G. W. Woodruff School of Mechanical Engineering
Ph.D. Qualifying Exam, Spring 2005
Thermodynamics

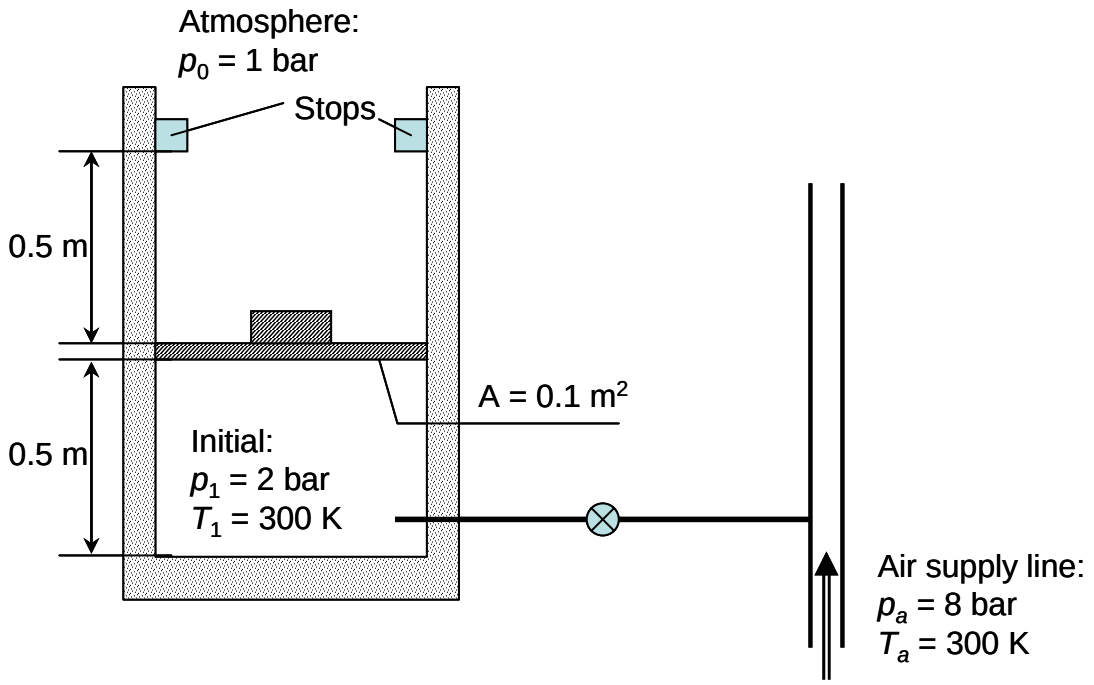
Problem 1

A well-insulated piston-cylinder assembly is connected by a valve to an air supply line at 8 bar and 300 K, as shown below. Initially, the air inside the cylinder is at 2 bar, 300 K, and the piston is located 0.5 m above the bottom of the cylinder. The atmosphere pressure is 1 bar, and the piston area is 0.1 m^2. The valve is opened and air is admitted slowly until the pressure inside the cylinder reaches 4 bar. Note that the volume when the piston is at the stop is twice the initial volume. Ideal gas properties of air are $R = 287\ \text{J/kg}\cdot\text{K}$, $c_p = 1004\ \text{J/kg}\cdot\text{K}$, and $c_v = 717\ \text{J/kg}\cdot\text{K}$.

Show the process in a $p - V$ diagram.

List all assumptions you have to make in order to analyze this problem.

Find the final temperature and mass inside the cylinder.



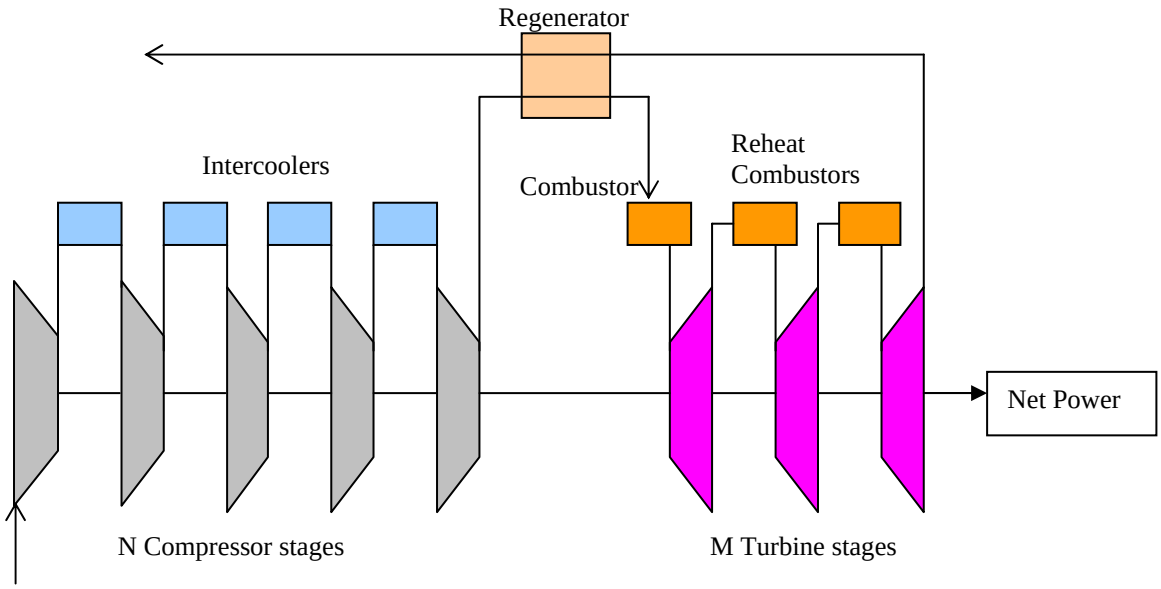
Problem 2

A general gas turbine power system schematic is depicted. For the case of one turbine stage (therefore, no reheat), compare the thermal efficiency of a system (System 1) having five compressor stages with the thermal efficiency of a system (System 2) having only one compressor stage. For reference purposes, also determine the thermal efficiency of a hypothetical system (System 3) having an infinite number of compressor and turbine stages. Analyze these three systems using a cold air standard model. Finally, to check the accuracy of the cold air standard model, re-do the System 2 analysis, allowing for variable specific heat. Summarize your results in the table below.

The compressor inlet temperature is 300 K and the inlet pressure is 1 atm. The turbine inlet temperature is 1200 K and the inlet pressure is 10 atm. In cases with multiple stages, the pressure ratios are equal across all stages. Assume all processes are ideal. In particular, assume:

- The intercoolers cool the air to 300 K
- The regenerator effectiveness is 100%
- The reheat combustors heat the air to 1200 K
- The compression and expansion are adiabatic and reversible.

System	Compressor stages	Turbine stages	Thermal efficiency
1	5	1	
2	1	1	
3	∞	∞	
2 (variable c_p)	1	1	



Problem 3

Consider the figure below. Outline in detail how you could determine the maximum theoretical turbine work that can be produced as the steam is allowed to flow from tank A to tank B, assuming the entire system is perfectly insulated.