

Heat Engine



Setup



Detail of Piston and Pulley

Purpose: Students see, on a PV diagram, as a real heat engine goes through a cycle.

This is a *DataStudio* experiment, which can be projected on the lecture room screens. The students can see a real heat engine go

through a cycle, and the work it performs is equal to the PV cycle area.

The heat engine and Carnot's cycle is one of the most esoteric items we inflict on the students. While this demo is a little more involved, it is well worth doing.

Directions:

The heat engine consists of an aluminum reservoir (can) and a piston assembly.

SETUP:

The reservoir and pressure sensor are connected to the piston by tubes with quick (twist and pull) connectors. To set up, make sure the piston is in about mid position. If not, disconnect one of the tubes, position it, and reconnect.

The pressure sensor connects to analog channel A of the interface box, located on the laptop cart.

The piston's displacement is measured by the movement of the counterweight suspended over a 'smart' pulley. The smart pulley has two digital outputs which connect to inputs 1 (yellow plug) and 2 (black plug) of the interface box (They are labeled.).

The *DataStudio* converts the pulley's rotation and radius into piston displacement and volume change. Make sure the thread connecting the counterweight is in the largest pulley groove and wrapped in the direction shown in the photo. This direction gives the correct sense of change.

The piston diameter is 32.5 mm so the piston displacement Δh is linked to gas volume change by

$$\Delta V = (8.296 \times 10^{-4} \text{ m}^2)\Delta h.$$

The volume scale for the PV graph is in 10^{-4} m^3 .

EXPERIMENT:

To begin the experiment make sure the laptop cart is plugged in. Then double click on the 'HEAT ENGINE' icon on the laptop's desktop. This launches the *DataStudio* script program. Once the program is loaded and the graphs appear, you can begin collecting data by clicking the start button.

There are two graph windows: on top is the *PV* diagram – which is best to view while going through the heat engine cycle. The other graph is piston displacement vs. time and useful for figuring the mechanical work done in lifting a weight. You can change from graph to graph in the usual way, either using the view menu or by max- and minimizing the desired graph windows.

- A) Start the cycle with the piston unloaded and the reservoir can in the ice bath (point A on the graphs shown below).
- B) Add the 200 g weight to the piston top, which causes an isothermal (or more likely, adiabatic) compression to point B.
- C) Move the reservoir can to the hot bath. The system expands under constant pressure to point C.
- D) Remove the weight, and the system expands further (adiabatic?) to point D.
- E) Finally, change the reservoir can back to the ice bath to return the system to point A.

While it is nice just to see that a heat engine actually goes through a cycle as texts claim (This is not a Carnot Cycle.), it is also interesting to compute the work done by the engine.

This is simply found from the distance the piston raises the extra 200 g weight, $W=mgh$. The distance the piston raises the weight can be found from the 2nd graph of piston position vs. time (See the sample graphs and calculations below.).

Compare this with the area of the cycle loop on the PV diagram. Since the upper and lower limits are constant, and the sides of the loop are reasonably straight, all you need to do is approximate a rectangle, $W \approx \Delta P \Delta V$ (again, see below).

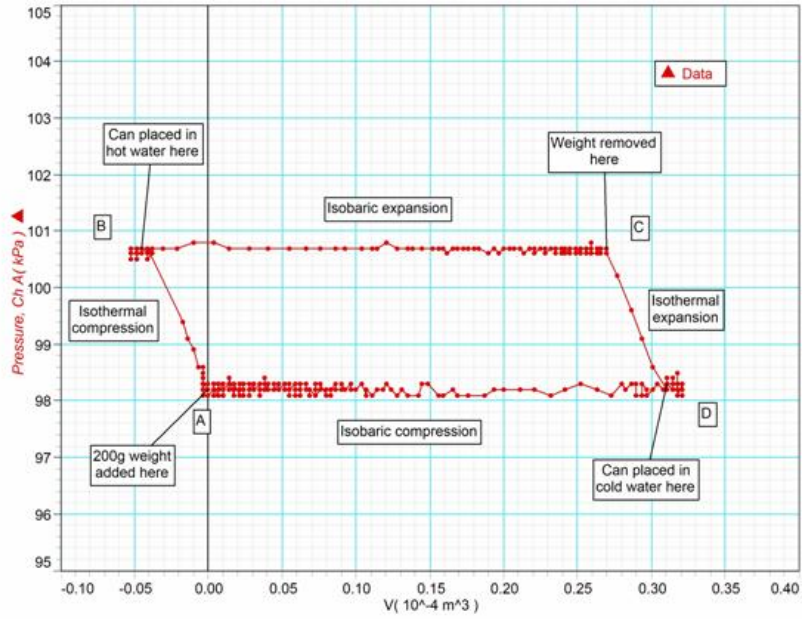
Tips:

If you have a false start, you can always delete old data from the charts on the 'experiment' menu. It might also be fun to repeat the experiment (keeping the old data graphed) with extra weight.

Extra Equipment: DataStudio laptop, can of ice water (ice machine located in back of room 509), hot plate and can to boil water (Starting with hot tap water, I have found that the hot plate heats up the water enough in 5 min.).

Location: Shelf D3

Example



carnot.ds

Graph 4

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