GEOS 24705 / ENST 24705
Problem set #7
Due: Thurs. Apr. 23

Problem 1: Engines and Carnot efficiency

A heat engine operates by extracting mechanical work (W) while moving heat down a temperature gradient, from something hot (at a temperature T_h) to something cold (at T_c).

Carnot first derived the limiting efficiency (work out / heat in) for a heat engine:

$$\varepsilon = 1 - T_c/T_h$$

(Don't forget that you need to express temperatures in Kelvin, referenced to absolute zero).

A By Carnot's theory, what was the maximum efficiency that Newcomen's or Watt's early atmospheric heat engines could have achieved?

B If you want to achieve an engine efficiency of 75%, what temperature would you have to run the engine at if were otherwise ideal?

C Steel loses 90% of its strength above 800 C. Can you make a 75% efficient engine out of steel? Comment on how this may relate to research on ceramic engine components.

D ***(Optional):*** Toward the end of the steam era, in the quest for increased efficiency, high-pressure boilers were heated to around 275 Celsius. What would the Carnot efficiency be at this temperature? What was the pressure of steam produced at this temperature? What would the pressure be of air heated to 275 Celsius? Comment on whether and how these numbers may be relevant to the eventual disappearance of the steam engine.

E ***(Optional):*** Boilers in steam engines (and in modern steam turbines) were sometimes followed by a "superheating" stage where the steam was isolated from liquid water and further heated. What is the advantage of this? And, if it is so advantageous, why use steam at all – why not simply heat air?