GEOS 24705 / ENST 24705
Problem set #5
Due: Th. Apr. 16

Problem 1: Air pressure.
In class you heard that air pressure (at sea level) is 14 psi – that is, the atmosphere above you pushes down with 14 pounds-force on each square inch of surface area. These units are horrible in one respect, but they're very useful in another: the English unit system helpfully uses the word "pounds" to mean two different things: 1) mass and 2) the force that would be exerted by gravity on that mass. So when we say that pressure is 14 pounds-force per square inch, that's the same as saying that the atmosphere exerts the same pressure as that exerted by an object of 14 pounds-mass sitting on that square inch.

Draw a diagram showing how atmospheric pressure can raise a column of water weighing 14 pounds over each square inch. **How tall that is that column, in standard metric units?** *(It is generally easiest to start by converting pounds mass per square inch into the metric units of kilograms per square meter).* This is the maximum height that Savery's suction engine could possibly have pumped water. **Galloway claims that Savery's engine could raise water only "sixty or eighty feet". Is that claim accurate?** (Again, convert to metric.)

In the U.S., most engineers still use English units (see this article on the famous loss of the Mars Climate Orbiter: http://www.wired.com/2010/11/1110mars-climate-observer-report/) so it is helpful to be able to mentally go back and forth.

Problem 2: Virtual steam engine field trips
Since we have no opportunity to see a large-scale steam engine in action in person, take a virtual field trip.

A. ***Newcomen engine***
Watch this film of a replica of Newcomen's 1712 engine, running fully operational as it would have in the past:
https://www.youtube.com/watch?v=HC6LUWSBXjk
The engine noise is so loud that it's difficult to hear the commentary, but you can get a sense of the size, scale, complexity, and basic operation. **What is the stroke rate – how many piston strokes per minute?**

Then, watch a section of this video that has commentary about the engine you can actually understand. Watch 1:57 to 4:34.
https://www.youtube.com/watch?v=QltRwiu4U2Q

At 3:57-3:53 you see a model of the whole system. **After water in the cylinder condenses, where does it go? What is the function of each of the vertical pipes on the far right?**

B. Watt engines*.* If you continue watching the video above, the narrator begins to describe a Watt steam engine. This is a bit confusing pedagogically, because the engine they're showing isn't Watt's first (from 1769, 57 years after Newcomen's). Instead it looks like Watt's famous 1788 engine from 1788, with 20 more years of technological development. Watt's big invention was the separate condenser, but the model shown here incorporates many other innovations that improve on Newcomen's engine. **Watch the rest of the video and list all the other technological improvements that you can see besides the condenser.**

Then, watch an animation of Watt's earlier 1777 "Old Bess" engine: go to http://www.sciencemuseum.org.uk/on-line/energyhall/section5.asp and click on "Old Bess at work" and click through the animation. **What improvements that you had noted for the 1788 engine were not yet present in the 1777 one?. Why was the engine used to pump water to move a water wheel?**

Note the website claim about fuel efficiency: that Watt's engine used ¼ the fuel of Newcomen's engine. That's what the separate condenser is for.

C. ***Steam engines a century later.*** As often happens in industry, steam engines got larger and more powerful over time. Watch this video of the great beam engine built to pump sewage up from London's new sewers and dump it in the Thames River: http://www.youtube.com/watch?v=Zlp1aG1VJRI This engine was part of the great public works project to clean up the fetid city, and began operation in 1865, over 150 years after the Newcomen engine, and nearly 100 years after Watt's first engine. (Some of what you see here is in fact part of an upgrade from 1899-1901, so nearly 200 years after Newcomen). Note the elaborate decoration for a sewage pump. Engines were celebrated in Victorian England in a way that we no longer celebrate our energy-conversion technology. The "Prince Consort" engine shown here was operational for 88 years (last run for pumping in 1953) before begin decommissioned. It was restored to operation in 2003.
What features of this engine are similar to those in the 1788 Watt engine? What features are different? *(Optional): discuss why there is a "high pressure" and a "low pressure" cylinder.*