PRINCE OF SONGKLA UNIVERSITY

FACULTY OF ENGINEERING

Final Examination : Semester II | Academic Year : 2006

Date : 21 February 2006 | Time : 13.30 - 16.30

Subject : 230 - 432 Chemical Engineering Plant Design | Room : R201

Student Name: .... Code: ....

Number of questions : 4 (Total 17 pages)

Time : 3 hours

Total marks : 85

Books and notes are not allowed

Calculators and writing in pencil are allowed.

Interest Tables are provided at the back of this examination paper.

Question	Full Marks	Marks Received
1	25	
2	20	
3	15	
4	25	
Total	85	

ทุจริตในการสอบโทษขั้นต่ำคือ ปรับตกในรายวิชาที่ทุจริต และพักการเรียน 1 ภาคการศึกษา

Student Name: .... Code : ....

1. a) The total capital investment for a chemical plant is $1,500,000 , and the plant produces 3 million kg of product annually. The selling price of the product is $0.82/kg. Working capital amounts to 15 percent of the total capital investment. The investment is from the company funds, and no interest is charged. Delivered raw materials costs for the product are $0.09/kg; labor, $0.08/kg; utilities, $0.05 /kg; and packaging, $0.008/kg. Distribution costs are 5 percent of sales revenue. Estimate the following:

a.1) Manufacturing cost per kilogram of product

a.2) Total product cost per year

a.3) Profit per kilogram of product before taxes

Note: (10 marks)

Manufacturing cost	= Direct production costs + fixed charges + plant-overhead costs
Fixed charges	= 10% of fixed-capital investment
Plant-overhead costs	= 70% of cost for labor
Total product costs	= manufacturing costs + general expenses
General expenses	= 15% of cost for labor + distribution cost + R&D costs
R&D costs	= 5% of sales revenue

b) Two types of pump are being considered for purchase, A (carbon steel) and B(alloy). Cost estimates for the two types are given in the table below. The company policy has been set to use 10% rate of return. Determine which pump type is more economical?

Pump type	A	B
Purchased cost, $	19,000	27,000
Annual maintenance costs, $	4,000	2,800
Salvage value, $	500	1,500
Service life, years	2	3

(10 marks)

c) Explain the meaning of "mutually exclusive projects". Give one example of such project.

(5 marks)

2. A proposed chemical plant is to be built for two years before it can operate at full capacity. The fixed-capital costs are $10 million for the first year and $15 million for the second year. A working capital investment of $6 million is needed at the time when the plant starts operation. The estimated useful life of the plant is 9 years of production. Salvage value of the plant is $500,000.

The plant begins operation at the third year of the project at 100% capacity. The estimated annual sales revenue and production costs are given below. The depreciation is a MACRS schedule for 8 years as follows: 14.29%, 24.49%, 17.49%, 12.49%, 8.93%, 8.92%, 8.93% and 4.46%. The income tax rate is 35%.

Operating year	Annual sales revenue ($ million)	Production costs ($ million)
1	7.00	4.00
2	10.00	5.60
3	15.00	6.80
4	20.00	7.80
5	22.50	8.80
6	24.00	9.60
7	25.00	10.00
8	27.00	11.00
9	29.0	12.50

Write after-tax cashflow for 9-year production.

Calculate the NPV of the project at 12% interest rate.

Calculate the %IRR of the project.

(20 marks)

3. Consider a condenser in which heat must be removed from a condensing vapor at a given rate designated by q kJ/h by using cooling water. The vapor condenses at a constant temperature of t ' or T_{COND} °C, and cooling water is supplied at a temperature of t_1 °C. The following additional notation applies:

m = flow rate of cooling water, kg/h

c_p = heat capacity of cooling water, kJ/(kg.K)

t ' or T_{COND} = condensation temperature of vapor, °C

t_1 = inlet temperature of cooling water to condenser, °C

t_2 = temperature of cooling water leaving condenser, °C

U = constant overall coefficient of heat transfer determined at optimum conditions, kJ/(m^2.s.K)

A = area of heat transfer, m^2

Δt_{lm} = log-mean temperature-difference driving force over condenser, °C

H_y = hours the condenser is operated per year, h/year

C_w = cooling-water cost assumed as directly proportional to amount of water supplied, $/kg

C_A = installed cost of heat exchanger per square foot of heat-transfer area, $/m

K_F = annual fixed charges including maintenance, expressed as a fraction of initial cost for completely installed equipment

The rate of heat transfer as kJ per second can be expressed as

$$q = mc_p\,(t_2 - t_1) = UA\Delta t_{lm} = \frac{UA\,(t_2 - t_1)}{\ln\,(t' - t_1)/(t' - t_2)} \qquad (1)$$

Solving for m,

$$m = \frac{q}{c_p\,(t_2 - t_1)} \qquad (2)$$

The design conditions set the values of q and t, and the heat capacity of water may ordinarily be approximated as 4.2 kJ/(kg.K). Therefore, Eq. (2) shows that the flow rate of the cooling water is fixed if the temperature of the water leaving the condenser (t_2) is fixed. Under these conditions, the optimum flow rate of cooling water can be found directly from the optimum value of t_2.

The optimum cooling-water rate occurs when the total annual cost is a minimum. Thus, the following equation is obtained:

$$\frac{t' - t_1}{t' - t_{2,\,opt}} - 1 + \ln \frac{t' - t_{2,\,opt}}{t' - t_1} = \frac{U H_y C_w}{K_F c_p C_A} \qquad (3)$$

A condenser for a distillation unit must be designed to condense 3000 kg of vapor per hour. The effective condensation temperature for the vapor is 80°C. The heat of condensation for the vapor is 500 kJ/kg. Cooling water is available at 21°C. The cost of the cooling water is $2.8 per 100 m^3. The overall heat-transfer coefficient at the optimum conditions may be taken as 0.3 kJ/(m^2.s.K). The cost for the installed heat exchanger is $400 per square meter of heat-transfer area, and annual fixed charges including maintenance are 20 percent of the initial investment. The heat capacity of the water may be assumed to be constant at 4.2 kJ/(kg.K). If the condenser is to operate 6000 h/yr, determine the cooling-water flow rate in kilograms per hour for optimum economic conditions.

(15 marks)

Answer to Question 3

4. a) A carbon steel sieve-tray distillation column with 10 trays operated at an average pressure of 400 mmHg, and average temperature of 280^{0}C, and a reflux ratio of 8:1 is used to separate biphenyl from a feed mixture. The top product contains 98 mole percent of biphenyl. The distillate product rate is 0.12 kg mol/s. Physical properties at top of the column are:

ρ_V = 60 kg/m^3

ρ_L = 720 kg/m^3

Molecular weight for biphenyl vapor = 154.2

Surface tension of liquid = 20 dyne/cm

Foaming factor = 0.9 and $A_h/A_a > 0.1$

Calculate column diameter at top of column.

(20 marks)

Note:

L/V = R/(R+1), V=D(R+1), R = reflux ratio, D= distillate rate, kg mol/s

L andV = liquid and vapor flow rate, kg mol/s

flooding velocity $$V_{nf} = C\left(\frac{\rho_L - \rho_V}{\rho_V}\right)^{1/2} \qquad \text{---- (1)}$$

where V_{nf} = net vapour (gas) velocity at flooding, m/s

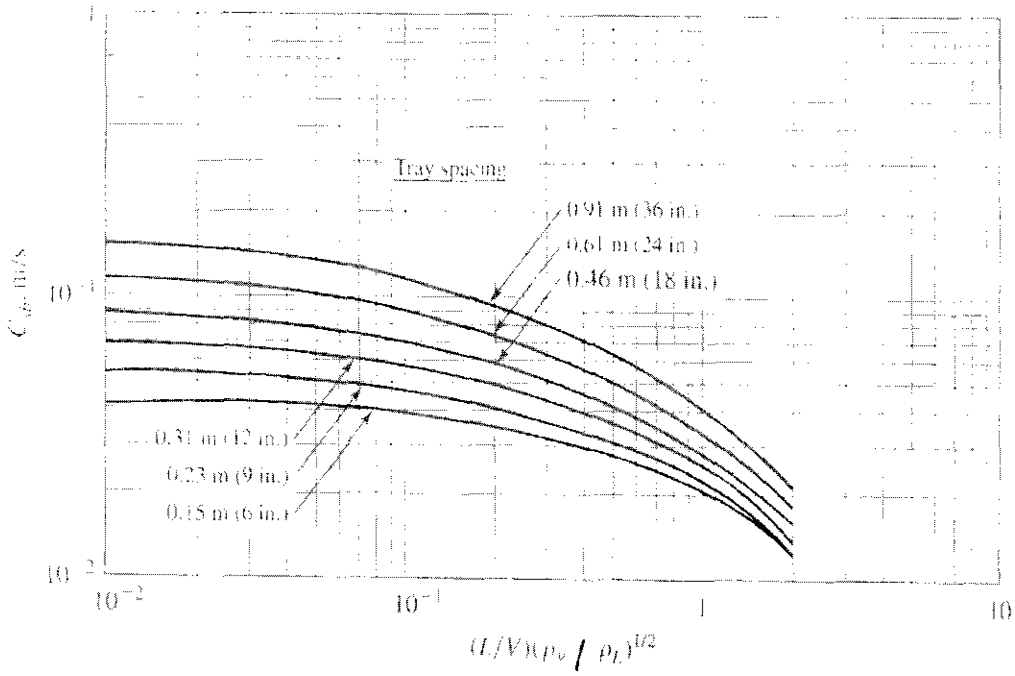
C = capacity parameter of Souders and Brown

Fair gave a plot of C_{sb}, in the form C_{sb} = f (tray spacing, F_{LV})

where $F_{LV} = \left(\frac{L}{V}\right)\left(\frac{\rho_V}{\rho_L}\right)^{0.5}$ Both L are V are in kg mol/s

F_{LV} is callled "kinetic energy ratio"

C_{sb} is Souders and Brown factor



Figure

Chart for estimating values of C_{sb} ($\pm$10 percent) in Eq. (15-7). [*Adapted from J. R. Fair: Petro/Chem. Eng., 33(10): 45 (1961) with permission.*]

value of C in equation (1) can be calculated from C_{sb}

$$C = F_{ST} F_F F_{HA} C_{sb} \qquad \text{------ (2)}$$

โดย F_{ST} = surface tension factor = $(\sigma/20)^{0.2}$

F_F = foaming factor (= 1.0 for nonfoaming systems)

F_{HA} = hole area factor = 1.0 for $A_h/A_a > 0.10$

A_h = vapour hole area, m^2

C_{sb} = Souders and Brown factor at flood conditions, m/s

σ = liquid surface tension, dynes/cm

from the value of C_{sb} obtained from the plot, it is used to find C from equation (2) and then find V_{nf} from equation (1)

Column diameter can be calculated from

$$\text{column diameter, } D = \left[\frac{4VM_V}{0.85\, V_{nf}\, \pi \left(1 - \frac{A_d}{A}\right) \rho_V} \right]^{0.5} \qquad \text{---- (3)}$$

where M_V = molecular weight of vapor

and A = total column cross-sectional area

$$A = \frac{\pi D^2}{4} \quad \text{Or} \quad D = (4A/\P)^{0.5}$$

A_d = area of one downcomer

Oliver suggested that A_d/A can be estimated from the value of F_{LV} as follow

$A_d/A = 0.1$ when $F_{LV} \leq 0.1$

$A_d/A = 0.1 + \frac{(F_{LV} - 0.1)}{9}$ when $0.1 \leq F_{LV} \leq 1.0$

$A_d/A = 0.2$ when $F_{LV} \geq 1.0$

b) If the column in part a) has tray spacing of 0.61 m estimate the column height. Explain how you would estimate the cost of this column if cost curves are available.

(5 marks)

-- End of Examination Questions

Appendix A *8% Interest Rate Factors*

N	Single Payment: Compound Amount Factor, (*F/P, i, N*)	Single Payment: Present-Worth Factor, (*P/F, i, N*)	Equal-Payment Series: Compound Amount Factor, (*F/A, i, N*)	Equal-Payment Series: Sinking-Fund Factor, (*A/F, i, N*)	Equal-Payment Series: Present-Worth Factor, (*P/A, i, N*)	Equal-Payment Series: Capital Recovery Factor, (*A/P, i, N*)	Uniform Gradient Series Factor, (*A/G, i, N*)
1	1.08000	0.9259259	1.00000	1.0000000	0.9259259	1.0800000	0.0000000
2	1.16640	0.8573388	2.08000	0.4807692	1.7832647	0.5607692	0.4807692
3	1.25971	0.7938322	3.24640	0.3080335	2.5770970	0.3880335	0.9487432
4	1.36049	0.7350299	4.50611	0.2219208	3.3121268	0.3019208	1.4039598
5	1.46933	0.6805832	5.86660	0.1704565	3.9927100	0.2504565	1.8464716
6	1.58687	0.6301696	7.33593	0.1363154	4.6228797	0.2163154	2.2763460
7	1.71382	0.5834904	8.92280	0.1120724	5.2063701	0.1920724	2.6936649
8	1.85093	0.5402689	10.63663	0.0940148	5.7466389	0.1740148	3.0985239
9	1.99900	0.5002490	12.48756	0.0800797	6.2468879	0.1600797	3.4910327
10	2.15892	0.4631935	14.48656	0.0690295	6.7100814	0.1490295	3.8713139
11	2.33164	0.4288829	16.64549	0.0600763	7.1389643	0.1400763	4.2395030
12	2.51817	0.3971138	18.97713	0.0526950	7.5360780	0.1326950	4.5957475
13	2.71962	0.3676979	21.49530	0.0465218	7.9037759	0.1265218	4.9402067
14	2.93719	0.3404610	24.21492	0.0412969	8.2442370	0.1212969	5.2730508
15	3.17217	0.3152417	27.15211	0.0368295	8.5594787	0.1168295	5.5944603
16	3.42594	0.2918905	30.32428	0.0329769	8.8513692	0.1129769	5.9046256
17	3.70002	0.2702690	33.75023	0.0296294	9.1216381	0.1096294	6.2037458
18	3.99602	0.2502490	37.45024	0.0267021	9.3718871	0.1067021	6.4920284
19	4.31570	0.2317121	41.44626	0.0241276	9.6035992	0.1041276	6.7696885
20	4.66096	0.2145482	45.76196	0.0218522	9.8181474	0.1018522	7.0369478
21	5.03383	0.1986557	50.42292	0.0198323	10.0168032	0.0998323	7.2940343
22	5.43654	0.1839405	55.45676	0.0180321	10.2007437	0.0980321	7.5411812
23	5.87146	0.1703153	60.89330	0.0164222	10.3710589	0.0964222	7.7786264
24	6.34118	0.1576993	66.76476	0.0149780	10.5287583	0.0949780	8.0066115
25	6.84848	0.1460179	73.10594	0.0136788	10.6747762	0.0936788	8.2253815
26	7.39635	0.1352018	79.95442	0.0125071	10.8099780	0.0925071	8.4351838
27	7.98806	0.1251868	87.35077	0.0114481	10.9351648	0.0914481	8.6362675
28	8.62711	0.1159137	95.33883	0.0104889	11.0510785	0.0904889	8.8288830
29	9.31727	0.1073275	103.96594	0.0096185	11.1584060	0.0896185	9.0132810
30	10.06266	0.0993773	113.28321	0.0088274	11.2577833	0.0888274	9.1897125
31	10.86767	0.0920160	123.34587	0.0081073	11.3497994	0.0881073	9.3584274
32	11.73708	0.0852000	134.21354	0.0074508	11.4349994	0.0874508	9.5196747
33	12.67605	0.0788889	145.95062	0.0068516	11.5138884	0.0868516	9.6737016
34	13.69013	0.0730453	158.62667	0.0063041	11.5869337	0.0863041	9.8207532
35	14.78534	0.0676345	172.31680	0.0058033	11.6545682	0.0858033	9.9610718
36	15.96817	0.0626246	187.10215	0.0053447	11.7171928	0.0853447	10.0948967
37	17.24563	0.0579857	203.07032	0.0049244	11.7751785	0.0849244	10.2224638
38	18.62528	0.0536905	220.31595	0.0045389	11.8288690	0.0845389	10.3440053
39	20.11530	0.0497134	238.94122	0.0041851	11.8785824	0.0841851	10.4597493
40	21.72452	0.0460309	259.05652	0.0038602	11.9246133	0.0838602	10.5699192
42	25.33948	0.0394641	304.24352	0.0032868	12.0066987	0.0832868	10.7744086
48	40.21057	0.0248691	490.13216	0.0020403	12.1891365	0.0820403	11.2758404
50	46.90161	0.0213212	573.77016	0.0017429	12.2334846	0.0817429	11.4107136
60	101.25706	0.0098759	1253.21330	0.0007979	12.3765518	0.0807979	11.9015384
70	218.60641	0.0045744	2720.08007	0.0003676	12.4428196	0.0803676	12.1783183
72	254.98251	0.0039218	3174.78140	0.0003150	12.4509770	0.0803150	12.2165159
75	321.20453	0.0031133	4002.55662	0.0002498	12.4610840	0.0802498	12.2657747
80	471.95483	0.0021188	5886.93543	0.0001699	12.4735144	0.0801699	12.3301323
90	1018.91509	0.0009814	12723.93862	0.0000786	12.4877320	0.0800786	12.4115840
100	2199.76126	0.0004546	27484.51570	0.0000364	12.4943176	0.0800364	12.4545198

Appendix A *10% Interest Rate Factors*

N	Single Payment: Compound Amount Factor, (*F/P, i, N*)	Single Payment: Present-Worth Factor, (*P/F, i, N*)	Equal-Payment Series: Compound Amount Factor, (*F/A, i, N*)	Equal-Payment Series: Sinking-Fund Factor, (*A/F, i, N*)	Equal-Payment Series: Present-Worth Factor, (*P/A, i, N*)	Equal-Payment Series: Capital Recovery Factor, (*A/P, i, N*)	Uniform Gradient Series Factor, (*A/G, i, N*)
1	1.10000	0.9090909	1.00000	1.0000000	0.9090909	1.1000000	0.0000000
2	1.21000	0.8264463	2.10000	0.4761905	1.7355372	0.5761905	0.4761905
3	1.33100	0.7513148	3.31000	0.3021148	2.4868520	0.4021148	0.9365559
4	1.46410	0.6830135	4.64100	0.2154708	3.1698654	0.3154708	1.3811679
5	1.61051	0.6209213	6.10510	0.1637975	3.7907868	0.2637975	1.8101260
6	1.77156	0.5644739	7.71561	0.1296074	4.3552607	0.2296074	2.2235572
7	1.94872	0.5131581	9.48717	0.1054055	4.8684188	0.2054055	2.6216150
8	2.14359	0.4665074	11.43589	0.0874440	5.3349262	0.1874440	3.0044786
9	2.35795	0.4240976	13.57948	0.0736405	5.7590238	0.1736405	3.3723515
10	2.59374	0.3855433	15.93742	0.0627454	6.1445671	0.1627454	3.7254605
11	2.85312	0.3504939	18.53117	0.0539631	6.4950610	0.1539631	4.0640544
12	3.13843	0.3186308	21.38428	0.0467633	6.8136918	0.1467633	4.3884022
13	3.45227	0.2896644	24.52271	0.0407785	7.1033562	0.1407785	4.6987919
14	3.79750	0.2633313	27.97498	0.0357462	7.3666875	0.1357462	4.9955287
15	4.17725	0.2393920	31.77248	0.0314738	7.6060795	0.1314738	5.2789335
16	4.59497	0.2176291	35.94973	0.0278166	7.8237086	0.1278166	5.5493407
17	5.05447	0.1978447	40.54470	0.0246641	8.0215533	0.1246641	5.8070972
18	5.55992	0.1798588	45.59917	0.0219302	8.2014121	0.1219302	6.0525600
19	6.11591	0.1635080	51.15909	0.0195469	8.3649201	0.1195469	6.2860950
20	6.72750	0.1486436	57.27500	0.0174596	8.5135637	0.1174596	6.5080750
21	7.40025	0.1351306	64.00250	0.0156244	8.6486943	0.1156244	6.7188781
22	8.14027	0.1228460	71.40275	0.0140051	8.7715403	0.1140051	6.9188862
23	8.95430	0.1116782	79.54302	0.0125718	8.8832184	0.1125718	7.1084831
24	9.84973	0.1015256	88.49733	0.0112998	8.9847440	0.1112998	7.2880537
25	10.83471	0.0922960	98.34706	0.0101681	9.0770400	0.1101681	7.4579620
26	11.91818	0.0839055	109.18177	0.0091590	9.1609455	0.1091590	7.6186500
27	13.10999	0.0762777	121.09994	0.0082576	9.2372232	0.1082576	7.7704366
28	14.42099	0.0693433	134.20994	0.0074510	9.3065665	0.1074510	7.9137163
29	15.86309	0.0630394	148.63093	0.0067281	9.3696059	0.1067281	8.0488583
30	17.44940	0.0573086	164.49402	0.0060792	9.4269145	0.1060792	8.1762255
31	19.19434	0.0520987	181.94342	0.0054962	9.4790132	0.1054962	8.2961737
32	21.11378	0.0473624	201.13777	0.0049717	9.5263756	0.1049717	8.4090507
33	23.22515	0.0430568	222.25154	0.0044994	9.5694324	0.1044994	8.5151959
34	25.54767	0.0391425	245.47670	0.0040737	9.6085749	0.1040737	8.6149398
35	28.10244	0.0355841	271.02437	0.0036897	9.6441590	0.1036897	8.7086032
36	30.91268	0.0323492	299.12681	0.0033431	9.6765082	0.1033431	8.7964970
37	34.00395	0.0294083	330.03949	0.0030299	9.7059165	0.1030299	8.8789220
38	37.40434	0.0267349	364.04343	0.0027469	9.7326514	0.1027469	8.9561685
39	41.14478	0.0243044	401.44778	0.0024910	9.7569558	0.1024910	9.0285162
40	45.25926	0.0220949	442.59256	0.0022594	9.7790507	0.1022594	9.0962342
42	54.76370	0.0182603	537.63699	0.0018600	9.8173973	0.1018600	9.2188038
48	97.01723	0.0103074	960.17234	0.0010415	9.8969255	0.1010415	9.5000897
50	117.39085	0.0085186	1163.90853	0.0008592	9.9148145	0.1008592	9.5704130
60	304.48164	0.0032843	3034.81640	0.0003295	9.9671573	0.1003295	9.8022945
70	789.74696	0.0012662	7887.46957	0.0001268	9.9873377	0.1001268	9.9112516
72	955.59382	0.0010465	9545.93818	0.0001048	9.9895353	0.1001048	9.9245753
75	1271.89537	0.0007862	12708.95371	0.0000787	9.9921377	0.1000787	9.9409865
80	2048.40021	0.0004882	20474.00215	0.0000488	9.9951181	0.1000488	9.9609261
90	5313.02261	0.0001882	53120.22612	0.0000188	9.9981178	0.1000188	9.9830573
100	13780.61234	0.0000726	137796.12340	0.0000073	9.9992743	0.1000073	9.9927429

Appendix A 12% *Interest Rate Factors*

	Single Payment		Equal-Payment Series				Uniform Gradient Series
N	Compound Amount Factor, $(F/P, i, N)$	Present-Worth Factor, $(P/F, i, N)$	Compound Amount Factor, $(F/A, i, N)$	Sinking-Fund Factor, $(A/F, i, N)$	Present-Worth Factor, $(P/A, i, N)$	Capital Recovery Factor, $(A/P, i, N)$	Uniform Gradient Series Factor, $(A/G, i, N)$
1	1.12000	0.8928571	1.00000	1.0000000	0.8928571	1.1200000	0.0000000
2	1.25440	0.7971939	2.12000	0.4716981	1.6900510	0.5916981	0.4716981
3	1.40493	0.7117802	3.37440	0.2963490	2.4018313	0.4163490	0.9246088
4	1.57352	0.6355181	4.77933	0.2092344	3.0373493	0.3292344	1.3588521
5	1.76234	0.5674269	6.35285	0.1574097	3.6047762	0.2774097	1.7745945
6	1.97382	0.5066311	8.11519	0.1232257	4.1114073	0.2432257	2.1720474
7	2.21068	0.4523492	10.08901	0.0991177	4.5637565	0.2191177	2.5514654
8	2.47596	0.4038832	12.29969	0.0813028	4.9676398	0.2013028	2.9131439
9	2.77308	0.3606100	14.77566	0.0676789	5.3282498	0.1876789	3.2574167
10	3.10585	0.3219732	17.54874	0.0569842	5.6502230	0.1769842	3.5846530
11	3.47855	0.2874761	20.65458	0.0484154	5.9376991	0.1684154	3.8952546
12	3.89598	0.2566751	24.13313	0.0414368	6.1943742	0.1614368	4.1896526
13	4.36349	0.2291742	28.02911	0.0356772	6.4235484	0.1556772	4.4683039
14	4.88711	0.2046198	32.39260	0.0308712	6.6281682	0.1508712	4.7316880
15	5.47357	0.1826963	37.27971	0.0268242	6.8108645	0.1468242	4.9803034
16	6.13039	0.1631217	42.75328	0.0233900	6.9739862	0.1433900	5.2146643
17	6.86604	0.1456443	48.88367	0.0204567	7.1196305	0.1404567	5.4352969
18	7.68997	0.1300396	55.74971	0.0179373	7.2496701	0.1379373	5.6427366
19	8.61276	0.1161068	63.43968	0.0157630	7.3657769	0.1357630	5.8375242
20	9.64629	0.1036668	72.05244	0.0138788	7.4694436	0.1338788	6.0202033
21	10.80385	0.0925596	81.69874	0.0122401	7.5620032	0.1322401	6.1913173
22	12.10031	0.0826425	92.50258	0.0108105	7.6446457	0.1308105	6.3514067
23	13.55235	0.0737880	104.60289	0.0095600	7.7184337	0.1295600	6.5010067
24	15.17863	0.0658821	118.15524	0.0084634	7.7843158	0.1284634	6.6406450
25	17.00006	0.0588233	133.33387	0.0075000	7.8431391	0.1275000	6.7708396
26	19.04007	0.0525208	150.33393	0.0066519	7.8956599	0.1266519	6.8920974
27	21.32488	0.0468936	169.37401	0.0059041	7.9425535	0.1259041	7.0049123
28	23.88387	0.0418693	190.69889	0.0052439	7.9844228	0.1252439	7.1097639
29	26.74993	0.0373833	214.58275	0.0046602	8.0218060	0.1246602	7.2071167
30	29.95992	0.0333779	241.33268	0.0041437	8.0551840	0.1241437	7.2974189
31	33.55511	0.0298017	271.29261	0.0036861	8.0849857	0.1236861	7.3811020
32	37.58173	0.0266087	304.84772	0.0032803	8.1115944	0.1232803	7.4585796
33	42.09153	0.0237577	342.42945	0.0029203	8.1353521	0.1229203	7.5302482
34	47.14252	0.0212123	384.52098	0.0026006	8.1565644	0.1226006	7.5964858
35	52.79962	0.0189395	431.66350	0.0023166	8.1755039	0.1223166	7.6576527
36	59.13557	0.0169103	484.46312	0.0020641	8.1924142	0.1220641	7.7140911
37	66.23184	0.0150985	543.59869	0.0018396	8.2075127	0.1218396	7.7661257
38	74.17966	0.0134808	609.83053	0.0016398	8.2209935	0.1216398	7.8140634
39	83.08122	0.0120364	684.01020	0.0014620	8.2330299	0.1214620	7.8581942
40	93.05097	0.0107468	767.09142	0.0013036	8.2437767	0.1213036	7.8987915
42	116.72314	0.0085673	964.35948	0.0010370	8.2619393	0.1210370	7.9703981
48	230.39078	0.0043405	1911.58980	0.0005231	8.2971629	0.1205231	8.1240834
50	289.00219	0.0034602	2400.01825	0.0004167	8.3044985	0.1204167	8.1597235
60	897.59693	0.0011141	7471.64111	0.0001338	8.3240493	0.1201338	8.2664136
70	2787.79983	0.0003587	23223.33190	0.0000431	8.3303441	0.1200431	8.3082149
72	3497.01610	0.0002860	29133.46753	0.0000343	8.3309503	0.1200343	8.3127385
75	4913.05584	0.0002035	40933.79867	0.0000244	8.3316372	0.1200244	8.3180648
80	8658.48310	0.0001155	72145.69250	0.0000139	8.3323709	0.1200139	8.3240928
90	26891.93422	0.0000372	224091.11853	0.0000045	8.3330235	0.1200045	8.3299865
100	83522.26573	0.0000120	696010.54772	0.0000014	8.3332336	0.1200014	8.3321360

Appendix A 18% *Interest Rate Factors*

	Single Payment		Equal-Payment Series				Uniform Gradient Series
N	Compound Amount Factor, $(F/P, i, N)$	Present-Worth Factor, $(P/F, i, N)$	Compound Amount Factor, $(F/A, i, N)$	Sinking-Fund Factor, $(A/F, i, N)$	Present-Worth Factor, $(P/A, i, N)$	Capital Recovery Factor, $(A/P, i, N)$	Uniform Gradient Series Factor, $(A/G, i, N)$
1	1.18000	0.8474576	1.00000	1.0000000	0.8474576	1.1800000	0.0000000
2	1.39240	0.7181844	2.18000	0.4587156	1.5656421	0.6387156	0.4587156
3	1.64303	0.6086309	3.57240	0.2799239	2.1742729	0.4599239	0.8901579
4	1.93878	0.5157889	5.21543	0.1917387	2.6900618	0.3717387	1.2946962
5	2.28776	0.4371092	7.15421	0.1397778	3.1271710	0.3197778	1.6728377
6	2.69955	0.3704315	9.44197	0.1059101	3.4976026	0.2859101	2.0252179
7	3.18547	0.3139250	12.14152	0.0823620	3.8115276	0.2623620	2.3525889
8	3.75886	0.2660382	15.32700	0.0652444	4.0775658	0.2452444	2.6558063
9	4.43545	0.2254561	19.08585	0.0523948	4.3030218	0.2323948	2.9358144
10	5.23384	0.1910645	23.52131	0.0425146	4.4940863	0.2225146	3.1936310
11	6.17593	0.1619190	28.75514	0.0347764	4.6560053	0.2147764	3.4303320
12	7.28759	0.1372195	34.93107	0.0286278	4.7932249	0.2086278	3.6470350
13	8.59936	0.1162877	42.21866	0.0236862	4.9095126	0.2036862	3.8448850
14	10.14724	0.0985489	50.81802	0.0196781	5.0080615	0.1996781	4.0250399
15	11.97375	0.0835160	60.96527	0.0164028	5.0915776	0.1964028	4.1886570
16	14.12902	0.0707763	72.93901	0.0137101	5.1623539	0.1937101	4.3368814
17	16.67225	0.0599799	87.06804	0.0114853	5.2223338	0.1914853	4.4708355
18	19.67325	0.0508304	103.74028	0.0096395	5.2731642	0.1896395	4.5916099
19	23.21444	0.0430766	123.41353	0.0081028	5.3162409	0.1881028	4.7002559
20	27.39303	0.0365056	146.62797	0.0068200	5.3527465	0.1868200	4.7977799
21	32.32378	0.0309370	174.02100	0.0057464	5.3836835	0.1857464	4.8851384
22	38.14206	0.0262178	206.34479	0.0048463	5.4099012	0.1848463	4.9632352
23	45.00763	0.0222185	244.48685	0.0040902	5.4321197	0.1840902	5.0329189
24	53.10901	0.0188292	289.49448	0.0034543	5.4509489	0.1834543	5.0949826
25	62.66863	0.0159569	342.60349	0.0029188	5.4669058	0.1829188	5.1501630
26	73.94898	0.0135228	405.27211	0.0024675	5.4804287	0.1824675	5.1991421
27	87.25980	0.0114600	479.22109	0.0020867	5.4918887	0.1820867	5.2425476
28	102.96656	0.0097119	566.48089	0.0017653	5.5016006	0.1817653	5.2809557
29	121.50054	0.0082304	669.44745	0.0014938	5.5098310	0.1814938	5.3148927
30	143.37064	0.0069749	790.94799	0.0012643	5.5168060	0.1812643	5.3448380
31	169.17735	0.0059110	934.31863	0.0010703	5.5227169	0.1810703	5.3712263
32	199.62928	0.0050093	1103.49598	0.0009062	5.5277262	0.1809062	5.3944514
33	235.56255	0.0042452	1303.12526	0.0007674	5.5319713	0.1807674	5.4148681
34	277.96381	0.0035976	1538.68781	0.0006499	5.5355689	0.1806499	5.4327958
35	327.99729	0.0030488	1816.65161	0.0005505	5.5386177	0.1805505	5.4485210
36	387.03680	0.0025837	2144.64890	0.0004663	5.5412015	0.1804663	5.4623002
37	456.70343	0.0021896	2531.68570	0.0003950	5.5433911	0.1803950	5.4743624
38	538.91004	0.0018556	2988.38913	0.0003346	5.5452467	0.1803346	5.4849118
39	635.91385	0.0015725	3527.29918	0.0002835	5.5468192	0.1802835	5.4941299
40	750.37834	0.0013327	4163.21303	0.0002402	5.5481519	0.1802402	5.5021780
42	1044.82681	0.0009571	5799.03782	0.0001724	5.5502384	0.1801724	5.5153190
48	2820.56655	0.0003545	15664.25859	0.0000638	5.5535859	0.1800638	5.5385317
50	3927.35686	0.0002546	21813.09367	0.0000458	5.5541410	0.1800458	5.5428211