M E 417 Thermodynamics II
Midterm Examination
October 2001, D.J. Bergstrom

TIME: 1 ½ hours

Provide complete answers to the following questions. State the major assumptions. Where applicable, sketch the process diagram and identify the state points. Reference all property tables that are used.

You are permitted to use the property tables in the appendices of the text, the conversion tables on the inside front cover, and your own problem solutions. A generic version of a formula sheet is also attached.

---

1. [20 marks] Consider a heat pump with a power input of *0.2 kW* used to heat a building for which the thermal losses are 10^4 *kJ/h*.
   a) Explain the function of a heat pump.
   b) For what conditions can we assume that $\frac{\dot{Q}_c}{\dot{Q}_h} = \frac{T_c}{T_h}$?
   c) Determine the maximum possible temperature inside the building if the outside air temperature is *-10 °C*.
   d) Determine the coefficient of performance.

2. [55 marks] An air-standard dual cycle has a compression ratio of *17* and a cut-off ratio of *1.2*. At the beginning of the compression stroke, the initial pressure and temperature are $p_1 = 95\ kPa$ and $T_1 = 310\ K$, respectively. The pressure doubles during the constant volume heat addition process, and the mass of air within the engine is *0.5 kg*. Assume that the compression and power strokes are both isentropic.
   a) Sketch the cycle on a *p-v* diagram and determine the state points.
   b) Calculate the net work for the cycle.
   c) Calculate the thermal efficiency.
   d) Do you expect the thermal efficiency to be greater or less than that of an Otto cycle? Justify your answer.

3. [15 marks] In question (2), let the compression work be represented by a polytropic process $pv^n = c$, with $n = 1.3$.
   a) Derive an exact expression for the compression work (per unit mass) in terms of the endpoint temperatures.
   b) Calculate the heat transfer for the polytropic process.
   c) Give a physical explanation for why the polytropic work is less than the isentropic work.

4. [10 marks] Use axiomatic theory to answer the following questions:
   a) Give the thermodynamic definition of pressure.
   b) For an ideal gas, if $k = 1.3$, and $M = 32$, determine c_v.
   c) Give the thermodynamic condition for equilibrium.
   d) [Bonus] What does *axiomatic* mean?