Department of Mechanical & Aerospace Engineering
Ph.D. Qualifying Exam – January 2003

Thermodynamics

(2 hours; Closed Book & Notes)

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1. *First Law Analysis*

Using the *1st Law of Thermodynamics*, analyze each of the following phenomena. **In each case be sure to:** **(i)** identify which ***energies*** are changing, *and* **(ii)** compute the ***work*** associated with the system or control volume process you analyze.

(a) an object falling through the atmosphere at its terminal velocity;

(b) a bare copper wire through which a steady, DC electrical current is flowing;

(c) fluid flowing through an orifice in an insulated pipe where the specific enthalpy of the fluid (h) obeys the following equation of state:

$$\mathrm{d}h = c_p\,\mathrm{d}T + v(1 - T\alpha)\,\mathrm{d}p$$

where
$v = 1/\rho$
α = coefficient of thermal expansion
c_p = constant pressure specific heat

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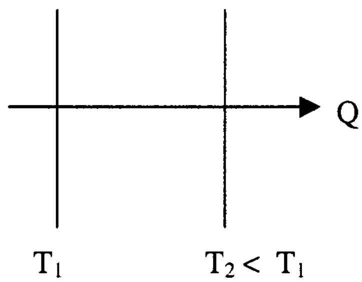
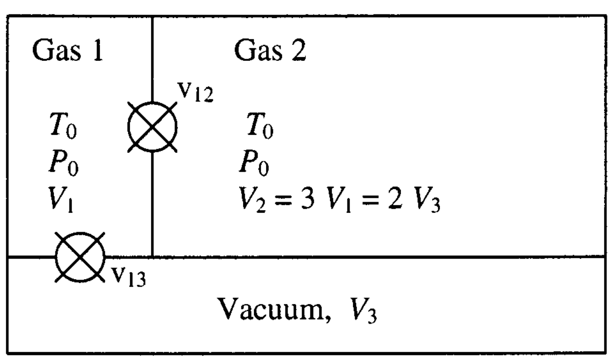
2. *Entropy*

(a) Determine the rate at which entropy is generated in the slab of material lying between T_1 and T_2. The rate of heat transfer through the slab, Q, is known.



The diagram below applies to parts (b), (c) and (d). The outer surface of the composite container (V_1+V_2+V_3) is insulated; the inner walls are thermally conductive. The symbol ⊠ indicates a valve. The initial state is as shown with both valves closed. The gases may be considered to be *ideal gases.*



Determine the change in entropy when:

(b) Gas 1 = nitrogen; Gas 2 = nitrogen. Valve v_{12} is opened.

(c) Gas 1 = argon; Gas 2 = nitrogen. Valve v_{12} is opened.

(d) Gas 1 = argon; Gas 2 = nitrogen. Valve v_{13} is opened.

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3. Given that: $dv(T, P) = v\alpha\, dT - v\beta\, dP$, $v = 1/\rho$

   where $\alpha = (1/v)\,(\partial v/\partial T)_P$, coefficient of thermal expansion

   $\beta = -(1/v)\,(\partial v/\partial P)_T$, isothermal compressibility

   and noting: $c_p - c_v = T\, v\, \alpha^2/\beta$

   (a) Determine: $ds(T, P)$

   (b) (i) Sketch the **Carnot cycle** in the ***P- v*** **plane**.

   (ii) Determine analytically which set of lines has the greater $|\textit{slope}|$.
