B. Joseph ChE 477 Fall 1998

Test 1

Time: 55 minutes
Closed Book. One 8.5x11 sheet allowed.
5% Bonus for neatness and clarity.

There are 4 problems. Do all 4.

Problem 1.(15 points) Cyclohexanone Process Description

10 lbmoles/hr of fresh cyclohexanol raw material is mixed with 10 lbmoles/hr of recycled stream of unreacted cyclohexanol and fed to a continuous stirred tank reactor. Cyclohexanol reacts as follows:

cyclohexanol(liq) ⟶ cyclohexanone (liq) + hydrogen (gas)

cyclohexanol(liq) + cyclohexanone(liq) ⟶ highboiler (liq)

The H_2 is removed as a gas from the reactor. The conversion of cyclohexanol is 50% by mole. The liquid withdrawn from the reactor is fed to a flash drum where the highboiler is taken out as a liquid and most of the cyclohexanol and cyclohexanol are removed as vapor. The vapor product is fed to a distillation column where the cyclohexanone product is removed as a distillate. The unreacted cyclohexanol is removed as the bottoms product from this distillation column. It is then split into two streams: 90% of the bottoms is recycled back to the reactor and 10% is taken off and sent to storage.

(a) Draw a block flow (BFD) diagram of the process (3 points).

(b) Draw a process flow diagram (PFD) using the standard equipment symbols shown in the attached figure. Label all streams and number all equipment. (6 points)

(c) Draw an Aspen Simulation block diagram of the process using the standard Aspen Unit operation subroutines listed in the table. In this diagram, all streams must be labeled with stream IDs, the blocks must be labeled with block IDs and the unit subroutine used for each block must be identified also. (6 points)

(a) ASPEN PLUS (excluding solids-handling equipment—see Table A-IV.2)

Mixers and splitters	MIXER	Stream mixer
	FSPLIT	Stream splitter
Separators	SEP	Component separator—multiple outlets
	SEP2	Component separator—two outlets
Flash drums	FLASH2	Two-outlet flash drums
	FLASH3	Three-outlet flash drums
Approximate distillation	DSTWU	Winn–Underwood–Gilliland design
	DISTL	Edmister simulation
	SCFRAC	Edmister simulation—complex columns
Multistage separation (Equilibrium-based simulation)	RADFRAC	Two and three phases, with or without reaction
	MULTIFRAC	Ditto—with interlinked column sections
	PETROFRAC	Ditto—for petroleum refining
	ABSBR	Absorbers and Strippers
	EXTRACT	Liquid–liquid extractors
(Mass transfer simulation)	RATEFRAC	Two phases—mass transfer model for staged or packed columns
Heat exchange	HEATER	Heater or cooler
	HEATX	Two-stream heat exchanger
	MHEATX	Multistream heat exchanger
Reactors	RSTOIC	Extent of reaction specified
	RYIELD	Reaction yields specified
	RGIBBS	Multiphase, chemical equilibrium
	REQUIL	Two-phase, chemical equilibrium
	RCSTR	Continuous-stirred tank reactor
	RPLUG	Plug-flow tubular reactor
Pumps, compressors, and turbines	PUMP	Pump or hydraulic turbine
	COMPR	Compressor or turbine
	MCOMPR	Multistage compressor or turbine
	VALVE	Control valves and pressure reducers
Pipeline	PIPE	Pressure drop in a pipe
	PIPELINE	Pressure drop in a pipe
Stream manipulators	MULT	Stream multiplier
	DUPL	Stream duplicator

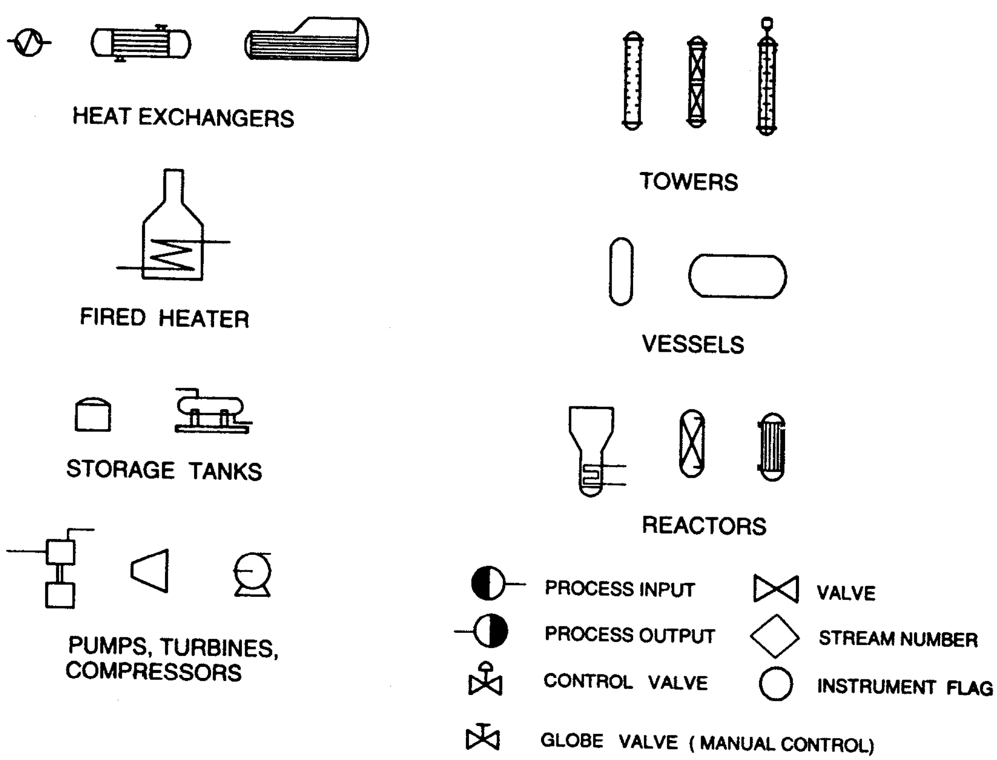


Figure 1.4 Symbols for building process flow diagrams.

Problem 2 (10 points)

Identify whether the following expenses are fixed capital costs, manufacturing costs or working capital costs.

	Fixed Capital	Working Capital	Cost of Manufacturing
1. Raw Material Cost			
2. Contractor's fee paid for plant construction			
3. Land cost			
4. Sales tax paid on purchase of equipment for plant			
5. Cost of transporting product to market			
6. Freight charges for delivery of equipment needed for plant construction			
7. Royalty fees (Paid as % of sales each year)			
8. Research and development costs			
9. Sales tax paid on purchase of raw material			
10. Construction cost for cooling tower			
11. Cooling water costs			
12. Cost of insulation put on steam piping			
13. Labor cost for installing insulation on piping			
14. Operating labor cost			
15. Accounts receivable on product sales			
16. Cost of building a tank to store raw materials			
17. Cost of disposing waste by-product			
18. Catalyst make-up charges (yearly cost)			
19. Rent paid on land			
20. Insurance on plant			

Tear off this sheet and
Submit with your solution.

Problem 3 (10 points)

Attached figure shows the process flowsheet for a light gas separations unit. Estimate the annual operating labor cost required to run this plant in 1998. Use the attached table for labor cost estimates for each equipment.

Additional data:

a. Average operator's salary = $42,000/yr in 1993.
b. Cost index table is attached.

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% p.a. is an effective annual interest rate.)

6

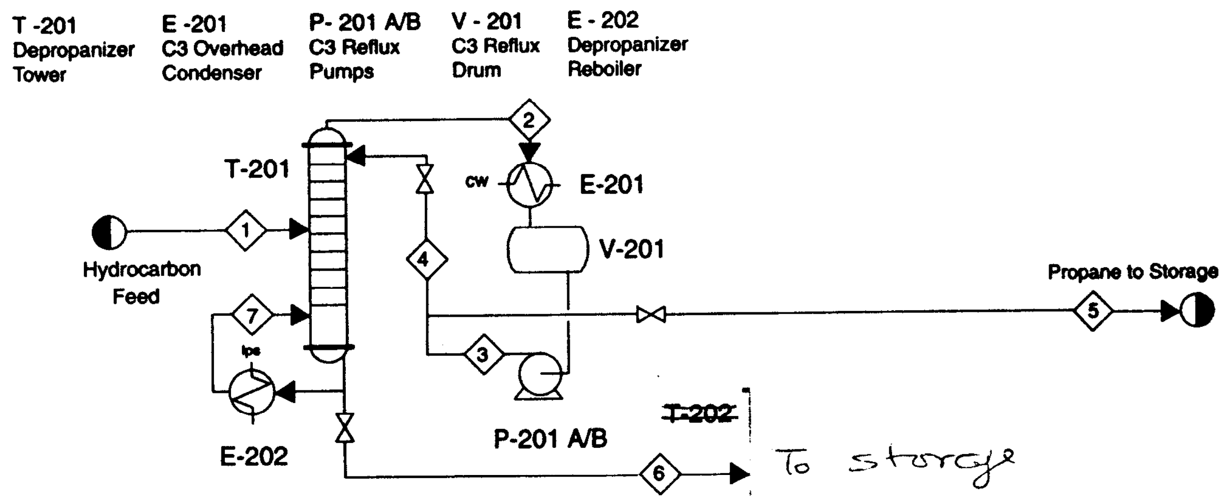


Figure for Problem 3.

Table 2.4 Values for the Chemical Engineering Plant Cost Index and the Marshall and Swift Equipment Cost Index from 1978 to 1996

Year	Marshall & Swift Equipment Cost Index	Chemical Engineering Plant Cost Index
1978	552	219
1979	607	239
1980	675	261
1981	745	297
1982	774	314
1983	786	317
1984	806	323
1985	813	325
1986	817	318
1987	814	324
1988	852	343
1989	895	355
1990	915	358
1991	931	361
1992	943	358
1993	964	359
1994	993	368
1995	1028	381
1996 (mid year)	1037	382
1997	1057	386.5
1998	1060	386.7

Process Equipment	
Evaporators	0.3
Vaporizers	0.05
Furnaces	0.5
Fans*	0.05
Blowers and Compressors*	0.15
Heat Exchangers	0.1
Towers	0.35
Vessels	0.0
Pumps*	0.0
Reactors	0.5

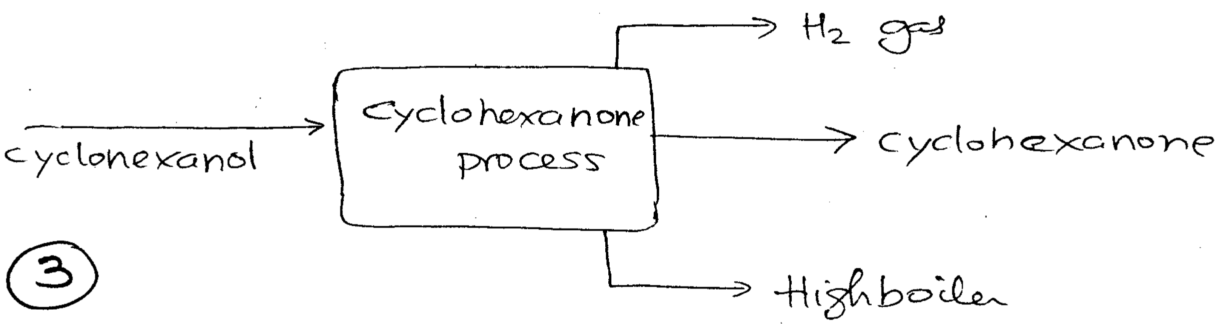
*For equipment with spares such as compressors and pumps, just count equipment plus spare as one item.

Table. Operator Requirements for various unit equipment.

Solution To Test 1, Fall 1998

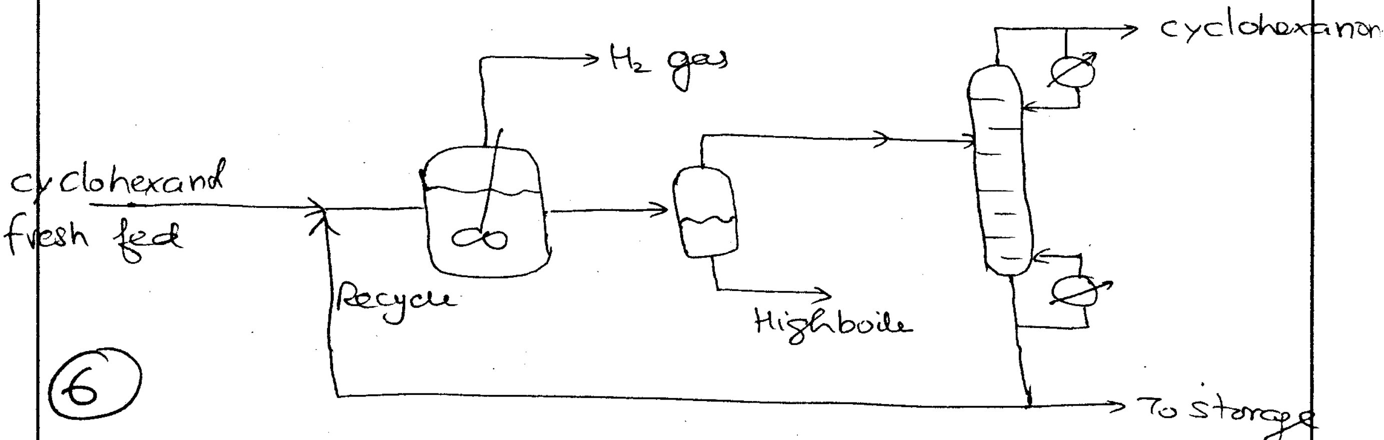
Problem 1

(a) Block Flow Diagram



(3)

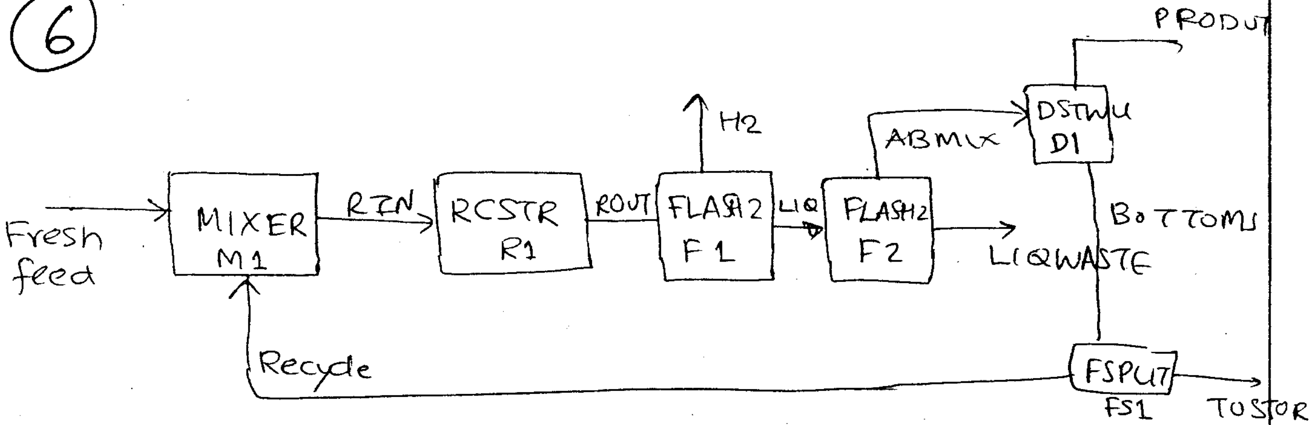
(b)



(6)

(c)

(6)



Note:

- Mixer added to mix feed + recycle
- FSplit used to split a stream

Problem 2

a. F Capital
b. W capital
c. COM

(10)

1. (c)
2. (a)
3. (a)
4. (a)
5. c.
6. a
7. c.
8. c.
9. c.
10. a.
11. c.
12. a.
13. a
14. c.
15. b
16. a.
17. c.
18. ~~a~~ c.
19. c.
20. c.

(10)

Problem 3

Equipment	Labor
T-201 Tower	0.35
E-201 Condenser	0.1
E201A/B Pump	0.0
C3 - Reflux Drum	0.0
E202 Reboiler	0.1
Total	.55

(10)

No. of operators needed:

$$= \frac{0.55\ op.}{shift} \times \frac{3\ shifts}{day} \times \frac{365\ days}{year} \times \frac{8\ hours}{shift} \times \left[\frac{year\ (op)}{1960\ op.\ hrs}\right]$$

= 2.45 ~~1.56~~ operators / yr

1 operator can provide ≈ 40 $\frac{hours}{week} \times \frac{49\ weeks}{year}$ = 1960 $\frac{op\ hrs}{yr}$

~~Operating Cost of~~

∴ operating labor cost = $\frac{2.45\ \text{(~~1.56~~)}\ op.}{yr} \times \frac{\$42,000}{yr.\ opr}$

= ~~$65,700~~ $103,183 /yr in 1993.

= $103,183 (~~65,700~~) * $\frac{386.7}{359}$ in 1994

= ~~$70,769.33~~

= $ 111,000 (~~70,000~~) /yr

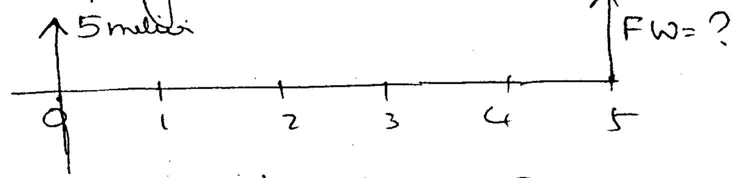
Problem 4

Investment = $5 million

$i_{eff} = 10\%$

Loan repayment schedule

(a)

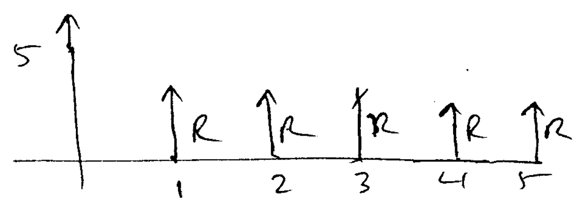


(5)

$FW = \$5 * (1+i)^5 = \$5(1+.10)^5$

$= \$8,052,550$

(b)



(5)

PW of Annuity $= R . \dfrac{(1+i)^n - 1}{(1+i)^n i}$

$= R \dfrac{(1.1)^5 - 1}{(1.1)^5 (0.1)} = 3.790 R$

$\$5 m = 3.790 R$

$\therefore R = \$1,318,987.$

(c) 60 equal monthly payments

compute monthly interest rate equivalent to

(5)

$(1 + i/k)^k = (1 + i_{eff}) = 1 + 0.1 = 1.1$

For $k = 12$, $1 + \dfrac{i_{nom}}{k} = 1.0079741$

$\left(\dfrac{i_{nom}}{k}\right) = .0079741$

Annunity @ monthy rate of $\left(\dfrac{i_{nom}}{k}\right)$ for 60 months

$$= R \frac{(1.0079741)^{60} - 1}{(1.0079741)^{60}(0.0079741)}$$

$$= 47.538 R$$

$$= \$5 \text{ million}$$

R = $105,177.70

Pay $105,177/month for 60 months

Joseph ChE 477 Test 1 Fall 1991

Open Text, Bound Copy of Lecture Notes

Time: 55 Minutes

5% Reserved for Neatness, Clarity, etc.

Problem 1 (15%)

Some of the costs associated with a plant for producing acetylene from natural gas are given below. Classify each item as:

a. Fixed capital cost.

b. Working capital cost.

c. Operating cost.

d. None of the above.

1. Natural Gas.
2. Steam.
3. Steam Plant.
4. Electricity.
5. Solvent Inventory
6. Solvent Makeup.
7. Operating Labor.
8. Construction Labor.
9. Contractor's Fee for Plant Construction.
10. Real Estate Rent.
11. Real Estate Purchase.
12. Interest Payments on Borrowed Money.
13. Depreciation.
14. Royalties.
15. Waste Treatment Plant.

Problem 2 (15%)

The operating costs associated with a sulfuric acid plant are given below.

Fixed Capital Investment	=	$10 Million
Working Capital	=	$ 1 Million
Annual Sales	=	$ 5 Million/Year
Annual Operating Costs (Excluding Depreciation)	=	$ 3 Million/Year
Estimated Life	=	10 Years
Salvage Value	=	0

(20)

Straight-line Method of Depreciation is Used.

Tax Rate = 33%

Compute the following: (#/yr)

1. Gross Profit.
2. Net Profit.
3. Net Profit After Taxes.
4. Total Cash Flow From the Project.

Problem 3 (30%)

An existing pump has a book value of $8,000 and market value of $4,000. A new pump will cost $6,000. The new pump will reduce operating costs (excluding depreciation) by $500/year. The company expects 10% return on its investments after taxes. The tax rate is 33%.

a. If both the existing pump and the new pump have a remaining life of ten (10) years, should the replacement be made? Why or why not?
b. If the old pump has a life of five (5) years and the new pump has a life of ten (10) years, should a replacement be made? Why or why not?

Problem 4 (25%)

A company has $1 million to invest. Two choices are available.

Project 1. Required $700,000 total investment and will generate a cash flow of $200,000/year for five (5) years.

Project 2. Requires $800,000 total investment and will generate the following cash flows:

Year	Cash Flow
1	200,000
2	400,000
3	200,000
4	300,000

The company earns an average of 10% return on its other investments. Should the company invest in any one of these projects? Which one? Why?

Problem 5 (10%)

A man deposits $1,000 in his account at the bank which pays compound interest (compounded daily). If at the end of one (1) year the account holds $1,060.00, what is the nominal and effective interest rates paid by the bank?

Solution To Test

Problem 1.

15

1. c	Natural Gas	Operating Cost	c
2 c	Steam	OC	c
3 a	Steam Plant	FC	a
4 c	Electricity	OC	c
5 b	Solvent Inventory	WC	b
6 c	Solvent Makeup	OC	c
7 c	Operating Labor	OC	c
8 a	Construction Labor	FC	a
9 a	Contractors' Fee	FC	a
10 c	Rent	OC	c
11 a	Real Estate Purch	FC	a
12 c	Interest	OC	c
13 c	Depre	OC	c
14 c	Royalt	OC	c
15 a	Wast Treat Plant	FC	a

15

Problem 2

FCI = $10,000 K
WC = $1,000 K
Sales = $ 5,000 K/yr
Op. Cost = $ 3,000 K/yr
~~Dep = 300 K/yr~~
Gross Profit = $2,000 K/yr a

Net Profit = $ 2,000K − Dep
= $ 2,000 K/yr − 1,000 K/yr
= $ 1,000 K/yr b

Taxes = $ 330 K/yr
NPAT = $670 K/yr c

Net Cash Flow = $1670 /yr.

Problem 3

Capital Need = Cost of new Pump − Market Value of Old Pump

= $6,000 − $4,000

= $2000.

Savings in op. Cost = $500/yr

Increase in Dep = $6,000/10 − $4,000/10

= $600 − $400

= $200/yr

20

Saving after dep = $500 − $200/yr

= $300/yr

Taxes (33%) = $99/yr

Saving after tax = $201/yr

ROII after Taxes = $201/yr / $2000

= 10.05% ✓

(a) Yes, Make Replacement

10 (b) Yes, because increased life mean for service (also dep difference is less).

Problem 3 4

Compare using Net Present Worth

Alternative 1. No Investment

NPW = \$ 1,000 K

Alternative 2

$$NPW = \$300\,K \text{ (after initial inv)} + \frac{200\,K}{yr}\left[\frac{(1+i)^n - 1}{i(1+i)^n}\right] \qquad i = .1,\ n = 5$$

25

$$= \$\,1058.1\,K$$

Alternative 3

$$NPW = \$2{,}000\,K + \frac{\$200\,K}{1+i} + \frac{\$400\,K}{(1+i)^2} + \frac{\$200\,K}{(1+i)^3} + \frac{\$300\,K}{(1+i)^4}$$

$$= 200 + 181.81 + 330.57 + 150.26 + 204.90$$

$$= \$1067.54\,K$$

Choose Alternative 2 which maximizes NPW

Problem 5

Annual Effective Interest Rate

$$i_{eff} = \frac{\$1060 - \$1000}{\$1000} \times 100$$

$$= 6\%$$

(10) nominal interest rate $= i_n$

$$(1 + i_n/365)^{365} = 1 + i_{eff}$$

$$365 \ln(1 + i_n/365) = \ln(1 + i_{eff})$$

$$i_n = 5.827\%$$

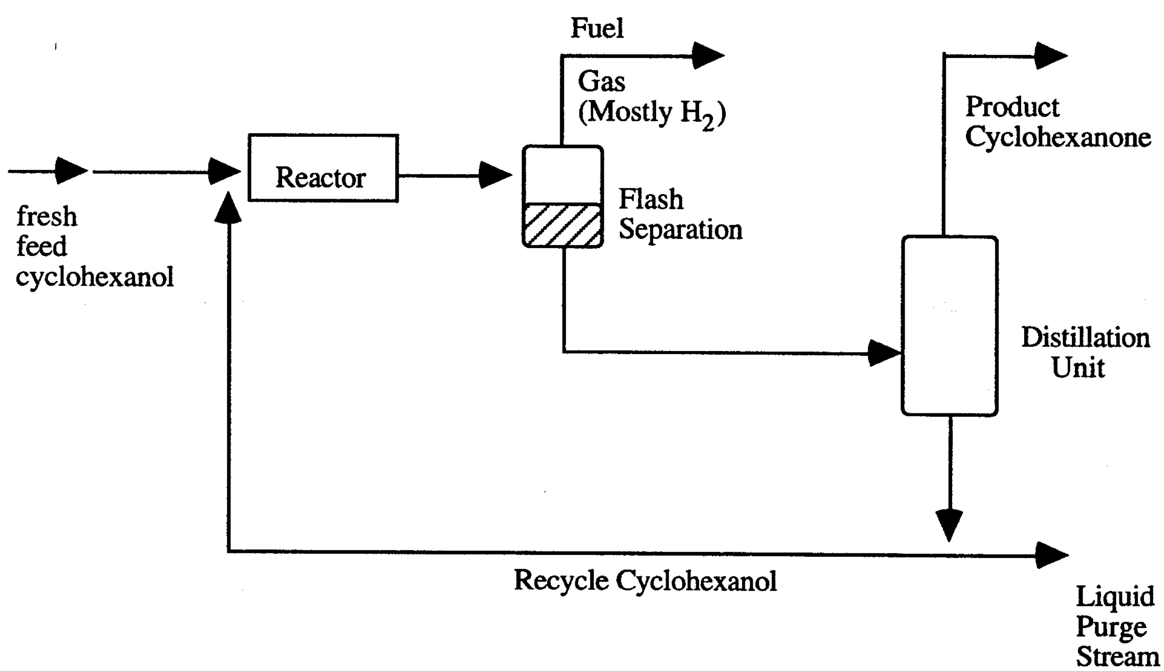
ChE 477 TEST 1 Fall 1994 B. Joseph

TIME: 55 MINUTES

There are 5 problems. Answer all questions. Start each problem on a new page. 5% bonus for neatness, clarity and legibility of solution

Problem 1 (10 points)

Consider the following process for producing cyclohexanone. Draw an Aspen+ block diagram for simulating the process. Identify and label all streams and blocks. Identify unit operation models used.

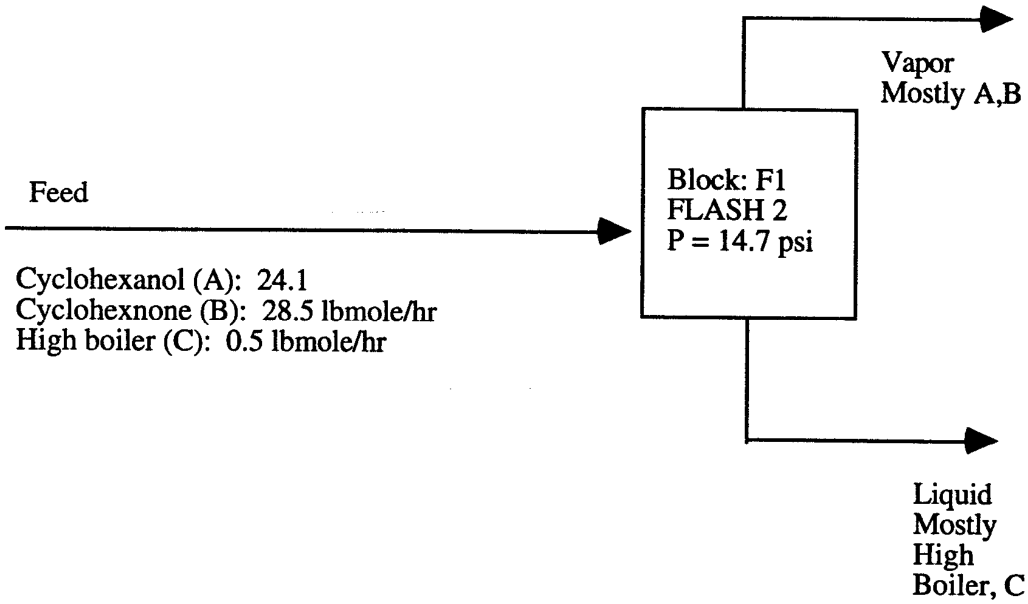


Show Flowsheet Connectivity Table below:

Block	Model Name	Inlet Streams	Outlet Streams

Problem 2 (10 points)

A flash block was used to remove a high boiling compound C, from low boiling compounds A and B. The block diagram for the Aspen + simulation is shown below:



In order to determine the temperature required to remove most of the high boiler, a Design Specification was added to the simulation. The design specification was set up as follows:

Vary: temperature of Block F1 from 0 to 1000 °F

Spec: mole fraction of C in vapor stream is 1%

Tolerance: $\pm$ .001

The simulation terminated abnormally because the design specifications failed to converge.

Examine the problem specifications to determine why Aspen + cannot meet the design specifications by varying the flash temperature.

Suggest how you might set up the correct design specification to calculate the temperature at which most of the C is removed in the bottoms stream and most of A and B is removed at the top in the vapor phase.

Problem 3 (10 points)

Acetone (C_2H_6CO) is made from Isopropanol, IPA, (C_2H_6CHOH) by the vapor phase catalytic reaction.

$$C_2H_6CHOH \rightarrow C_2H_6CO + H_2 \qquad \text{(96\% conversion)}$$

Reaction is carried at 570 °F, 1 atm. It is desired to design a plant to manufacture 50 lbmole/hr of acetone. Assume plant operates 340 days/year. Raw material used is an azeotropic mixture of 70 mole % IPA and 30 mole % water. Water is an acceptable impurity in the reactor.

Costs

Raw material (70% IPA, 30% H_2O)	=	\$10.08/lbmole of mixture
Acetone	=	\$15.66/lbmole
Hydrogen	=	\$ .08/lbmole
Water	=	negligible cost

(a) Draw an input/output structure of the flow sheet. Show the flow of all material into and out of the blackbox representing the plant (in lbmoles/hr).

(b) Calculate the economic potential of the plant in \$/year assuming all of the unreacted IPA is recycled back to the reactor.

Problem 4

The following mixture is to be separated into pure components using distillation:

	NBP, °C	Mole Flow
O-Xylene	144	30
Benzene	80	30
Tuluene	110	30

Using the Heuristic Rules of Nodgir and Liu, synthesize a distillation sequence to produce nearly pure Benzene, Tolene and O-xylene. Show a schematic of the synthesized flowsheet. Explain clearly how you arrived at your sequence.

All components are equally corrosive and hazardous.

29

Problem 5 (10 points)

A process has the following heating and cooling requirements:

Stream	Inlet °F	Outlet °F	M_{cp} KBtu/hr °F
A	200	100	50
B	100	200	40

Assume a minimum approach temperature of 10 °F. What are the minimum heating and cooling utility requirements for this system?

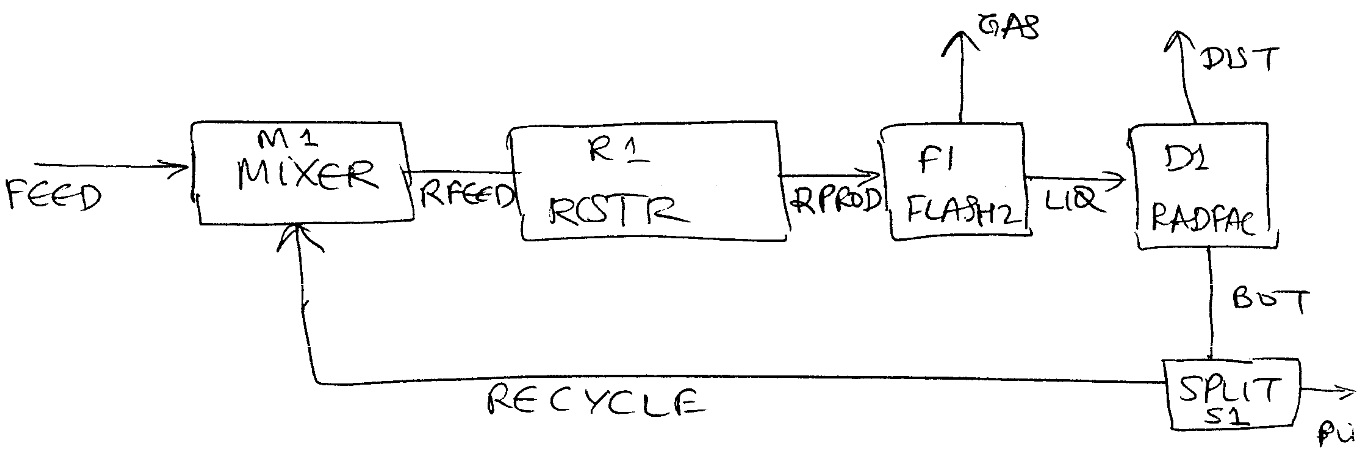
(It is not necessary to use temperature intervals diagram for solving this problem, although you may do so.)

Fall 94

(30)

Solution to Test 1

Problem 1



5 blocks
9 streams

Connectivity

		Inlet	Outlet
M1	MIXER	FEED RECYCLE	RFEED
R1	RCSTR	RFEED	RPROD
F1	FLASH2	RPROD	GAS LIQ
D1	RADFRAC	LIQ	DIST BOT
S1	SPLIT	BOT	RECYCLE PUR

Problem 2

The mole fraction of C in feed is only 0.0094 ~~0~~ (.94%). & which is less than 1% specified in the vapor phase.

Even at very high temp when all C is vaporized, the mole fraction of C in vapor can go only up to .94%. Hence Design spec cannot be met. (cannot converge)

The better way is to specify a mole recovery of C in the vapor stream or liquid stream:

Spec: mole recovery of C in liquid is 99%.

Vary: Flash temp

Problem 2

The design spec cannot be met because the mole fraction of C in the feed is only

$$= \frac{0.5}{241. + 28.5 + 0.5}$$

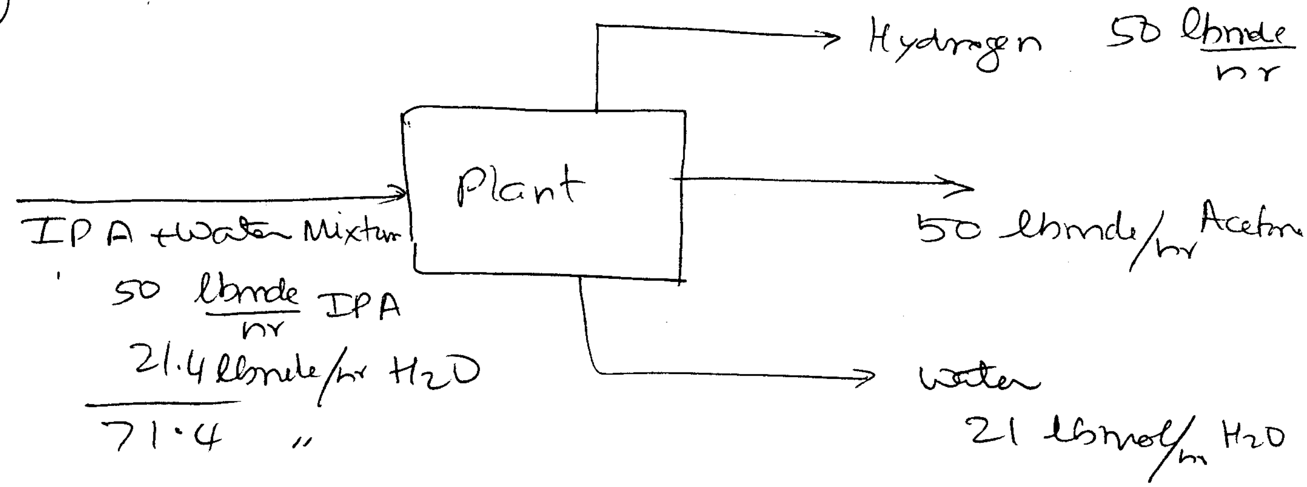
$$= 0.0094$$

$$= 0.94\,\%$$

Even if all of the feed is vaporized by raising the temperature, the mole fraction can only get to .94 %.

Problem 3

(a)



From stoichiometry

50 lbmole/hr Acetone requires

50 lbmole/hr of IPA

∴ Water fed $= 50 \frac{lbmole}{hr} \times \frac{30 \text{ mole } H_2O}{70 \text{ mole IPA}}$

$= 21.4$ lbmole/hr

Hydrogen produced $= \Rightarrow 50 \frac{lbmole}{hr}$.

(b) Economic Potential:

EP = $50 \times \$15.66 - 71.4 * \$10.08$
$+ 50 \times 0.8$

$=$ \$ ~~103.288~~ 66.98 /hr × 340 × 24 hr/yr =

$=$ \$ ~~8240842,830~~ 546,600 /yr

Problem 4

Mole flow

Mole flow			ΔT	CES
~~75~~ 30	Benzene	80		~~10~~ 15
			30	
~~5~~ 30	Toluene	110		
			34	
~~20~~ 30	O-xylene	144		~~8.5~~ 17

$$CES = \Delta T * f$$

For B/T split $f = \frac{30}{60} = 0.5$ (~~.75~~ ~~25~~ / ~~75~~; ~~.333~~)

$\Delta T = 30$ ∴ $CES =$ ~~10~~ **15**

for T/X split $f = \frac{30}{60} = 0.5$ (~~.25~~)

$\Delta T = 34$ ∴ $CES =$ ~~8.5~~ **17**

Accordingly T/X split first is favored.

Applying Heuristic Rules:

Rule M1 : Favor distillation, okay

Rule M2 : Avoid vacuum / refrigeration okay

Rule D1 : Favor smallest product set. okay

Rule S1 : Remove corrosive / hazardous material first

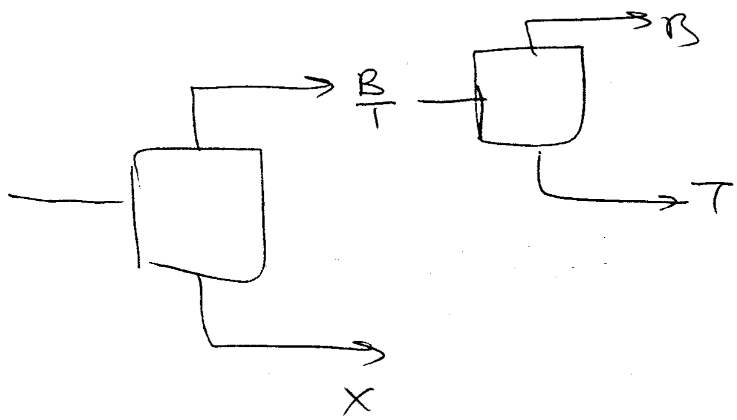
Rule S2 : Perform difficult sepn last. No difficult separations

~~He~~ Rule C1: Remove most plentiful components first

~~⇒ Remove Benzene first.~~
Not apply

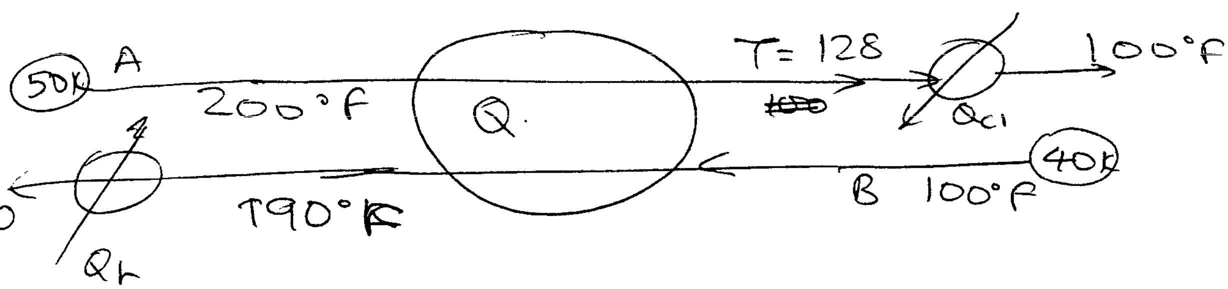
Rule C2: Favor 50/50 split.
Perform highest CES first

⇒ perform ~~B~~ Toluene / xylene split first



Problem 5

Exchange A, B first

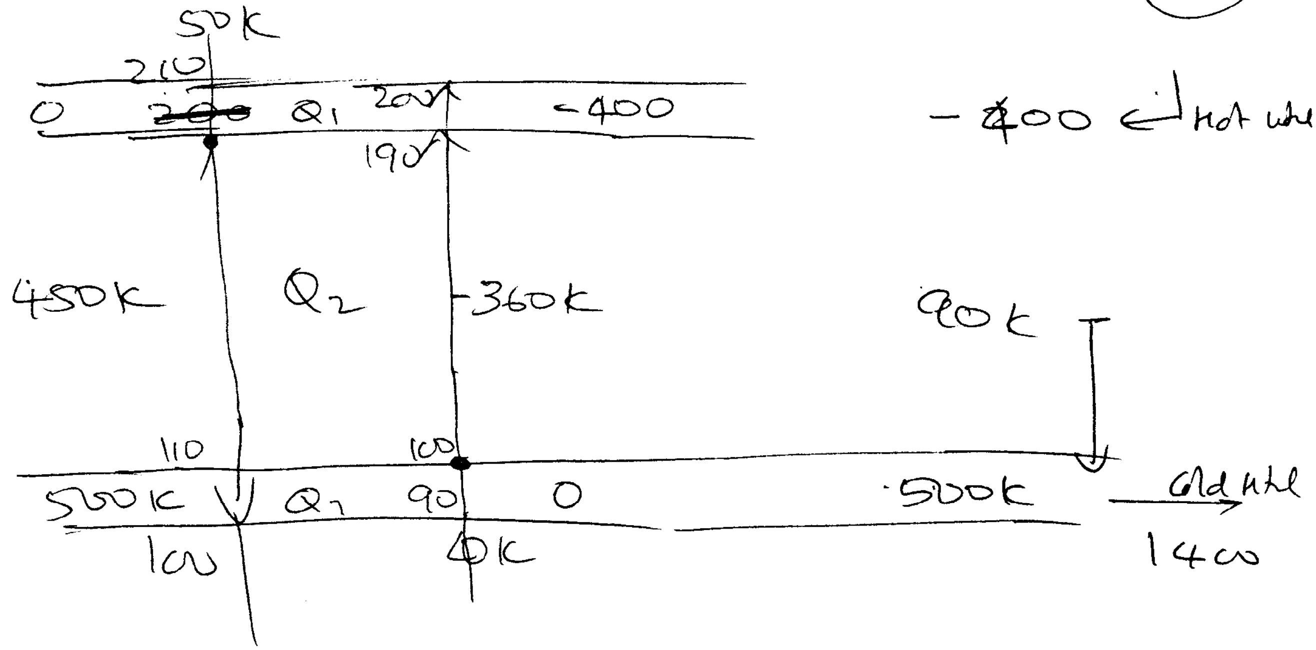


$Q_1 = 40\,(190-100) = 360\text{ K}$

$(\Delta T)_A = \frac{360}{50} = 72\,°F$

$Q_h = 40\text{ K} \times (200-190) = \underline{\underline{400}}\ \frac{\text{KBtu}}{\text{hr}}$

$Q_c = 50\text{ K}\,(128-100) = \underline{\underline{1400}}\ \frac{\text{KBtu}}{\text{hr}}$


50K
210
0
Q1
200
-400
190
-400 ← Hot util
450K
Q2
-360K
90K
110
100
500K
Q1
90
0
500K
Cold util
100
40K
1400

(38)

B. JOSEPH **CHE 477** **FALL 1996**

TEST #2

Time: 55 minutes
Open: Text
1 - 2 points bonus for neatness, clarity, and organization.

PROBLEM 1 (10 points)

A heat exchanger is to be constructed by forming copper tubing into a coil and placing it inside an insulated steel shell. If the following data apply, what should be the length of the coil?

a) Water will flow inside the tubing, and a hydrocarbon vapor will condense on the outside of the tubing.
b) ID of tubing = 0.5 in.
c) OD of tubing = 0.6 in.
d) Condensate rate = 1000 lb/h.
e) Temperature of condensation = 190°F.
f) Heat of vaporization of hydrocarbon at 190°F = 144 Btu/lb.
g) Overall heat-transfer coefficient for condensing vapor = 250 Btu/(h) (ft^2) (°F) (based on inside area).
h) Inlet water temperature = 50°F.
i) Outlet water temperature = 90°F.
j) Heat losses from the shell may be neglected.

PROBLEM 2 (10 points)

The sales income from a project is $1.1 million/year. The operating expenses (excluding depreciation) is $0.82 million/yr. The total capital investment in the project is $1.5 million out of which 20% is for working capital and 80% is for fixed capital investment. Part of the fixed capital is land costing $0.1 million. The estimated life of the plant is 10 years at which time the plant is estimated to have a salvage value of $0.2 million. The income tax rate is 40%. Compute the cash flow in $/year resulting from the plant operation. Assume straight-line depreciation.

PROBLEM 3 (10 points)

You win the Missouri Lotto Jackpot worth 20 million. You are given two choices

a) $20 million paid in 20 installments of $1 million each year. The first payment is immediate and then on the anniversary date for every year thereafter.

b) $6 million in cash right now as one lump sum payment.

Assume income tax rate is 37%. Your investments can be expected to give a return of 10% per year after taxes (effective annual interest rate on your savings).

Which option would you select if you want to maximize your present worth. Neglect inflation.

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PROBLEM 4 (10 points)

(Based on Aspen project work)

It is desired to design a separation column using DSTWU model with the following stream as feed.

Flow of cyclohexanol, A	10 lbmoles/hr
Flow of cyclohexanone, B	10 lbmoles/hr
Flow of High Boiler, C	0.01 lbmoles/hr

We would like to separate a product consisting of 95 mole% B and 5% A. You may assume that 1% of B entering the feed leaves with the recycle stream. Aspen DSTWU block requires the following specifications: Answer these questions.

a) What is the light key component?
b) What is the heavy key component?
c) What is recovery of light key component in distillate?
d) What is recovery of heavy key in distillate?
e) Either actual reflux ratio or the reflux ratio as multiple of the minimum reflux ratio. Which one will you enter. What is a recommended value? Why?

f) After completing this run, the student includes a small amount of H_2 dissolved in the feed and Aspen fails to complete normally, reporting a problem with DSTWU calculations. Why would adding a trace amount of H_2 cause a problem? Will this change your column design significantly? How?

Solution To Test 2

Problem 1

1. Conductivity of copper is high. Neglect wall resistance to heat transfer

$$q = u A (\Delta T)_{lm}$$

$$\Delta T_1 = 190 - 50 = 140^\circ F$$

$$\Delta T_2 = 190 - 90 = 100^\circ F$$

$$(\overline{\Delta T})_{lm} = 1 \Big/ \frac{\ln (\Delta T_1/\Delta T_2)}{(\Delta T)_1 - (\Delta T)_2} = 118.8^\circ$$

$$q = (m c_p \Delta T)_w = (\lambda \cdot m)_{vapor} = 144 \frac{Btu}{lb} \times 1000 \frac{lb}{hr} = 144{,}000 \frac{Btu}{hr}$$

$$= u A \Delta T$$

$$A = \frac{\pi D^2}{4} \; (\pi D) L = \frac{\pi (0.5)}{12} ft \times L$$

$$\therefore L = \frac{14{,}4000 \; Btu/hr \; ft}{250 \frac{Btu}{hr\, ft^2 \, ^\circ F} \times 118.8^\circ F \times \frac{\pi (.5)}{12} ft^2} = 37. ft$$

Problem 2

Sales Income = ~~$11~~ $1100 k/yr

Op. Exp = $820 k/yr

TCI = ~~$15~~ $1500 k

FCI = $1200 k

WCI = 300 k

land = 100 k

n = 10 years

Salv = $200k

tax = 0.40

depreciation = (FCI − land − salvage value)/n

$$= \frac{\$1200 - \$100k - \$200k}{10 \text{ yrs}}$$

= $90 k/yr

Gross profit = ~~$820k~~ $1100 k − $820k

GP = $280 k

Net Profit = GP − deprec.

= $280 k − $90k = $190k /yr

Tax = NP × tax = $190 × .40 = $76.00/y

Net Profit After Tax = $114 k/yr

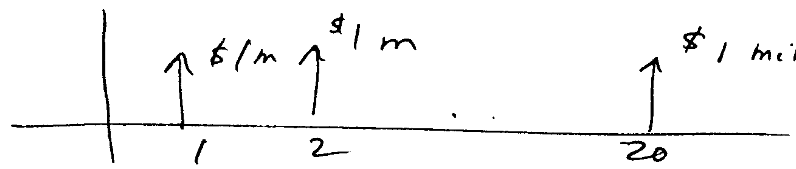
Net Cash Flow = $114k + $ dep

= $114k + $90k

= **$204 k/yr**

Problem 3

(a) 2 Choices



20 payments of $1 million each

If you collect \$ ~~15~~ 6 million now, after tax you will have

$= \$6\ (1 - .37) = \$3.78$ million (~~9.45~~)

$FW_{20} = S_{20} = \$25.4 \times 10^6$

~~The present worth of~~

If you took the annuity option, you will get $= \$1 \text{ mil} \times (1 - .37) = .63$ mil/yr

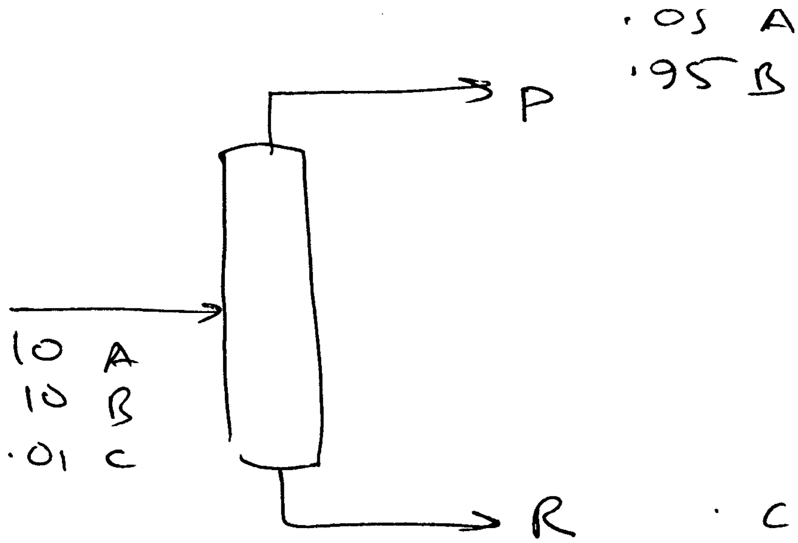
$$PW \text{ of annuity} = R \; \frac{(1+i)^n - 1}{(1+i)^n \, i}$$

$$= .63 \times \frac{(1+.1)^{20} - 1}{(1.1)^{20} (0.1)}$$

$= \$5.3$ million (~~3.30~~)

$FW_{20} = \$36.0$ mill (~~22.2~~)

Take the ~~\$ 6 million~~ Annuity option



C = .01
B = .1
A = ? x

we have

Total

$$10 + 10 + .01 = P + .01 + .1 + x$$
$$20.01 = P + x + .11$$
$$P + x = 19.9$$

B. alance on B

$$10 = .95P + .1$$
$$P = 10.42$$
$$x = 9.48$$

~~Check Balance on A~~

~~$10 = 10.42 \times .05 + x$~~
~~$= 10.001$ ok~~

(a) Light key is ~~A~~ B
(b) Heavy key is A
(c) Recovery of HK in Dist $\frac{.05 \times P}{10} = .0521$
(d) " LK " Dist $\frac{.95 \times P}{10} = .9899$
(e) ~~Act~~ Use 1.2 times min Reflux Ratio

f) Because H_2 cannot be condensed easily at the top. DSTWU assumes distillate is all liquid. With H_2 you need to specify a vapor distillate product as well.