e)

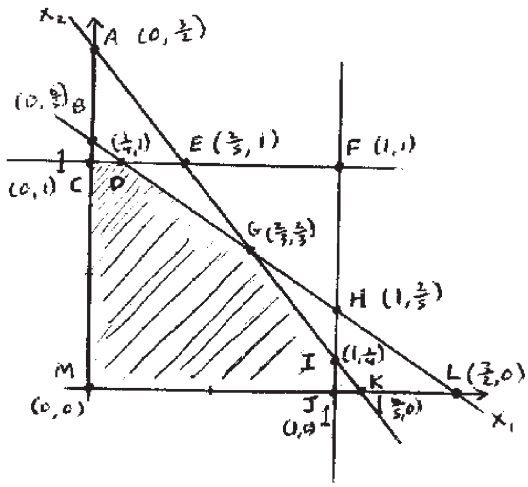
Corner Point	Profit = $3x_1 + 2x_2$	Next Step
D: (0,0)	0	Check points A and C.
A: (0,3)	6	Move to C.
C: (3,0)	9	Check point B.
B: (2,2)	10	Stop, (2,2) is optimal. *

* the next corner point is A, which has already been checked

4.1-4 a), b)

	CP sol'n	Feasible?	Value
A	$(0, \frac{3}{2})$	Infeas.	6750
B	$(0, \frac{6}{5})$	Infeas.	5400
C	$(0, 1)$	Feas.	4500
D	$(\frac{1}{4}, 1)$	F	5625
E	$(\frac{2}{5}, 1)$	I	6300
F	$(1, 1)$	I	9000
G	$(\frac{2}{3}, \frac{2}{3})$	F	6000 *
H	$(1, \frac{2}{5})$	I	6300
I	$(1, \frac{1}{4})$	F	5625
J	$(1, 0)$	F	4500
K	$(\frac{6}{5}, 0)$	I	5400
L	$(\frac{3}{2}, 0)$	I	6750
M	$(0, 0)$	F	0

* optimal



c) Initial Pt M [(0,0)] ⟶ Not optimal since C and J [(0,1) and (1,0)] are better.

Since C and J give same objective value, either can be chosen. We will choose C.

C is not optimal since D [$(\frac{1}{4}, 1)$] is adjacent and better. Move to D.

(Note that B is CP soln but not feasible)

D is not optimal since G [$(\frac{2}{3}, \frac{2}{3})$] is adjacent and better. Move to G.

(Note that G is the only better adjacent CPF sol'n, D is CPF, but worse.)

G is optimal since CPF's D and I give objective values 5625 < 6000.

Note: If J is chosen at first step, the path will be: M - J - I - G (with the same arguments as above).

4.2-3. a) augmented form:

$$\text{Max } 3x_1 + 2x_2$$

s.t.

$$\begin{aligned} x_1 \quad\quad\quad + x_3 \quad\quad\quad &= 4 \\ x_1 + 3x_2 \quad\quad + x_4 \quad &= 15 \\ 2x_1 + x_2 \quad\quad\quad\quad + x_5 &= 10 \end{aligned}$$

$x_1 \geq 0,\ x_2 \geq 0,\ x_3 \geq 0,\ x_4 \geq 0,\ x_5 \geq 0$

b)

	CPF Sol'n	BF Sol'n	Non-basic Var's	Basic Var's
A	(0,0)	(0,0,4,15,10)	x_1, x_2	x_3, x_4, x_5
B	(0,5)	(0,5,4,0,5)	x_1, x_4	x_2, x_3, x_5
C	(3,4)	(3,4,1,0,0)	x_4, x_5	x_1, x_2, x_3
D	(4,2)	(4,2,0,5,0)	x_3, x_5	x_1, x_2, x_4
E	(4,0)	(4,0,0,11,2)	x_2, x_3	x_1, x_4, x_5

c)

BF Sol'n	Set Non-basic Vars to zero	Solve:
A	$x_1 = x_2 = 0$	$x_3 = 4,\ x_4 = 15,\ x_5 = 10$
B	$x_1 = x_4 = 0$	$x_3 = 4$, $3x_2 = 15$, $x_2 + x_5 = 10$ ⟹ $x_2 = 5$, $x_5 = 10 - 5 = 5$
C	$x_4 = x_5 = 0$	$x_1 + x_3 = 4$; $x_1 + 3x_2 = 15$, $2x_1 + x_2 = 10$ ⟹ $2x_1 + 6x_2 = 30$, $2x_1 + x_2 = 10$, $5x_2 = 20$ ⟹ $x_2 = 4$, $x_1 = 3$, $x_3 = 4 - 3 = 1$
D	$x_3 = x_5 = 0$	$x_1 = 4$, $x_1 + 3x_2 + x_4 = 15$, $2x_1 + x_2 = 10$ ⟹ $x_2 = 10 - 2(4) = 2$, $x_4 = 15 - 4 - 3(2) = 5$
E	$x_2 = x_3 = 0$	$x_1 = 4$, $x_1 + x_4 = 15$, $2x_1 + x_5 = 10$ ⟹ $x_4 = 15 - 4 = 11$, $x_5 = 10 - 2(4) = 2$

4.3-2

a) $\max Z = x_1 + 2x_2$

s.t. $x_1 + 3x_2 + x_3 = 8$

$x_1 + x_2 + x_4 = 4$

$x_1 \geq 0,\ x_2 \geq 0,\ x_3 \geq 0,\ x_4 \geq 0$

Initialization: $x_1 = x_2 = 0 \Rightarrow x_3 = 8,\ x_4 = 4$

$Z = x_1 + 2x_2 \Rightarrow Z = 0$, not optimal since improvement rates > 0

Increase x_2 (rate of improvement $= 2$)

"entering basic variable for iteration 1"

$x_1 = 0$, so $x_3 = 8 - 3x_2 \geq 0 \Rightarrow x_2 \leq 8/3 \leftarrow$ min

$x_4 = 4 - x_2 \geq 0 \Rightarrow x_2 \leq 4$

Thus, x_2 can be increased to $8/3 \Rightarrow x_3 = 0$

"leaving basic variable for iteration 1"

Using Gaussian elimination, we get:

$$Z = \frac{1}{3}x_1 - \frac{2}{3}x_3 + \frac{16}{3}$$

$$\frac{1}{3}x_1 + x_2 + \frac{1}{3}x_3 = \frac{8}{3}$$

$$\frac{2}{3}x_1 - \frac{1}{3}x_3 + x_4 = \frac{4}{3} \qquad (x_1, x_2, x_3, x_4 \geq 0)$$

Again $(0, 8/3, 0, 4/3)$ is not optimal since rate of improvement for x_1 is > 0.

Increase x_1, $(x_3 = 0)$

$x_2 = \frac{8}{3} - \frac{1}{3}x_1 \geq 0 \Rightarrow x_1 \leq 8$

$x_4 = \frac{4}{3} - \frac{2}{3}x_1 \geq 0 \Rightarrow x_1 \leq 2 \leftarrow$ min

x_1 can be increased to $2 \Rightarrow x_4 = 0$

4.3-2 a) (cont')

Again, using Gaussian elimination:

$$Z = -\tfrac{1}{2}x_3 - \tfrac{1}{2}x_4 + 6$$

$$x_2 + \tfrac{1}{2}x_3 + \tfrac{1}{2}x_4 = 2$$

$$x_1 \quad - \tfrac{1}{2}x_3 + \tfrac{3}{2}x_4 = 2 \qquad (x_1, x_2, x_3, x_4 \geq 0)$$

Now, we are <u>optimal</u> since increasing x_3 or x_4 would <u>decrease</u> Z.

$$x^* = (2, 2, 0, 0), \quad Z^* = 6 \qquad (\text{i.e. } x_1^* = 2, x_2^* = 2)$$

b) Computer output:

Solve Interactively by the Simplex Method:

```
0) Z-   1 X1-   2 X2+   0 X3+   0 X4 = 0
1)      1 X1+   3 X2+   1 X3+   0 X4 = 8
2)      1 X1+   1 X2+   0 X3+   1 X4 = 4
```

$X_1 \geq 0,\ X_2 \geq 0,\ X_3 \geq 0,\ X_4 \geq 0.$

```
0) Z-0.33 X1+    0 X2+0.67 X3+    0 X4 = 5.33333
1)  0.333 X1+    1 X2+0.33 X3+    0 X4 = 2.66667
2)  0.667 X1+    0 X2-0.33 X3+    1 X4 = 1.33333
```

$X_1 \geq 0,\ X_2 \geq 0,\ X_3 \geq 0,\ X_4 \geq 0.$

```
0) Z+   0 X1+   0 X2+ 0.5 X3+ 0.5 X4 = 6
1)      0 X1+   1 X2+ 0.5 X3- 0.5 X4 = 2
2)      1 X1+   0 X2- 0.5 X3+ 1.5 X4 = 2
```

$X_1 \geq 0,\ X_2 \geq 0,\ X_3 \geq 0,\ X_4 \geq 0.$

$$x_1^* = x_2^* = 2, \quad Z^* = 6$$

c) Again, you get the same solution:

Optimal Solution

Value of the
Objective Function: Z = 6

Variable	Value
X_1	2
X_2	2

Sensitivity Analysis

Objective Function Coefficient

Current Value	Allowable Range To Stay Optimal: Minimum	Maximum
1	0.66667	2
2	1	3

45-1. a) True. The Ratio test tells us how far we can increase the entering basic variable before one of the current basic variables goes to zero. If two variables "tie" for which should be the leaving variable, then <u>both</u> variables go to zero at the same value of the entering basic variable. Since only <u>one</u> variable can become non-basic in any iteration, the other will be basic and zero.

b) False. If there is no leaving basic variable, then the solution is unbounded. (Can increase the entering basic variable indefinitely)

c) True, usually. If we pivot on the column with the zero coefficient, then we will get another optimal solution (remember that the objective value will not change since the "rate of improvement" is zero. The <u>exception</u> occurs when the problem is also <u>degenerate</u>. If the basic variable (which has a coefficient of zero) is itself equal to zero (ie. degenerate), then pivotting on that column will <u>not</u> change the optimal solution.

d) False. Examples: (i) Max $x_1 - x_2$

$$x_1 - x_2 \le 1$$
$$x_1 \ge 0, x_2 \ge 0$$

Clearly, $Z^* = 1$ (optimal) but $x_1^* = k+1,\ x_2^* = k \quad k \in [0, \infty)$

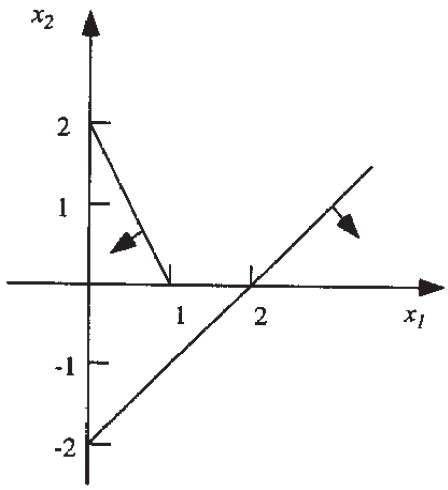
(ii) Max $-x_1$

$$x_1 + x_2 \ge -1$$
$$x_1 \ge 0, x_2 \ge 0$$

This is a trivial example. $x_1^* = 0$, $x_2^* \ge 0$, $Z^* = 0$

4.6-6

a)



b)

Constraint	Activity 1	Activity 2	Totals		Resource
	Contribution Per Unit of Each Activity				
1	2	1	2	≤	2
2	1	-1	1	≥	2
Unit Profit	90	70	**$ 90**		
Solution	**1**	**0**			

Solver could not find a feasible solution.

c)

(0)

Bas Var	Eq No	Z	X1	X2	X3	X4	X5	Right side
Z	0	1	−90	−70	1.0e6	0	1.0e6	0
X1	1	0	2*	1	1	0	0	2
X1	2	0	1	−1	0	−1	1	2

(1)

Bas Var	Eq No	Z	X1	X2	X3	X4	X5	Right side
Z	0	1	0	−25	1.0e6	0	1.0e6	90
X1	1	0	1	0.5	0.5	0	0	1
X1	2	0	0	−1.5	−0.5	−1	1*	1

(2)

Bas Var	Eq No	Z	X1	X2	X3	X4	X5	Right side
Z	0	1	0	1.5e6	1.5e6	1.0e6	0	−1e6
X1	1	0	1	0.5	0.5	0	0	1
X5	2	0	0	−1.5	−0.5	−1	1	1

d)

(0)

Bas Var	Eq No	Z	X1	X2	X3	X4	X5	Right side
Z	0	1	0	0	1	0	1	0
X1	1	0	2*	1	1	0	0	2
X1	2	0	1	−1	0	−1	1	2

(1)

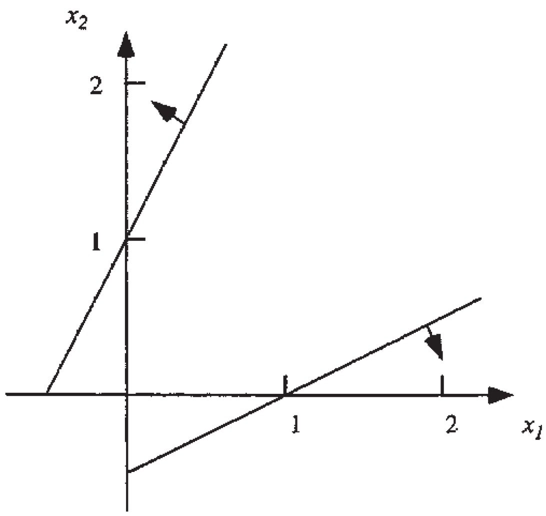
Bas Var	Eq No	Z	X1	X2	X3	X4	X5	Right side
Z	0	1	0	0	1	0	1	0
X1	1	0	1	0.5	0.5	0	0	1
X1	2	0	0	−1.5	−0.5	−1	1*	1

(1)

Bas Var	Eq No	Z	X1	X2	X3	X4	X5	Right side
Z	0	1	0	1.5	1.5	1	0	−1
X1	1	0	1	0.5	0.5	0	0	1
X5	2	0	0	−1.5	−0.5	−1	1	1

4.6-7

a)



b)

Benefit	Benefit Contribution Per Unit of Each Activity: Activity 1	Activity 2	Totals		Minimum Level
1	-2	1	0	≥	1
2	1	-2	0	≥	1
Unit Cost	5000	7000	$ -		
Solution	0	0			

Solver could not find a feasible solution.

c)

(0)

Bas Var	Eq No	Z	X1	X2	X3	X4	X5	X6	Right side
Z	0	1	5000	7000	0	0	1.0e6	1.0e6	0
X1	1	0	−2	1	−1	0	1	0	1
X1	2	0	1*	−2	0	−1	0	1	1

(1)

Bas Var	Eq No	Z	X1	X2	X3	X4	X5	X6	Right side
Z	0	1	0	17000	0	5000	1.0e6	1.0e6	−5000
X1	1	0	0	−3	−1	−2	1	2	3
X1	2	0	1	−2	0	−1	0	1*	1

(2)

Bas Var	Eq No	Z	X1	X2	X3	X4	X5	X6	Right side
Z	0	1	−1e6	2.0e6	0	1.0e6	1.0e6	0	−1e6
X1	1	0	−2	1	−1	0	1*	0	1
X6	2	0	1	−2	0	−1	0	1	1

(CONT'D)

(CONT'D)

(3)

Bas Var	Eq No	Z	X1	X2	X3	X4	X5	X6	Right side
Z	0	1	1.0e6	1.0e6	1.0e6	1.0e6	0	0	−2e6
X5	1	0	−2	1	−1	0	1	0	1
X6	2	0	1	−2	0	−1	0	1	1

d)

(0)

Bas Var	Eq No	Z	X1	X2	X3	X4	X5	X6	Right side
Z	0	1	0	0	0	0	1	1	0
X1	1	0	−2	1	−1	0	1	0	1
X1	2	0	1*	−2	0	−1	0	1	1

(1)

Bas Var	Eq No	Z	X1	X2	X3	X4	X5	X6	Right side
Z	0	1	0	0	0	0	1	1	0
X1	1	0	0	−3	−1	−2	1*	2	3
X1	2	0	1	−2	0	−1	0	1	1

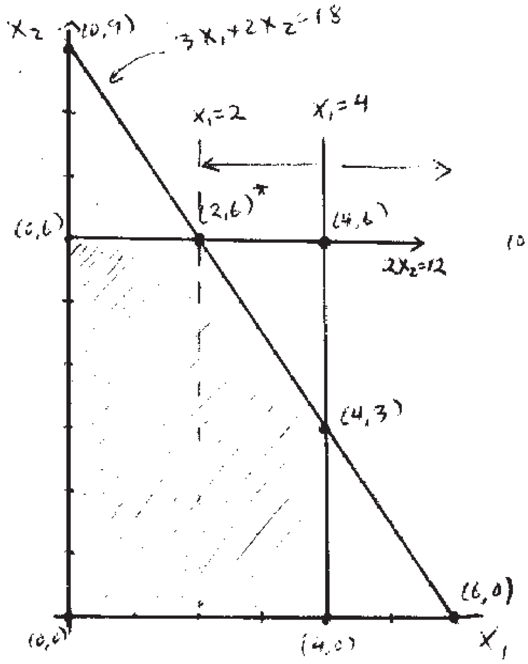
(2)

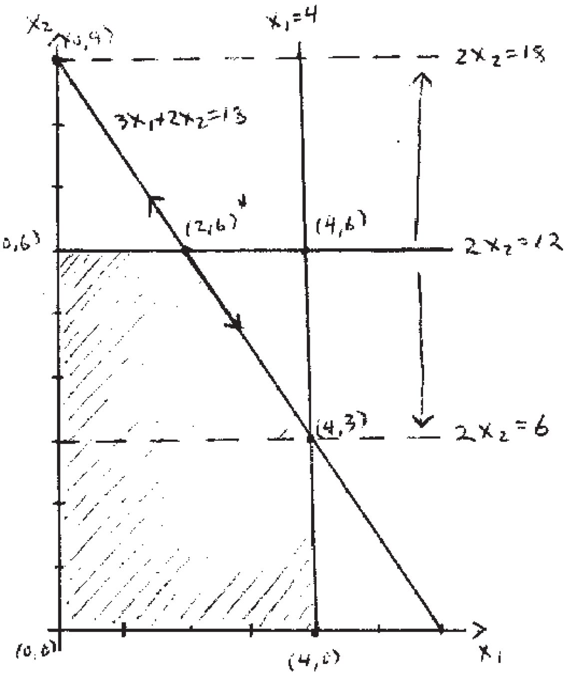
Bas Var	Eq No	Z	X1	X2	X3	X4	X5	X6	Right side
Z	0	1	0	3	1	2	0	−1	−3
X5	1	0	0	−3	−1	−2	1	2	3
X1	2	0	1	−2	0	−1	0	1*	1

(3)

Bas Var	Eq No	Z	X1	X2	X3	X4	X5	X6	Right side
Z	0	1	1	1	1	1	0	0	−2
X5	1	0	−2	1	−1	0	1	0	1
X6	2	0	1	−2	0	−1	0	1	1

4.7-1.

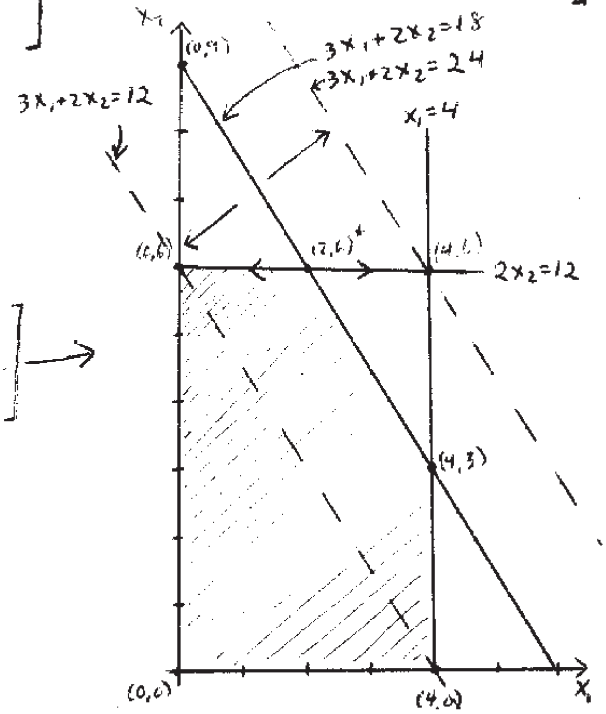




The CP Sol'n (2,6) remains feasible for $x_1 = k$ $2 \le k < \infty$. For $k < 2$, that CP Sol'n become infeasible.
*(2,6) is, of course, the optimal.

The CP Sol'n $\left(\frac{18-k}{3}, \frac{k}{2}\right)$ remains feasible for $2x_2 = k$ $6 \le k \le 18$ only.

The CP Sol'n $\left(\frac{k}{3}-4, 6\right)$ remains feasible for $3x_1+2x_2=k$ $12 \le k \le 24$. (Infeasible for other values of k)



4.7-2. (CONT'D)

Looking at the "— — —" lines, the CP Sol'n ranges from (4,0) to (0,4) as b_1 ranges from 4 to 12. The CP Sol'n becomes infeasible for values of b_1 outside of this range.

[illegible] looking at the "-·-·-" lines, the CP Sol'n ranges from (0,3) [illegible] from $\frac{8}{3}$ to 8.

The allowable ranges are, therefore,

$$4 \le b_1 \le 12$$

$$\text{and } \frac{8}{3} \le b_2 \le 8$$

e)

	1	2		6	Optimal Value
Variables	2	2			
				RHS	
Constraints	1	3	8 <=	8	
	1	1	4 <=	4	

Adjustable Cells

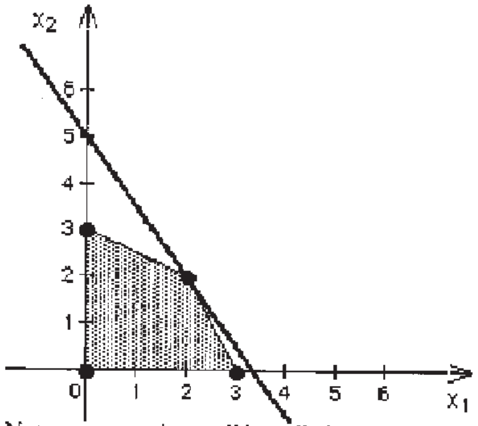
Cell	Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
B2		2	0	1	1	0.333333
C2		2	0	2	1	1

Constraints

Cell	Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
E4		8	0.5	8	4	4
E5		4	0.5	4	4	1.333333

Solution Keys to Chapter 4 Assignment

4.1-2a) a) Optimal Solution: $(x_1, x_2) = (2,2)$ and Profit = 10.



Note: corner points will be called A, B, C, and D going clockwise from (0,3).

b)

Corner Point	Corresponding Constraint Boundary Equations	Corner Point Satisfies the Equations
A: (0,3)	$x_1 = 0$ $x_1 + 2x_2 = 6$	0=0 0+2(3)=6
B: (2,2)	$x_1 + 2x_2 = 6$ $2x_1 + x_2 = 6$	2+2(2)=6 2(2)+2=6
C: (3,0)	$2x_1 + x_2 = 6$ $x_2 = 0$	2(3)+0=6 0=0
D: (0,0)	$x_2 = 0$ $x_1 = 0$	0=0 0=0

c)

Corner Point	Its Adjacent Corner Points
A: (0,3)	(0,0) and (2,2)
B: (2,2)	(0,3) and (3,0)
C: (3,0)	(2,2) and (0,0)
D: (0,0)	(3,0) and (0,3)

d)

Corner Point (x_1, x_2)	Profit $= 3x_1 + 2x_2$
(0,3)	6
(2,2)	10
(3,0)	9
(0,0)	0

Optimal Solution: $(x_1, x_2) = (2,2)$ and Profit = 10.

e)

Corner Point	Profit $= 3x_1 + 2x_2$	Next Step
D: (0,0)	0	Check points A and C.
A: (0,3)	6	Move to C.
C: (3,0)	9	Check point B.
B: (2,2)	10	Stop, (2,2) is optimal. *

* the next corner point is A, which has already been checked

4.3-5 (OUTPUT)

Solve Interactively by the Simplex Method:

```
0) Z-   1 X1-   2 X2-   4 X3+   0 X4+   0 X5+   0 X6 = 0
1)      3 X1+   1 X2+   5 X3+   1 X4+   0 X5+   0 X6 = 10
2)      1 X1+   4 X2+   1 X3+   0 X4+   1 X5+   0 X6 = 8
3)      2 X1+   0 X2+   2 X3+   0 X4+   0 X5+   1 X6 = 7

X1 ≥ C, X2 ≥ 0, X3 ≥ 0, X4 ≥ 0, X5 ≥ 0, X6 ≥ 0.
```

```
C) Z+ 1.4 X1- 1.2 X2+   0 X3+ 0.8 X4+   0 X5+   0 X6 = 8
1)    0.6 X1+ 0.2 X2+   1 X3+ 0.2 X4+   0 X5+   0 X6 = 2
2)    0.4 X1+ 3.8 X2+   0 X3- 0.2 X4+   1 X5+   0 X6 = 6
3)    0.8 X1- 0.4 X2+   0 X3- 0.4 X4+   0 X5+   1 X6 = 3

X1 ≥ 0, X2 ≥ 0, X3 ≥ 0, X4 ≥ 0, X5 ≥ 0, X6 ≥ 0.
```

```
0) Z+1.53 X1+   0 X2+   0 X3+0.74 X4-C.32 X5+   0 X6 = 9.89474
1)   0.579 X1+  0 X2+   1 X3+0.21 X4-C.05 X5+   0 X6 = 1.68421
2)   0.105 X1+  1 X2+   0 X3-0.05 X4-C.26 X5+   0 X6 = 1.57895
3)   0.842 X1+  0 X2+   0 X3-0.42 X4-C.11 X5+   1 X6 = 3.63158

X1 ≥ 0, X2 ≥ 0, X3 ≥ 0, X4 ≥ 0, X5 ≥ 0, X6 ≥ 0.
```

Optimal solution is : $(0, 30/19, 32/19) = (x_1^*, x_2^*, x_3^*)$, $Z^* = 9\frac{17}{19}$

4.3-8

(a) Because $x_2=0$ in the optimal solution, we need only solve the linear program:

Maximize $z = 2x_1 + 3x_3$

subject to:

$$x_1 + 2x_3 \le 30$$
$$x_1 + x_3 \le 24$$
$$3x_1 + 3x_3 \le 60$$
$$x_1 \ge 0,\ x_3 \ge 0.$$

or, equivalently,

Maximize $z = 2x_1 + 3x_3$

subject to:

$$x_1 + 2x_3 \le 30$$
$$x_1 + x_3 \le 20$$
$$x_1 \ge 0 \quad x_3 \ge 0.$$

Since $x_1 > 0$ and $x_3 > 0$ in the optimal solution, they must be basic variables in the optimal solution. Choosing x_1 and x_3 as the first two entering variables will lead directly to the optimal solution. Leaving variables must still be determined by a minimum ratio test.

(b)

(0)

Bas Var	Eq No	Z	X1	X3	X4	X5	Right side
Z	0	1	-2	-3	0	0	0
X4	1	0	1	2*	1	0	30
X5	2	0	1	1	0	1	20

(1)

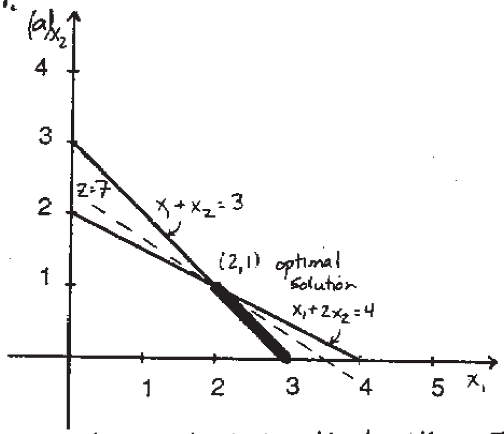
Bas Var	Eq No	Z	X1	X3	X4	X5	Right side
Z	0	1	-0.5	0	1.5	0	45
X3	1	0	0.5	1	0.5	0	15
X5	2	0	0.5*	0	-0.5	1	5

(2)

Bas Var	Eq No	Z	X1	X3	X4	X5	Right side
Z	0	1	0	0	1	1	50
X3	1	0	0	1	1	-1	10
X1	2	0	1	0	-1	2	10

$(x_1, x_2, x_3) = (10, 0, 10)$ is optimal with $z = 50$

4.6-1.



$(x_1, x_2) = (2, 1)$ is optimal with $z = 7$

b)

(0)

Bas Var	Eq No	Z	X_1	X_2	X_3	$\bar{X}_4$	Right Side
Z	0	1	-1M -2	-1M -3	0	0	-3M
$\bar{X}_3$	1	0	1	2	1	0	4
$\bar{X}_4$	2	0	1	1	0	1	3

The initial artificial basic feasible solution is $(x_1, x_2, x_3, x_4) = (0, 0, 4, 3)$.

c)

(1)

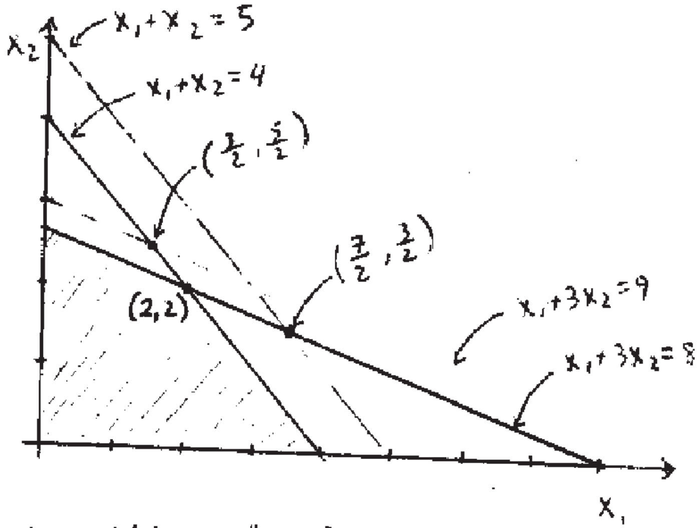
Bas Var	Eq No	Z	X_1	X_2	X_3	$\bar{X}_4$	Right Side
Z	0	1	-0.5M -0.5	0	0.5M +1.5	0	-1M +6
X_2	1	0	0.5	1	0.5	0	2
$\bar{X}_4$	2	0	0.5	0	-0.5	1	1

(2)

Bas Var	Eq No	Z	X_1	X_2	X_3	$\bar{X}_4$	Right Side
Z	0	1	0	0	1	1M +1	7
X_2	1	0	0	1	1	-1	1
X_1	2	0	1	0	-1	2	2

Optimal: $(x_1^*, x_2^*) = (2, 1)$, $Z^* = 7$

4.7-2. a)



Constraint 1 ("– – –" line):

$$\left.\begin{array}{l} x_1+3x_2=8 \rightarrow Z=(2)+2(2)=6 \\ x_1+3x_2=9 \rightarrow Z=(\frac{3}{2})+2(\frac{5}{2})=\frac{13}{2} \end{array}\right\} \Delta Z=\frac{1}{2}=y_1^*$$

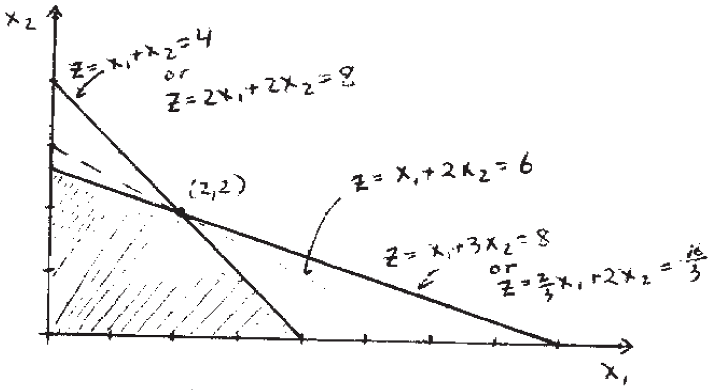
Constraint 2 ("—·—·—" line)

$$\left.\begin{array}{l} x_1+x_2=4 \rightarrow Z=(2)+2(2)=6 \\ x_1+x_2=5 \rightarrow Z=(\frac{7}{2})+2(\frac{3}{2})=\frac{13}{2} \end{array}\right\} \Delta Z=\frac{1}{2}=y_2^*$$

4.7-2

b) From (a), we see that $b_1 = 8$, $b_2 = 4$ are sensitive parameters.
As will be seen in part (c), $c_1 = 1$, $c_2 = 2$ are not sensitive parameters.
As can be seen in the figure in part (a), both constraints are active or binding, so all coefficients $a_{11} = 1$, $a_{12} = 3$, $a_{21} = 1$, $a_{22} = 1$ are sensitive parameters.

c)

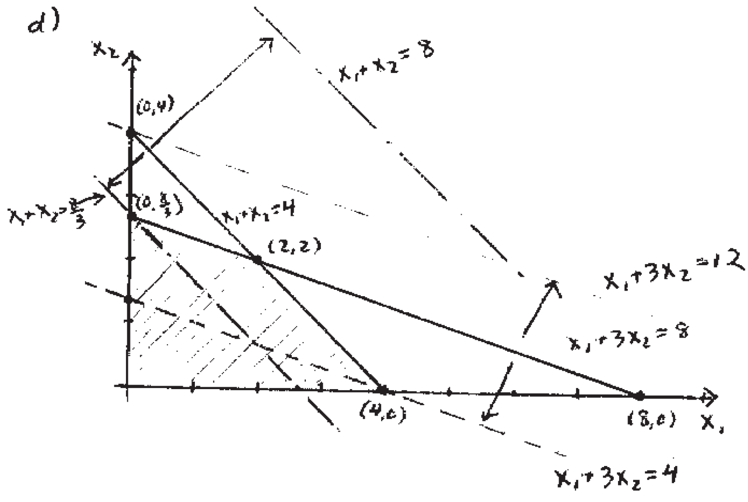


We see that the optimal solution remains the same for:

$$\frac{2}{3} \le c_1 \le 2 \quad (c_2 \text{ fixed at } 2)$$

$$\text{and} \quad 1 \le c_2 \le 3 \quad (c_1 \text{ fixed at } 1)$$

d)



(CONT'D)

4.7-6. a)

(0)

Bas Var	Eq No	Z	x_1	x_2	x_3	x_4	x_5	x_6	Right Side
Z	0	1	-2	2	-3	0	0	0	0
x_4	1	0	-1	1	1	1	0	0	4
x_5	2	0	2	-1	1	0	1	0	2
x_6	3	0	1	1	3	0	0	1	12

(1)

Bas Var	Eq No	Z	x_1	x_2	x_3	x_4	x_5	x_6	Right Side
Z	0	1	4	-1	0	0	3	0	6
x_4	1	0	-3	2	0	1	-1	0	2
x_3	2	0	2	-1	1	0	1	0	2
x_6	3	0	-5	4	0	0	-3	1	6

(2)

Bas Var	Eq No	Z	x_1	x_2	x_3	x_4	x_5	x_6	Right Side
Z	0	1	2.5	0	0	0.5	2.5	0	7
x_2	1	0	-1.5	1	0	0.5	-0.5	0	1
x_3	2	0	0.5	0	1	0.5	0.5	0	3
x_6	3	0	1	0	0	-2	-1	1	2

Optimal: $(x_1^*, x_2^*, x_3^*) = (0, 1, 3)$, $Z^* = 7$

b) The shadow prices are:

$y_1^* = \frac{1}{2}$, $y_2^* = \frac{5}{2}$, $y_3^* = 0$

They are the marginal values of resources 1, 2 and 3, respectively.

c)

	2	-2	3		7	Optimal Value
Variables	0	1	3			
					RHS	
Constraints	-1	1	1	4 <=	4	
	2	-1	1	2 <=	2	
	1	1	3	10 <=	12	

Adjustable Cells

Cell	Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
B3	Variables	0	-2.5	2	2.5	1E+30
C3	Variables	1	0	-2	1.6666667	1
D3	Variables	3	0	3	1E+30	1

Constraints

Cell	Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
F5	Constraints	4	0.5	4	1	2
F6		2	2.5	2	2	6
F7		10	0	12	1E+30	2