B. Joseph/ChE 477 Test 1 1999

Time: 55 minutes
Closed Book: One 8.5 x 11" sheet of notes allowed
5% bonus for neatness, clarity and organization

Problem 1. (8 points)

The purchased cost of a shell and tube heat exchanger with 100 ft^2 of heating surface was $3000 in 1995. Estimate the cost of a 200 ft^2 heat exchanger in 1997 if the cost-capacity exponent for heat exchangers follows the six-tenths rule. Use the data in attached sheet for cost-indices.

Problem 2. (12 points)

(a). Given the following process description, draw a PFD (Process Flow Diagram) using appropriate flow sheet symbols. Label and identify all equipment assuming that this is part of a plant and this is Unit 100.

Fresh feed of pure cyclohexanol (A) is mixed with a recycled A and fed to a CSTR (continuous stirred tank reactor). Here the cyclohexanol reacts to form cyclohexanone (B), hydrogen and high boiler (C). Most of the hydrogen bubbles out of the liquid in the reactor and is removed as a gas from the top of the CSTR. The liquid product consisting of mostly A, B and C and some trace amounts of dissolved hydrogen is fed to a reboiled absorber consisting of two theoretical stages. Most of the C is removed as a bottom product. Most of the C is removed from the bottom of the reboiled absorber and send to a waste treatment facility. The vapor from the absorber is fed to the 12^{th} stage of a 33-stage distillation column. The column has a partial condenser at the top. The output from the condenser is sent to a reflux accumulator drum. Any uncondensed gases are removed from the top of the drum. The liquid condensate is withdrawn and split into two parts. One part is taken out as product as sent to storage. The other is sent back to the top stage of the column as reflux. The liquid leaving the bottom of the column is split into two parts. One part is withdrawn and is sent back to the reactor as recycle A. The other part is sent to a reboiler using medium pressure steam. Here the liquid is vaporized and fed back to the bottom stage of the column.

(b) Assuming the recycle is nearly pure A, product is nearly pure B, most of the hydrogen is removed as a gas from the reactor and waste is nearly pure C, draw a BFD (Block Flow Diagram) of the process showing all feed and product streams entering and leaving the process. Show their respective flow rates in lbmoles/hr.

Basis: 10 lbmoles/hr of A fed to the reactor.

Chemistry: $A \rightarrow B + H_2$

$A+B \rightarrow C$

Product from the reactor: 7 lbmoles/hr of B, 8 lbmoles/hr of Hydrogen, 1 lbmole/hr of C, and 1 lbmole/hr of A.

(c) If A =$58/lbmole, B=$120/lbmoe, C = $0/lbmole, and Hydrogen=$0/lbmole, what is the economic potential of the process in $/hr?
What is the maximum attainable economic potential in $/hr?
What changes would you recommend in the process to make it more economical?

Problem 3. (15 points)

Estimate the manufacturing cost in $/lb. of product and $/year under the following conditions:

Fixed Capital Investment	= $2 million
Working Capital Investment	= $0.4 million
Annual Production Output	= $10 million lb.
Raw Materials Cost	= $0.12/lb of product

Medium Pressure Steam:	50 lb./lb. of product
Electricity:	4 kWh/ lb. of product
Cooling Water: .	028 m^3/lb of product
Operating Labor	20 men/women/shift
Plant Operated	300, 24-hour days/year
No wastes are produced.	

If the product sells for $2.00/lb, what is the After Tax Cash Flow in $/year?

Data: Operator salary $46,800/year .
Depreciation charges may be assumed to be 10% of FCI/year.
Tax Rate = 40%. See attached table for utility costs.
All costs are given in 1996 dollars. Answers should be given in 1996 dollars also.

Problem 4. (15 points)

A small manufacturer of pharmaceutical products currently produces its top-selling drug (SPRAIN) in a batch process. In order to meet the projected increase in sales over the next five years, the company has been considering an investment to upgrade its facility to a continuous process. The company estimates that this upgrade will require an investment of $5 million dollars and that the bank that they are dealing with will lend them the money at an effective annual interest rate of 10%. For the following three repayment schemes, calculate the loan repayment schedule for the five years that the loan will be made.

a. Repay the loan as a lump sum at the end of five years.
b. Repay the loan in five equal payments at the end of each year.
c. Repay the loan with 60 equal monthly payments. (Remember that the 10% .per annum is an effective annual interest rate.

Solution to Test 1

Problem 1

Given :

Purchased cost of HX with Area of $100\ ft^2$

$$C_{100}^{1995} = \$3000$$

Calculate :

Cost of HX with Area $= 200\ ft^2$

Use the equation

$$C_B = C_A \cdot (B/A)^{0.6} \quad : \text{six-tenth rule}$$

$$\therefore C_{200}^{1995} = C_{100}^{1995} \cdot \left(\frac{200}{100}\right)^{0.6}$$

$$= \$3000 \times \left(\frac{200}{100}\right)^{0.6}$$

$$= \$4547.15$$

From given Chem. Engg. Tables :

CEPCI in 1995 = 381.1

CEPCI in 1997 = 386.5

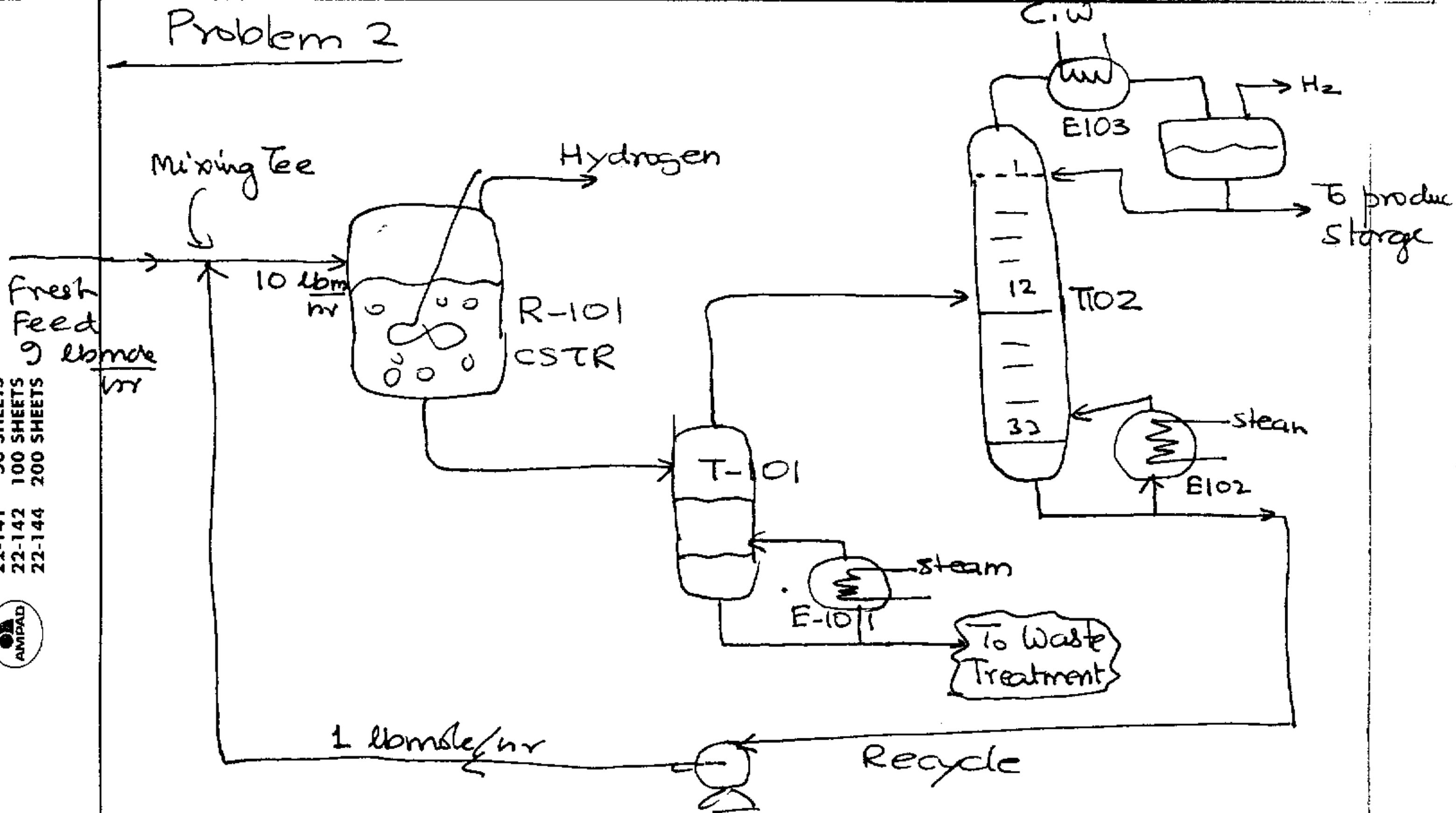
$$C_{200}^{1997} = C_{200}^{1996} \times \frac{CEPCI^{1997}}{CEPCI^{1995}}$$

$$= \$4547.15 * \frac{386.5}{381.5}$$

$$\boxed{C_{200}^{1997} = \$4611.58} \quad \text{Ans.}$$

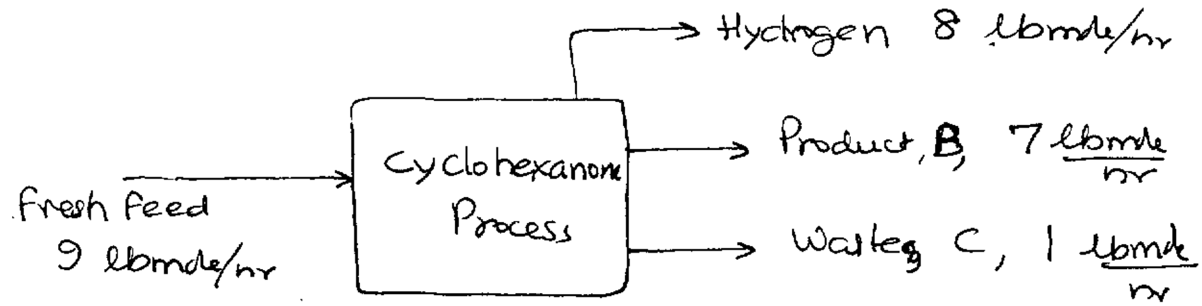
∴ U can use Marshal & Swift Index also. The answer is very similar.

Problem 2



Cyclohexanone Process PFD.

BFD (Block Flow Diagram)



Note: (a) internal Recycle streams are not shown
(b) Only 9 lbmole/hr of fresh feed required for the given Basis.

Economic Potential:

= Value of Products − Cost of Raw Materials

= 7 × \$120 − 9 × \$58 = \$318/hr

Maximum Economic Potential: when all A is converted to B, no C is produced. EP_{max} = 9 × \$120 − 9 × \$58 = \$558.0/hr

To reduce C, change reactor operating conditions.

Problem 3

(From Text)

$$COM = 0.304\ FCI + 2.73\ C_{OL} + 1.23[C_{UT} + C_{RM}]$$

Given: FCI = \$2 mil.

$$C_{OL} = 20\ \frac{men}{shift} \times 4.5\ \frac{oper}{men/shift} \times \$46{,}800 = \$4.212\ mil$$

$$C_{UT} = C_{steam} + C_{elec.} + C_{water}$$

$$= 50\ \frac{lb}{lb} \times \frac{\$7.31}{1000\ kg} \times \frac{1\ kg}{2.2\ lb} \times \cancel{500}\ 10\ \frac{mil\ lb}{yr}$$

$$+ 4\ \frac{kWh}{lb} \times \frac{\$0.06}{kWhr} \times 10\ \frac{mil\ lb}{yr}$$

$$+ .028\ \frac{m^3}{lb} \times \frac{\$6.7}{1000\ m^3} \times 10\ \frac{mil\ lb}{yr} =$$

$$= (\$1.661 + \$2.4 + \$.0018)\ mil/yr$$

$$\therefore COM = \$0.304 \times \$2 + 2.73 \times \$4.212 + 1.23[1.661 + 2.4 + .0018)\ mil/yr$$

$$\boxed{= \$18.579\ mil/yr}$$ Ans.

$$\boxed{= \$1.8579\ /lb\ of\ product}$$ Ans.

$$\text{After Tax Cash Flow} = (R - COM)(1-t) + d$$

$$= (\$20 - 18.579)(1 - .40) + 2 \times 0.1$$

(since $d = 10\%$ of FCI $= \$.2$ mil/yr)

$$\boxed{= \$1.0526 \times 10^6\ /yr}$$ Ans.

Notes:

1. Common mistake is in computing operating labor. To provide 1 man/shift you need 4.5 operators/year. (See text). Also, even though plant operates only 300 days/year, operators are needed year around.
2. Depreciation is given to be 10% of FCI.
3. COM includes depreciation charge.

Problem 4

(a) $P = \$5$ mil (Present Worth of Money)

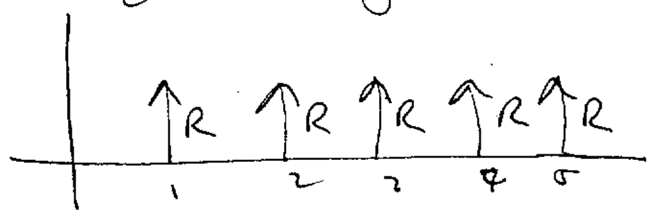
$i_{eff} = 0.10$ → effective annual interest rate

$F = P(1+i)^n$: Future Worth at interest rate i. (n → no of years.)

$n = 5$, ∴ $F = \$5(1+.1)^5 = \$8.05255$ mil

Ans

(b) Make 5 equal (annual) payments



$i = .10$

$$PW = R\,\frac{(1+i)^n - 1}{i(1+i)^n} = \$5 \text{ mil}$$

∴ $R = \$1,318,987.40/yr$ Ans

(c) Make 60 equal monthly payments:
first compute monthly interest rate, i_m

$$(1+i_m)^{12} = 1 + i_{eff} = 1 + 0.10$$

$$\therefore i_m = 0.0079741$$

Annuity of sixty monthly payment ($n=60$, i_m)

$$\therefore \$5 \text{ mil} = R_m \frac{(1+i_m)^{60} - 1}{i_m(1+i_m)^{60}}$$

∴ $R_m =$ ~~\$1,052,600~~ \$105,177.70 Ans.

Common mistake here is in using $i_m = 0.1/12$. This is true only for nominal interest rate.