UNIVERSITY OF GHANA

B.Sc ENGINEERING

FIRST SEMESTER EXAMINATION: 2015/2016

DEPARTMENT OF FOOD PROCESS ENGINEERING

FAEN 205: THERMODYNAMICS (3 Credits)

Answer FOUR questions **TIME: TWO AND HALF (2 $^1/2$) HRS**

Question 1

a) A steam turbine, operating reversibly and adiabatically, takes in superheated steam at 500 kPa and 300°C and discharges at 50 kPa. What is the power output of the turbine if it operates under these conditions and the steam rate is 5 kg/s?

b) One kilogram of steam is contained in a piston/cylinder device at 800 kPa and 200°C. If it undergoes a mechanically reversible, isothermal expansion to 150 kPa, how much heat does it absorb?

(Use the steam tables provided.)

Question 2

One mole of an ideal gas is compressed isothermally but irreversibly at 450K from 3 bar to 8 bar in a piston/cylinder device. The work required is 40% greater than work of reversible isothermal compression. The heat transferred from the gas during compression flows to a heat reservoir at 30°C.

a) Calculate the entropy change of the gas
b) Calculate the entropy change of the heat reservoir
c) Calculate the total entropy of both system and surroundings
d) Is the second law of thermodynamics violated in (c) or not. Comment.

Question 3

a) Calculate the amount of heat Q required to raise the temperature of 1 mol of ethane from 250 to 500°C in a steady-flow process at a pressure sufficiently low that ethane may be considered an ideal gas. Temperature dependence of specific heat capacity is given by:

$$\frac{C_P^{ig}}{R} = A + BT + CT^2 + DT^{-2}$$

R=8.314 J/mol.K; A=1.131; 10^3B=19.225; 10^6C= -5.561; 10^5D=0

b) Steam at 250 (psia) and 600 (°F) [state 1] enters a turbine through a 3-inch diameter pipe with a velocity of 12 (ft)(s)$^{-1}$. The exhaust from the turbine is carried through a 10-inch diameter pipe and is at 5 (psia) and 200 (°F) [state 2]. What is the power output of the turbine?

H_1=1322.6 Btu/lb$_m$ V_1=3.058 ft^3/lb$_m$

H_2=1148.6Btu/lb$_m$ V_2=78.14 ft^3/lb$_m$ g_c=32.174 lb$_m$ ft/lb$_f$ .s^2

[1 ft-lb$_f$ = 0.01285 Btu]

Question 4

a) Determine the molar volume of n-propane at 362.4K and 21.24 bar by each of the following methods:

(i) The ideal-gas equation
(ii) The generalized compressibility-factor correlation

T_c = 369.8 K, P_c = 42.48 bar, ω =0.152, R=83.14 cm^3-bar/mol-K

(b) A particular power plant operates with a heat-source reservoir at 350°C and a heat sink reservoir at 30°C. It has a thermal efficiency equal to 45 % of the Carnot-engine thermal efficiency for the same temperatures. What is the thermal efficiency of the plant? And to what temperature must the heat-source reservoir be raised to increase the thermal efficiency of the plant to 35%? Again the η is 45% of the Carnot-engine value.

Question 5

a) Given that U is a function of T and V, i.e. $U=U(T,V)$, derive the following expression

$$dU = C_v dT + \left[T\left(\frac{\partial P}{\partial T}\right)_V - P\right]dV$$

where U is the internal energy of the system, and all other variables have the usual meanings.

b) Steam at 2100 kPa and 250°C expands at constant enthalpy (as in a throttling process) to 125 kPa. What is the temperature of the steam in its final state?

(Use the steam tables provided)