Chapter 13

Breakeven Analysis

Solutions to Problems

13.1 (a) Q_{BE} = 1,000,000/(8.50-4.25) = 235,294 units

(b) Profit = R – TC
= 8.50Q – 1,000,000 - 4.25Q

at 200,000 units: Profit = 8.50(200,000) – 1,000,000 - 4.25(200,000)
= $-150,000 (loss)

at 350,000 units: Profit = $487,500

For computer plot: Develop an Excel graph for different Q values using the relation:

Profit = 4.25Q – 1,000,000

13.2 One is linear and the other is parabolic. Another is two parabolic. The curves would have the intersecting at real number points to ensure the 2 breakeven points.

13.3 Set revenue at efficiency E equal to the total cost

$$12{,}000(E)(250) = 15{,}000{,}000(A/P,1\%, 20) + (4{,}100{,}000)E^{1.8}$$

$$3{,}000{,}000(E) = 15{,}000{,}000(0.01435) + (4{,}100{,}000)E^{1.8}$$

$$3{,}000{,}000(E) – 4{,}100{,}000E^{1.8} = 215{,}250$$

Solve for E by trial and error:

at E = 0.55: 252,227 > 215,250
at E = 0.57: 219,409 > 215,250
at E = 0.58: 202,007 < 215,250

E = 0.572 or 57.2% minimum removal efficiency

13.4 Using Equation [13.2] on a per month basis.
(a) Q_{BE} = (4,000,000/12)/(39.95-24.75) = 333,333.3/15.2

= 21,930 units/month

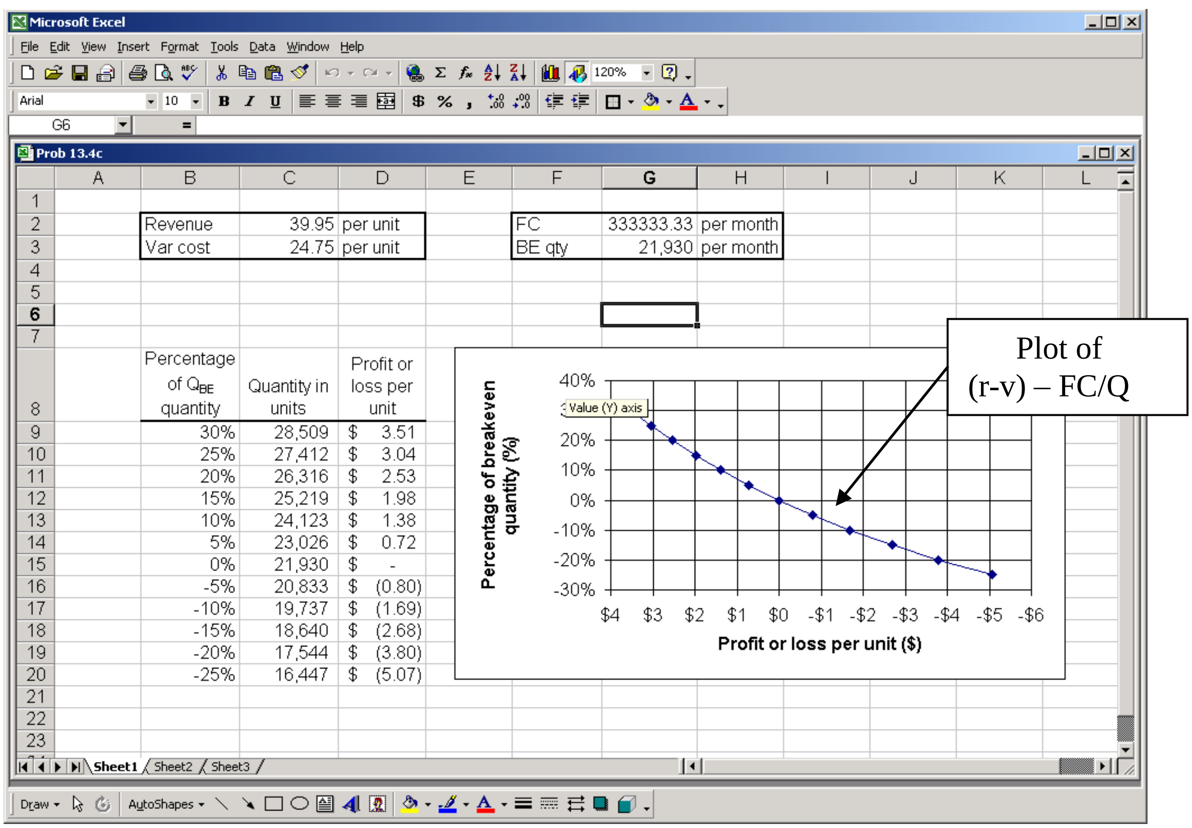
(b) In Equation [13.3] in Example 13.1 divide by Q to get profit (loss) per unit.

Profit (loss) = (r-v) – FC/Q

10% below Q_{BE} : Loss = (r-v) – FC/Q
= (39.95 – 24.75) – (333,333.3)/(21,930)(0.9)
= 15.20 – 16.89
= \$-1.69 per unit

10% above Q_{BE} : Profit = (r-v) – FC/Q
= (39.95 – 24.75) – (333,333.3)/(21,930)(1,1)
= 15.20 – 13.82
= \$ 1.38 per unit

(c) To plot the profit or loss per unit, use the equation in part (b).
Profit or loss = (r-v) – FC/Q



Revenue	39.95	per unit		
Var cost	24.75	per unit		
FC	333333.33	per month		
BE qty	21,930	per month		

Percentage of Q_{BE} quantity	Quantity in units	Profit or loss per unit
30%	28,509	\$ 3.51
25%	27,412	\$ 3.04
20%	26,316	\$ 2.53
15%	25,219	\$ 1.98
10%	24,123	\$ 1.38
5%	23,026	\$ 0.72
0%	21,930	\$ -
-5%	20,833	\$ (0.80)
-10%	19,737	\$ (1.69)
-15%	18,640	\$ (2.68)
-20%	17,544	\$ (3.80)
-25%	16,447	\$ (5.07)

13.5 From Equation [13.4], plot C_u = 160,000/Q + 4. Plot is shown below.

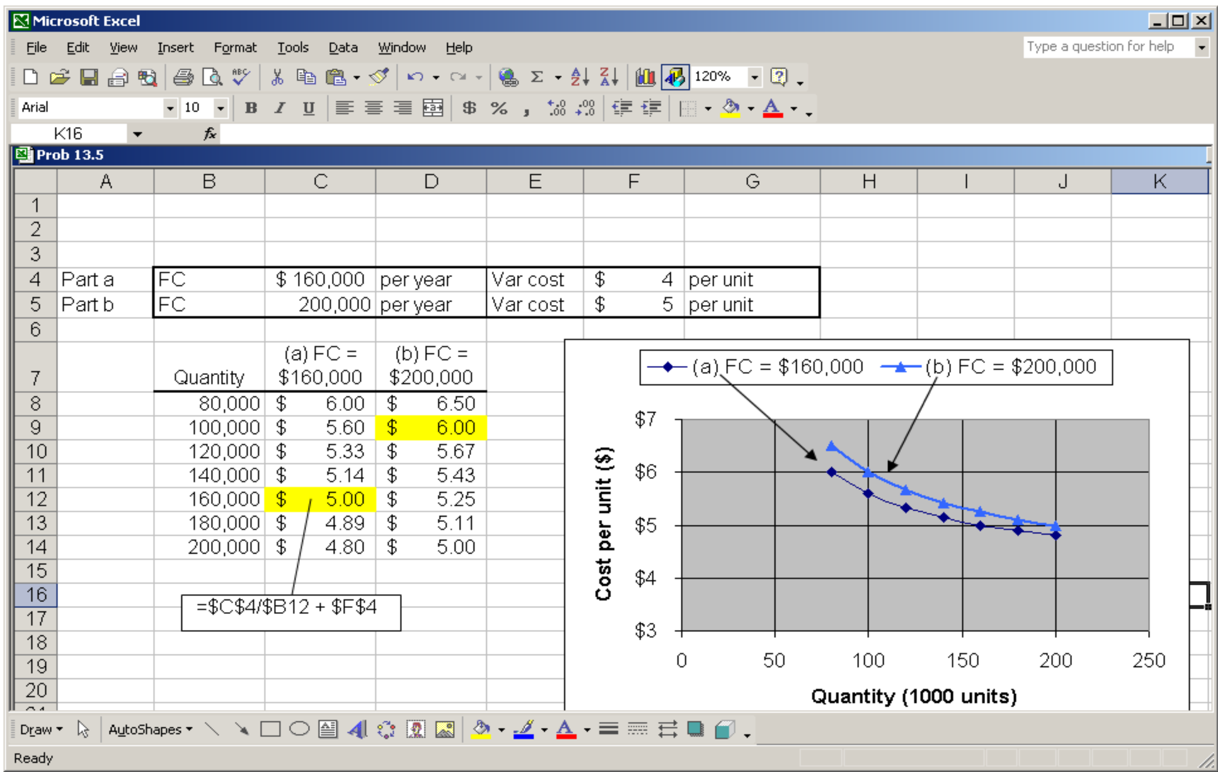
(a) If C_u = \$5, from the graph, Q is approximately 160,000. If Q is determined by Equation [13.4], it is

$5 = 160{,}000/Q + 4$
$Q = 160{,}000/1 = 160{,}000$ units

(b) From the plot, or by equation, Q = 100,000 units.

$C_u = 6 = 200{,}000/Q + 4$

$Q = 200{,}000/2 = 100{,}000$ units



13.6 (a) $Q_{BE} = \dfrac{775{,}000}{3.50 - 2} = 516{,}667$ calls per year

This is 37% of the center's capacity

(b) Set Q_{BE} = 500,000 and determine r at v = \$2 and FC = 0.5(900,000).

$$500{,}000 = \frac{450{,}000}{r - 2}$$

$$r - 2 = \frac{450{,}000}{500{,}000}$$

$r = 0.9 + 2 = \$2.90$ per call

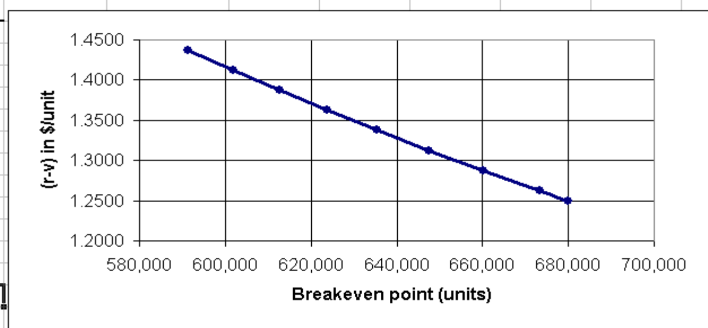
Average revenue required for the new product only is 60 cents per call lower.

13.7 Calculate $Q_{BE} = FC/(r\text{-}v)$ for (r-v) increases of 1% through 15% and plot.

Microsoft Excel — Prob 13.7

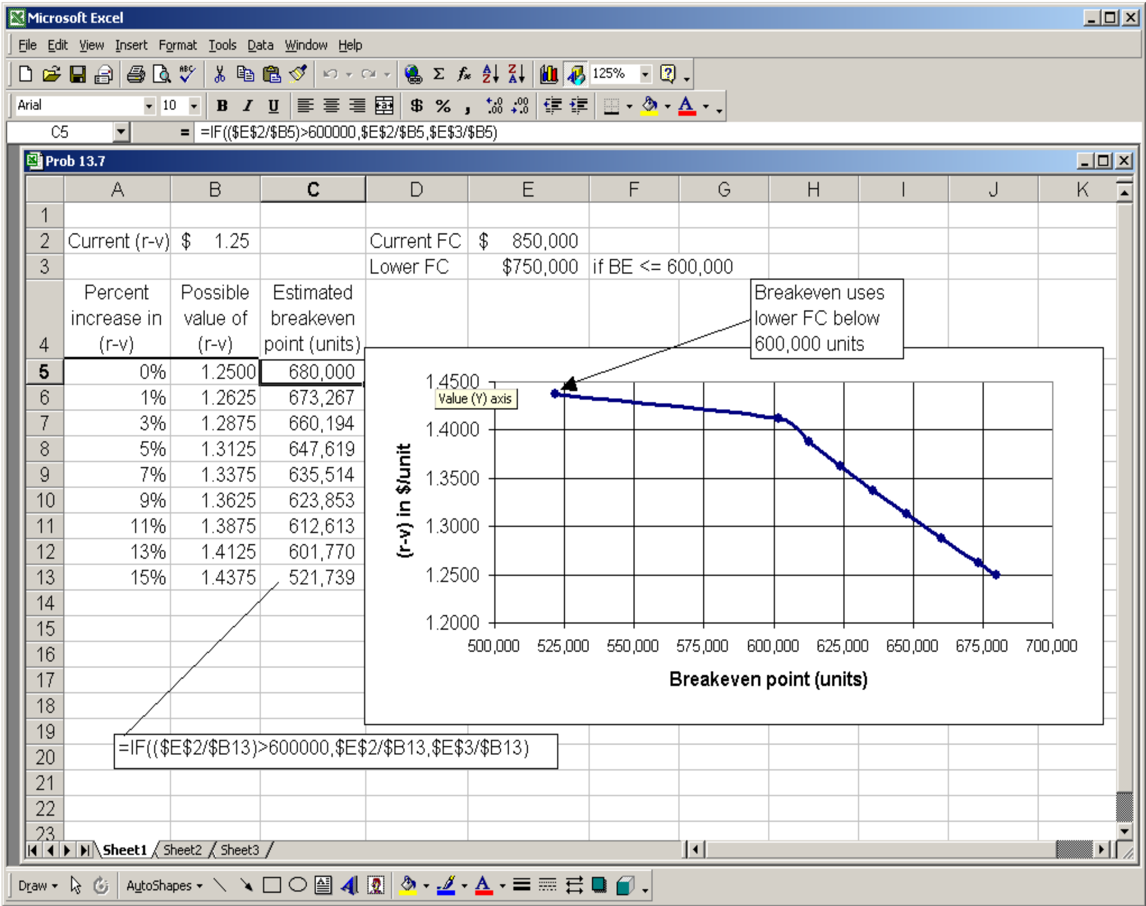
Current (r-v) $ 1.25 Current FC $ 850,000

Percent increase in (r-v)	Possible value of (r-v)	Estimated breakeven point (units)
0%	1.2500	680,000
1%	1.2625	673,267
3%	1.2875	660,194
5%	1.3125	647,619
7%	1.3375	635,514
9%	1.3625	623,853
11%	1.3875	612,613
13%	1.4125	601,770
15%	1.4375	591,304



The breakeven point decreases linearly from 680,000 currently to 591,304 if a 15% increase in (r-v) is experienced. If r and FC are constant, this means all the reduction must take place in a **lower variable cost per unit**.

13.8 Rework the spreadsheet above to include an IF statement for the computation of Q_{BE} for the reduced FC of \$750,000. The breakeven point falls substantially to 521,739 when the lower FC is in effect.



	A	B	C	D	E	F
2	Current (r-v)	$ 1.25		Current FC	$ 850,000	
3				Lower FC	$750,000	if BE <= 600,000
4	Percent increase in (r-v)	Possible value of (r-v)	Estimated breakeven point (units)			
5	0%	1.2500	680,000			
6	1%	1.2625	673,267			
7	3%	1.2875	660,194			
8	5%	1.3125	647,619			
9	7%	1.3375	635,514			
10	9%	1.3625	623,853			
11	11%	1.3875	612,613			
12	13%	1.4125	601,770			
13	15%	1.4375	521,739			

Note: To guarantee that the cell computations in column C correctly track when the breakeven point falls below 600,000, the same IF statement is used in all cells. With this feature, sensitivity analysis on the 600,000 estimate may also be performed.

13.9 Let x = gradient increase per year. Set revenue = cost.

$$[4000 + x(A/G,12\%,3)](33{,}000 - 21{,}000) = -200{,}000{,}000(A/P,12\%,3) + (0.20)(200{,}000{,}000)(A/F,12\%,3)$$

$$[4000 + x\,(0.9246)](12{,}000) = -200{,}000{,}000(0.41635) + 40{,}000{,}000(0.29635)$$

$$x = 2110 \text{ cars/year increase}$$

13.10 (a) $\text{Profit} = R - TC = 25Q - 0.001Q^2 - 3Q - 2$

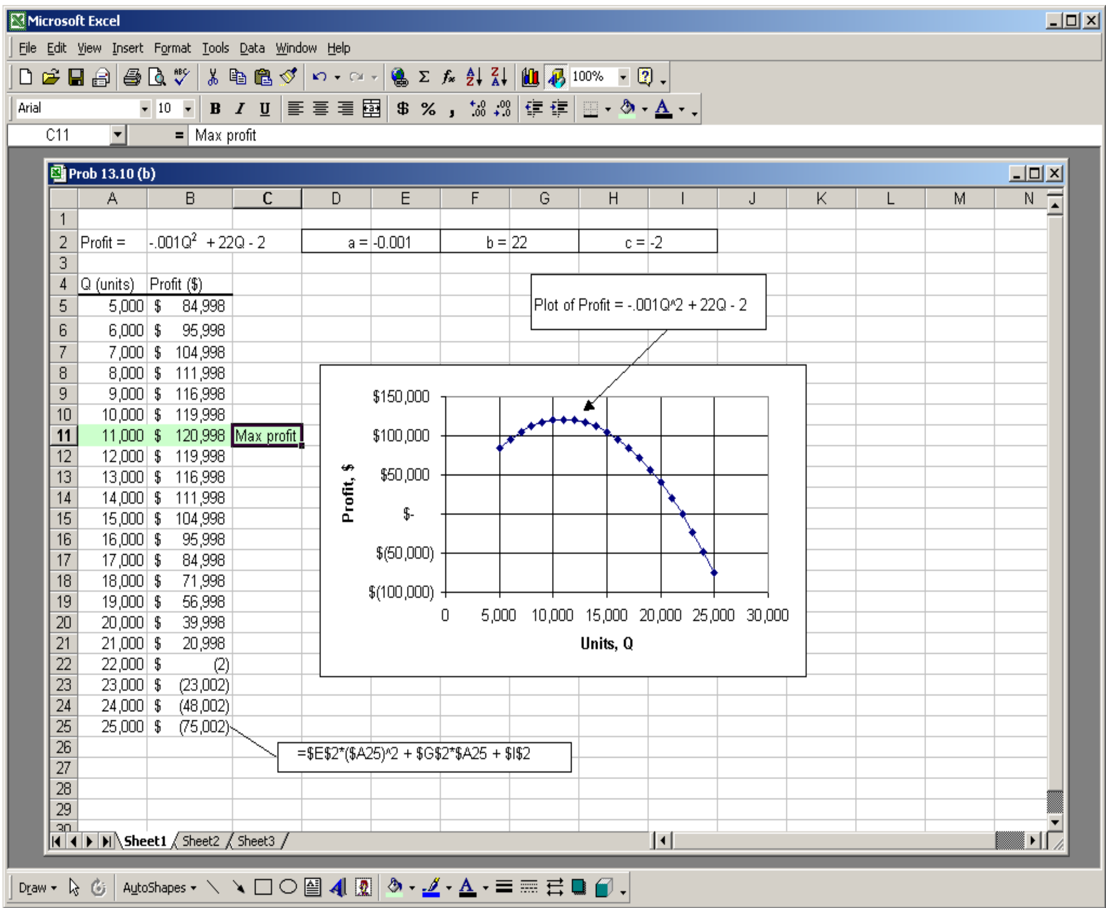
$= -0.001Q^2 + 22Q - 2$

Q	Profit (approximate)
5,000	$ 85,000

10,000	120,000
11,000	121,000
15,000	105,000
20,000	40,000
25,000	-75,000

About 11,000 cases per year is breakeven with profit of $121,000.

(b) Develop the Excel graph for Q vs Profit = $-0.001Q^2 + 22Q - 2$ that indicates a max profit of $120,998 at Q = 11,000 units.



(c) In general, Profit = R - TC = $aQ^2 + bQ + c$

The a, b and c are constants. Take the first derivative, set equal to 0, and solve.

$$Q_{max} = -b/2a$$

Substitute into the profit relation.

$$Profit_{max} = (-b^2/4a) + c$$

Here, Q_{max} = 22/2(0.001)
= 11,000 cases per year

$Profit_{max}$ = [-(22)^2/4(-0.001)] - 2
= $120,998 per year

13.11 FC = $305,000 v = $5500/unit

(a) Profit = (r – v)Q – FC

0 = (r – 5500)5000 – 305,000
(r – 5500) = 305,000 / 5000
r = 61 + 5500
= $5561 per unit

(b) Profit = (r – v)Q – FC

500,000 = (r – 5500)8000 – 305,000
(r – 5500) = (500,000 + 305,000) / 8000
r = $5601 per unit

13.12 Let x = ads per year

-12,000(A/P,8%,3) – 45,000 + 2000(A/F,8%,3) –8x = -20x
-12,000(0.38803) – 45,000 + 2000(0.30803) = -12x
-49,040 = -12x

x = 4087 ads per year

At 4000 ads per year, select the outsource option at $20 per ad for a total cost of $80,000 versus the inhouse option cost of $49,040 +8(4000) = $81,040.

13.13 Let n = number of months

-15,000(A/P, 0.5%, n) – 80 = -1000
-15,000(A/P, 0.5%, n) = -920
(A/P, 0.5%, n) = 0.0613

n is approximately 17 months

13.14 Let x = hours per year

-800(A/P,10%,3) - (300/2000)x -1.0x = -1,900(A/P,10%,5) - (700/8000)x - 1.0x

-800(0.40211) - 0.15x - 1.0x = -1,900(0.2638) - 0.0875x - 1.0x

$$0.0625x = 179.532$$
$$x = 2873 \text{ hours per year}$$

13.15 Set $AW_1 = AW_2$ where P_2 = first cost of Proposal 2. The final term in AW_2 removes the repainting cost in year 8.

$$-250{,}000(A/P,12\%,4) - 3{,}000 = -P_2(A/P,12\%,8) - 3{,}000(A/F,12\%,2) + 3{,}000(A/F,12\%,8)$$

$$-250{,}000(0.32923) - 3{,}000 = -P_2(0.2013) - 3{,}000(0.4717) + 3{,}000(0.0813)$$

$$-85{,}307.50 = -P_2(0.2013) – 1171.20$$
$$-84{,}136.30 = -P_2(0.2013)$$
$$P_2 = \$417{,}965$$

13.16 Let x = production in year 4. Determine variable costs in year 4 and set the cost relations equal. The 10% interest rate is not needed.

$$-400{,}000 – 86x = -750{,}000 – 62x$$
$$24x = 350{,}000$$
$$x = 14{,}584 \text{ units}$$

13.17 (a) Let x = breakeven days per year. Use annual worth analysis.

$$-125{,}000(A/P,12\%,8) + 5{,}000(A/F,12\%,8) - 2{,}000 - 40x = -45(125 +20x)$$
$$-125{,}000(0.2013) + 5{,}000(0.0813) - 2{,}000 - 40x = -5625 –900x$$
$$-26{,}756 – 40x = -5625 – 900x$$
$$-21{,}131 = -860x$$
$$x = 24.6 \text{ days per year}$$

(b) Since 75 > 24.6 days, select the buy. Annual cost is

$$-26{,}756 – 40(75) = \$-29{,}756$$

13.18 Let FC_B = fixed cost for B. Set total cost relations equal at 2000 units per year.

Variable cost for B = 2000/200 = $10/unit

$$40{,}000 + 60(2000 \text{ units}) = FC_B + 10(2000 \text{ units})$$

$$FC_B = \$140{,}000 \text{ per year}$$

13.19 (a) Let x = days per year to pump the lagoon. Set the AW relations equal.

$$-800(A/P,10\%,8) - 300x = -1600(A/P,10\%,10) - 3x - 12(8200)(A/P,10\%,10)$$

$$-800(0.18744) - 300x = -1600(0.16275) - 3x – 98{,}400(0.16275)$$
$$-149.95 - 300x = -16275 - 3x$$
$$297x = 16125.05$$

$$x = 54.3 \text{ days per year}$$

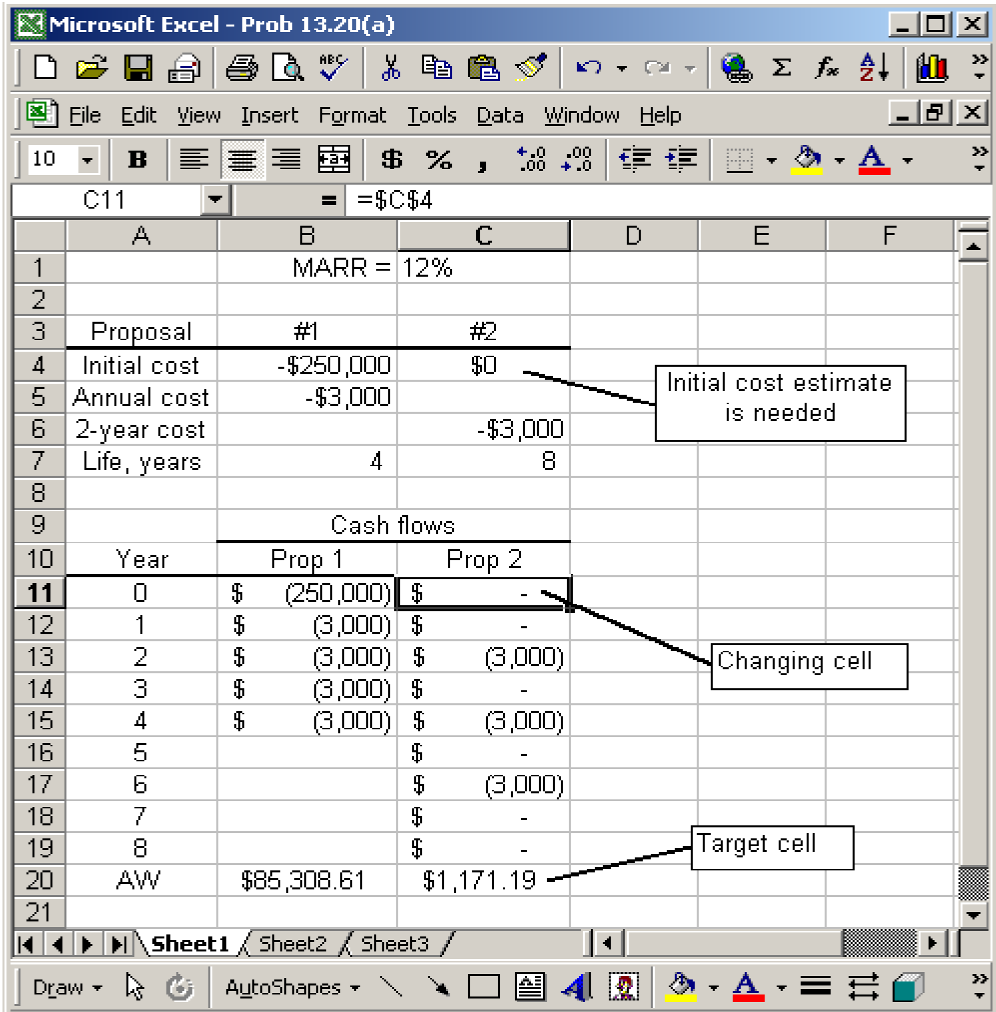
(b) If the lagoon is pumped 52 times per year and P = cost of pipeline, the breakeven equation in (a) becomes:

$$-800(0.18744) - 300(52) = -1600(0.16275) - 3(52) + P\,(0.16275)$$

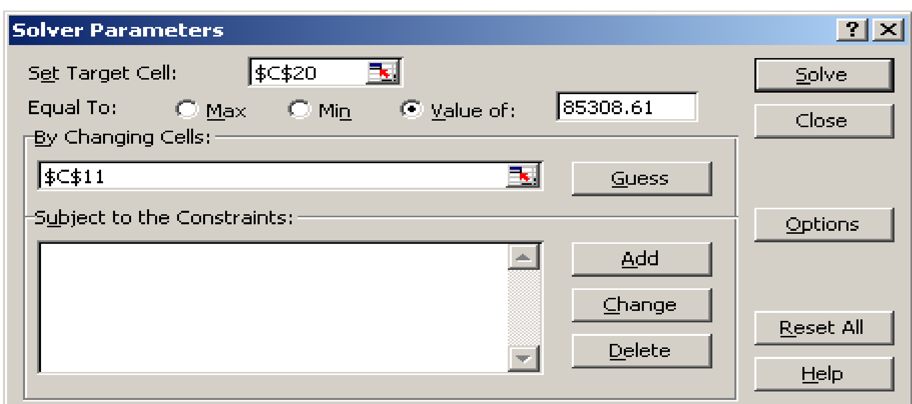
$$-15{,}750 = -416.4 + 0.16275P$$

$$P = \$-94{,}216$$

13.20 (a) Excel spreadsheet, SOLVER entries, and solution for P = -$417,964 are below.



	A	B	C
1		MARR =	12%
2			
3	Proposal	#1	#2
4	Initial cost	-$250,000	$0
5	Annual cost	-$3,000	
6	2-year cost		-$3,000
7	Life, years	4	8
8			
9		Cash flows	
10	Year	Prop 1	Prop 2
11	0	$ (250,000)	$ -
12	1	$ (3,000)	$ -
13	2	$ (3,000)	$ (3,000)
14	3	$ (3,000)	$ -
15	4	$ (3,000)	$ (3,000)
16	5		$ -
17	6		$ (3,000)
18	7		$ -
19	8		$ -
20	AW	$85,308.61	$1,171.19



13.20 (a) (cont)

Microsoft Excel - Prob 13.20(a) - solution

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C20 = =PMT(C1,C7,(NPV(C1,C12:C19)+C11))

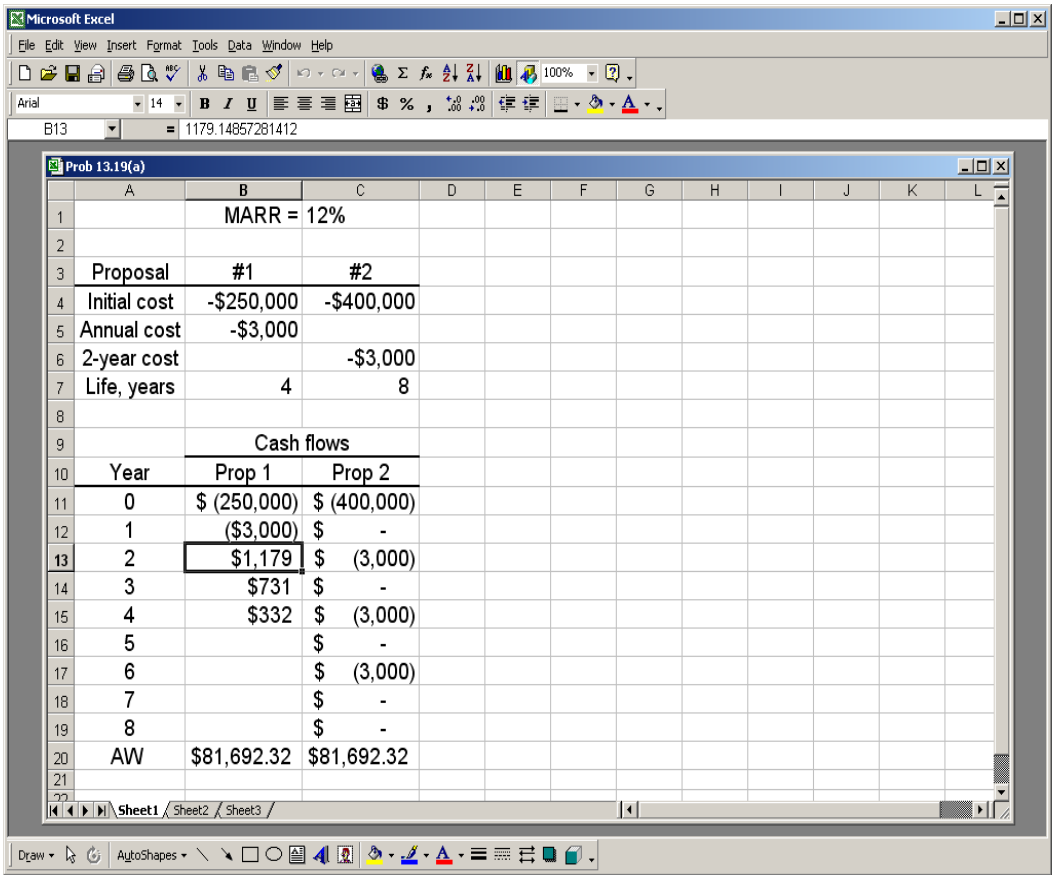
	A	B	C	D	E	F
1		MARR =	12%			
2						
3	Proposal	#1	#2			
4	Initial cost	-$250,000	$0			
5	Annual cost	-$3,000				
6	2-year cost		-$3,000			
7	Life, years	4	8			
8						
9		Cash flows				
10	Year	Prop 1	Prop 2			
11	0	$ (250,000)	$ (417,964)			
12	1	$ (3,000)	$ -			
13	2	$ (3,000)	$ (3,000)			
14	3	$ (3,000)	$ -			
15	4	$ (3,000)	$ (3,000)			
16	5		$ -			
17	6		$ (3,000)			
18	7		$ -			
19	8		$ -			
20	AW	$85,308.61	$85,308.61			

Solution with
P = $-417,964

Sheet1 / Sheet2 / Sheet3

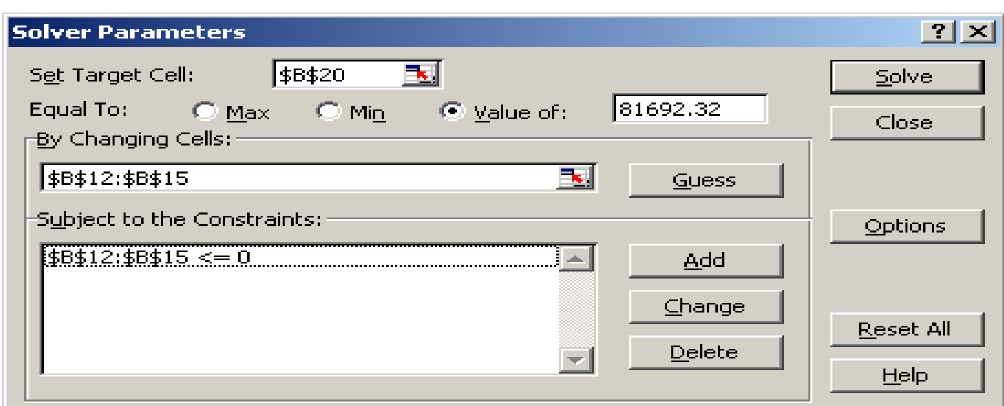
Draw AutoShapes

13.20 (b) Set cell C2 to –$400,000. The changing cells in SOLVER are B12 through B15. If no constraints are placed on the annual cash flows for proposal 1, the SOLVER solution has positive annual ‘costs’ in years 2, 3 and 4, which are not acceptable. The answer is ‘no’.



	A	B	C
1		MARR =	12%
2			
3	Proposal	#1	#2
4	Initial cost	-$250,000	-$400,000
5	Annual cost	-$3,000	
6	2-year cost		-$3,000
7	Life, years	4	8
8			
9		Cash flows	
10	Year	Prop 1	Prop 2
11	0	$ (250,000)	$ (400,000)
12	1	($3,000)	$ -
13	2	$1,179	$ (3,000)
14	3	$731	$ -
15	4	$332	$ (3,000)
16	5		$ -
17	6		$ (3,000)
18	7		$ -
19	8		$ -
20	AW	$81,692.32	$81,692.32

If constraints are made using SOLVER for cells B12 through B15 to not become positive, SOLVER finds no solution for break even. The answer, again, is ‘no’.



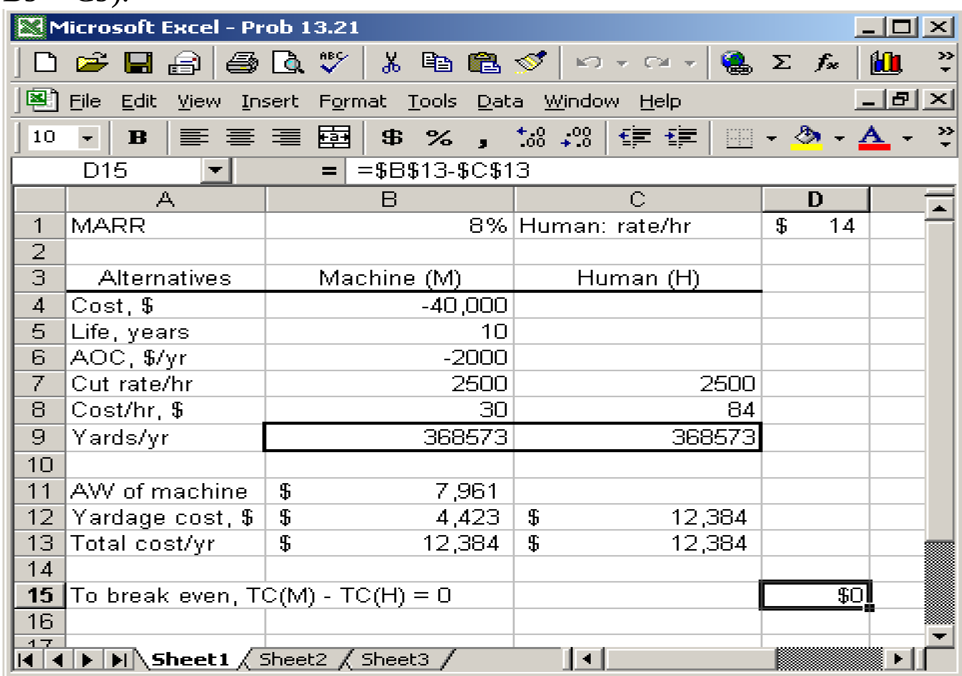
13.21 Let x = yards per year to breakeven

(a) Solution by hand

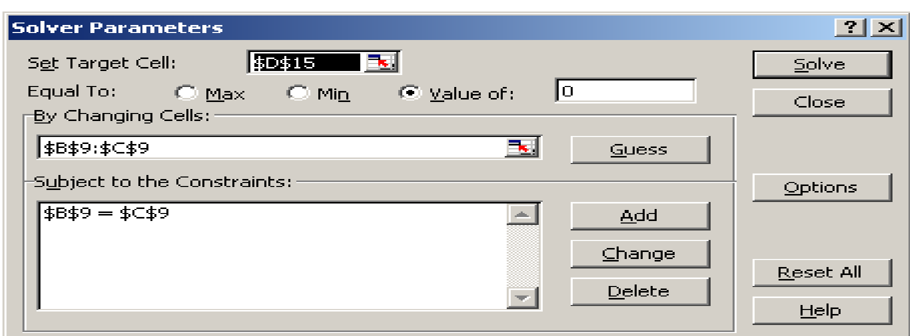
$$-40{,}000(A/P{,}8\%{,}10) - 2{,}000 - (30/2500)x = -[6(14)/2500]x$$
$$-40{,}000(0.14903) - 2{,}000 - 0.012x = -0.0336x$$
$$-7961.20 = -0.0216x$$
$$x = 368{,}574 \text{ yards per year}$$

(b) Solution by computer

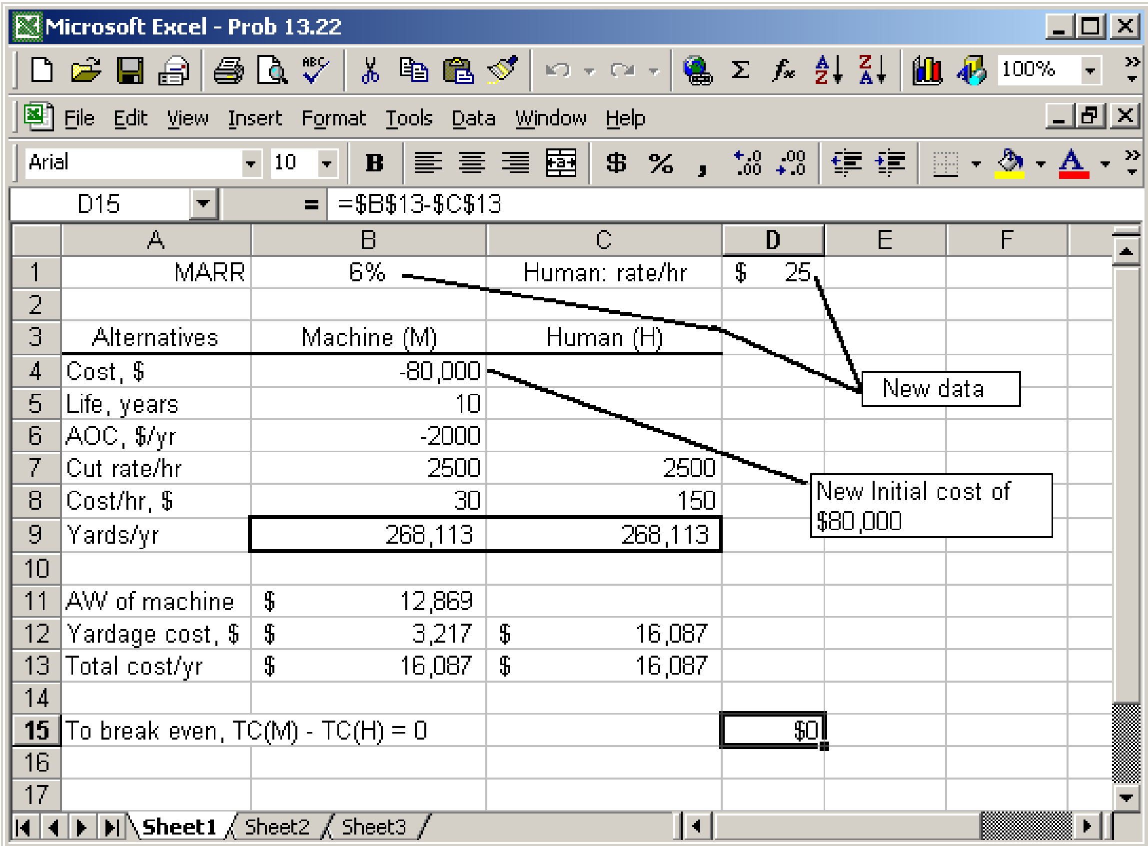
There are many Excel set-ups to work the problem. One is: Enter the parameters for each alternative, including some number of yards per year as a guess. Use SOLVER to force the breakeven equation (target cell D15) to equal 0, with a constraint in SOLVER that total yardage be the same for both alternatives (cell B9 = C9).



	A	B	C	D
1	MARR	8%	Human: rate/hr	$ 14
2				
3	Alternatives	Machine (M)	Human (H)	
4	Cost, $	-40,000		
5	Life, years	10		
6	AOC, $/yr	-2000		
7	Cut rate/hr	2500	2500	
8	Cost/hr, $	30	84	
9	Yards/yr	368573	368573	
10				
11	AW of machine	$ 7,961		
12	Yardage cost, $	$ 4,423	$ 12,384	
13	Total cost/yr	$ 12,384	$ 12,384	
14				
15	To break even, TC(M) - TC(H) = 0			$0
16				



13.22 Put in new values, use the Same SOLVER screen and obtain B_E = 268,113 yards/year.



	A	B	C	D
1	MARR	6%	Human: rate/hr	$ 25
2				
3	Alternatives	Machine (M)	Human (H)	
4	Cost, $	-80,000		
5	Life, years	10		
6	AOC, $/yr	-2000		
7	Cut rate/hr	2500	2500	
8	Cost/hr, $	30	150	
9	Yards/yr	268,113	268,113	
10				
11	AW of machine	$ 12,869		
12	Yardage cost, $	$ 3,217	$ 16,087	
13	Total cost/yr	$ 16,087	$ 16,087	
14				
15	To break even, TC(M) - TC(H) = 0			$0
16				
17				

Since now the annual yardage rate of 300,000 > 268,113, the lower variable cost alternative of the machine should be selected.

13.23 (a) Let n = number of years. Develop the relation

$$AW_{own} + AW_{lease} + AW_{sell} = 0$$

-(100,000 +12,000)(A/P,8%,n) -3800 - 2500 – [1000(P/F,8%,k)](A/P,8%,n)
+ 12,000 + (60 + 1.5n)(2,500)(A/F,8%,n) = 0
where k = 6, 12, 18, ..., and $k \leq n$.

Use trial and error to determine the breakeven n value.

n = 14: -112,000(0.12130) + 5700 –[1000(0.6302 + 0.3971)] (0.12130) + [60 + 1.5(14)](2,500) (0.04130) ?= 0

-13,586 + 5700 - 125 + 8363 = $+352 > 0

13.23 (cont)

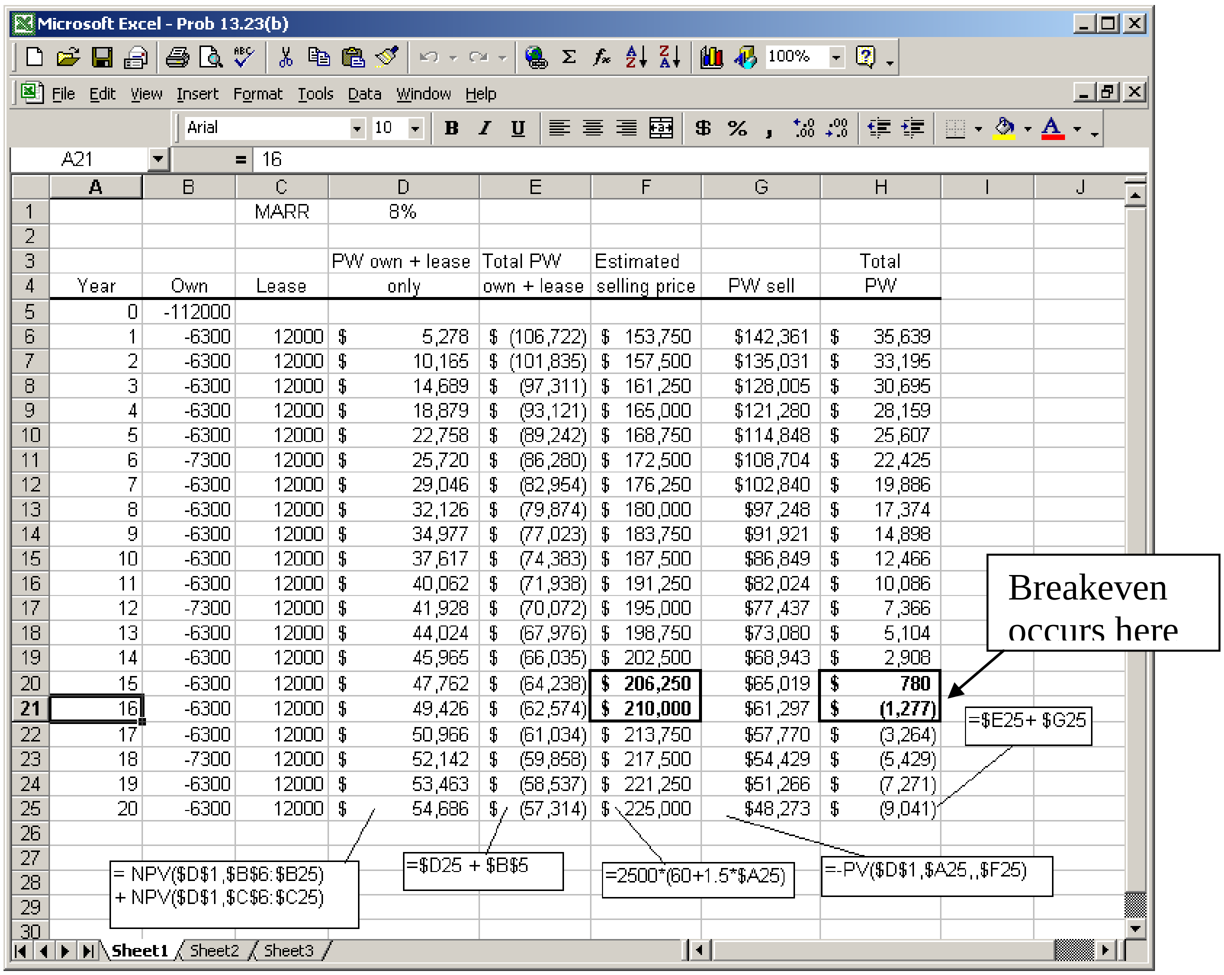
n = 16: -112,000 (0.11298) + 5700 – [1000(0.6302 + 0.3971)](0.11298) + [60 + 1.5(16)] (2,500) (0.03298) ?= 0

-12,654 + 5700 - 116 + 6926 = $-144 < 0

By interpolation, n = 15.42 years

Selling price = [60 + 1.5(15.42)] (2,500)
= $207,825

(b) Enter the cash flows and carefully develop the PW relations for each column. Breakeven is between 15 and 16 years. Selling price is estimated to be between $206,250 and $210,000. Linear interpolation can be used as in the manual trial and error method above.



	A	B	C	D	E	F	G	H
1			MARR	8%				
2								
3				PW own + lease	Total PW	Estimated		Total
4	Year	Own	Lease	only	own + lease	selling price	PW sell	PW
5	0	-112000						
6	1	-6300	12000	$ 5,278	$ (106,722)	$ 153,750	$142,361	$ 35,639
7	2	-6300	12000	$ 10,165	$ (101,835)	$ 157,500	$135,031	$ 33,195
8	3	-6300	12000	$ 14,689	$ (97,311)	$ 161,250	$128,005	$ 30,695
9	4	-6300	12000	$ 18,879	$ (93,121)	$ 165,000	$121,280	$ 28,159
10	5	-6300	12000	$ 22,758	$ (89,242)	$ 168,750	$114,848	$ 25,607
11	6	-7300	12000	$ 25,720	$ (86,280)	$ 172,500	$108,704	$ 22,425
12	7	-6300	12000	$ 29,046	$ (82,954)	$ 176,250	$102,840	$ 19,886
13	8	-6300	12000	$ 32,126	$ (79,874)	$ 180,000	$97,248	$ 17,374
14	9	-6300	12000	$ 34,977	$ (77,023)	$ 183,750	$91,921	$ 14,898
15	10	-6300	12000	$ 37,617	$ (74,383)	$ 187,500	$86,849	$ 12,466
16	11	-6300	12000	$ 40,062	$ (71,938)	$ 191,250	$82,024	$ 10,086
17	12	-7300	12000	$ 41,928	$ (70,072)	$ 195,000	$77,437	$ 7,366
18	13	-6300	12000	$ 44,024	$ (67,976)	$ 198,750	$73,080	$ 5,104
19	14	-6300	12000	$ 45,965	$ (66,035)	$ 202,500	$68,943	$ 2,908
20	15	-6300	12000	$ 47,762	$ (64,238)	**$ 206,250**	$65,019	**$ 780**
21	16	-6300	12000	$ 49,426	$ (62,574)	**$ 210,000**	$61,297	**$ (1,277)**
22	17	-6300	12000	$ 50,966	$ (61,034)	$ 213,750	$57,770	$ (3,264)
23	18	-7300	12000	$ 52,142	$ (59,858)	$ 217,500	$54,429	$ (5,429)
24	19	-6300	12000	$ 53,463	$ (58,537)	$ 221,250	$51,266	$ (7,271)
25	20	-6300	12000	$ 54,686	$ (57,314)	$ 225,000	$48,273	$ (9,041)

13.24 Let x = number of samples per year. Set AW values for complete and partial labs equal to the complete outsource cost.

(a) Complete lab option

-50,000(A/P,10%,6) - 26,000 - 10x = -120x

-50,000(0.22961) - 26,000 = -110x

x = 341 samples per year

(b) Partial lab option

$$-35{,}000(A/P,10\%,6) - 10{,}000 - 3x - 40x = -120x$$
$$-35{,}000(0.22961) - 10{,}000 = -77x$$

$x = 234$ samples per year

(c) Equate AW of complete and partial labs

$$-50{,}000(A/P,10\%,6) - 26{,}000 - 10x = -35{,}000(A/P,10\%,6) - 10{,}000 - 3x - 40x$$
$$-50{,}000(0.22961) - 26{,}000 - 10x = -35{,}000(0.22961) - 10{,}000 - 43x$$
$$33x = 19{,}444$$

$x = 589$ samples per year

Ranges for the lowest total cost are:

$0 < x \le 234$	select outsource
$234 < x \le 589$	select partial lab
$589 < x$	select complete lab

(d) At 300 samples per year, the partial lab option is the best economically at TC = \$30,936.

13.25 Let P = initial cost of plastic lining. Use AW analysis.

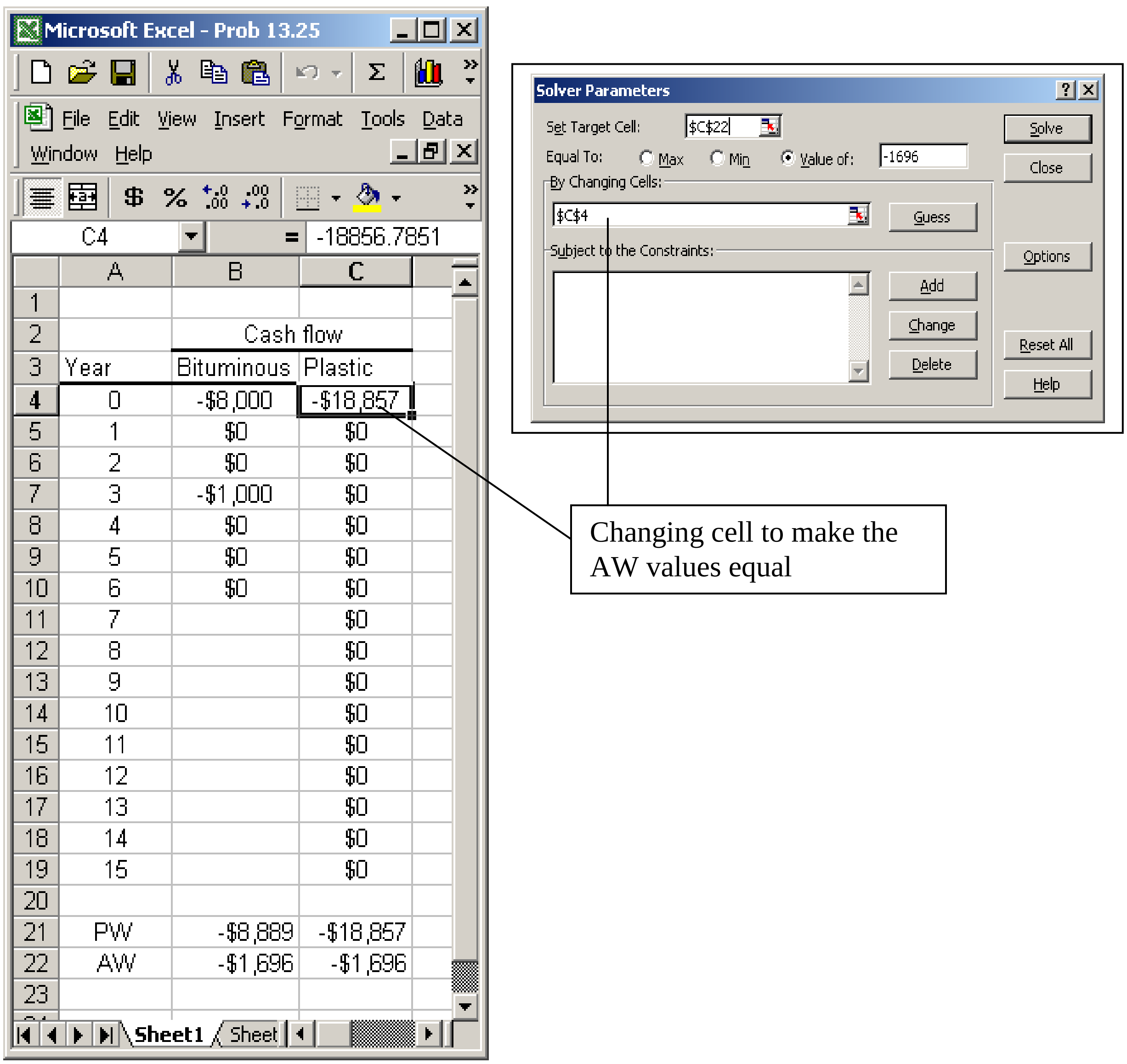
(a) by hand: -8,000(A/P,4 %,6) - 1000(P/F,4 %,3)(A/P,4 %,6) = -P(A/P,4 %,15)

-8,000(0.19076) - 1000(0.8890)(0.19076) = -P(0.08994)

-1695.66 = -P(0.08994)

P = $18,853

(b) by computer: Enter cash flows and set SOLVER to find the initial cost of plastic liner alternative (Cell C4 here).



13.26 (a) By hand: Let P = first cost of sandblasting. Equate the PW of painting each 4 years to PW of sandblasting each 10 years, up to a total of 38 years for each option.

PW of painting

PW_p = -2,800 - 3,360(P/F,10%,4) - 4,032(P/F,10%,8) - 4,838(P/F,10%12) – 5,806(P/F,10%,16) - 6,967(P/F,10%,20) -8,361(P/F,10%,24) – 10,033(P/F,10%,28) - 12,039(P/F,10%,32) -14,447(P/F,10%,36)

= -2,800 - 3,360(0.6830) - 4,032(0.4665) - 4,838(0.3186) -5,806(0.2176) - 6,967(0.1486) - 8,361(0.1015) - 10,033(0.0693) -12,039(0.0474) - 14,447(0.0323)

= \$-13,397

PW of sandblasting

PW_s = -P - 1.4P(P/F,10%,10) - 1.96P(P/F,10%,20) - 2.74P(P/F,10%,30)
-P[1 + 1.4(0.3855) + 1.96(0.1486) + 2.74(0.0573)]

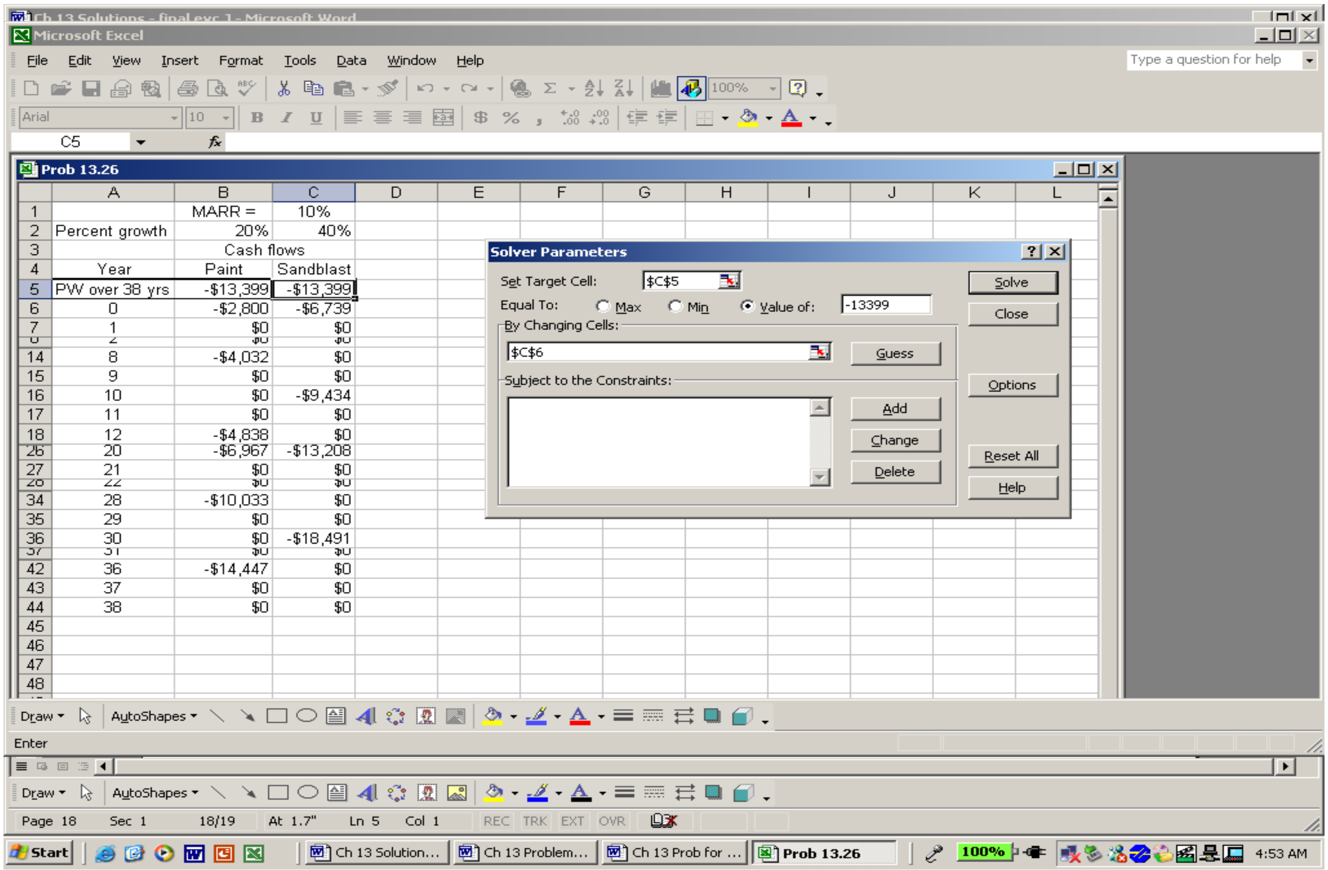
= -1.988P

Equate the PW relations.

-13,397 = -1.988P
P = \$6,739

(b) By computer: Enter the periodic costs. Enter 0 for the P of the sandblasting option. Use SOLVER to find breakeven at P = -\$6739 (cell C6). (Note that many of the year entries are hidden in the Excel image below.)

13.26 (b) (cont)



(c) Change cell C2 to 30% and then 20% and re-SOLVER to get:

30%: P = -$7133 20%: P = -$7546

Case Study Solution

1. Savings = 40 hp * 0.75 kw/hp * 0.06 $/kwh * 24 hr/day * 30.5 days/mo ÷ 0.90
   = $1464/month

2. A decrease in the efficiency of the aerator motor renders the selected alternative of "sludge recirculation only" *more* attractive, because the cost of aeration would be higher, and, therefore the net savings from its discontinuation would be greater.

3. If the cost of lime increased by 50%, the lime costs for "sludge recirculation only" and "neither aeration nor sludge recirculation" would increase by 50% to $393 and $2070, respectively. Therefore, the cost difference would *increase*.

4. If the efficiency of the sludge recirculation pump decreased from 90% to 70%, the net savings between alternatives 3 and 4 would *decrease*. This is because the $262 saved by not recirculating with a 90% efficient pump would increase to a monthly savings of $336 by not recirculating with a 70% efficient pump.

5. If hardness removal were discontinued, the extra cost for its removal (column 4 in Table 13-1) would be zero for all alternatives. The favored alternative under this scenario would be alternative 4 (neither aeration nor sludge recirculation) with a total savings of $2,471 – 469 = $2002 per month.

6. If the cost of electricity decreased to 4¢/kwh, the aeration and sludge recirculation monthly costs would be $976 and $122, respectively. The net savings for alternative 2 would then be $-1727, for alternative 3 would be $-131, and for alternative four -$751---all losses. Therefore, the best alternative would be number 1, continuation of the normal operating condition.

7. (a) For alternatives 1 and 2 to breakeven, the total savings would have to be equal to the total extra cost of $1,849. Thus,

$$1{,}849/30.5 = (5)(0.75)(x)(24) / 0.90$$
$$x = 60.6 \text{ cents per kwh}$$

(b) $$1107/30.5 = (40)(0.75)(x)(24) / 0.90$$
$$x = 4.5 \text{ cents per kwh}$$

(c) $$1{,}849/30.5 = (5)(0.75)(x)(24) / 0.90 + (40)(0.75)(x)(24) / 0.90$$
$$x = 6.7 \text{ cents per kwh}$$