NATIONAL INSTITUTE OF TECHNOLOGY HAMIRPUR
(An Institute of National Importance under Ministry of HRD)
Department of Chemical Engineering

CH-430 OPTIMIZATION OF CHEMICAL PROCESSES
END-SEMESTER EXAMINATION

Maximum Marks: 50 | Time: 14:00-16:00 | Date: December 14, 2020

Instructions:

- Make suitable assumptions if necessary, by clearly stating them.
- Marks will be deducted for omitting steps.
- Draw the figure wherever needed.
- **Only one file needs to be uploaded with answers written in sequence.**
- **Uploaded answer booklet must have Name, Roll No., Subject Name and Subject Code on top of first sheet and Signature with Date at the bottom of each sheet. Answer booklet without above-mentioned requirements will not be considered for evaluation.**
- **Problem solved using MS Excel/other software will not be considered for evaluation.**

Q1. (10 Marks)

A manufacturer requires an alloy consisting of 40 % tin, the remainder being made up of lead and zinc in equal proportions. This alloy can be made up by mixing a number of available tin-lead-zinc alloys, the properties and costs of which are shown in Table Q1. Determine the cost of the cheapest blend and the amount of each type of alloy which should be purchased per pound of alloy produced.

Table Q1

		Available alloy				
		1	**2**	**3**	**4**	**5**
Analysis	**Percent lead**	10	10	40	60	30
	Percent zinc	10	30	50	30	30
	Percent tin	80	60	10	10	40
Cost	**$/lb metal**	4.1	4.3	5.8	6.0	7.6

Q2. (10 Points)

A simplified network with two heat exchangers is shown in Fig. Q2. In this system, one stream with flow rate F_1 is to be heated from 100 °F to 300 °F by exchanging heat with two hot streams with flow rates F_2 and F_3, available at 600 °F and 900 °F, respectively. Assume that all three flows are equal to 10^4 lb/h; all stream heat capacities are equal to 1 Btu/(lb. °F); both overall heat transfer coefficients U_1 and U_2 are equal to 200 Btu/(hr.ft^2. ^{o}F); and exchanger costs are given by Cost=35(area)$^{0.6}$ where area is given in ft^2. Determine the unknown temperatures T_1, T_2 and T_3 so that the combined cost of two heat exchangers is minimized.

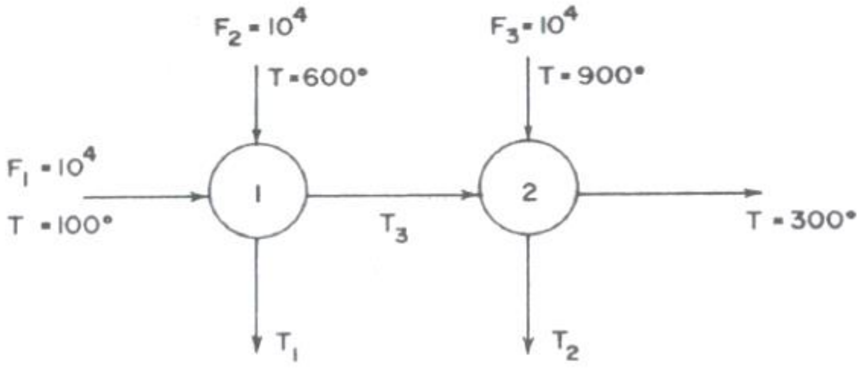

Figure Q2

Q3. (15 Points)

Consider the NLP problem given by

Min. $f(x) = 1 - 2x_1 - 4x_1x_2$

Subject to $x_1 + 4x_1x_2 \leq 4$

$x_1 \geq 0$ and $x_2 \geq 0$

a) Is the feasible region of the above NLP problem a convex set?
b) Write down Kuhn-Tucker conditions for this NLP problem.
c) Now let $y_1 = x_1$ and $y_2 = x_1\, x_2$. Write the given problem in terms of (y_1, y_2).
d) Is the feasible region of the transformed problem a convex set?
e) Solve the transformed problem for optimal values of *y*. Obtain corresponding values of *x*.

Q4. (15 Points)

Underwood's equation for the minimum reflux ratio (R_m) for multicomponent mixtures normally requires a trail-and-error solution. That is, for an *AB*/(*CD*) split, we first solve the equation below for the value of θ between α_{BC} and 1:

$$\frac{\propto_{AC}\, x_{AF}}{\propto_{AC} - \theta} + \frac{\propto_{BC}\, x_{BF}}{\propto_{BC} - \theta} + \frac{x_{CF}}{1 - \theta} + \frac{\propto_{DC}\, x_{DF}}{\propto_{DC} - \theta} = 1 - q$$

Eq. 1

and then we use this result to calculate R_m (assuming a sharp *AB*/(*CD*) split and that no *D* goes overhead):

$$\frac{\propto_{AC}\ x_{AD}}{\propto_{AC}-\theta}+\frac{\propto_{BC}\ x_{BD}}{\propto_{BC}-\theta}+\frac{x_{CD}}{1-\theta}=R_m+1$$

Eq. 2

It is advantageous to avoid trail-and-error calculations when we are attempting to determine the best separation sequence because the number of columns that need to be designed increases rapidly as the number of components increases. Malone suggested a procedure for bounding the values of θ in Eq. 1. He first rewrites the equation as

$$\frac{\propto_{BC}\ x_{BF}}{\propto_{BC}-\theta}+\frac{x_{CF}}{1-\theta}=1-q-\frac{\propto_{AC}\ x_{AF}}{\propto_{AC}-\theta}-\frac{\propto_{DC}\ x_{DF}}{\propto_{DC}-\theta}$$

Eq. 3

The desired value of θ must be in the range of $\alpha_{BC} < \theta < 1$.

a) Considering a case where $x_{AF} = x_{BF} = x_{CF} = x_{DF} = 0.25$, $\alpha_{AB} = 4$, $\alpha_{BC} = 2$, $\alpha_{DC} = 0.5$ and q =1, find the bounds on θ.

b) For a case where $F = 100$, all the A and 99.5 % of B are recovered overhead, and all the D and 99.3 % of the C are recovered in the bottoms, find the bounds on R_m.

************END OF QUESTION PAPER************