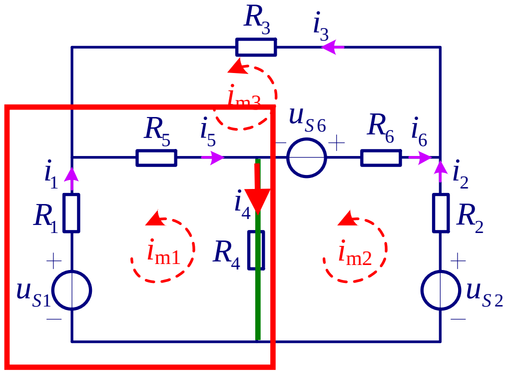
2、网孔分析法



$$\begin{cases} i_1 = -i_{m1} \\ i_2 = i_{m2} \\ i_3 = i_{m3} \\ i_4 = i_{m2} - i_{m1} \\ i_5 = i_{m3} - i_{m1} \\ i_6 = i_{m3} - i_{m2} \end{cases}$$

$$\begin{cases} i_1R_1 + i_5R_5 + i_4R_4 = u_{s1} \\ i_2R_2 + i_4R_4 - i_6R_6 = u_{s2} - u_{s6} \\ i_3R_3 + i_5R_5 + i_6R_6 = u_{s6} \end{cases}$$

$$\begin{cases} i_{m1}R_1 + (i_{m1} - i_{m3})R_5 + (i_{m1} - i_{m2})R_4 = -u_{s1} \\ i_{m2}R_2 + (i_{m2} - i_{m1})R_4 - (i_{m3} - i_{m2})R_6 = u_{s2} - u_{s6} \\ i_{m3}R_3 + (i_{m3} - i_{m1})R_5 + (i_{m3} - i_{m2})R_6 = u_{s6} \end{cases}$$

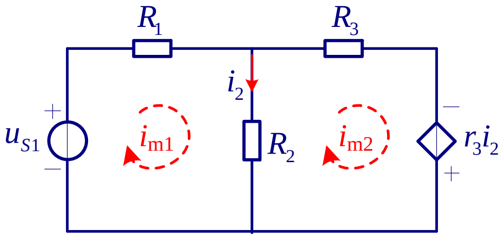
自电阻　　互电阻

$$\begin{bmatrix} R_1 + R_4 + R_5 & -R_4 & -R_5 \\ -R_4 & R_2 + R_4 + R_6 & -R_6 \\ -R_5 & -R_6 & R_3 + R_5 + R_6 \end{bmatrix} \begin{bmatrix} i_{m1} \\ i_{m2} \\ i_{m3} \end{bmatrix} = \begin{bmatrix} -u_{s1} \\ u_{s2} - u_{s6} \\ u_{s6} \end{bmatrix}$$

$$\begin{cases} (R_1 + R_4 + R_5)i_{m1} - R_4i_{m2} - R_5i_{m3} = -u_{s1} \\ -R_4i_{m1} + (R_2 + R_4 + R_6)i_{m2} - R_6i_{m3} = u_{s2} - u_{s6} \\ -R_5i_{m1} - R_6i_{m2} + (R_3 + R_5 + R_6)i_{m3} = u_{s6} \end{cases}$$

回路中所有电压源电压升的代数和

例：试列出图示含受控源网络的网孔电流方程 **思考：**

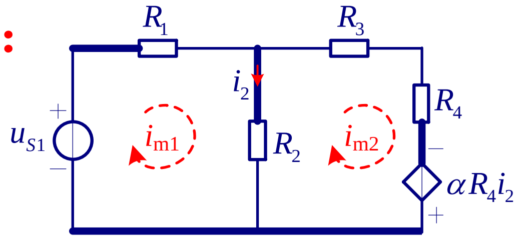


$$\begin{bmatrix} R_1+R_2 & -R_2 \\ -R_2 & R_2+R_3 \end{bmatrix}\begin{bmatrix} i_{m1} \\ i_{m2} \end{bmatrix}=\begin{bmatrix} u_{s1} \\ r_3 i_2 \end{bmatrix}$$

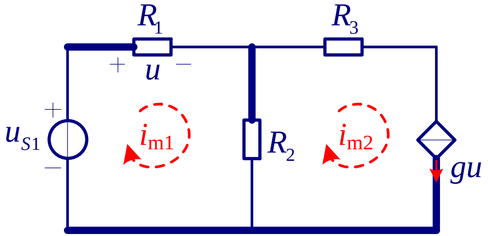
$$\because i_2 = i_{m1} - i_{m2}$$

$$\begin{bmatrix} R_1+R_2 & -R_2 \\ -R_2 & R_2+R_3 \end{bmatrix}\begin{bmatrix} i_{m1} \\ i_{m2} \end{bmatrix}=\begin{bmatrix} u_{s1} \\ r_3(i_{m1}-i_{m2}) \end{bmatrix}$$

$$\begin{bmatrix} R_1+R_2 & -R_2 \\ -R_2-r_3 & R_2+R_3+r_3 \end{bmatrix}\begin{bmatrix} i_{m1} \\ i_{m2} \end{bmatrix}=\begin{bmatrix} u_{s1} \\ 0 \end{bmatrix}$$



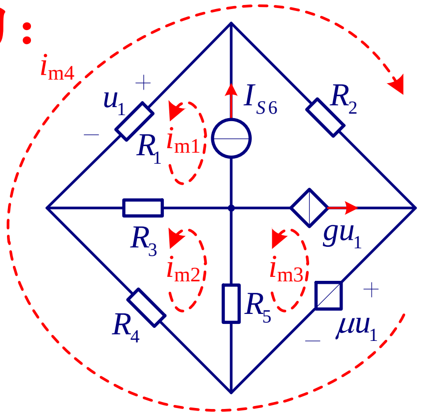
$$\begin{bmatrix} R_1+R_2 & -R_2 \\ -R_2-\alpha R_4 & R_2+R_3+R_4+\alpha R_4 \end{bmatrix}\begin{bmatrix} i_{m1} \\ i_{m2} \end{bmatrix}=\begin{bmatrix} u_{s1} \\ 0 \end{bmatrix}$$



$$\begin{cases} (R_1+R_2)i_{m1} - R_2 i_{m2} = u_{s1} \\ i_{m2} = gu \\ u = R_1 i_{m1} \end{cases}$$

$$\begin{bmatrix} R_1+R_2 & -R_2 \\ -gR_1 & 1 \end{bmatrix}\begin{bmatrix} i_{m1} \\ i_{m2} \end{bmatrix}=\begin{bmatrix} u_{s1} \\ 0 \end{bmatrix}$$

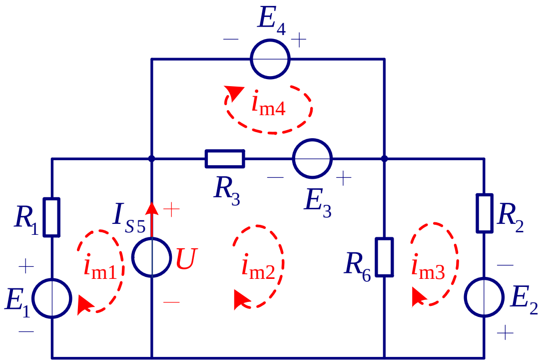
练习：



虚网孔法

$$\begin{bmatrix} 1 & 0 & 0 & 0 \\ -R_3 & R_3+R_4+R_5 & -R_5 & -R_4 \\ gR_1 & 0 & 1 & -gR_1 \\ -R_1+\mu R_1 & -R_4 & 0 & R_1+R_2+R_4-\mu R_1 \end{bmatrix} \begin{bmatrix} i_{m1} \\ i_{m2} \\ i_{m3} \\ i_{m4} \end{bmatrix} = \begin{bmatrix} I_{S6} \\ 0 \\ 0 \\ 0 \end{bmatrix}$$

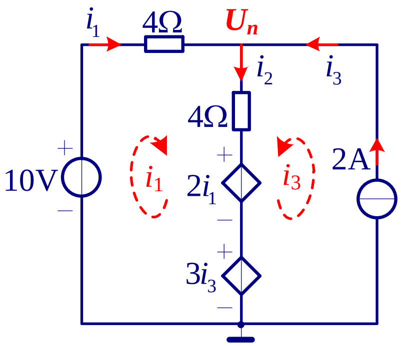
$$u_1 = R_1(i_{m1} - i_{m4})$$



改进的网孔法

$$\begin{bmatrix} R_1 & 0 & 0 & 0 & 1 \\ 0 & R_3+R_6 & -R_6 & -R_3 & -1 \\ 0 & -R_6 & R_2+R_6 & 0 & 0 \\ 0 & -R_3 & 0 & R_3 & 0 \\ -1 & 1 & 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} i_{m1} \\ i_{m2} \\ i_{m3} \\ i_{m4} \\ U \end{bmatrix} = \begin{bmatrix} E_1 \\ E_3 \\ E_2 \\ E_4 - E_3 \\ I_{S5} \end{bmatrix}$$

课前练习：试用结点分析法/网孔（或回路）分析法求出下图中的i_1和U_n



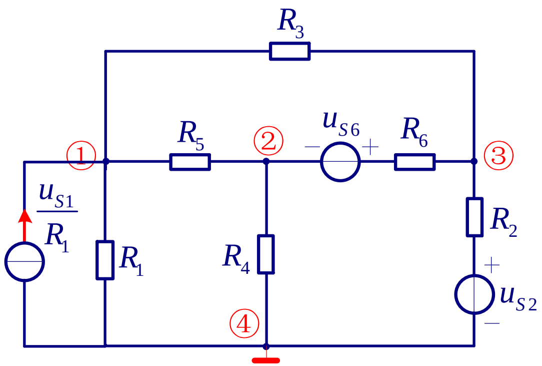
$$\begin{cases}\left(\frac{1}{4}+\frac{1}{4}\right)U_n=\frac{10}{4}+\frac{2i_1+3i_3}{4}+2\\ i_3=2\\ i_1=\frac{10-U_n}{4}\end{cases}$$

$$\begin{cases}U_n=11.6\text{V}\\ i_1=-0.4\text{A}\end{cases}$$

$$\begin{bmatrix}4+4 & 4\\ 0 & 1\end{bmatrix}\begin{bmatrix}i_1\\ i_3\end{bmatrix}=\begin{bmatrix}10-2i_1-3i_3\\ 2\end{bmatrix}$$

$$\begin{cases}10=4i_1+4(i_1+i_3)+2i_1+3i_3\\ i_3=2\\ U_n=10-4i_1\end{cases}$$

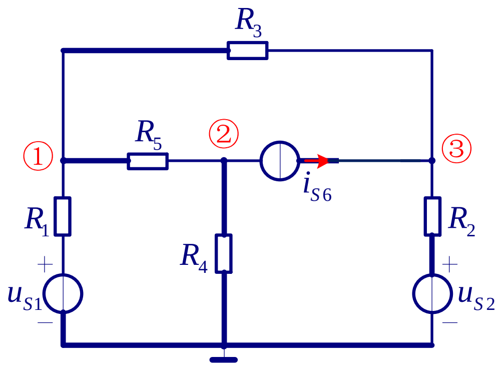
3、结点分析法



结点①的KCL：$$\frac{u_{n1}}{R_1}+\frac{u_{n1}-u_{n2}}{R_5}+\frac{u_{n1}-u_{n3}}{R_3}=\frac{u_{S1}}{R_1}$$

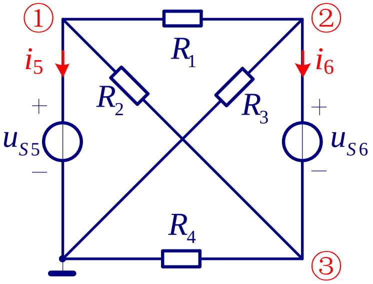
$$\underbrace{(G_1+G_3+G_5)}_{\text{自电导}}u_{n1}\underbrace{-G_5}_{\text{互电导}}u_{n2}\underbrace{-G_3}u_{n3}=G_1u_{S1}$$

$$\begin{bmatrix} G_1+G_3+G_5 & -G_5 & -G_3 \\ -G_5 & G_4+G_5+G_6 & -G_6 \\ -G_3 & -G_6 & G_2+G_3+G_6 \end{bmatrix}\begin{bmatrix} u_{n1} \\ u_{n2} \\ u_{n3} \end{bmatrix}=\begin{bmatrix} G_1u_{S1} \\ -G_6u_{S6} \\ G_2u_{S2}+G_6u_{S6} \end{bmatrix}$$



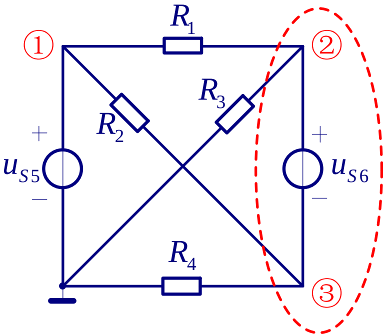
$$\begin{bmatrix} G_1+G_3+G_5 & -G_5 & -G_3 \\ -G_5 & G_4+G_5 & 0 \\ -G_3 & 0 & G_2+G_3 \end{bmatrix}\begin{bmatrix} u_{n1} \\ u_{n2} \\ u_{n3} \end{bmatrix}=\begin{bmatrix} G_1u_{S1} \\ -i_{S6} \\ G_2u_{S2}+i_{S6} \end{bmatrix}$$

例：试列出图示含无伴电压源支路网络的结点电压方程



$$\begin{bmatrix} G_1+G_2 & -G_1 & -G_2 & 1 & 0 \\ -G_1 & G_1+G_3 & 0 & 0 & 1 \\ -G_2 & 0 & G_2+G_4 & 0 & -1 \\ 1 & 0 & 0 & 0 & 0 \\ 0 & 1 & -1 & 0 & 0 \end{bmatrix}\begin{bmatrix} u_{n1} \\ u_{n2} \\ u_{n3} \\ i_5 \\ i_6 \end{bmatrix}=\begin{bmatrix} 0 \\ 0 \\ 0 \\ u_{S5} \\ u_{S6} \end{bmatrix}$$

改进的结点法

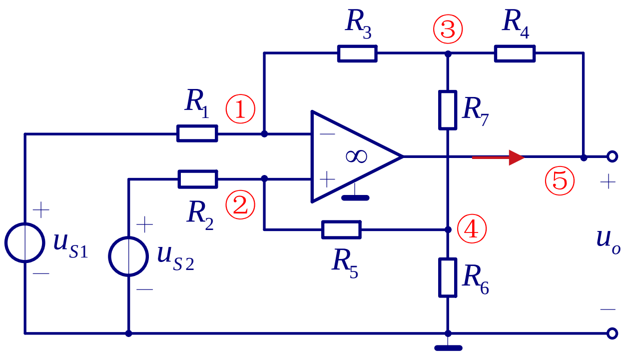


$$\begin{cases} u_{n1}=u_{S5} \\ G_1(u_{n2}-u_{n1})+G_3u_{n2}+G_2(u_{n3}-u_{n1})+G_4u_{n3}=0 \\ u_{n2}-u_{n3}=u_{S6} \end{cases}$$

$$\begin{bmatrix} 1 & 0 & 0 \\ -(G_1+G_2) & G_1+G_3 & G_2+G_4 \\ 0 & 1 & -1 \end{bmatrix}\begin{bmatrix} u_{n1} \\ u_{n2} \\ u_{n3} \end{bmatrix}=\begin{bmatrix} u_{S5} \\ 0 \\ u_{S6} \end{bmatrix}$$

虚结点与广义结点

例：列出含理想运算放大器电路的结点电压方程

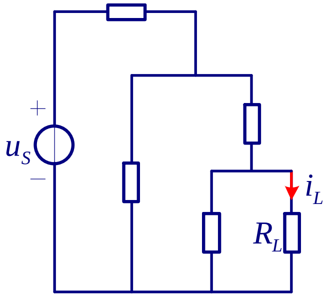


$$\begin{bmatrix} G_1+G_3 & 0 & -G_3 & 0 & 0 \\ 0 & G_2+G_5 & 0 & -G_5 & 0 \\ -G_3 & 0 & G_3+G_4+G_7 & -G_7 & -G_4 \\ 0 & -G_5 & -G_7 & G_5+G_6+G_7 & 0 \\ 1 & -1 & 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} u_{n1} \\ u_{n2} \\ u_{n3} \\ u_{n4} \\ u_{n5} \end{bmatrix} = \begin{bmatrix} G_1 u_{S1} \\ G_2 u_{S2} \\ 0 \\ 0 \\ 0 \end{bmatrix}$$

电路定理

1、齐次定理

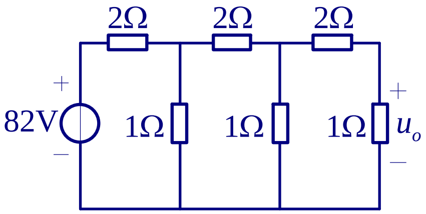
线性网络中，当全部激励（独立电压源和独立电流源）同时增大**k**（**k**为任意常数）倍时，其响应也相应增大**k**倍。此结论称为齐次定理，也称齐次性。若线性电路中只有一个独立源，则根据齐次定理，该线性电路中的响应与该激励成正比。



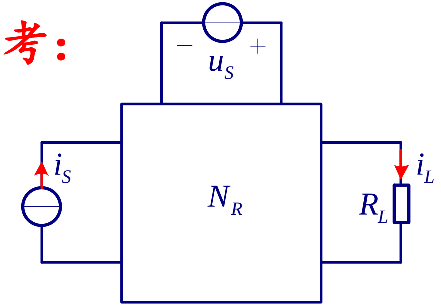
$$\frac{i_L}{u_S} = K$$

$$\therefore i_L = K u_S$$

练习：求出图中的u_o



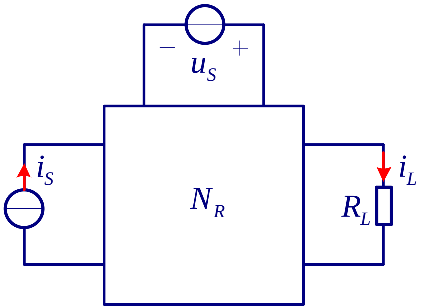
思考：

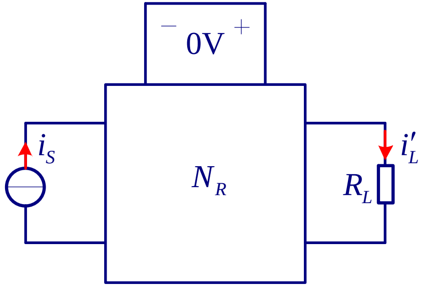


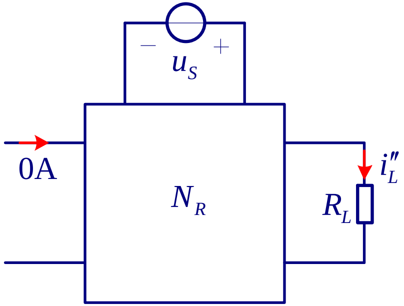
$$i_L = f(u_S, i_S)$$

2、叠加定理

由线性元件和独立电源组成的网络N，其中每一支路的响应(电压或电流)都等于各个独立源单独作用于网络 N 时在该支路中产生的响应的代数和。







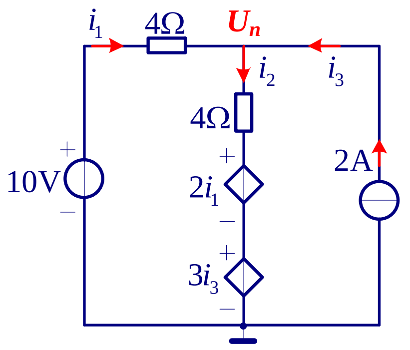
$$i_L = f(u_S, i_S) = f(0, i_S) + f(u_S, 0)$$

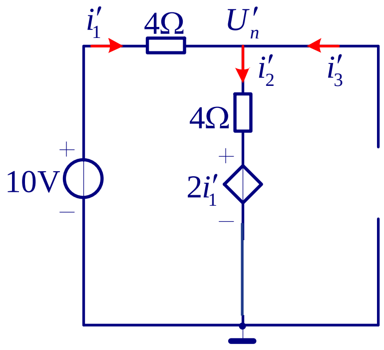
$$i_L' = K_1 i_S$$

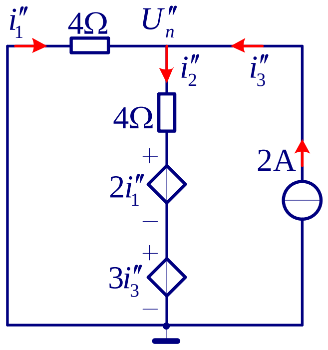
$$i_L'' = K_2 u_S$$

$$\therefore i_L = K_1 i_S + K_2 u_S$$

例：试用叠加定理求出下图中的i_1和U_n







$$i_1 = i_1' + i_1'' = -0.4\text{A}$$

$$U_n = 4(i_1+2)+2i_1+3\times 2$$
$$= 6i_1 + 14 = 11.6\text{V}$$

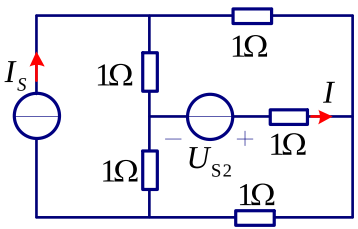
$$10 = 4i_1' + 4i_1' + 2i_1'$$
$$i_1' = 1\text{A}$$
$$U_n' = 6i_1' = 6\text{V}$$

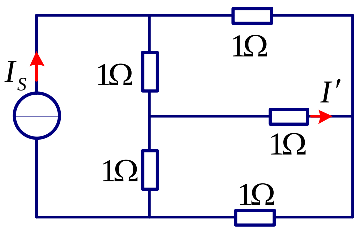
$$4i_1'' + 4(i_1''+2) + 2i_1'' + 3\times 2 = 0$$
$$i_1'' = -1.4\text{A}$$
$$U_n'' = -4i_1'' = 5.6\text{V}$$

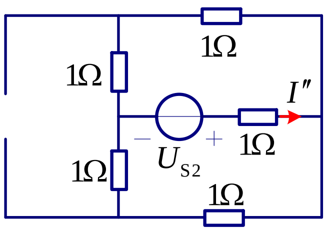
$P_{us} = 10i_1 = -4\text{W}$ $\quad P_{is} = 2U_n = 23.2\text{W}$

功率一般不要用叠加定理求得

练习：试求图示电路中的I







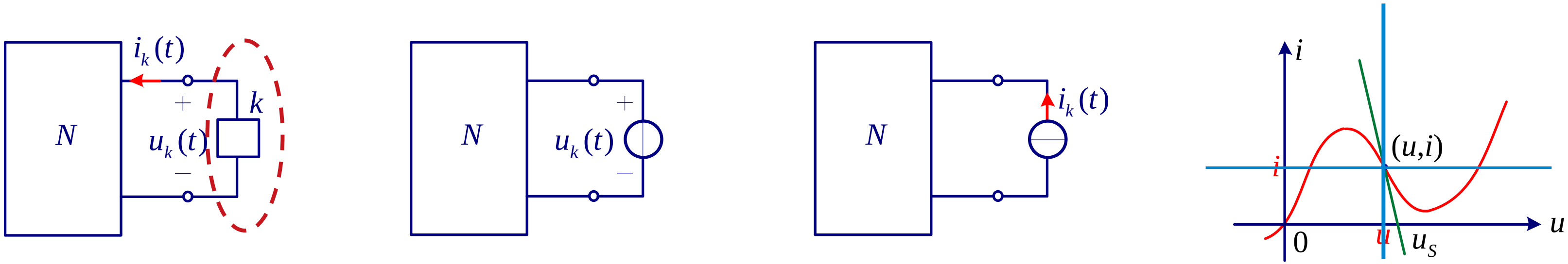
$$I = I' + I'' = \frac{U_{S2}}{2}$$

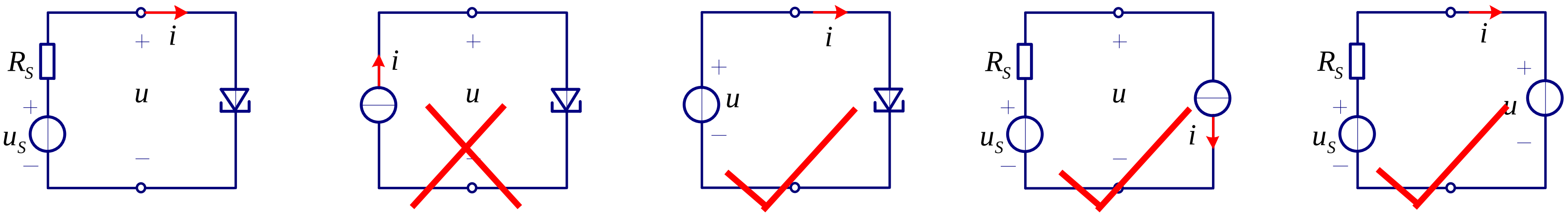
$$I' = 0\text{A}$$

$$I'' = \frac{U_{S2}}{2}$$

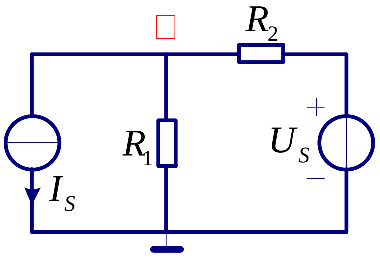
3、置换定理

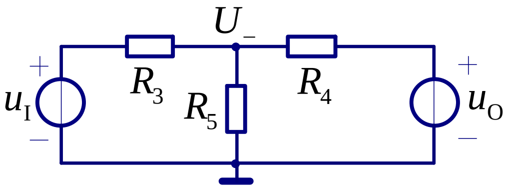
一个有**唯一解**的网络N，若已知第k条支路的电压和电流为u_k、i_k，则不论该支路是由什么元件组成，总可以用电压为$u_S=u_k$的电压源或电流为$i_S=i_k$的电流源替代，此时整个网络N的工作状态不受影响。





应用：





$$(G_1+G_2)U_{n1}=G_2U_S-I_S$$

$$U_{n1}=\frac{G_2U_S-I_S}{G_1+G_2}$$

$$U_-=\frac{G_3u_I+G_4u_O}{G_3+G_4+G_5}$$

两结点网络的结点电压公式