CLEMSON UNIVERSITY

Department of Mechanical Engineering

Spring 2009 Ph.D. Qualifying Exam

THERMODYNAMICS

INSTRUCTIONS:

- **A calculator is NOT permitted for this exam.**
- **No books, notes or equations sheets are permitted**
- **All problems are weighted equally.**

HONORS PLEDGE: *"I have neither given nor received aid on this examination."*

Sign Here: ___________________ (use your assigned identifier number)

For a gas obeying the equation of state:

$$v = \frac{RT}{p} - \frac{A}{T} + B$$

where A and B are constants, derive an equation for the temperature at the Joule-Thompson inversion state. Present your equation in simplest possible form. The following two equations may be of use:

$$\mu_J = \left(\frac{\partial T}{\partial p}\right)_h$$

$$c_p = \frac{1}{\mu_J}\left[T\left(\frac{\partial v}{\partial T}\right)_p - v\right]$$

Starting with the equation:

$$Tds = du + pdv,$$

obtain the simplest expression for the enropy change Δs of an ideal gas with constant specific heats.

An insulated combustor burns a stream of methane gas (CH_4) with a stream of theoretical air. Both streams enter at $25°C$ and $1atm$. The combustion products exit at $2260K$. Despite having theoretical air the carbon combustion is incomplete such that the product species consist of CO_2, CO, H_2O, O_2, and inert N_2. If the exiting H_2O and N_2 remain the theoretical amounts, determine the percentage of the entering carbon, x, that burns to form CO_2. You do not have to enter numerical values for any properties, such as enthalpies (ie. the answer can be in symbolic form for these properties but you must indicate any temperatures at which they are to be evaluated).

The pressure-volume diagram of a Carnot power cycle executed by an ideal gas with constant specific heat ratio k is shown.

Demonstrate that:

a) $V_4 V_2 = V_1 V_3$

b) $T_2/T_3 = (P_2/P_3)^{(k-1)/k}$

c) $T_2/T_3 = (V_3/V_2)^{k-1}$