MANICALAND STATE UNIVERSITY OF APPLIED SCIENCES

FACULTY OF ENGINEERING

DEPARTMENT: CHEMICAL AND PROCESSING ENGINEERING

MODULE: PLANT AND EQUIPMENT DESIGN

CODE: HCHE 321

SESSIONAL EXAMINATIONS
DECEMBER 2022

DURATION: 3 HOURS

EXAMINER: MR C.K. SIMENDE

INSTRUCTIONS

1. *Answer **any four questions**.*
2. *Start a new question on a fresh page*
3. *Total marks 100*

Additional material(s): *Calculator, Graph paper*

QUESTION 1

a) Estimate the heat exchanger area needed to cool 55,000 lb/hr of a light oil (specific heat = 0.74 Btu/lb.°F) from 190°F to 140°F using cooling water that is available at 50°F. The cooling water can be allowed to heat to 90°F. An initial estimate of the Overall Heat Transfer Coefficient is 120 Btu/hr.ft².°F. Also estimate the required mass flow rate of cooling water. The schematic for the heat exchanger is shown in Figure 1. [10]

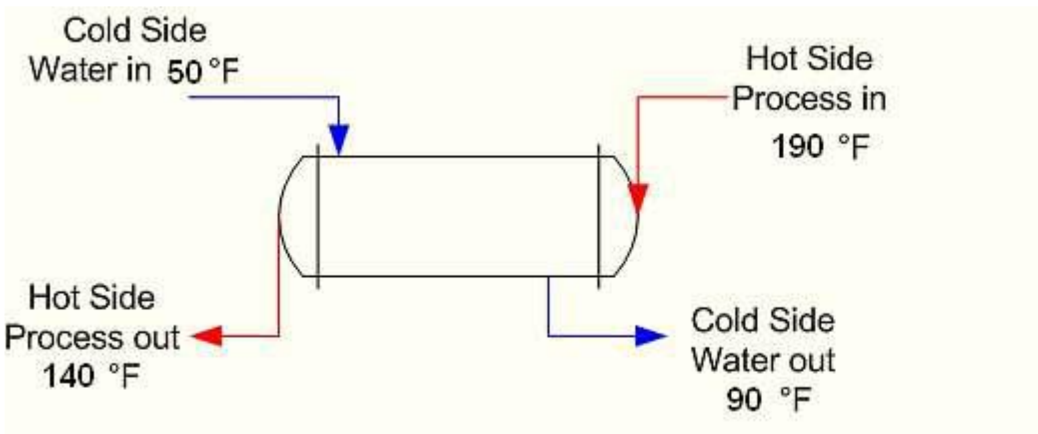

Figure 1: Heat Exchanger

b) Taking the shell and tube heat exchanger described in a, how many tubes of 3 inch diameter and 10 ft length should be used? [5]

c) A continuous single-effect evaporator concentrates 9072 kg/h of a 1.0 wt % salt solution entering at 38ºC to a final concentration of 1.5 wt %. The vapor space of the evaporator is at 101.325 kPa (1.0 atm abs) and the steam supplied is saturated at 150 kPa. The overall coefficient U = 1704 W/m².K. Calculate the amounts of vapor and liquid products and the heat-transfer area required. Assumed that, since it its dilute, the solution has the same boiling point as water. [10]

QUESTION 2

a) Engineering design of new chemical and petrochemical plants and the expansion or revision of existing ones require the use of engineering principles and theories combined with a practical realization of the limits imposed by industrial conditions. A successful engineer needs more than a knowledge and understanding of the fundamental sciences and the related engineering subjects such as thermodynamics, reaction kinetics, and computer technology. The engineer must also have the ability to apply this knowledge to practical situations for the purpose of accomplishing something that will be beneficial to society. Define the following parameters as they are used in plant design:

i) Design [1]
ii) Process design [3]
iii) Plant design [1]

b) Describe the steps in the design of a chemical process using a flowchart and fully explain what happens at each and every stage? [20]

QUESTION 3

a) Outline the three methods of estimating purchased equipment cost (PEC)? [6]

b) Calculate the Total Capital Investment (TCI) for a chemical processing plant using the information in Table 1. For this particular plant the Purchased Equipment Cost (PEC) is $12.4million and the working capital for a 30 day period is $7 million. [19]

Table 1: Process factors

Description	**Factor**
Installation	1.0
Process piping	0.75
Instrumentation	0.8
Insulation	0.05
Electrical	0.15
Buildings	2.5
Yard improvement	0.15
Auxiliary facilities	0.8
Engineering	0.25
Construction	0.35
Contractor’s fee	0.06
Contingency	0.1
Startup / Validation cost	0.05

QUESTION 4

a) A new plant ordered a set of floating head heat exchangers (Area = 100 m^2) cost $92,000.What would cost be for a heat exchanger for similar service if area = 50 m^2 and n= 0.44? Use the information to explain the meaning of the term Economy of Scale. [6]

b) What are the five capital cost estimating techniques? Order them in terms of their accuracy. [19]

QUESTION 5

a) Define the following terms as they are used in chemical and processing engineering:

i) Batch process [1]

ii) Continuous process [1]

iii) Steady-state process [1]

b) A research chemical engineer has devised the processing scheme described below for the manufacture of a commodity chemical. The overall chemistry of the process can be represented by the equations:

$$A + 2B \rightarrow C + D$$

$$C + E \rightarrow F + G$$

A is an organic liquid. B is a gas. D is an unwanted gaseous byproduct which can be used as a fuel. E is an organic liquid. F is the desired product, an organic liquid. G is an unwanted organic byproduct which can be used as a fuel. In the laboratory, the first reaction readily took place at 240°F and 150 psig, requiring about 30 minutes to go to completion. It was endothermic, with a heat of reaction of about 65 kcal/gmol of A reacted. The reactor used consisted of a one-liter stainless steel flask with the gases sparged in at the bottom. A reflux condenser was used to keep product C while venting D.

The second reaction takes place almost instantaneously upon addition of E to C at ambient conditions. It is exothermic, with a heat of reaction of about 25 kcal/gmol of C reacted. In the laboratory, this reaction was carried out by slowly adding E to the C, still contained in the stainless steel flask. Finally, F and G were separated by distillation in a laboratory column. F boils at about 240°F and G boils at 155°F at atmospheric pressure. Both remain liquid at ambient temperature.

Develop a preliminary flowsheet for a continuous plant to carry out the process.[12]

c) The product "C" may be produced from "A" and "B" via the reaction:

$$A + B \rightarrow C$$

In a laboratory, you may have produced this reaction by pouring chemical A into a test tube and chemical B into another test tube (Figure 2). You may have then heated each test tube over a laboratory burner or heater to increase the temperatures of those two materials.

The next step might have been to mix the two chemicals together so that they would react to form chemical C. Finally, because other chemicals were present along with the C in the product mixture, you probably needed to separate C from the mixture by boiling it off from the mixture, by allowing it to settle to the bottom of a flask, or by some other means. These manual steps are illustrated in Figure 2. One of the things that chemical engineers do is to build upon laboratory-type manual processes to create useful automated processes. They may create new processes to make new products or to utilize better strategies for making existing products through increased efficiency and the use of environmentally friendly methods. Formulate an automated process to replace the laboratory scheme (Figure 2.)? [10]

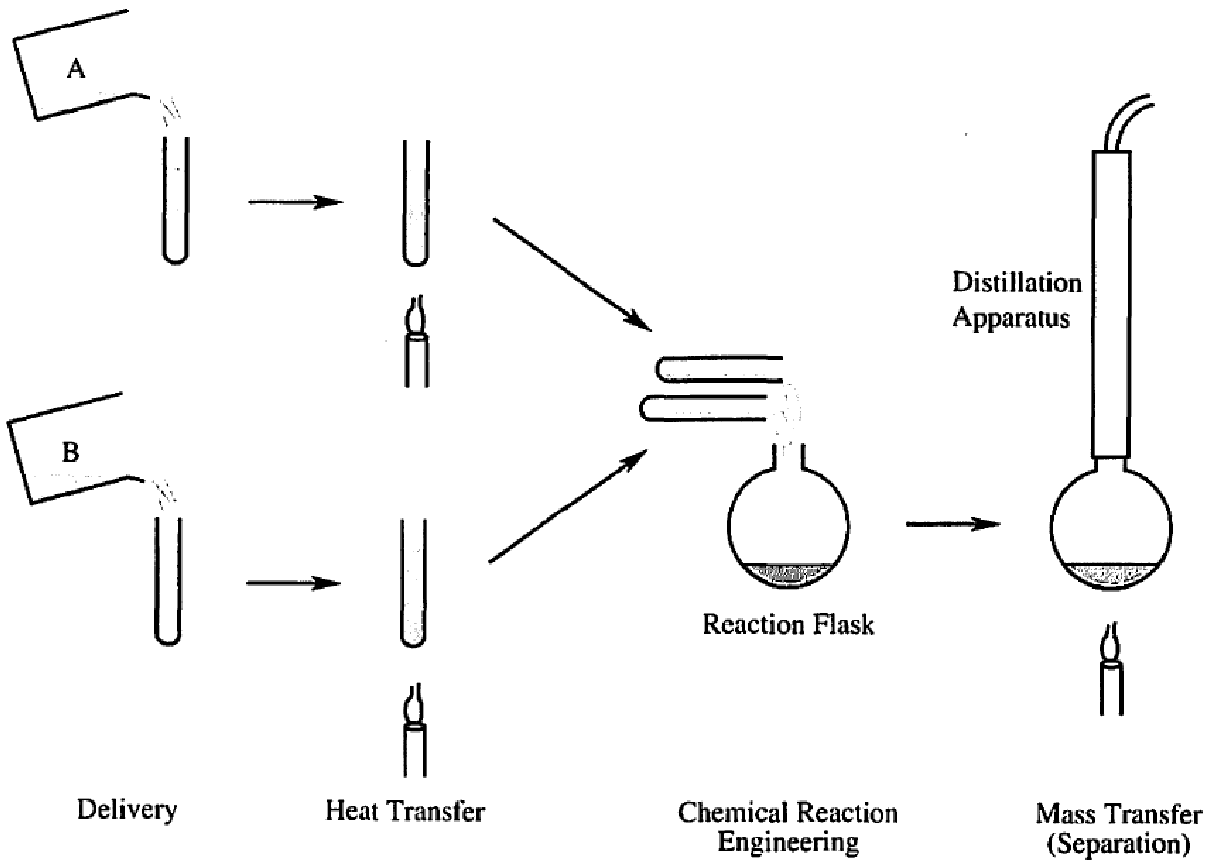

Figure 2: Diagram of a manual laboratory scheme for producing C from A and B

END OF EXAMINATION