俞??? 23S003111

1、a) 令 $S_1=\{x \mid x<1\}$ $S_2=\{x \mid x>2\}$

S_1是凸集 $\forall x_1,x_2\in S_1$ $\lambda x_1+(1-\lambda)x_2<\lambda+1-\lambda<1 \in S_1$

S_2是凸集 $\forall x_1,x_2\in S_2$ $\lambda x_1+(1-\lambda)x_2>2\lambda+2(1-\lambda)>2 \in S_2$

$S_1\cup S_2$不是凸集 取$x_1=0$ $x_2=3$ $\lambda=\frac{1}{2}$

有 $\lambda x_1+(1-\lambda)x_2=\frac{3}{2}\notin S_1\cup S_2$

故$S_1\cup S_2$非凸集

b) $\forall x_1,x_2\in S_1, y_1,y_2\in S_2, \lambda\in[0,1]$ 有 $\lambda(x_1+y_1)+(1-\lambda)(x_2+y_2)$

$=\lambda x_1+(1-\lambda)x_2+y_1+(1-\lambda)y_2$

因 S_1, S_2凸

故 $\lambda x_1+(1-\lambda)x_2\in S_1$，记为$x_3$，$x_3\in S_1$

$\lambda y_1+(1-\lambda)y_2\in S_2$，记为$y_3$，$y_3\in S_2$

故 $\lambda x_1+(1-\lambda)x_2+y_1+(1-\lambda)y_2=x_3+y_3\in S_1+S_2$，凸

c) $\forall x_1,x_2\in S_1, y_1,y_2\in S_2, \lambda\in[0,1]$ 有 $\lambda(x_1-y_1)+(1-\lambda)(x_2-y_2)$

$=\lambda x_1+(1-\lambda)x_2-(\lambda y_1+(1-\lambda)y_2)$

S_1,S_2凸 $\Rightarrow$ $\lambda x_1+(1-\lambda)x_2\in S_1$ 记为x_3，$x_3\in S_1$

同理 $\lambda y_1+(1-\lambda)y_2\in S_2$，记为$y_3$，$y_3\in S_2$

故 $\lambda x_1+(1-\lambda)x_2-(\lambda y_1+(1-\lambda)y_2)\in S_1-S_2$

小即 S_1-S_2 凸

2、a) $(0,-2)\in S$ $(2,0)\in S$

取 $\lambda=\frac{1}{2}$ $\frac{1}{2}(0,-2)+\frac{1}{2}(2,0)=(1,-1)$

显然 $(1,-1)\notin S$，S非凸

b) $\forall (x_1,x_2)\in S$, $(x_3,x_4)\in S$

有 $\begin{cases} x_1+x_2\le 6 \\ -2x_1+3x_2\le 2 \\ 4x_1-x_2\le 2 \end{cases}$ $\begin{cases} x_3+x_4\le 6 \\ -2x_3+3x_4\le 2 \\ 4x_3-x_4\le 12 \end{cases}$

对于 $\forall \lambda\in[0,1]$ ① $\lambda x_1+(1-\lambda)x_3+\lambda x_2+(1-\lambda)x_4$

$= \lambda(x_1+x_2)+(1-\lambda)(x_3+x_4)$

$\le 6\lambda+6(1-\lambda)$

≤ 6

② $-2(\lambda x_1+(1-\lambda)x_3)+3(\lambda x_2+(1-\lambda)x_4)$

$= -2\lambda x_1+3\lambda x_2+(-2)(1-\lambda)x_3+3(1-\lambda)x_4$

$\le 2\lambda+2(1-\lambda)$

≤ 2

③ $4(\lambda x_1+(1-\lambda)x_3)-(\lambda x_2+(1-\lambda)x_4)$

$= 4\lambda x_1-\lambda x_2+4(1-\lambda)x_3-(1-\lambda)x_4)$

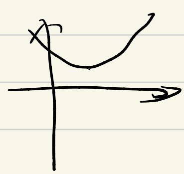
$\le 2\lambda+2(1-\lambda)$

≤ 2

由①②③，$\forall \lambda\in[0,1]$，$\lambda(x_1,x_2)+(1-\lambda)(x_3,x_4)\in S$，

S 凸

c) 记 $S_1=\{x \mid -(x_1-1)^2+x_2\ge 1\}$



$\begin{cases} x_2\ge (x_1-1)^2+1 \\ x_4\ge (x_3-1)^2+1 \end{cases}$

令 $f(x)=(x-1)^2+1$

$\nabla^2 f(x)=2>0$

$\Rightarrow f(x)$ 凸

故 $\lambda f(x_1)+(1-\lambda)f(x_2)\ge f(\lambda x_1+(1-\lambda)x_2)$

有 $\lambda x_2+(1-\lambda)x_4$

$\ge f(\lambda x_1+(1-\lambda)x_3)$

$\ge 1+(\lambda x_1+(1-\lambda)x_3-1)^2$

故 S_1 凸

易得 $S_2=\{x|x_1+x_2\geq 3\}$，$S_3=\{x_1\geq 1\}$ 凸.

$S=S_1\cap S_2\cap S_3$，由凸集交集为凸可得 S 为凸

d) 取 $x_1=-1$ $x_2=1$ $\lambda=\frac{1}{2}$

即 $\lambda x_1+(1-\lambda)x_2=0\notin S$，$S$ 非凸

3、a) 由于 $f_i(x)$ 凸，$i\in 1,\dots,m$ 故 $\forall x_1,x_2\in R$ $\lambda f_i(x_1)+(1-\lambda)f_i(x_2)\geq f_i(\lambda x_1+(1-\lambda)x_2)$ $i\in 1,\dots,m$

$g(x_1)=\max\{f_i(x_1)|i\in 1\dots m\}$ $g(x_2)=\max\{f_i(x_2)|i\in 1,\dots m\}$

$$\begin{aligned}\lambda g(x_1)+(1-\lambda)g(x_2)&=\lambda\max\{f_i(x_1)\}+(1-\lambda)\max\{f_i(x_2)\}\\&\geq\max\{\lambda f_i(x_1)+(1-\lambda)f_i(x_2))|i\in 1\dots m\}\\&\geq g(\lambda x_1+(1-\lambda)x_2)\end{aligned}$$

故 $g(x)$ 凸

b) 非凸

令 $f_1(x)=x$ $f_2(x)=-x$ 显然 f_1,f_2 凸

$$g=\min\{f_i x\}=\begin{cases}x & x\leq 0\\-x & x>0\end{cases}$$

取 $x_1=-1$ $x_2=1$ $\lambda=\frac{1}{2}$

$$\frac{1}{2}g(-1)+\frac{1}{2}g(1)=-1\leq g(\frac{1}{2}\cdot(-1)+\frac{1}{2}\cdot 1)=g(0)=0$$

故 g 非凸

c) $g(x)=\sum_{i=1}^{n}x_i\log x_i$ $\Rightarrow g(\lambda x^{(1)}+(1-\lambda)x^{(2)})=\sum_{i=1}^{n}(\lambda x_i^{(1)}+(1-\lambda)x_i^{(2)})\log(\lambda x_i^{(1)}+(1-\lambda)x_i^{(2)})$

由于 $\partial^2(x\log x)=\frac{1}{x}$ $(x>0)$ 故 $x\log x$ 凸 则 $(\lambda x_1+(1-\lambda)x_2)\log(\lambda x_1+(1-\lambda)x_2)$
$\leq\lambda x_1\log x_1+(1-\lambda)x_2\log((1-\lambda)x_2)$

则 $\sum_{i=1}^{n}(\lambda x_i^{(1)}+(1-\lambda)x_i^{(2)})\log(\lambda x_i^{(1)}+(1-\lambda)x_i^{(2)})\leq\sum_{i=1}^{n}\lambda x_i^{(1)}\log\lambda x_i^{(1)}+\sum_{i=1}^{n}(1-\lambda)x_i^{(2)}\log((1-\lambda)x_i^{(2)})$

$g(x)$ 凸

d) $g(x) = \lfloor x \rfloor = \max\{k \le x,\ k \in \mathbb{Z}\}$ 非凸

$x_1 = 1.9$ $x_2 = 0.9$ 2.8

$\lambda = \frac{1}{2}$

$\lambda g(x_1) + (1-\lambda) g(x_2) = \frac{1}{2}$

$g(x_1 + (1-\lambda) x_2) = \lfloor \frac{1}{2} \times 1.9 + \frac{1}{2} \times 0.9 \rfloor = 1$

故 $\lambda g(x_1) + (1-\lambda) g(x_2) \le g(x_1 + (1-\lambda) x_2)$，非凸

e) $\lambda g(x_1) + (1-\lambda) g(x_2) = \lambda \sum_{i=1}^{k} x_{1(i)} + (1-\lambda) \sum_{i=1}^{k} x_{2(i)}$

$= \lambda x_{1(1)} + \lambda x_{1(2)} + \cdots \lambda x_{1(k)} + (1-\lambda) x_{2(1)} + \cdots + (1-\lambda) x_{2(k)}$

$= (\lambda x_{1(1)} + (1-\lambda) x_{2(1)}) + \cdots + (\lambda x_{1(k)} + (1-\lambda) x_{2(k)})$

$= g(\lambda x_1 + (1-\lambda) x_2)$ $g(x)$ 凸

4. a) $\text{Min } z = -2x_1 - x_2 + 2x_3' - 2x_3''$ s.t. $\begin{cases} x_1 + x_2 + x_3' - x_3'' = 4 \\ x_1 + x_2 - x_3' + x_3'' + x_4 = 6 \\ x_1, x_2, x_3', x_3'', x_4 \ge 0 \end{cases}$

$A = \begin{pmatrix} 1 & 1 & 1 & -1 & 0 \\ 1 & 1 & -1 & 1 & 1 \end{pmatrix}$

$B = (P_1, P_3) \Rightarrow x = (5, 0, -1, 0, 0)^T$ 不满足约束

$B = (P_1, P_4) \Rightarrow x = (5, 0, 0, 1, 0)^T \Rightarrow z = -12$

$B = (P_1, P_5) \Rightarrow x = (4, 0, 0, 0, 2)^T \Rightarrow z = -8$

$B = (P_2, P_3) \Rightarrow x = (0, 5, -1, 0, 0)^T$ 不满足

$B = (P_2, P_4) \Rightarrow x = (0, 5, 0, 1, 0)^T \Rightarrow z = -7$

$B = (P_2, P_5) \Rightarrow x = (0, 4, 0, 0, 2)^T \Rightarrow z = -4$

$B = (P_3, P_5) \Rightarrow x = (0, 0, 4, 0, 10)^T \Rightarrow z = 8$

$B = (P_4, P_5) \Rightarrow x = (0, 0, 0, -4, 2)^T$ 不满足

故最优解 $(5, 0, -1)^T$ $\min z = -12$

b) $\min z = 2x_1 - x_2 + 3x_3 + x_4' - x_4''$ s.t. $\begin{cases} x_1 - x_2 + x_3 + x_4' - x_4'' + x_5 = 7 \\ -2x_1 - 3x_2 - 5x_3 = 8 \\ x_1 - 2x_3 + 2x_4' - 2x_4'' - x_6 = 1 \\ x_1,\ x_2,\ x_3,\ x_4',\ x_4'',\ x_5,\ x_6 \geq 0 \end{cases}$

?

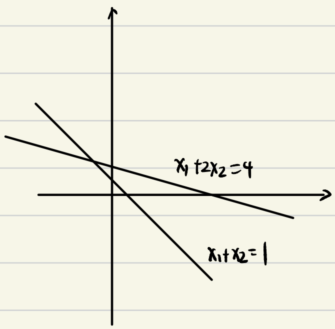
$$A = \begin{pmatrix} 1 & -1 & 1 & 1 & -1 & 1 & 0 \\ -2 & -3 & -5 & 0 & 0 & 0 & 0 \\ 1 & 0 & -2 & 2 & -2 & & -1 \end{pmatrix}$$

由 $-2x_1 - 3x_2 - 5x_3 = 8$ 可知

$x_1,\ x_2,\ x_3$ 至少一者为负，不满足约束

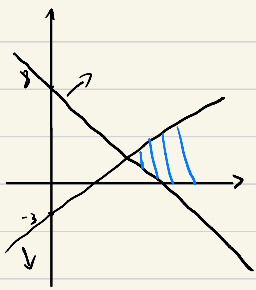
故无基本解

5 a)



可行域为空，无解

b)



$\min f = -x_1 + 3x_2$

由图可知 $x_2 \geq 0$，$x_1 \geq 0$

故 $\min f = -\infty$

6. $A = \begin{pmatrix} 1 & 2 & 3 & -1 & 1 \\ -1 & 1 & -3 & 2 & -1 \end{pmatrix}$ $b = \begin{pmatrix} 4 \\ -5 \end{pmatrix}$

$2x_2 + 3x_3 = 4$

$x_2 - 3x_3 = -5$

$B = (P_1, P_2) \Rightarrow x^T = (\frac{14}{3}, -\frac{1}{3}, 0, 0, 0)$

$-\frac{15}{3}$

$B = (P_1, P_4) \Rightarrow x^T = (3, 0, 0, -1, 0)$

$-\frac{14}{3}$

$B = (P_2, P_3) \Rightarrow x^T = (0, -\frac{1}{3}, \frac{14}{9}, 0, 0)$

7. $B=\begin{pmatrix}2 & 4\\ 4 & 10\end{pmatrix} \Rightarrow B^{-1}=\begin{pmatrix}\frac{5}{2} & -1\\ -1 & \frac{1}{2}\end{pmatrix}$ $\quad N=\begin{pmatrix}2 & 2\\ 0 & 8\end{pmatrix}$

$X_B=\begin{pmatrix}-2\\ 2\end{pmatrix}$ $\quad X_N=\begin{pmatrix}0\\ 0\end{pmatrix}$

$B=\begin{pmatrix}2 & 2\\ 4 & 6\end{pmatrix} \Rightarrow B^{-1}=\begin{pmatrix}1, & -\frac{1}{4}\\ -\frac{1}{2}, & \frac{1}{4}\end{pmatrix}$ $\quad N=\begin{pmatrix}4 & 2\\ 10 & 8\end{pmatrix}$

$X_B=\begin{pmatrix}0\\ 2\end{pmatrix}$ $\quad X_N=\begin{pmatrix}0\\ 0\end{pmatrix}$

8. 必要性　若可行解 x 是基本可行解，不失一般性，设 $x_1,\dots,x_m$ 为基变量，即 $(p_1,\dots p_m)$ 为基矩阵而非基变量 $x_{m+1},\dots x_n=0$. 因是可行解，$x\geq 0$，因此 $x_i\geq 0$。设其中正分量个数为 k，$k\leq m$ 其对应的系数列向量为 $p_1\cdots p_k$，显然 $(p_1\cdots p_k)\subseteq(p_1,\dots,p_m)$. 因为 $p_1\dots p_m$ 线性无关，因此 $p_1\cdots p_k$ 线性无关

充分性　设 $x^T=(x_1,\dots x_k,0\cdots 0)^T$ 是 LP 的可行解，其中正分量 $x_1\dots x_k$ 所对应的系数列向量线性无关，因为 $r(A)=m$，故 $k\leq m$

① $k=m$. 因 $x_i\geq 0$，则由定义，x 为基本可行解

② $k<m$，则 $p_1\dots p_k$ 线性无关，又 $r(A)=r(p_1\cdots p_k,p_{k+1}\cdots p_n)=m$

因此必定可从 $n-k$ 个列向量 $(p_{k+1},\dots p_n)$ 中选出 $(m-k)$ 个列向量，(不失一般性设为 $p_{k+1}\dots p_m$)，与 $p_1\cdots p_k$ 合起来线性无关，即 $(p_1\cdots p_k p_{k+1}\cdots p_m)$ 构成一个基矩阵。与其对应的基变量 $x_i>0$ $(i=1,2,\cdots,k)$ $x_j=0$ $(j=k+1,\dots m)$，其余非基变量均为 0，因此 x 是一个基本可行解.

9. a)　$\max\ z=6x_1+14x_2+13x_3$，s.t. $\begin{cases}x_1+4x_2+2x_3+x_4=48\\ x_1+2x_2+4x_3+x_5=60\\ x_1,x_2,x_3,x_4,x_5\geq 0\end{cases}$

c_B	X_B	b	6	14	13	0	0	
			x_1	x_2	x_3	x_4	x_5	
0	x_4	48	1	$\boxed{4}$	2	1	0	12
0	x_5	60	1	2	4	0	1	30
			6	$\boxed{14}$	13	0	0	
14	x_2	12	$\frac{1}{4}$	1	$\frac{1}{2}$	$\frac{1}{4}$	0	24
0	x_5	36	$\frac{1}{2}$	0	$\boxed{3}$	$-\frac{1}{2}$	1	12
			$\frac{5}{2}$	0	$\boxed{6}$	$-\frac{7}{2}$	0	
14	x_2	6	$\boxed{\frac{1}{6}}$	1	0	$\frac{1}{3}$	$-\frac{1}{6}$	36
13	x_3	12	$\frac{1}{6}$	0	1	$-\frac{1}{6}$	$\frac{1}{3}$	72
			$\boxed{\frac{3}{2}}$	0	0	$-\frac{5}{2}$	-2	
6	x_1	36	1	6	0	2	-1	
13	x_3	6	0	-1	1	$-\frac{1}{2}$	$\frac{1}{2}$	
			0	-22	0	$-\frac{11}{2}$	$-\frac{1}{2}$	

从而有 $X^T=(36,0,6,0,0)$

$\max z = 294$

b) $\max z = -3x_1 + 2x_2 + 4x_3$ s.t. $\begin{cases} 4x_1 + 5x_2 - 2x_3 + x_4 = 22 \\ x_1 - 2x_2 + x_3 + x_5 = 30 \\ x_1, x_2, x_3, x_4, x_5 \geq 0 \end{cases}$

c_B	X_B	b	-3	2	4	0	0	
			x_1	x_2	x_3	x_4	x_5	
0	x_4	22	4	5	-2	1	0	-11
0	x_5	30	1	-2	$\boxed{1}$	0	1	30
			-3	2	$\boxed{4}$	0	0	
0	x_4	82	6	$\boxed{1}$	0	1	2	82
4	x_3	30	1	-2	1	0	1	-15
			-7	$\boxed{10}$	0	0	-4	
2	x_2	82	6	1	0	1	2	
4	x_3	194	13	0	1	2	5	
			-67	0	0	-10	-24	

从而 $X^T=(0,82,194,0,0)$

$\max z = 940$

$\Rightarrow \min = -940$

(c) $\max z = x_1 + x_2 + x_3$, s.t.
$$\begin{cases} -x_1 - 2x_3 + x_4 = 5 \\ 2x_1 - 3x_2 + x_3 + x_5 = 3 \\ 2x_1 - 5x_2 + 6x_3 + x_6 = 5 \\ x_i \geq 0 \quad i = 1 \dots 6 \end{cases}$$

			1	1	1	0	0	0	
			x_1	x_2	x_3	x_4	x_5	x_6	
0	x_4	5	-1	0	-2	1	0	0	-5
0	x_5	3	2	-3	1	0	1	0	$\frac{3}{2}$
0	x_6	5	2	-5	6	0	0	1	$\frac{5}{2}$
			$\boxed{1}$	1	1	0	0	0	
0	x_4	$\frac{13}{2}$	0	$-\frac{3}{2}$	$-\frac{3}{2}$	1	$\frac{1}{2}$	0	$-\frac{13}{3}$
1	x_1	$\frac{3}{2}$	1	$-\frac{3}{2}$	$\frac{1}{2}$	0	$\frac{1}{2}$	0	3
0	x_6	2	0	-2	$\boxed{4}$	0	-2	1	$\frac{1}{2}$
			0	$\frac{5}{2}$	$\boxed{\frac{1}{2}}$	0	$-\frac{1}{2}$	0	
0	x_4	$\frac{29}{4}$	0	$-\frac{9}{4}$	0	1	$-\frac{1}{4}$	$\frac{3}{8}$	-29
1	x_1	$\frac{5}{4}$	1	$-\frac{5}{4}$	0	0	$\boxed{\frac{1}{4}}$	$-\frac{1}{8}$	5
1	x_3	$\frac{1}{2}$	0	$-\frac{1}{2}$	1	0	$-\frac{1}{2}$	$\frac{1}{4}$	-1
			0	$\frac{7}{4}$	0	0	$\boxed{\frac{1}{4}}$	$-\frac{1}{8}$	
0	x_4	$\frac{17}{2}$	1	$-\frac{7}{2}$	0	1	0	$\frac{1}{4}$	
0	x_5	5	4	-5	0	0	1	$-\frac{1}{2}$	
1	x_3	3	2	-3	1	0	0	0	
			-1	$\boxed{2}$	0	0	0	0	

无有界极值。

大M法

10. $\max z = 4x_1 + 2x_2 + 8x_3 - Mx_5$ s.t. $\begin{cases} 2x_1 - x_2 + 3x_3 + x_4 = 30 \\ x_1 + 2x_2 + 4x_3 + x_5 = 40 \\ x_1, x_2, x_3, x_4, x_5 \geq 0 \end{cases}$

			4	2	8	0	$-M$	
			x_1	x_2	x_3	x_4	x_5	
0	x_4	30	2	-1	3	1	0	10
$-M$	x_5	40	1	2	$\boxed{4}$	0	1	10
			$4+M$	$2+2M$	$8+4M$	0	0	
0	x_4	0	$\boxed{\frac{5}{4}}$	$-\frac{5}{2}$	0	1	$-\frac{3}{4}$	0
8	x_3	10	$\frac{1}{4}$	$\frac{1}{2}$	1	0	$\frac{1}{4}$	$\frac{5}{2}$
			$\boxed{2}$	-2	0	0	$-M-2$	
4	x_1	0	1	-2	0	$\frac{4}{5}$	$-\frac{3}{5}$	-0
8	x_3	10	0	$\boxed{1}$	1	$-\frac{1}{5}$	$\frac{2}{5}$	10
			0	2	0	$-\frac{8}{5}$	$-\frac{4}{5}-M$	
4	x_1	20	1	0	2	$\frac{2}{5}$	$\frac{1}{5}$	
2	x_2	10	0	1	1	$-\frac{1}{5}$	$\frac{2}{5}$	
			0	0	-2	$-\frac{6}{5}$	$-M-\frac{8}{5}$	

大M法 $X^T = (20, 10, 0, 0, 0)$

$\max z = 100$

二阶段法，约束不变 $\max h = -x_5$

			0	0	0	0	-1	
			x_1	x_2	x_3	x_4	x_5	
0	x_4	30	2	-1	3	1	0	10
-1	x_5	40	1	2	$\boxed{4}$	0	1	10
			1	2	$\boxed{4}$	0	0	
0	x_4	0	$\frac{5}{4}$	$-\frac{5}{2}$	0	1	$-\frac{3}{4}$	
0	x_3	10	$\frac{1}{4}$	$\frac{1}{2}$	1	0	$\frac{1}{4}$	
			0	0	0	0	-1	

$X^T = (0, 0, 10, 0, 0)$

$h^* = 0$

得到基本解 $X^T = (0, 0, 10, 0)$

			4	2	8	0	
			x_1	x_2	x_3	x_4	
0	x_4	0	$\boxed{\frac{5}{4}}$	$-\frac{5}{2}$	0	1	0
8	x_3	10	$\frac{1}{4}$	$\frac{1}{2}$	1	0	40
			2	-2	0	0	
4	x_1	0	1	-2	0	$\frac{4}{5}$	-2
8	x_3	10	0	$\boxed{1}$	1	$-\frac{1}{5}$	8
			0	2	0	$-\frac{8}{5}$	
4	x_1	20	1	0	2	$\frac{2}{5}$	
2	x_2	10	0	1	1	$-\frac{1}{5}$	
			0	0	-2	$-\frac{6}{5}$	

$x^T = (20, 10, 0, 0)$

$\max z^* = 100$

11. LP: $\begin{cases} \max z = c^T x \\ s.t.\ Ax \le b \\ x \ge 0 \end{cases}$ 的对偶 DP: $\begin{cases} \min f = b^T y \\ s.t.\ A^T y = c \\ x \ge 0 \end{cases}$

对于DP，其对偶为 $\begin{cases} \max g = c^T t \\ s.t.\ (A^T)^T t = b \\ t \ge 0 \end{cases} \Rightarrow \begin{cases} \max g = c^T t \\ s.t.\ At = b \\ t \ge 0 \end{cases}$ 即LP.

12、线性规划问题的原问题与对偶问题具有对称关系，揭示了同一问题的两个侧面

13、a) 正确　有界可行集的最优解必定为极点，故必定为基本解，又因解在可行域内，故为可行解.

b) 正确　多个解则存在非基变量检验数为0，故有无穷解

c) 正确　$r(A) = m$，故基变量为 m 个，其余变量必定为0.

d) 错误　每个顶点都是一个基本可行解，故 m 个基变量，$n-m$ 个非基变量，相邻顶点有1个基与原顶点不同，至多 $m(n-m)$ 种.

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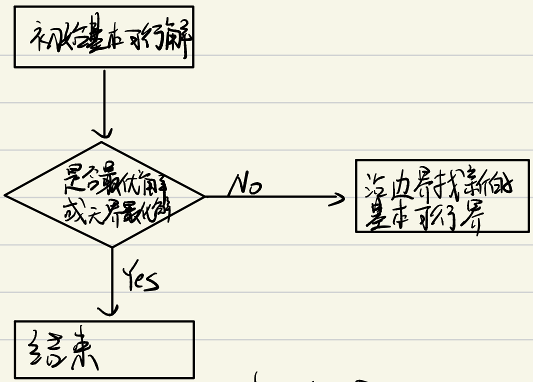

对 9 a) 进行测试，结果如下

```
PS E:\Code\Julia> & "C:/Program Files/Python312/python.exe" e:/Code/Julia/simplex_method.py
model=
 [[ 1.  4.  2.  1.  0. 48.]
 [ 1.  2.  4.  0.  1. 60.]
 [ 6. 14. 13.  0.  0.  0.]]
x= [35.99999999999999, 0.0, 6.000000000000002, 0.0, 0.0]
value= 294.0
```

15.

```julia
using JuMP
using GLPK
model = Model(GLPK.Optimizer)
@variable(model, x1 >= 0, Int)
@variable(model, x2 >= 0, Int)
@variable(model, x3 >= 0, Int)
@variable(model, x4 >= 0, Int)
@variable(model, x5 >= 0, Int)
@constraint(model, c1, x1 + 2x2 + x4 == 100)
@constraint(model, c2, 2x3 + 2x4 + x5 == 100)
@constraint(model, c3, 3x1 + x2 + 2x3 + 3x5 == 100)
@objective(model, Min, 0.1x2 + 0.2x3 + 0.3x4 + 0.8x5)
print(model)
optimize!(model)
println("min=",objective_value(model))
println("x1=", value(x1))
println("x2=", value(x2))
println("x3=", value(x3))
println("x4=", value(x4))
println("x5=", value(x5))
```

问题　输出　调试控制台　终端　端口

```
Min 0.1 x2 + 0.2 x3 + 0.3 x4 + 0.8 x5
Subject to
 c1 : x1 + 2 x2 + x4 == 100
 c2 : 2 x3 + 2 x4 + x5 == 100
 c3 : 3 x1 + x2 + 2 x3 + 3 x5 == 100
 x1 >= 0
 x2 >= 0
 x3 >= 0
 x4 >= 0
 x5 >= 0
 x1 integer
 x2 integer
 x3 integer
 x4 integer
 x5 integer
min=16.0
x1=30.0
x2=10.0
x3=0.0
x4=50.0
x5=0.0

julia> z
```