Project Notes

- We highly recommend that groups pool resources in order to buy certain supplies together. This is not an expensive project, but there's no need to waste money.
- This will take some time and involve some trips into the Outside World. I found everything I needed at a Walgreens and a hardware store within walking distance of school.
- We will hold on to your engine once completed, then give it back to you at midterm time.
- Groups of no more than 2 are allowed. The two students can be in different sections of physics honors.
- This project is not simply about cutting the tin and building the engine. Most of the heavy duty work (and thinking) comes in assembly and debugging. That said, be careful while building that you do not do anything sloppy.
- If you find that you are working on the thing but just "doing stuff" to get it to work, take a break and work on your other classes. This project can consume hours & hours with no progress if you're not approaching it the right way. Make sure you are in a space where you are thinking like this: "What's not working? How can I improve that?" Use your *physics knowledge*. Our job is to teach you to think like this -- so feel free to bring the project by and say 'What needs to be improved?' Keep in mind that the engine *will work.*
- A small amount of time spent discussing your project with an instructor can be much more productive than a large amount of time spent hammering away at the thing to no avail.
- One of the important things to get right is the relationship between the displacer and the crank shaft. When the crank shaft turns, you want to move the displacer up and down without hitting top or bottom and without scraping on the walls. This is one reason it is so important that the pin coming out of the displacer is centered and straight.
- We have found that the best fit displacer is made from a Coors Light "Frost Brew" 12 Oz beer can. Ask your parents to buy two and empty the contents. If they are concerned that you're feeding them a line to get beer, show them this site. Fit the second one into the first one / ask your instructor for details. We have some empty cans for your use as well.
- Students have written asking about the silicone gasket sealant. Red RTV is preferred by the plans, but it really makes no difference. One of us used some black stuff that isn't Red or RTV. But it is silicone gasket sealant and works at high temperature.
- Be sure to download and check out all the engine videos on the project website. They give you a good feel for the way the engine will work and the variety in engine types. Also check out the YouTube videos above.
- Once you have completed the engine's construction, there is still a significant period of debugging and testing you need to do to get it to work. Many computer scientists and engineers plan for at least

50% of their time spent debugging the "completed" thing. The project is going to take a **significant amount of time** -- many students are not used to ANYTHING that takes more than a weekend to complete. Don't fall into that trap -- it WILL take longer than one weekend. We have lightened the homework load to justify this.

- You'll likely need to remake several of the subsystems based on problems you discover only after building the 1st draft. This means you might make a 2nd draft.
- You can work on different parts of it at the same time. You can build subsystem that includes the crankshaft, crankshaft supports, and CD and try to streamline it while your partner is building the pressure vessel and displacer.
- We've found it handy to have four types of glue/epoxy on hand: superglue, quick-drying epoxy (like JB Kwik), slow-drying epoxy (JB Weld), and silicone gasket sealant (RTV). That said, one of us has found you can do everything with JB Kwik -- this makes it, in principle, possible to build an engine from scratch in just a few hours.
- We've found uses for scrap metal from cans we've destroyed, so keep a trash bag and don't throw it away until the end.
- We've had to improvise a few times. This can be very rewarding at times, very frustrating at others.
- We've found it very useful to have a small spool of 20-gauge steel wire around. This wire is stiff enough to hold things in place but flexible enough to easily bend.
- We've found it useful to have some miniature needle-nose pliers around.
- We've found it useful to have our entire project contained on a battered wooden tray to carry it from place to place.
- It is important to realize physically that your engine is NOT ever going to be strong enough to start from 'scratch.' In principle, in the absence of friction, if you spun your flywheel with the candle OFF, it would spin and spin forever. This is because of Newton's 1st Law. FRICTION and other non-recoverable energy losses eventually slow the system down. The job of your engine is to provide just enough energy to overcome FRICTIONAL losses. So you want your system to turn smoothly, be balanced properly (with a coin on the flywheel CD), etc. so that the engine is needed to provide only a small extra push every turn.
- One test you can do is to detach the crankshaft from the displacer and from the balloon (that is, remove the connecting rods). Then, move the displacer up and down with the candle lit. If the balloon moves up and down in response, then you are doing good. At this point you just need to eliminate friction.
- Another important test is the 'soap-film' test -- use a mixture of dishsoap and water (not frothy) and coat your engine. Then place a candle underneath and see if bubbles form anywhere -- these locations are leaks. A better test is to attach an inflated balloon to your PVC pipe, pinch it off, place

the entire engine underwater, and release the air from the balloon slowly. You'll see bubbles form underwater where your pressure vessel is leaking.

- The fit between the displacer pin and the top of the pressure vessel must be **very** good for the engine to work.
- If you find the engine is 'hanging' or that the displacer rises but does not fall, even under its own weight, then you might have too short of a connecting rod between the displacer pin and the crankshaft. If this pin is too short, the angle it makes is too great the displacer is pushed to the side. This generates friction.
- While working with student engines, the **dominant failure modes** have been leaks in the pressure vessel, too large an aperture at the displacer pin, and too short a connecting rod between the displacer pin and crankshaft.