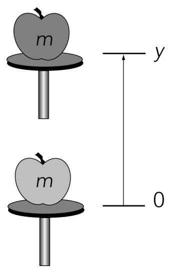


Fig. 18.10. Doing useful mechanical work by lifting a mass, *m*, through a height, Δy.

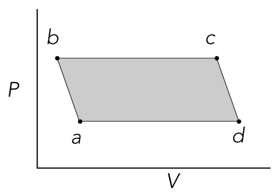


Fig. 18.11. Doing thermodynamic work in a heat engine cycle.

200g from a processing conveyer belt to the packing conveyer belt that is 10cm higher. The engine you are to experiment with is a "real" thermal engine that can be taken through a four-stage expansion and compression cycle and that can do useful mechanical work by lifting small masses from one height to another. In this experiment we would like you to verify experimentally that the useful mechanical work done in lifting a mass, m, through a vertical distance, Δy, is equal to the net thermodynamic work done during a cycle as determined by finding the enclosed area on a P-V diagram. Essentially you are comparing useful mechanical "$mg\Delta y$" work (which we hope you believe in and understand from earlier units) with the accounting of work in an engine cycle as a function of pressure and volume changes given by the expression in Equation 18.5.

Although you can prove mathematically that this relationship holds, the experimental verification will allow you to become familiar with the operation of a real heat engine. To carry out this experiment you will need:

- 1 syringe, 10 cc*
- 1 length of Tygon® tubing, 30 cm (1/8" ID)
- 1 Erlenmeyer flask, 25 ml
- 1 #0 one-hole rubber stopper
- 1 rod stand
- 1 rod
- 1 test tube clamp
- 2 coffee mugs (to use as reservoirs)
- 1 50 g mass
- crushed ice, approx. 50 ml
- small tray (to prevent spilling)
- 1 electronic scale

OPTIONAL

- A computer data acquisition system
- 1 pressure sensor

Recommended Group Size:	2	Interactive Demo OK?:	N

The Incredible Mass Lifter Engine

The heat engine consists of a hollow cylinder with a plunger or piston that can move along the axis of the cylinder with very little friction. The piston has a small platform attached to it for lifting masses. A short length of flexible Tygon® tubing attaches the cylinder to an air chamber (consisting of a small flask sealed with a rubber stopper) that can be placed alternately in the cold reservoir and the hot reservoir. A diagram of this mass lifter is shown in Figure 18.12.

If the temperature of the air trapped inside the syringe, cylinder, tubing, and flask is increased, then its volume will increase, causing the platform to rise. Thus, you can increase the volume of the trapped air by moving the flask from the cold to the hot reservoir. Then, when an apple has been raised through a distance Δy, it can be removed from the platform. The platform should then rise

*This project can also be done using the PASCO scientific Heat Engine/Gas Law Apparatus (TD-8572).

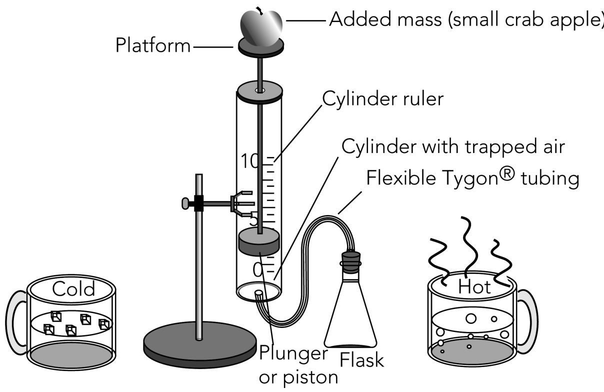


Fig. 18.12. A schematic diagram of the incredible mass lifter heat engine.

a bit more as the pressure on the cylinder of gas decreases a bit. Finally, the volume of the gas will decrease when the air chamber is returned to the cold reservoir. This causes the plunger (or piston) to descend to its original position once again. The various stages of the mass lifter cycle are shown in the following diagram.

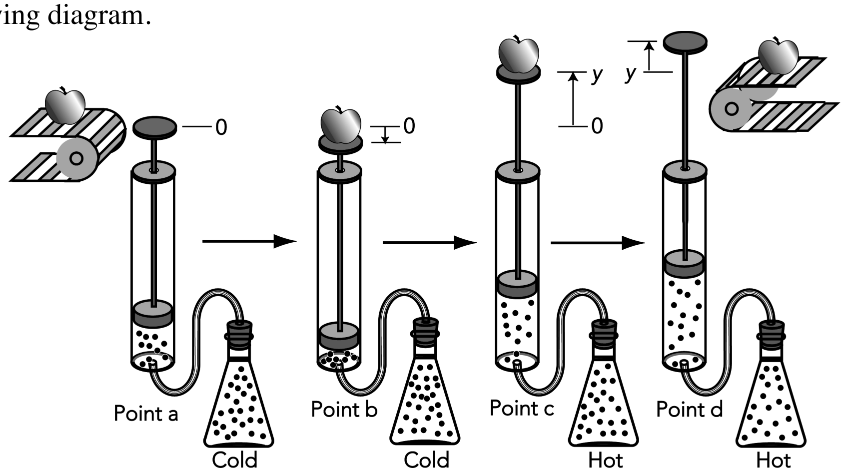


Fig. 18.13. A simplified diagram of the mass lifter heat engine at different stages of its cycle.

Before taking data on the pressure, air volume, and height of lift with the heat engine, you should set it up and run it through a few cycles to get used to its operation. A good way to start is to fill one mug with an ice and water mixture and another with preheated water at about 60–70°C. The engine cycle is much easier to describe if you begin with the plunger resting above the bottom of the cylinder. Thus, we suggest you raise the plunger to the 40 mm mark before inserting the rubber stopper firmly in the small flask. Also, air does leak out of the syringe slowly. If a large mass is being lifted, the leakage rate increases, so we suggest that you use a 200 g mass instead of an apple.

Warning: If you use a larger flask or a greater temperature difference with a 10 cc syringe, the plunger might shoot out of the syringe and break!

After observing a few engine cycles, you should be able to describe each of the points *a, b, c,* and *d* of a cycle carefully, indicating which of the transitions between points are approximately adiabatic and which are isobaric.

c. Use the measurements at point *b* to calculate the total volume and pressure of the air in the system at that point in the cycle. Show your equations and calculations in the space below and summarize your results with units.

P_b = __________ V_b = __________

d. What is the height, Δy, through which the added mass is lifted in the transition from *b* to *c*?

e. Use the measurements at point *c* to calculate the total volume and pressure of the air in the system at that point in the cycle. Show your equations and calculations in the following space and summarize your results with units.

P_c = __________ V_c = __________

f. Remove the added mass and make any measurements needed to calculate the volume and pressure of air in the system at point *d* in the cycle. Show your equations and calculations in the space below and summarize your results with units.

P_d = __________ V_d = __________

g. We suspect that transitions from $a \mapsto b$ and from $c \mapsto d$ are approximately adiabatic. Explain why.

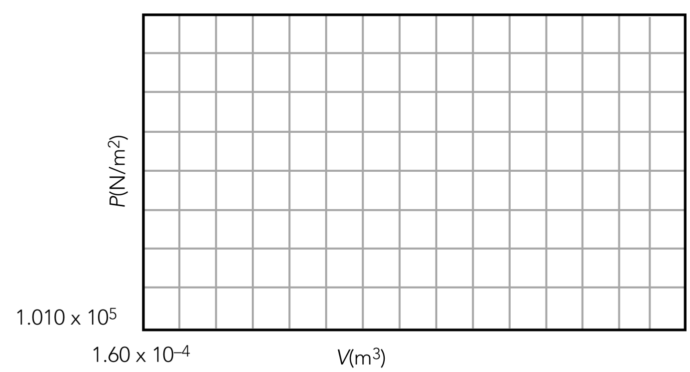
h. You should have found that the transitions from $b \mapsto c$ and from $d \mapsto a$ are isobaric. Explain why this is the case.

Finding Thermodynamic Work from the *P-V* Diagram

In the next activity you should draw a *P-V* diagram for your cycle and determine the thermodynamic work for your engine.

18.10.4. Activity: Plotting and Interpreting a *P-V* Diagram

a. Fill in the appropriate numbers on the scale on the graph frame that follows and plot the *P-V* diagram for your engine cycle. Alternatively, generate your own graph using a computer graphing routine and affix the result in the space below.



b. On the graph in part a. label each of the points on the cycle (a, b, c, and d). Indicate on the graph which of the transitions ($a \mapsto b$, $b \mapsto c$, etc.) are adiabatic and which are isobaric.

Next you need to find a way to determine the area enclosed by the *P-V* diagram. The enclosed area doesn't change very much if you assume that P is approximately a linear function of V for the adiabatic transitions. By making this approximation, the figure is almost a parallelogram so you can obtain the enclosed area using one of several methods. Three of the many possibilities are listed on the next page. *Creative students have come up with even better methods than these, so you should think about your method of analysis carefully.*