2

GEORGIA INSTITUTE OF TECHNOLOGY

The George W. Woodruff
School of Mechanical Engineering

Ph.D. Qualifiers Exam - Fall Quarter 1996

THERMODYNAMICS
EXAM AREA

Assigned Number **(DO NOT SIGN YOUR NAME)**

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

THERMODYNAMICS

WRITTEN

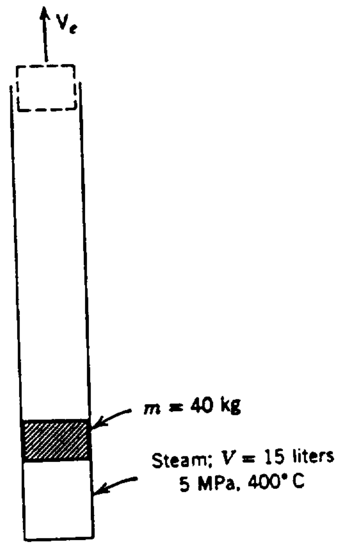
QUALIFIER EXAM

FALL 96

Four Problems

Problem #1

A mass of 40 kg is held in position in a length of 125 mm diameter tube by a pin, as shown below. Below this mass is a volume of 15 liters of steam at 5 MPa, 400C. The pin is released and the mass is accelerated upwards, leaving the top of the tube with a certain velocity. If the steam undergoes a reversible adiabatic expansion, and the pressure when its exits the top is 600 kPa, what is the exit velocity of the mass?



Problem #2

Using general considerations and relationships and the following Gibbs equations,

$$T\,ds = du + P\,dv$$
$$T\,ds = dh - v\,dP$$

(a) Formulate the differential relationship for the enthalpy in terms of temperature and pressure, i.e. derive the differential equation of the form:

$$dh = C_p\ dT + \left(v - T\left(\frac{\partial v}{\partial T}\right)_P\right)dP$$

Now consider the following truncated virial equation of state, $P\,v = a + b\,P$

(b) Explain why it must be true that $a = R\,T$ where R is the familiar ideal gas constant.

Next, assume that $b = b(T,\ \text{only})$, and when necessary write $\frac{db}{dT} = b'$.

(3) Then using the truncated equation of state above, find the analytical formula for the difference between the enthalpy of a real fluid at arbitrary T and P and the enthalpy of the same fluid in an ideal gas state at the same temperature, i.e. find:

$$h(T,P) - h_{ig}(T) =$$

Problem #3

A cubic, rigid, metal tank with an interior volume of 1 m^3 is filled with saturated liquid water at T=300C. The water is allowed to equilibrate with the environment at T_o = 20C.

a) Describe quantitatively where the meniscus (liquid level) of the final state is located.

b) Calculate the heat transfer.

c) Calculate the actual work.

d) Treat the tank process as an energy supply and describe a system to produce optimum work during the same temperature change.

e) Outline in detail a method to show that the described system can indeed produce the optimum work. Do **not** do the calculation.

Problem #4

An inventor has applied for a patent for an adiabatic steady-flow steam nozzle. The inlet conditions are 1 MPa, 300 C, and a velocity of 30 m/s. For a nozzle exit pressure of 0.3 MPa, the inventor claims the exit velocity to be 900 m/s.

You are to evaluate the thermodynamic feasibility of this patent application. Please show all of your work and provide thermodynamic reasoning for your result.