GEORGIA INSTITUTE OF TECHNOLOGY

The George W. Woodruff
School of Mechanical Engineering

Ph.D. Qualifiers Exam - Fall Quarter 1997

Thermodynamics
EXAM AREA

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Assigned Number (DO NOT SIGN YOUR NAME)

- **Please sign your name on the back of this page—**

1. Consider an ideal Otto cycle using air as the working fluid. The following information is provided:

Inlet conditions are 100 kPa and 300 K.

Displacement volume is 2.0 liters.

Volume ratio of compression is 10:1.

Pressure at the end of "combustion" is 4 times the pressure at the end of compression.

Property data: $C_v = 0.717$ kJ/kg-K, $k = 1.4$, and the molar mass, M, is 29 kg/kmole.

Recall that for an isentropic ideal gas process, PV^k = constant and that the ideal gas equation of state is $PV = mRT$. Then accomplish the following:

(a) Draw the cycle on the P-V diagram. Estimate the values of P, T, and V at the end of each of the four processes. Tabulate your answers.

(b) Estimate the net work per cycle and the thermal efficiency.

(c) For an automobile equipped with this engine operating on a four stroke cycle and running at 3000 RPM, estimate the maximum power.

(d) Modify the ideal P - V diagram to represent the operation of an actual gasoline engine. Using the modified diagram, illustrate and explain the relationship between the actual work and the ideal work.

2. Given a new substance, describe how you could determine the numbers to put in the thermodynamic tables of energy, enthalpy, and entropy for that substance. Simplify your description with the following assumptions:

   (1) Assume the substance is a simple compressible substance.

   (2) If you take advantage of an experimental technique, assume that the name of the technique suffices to describe it. In other words, no further experimental details need be given.

   (3) If you take advantage of a computational technique, assume that the name of the technique suffices to describe it. In other words, no further computational details need be given.

Do not spend more than 30 minutes writing about this, but proceed toward the goal of showing how a comprehensive set of tables could be established.

3. Hot water at 500 kPa and 150 C is fed on a steady state basis through a throttling valve, where the pressure is reduced to 200 kPa, and is exhausted into an insulated tank. Some of the water vaporizes so that the tank contains a saturated mixture of liquid and vapor. The saturated liquid is drained from the bottom at 200 kPa. The 200 kPa saturated vapor is taken off the top to an adiabatic steam power turbine which has an adiabatic (i.e., relative to an isentropic turbine) efficiency of 80%. The turbine exit pressure is 15 kPa. Calculate the turbine shaft power per unit mass of inlet water to the tank. All processes are steady state.

4. A rigid container with a volume of 200 liters is divided into two equal volumes by a partition. Both compartments contain nitrogen (M = 28 kg/kmole). One side initially is at 2 MPa and 300 C, and the other side is initially at 1 MPa and 50 C. The partition ruptures and the nitrogen comes to a uniform equilibrium state. Assuming that the surroundings are at 25 C, find the following:

(a) Final pressure of the nitrogen

(b) Final temperature of the nitrogen

(c) Heat transfer to the surroundings

(d) The irreversibility of the process