screen of data is displayed. Save the screen (print, photo, screen shot etc). Also record the temperature of both the top and bottom plates.

8.In order to integrate the PV plot you must have a waveform that starts and stops at the same point on the graph. Create two new manual columns (Data menu) named Press Man and Vol Man, or similar. Select one cycle of Pressure data that starts and ends at the same value and copy it into the Press Man column. Copy the corresponding Volume data into the Vol Man column. Create a new graph (Insert menu) and click on the Y axis label and change it to Press Man. Similarly change the X axis label to Press Man. Now click the Integrate button on the toolbar



9.If you have selected a non-overlapping set of data the integral should give you just the area of the PV loop. If you data has a column done to zero you could just subtract this area from the total.

10.A small piece of foam is supplied on a retort stand. Use this to provide a light load to the flywheel. The engine will slow. Record another full screen of data and take the integral of the loop.

11.From your data you can now calculate the work and then power of the engine.

12.Cool the water to around 45°C and repeat the above measurements

13.This Stirling engine will actually run using the heat from a human body and can run on your hand. If you have time you might like to explore the unloaded performance of the engine at human body temperature. Do not use your hand as it will not provide a safe and stable support for the equipment. Simply use water at 38°C.

REPORT

Your results should show all the answers to questions and the requested data. You will also be required to fully discuss all of your results. You need to be observant with all the data you collect and point out any relevant features. Don't forget your performance in the lab and your final report will contribute to your mark.