# Chapter 12

# Selection from Independent Projects Under Budget Limitation

**Solutions to Problems**

12.1 The paragraph should mention: independent projects versus mutually exclusive alternatives; limit placed on total capital invested using the sum of initial investment amounts; selection of a project in its entirely or to not select it (do-nothing); and to maximize the return using some measure such as PW of net cash flows at the MARR.

12.2 Any net positive cash flows that occur in any project are reinvested at the MARR from the time they are realized until the end of the longest-lived project being evaluated. (This is similar to the assumption made in Section 7.5 when the composite rate of return is determined, but here the only rate involved is the MARR.) In effect, this makes the lives equal for all projects, a requirement to correctly apply the PW method.

12.3 There are $2^4 = 16$ possible bundles. Considering the selection restrictions, the 9 viable bundles are:

| | | |
|---|---|---|
| DN | 4 | 34 |
| 1 | 13 | 123 |
| 3 | 23 | 234 |

Not acceptable bundles: 2, 12, 14, 24, 124, 134, 1234

12.4 There are $2^4 = 16$ possible bundles. Considering the selection restriction and the $400 limitation, the viable bundles are:

| Projects | Investment |
|---|---|
| DN | $ 0 |
| 2 | 150 |
| 3 | 75 |
| 4 | 235 |
| 2, 3 | 225 |
| 2, 4 | 385 |
| 3, 4 | 310 |

12.5 (a) Develop the bundles with less than $325,000 investment, and select the one with the largest PW value.

| Bundle | Projects | Initial investment, $ | NCF, $/year | PW at 10%, $ |
|---|---|---|---|---|
| 1 | A | -100,000 | 50,000 | 166,746 |
| 2 | B | -125,000 | 24,000 | 3,038 |
| 3 | C | -120,000 | 75,000 | 280,118 |
| 4 | D | -220,000 | 39,000 | -11,938 |
| 5 | E | -200,000 | 82,000 | 237,464 |
| 6 | AB | -225,000 | 74,000 | 169,784 |
| 7 | AC | -220,000 | 125,000 | 446,864 |
| 8 | AD | -320,000 | 89,000 | 154,807 |
| 9 | AE | -300,000 | 132,000 | 404,208 |
| 10 | BC | -245,000 | 99,000 | 283,156 |
| 11 | BE | -325,000 | 106,000 | 240,500 |
| 12 | CE | -320,000 | 157,000 | 517,580 |
| 13 | DN | 0 | 0 | 0 |

$PW_1 = -100,000 + 50,000(P/A,10\%,8)$
$= -100,000 + 50,000(5.3349)$
$= \$166,746$

$PW_2 = -125,000 + 24,000(P/A,10\%,8)$
$= -125,000 + 24,000(5.3349)$
$= \$3038$

$PW_3 = -120,000 + 75,000(P/A,10\%,8)$
$= -120,000 + 75,000(5.3349)$
$= \$280,118$

$PW_4 = -220,000 + 39,000(P/A,10\%,8)$
$= -220,000 + 39,000(5.3349)$
$= \$-11,939$

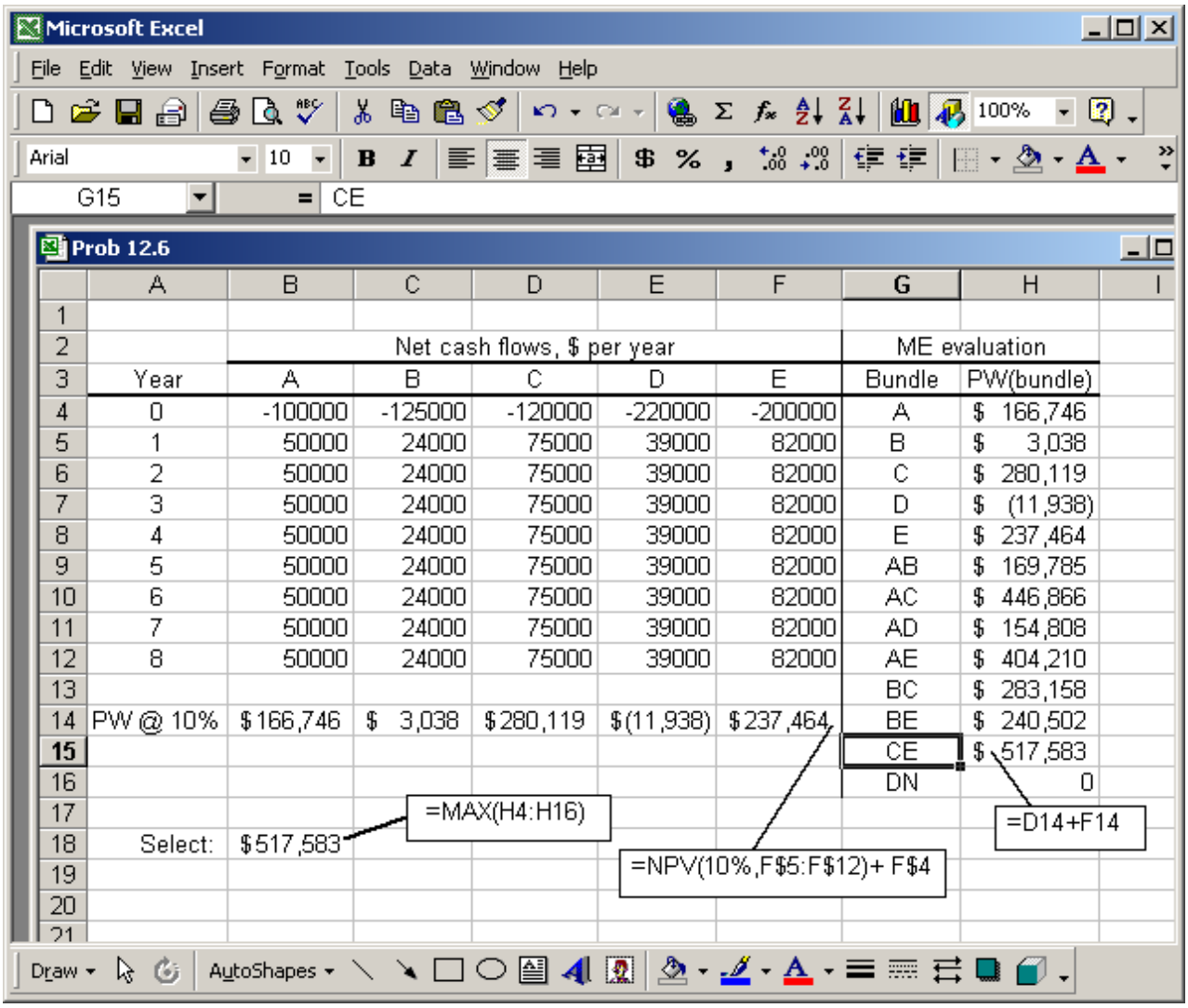
$PW_5 = -200,000 + 82,000(P/A,10\%,8)$
$= -200,000 + 82,000(5.3349)$
$= \$237,462$

All other PW values are obtained by adding the respective PW for bundles 1 through 5.

Conclusion: Select PW = $517,580, which is bundle 12 (projects C and E) with $320,000 total investment.

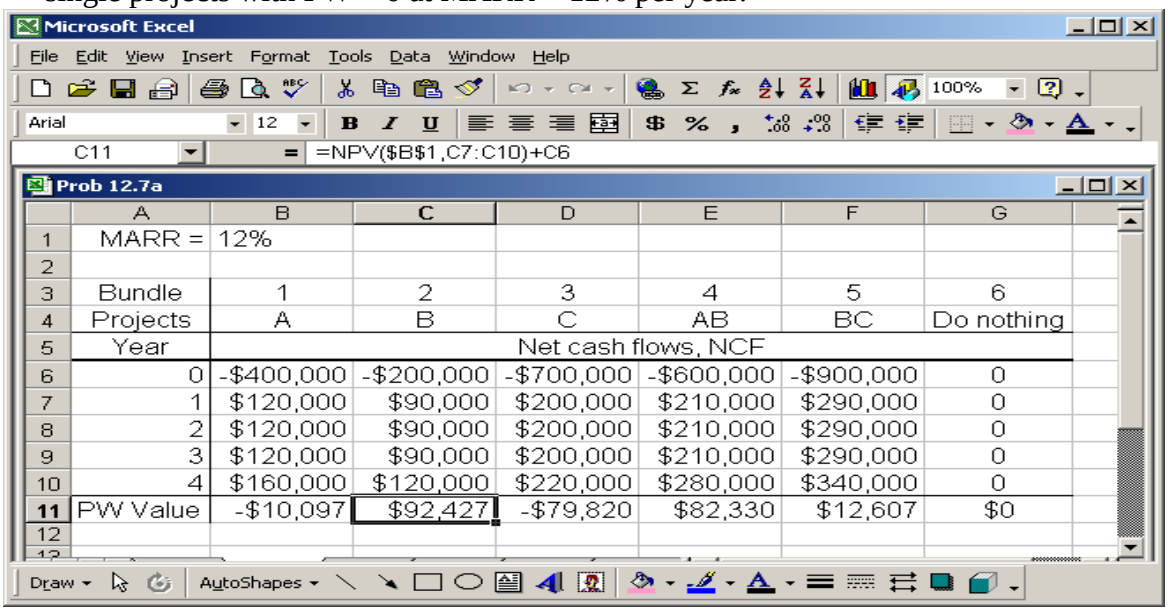
(b) For mutually exclusive alternatives, select the single project with the largest PW. This is C with PW = $280,118.

12.6 Determine PW at 10% for each single project (row 14). Determine the feasible bundles (from Problem 12.5) and add the respective PW values (column H). Select the largest PW value, which is for the bundle containing projects C and E.



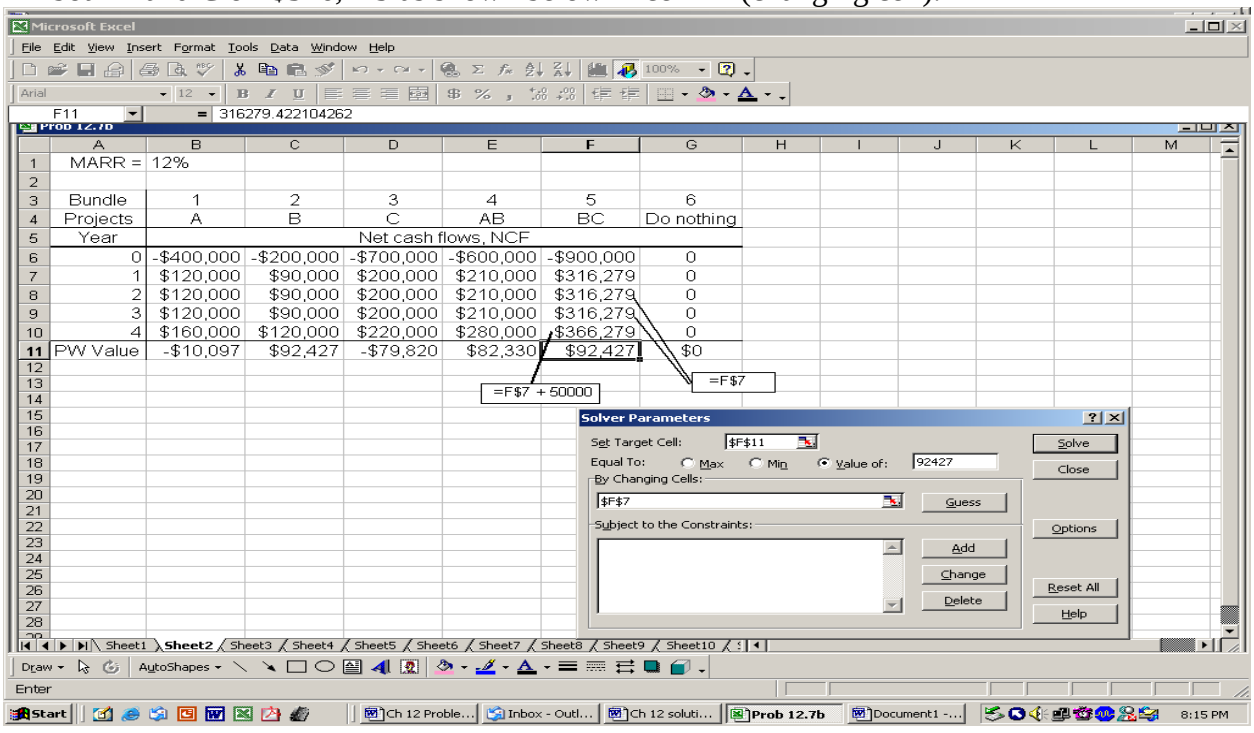

| | A | B | C | D | E | F | G | H | I |
|---|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | | | |
| 2 | | Net cash flows, $ per year | | | | | ME evaluation | | |
| 3 | Year | A | B | C | D | E | Bundle | PW(bundle) | |
| 4 | 0 | -100000 | -125000 | -120000 | -220000 | -200000 | A | $ 166,746 | |
| 5 | 1 | 50000 | 24000 | 75000 | 39000 | 82000 | B | $ 3,038 | |
| 6 | 2 | 50000 | 24000 | 75000 | 39000 | 82000 | C | $ 280,119 | |
| 7 | 3 | 50000 | 24000 | 75000 | 39000 | 82000 | D | $ (11,938) | |
| 8 | 4 | 50000 | 24000 | 75000 | 39000 | 82000 | E | $ 237,464 | |
| 9 | 5 | 50000 | 24000 | 75000 | 39000 | 82000 | AB | $ 169,785 | |
| 10 | 6 | 50000 | 24000 | 75000 | 39000 | 82000 | AC | $ 446,866 | |
| 11 | 7 | 50000 | 24000 | 75000 | 39000 | 82000 | AD | $ 154,808 | |
| 12 | 8 | 50000 | 24000 | 75000 | 39000 | 82000 | AE | $ 404,210 | |
| 13 | | | | | | | BC | $ 283,158 | |
| 14 | PW @ 10% | $166,746 | $ 3,038 | $280,119 | $(11,938) | $237,464 | BE | $ 240,502 | |
| 15 | | | | | | | CE | $ 517,583 | |
| 16 | | | | | | | DN | 0 | |
| 17 | | | | | | | | | |
| 18 | Select: | $517,583 | | | | | | | |
| 19 | | | | | | | | | |
| 20 | | | | | | | | | |
| 21 | | | | | | | | | |

12.7 (a) PW analysis of the 6 viable bundles is shown below. NPV functions are used to find PW values. Select project B for a total of $200,000, since it is the only one of the three single projects with PW > 0 at MARR = 12% per year.



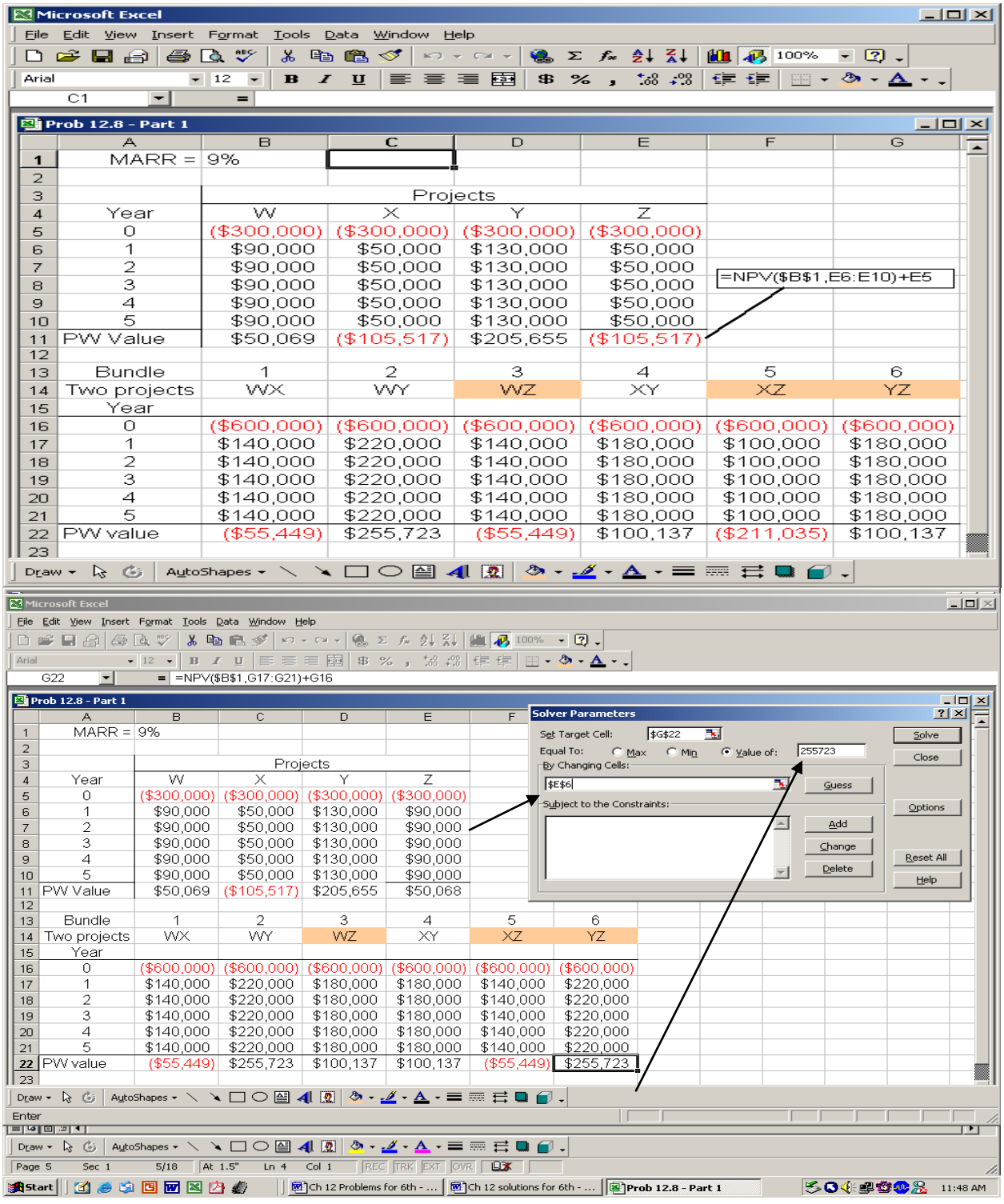

| | A | B | C | D | E | F | G |
|---|---|---|---|---|---|---|---|
| 1 | MARR = | 12% | | | | | |
| 2 | | | | | | | |
| 3 | Bundle | 1 | 2 | 3 | 4 | 5 | 6 |
| 4 | Projects | A | B | C | AB | BC | Do nothing |
| 5 | Year | Net cash flows, NCF | | | | | |
| 6 | 0 | -$400,000 | -$200,000 | -$700,000 | -$600,000 | -$900,000 | 0 |
| 7 | 1 | $120,000 | $90,000 | $200,000 | $210,000 | $290,000 | 0 |
| 8 | 2 | $120,000 | $90,000 | $200,000 | $210,000 | $290,000 | 0 |
| 9 | 3 | $120,000 | $90,000 | $200,000 | $210,000 | $290,000 | 0 |
| 10 | 4 | $160,000 | $120,000 | $220,000 | $280,000 | $340,000 | 0 |
| 11 | PW Value | -$10,097 | $92,427 | -$79,820 | $82,330 | $12,607 | $0 |
| 12 | | | | | | | |

(b) Change the NCF for bundle 5 (B and C) such that the PW is equal to $PW_2$ = $92,427. Use SOLVER with cell F11 as the target cell to find the necessary minimum NCF for both B and C of $316,279 as shown below in cell F7 (changing cell).




| | A | B | C | D | E | F | G | H | I | J | K | L | M |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | MARR = | 12% | | | | | | | | | | | |
| 2 | | | | | | | | | | | | | |
| 3 | Bundle | 1 | 2 | 3 | 4 | 5 | 6 | | | | | | |
| 4 | Projects | A | B | C | AB | BC | Do nothing | | | | | | |
| 5 | Year | Net cash flows, NCF | | | | | | | | | | | |
| 6 | 0 | -$400,000 | -$200,000 | -$700,000 | -$600,000 | -$900,000 | 0 | | | | | | |
| 7 | 1 | $120,000 | $90,000 | $200,000 | $210,000 | $316,279 | 0 | | | | | | |
| 8 | 2 | $120,000 | $90,000 | $200,000 | $210,000 | $316,279 | 0 | | | | | | |
| 9 | 3 | $120,000 | $90,000 | $200,000 | $210,000 | $316,279 | 0 | | | | | | |
| 10 | 4 | $160,000 | $120,000 | $220,000 | $280,000 | $366,279 | 0 | | | | | | |
| 11 | PW Value | -$10,097 | $92,427 | -$79,820 | $82,330 | $92,427 | $0 | | | | | | |
| 12 | | | | | | | | | | | | | |

12.8 (Solution description on next page.)




| | A | B | C | D | E | F | G |
|---|---|---|---|---|---|---|---|
| 1 | MARR = | 9% | | | | | |
| 2 | | | | | | | |
| 3 | | Projects | | | | | |
| 4 | Year | W | X | Y | Z | | |
| 5 | 0 | ($300,000) | ($300,000) | ($300,000) | ($300,000) | | |
| 6 | 1 | $90,000 | $50,000 | $130,000 | $50,000 | | |
| 7 | 2 | $90,000 | $50,000 | $130,000 | $50,000 | | |
| 8 | 3 | $90,000 | $50,000 | $130,000 | $50,000 | | |
| 9 | 4 | $90,000 | $50,000 | $130,000 | $50,000 | | |
| 10 | 5 | $90,000 | $50,000 | $130,000 | $50,000 | | |
| 11 | PW Value | $50,069 | ($105,517) | $205,655 | ($105,517) | | |
| 12 | | | | | | | |
| 13 | Bundle | 1 | 2 | 3 | 4 | 5 | 6 |
| 14 | Two projects | WX | WY | WZ | XY | XZ | YZ |
| 15 | Year | | | | | | |
| 16 | 0 | ($600,000) | ($600,000) | ($600,000) | ($600,000) | ($600,000) | ($600,000) |
| 17 | 1 | $140,000 | $220,000 | $140,000 | $180,000 | $100,000 | $180,000 |
| 18 | 2 | $140,000 | $220,000 | $140,000 | $180,000 | $100,000 | $180,000 |
| 19 | 3 | $140,000 | $220,000 | $140,000 | $180,000 | $100,000 | $180,000 |
| 20 | 4 | $140,000 | $220,000 | $140,000 | $180,000 | $100,000 | $180,000 |
| 21 | 5 | $140,000 | $220,000 | $140,000 | $180,000 | $100,000 | $180,000 |
| 22 | PW value | ($55,449) | $255,723 | ($55,449) | $100,137 | ($211,035) | $100,137 |

12.8 (cont.) There are 6 2-project bundles. First spreadsheet shows cash flows and PW values at 9% for single projects and bundles. If the NCF for Z is $50,000, Projects WY are selected with $PW_2$ = $255,723. Minimum NCF for project Z must make PW for either bundle WZ, XZ, or YZ have a PW of at least that of projects WY. Use SOLVER (second spreadsheet) to find

Min NCF for Z = $90,000

to obtain min $PW_6$ = $255,723 for projects YZ. This is the minimum NCF for Z to be selected as part of the twosome.

If Solver is applied 2 more times the minimum NCF for the other bundles are as follows:

| Projects | Min NCF for Z |
|---|---|
| XZ | $170,000 |
| WZ | 130,000 |

12.9 b = $800,000 i = 10% $n_j$ = 4 years 6 viable bundles

| Bundle | Projects | $NCF_{j0}$ | $NCF_{jt}$ | S | PW at 10% |
|---|---|---|---|---|---|
| 1 | A | $-250,000 | $ 50,000 | $ 45,000 | $-60,770 |
| 2 | B | -300,000 | 90,000 | -10,000 | -21,539 |
| 3 | C | -550,000 | 150,000 | 100,000 | - 6,215 |
| 4 | AB | -550,000 | 140,000 | 35,000 | -82,309* |
| 5 | AC | -800,000 | 200,000 | 145,000 | -66,985* |
| 6 | Do nothing | 0 | 0 | 0 | 0 |

$PW_j = NCF_j(P/A,10\%,4) + S(P/F,10\%,4) - NCF_{j0}$

*Add single-project PW values for j = 4 and 5. Since PW < 0 for A, B and C, by inspection, bundles 4 and 5 will have PW < 0. There is no need to determine their PW values. Since no PW > 0,

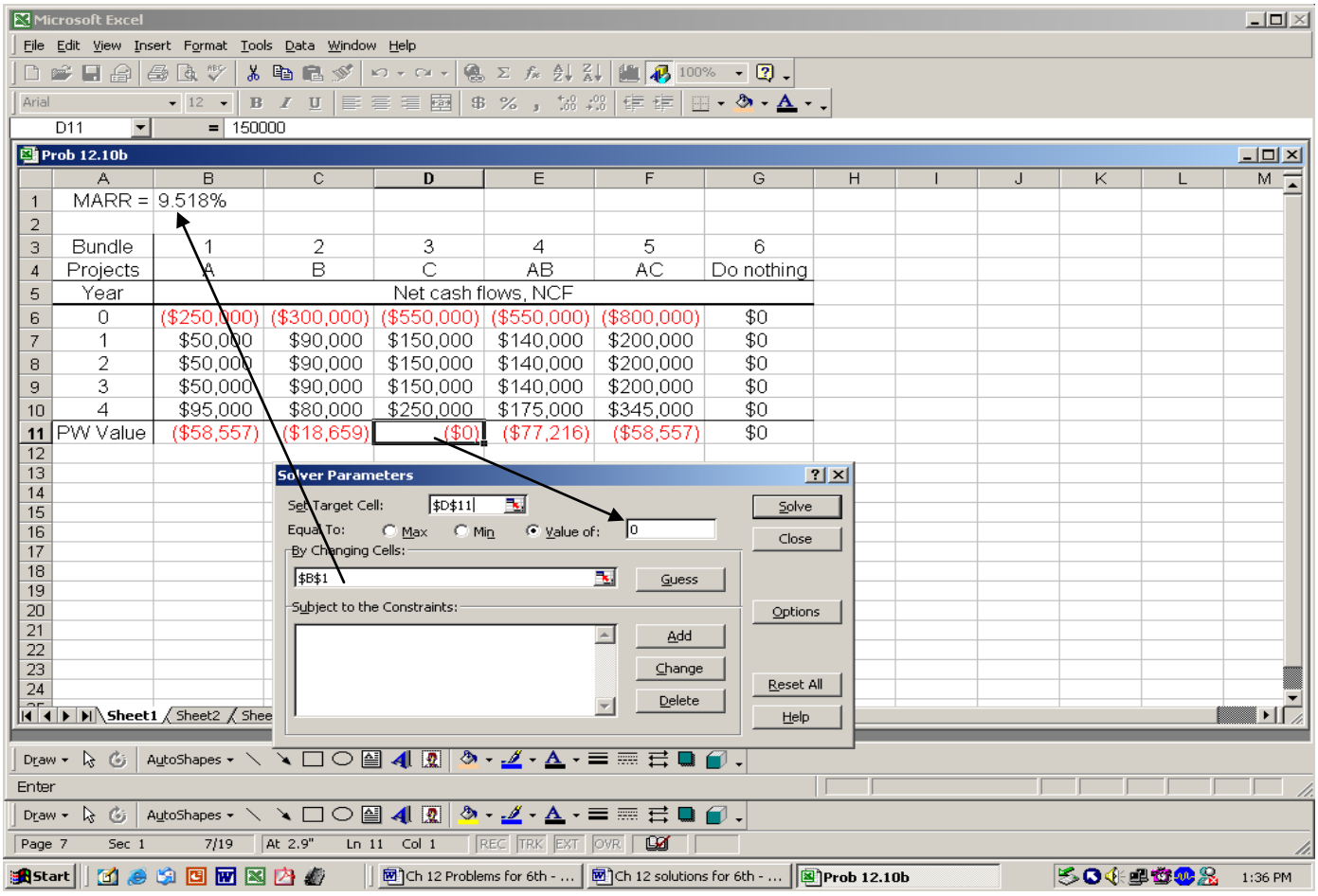
Select DO NOTHING project.

12.10 Set up spreadsheet and determine that the Do Nothing bundle is the only acceptable one with PW = $-6219.

(a) Since the initial investment occurs at time t = 0, maximum initial investment for C at which PW = 0 is

-550,000 + (-6219) = $-543,781

(b) Use SOLVER with the target cell as D11 for PW = 0. Result is MARR = 9.518% in cell B1.



12.11 (a) There are $2^8 = 256$ separate bundles possible. Only 1, 2 or 3 projects can be accepted. With b = $400,000 and selection restrictions, there are only 4 viable bundles.

| Bundle | Projects | Initial investment, $ | PW at 10%, $ |
|---|---|---|---|
| 1 | 2 | -300,000 | 35,000 |
| 2 | 5 | -195,000 | 125,000 |
| 3 | 8 | -400,000 | 110,000 |
| 4 | 2,7 | -400,000 | 97,000 |

Select project 5 with PW = $125,000 and $195,000 invested. This assumes the remaining $205,000 is invested at the MARR of 10% per year in other investment opportunities.

(b) The second best choice is project 8 with PW = $110,000. This is a good choice, since it invests the entire $400,000 at a rate of return in excess of the 10% MARR since PW is significantly above zero.

12.12 (a) For b = $30,000 only 5 bundles are viable of the 32 possibilities.

| Bundle | Projects | Initial investment, $ | PW at 12%, $ |
|---|---|---|---|
| 1 | S | -15,000 | 8,540 |
| 2 | A | -25,000 | 12,325 |
| 3 | M | -10,000 | 3,000 |
| 4 | E | -25,000 | 10 |
| 5 | SM | -25,000 | 11,540 |

Select project A with PW = $12,325 and $25,000 invested.

(b) With b = $60,000, 11 more bundles are viable.

| Bundle | Projects | Initial investment, $ | PW at 12%, $ |
|---|---|---|---|
| 6 | H | -40,000 | 15,350 |
| 7 | SA | -40,000 | 20,865 |
| 8 | SE | -40,000 | 8,550 |
| 9 | SH | -55,000 | 23,890 |
| 10 | AM | -35,000 | 15,325 |
| 11 | AE | -50,000 | 12,335 |
| 12 | ME | -35,000 | 3,010 |
| 13 | MH | -50,000 | 18,350 |
| 14 | SAM | -50,000 | 23,865 |
| 15 | SME | -50,000 | 11,550 |
| 16 | AME | -60,000 | 15,335 |

Select projects S and H with PW = $23,890 and $55,000 invested.
(A close second are projects S, A and M with PW = $23,865 and $50,000 invested.)

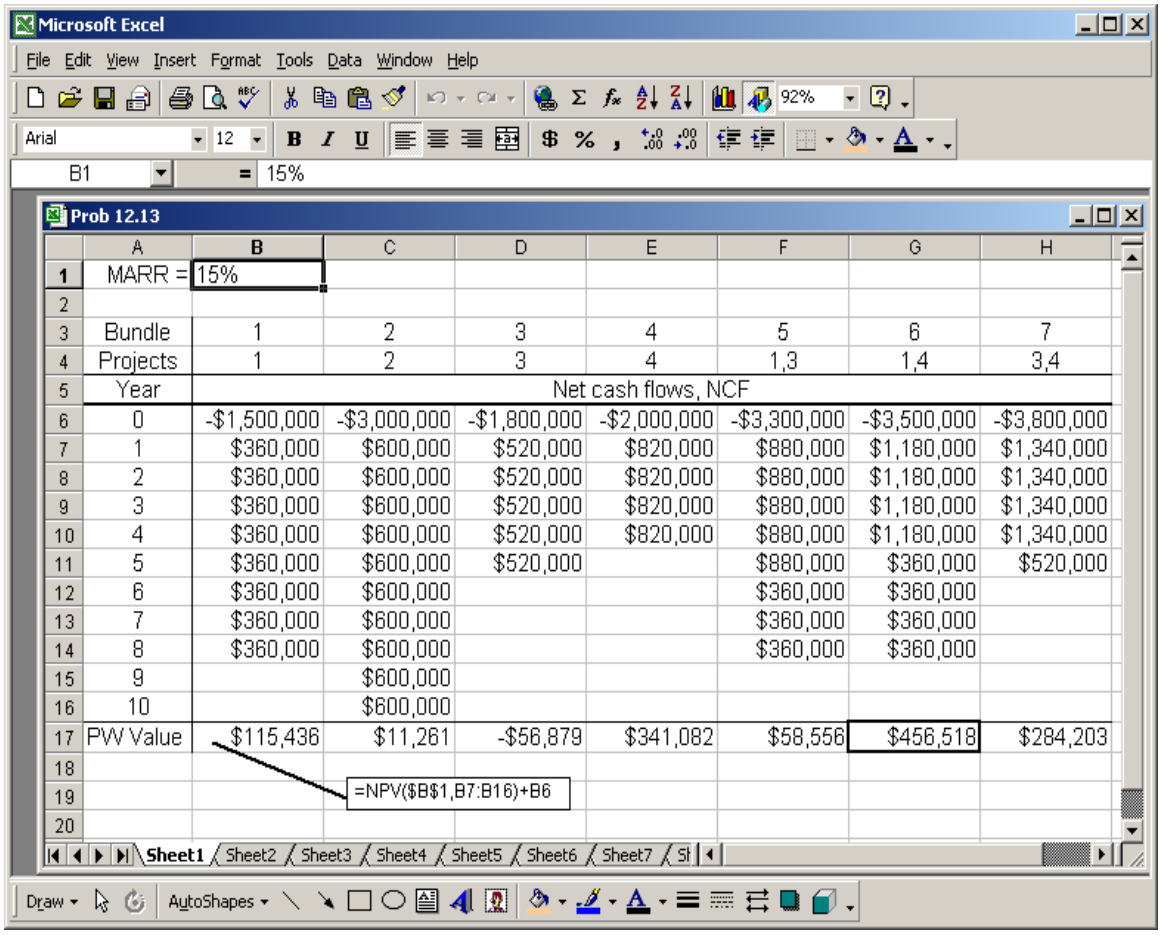
(c) Select all projects since they each have PW > 0 at 12%.

12.13 (a) The bundles and PW values are determined at MARR = 15% per year.

| Bundle | Projects | Initial investment, $ | NCF, $ per year | Life, years | PW at 15% |
|---|---|---|---|---|---|
| 1 | 1 | -1.5 mil | 360,000 | 8 | $115,428 |
| 2 | 2 | -3.0 | 600,000 | 10 | 11,280 |
| 3 | 3 | -1.8 | 520,000 | 5 | - 56,856 |
| 4 | 4 | -2.0 | 820,000 | 4 | 341,100 |
| 5 | 1,3 | -3.3 | 880,000 | 1-5 | 58,572 |
| | | | 360,000 | 6-8 | |
| 6 | 1,4 | -3.5 | 1,180,000 | 1-4 | 456,528 |
| | | | 360,000 | 5-8 | |
| 7 | 3,4 | -3.8 | 1,340,000 | 1-4 | 284,244 |
| | | | 520,000 | 5 | |

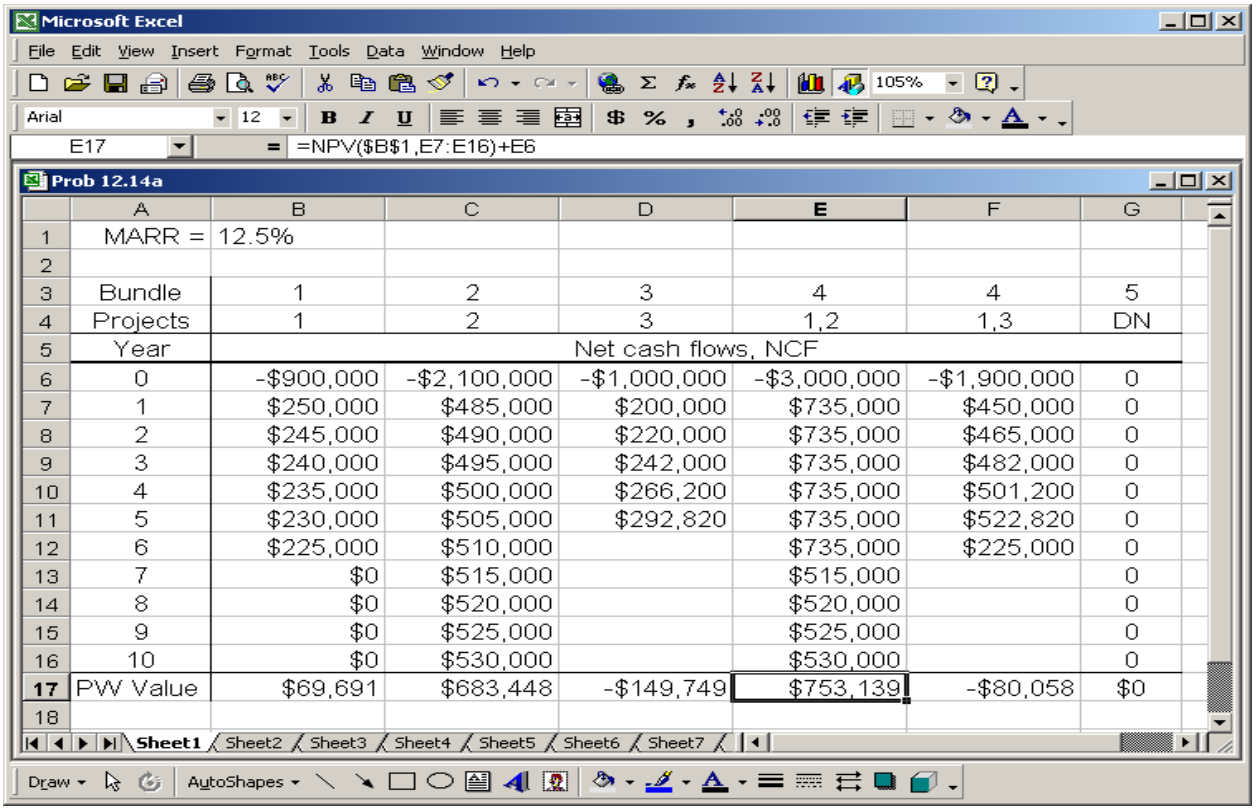
Select PW = $456,528 for projects 1 and 4 with $3.5 million invested.

12.13 (cont) (b) Set up a spreadsheet for all 7 bundles. Select projects 1 and 4 with the largest PW = $456,518 and invest $3.5 million.




| | A | B | C | D | E | F | G | H |
|---|---|---|---|---|---|---|---|---|
| 1 | MARR = | 15% | | | | | | |
| 2 | | | | | | | | |
| 3 | Bundle | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 4 | Projects | 1 | 2 | 3 | 4 | 1,3 | 1,4 | 3,4 |
| 5 | Year | Net cash flows, NCF | | | | | | |
| 6 | 0 | -$1,500,000 | -$3,000,000 | -$1,800,000 | -$2,000,000 | -$3,300,000 | -$3,500,000 | -$3,800,000 |
| 7 | 1 | $360,000 | $600,000 | $520,000 | $820,000 | $880,000 | $1,180,000 | $1,340,000 |
| 8 | 2 | $360,000 | $600,000 | $520,000 | $820,000 | $880,000 | $1,180,000 | $1,340,000 |
| 9 | 3 | $360,000 | $600,000 | $520,000 | $820,000 | $880,000 | $1,180,000 | $1,340,000 |
| 10 | 4 | $360,000 | $600,000 | $520,000 | $820,000 | $880,000 | $1,180,000 | $1,340,000 |
| 11 | 5 | $360,000 | $600,000 | $520,000 | | $880,000 | $360,000 | $520,000 |
| 12 | 6 | $360,000 | $600,000 | | | $360,000 | $360,000 | |
| 13 | 7 | $360,000 | $600,000 | | | $360,000 | $360,000 | |
| 14 | 8 | $360,000 | $600,000 | | | $360,000 | $360,000 | |
| 15 | 9 | | $600,000 | | | | | |
| 16 | 10 | | $600,000 | | | | | |
| 17 | PW Value | $115,436 | $11,261 | -$56,879 | $341,082 | $58,556 | $456,518 | $284,203 |
| 18 | | | | | | | | |
| 19 | | | | | | | | |
| 20 | | | | | | | | |

12.14 (a) Spreadsheet shows the solution. Select projects 1 and 2 for a budget of $3.0 million and PW = $753,139.



Microsoft Excel

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Arial 12 105%

E17 = =NPV($B$1,E7:E16)+E6

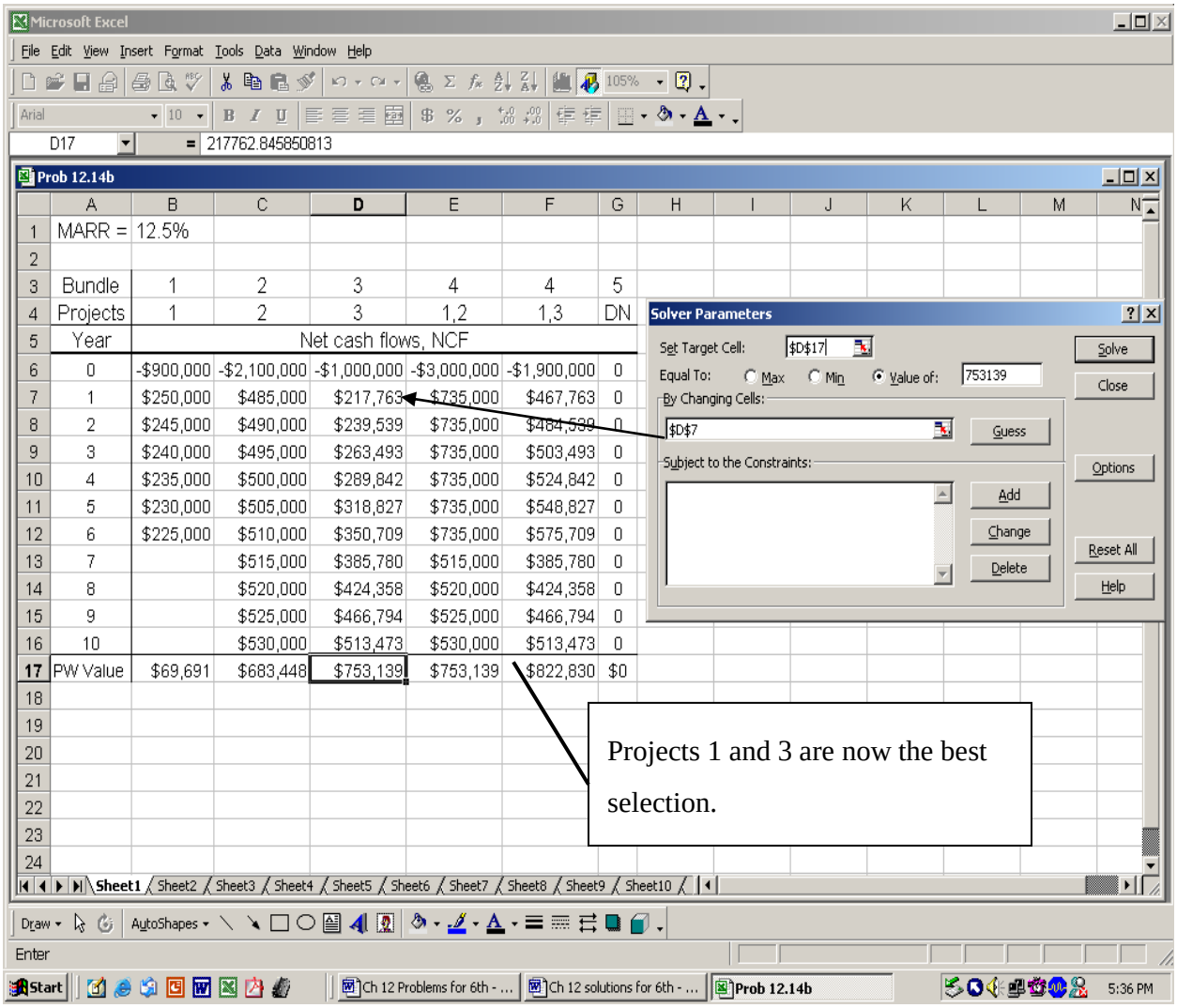
Prob 12.14a

| | A | B | C | D | E | F | G |
|---|---|---|---|---|---|---|---|
| 1 | MARR = | 12.5% | | | | | |
| 2 | | | | | | | |
| 3 | Bundle | 1 | 2 | 3 | 4 | 4 | 5 |
| 4 | Projects | 1 | 2 | 3 | 1,2 | 1,3 | DN |
| 5 | Year | Net cash flows, NCF | | | | | |
| 6 | 0 | -$900,000 | -$2,100,000 | -$1,000,000 | -$3,000,000 | -$1,900,000 | 0 |
| 7 | 1 | $250,000 | $485,000 | $200,000 | $735,000 | $450,000 | 0 |
| 8 | 2 | $245,000 | $490,000 | $220,000 | $735,000 | $465,000 | 0 |
| 9 | 3 | $240,000 | $495,000 | $242,000 | $735,000 | $482,000 | 0 |
| 10 | 4 | $235,000 | $500,000 | $266,200 | $735,000 | $501,200 | 0 |
| 11 | 5 | $230,000 | $505,000 | $292,820 | $735,000 | $522,820 | 0 |
| 12 | 6 | $225,000 | $510,000 | | $735,000 | $225,000 | 0 |
| 13 | 7 | $0 | $515,000 | | $515,000 | | 0 |
| 14 | 8 | $0 | $520,000 | | $520,000 | | 0 |
| 15 | 9 | $0 | $525,000 | | $525,000 | | 0 |
| 16 | 10 | $0 | $530,000 | | $530,000 | | 0 |
| 17 | PW Value | $69,691 | $683,448 | -$149,749 | $753,139 | -$80,058 | $0 |
| 18 | | | | | | | |

Sheet1 Sheet2 Sheet3 Sheet4 Sheet5 Sheet6 Sheet7

Draw AutoShapes

12.14 (cont) (b) Use SOLVER with the target cell D17 to equal $753,139. Result is a required year one NCF for project 3 of $217,763 (cell D7). However, with this increased NCF and life for project 3, the best selection is now projects 1 and 3 with PW = $822,830 (cell F17).



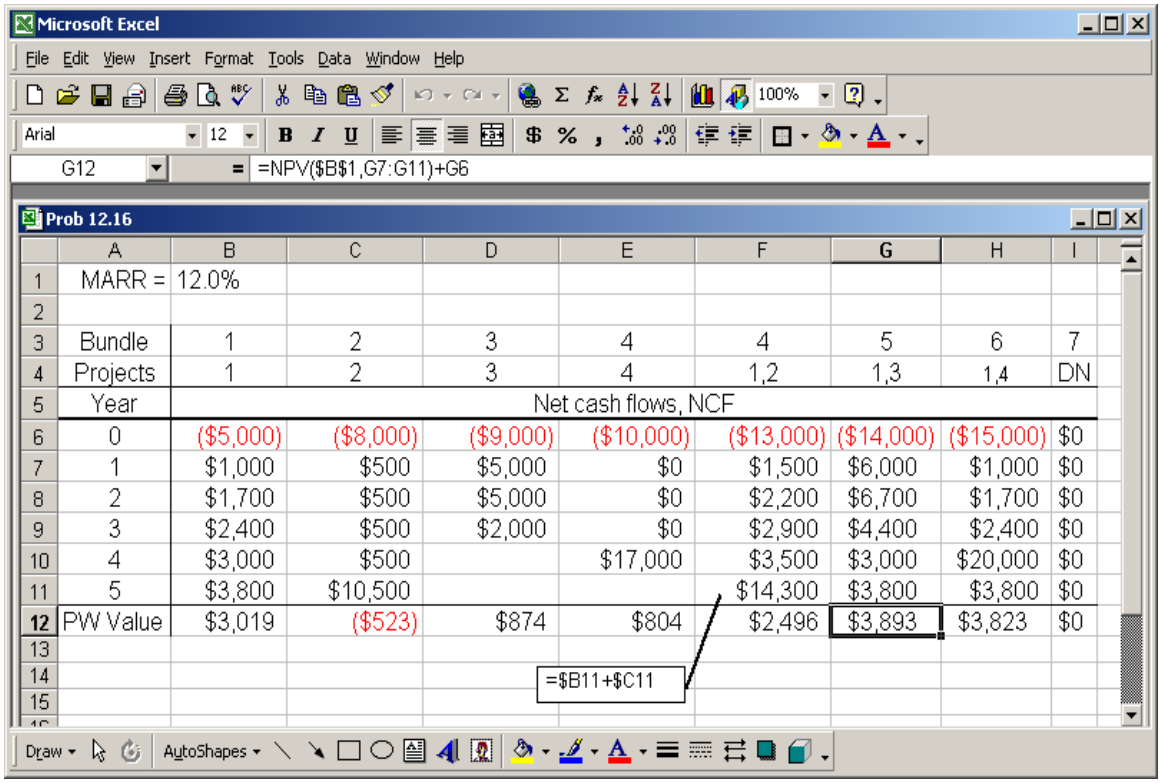

| | A | B | C | D | E | F | G |
|---|---|---|---|---|---|---|---|
| 1 | MARR = | 12.5% | | | | | |
| 2 | | | | | | | |
| 3 | Bundle | 1 | 2 | 3 | 4 | 4 | 5 |
| 4 | Projects | 1 | 2 | 3 | 1,2 | 1,3 | DN |
| 5 | Year | Net cash flows, NCF | | | | | |
| 6 | 0 | -$900,000 | -$2,100,000 | -$1,000,000 | -$3,000,000 | -$1,900,000 | 0 |
| 7 | 1 | $250,000 | $485,000 | $217,763 | $735,000 | $467,763 | 0 |
| 8 | 2 | $245,000 | $490,000 | $239,539 | $735,000 | $484,539 | 0 |
| 9 | 3 | $240,000 | $495,000 | $263,493 | $735,000 | $503,493 | 0 |
| 10 | 4 | $235,000 | $500,000 | $289,842 | $735,000 | $524,842 | 0 |
| 11 | 5 | $230,000 | $505,000 | $318,827 | $735,000 | $548,827 | 0 |
| 12 | 6 | $225,000 | $510,000 | $350,709 | $735,000 | $575,709 | 0 |
| 13 | 7 | | $515,000 | $385,780 | $515,000 | $385,780 | 0 |
| 14 | 8 | | $520,000 | $424,358 | $520,000 | $424,358 | 0 |
| 15 | 9 | | $525,000 | $466,794 | $525,000 | $466,794 | 0 |
| 16 | 10 | | $530,000 | $513,473 | $530,000 | $513,473 | 0 |
| 17 | PW Value | $69,691 | $683,448 | $753,139 | $753,139 | $822,830 | $0 |

12.15 Budget limit, b = $16,000 MARR = 12% per year

| Bundle | Projects | Investment | NCF for years 1 through 5 | PW at 12% |
|---|---|---|---|---|
| 1 | 1 | $-5,000 | $1000,1700,2400, 3000,3800 | $3019 |
| 2 | 2 | - 8,000 | 500,500,500, 500,10500 | - 523 |
| 3 | 3 | - 9,000 | 5000,5000,2000 | 874 |
| 4 | 4 | -10,000 | 0,0,0,17000 | 804 |
| 5 | 1,2 | -13,000 | 1500,2200,2900, 3500,14300 | 2496 |
| 6 | 1,3 | -14,000 | 6000,6700,4400, 3000,3800 | 3893 |
| 7 | 1,4 | -15,000 | 1000,1700,2400, 20000,3800 | 3823 |

Since $PW_6$ = $3893 is largest, select bundle 6, which is projects 1 and 3.

12.16 Spreadsheet solution for Problem 12.15. Projects 1 and 3 are selected with PW = $3893.




| | A | B | C | D | E | F | G | H | I |
|---|---|---|---|---|---|---|---|---|---|
| 1 | MARR = | 12.0% | | | | | | | |
| 2 | | | | | | | | | |
| 3 | Bundle | 1 | 2 | 3 | 4 | 4 | 5 | 6 | 7 |
| 4 | Projects | 1 | 2 | 3 | 4 | 1,2 | 1,3 | 1,4 | DN |
| 5 | Year | Net cash flows, NCF | | | | | | | |
| 6 | 0 | ($5,000) | ($8,000) | ($9,000) | ($10,000) | ($13,000) | ($14,000) | ($15,000) | $0 |
| 7 | 1 | $1,000 | $500 | $5,000 | $0 | $1,500 | $6,000 | $1,000 | $0 |
| 8 | 2 | $1,700 | $500 | $5,000 | $0 | $2,200 | $6,700 | $1,700 | $0 |
| 9 | 3 | $2,400 | $500 | $2,000 | $0 | $2,900 | $4,400 | $2,400 | $0 |
| 10 | 4 | $3,000 | $500 | | $17,000 | $3,500 | $3,000 | $20,000 | $0 |
| 11 | 5 | $3,800 | $10,500 | | | $14,300 | $3,800 | $3,800 | $0 |
| 12 | PW Value | $3,019 | ($523) | $874 | $804 | $2,496 | $3,893 | $3,823 | $0 |
| 13 | | | | | | | | | |
| 14 | | | | | | | | | |
| 15 | | | | | | | | | |

12.17 For the bundle comprised of projects 3 and 4, the net cash flows are:

| Year | 0 | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| NCF | $-19,000 | 5000 | 5000 | 2000 | 17,000 | 0 |

Use Equation [12.2] to compute the PW value at 12%. The longest-lived of the four is project 2 with $n_L = 5$ years.

$$PW = -19{,}000 + [5{,}000(F/A,12\%,2)(F/P,12\%,3) + 2{,}000(F/P,12\%,2) + 17{,}000(F/P,12\%,1)](P/F,12\%,5)$$

$$= -19{,}000 + [5{,}000(2.12)(1.4049) + 2{,}000(1.2544) + 17{,}000(1.12)](0.5674)$$
$$= \$1676$$

The PW value using the NCF values directly is

$$PW = -19{,}000 + 5000(P/A,12\%,2) + 2000(P/F,12\%,3) + 17{,}000(P/F,12\%,4)$$
$$= -19{,}000 + 5000(1.6901) + 2000(0.7118) + 17{,}000(0.6355)$$
$$= \$1677$$

The PW values are the same (allowing for round-off error).

12.18 To develop the 0-1 ILP formulation, first calculate $PW_E$ since it was not included in Table 12-2. All amounts are in \$1000.

$$PW_E = -21{,}000 + 9500(P/A,15\%,9)$$
$$= -21{,}000 + 9500(4.7716)$$
$$= \$24{,}330$$

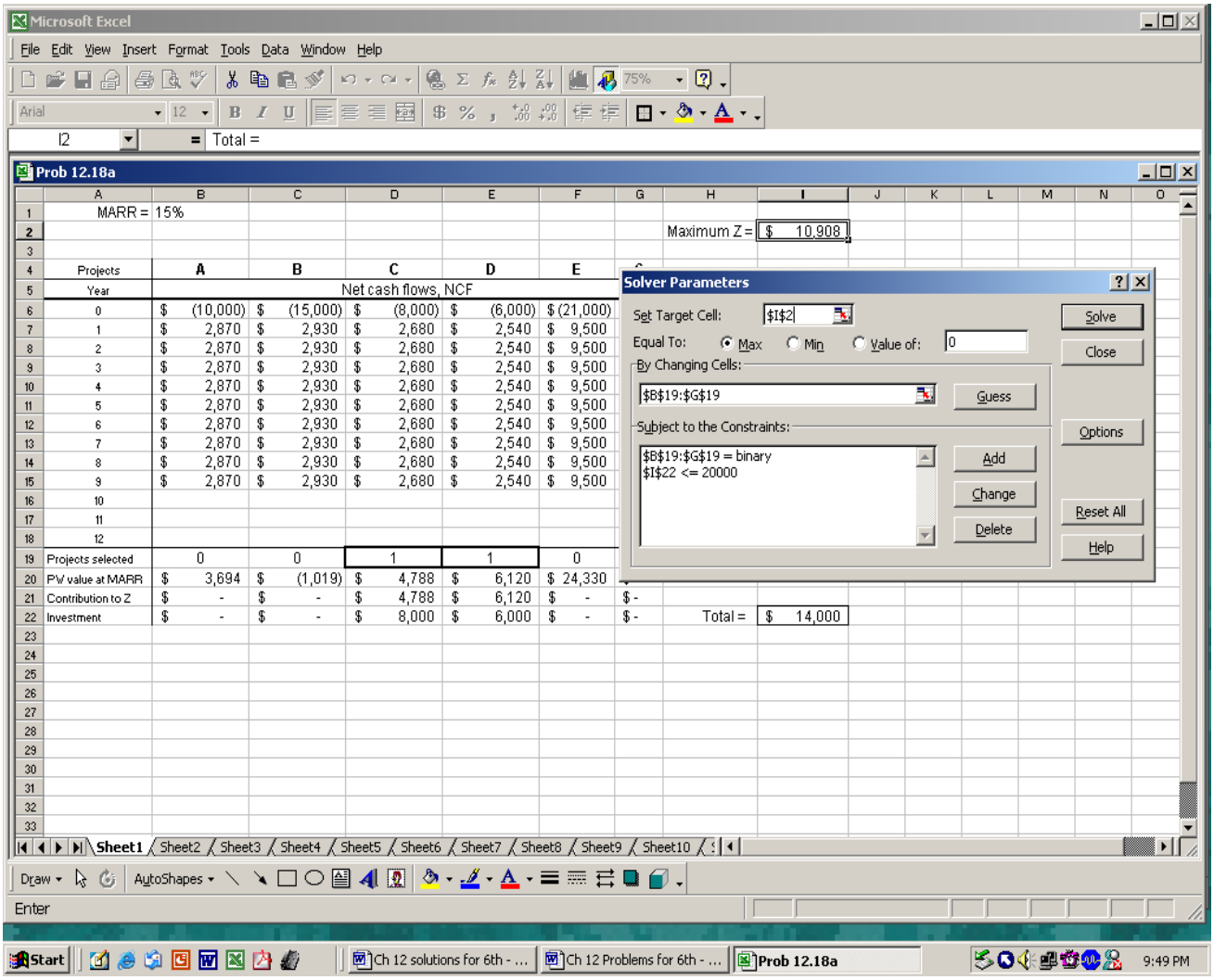
The linear programming formulation is:

$$\text{Maximize } Z = 3694x_1 - 1019\,x_2 + 4788\,x_3 + 6120\,x_4 + 24{,}330\,x_5$$

$$\text{Constraints: } 10{,}000x_1 + 15{,}000\,x_2 + 8000\,x_3 + 6000\,x_4 + 21{,}000\,x_5 < 20{,}000$$

$$x_k = 0 \text{ or } 1 \text{ for } k = 1 \text{ to } 5$$

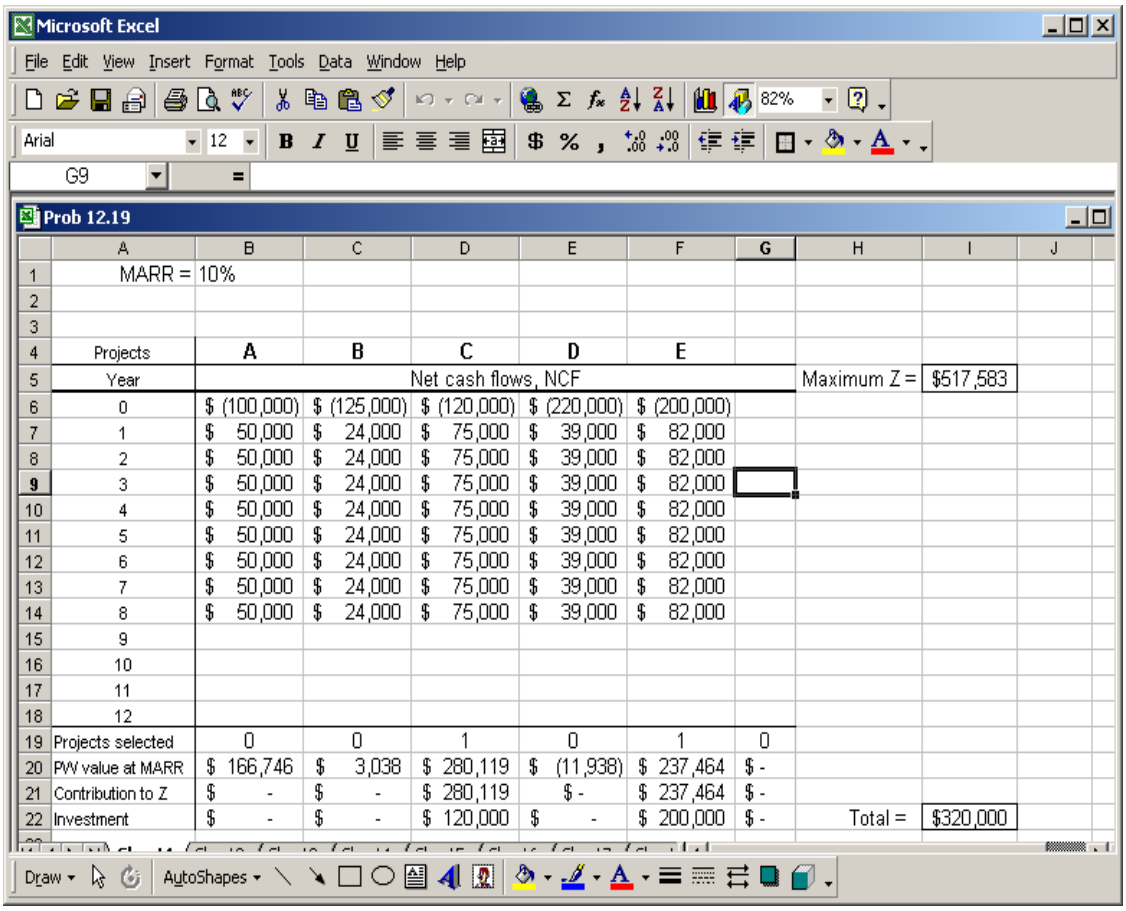
(a) For b = \$20,000: The spreadsheet solution uses the general template in Figure 12-5. MARR is set to 15% and a budget constraint is set to \$20,000 in SOLVER. Projects C and D are selected (row 19) for a \$14,000 investment (cell I22) with Z = \$10,908 (cell I2), as in Example 12.1.




| | Projects | A | B | C | D | E |
|---|---|---|---|---|---|---|
| | Year | Net cash flows, NCF | | | | |
| 0 | | $ (10,000) | $ (15,000) | $ (8,000) | $ (6,000) | $ (21,000) |
| 1 | | $ 2,870 | $ 2,930 | $ 2,680 | $ 2,540 | $ 9,500 |
| 2 | | $ 2,870 | $ 2,930 | $ 2,680 | $ 2,540 | $ 9,500 |
| 3 | | $ 2,870 | $ 2,930 | $ 2,680 | $ 2,540 | $ 9,500 |
| 4 | | $ 2,870 | $ 2,930 | $ 2,680 | $ 2,540 | $ 9,500 |
| 5 | | $ 2,870 | $ 2,930 | $ 2,680 | $ 2,540 | $ 9,500 |
| 6 | | $ 2,870 | $ 2,930 | $ 2,680 | $ 2,540 | $ 9,500 |
| 7 | | $ 2,870 | $ 2,930 | $ 2,680 | $ 2,540 | $ 9,500 |
| 8 | | $ 2,870 | $ 2,930 | $ 2,680 | $ 2,540 | $ 9,500 |
| 9 | | $ 2,870 | $ 2,930 | $ 2,680 | $ 2,540 | $ 9,500 |
| 10 | | | | | | |
| 11 | | | | | | |
| 12 | | | | | | |
| 19 | Projects selected | 0 | 0 | 1 | 1 | 0 |
| 20 | PW value at MARR | $ 3,694 | $ (1,019) | $ 4,788 | $ 6,120 | $ 24,330 |
| 21 | Contribution to Z | $ - | $ - | $ 4,788 | $ 6,120 | $ - |
| 22 | Investment | $ - | $ - | $ 8,000 | $ 6,000 | $ - |

(b) b = $13,000: Again, all amounts are in $1000 units. Simply change the budget constraint to b = $13,000 in SOLVER and obtain a new solution to select only project D with Z = $6120 and only $6000 of the $13,000 invested.

12.19 (a) Use the capital budgeting template with MARR = 10% and a budget constraint of $325,000. The solution is to select projects C and E (row 19) with $320,000 invested and a maximized PW = $517,583 (cell I5).



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Arial 12 G9

Prob 12.19

| | A | B | C | D | E | F | G | H | I | J |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | MARR = | 10% | | | | | | | | |
| 2 | | | | | | | | | | |
| 3 | | | | | | | | | | |
| 4 | Projects | A | B | C | D | E | | | | |
| 5 | Year | Net cash flows, NCF | | | | | | Maximum Z = | $517,583 | |
| 6 | 0 | $ (100,000) | $ (125,000) | $ (120,000) | $ (220,000) | $ (200,000) | | | | |
| 7 | 1 | $ 50,000 | $ 24,000 | $ 75,000 | $ 39,000 | $ 82,000 | | | | |
| 8 | 2 | $ 50,000 | $ 24,000 | $ 75,000 | $ 39,000 | $ 82,000 | | | | |
| 9 | 3 | $ 50,000 | $ 24,000 | $ 75,000 | $ 39,000 | $ 82,000 | | | | |
| 10 | 4 | $ 50,000 | $ 24,000 | $ 75,000 | $ 39,000 | $ 82,000 | | | | |
| 11 | 5 | $ 50,000 | $ 24,000 | $ 75,000 | $ 39,000 | $ 82,000 | | | | |
| 12 | 6 | $ 50,000 | $ 24,000 | $ 75,000 | $ 39,000 | $ 82,000 | | | | |
| 13 | 7 | $ 50,000 | $ 24,000 | $ 75,000 | $ 39,000 | $ 82,000 | | | | |
| 14 | 8 | $ 50,000 | $ 24,000 | $ 75,000 | $ 39,000 | $ 82,000 | | | | |
| 15 | 9 | | | | | | | | | |
| 16 | 10 | | | | | | | | | |
| 17 | 11 | | | | | | | | | |
| 18 | 12 | | | | | | | | | |
| 19 | Projects selected | 0 | 0 | 1 | 0 | 1 | 0 | | | |
| 20 | PW value at MARR | $ 166,746 | $ 3,038 | $ 280,119 | $ (11,938) | $ 237,464 | $ - | | | |
| 21 | Contribution to Z | $ - | $ - | $ 280,119 | $ - | $ 237,464 | $ - | | | |
| 22 | Investment | $ - | $ - | $ 120,000 | $ - | $ 200,000 | $ - | Total = | $320,000 | |

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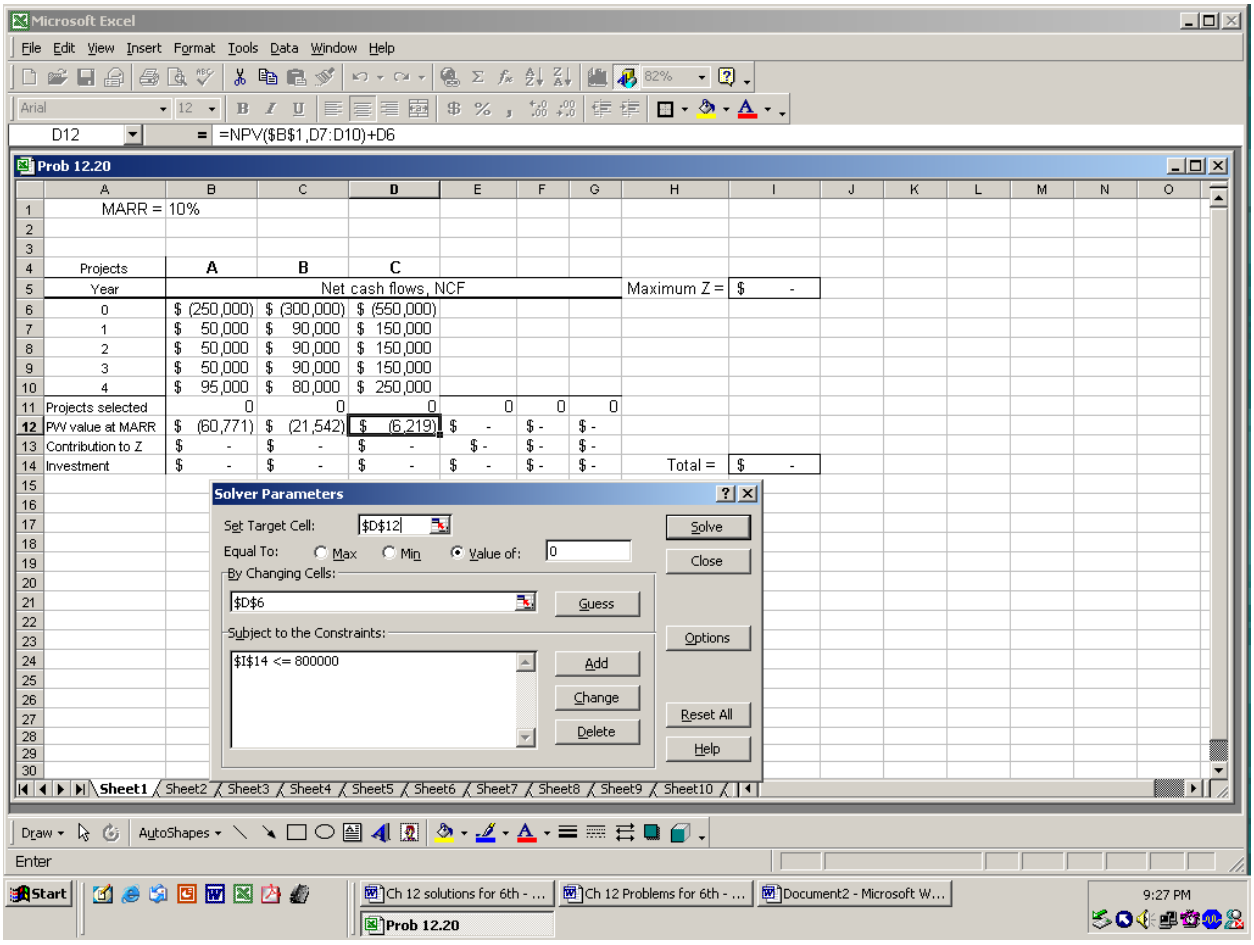
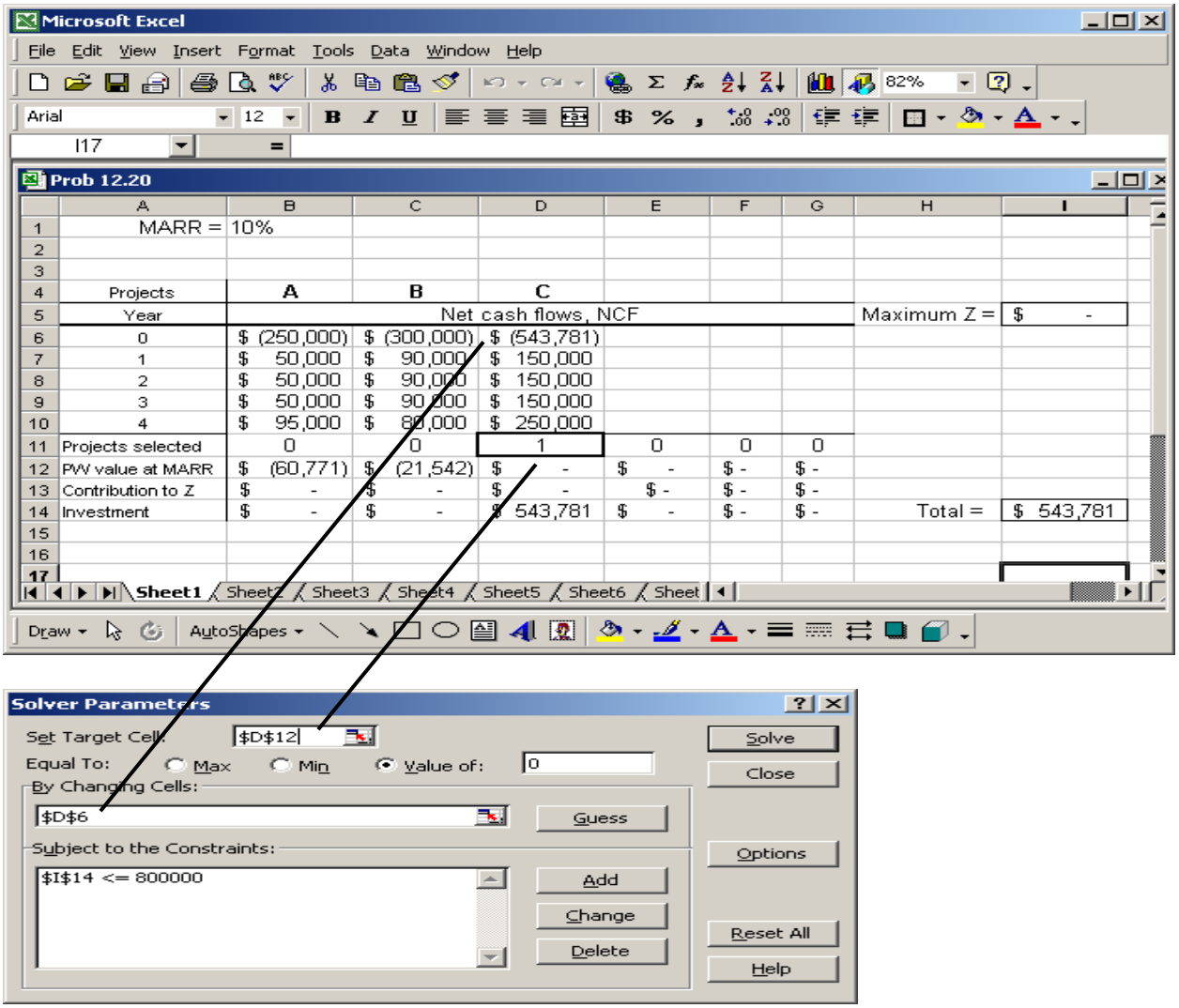
(b) Change cell B1 to 12% and the budget constraint to $500,000. Solution is

Select projects A, C and E for Z = $608,301 and a total of $420,000 invested.

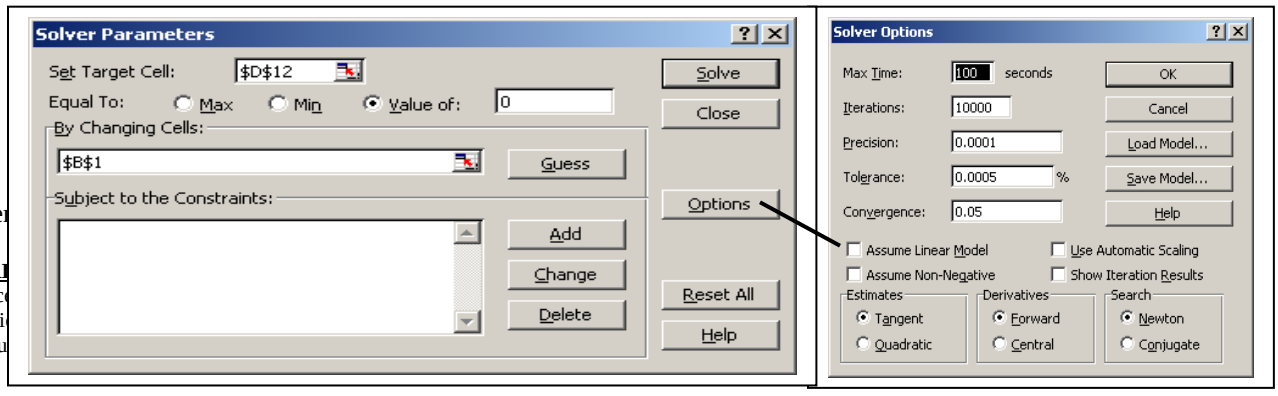
12.20 The capital budgeting solution with MARR = 10% and b = $800,000 is to Do Nothing since all three projects have PW < 0.



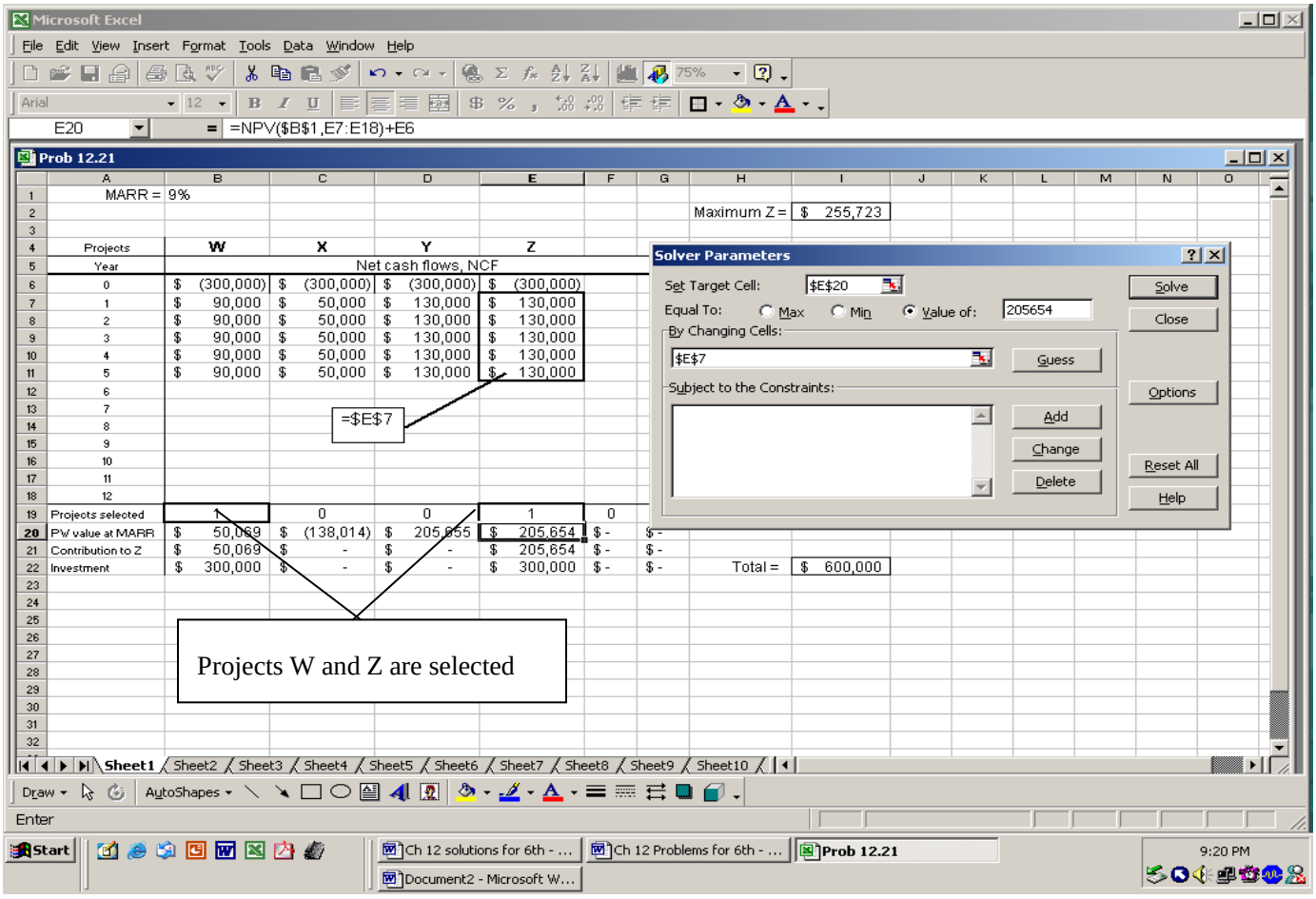
12.20 (cont) (a) To determine that the maximum investment in C is $543,781 using SOLVER, set up the solution with '1' in cell D11 to select project C only, target cell as D12 with a value of $0, changing cell as D6 and delete the binary constraint. Spreadsheet and SOLVER template are shown below.




(b) To find MARR = 9.518% in cell B1, use SOLVER with target cell D12 value of 0 and changing cell B1. Be sure the options box on SOLVER for 'assume linear model' is not checked and that the tolerance % is small (see below).



12.21 SOLVER can be used 4 times. First to get the selection of WY with Z = $255,723, or by simply observing that these have PW > 0 and the sum is this amount. Now it gets a little harder for the three 2-project selections of WZ, XZ, and YZ. Set up SOLVER for each selection with the target cell E20 as the difference 255,723 – NCF of the other project. For example, if W and Z are the projects, the required PW for Z is 255,723 – 50,069 = $205,654. The SOLVER solution for WZ is shown here where the minimum NCF for Z is $130,000 in the changing cell E7.

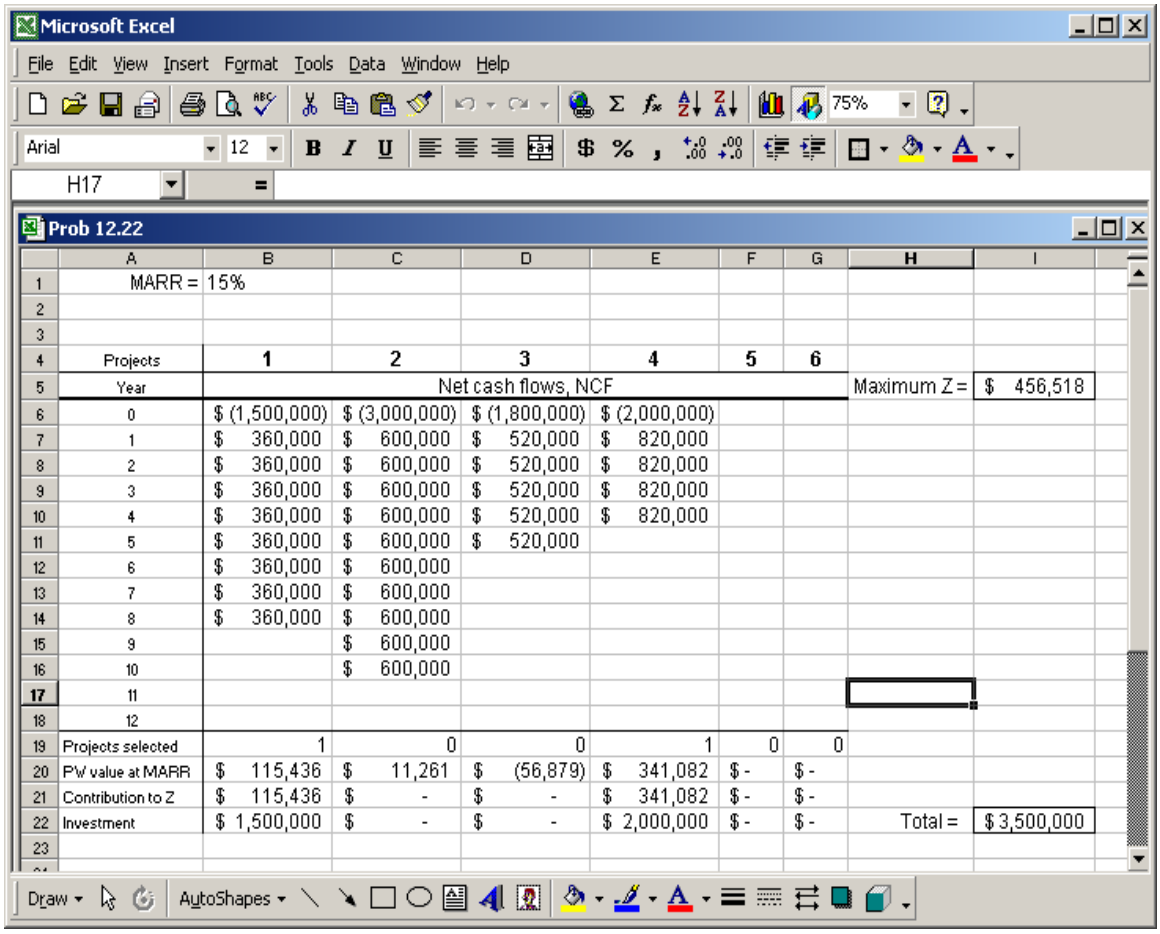



The 3 runs of SOLVER will generate the following results:

| Projects | Target value in cell E20 | Min NCF for Z |
|---|---|---|
| WZ | $205,654 | $130,000 |
| XZ | 361,240 | 170,000 |
| YZ | 50,068 | 90,000 |

The minimum NCF for Z is, therefore, $90,000 for the selection of the two projects Y and Z.

12.22 Use the capital budgeting problem template at 15% and a constraint on cell I22 of $4,000,000. Select projects 1 and 4 with $3.5 million invested and Z = $456,518.



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Arial 12 H17 =

Prob 12.22

| | A | B | C | D | E | F | G | H | I |
|---|---|---|---|---|---|---|---|---|---|
| 1 | MARR = | 15% | | | | | | | |
| 2 | | | | | | | | | |
| 3 | | | | | | | | | |
| 4 | Projects | 1 | 2 | 3 | 4 | 5 | 6 | | |
| 5 | Year | Net cash flows, NCF | | | | | | Maximum Z = | $ 456,518 |
| 6 | 0 | $ (1,500,000) | $ (3,000,000) | $ (1,800,000) | $ (2,000,000) | | | | |
| 7 | 1 | $ 360,000 | $ 600,000 | $ 520,000 | $ 820,000 | | | | |
| 8 | 2 | $ 360,000 | $ 600,000 | $ 520,000 | $ 820,000 | | | | |
| 9 | 3 | $ 360,000 | $ 600,000 | $ 520,000 | $ 820,000 | | | | |
| 10 | 4 | $ 360,000 | $ 600,000 | $ 520,000 | $ 820,000 | | | | |
| 11 | 5 | $ 360,000 | $ 600,000 | $ 520,000 | | | | | |
| 12 | 6 | $ 360,000 | $ 600,000 | | | | | | |
| 13 | 7 | $ 360,000 | $ 600,000 | | | | | | |
| 14 | 8 | $ 360,000 | $ 600,000 | | | | | | |
| 15 | 9 | | $ 600,000 | | | | | | |
| 16 | 10 | | $ 600,000 | | | | | | |
| 17 | 11 | | | | | | | | |
| 18 | 12 | | | | | | | | |
| 19 | Projects selected | 1 | 0 | 0 | 1 | 0 | 0 | | |
| 20 | PW value at MARR | $ 115,436 | $ 11,261 | $ (56,879) | $ 341,082 | $ - | $ - | | |
| 21 | Contribution to Z | $ 115,436 | $ - | $ - | $ 341,082 | $ - | $ - | | |
| 22 | Investment | $ 1,500,000 | $ - | $ - | $ 2,000,000 | $ - | $ - | Total = | $ 3,500,000 |
| 23 | | | | | | | | | |

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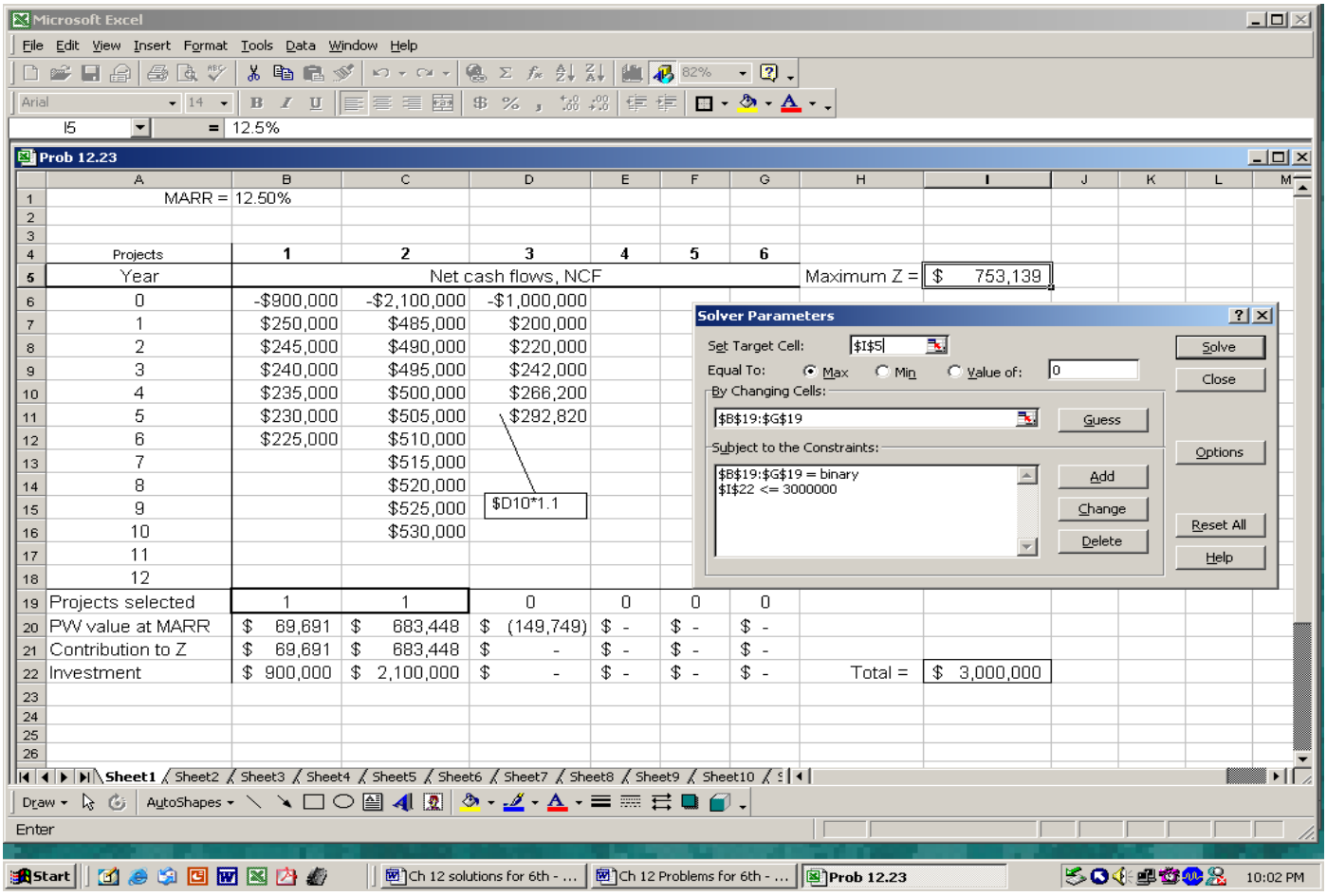
12.23 Enter the NCF values from Problem 12.14 into the capital budgeting template and b = $3,000,000 into SOLVER. Select projects 1 and 2 for Z = $753,139 with $3.0 million invested.



12.24 Enter the NCF values on a spreadsheet and b = $16,000 constraint in SOLVER to obtain the answer: Select projects 1 and 3 with Z = $3893 and $14,000 invested, the same as in Problem 12.15 where all viable mutually exclusive bundles were evaluated by hand.

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Arial 12 B I U 75%

B24 =

Prob 12.24

| | A | B | C | D | E | F | G | H | I |
|---|---|---|---|---|---|---|---|---|---|
| 1 | MARR = | 12% | | | | | | | |
| 2 | | | | | | | | | |
| 3 | | | | | | | | | |
| 4 | Projects | 1 | 2 | 3 | 4 | 5 | 6 | | |
| 5 | Year | Net cash flows, NCF | | | | | | Maximum Z = | $ 3,893 |
| 6 | 0 | $ (5,000) | $ (8,000) | $ (9,000) | $ (10,000) | | | | |
| 7 | 1 | $ 1,000 | $ 500 | $ 5,000 | $ - | | | | |
| 8 | 2 | $ 1,700 | $ 500 | $ 5,000 | $ - | | | | |
| 9 | 3 | $ 2,400 | $ 500 | $ 2,000 | $ - | | | | |
| 10 | 4 | $ 3,000 | $ 500 | | $ 17,000 | | | | |
| 11 | 5 | $ 3,800 | $ 10,500 | | | | | | |
| 12 | 6 | | | | | | | | |
| 13 | 7 | | | | | | | | |
| 14 | 8 | | | | | | | | |
| 15 | 9 | | | | | | | | |
| 16 | 10 | | | | | | | | |
| 17 | 11 | | | | | | | | |
| 18 | 12 | | | | | | | | |
| 19 | Projects selected | 1 | 0 | 1 | 0 | 0 | 0 | | |
| 20 | PW value at MARR | $ 3,019 | $ (523) | $ 874 | $ 804 | $- | $- | | |
| 21 | Contribution to Z | $ 3,019 | $ - | $ 874 | $ - | $- | $- | | |
| 22 | Investment | $ 5,000 | $ - | $ 9,000 | $ - | $- | $- | Total = | $ 14,000 |
| 23 | | | | | | | | | |

Draw AutoShapes

Solver Parameters

Set Target Cell: $I$5

Equal To: Max Min Value of: 0

By Changing Cells:

$B$19:$G$19

Guess

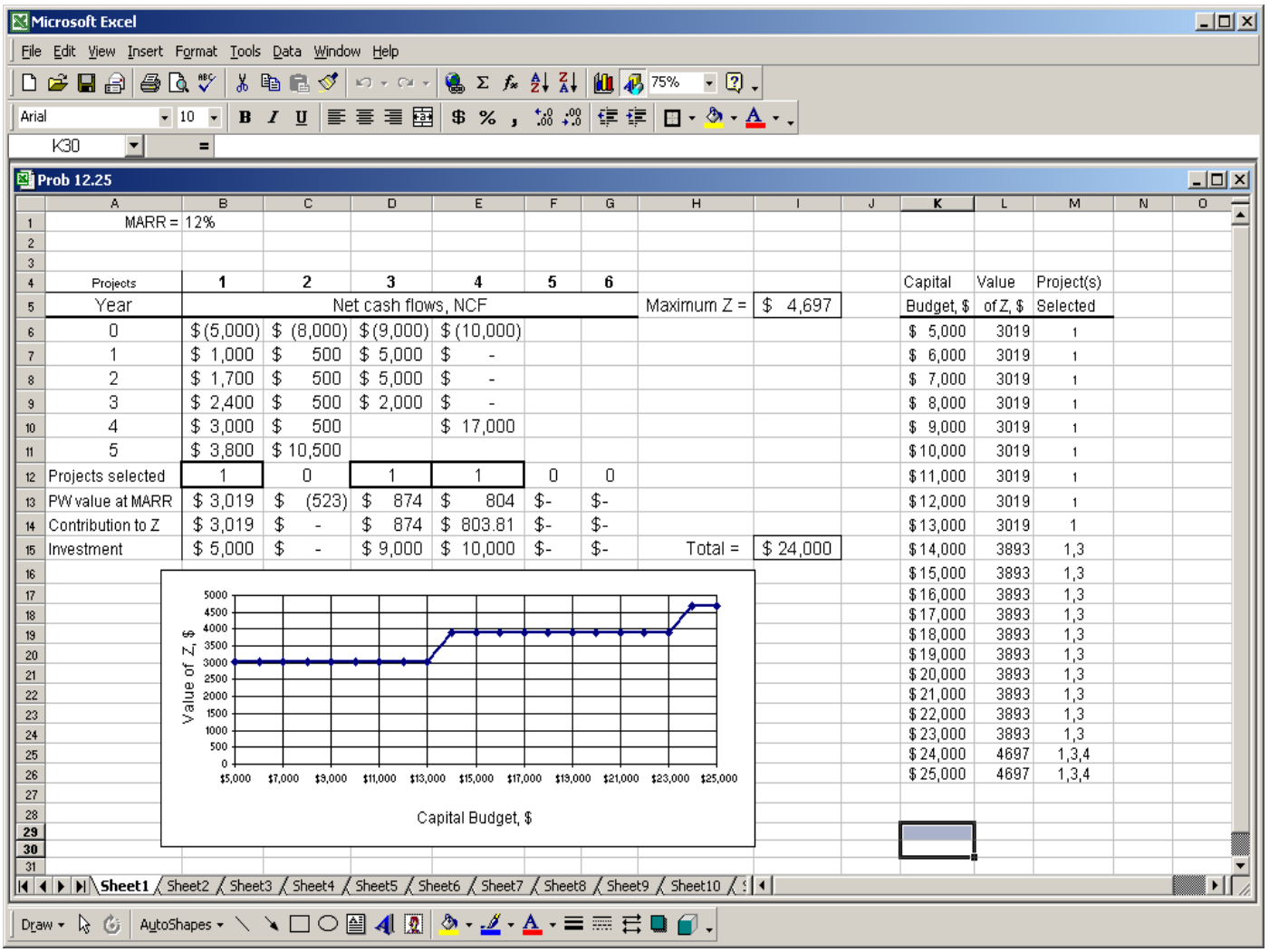
Subject to the Constraints:

$B$19:$G$19 = binary
$I$22 <= 8000

Add
Change
Delete

Solve
Close
Options
Reset All
Help

12.25 Build a spreadsheet and use SOLVER repeatedly at increasing values of b to find the best projects and value of Z. Develop an Excel chart for the two series.



Microsoft Excel

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Arial 10 K30

Prob 12.25

| | A | B | C | D | E | F | G | H | I | J | K | L | M | N | O |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | MARR = | 12% | | | | | | | | | | | | | |
| 2 | | | | | | | | | | | | | | | |
| 3 | | | | | | | | | | | | | | | |
| 4 | Projects | 1 | 2 | 3 | 4 | 5 | 6 | | | | Capital | Value | Project(s) | | |
| 5 | Year | Net cash flows, NCF | | | | | | Maximum Z = | $ 4,697 | | Budget, $ | of Z, $ | Selected | | |
| 6 | 0 | $ (5,000) | $ (8,000) | $ (9,000) | $ (10,000) | | | | | | $ 5,000 | 3019 | 1 | | |
| 7 | 1 | $ 1,000 | $ 500 | $ 5,000 | $ - | | | | | | $ 6,000 | 3019 | 1 | | |
| 8 | 2 | $ 1,700 | $ 500 | $ 5,000 | $ - | | | | | | $ 7,000 | 3019 | 1 | | |
| 9 | 3 | $ 2,400 | $ 500 | $ 2,000 | $ - | | | | | | $ 8,000 | 3019 | 1 | | |
| 10 | 4 | $ 3,000 | $ 500 | | $ 17,000 | | | | | | $ 9,000 | 3019 | 1 | | |
| 11 | 5 | $ 3,800 | $ 10,500 | | | | | | | | $ 10,000 | 3019 | 1 | | |
| 12 | Projects selected | 1 | 0 | 1 | 1 | 0 | 0 | | | | $ 11,000 | 3019 | 1 | | |
| 13 | PW value at MARR | $ 3,019 | $ (523) | $ 874 | $ 804 | $- | $- | | | | $ 12,000 | 3019 | 1 | | |
| 14 | Contribution to Z | $ 3,019 | $ - | $ 874 | $ 803.81 | $- | $- | | | | $ 13,000 | 3019 | 1 | | |
| 15 | Investment | $ 5,000 | $ - | $ 9,000 | $ 10,000 | $- | $- | Total = | $ 24,000 | | $ 14,000 | 3893 | 1,3 | | |
| 16 | | | | | | | | | | | $ 15,000 | 3893 | 1,3 | | |
| 17 | | | | | | | | | | | $ 16,000 | 3893 | 1,3 | | |
| 18 | | | | | | | | | | | $ 17,000 | 3893 | 1,3 | | |
| 19 | | | | | | | | | | | $ 18,000 | 3893 | 1,3 | | |
| 20 | | | | | | | | | | | $ 19,000 | 3893 | 1,3 | | |
| 21 | | | | | | | | | | | $ 20,000 | 3893 | 1,3 | | |
| 22 | | | | | | | | | | | $ 21,000 | 3893 | 1,3 | | |
| 23 | | | | | | | | | | | $ 22,000 | 3893 | 1,3 | | |
| 24 | | | | | | | | | | | $ 23,000 | 3893 | 1,3 | | |
| 25 | | | | | | | | | | | $ 24,000 | 4697 | 1,3,4 | | |
| 26 | | | | | | | | | | | $ 25,000 | 4697 | 1,3,4 | | |
| 27 | | | | | | | | | | | | | | | |
| 28 | | | | | | | | | | | | | | | |
| 29 | | | | | | | | | | | | | | | |
| 30 | | | | | | | | | | | | | | | |
| 31 | | | | | | | | | | | | | | | |



Sheet1 Sheet2 Sheet3 Sheet4 Sheet5 Sheet6 Sheet7 Sheet8 Sheet9 Sheet10

Draw AutoShapes

## Case Study Solution

(1) Rows 5 and 6 of the spreadsheet show the viable bundles for the $3.5 million spending limit and the project relationship.

(2) Projects B and C with PW = $895,000 are the economic choices. This commits only $2.2 million of the allowed $3.5 million.

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A20 =

C12-case study soln

| | A | B | C | D | E | F | G | H | I | J |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | | | | |
| 2 | MARR | 10% | per 6-months | | | | | | | |
| 3 | | | | | | | | | | |
| 4 | Bundle | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 5 | Projects | **A** | **C** | **D** | **AC** | **AD** | **BC** | **CD** | **ABC** | **ACD** |
| 6 | Investment | $(1,000) | $ (200) | $(1,000) | $(1,200) | $(2,000) | $(2,200) | $(1,200) | $(3,200) | $(2,200) |
| 7 | Period | | | | Net cash flows, NCF (X $1000) | | | | | |
| 8 | 0 | $ (500) | $ - | $ (300) | $ (500) | $ (800) | $(2,000) | $ (300) | $(2,500) | $ (800) |
| 9 | 1 | $ - | $ (200) | $ (300) | $ (200) | $ (300) | $ 300 | $ (500) | $ 300 | $ (500) |
| 10 | 2 | $ 100 | $ 50 | $ (100) | $ 150 | $ - | $ 550 | $ (50) | $ 650 | $ 50 |
| 11 | 3 | $ (300) | $ 100 | $ 300 | $ (200) | $ - | $ 700 | $ 400 | $ 400 | $ 100 |
| 12 | 4 | $ 400 | $ 150 | $ 300 | $ 550 | $ 700 | $ 850 | $ 450 | $ 1,250 | $ 850 |
| 13 | 5 | $ 400 | $ - | $ 300 | $ 400 | $ 700 | $ 800 | $ 300 | $ 1,200 | $ 700 |
| 14 | 6 | $ - | $ - | $ 300 | $ - | $ 300 | $ 1,000 | $ 300 | $ 1,000 | $ 300 |
| 15 | | | | | | | | | | |
| 16 | PW value | $ (121) | $ 37 | $ 131 | $ (84) | $ 9 | $ 895 | $ 168 | $ 774 | $ 46 |
| 17 | | | | | | | | | | |
| 18 | Overall i*/ 6-mth | 3.8% | 19.4% | 15.5% | 6.4% | 10.2% | 21.7% | 16.1% | 18.1% | 11.0% |
| 19 | | | | | | | | | | |
| 20 | | | | | | | | | | |

Sheet1 Sheet2 Sheet3 Sheet4 Sheet5 Sheet6 Sheet7 Sh

Draw AutoShapes

(3) Change cash flows, investment amount, life, etc. to obtain a PW and overall i* greater than the results for BC (column G).