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APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY

Seventh Semester B.Tech Degree Regular and Supplementary Examination December 2021 (2015 Scheme)

Course Code: CH405

Course Name: CHEMICAL ENGINEERING DESIGN II

Max. Marks: 100 Duration: 3 Hours

Instructions:

I. The following books and codes are permitted in the examination hall.
   i. IS Codes, Steam Tables, Duhring line and Psychrometric charts
   ii. Chemical Engineer's Handbook by J H Perry
   iii. Attested copies of relevant equations and charts for design of sieve tray from 'Mass Transfer Operations' by Robert E. Treybal (pages 169, 532 to 538), McGraw-Hill Int. Edn
II. Missing data may be assumed suitably
III. Graph sheets may be provided

Answer any two full questions, each carries 50 marks. Marks

1 a) In the manufacture of paper, wood chips are first digested with caustic soda under high pressure and temperature to dissolve off the lignin and resins present in wood. The liquor from the digester is filtered and the pulp is sent to the paper plant. The filtrate, called the black liquor, is now processed to recover caustic soda and recycled back to the digester. The black liquor is first concentrated in a triple effect backward feed forced circulation evaporator from 15% solids to 40% solids (by weight). The rate of feed to the evaporator is 72000 kg/hr at 75°C. Saturated steam at 380 kPa is admitted to the first effect and a vacuum of 660 mm Hg is maintained in the last effect. The overall heat transfer coefficient in the first, second, and third effects are 1488, 1675, and 1675 W/m^2K respectively. The liquor exhibits relatively low boiling point rise and negligible heat of mixing. It may be assumed that BPR varies linearly with concentration (% content of solids) (50)

BPR, °C	4	4.7	5.7	6.7
% solids	13	20	30	40

The specific heat of black liquor varies with concentration as given below

% solids	15	20	25	30	35	40
Specific heat, kJ/kg K	3.935	3.66	3.61	3.52	3.39	3.30

i. Obtain the material and heat balance for the evaporator (30)

ii. Calculate the total heat transfer area required (20)

2 a) A plant must distil 6000 kg/hr of a mixture containing 40 mole % acetone and 60 mole % acetic acid. The overhead product is to contain 95 mole% acetone and bottom product contains 5 mole % acetone. The feed is a saturated vapor and a reflux ratio of 1.5 times the minimum is used. The fractionator is equipped with a total condenser and the reflux is returned at its bubble point. The sieve plate distillation column operates at 1 atm pressure. The equilibrium data is given below (50)

T, °C	112.1	107.4	104.6	94.3	90.4	86.3	78.6	70.8	65.6	60.7
x	0.042	0.082	0.158	0.23	0.27	0.31	0.433	0.55	0.67	0.935
y	0.108	0.225	0.356	0.56	0.63	0.71	0.844	0.92	0.97	0.997

Design a sieve tray column for the purpose.

3 a) A cooling tower is to be designed to cool water from 40°C to 29°C by counter current contact with air of dry-bulb temperature 30°C and wet-bulb temperature of 25°C. The water rate is 63000 kg/h. Determine the height and diameter of the column if the overall mass transfer coefficient, $K_{Y'a}$=2700 kg/hm^3 ΔY. (25)

b) A sieve tray is to be designed for the extraction of 90% of the acetic acid from a water solution containing 4.0 wt% acid, using methyl isobutyl ketone, initially free of acid, as solvent, at 25°C. The flow rates are to be 5.76 m^3/hr aqueous and 11.52 m^3/hr organic. The ketone is to be dispersed. (25)

The physical properties of aqueous solution are: viscosity = 0.001 kg/m s; density = 998 kg/m^3; diffusivity of acetic acid = 1.0 x 10^{-9} m^2/s.

The physical properties of organic solution are: viscosity = 5.7 x 10^{-4} kg/m s; density = 801 kg/m^3; diffusivity of acetic acid = 1.3 x 10^{-9} m^2/s; distribution coefficient, (c in ketone)/(c in water) = 0.545; interfacial tension = 9.1 x 10^{-3} N/m.

i. Specify the tray dimensions and arrangements. (20)

ii. Estimate the stage efficiency (05)

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