(20%) 1. (a) A gas flow with sufficient low speed is expanded from a higher pressure p_1 to a lower pressure region p_2 (See Fig. 1(a)) through a porous plug B. Please describe the enthalpy change during the expansion process. Is this a cooling process or a heating process? (6%)

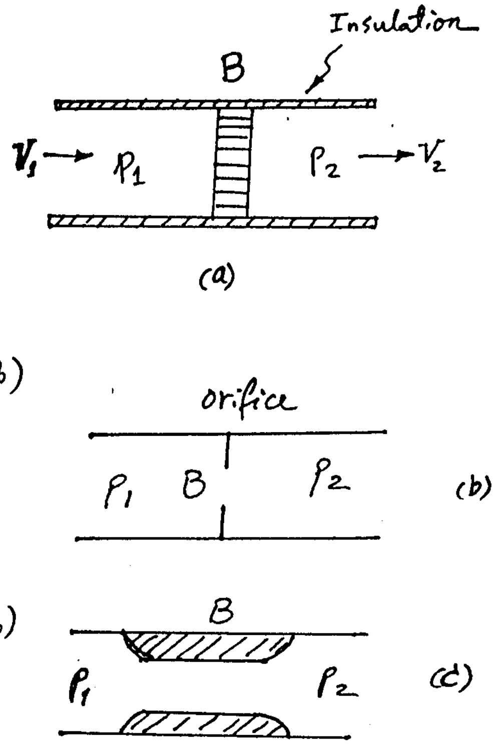

Fig. 1

(b) Repeat problem (1) when the porous plug B is replaced by a orifice plate (See Fig. 1(b)) or s long channel B (See Fig. 1(c)). (6%)

(c) By defining

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

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

and make comment that p, v, T should follow the idea gas law or not. (7%)

(20%) 2. A binary gas mixture contains 10 mol% A and 90 mol% B. At 50 atm total pressure and 100 °C the fugacity coefficients of A and B in this mixture are, respectively, 0.65 and 0.9. Please make the proper assumption and calculate the fugacity of the gaseous mixture.

(20%) 3. A chemical process happens in a rigid reactor after the gas in the reactor is raised from 100 °F and 25 psia to 660 °F and heat is supplied from a reservoir at 1500 °R. The volume of the reactor is 20 ft^3. The chemical process produced 250 Btu of heat. After the process the reactor is cooled to a final state at 100 °F. The surrounding atmosphere is at 60 °F and 14.7 psia. Please calculate (a) the availability of each process, in Btu. (b) the maximum useful work associated with each process (c) the irreversibility of the total processes. (for simplicity, the gas before and after the chemical process can be treated essentially as air with c_p = 0.24 Btu/ℓb° R and R_u = 10.73 (psia ft^3)/(ℓb mol °R) , C_v = 0.171 Btu/(ℓb °R) and 1 Btu = 778.16 ft · ℓbf. In addition, the gas can be treated as an ideal gas)

(20%) 4. Draw the S-P and S-T diagrams of the ideal Brayton cycle and derive an expression for its efficiency in terms of the pressure ratio. Discuss the role of the compressor in increasing the efficiency. Is there upper limit for this efficiency and why?

isentropic relation:

$$\frac{T_1}{T_0} = \left[\frac{P_1}{P_0}\right]^{\frac{\gamma-1}{\gamma}}$$

(20%) 5. Two separate tanks A and B are connected to a compressor. Tank A has a volume of 1 m^3 and initially contains air at 200 kPa and 300 K while tank B is initially evacuated. The entire air in tank A is then compressed to tank B and the final state of air in tank B is $P = 500$ kPa and $T = 300$ K. Please determine the minimum work required to drive the compressor if the temperature of the environment is 300 K.

Assume that c_p of air = 1.005 kJ/Kg K and $c_v = 0.718$ kJ/Kg K.