

# Question I

HWK4

(a) Original Objective  $\max 4x_1 + 5x_2 - 3x_3$

$$\Rightarrow \min -4x_1 - 5x_2 + 3x_3$$

$$\text{s.t. } x_1 + 2x_2 + 3x_3 = 10$$

$$x_1 - x_2 - x_4 = 6$$

$$x_1 + 3x_2 + x_3 + x_5 = 14$$

$$x_1, \dots, x_5 \geq 0$$

Since constrain 1. already meet the standard formation I, we don't need to introduce a unnecessary slack variable into the system, because the coefficients of the slack variable are not a identical matrix, it's necessary to introduce artificial variables in to the system, which are  $x_6, x_7, x_8$ .

PHASE I  $\min -4x_1 - 5x_2 + 3x_3 \Rightarrow \min x_6 + x_7 + x_8$

$$\text{s.t. } x_1 + 2x_2 + x_3 + x_6 = 10$$

$$x_1 - x_2 - x_4 + x_7 = 6$$

$$x_1 + 3x_2 + x_3 + x_5 = 14$$

x0	x1	x2	x3	x4	x5	x6	x7	RHS
1	0	0	0	0	-1	-1	-1	0
0	1	2	1	0	0	1	0	10
0	1	-1	0	-1	0	0	1	6
0	1	3	1	0	1	0	0	14

  

x0	x1	x2	x3	x4	x5	x6	x7	RHS
1	3	4	2	-1	0	0	0	30
0	1	2	1	0	0	1	0	10
0	1	-1	0	-1	0	0	1	6
0	1	3	1	0	1	0	0	14

  

x0	x1	x2	x3	x4	x5	x6	x7	RHS
1	1.6667	0	0.6667	-1	-1.333	0	0	11.333
0	0.3333	0	0.3333	0	-0.667	1	0	0.6667
0	1.3333	0	0.3333	-1	0.3333	0	1	10.667
0	0.3333	1	0.3333	0	0.3333	0	0	4.6667

  

x0	x1	x2	x3	x4	x5	x6	x7	RHS
1	0	0	-1	-1	2	-5	0	8
0	1	0	1	0	-2	3	0	2
0	0	0	-1	-1	3	-4	1	8
0	0	1	0	0	1	-1	0	4

  

x0	x1	x2	x3	x4	x5	x6	x7	RHS
1	0	0	-0.333	-0.333	0	-2.333	-0.667	2.6667
0	1	0	0.3333	-0.667	0	0.3333	0.6667	7.3333
0	0	0	-0.333	-0.333	1	-1.333	0.3333	2.6667
0	0	1	0.3333	0.3333	0	0.3333	-0.333	1.3333

we have the BFS,  $(x_1, x_2, x_5)$

## PHASE II

$$\min -4x_1 - 5x_2 + 3x_3$$

x0	x1	x2	x3	x4	x5	RHS
1	4	5	-3	0	0	0
0	1	0	0.3333	-0.667	0	7.3333
0	0	0	-0.333	-0.333	1	2.6667
0	0	1	0.3333	0.3333	0	1.3333

  

x0	x1	x2	x3	x4	x5	RHS
1	0	0	-6	1	0	-36
0	1	0	0.3333	-0.667	0	7.3333
0	0	0	-0.333	-0.333	1	2.6667
0	0	1	0.3333	0.3333	0	1.3333

  

x0	x1	x2	x3	x4	x5	RHS
1	0	-3	-7	0	0	-40
0	1	2	1	0	0	10
0	0	1	0	0	1	4
0	0	3	1	1	0	4

Since all the coefficients of  $R_0$  are  $\leq 0$ , which indicates that with the variable increase the objective value will increase, so the original objective will drop, so we got the optimal solution where  $(x_1, x_2, x_3) = (10, 0, 0)$ , so the max value of objective function is 40

(b) Big-M simplex method.

$$\max 4x_1 + 5x_2 - 3x_3$$

$$\Rightarrow \min -4x_1 - 5x_2 + 3x_3$$

$$\Rightarrow \min -4x_1 - 5x_2 + 3x_3 - Mx_6 - Mx_7$$

$$\text{s.t.} \quad x_1 + 2x_2 + x_3 + Mx_6 = 10$$

$$x_1 - x_2 - x_4 + Mx_7 = 6$$

$$x_1 + 3x_2 + x_3 + x_5 = 14$$

x0	x1	x2	x3	x4	x5	x6	x7	RHS
1	4	5	-3	0	0	-100	-100	0
0	1	2	1	0	0	1	0	10
0	1	-1	0	-1	0	0	1	6
0	1	3	1	0	1	0	0	14

  

x0	x1	x2	x3	x4	x5	x6	x7	RHS
1	204	105	97	-100	0	0	0	1600
0	1	2	1	0	0	1	0	10
0	1	-1	0	-1	0	0	1	6
0	1	3	1	0	1	0	0	14

  

x0	x1	x2	x3	x4	x5	x6	x7	RHS
1	169	0	62	-100	-35	0	0	1110
0	0.3333	0	0.3333	0	-0.667	1	0	0.6667
0	1.3333	0	0.3333	-1	0.3333	0	1	10.667
0	0.3333	1	0.3333	0	0.3333	0	0	4.6667

  

x0	x1	x2	x3	x4	x5	x6	x7	RHS
1	0	0	-107	-100	303	-507	0	772
0	1	0	1	0	-2	3	0	2
0	0	0	-1	-1	3	-4	1	8
0	0	1	0	0	1	-1	0	4

  

x0	x1	x2	x3	x4	x5	x6	x7	RHS
1	0	0	-6	1	0	-103	-101	-36
0	1	0	0.3333	-0.667	0	0.3333	0.6667	7.3333
0	0	0	-0.333	-0.333	1	-1.333	0.3333	2.6667
0	0	1	0.3333	0.3333	0	0.3333	-0.333	1.3333

  

x0	x1	x2	x3	x4	x5	x6	x7	RHS
1	0	-3	-7	0	0	-104	-100	-40
0	1	2	1	0	0	1	0	10
0	0	1	0	0	1	-1	0	4
0	0	3	1	1	0	1	-1	4

Since ..... (Same as two-phase) .....

So the last tableau give the optimal solution,  $(x_1, x_2, x_3) = (10, 0, 0)$ , and the max value of the objective function is 40.

## Question II

(a)

x0	x1	x2	x3	x4	x5	x6	x7	RHS	
1	0	53	41	-204	-20	0	0	0	
0	1	-11	-5	18	2	0	0	0	
0	0	4	2	-8	-1	1	0	0	
0	0	11	5	-18	-2	0	1	1	
x0	x1	x2	x3	x4	x5	x6	x7	RHS	
1	0	0	14.5	-98	-6.75	-13.25	0	0	
0	1	0	0.5	-4	-0.75	2.75	0	0	
0	0	1	0.5	-2	-0.25	0.25	0	0	
0	0	0	-0.5	4	0.75	-2.75	1	1	
x0	x1	x2	x3	x4	x5	x6	x7	RHS	
1	-29	0	0	18	15	-93	0	0	
0	2	0	1	-8	-1.5	5.5	0	0	
0	-1	1	0	2	0.5	-2.5	0	0	
0	1	0	0	0	0	0	1	1	
x0	x1	x2	x3	x4	x5	x6	x7	RHS	
1	-20	-9	0	0	10.5	-70.5	0	0	
0	-2	4	1	0	0.5	-4.5	0	0	
0	-0.5	0.5	0	1	0.25	-1.25	0	0	
0	1	0	0	0	0	0	1	1	
x0	x1	x2	x3	x4	x5	x6	x7	RHS	
1	22	-93	-21	0	0	24	0	0	
0	-4	8	2	0	1	-9	0	0	
0	0.5	-1.5	-0.5	1	0	1	0	0	
0	1	0	0	0	0	0	1	1	
x0	x1	x2	x3	x4	x5	x6	x7	RHS	
1	7.5	-49.5	-6.5	-29	0	-5	0	0	
0	0.5	-5.5	-2.5	9	1	0	0	0	
0	0.5	-1.5	-0.5	1	0	1	0	0	
0	1	0	0	0	0	0	1	1	
x0	x1	x2	x3	x4	x5	x6	x7	RHS	
1	0	33	31	-164	-15	-5	0	0	
0	1	-11	-5	18	2	0	0	0	
0	0	4	2	-8	-1	1	0	0	
0	0	11	5	-18	-2	0	1	1	
x0	x1	x2	x3	x4	x5	x6	x7	RHS	
1	0	0	14.5	-98	-6.75	-13.25	0	0	
0	1	0	0.5	-4	-0.75	2.75	0	0	
0	0	1	0.5	-2	-0.25	0.25	0	0	
0	0	0	-0.5	4	0.75	-2.75	1	1	
x0	x1	x2	x3	x4	x5	x6	x7	RHS	
1	-29	0	0	18	15	-93	0	0	
0	2	0	1	-8	-1.5	5.5	0	0	
0	-1	1	0	2	0.5	-2.5	0	0	
0	1	0	0	0	0	0	1	1	

We can see that the matrix is the same when we do 3rd pivot so this pivot rule would cause cycling

(b) Since the coefficients of the slack variables are identical, and the RHS are  $\geq 0$ , so we could start with  $x_5, x_6, x_7$  as bfs. without add artificial variables.

Starting  $x_5, x_6, x_7$ , we can reach the optimal

solution that the coefficients are all  $\geq 0$

So that with the variable growing the objective

value will grow up, so the optimal solution minimize .

is  $(x_1, x_2, x_3, x_4) = (1, 0, 1, 0)$ , the object

value is  $-1$ .

x0	x1	x2	x3	x4	x5	x6	x7	RHS	
1	0	53	41	-204	-20	0	0	0	
0	1	-11	-5	18	2	0	0	0	
0	0	4	2	-8	-1	1	0	0	
0	0	11	5	-18	-2	0	1	1	

  

x0	x1	x2	x3	x4	x5	x6	x7	RHS	
1	0	0	14.5	-98	-6.75	-13.25	0	0	
0	1	0	0.5	-4	-0.75	2.75	0	0	
0	0	1	0.5	-2	-0.25	0.25	0	0	
0	0	0	-0.5	4	0.75	-2.75	1	1	

  

x0	x1	x2	x3	x4	x5	x6	x7	RHS	
1	-29	0	0	18	15	-93	0	0	
0	2	0	1	-8	-1.5	5.5	0	0	
0	-1	1	0	2	0.5	-2.5	0	0	
0	1	0	0	0	0	0	1	1	

  

x0	x1	x2	x3	x4	x5	x6	x7	RHS	
1	-20	-9	0	0	10.5	-70.5	0	0	
0	-2	4	1	0	0.5	-4.5	0	0	
0	-0.5	0.5	0	1	0.25	-1.25	0	0	
0	1	0	0	0	0	0	1	1	

  

x0	x1	x2	x3	x4	x5	x6	x7	RHS	
1	22	-93	-21	0	0	24	0	0	
0	-4	8	2	0	1	-9	0	0	
0	0.5	-1.5	-0.5	1	0	1	0	0	
0	1	0	0	0	0	0	1	1	

  

x0	x1	x2	x3	x4	x5	x6	x7	RHS	
1	0	-27	1	-44	0	-20	0	0	
0	0	-4	-2	8	1	-1	0	0	
0	1	-3	-1	2	0	2	0	0	
0	0	3	1	-2	0	-2	1	1	

  

x0	x1	x2	x3	x4	x5	x6	x7	RHS	
1	0	-30	0	-42	0	-18	-1	-1	
0	0	2	0	4	1	-5	2	2	
0	1	0	0	0	0	0	1	1	
0	0	3	1	-2	0	-2	1	1	

