9.2: Activities

Equipment

- gas piston with plunger, in sealed attachment with metal canister
- Pasco box, pressure sensor, displacement sensor pulley, and software
- bottle "claw" clamp for holding canister in hot water
- pot of boiling water
- mug of ice water
- $200g$ weight

The General Idea

The concept of a *heat engine* is the focus of this lab. All of the critical features for a heat engine are present:

- There is a confined "working gas."
- The engine completes a full cycle – the working gas returns to its original thermodynamic state at the end of the cycle – which means that all the energy that comes into the engine (in any form) exits the engine by the end of the cycle (also in any form).
- Two thermal reservoirs are available to the engine for accepting or dumping heat energy.
- In the final accounting, there is a net amount of heat that enters the engine which equals the net amount of work that exits the engine, some of it going into gravitational potential energy of a weight, and the rest into work done by friction.

In this lab, we will "peek-in" on what is going on thermodynamically within the gas during the cycle, by keeping tabs on its pressure and volume. This will allow us to plot a cyclic P vs. V diagram, which contains all the information we need to compute the work done by the gas (a quantity we can verify by other means, since the work consists of lifting a weight), and the efficiency of the engine.

Some Things to Think About

The details of what is going on in this procedure are pretty well spelled-out in the Background Material, but there are a few things that bear emphasizing...

- ***Safety first! When immersing the cannister into the thermal reservoirs, you want to submerge them the best you can, but not at the expense of burning your fingers on the hot reservoir. Keep in mind that you don't need to touch the boiling water to burn yourself – steam does this very efficiently. Please use the "claw" to keep your fingers a safe distance from the steam.***
- The Pasco application you will be using is called "Heat_Engine."
- You should double-check the arrangement of the apparatus. The computer measures the displacement of the piston by detecting the rotation of the pulley. It does this by assuming the string doesn't slip over the pulley, and "knowing" its radius. The pulley has three radii available, and the one that the computer assumes is the *one in the middle*. Also, the computer will treat expansions of the piston as positive displacements only if the pulley rotates *clockwise* as the pulley rises. And finally, you want the piston to start somewhere near the center of the cylinder. If it is not located there, ask your TA for assistance.
- Two important bits of information you will need are the cross-sectional area of the piston and the mass of the weight placed on the plunger platform of the piston. These values are $8.3\times10^{-4}m^2$ and $200g$, respectively.
- You should obviously include a screen capture of your graphical data in your lab report.
- Do a "friction calculation run" (discussed in the Background Material) before moving on to the main event. The two processes you need may be a bit choppy, but a reasonable estimate for the two pressures you need should be obtainable.
- The PV diagram of your cyclic process, if done correctly, will look very much like a parallelogram. You can estimate area accordingly – there's no need to count boxes or rely on the touchy "area under curve" tool in the Pasco software.
- The work done by the engine is used to lift the weight from the height that you put it on the plunger to the height you take it off, *not* the distance that the plunger raises the weight during the "hot reservoir" process.
- The amount that the weight is lifted can be measured externally using the marks on the cylinder, and this might make a good double-check, but the computer/pulley provides this information, assuming you extract it correctly from the PV graph output.
- Be sure to discuss places where errors are likely to come in, and possible ways to improve the results.
- When computing the efficiency of the engine, you will not have *direct* measurements of heat exchanged, but you know some important facts that can still get you these values. You know what types of processes are occurring in the four legs (it's okay to ignore the small blips in the upper-left and lower-right corners for this part), and you know that the trapped gas is air, which is

basically diatomic. These facts give you a way to determine heat exchanged from work done, the latter of which you *can* measure.

Lab Report

Craft a lab report for these activities and analysis, making sure to include every contributing group member's name on the front page. You are ***strongly encouraged*** to refer back to the Read Me as you do this, to make sure that you are not leaving out anything important. You should also feel free to get feedback from your lab TA whenever you find that your group is at an impasse.

Every member of the group must upload a separate digital copy of the report to their lab assignment in Canvas *prior to leaving the lab classroom*. These reports are not to be written outside the lab setting.