

Department of Mechanical and Aerospace Engineering

PhD Qualifying Exam - Thermodynamics Portion - January 9, 2004, 1:00 - 3:00 PM

This is a closed-book exam. Answer all questions to the extent possible in the time available, but do not spend more than 20 minutes on any one of them. Instead, tell what you know about the problem and/or how you would solve it. Assuming a sufficient grade on this test, we will continue the discussion of these problems in the oral exam.

1. Imagine that you have been given the delightful job of serving as a Teaching Assistant in our sophomore course in Thermodynamics. Ten students come to your office (one hour before the final exam, of course !!) and want to know the definitions of certain terms. State (in no more than two short sentences) how you would define the following:

Work and Energy

State

Process

Property

Equilibrium

System and surroundings

Reversibility

Supercritical Fluid

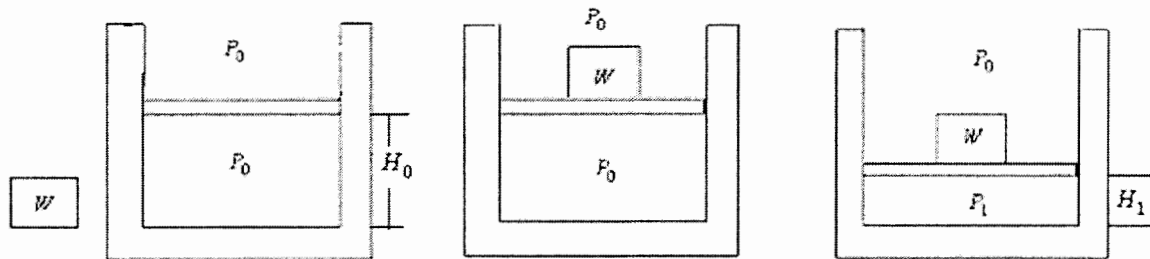
Gibbs Energy

2. The next question from the students is: "The textbook for this course spends a lot of time on a so-called energy equation, which contains lots of terms. We understand what internal and kinetic energy are, but what is enthalpy and why is it included in an *energy* equation?"

3. Then they ask: "What is irreversibility, and why does the professor make such a big deal out of it? In fact, the text says that the only way to get reversibility is to do things *infinitely* slowly, in contact with something called an *infinite* reservoir. What does this have to do with reality? - it sounds like an unattainable situation!"

OK - now the students have left. The remaining questions are based on the following problem:

Consider an ideal gas, contained in a perfectly insulated cylinder that is closed by a weightless piston. Initially, the gas is at pressure P_0 , temperature T_0 , density ρ_0 , and the piston is at a height H_0 . Then a weight W , initially at zero height, is raised to the top of the piston and dropped onto it. The piston descends, probably oscillates a few times, and finally comes to rest at a new height H_1 , and the gas properties are now P_1 , T_1 , and ρ_1



It can be shown from the first law of thermodynamics (*you do NOT have to derive this*) that the initial and final states are related by

$$\frac{T_1}{T_0} = \frac{1 + (k-1) \frac{P_1}{P_0}}{k}, \quad \frac{\rho_1}{\rho_0} = \frac{P_1 T_0}{P_0 T_1} = \frac{v_0}{v_1} = \frac{H_0}{H_1}$$

where k is the ratio of specific heats, considered here to be a constant.

In fact, if a series of weights is added in steps, allowing the gas to come to equilibrium after each step, then the temperature ratio for each step is

$$\frac{T_i}{T_{i-1}} = \frac{1 + (k-1) \frac{P_i}{P_{i-1}}}{k}$$

4. Calculate the temperature ratio that results if a pressure ratio of 2 is achieved in one step (use $k = 1.4$).

5. Calculate the final temperature ratio ($\frac{T_{final}}{T_0}$) that results if a final pressure ratio

($\frac{P_{final}}{P_0}$) equal to 2 is achieved in *two* steps. (Use $k = 1.4$ and use whatever intermediate

pressure you wish). Compare the results of this case with those of problem 4 and comment on any differences that you find.