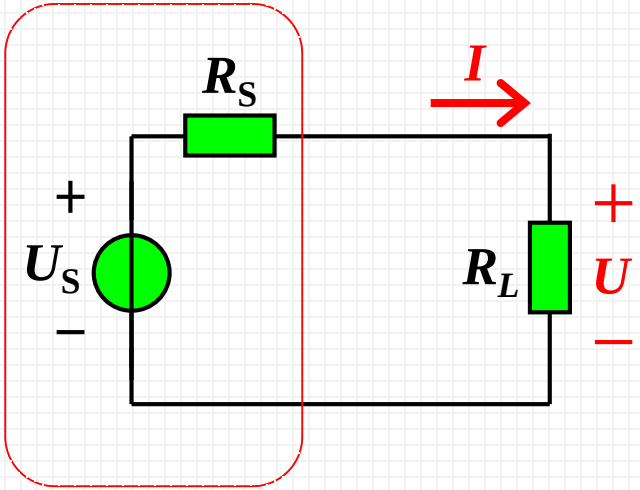

1
电路原理习题课

0、求能够获得最大功率的 R_L 并求其获得的最大功率。



解： $I=\dfrac{U_S}{R_S+R_L}$ $P_L=I^2R_L=\left(\dfrac{U_S}{R_S+R_L}\right)^2\cdot R_L$

$$\frac{\mathrm{d}P_L}{\mathrm{d}R_L}=U_S^2\left(\frac{1}{(R_S+R_L)^2}-\frac{2R_L}{(R_S+R_L)^3}\right)$$

$$=U_S^2\left(\frac{R_S-R_L}{(R_S+R_L)^3}\right)$$

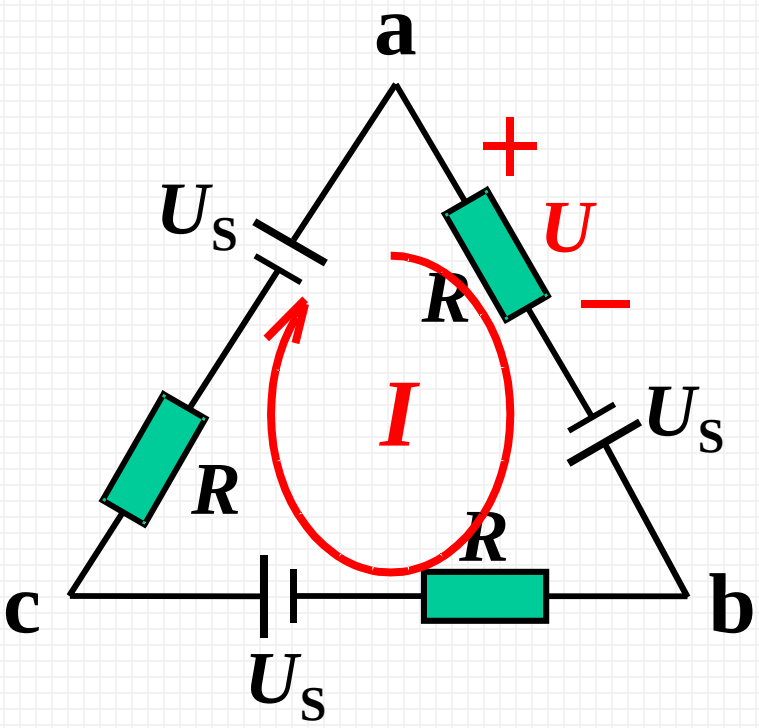
$R_L=R_S$ **是R_L获得最大功率的充要条件**

电阻匹配

$$U=\frac{U_S}{2},\ \eta=50\%,\ P_L=\frac{U_S^{\ 2}}{4R_S}$$

把负载获得最大电压和最大功率对比进行思考和记忆！！

一、求U_{ab}

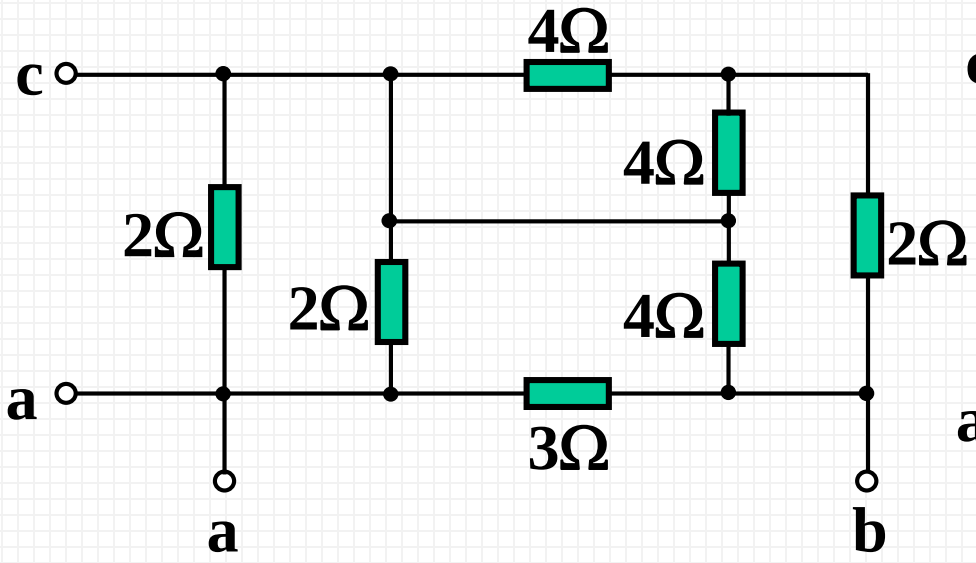


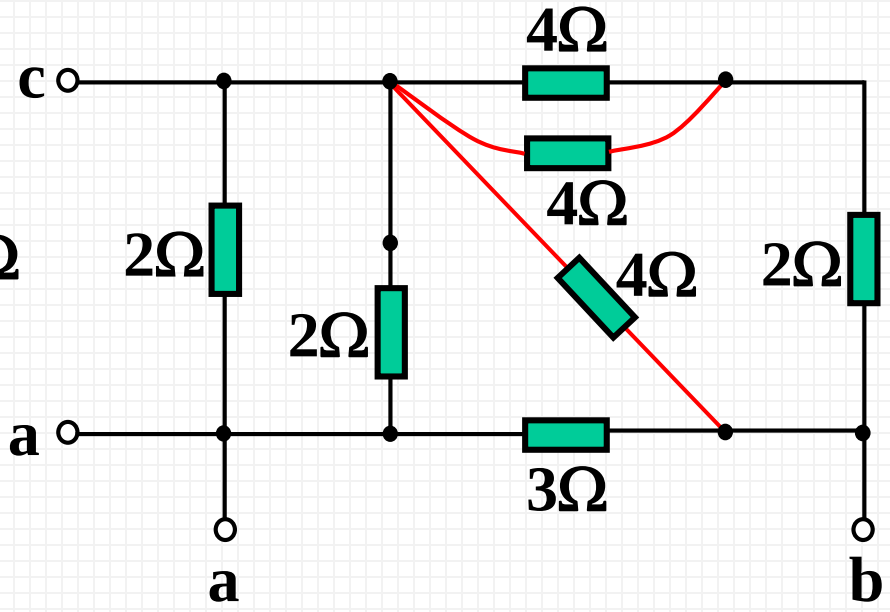
$$I=\frac{3U_S}{3R}=\frac{U_S}{R}$$

$$U=RI=R\times\frac{U_S}{R}=U_S$$

$$U_{ab}=U-U_S=U_S-U_S=0$$

二、(a) 求 R_{ab}、R_{ac}

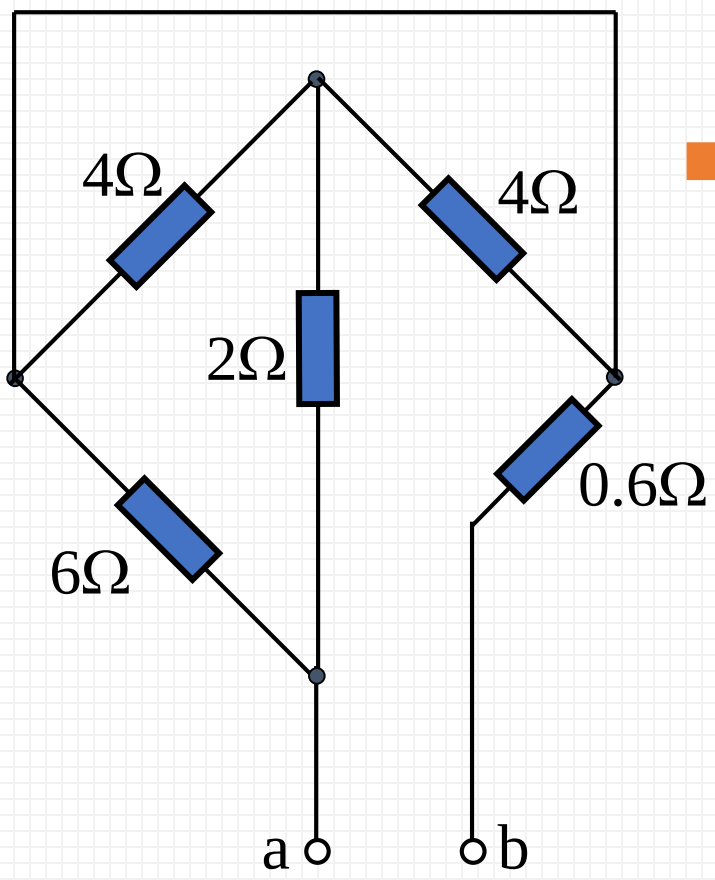


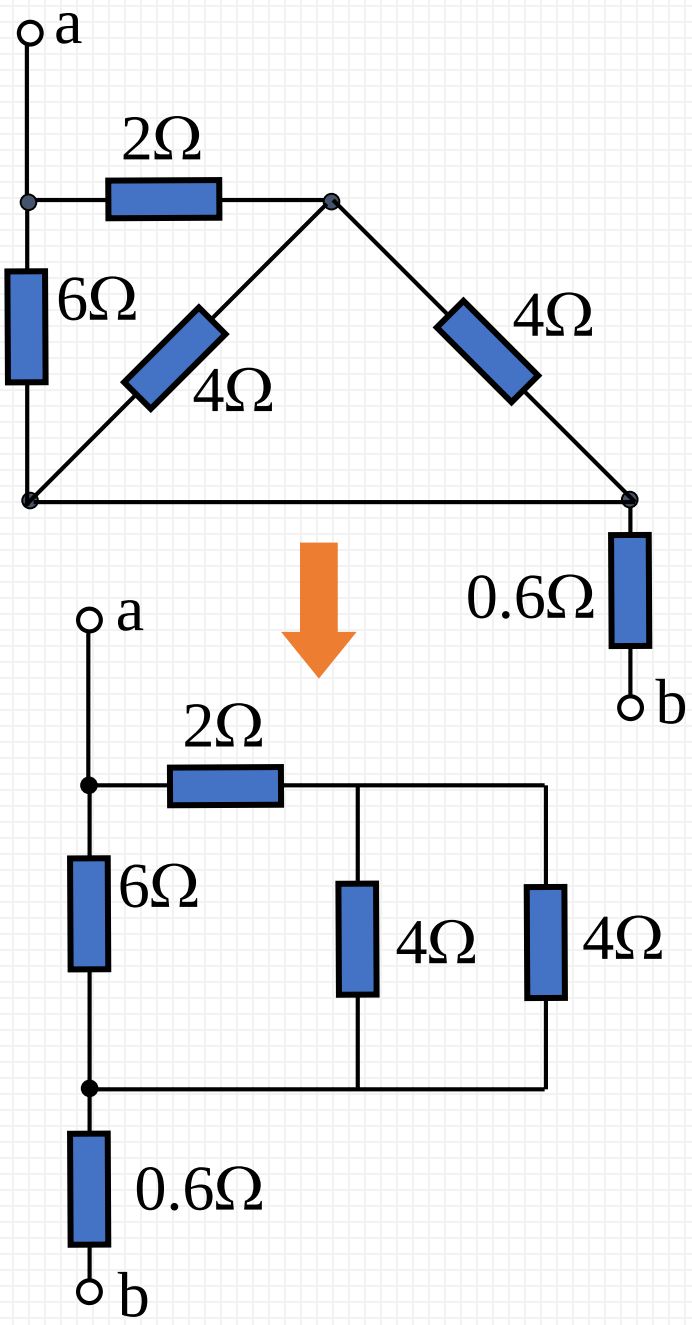


$$R_{ab} = 3//(2//2+4//(4//4+2)) = 1.5\Omega$$

$$R_{ac} = 2//2//(4//(4//4+2)+3) = \frac{5}{6}\Omega = 0.83\Omega$$

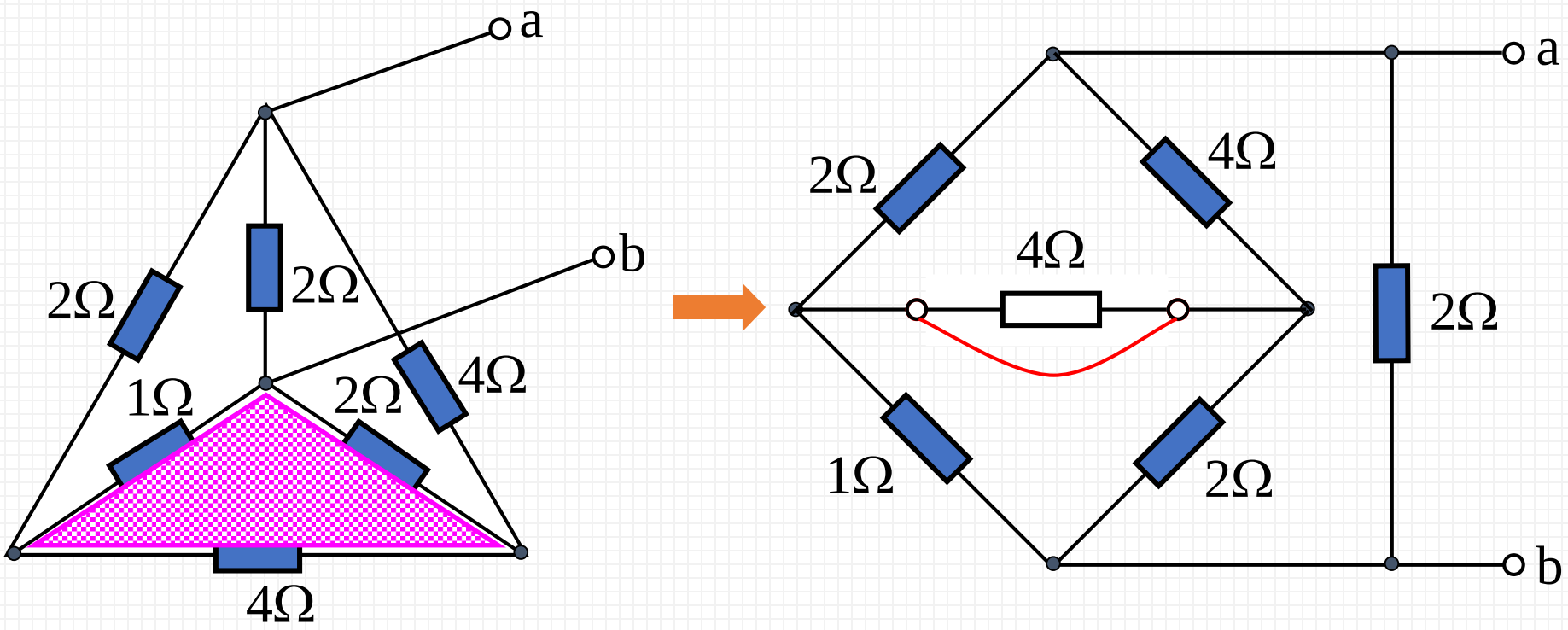
二、(b) 求 R_{ab}.





$$R_{ab}=\frac{4\times 6}{4+6}+0.6=3\Omega$$

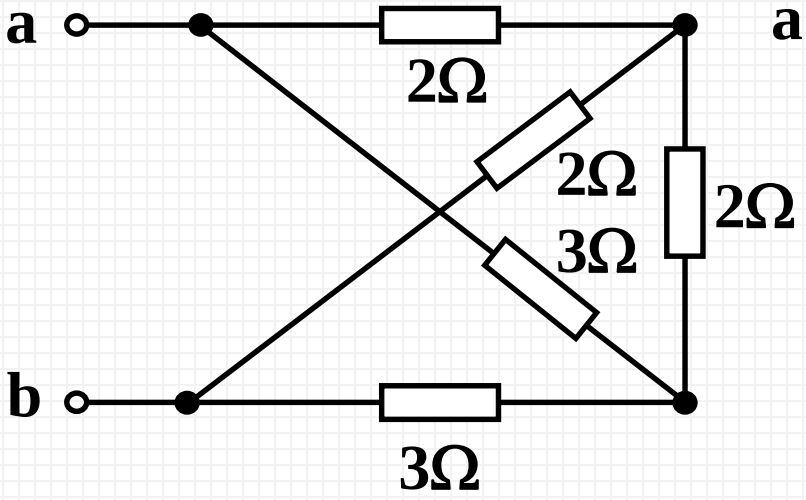
二、(c) 求 R_{ab}.

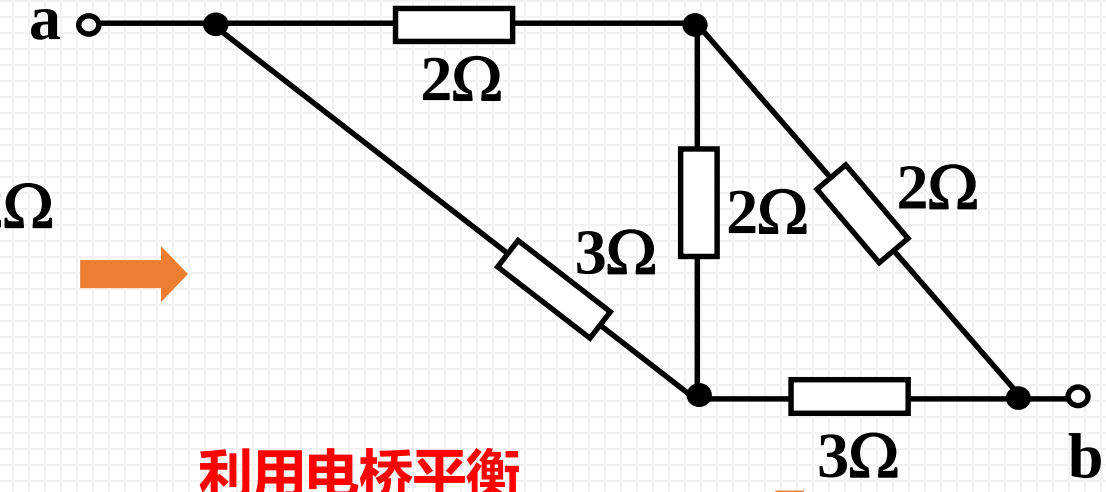


(a) 开路：$R_{ab}=2//(4+2)//(2+1)=1\Omega$

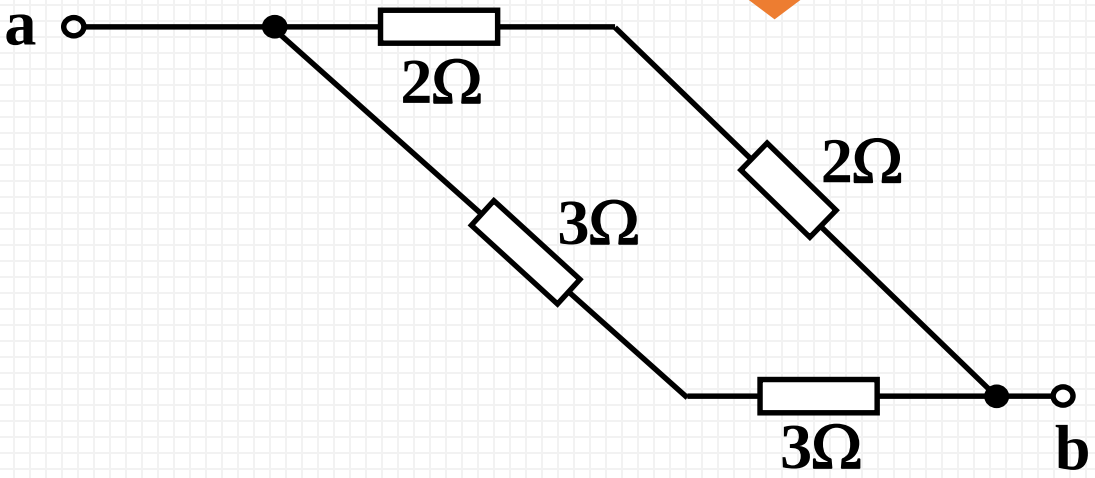
(b) 短路：$R_{ab}=2//(4//2+2//1)=1\Omega$

二、(d) 求 R_{ab}.





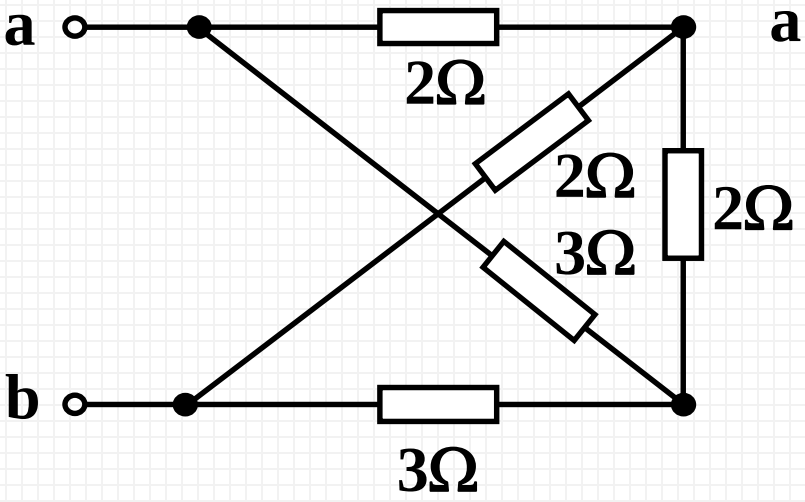
利用电桥平衡

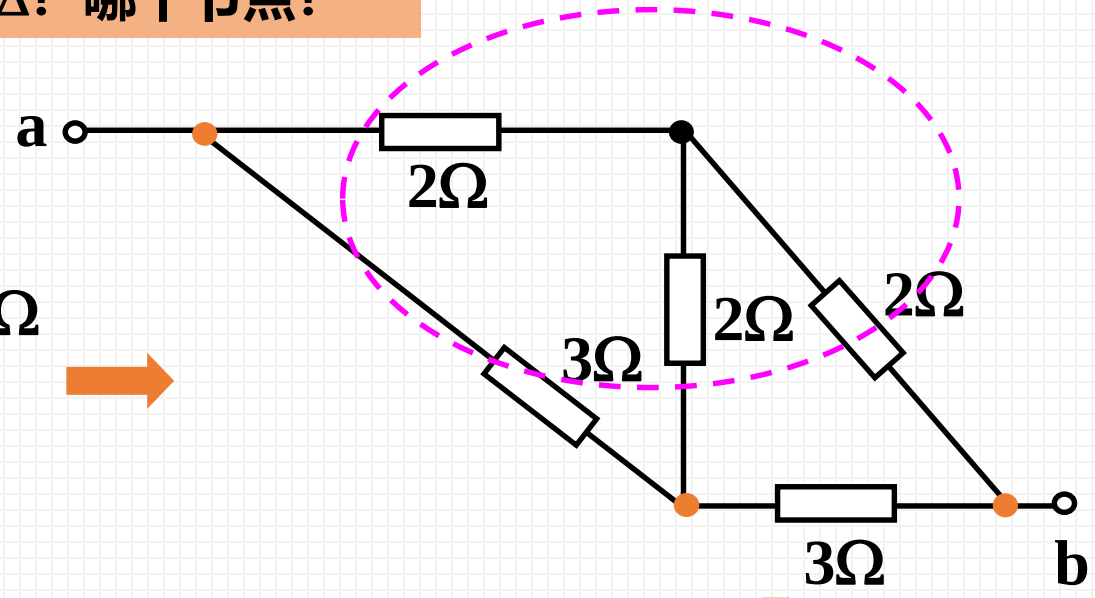


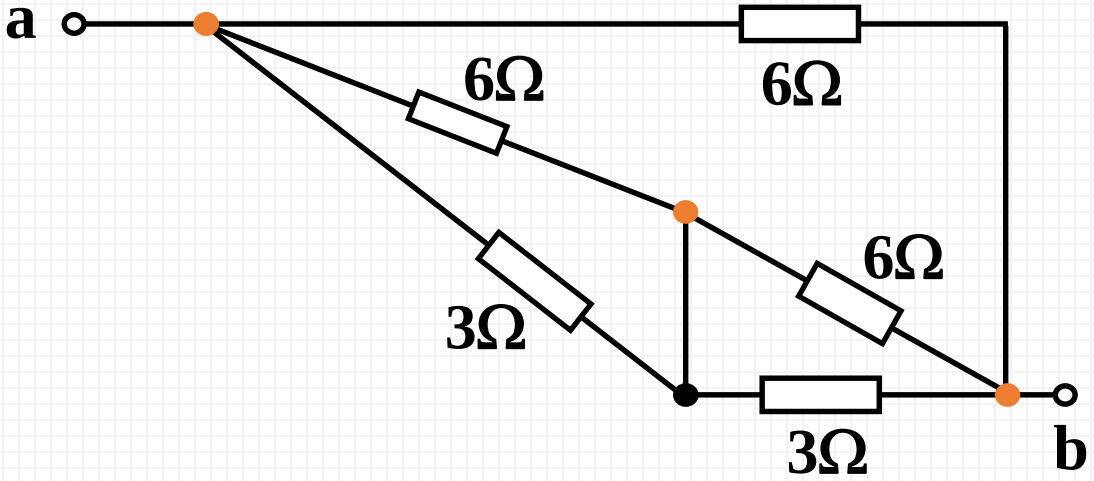
$$R_{ab}=(3+3)//(2+2)$$

$$=6//4=2.4\Omega$$

Y-Δ？哪个节点?



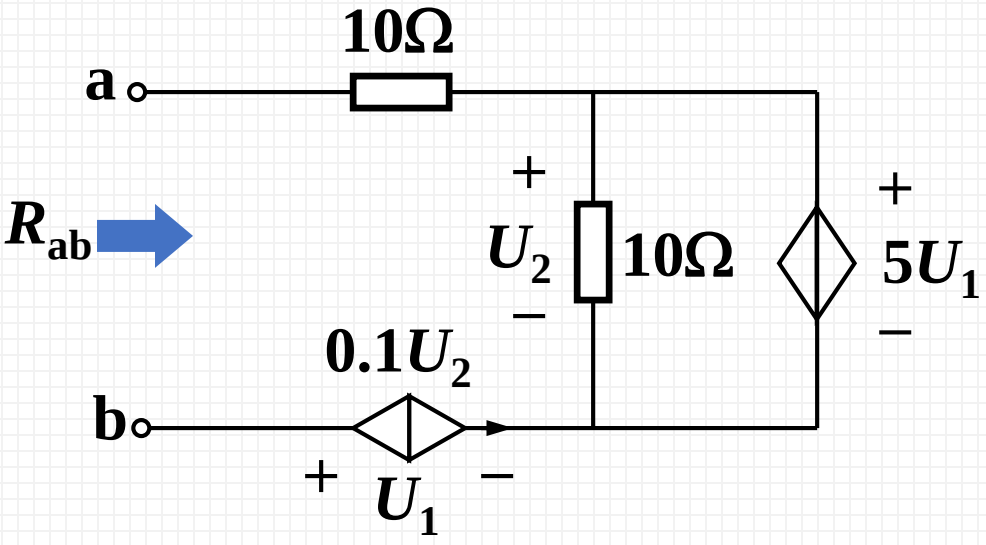


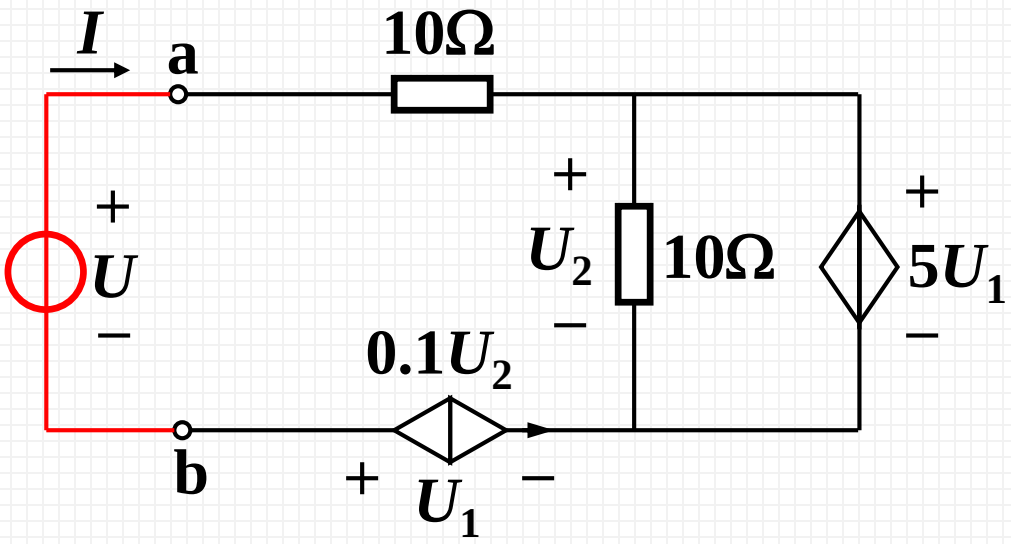


R_{ab}=(3//6+3 //6)//6

=(2+2) //6= 2.4Ω

三、 求入端电阻 R_{ab}





U_1=0.1U_2?

解：加压求流

$$\begin{cases} U_2 = 5U_1 \\ U = 10I + U_2 - U_1 \\ I = -0.1U_2 \end{cases}$$

U_2=-10I

U_1=-2I

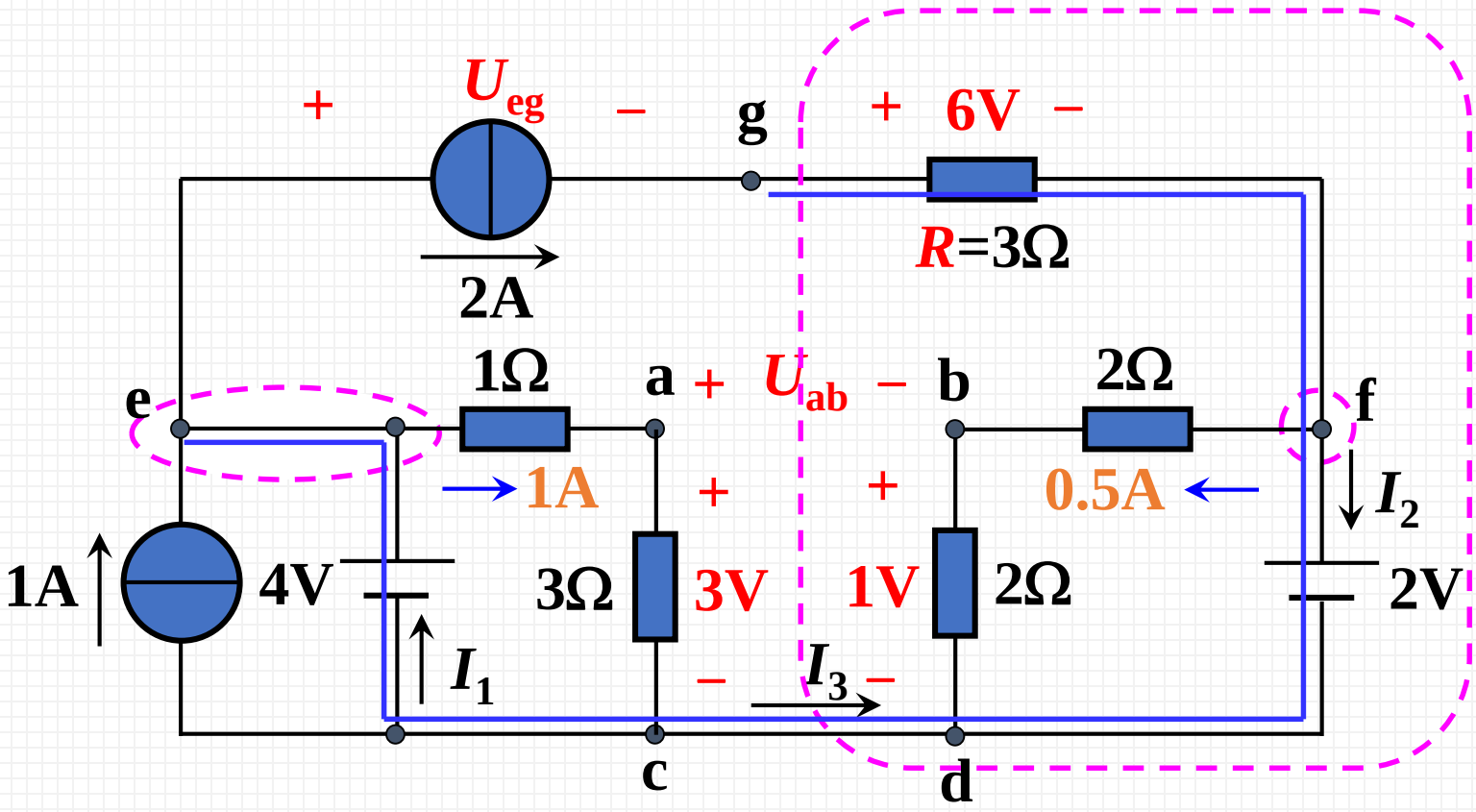
U=10I+U_2-U_1

=10I-10I+2I

=2I

R_{ab}= U/I = 2Ω

四、



(1) 求 I_1, I_2, I_3, U_{ab}, U_{eg};

(2) 若 R 变为 5Ω，问 U_{eg}, I_1 和 I_2 如何变化?

U_{ab}=3−1=2V

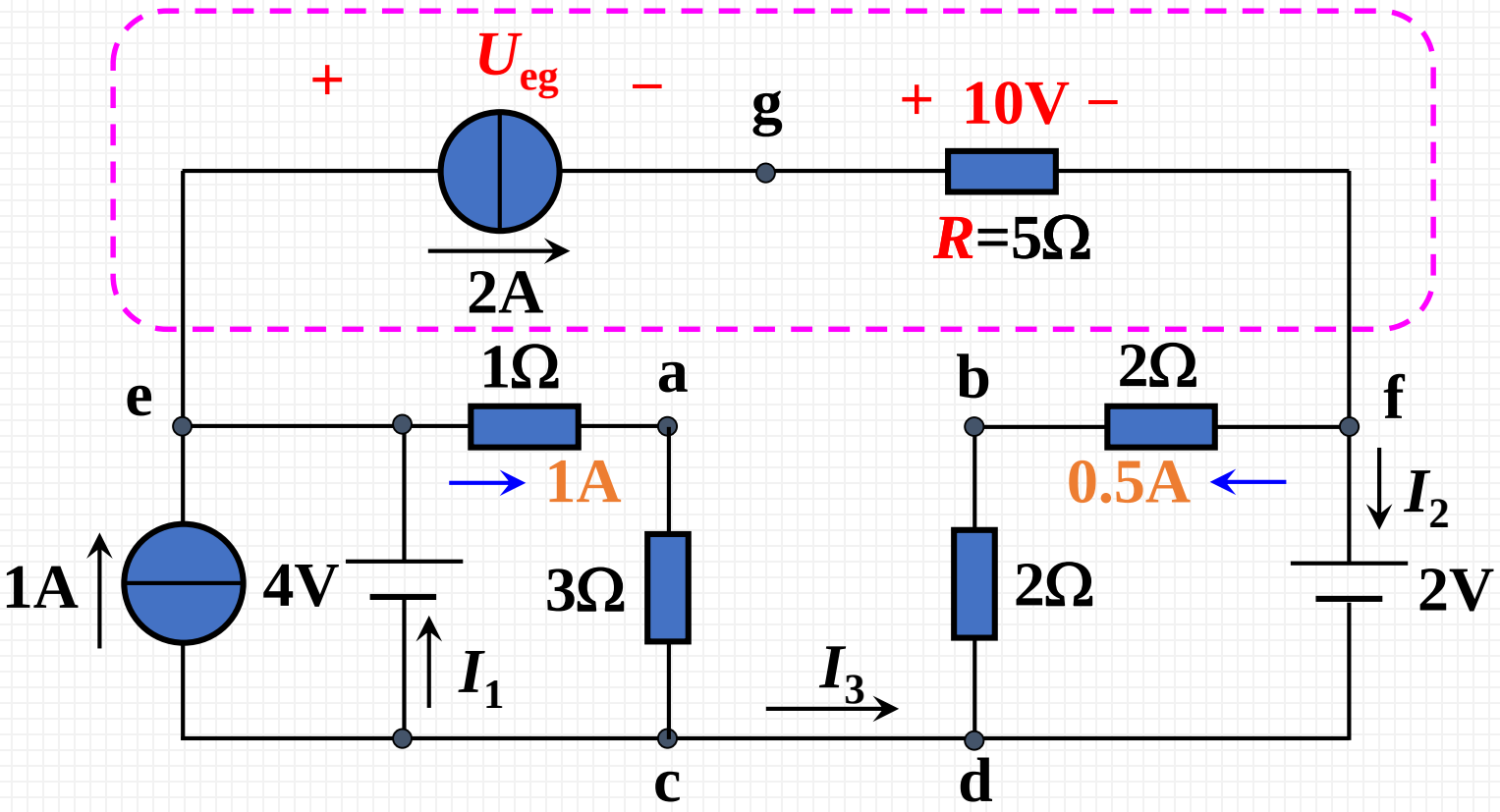
U_{eg}=4−2−6 =−4V

I_1=2+1−1=2A

I_2=2−0.5=1.5A

I_3= −2A

(2) 若 R 变为 5Ω，问 U_{eg}, I_1 和 I_2 如何变化?

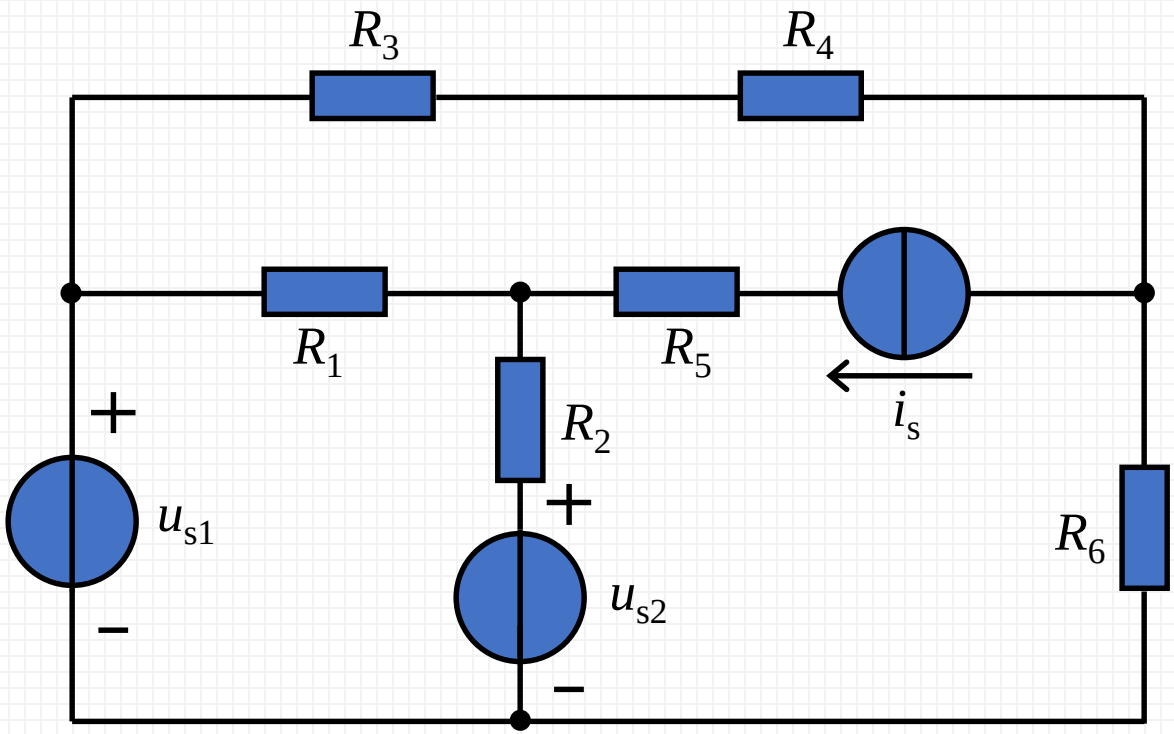


I_1, I_2 保持不变。

U_{eg}=4−2−10 = −8V

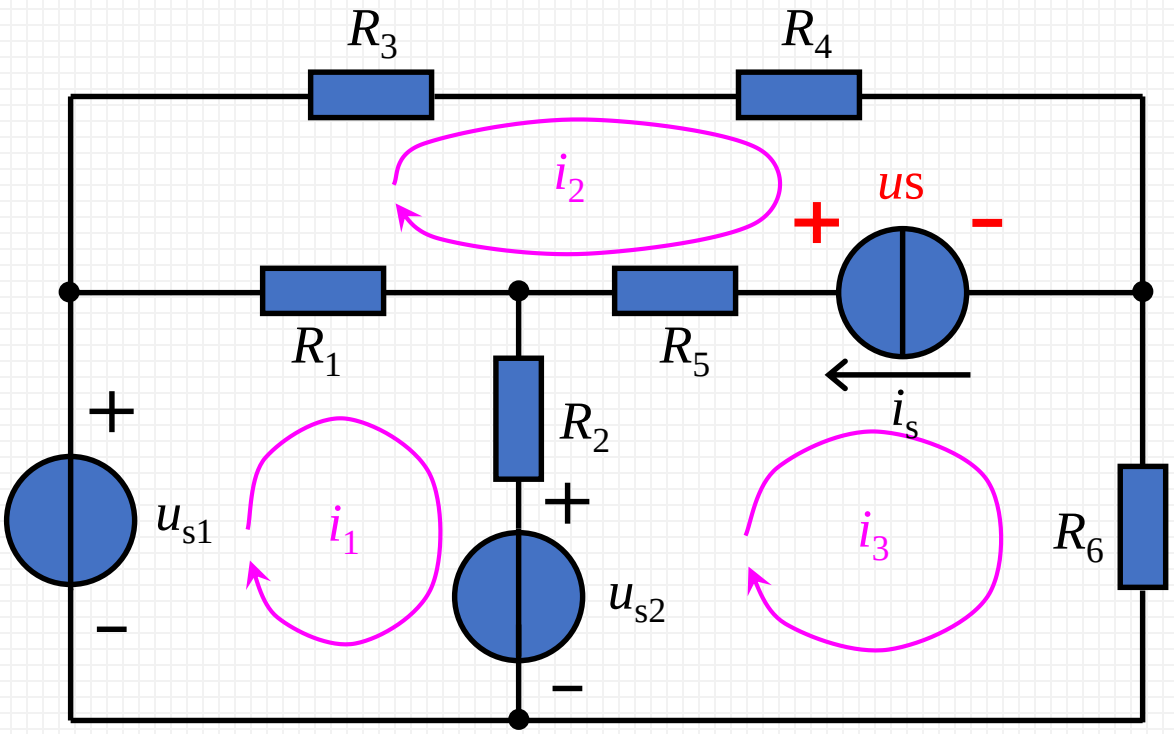
五、分别用**回路法**和**节点法**列写下图电路的方程。

列写方程时，既要掌握一般列写方法，又要注意其**中电压源支路，电流源支路及受控源支路**的处理方法。



此电路节点数n=4，支路数b=6，独立回路数$l=b$-n+1=3

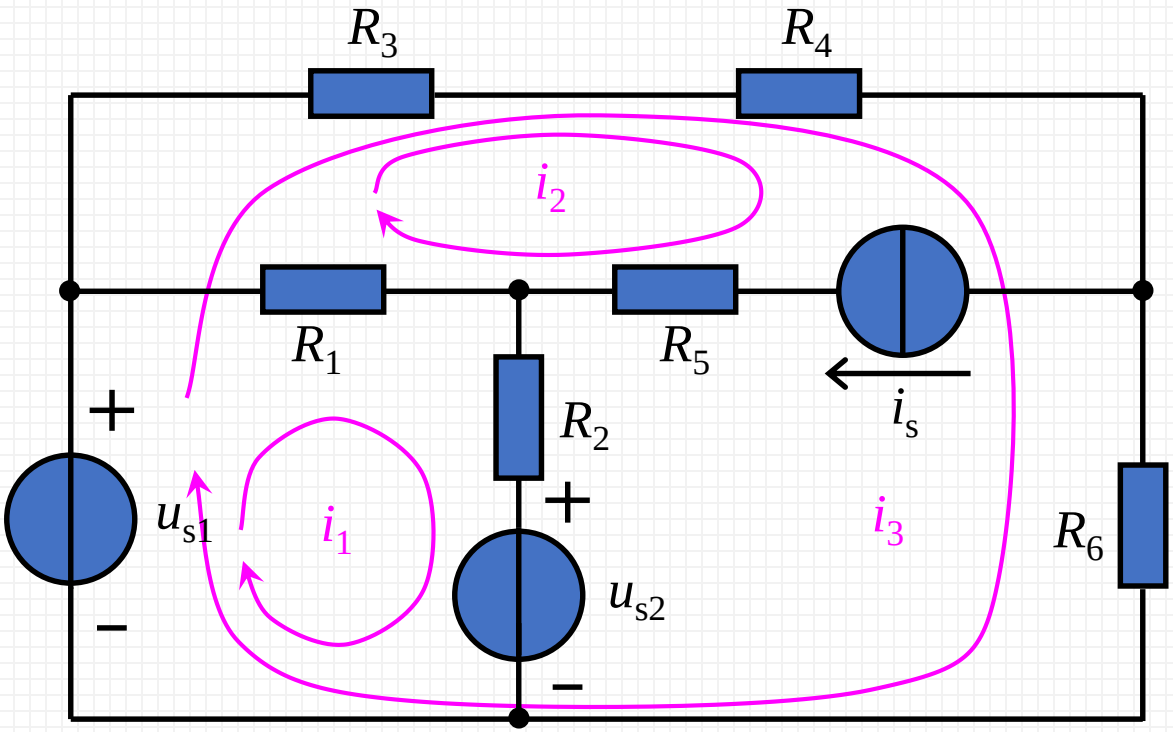
回路法： (1) 设电流源两端的电压为u_s:



$$\begin{cases} (\boldsymbol{R}_1+\boldsymbol{R}_2)\boldsymbol{i}_1-\boldsymbol{R}_1\boldsymbol{i}_2-\boldsymbol{R}_2\boldsymbol{i}_3=\boldsymbol{u}_{s1}-\boldsymbol{u}_{s2} \\ -\boldsymbol{R}_1\boldsymbol{i}_1+(\boldsymbol{R}_1+\boldsymbol{R}_3+\boldsymbol{R}_4+\boldsymbol{R}_5)\boldsymbol{i}_2-\boldsymbol{R}_5\boldsymbol{i}_3=\boldsymbol{u}_s \\ -\boldsymbol{R}_2\boldsymbol{i}_1-\boldsymbol{R}_5\boldsymbol{i}_2+(\boldsymbol{R}_2+\boldsymbol{R}_5+\boldsymbol{R}_6)\boldsymbol{i}_3=\boldsymbol{u}_{s2}-\boldsymbol{u}_s \\ \boldsymbol{i}_s=\boldsymbol{i}_2-\boldsymbol{i}_3 \end{cases}$$

补充方程：电流源支路电流与回路电流关系的方程。

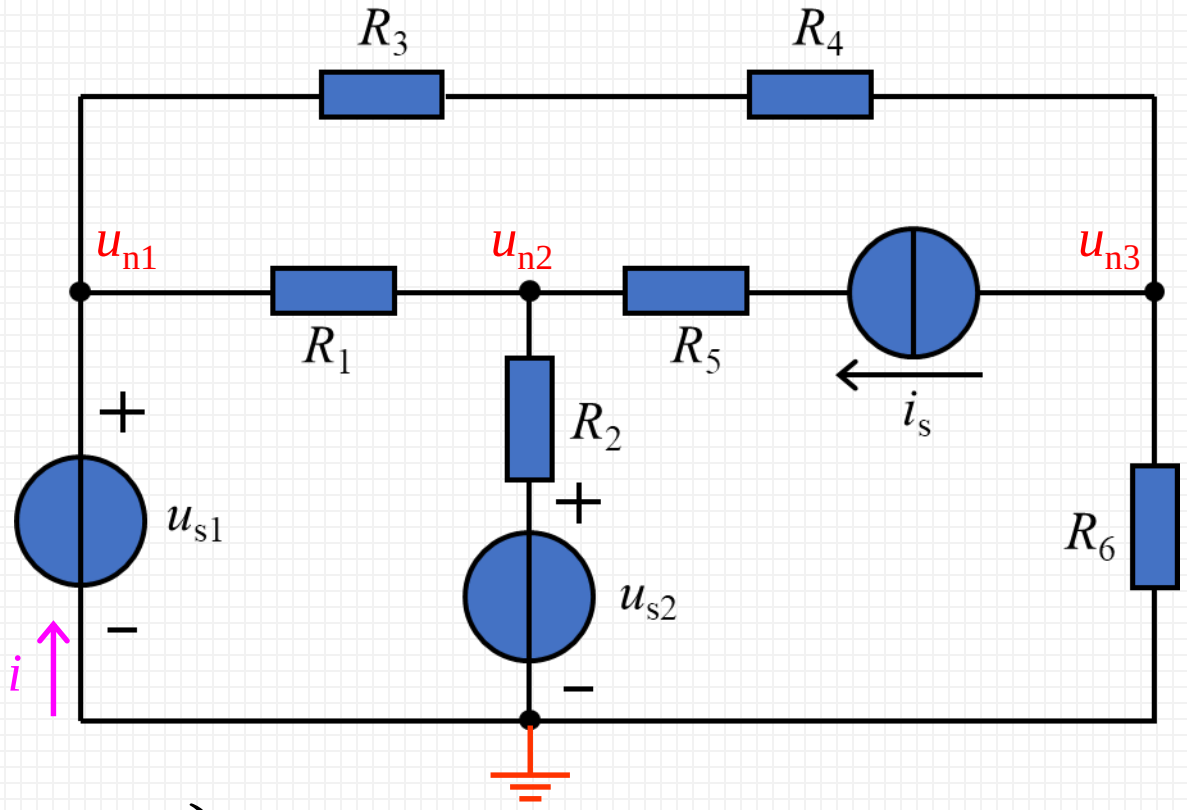
回路法： (2) 选择更合适的一组回路



$$\begin{cases} \boldsymbol{i}_2 = \boldsymbol{i}_s \\ (\boldsymbol{R}_1 + \boldsymbol{R}_2)\boldsymbol{i}_1 - \boldsymbol{R}_1\boldsymbol{i}_2 = \boldsymbol{u}_{s1} - \boldsymbol{u}_{s2} \\ (\boldsymbol{R}_3 + \boldsymbol{R}_4)\boldsymbol{i}_2 + (\boldsymbol{R}_3 + \boldsymbol{R}_4 + \boldsymbol{R}_6)\boldsymbol{i}_3 = \boldsymbol{u}_{s1} \end{cases}$$

节点法：

方法1：设电压源 u_{s1} 支路的电流为 i

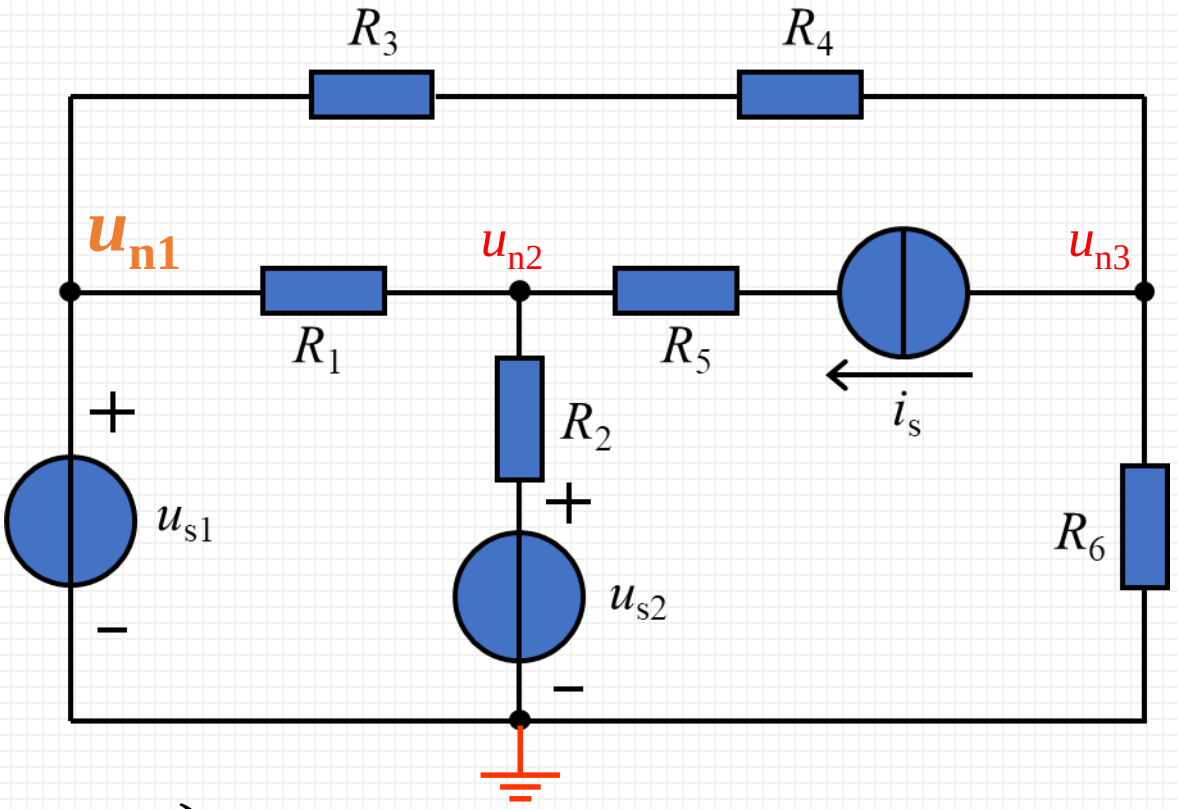


$$
\begin{cases}
\left(\dfrac{1}{R_1}+\dfrac{1}{R_3+R_4}\right)u_{n1}-\dfrac{1}{R_1}u_{n2}-\dfrac{1}{R_3+R_4}u_{n3}=i \\
-\dfrac{1}{R_1}u_{n1}+\left(\dfrac{1}{R_1}+\dfrac{1}{R_2}\right)u_{n2}=\dfrac{u_{S2}}{R_2}+i_S \\
-\dfrac{1}{R_3+R_4}u_{n1}+\left(\dfrac{1}{R_3+R_4}+\dfrac{1}{R_6}\right)u_{n3}=-i_S \\
u_{s1}=u_{n1}
\end{cases}
$$

补充 u_{s1} 与节点电压关系的方程

节点法：

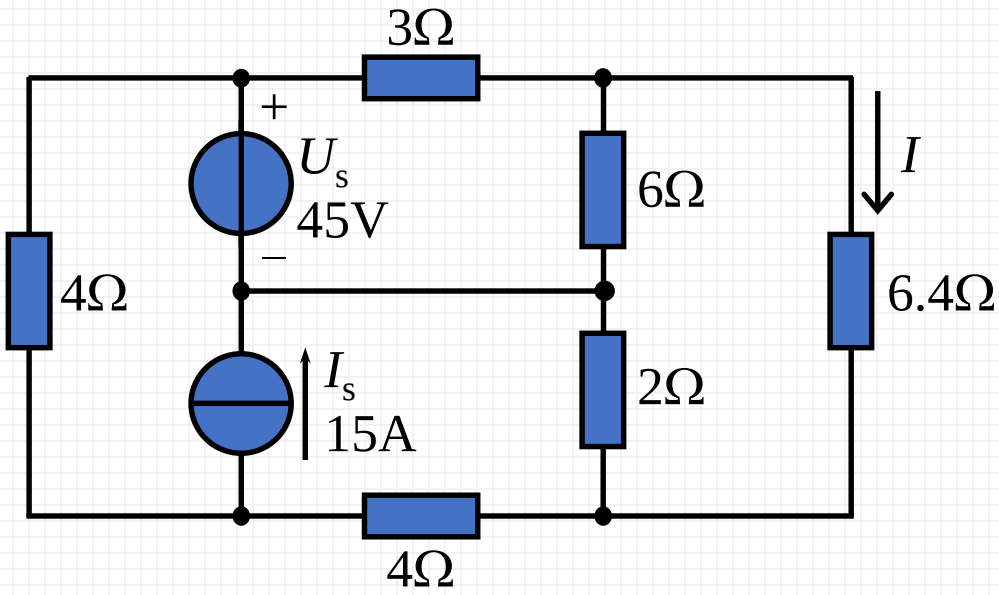
方法2：选电压源u_{s1}支路所接的节点之一作为参考节点，则$u_{n1}=u_{s1}$，此时可不必再列**节点1**的方程。



$$\begin{cases} \left(\dfrac{1}{R_1}+\dfrac{1}{R_3+R_4}\right)u_{n1}-\dfrac{1}{R_1}u_{n2}-\dfrac{1}{R_3+R_4}u_{n3}=i \\ -\dfrac{1}{R_1}u_{n1}+\left(\dfrac{1}{R_1}+\dfrac{1}{R_2}\right)u_{n2}=\dfrac{u_{S2}}{R_2}+i_S \\ -\dfrac{1}{R_3+R_4}u_{n1}+\left(\dfrac{1}{R_3+R_4}+\dfrac{1}{R_6}\right)u_{n3}=-i_S \end{cases}$$

$$u_{s1}=u_{n1}$$

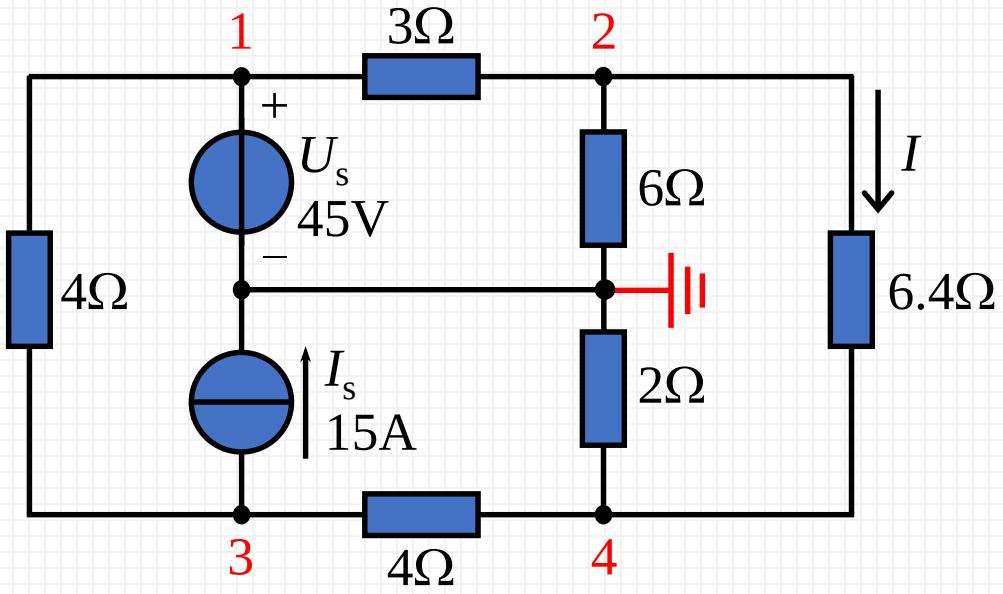
六、求电流 I。



8条支路，4个独立节点，4个独立回路

解法一：**节点法**

电压源支路的处理：选电压源的负端为参考节点



$$\begin{cases} U_{n1} = U_S \\ \left(\frac{1}{3}+\frac{1}{6}+\frac{1}{6.4}\right)U_{n2} - \frac{1}{3}U_{n1} - \frac{1}{6.4}U_{n4} = 0 \\ \left(\frac{1}{4}+\frac{1}{4}\right)U_{n3} - \frac{1}{4}U_{n1} - \frac{1}{4}U_{n4} = -15 \\ \left(\frac{1}{4}+\frac{1}{2}+\frac{1}{6.4}\right)U_{n4} - \frac{1}{4}U_{n3} - \frac{1}{6.4}U_{n2} = 0 \end{cases}$$

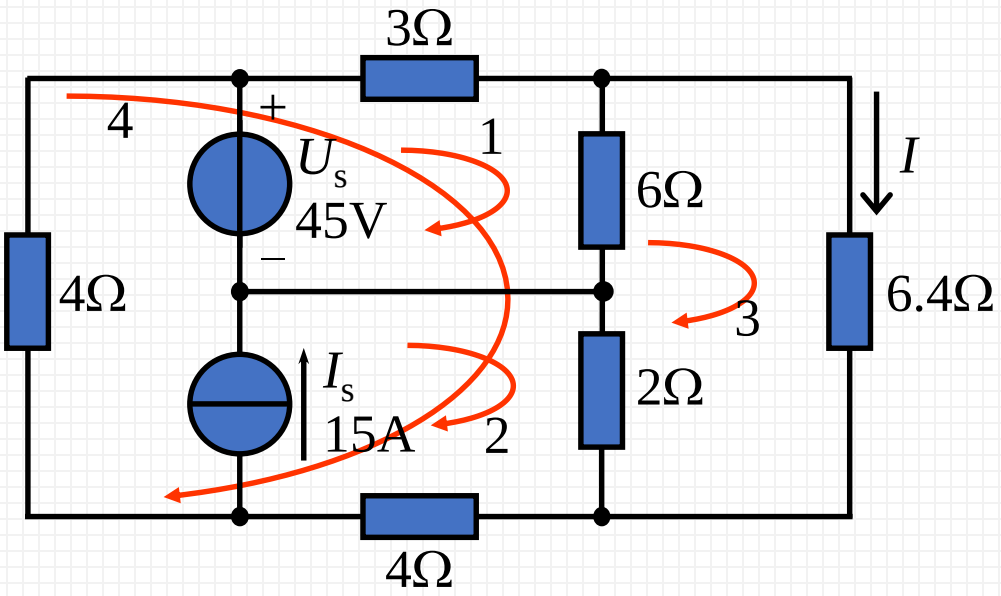
$$\begin{cases} U_{n1} = 45\text{V} \\ U_{n2} = 23.4\text{V} \\ U_{n3} = -6.36\text{V} \\ U_{n4} = 2.28\text{V} \end{cases}$$

$$I = \frac{U_{n2} - U_{n4}}{6.4} = 3.3\text{A}$$

解法二：回路法

电流源支路的处理：

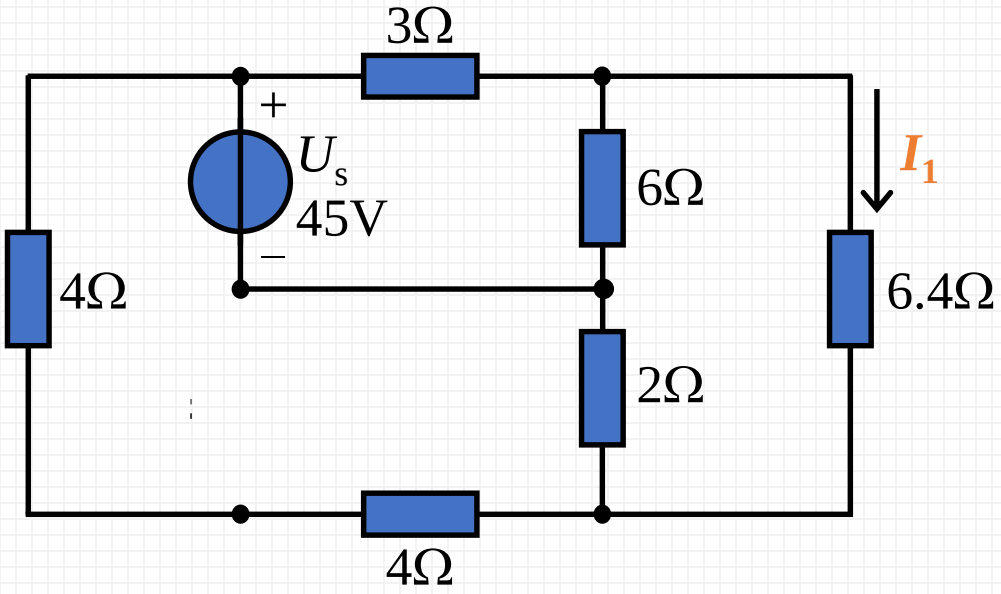
选一组合适的回路

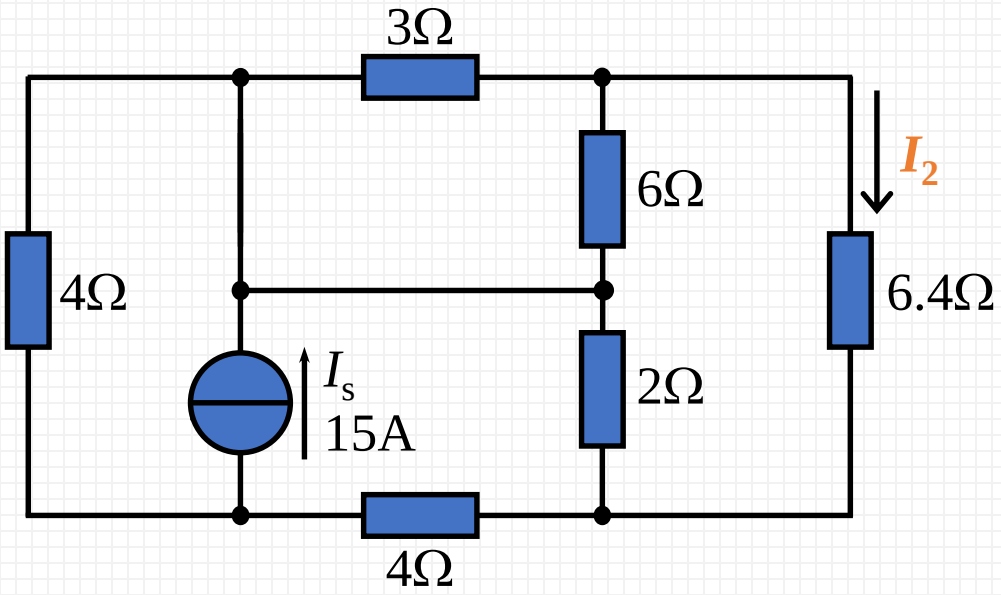


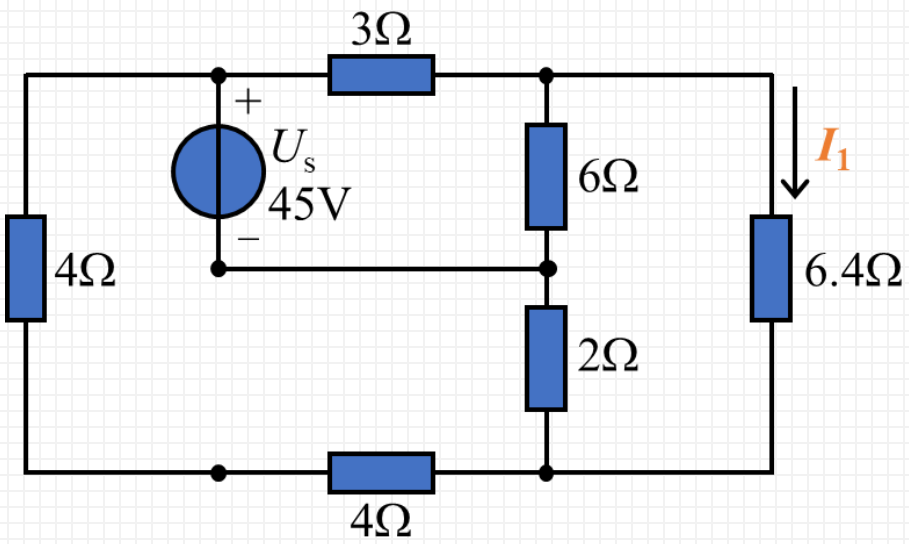
$$\begin{cases} I_{l2} = 15 \\ (3+6)I_{l1} + 9I_{l4} - 6I_{l3} = 45 \\ (2+6+6.4)I_{l3} - 6I_{l1} - 2I_{l2} - (6+2)I_{l4} = 0 \\ (4+3+6+2+4)I_{l4} + (3+6)I_{l1} + (2+4)I_{l2} - (6+2)I_{l3} = 0 \end{cases}$$

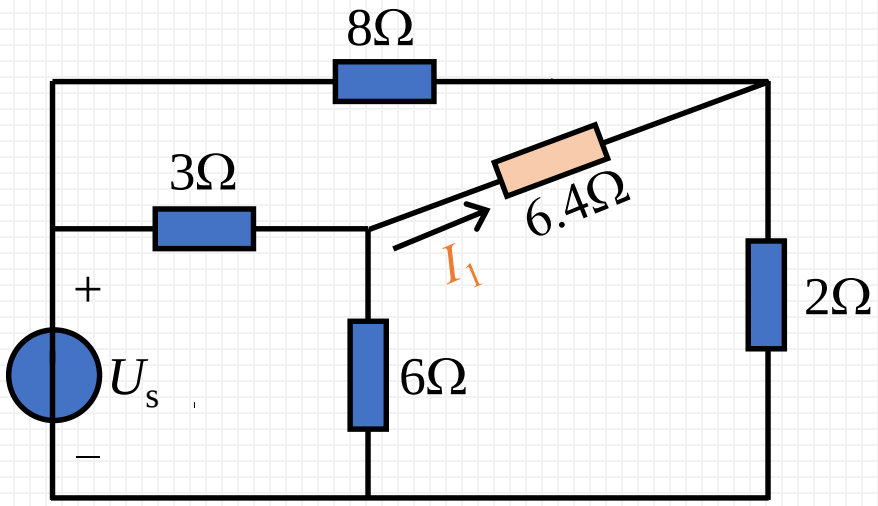
$$I = I_{l3} = 3.3\,\mathrm{A}$$

解法三：叠加定理

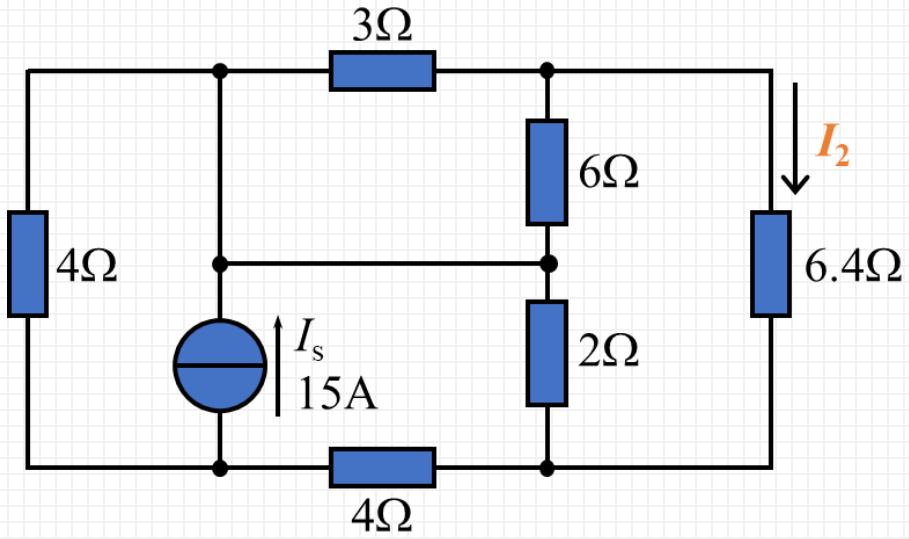


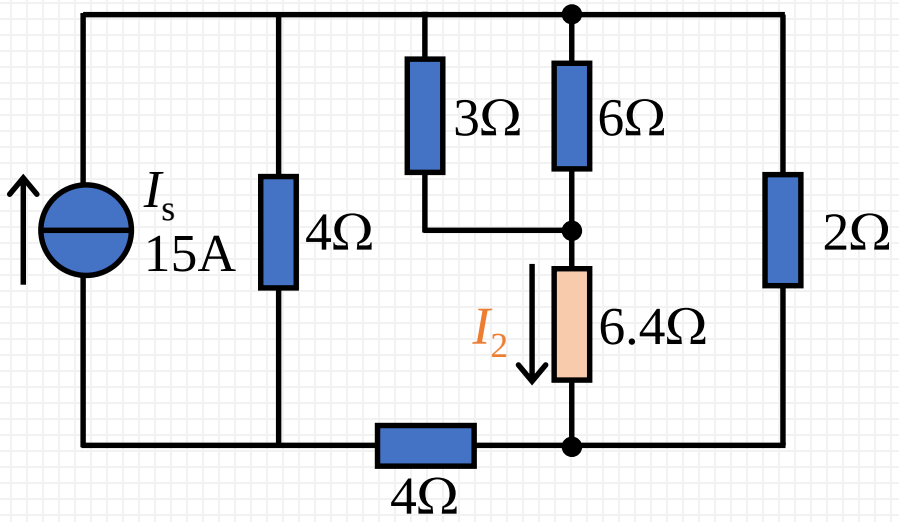






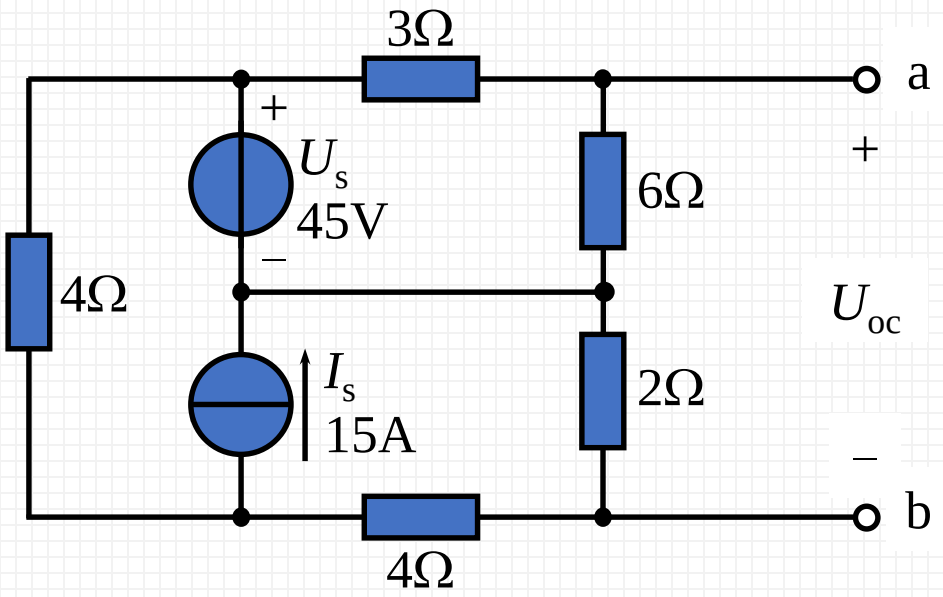
回路法，节点法　　$I_1 = 2.1\text{A}$

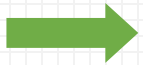


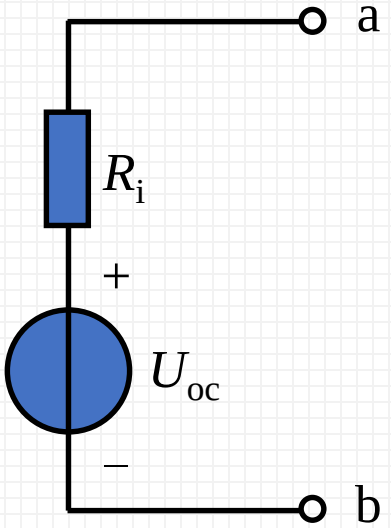


电阻串并联,电源变换　　$I_2 = 1.2\text{A}$

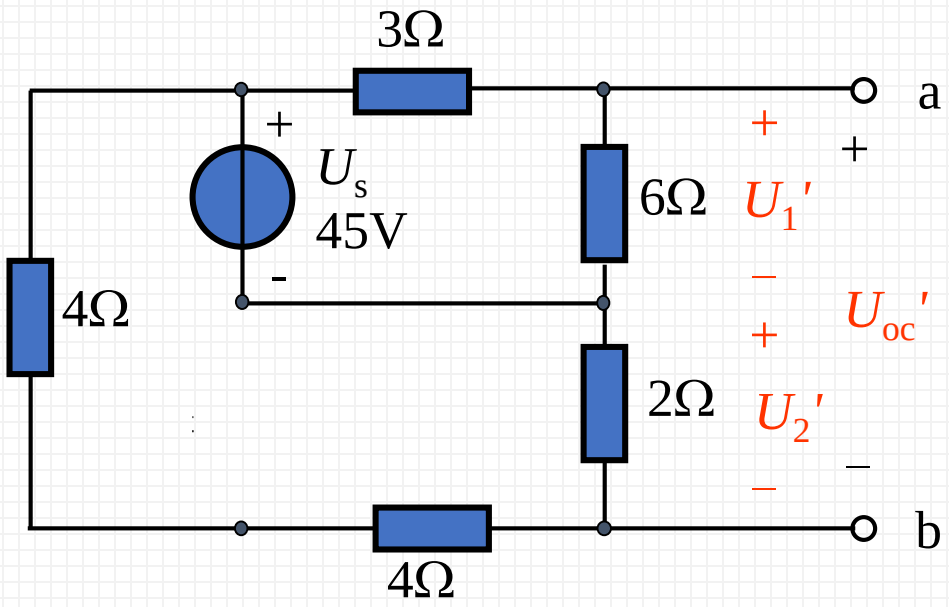
解法四： 用戴维南定理

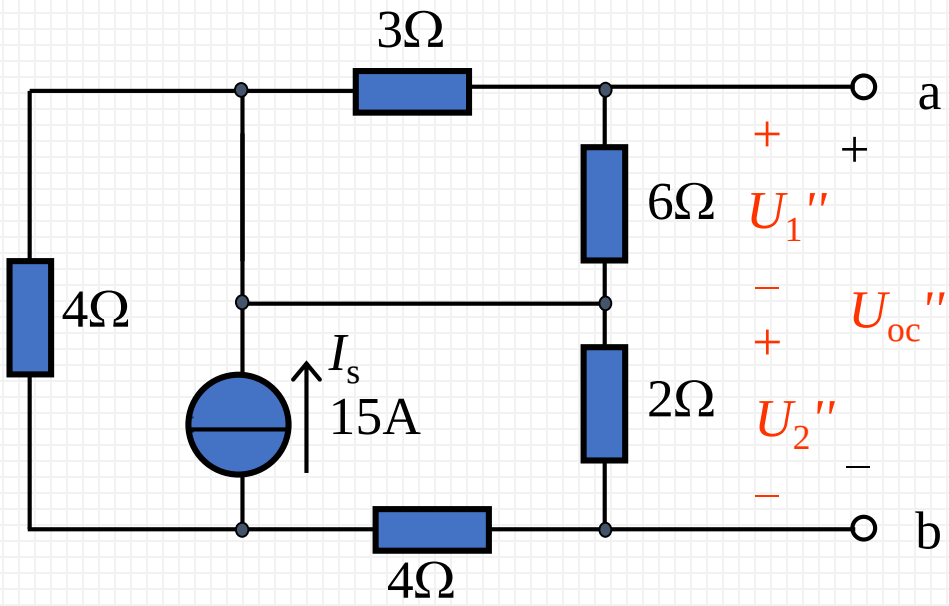






求开路电压 U_{oc}（叠加）：





$U_{oc}'=U_1'+U_2'$

$=30-9=21V$

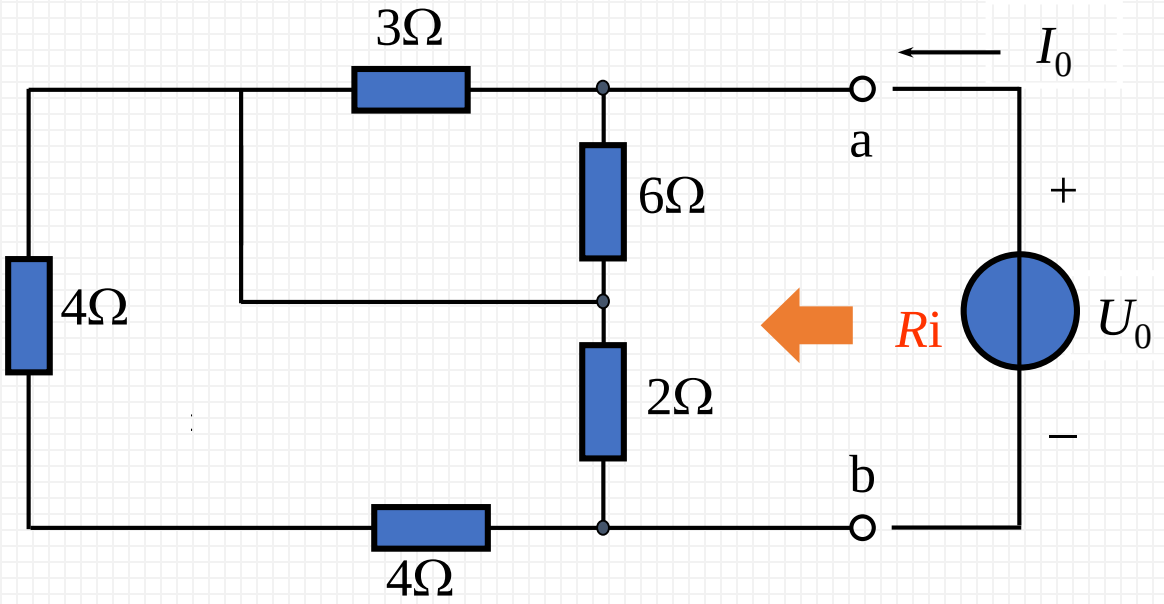
$U_{oc}''=U_1''+U_2''$

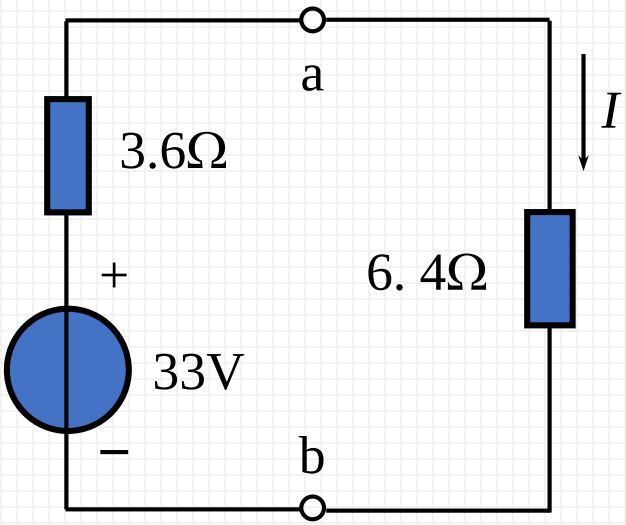
$=0+12=12V$

$U_{oc}=U_{oc}'+U_{oc}''$

$=21+12=33V$

求内阻R_i：





求内阻方法

1. 直接用串并联
2. 加压求流或加流求压
3. 开路电压、短路电流

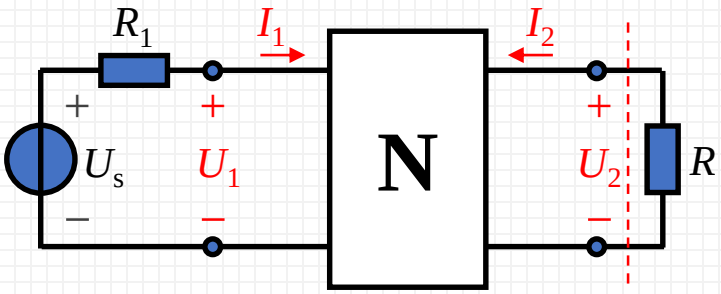
$R_i=3//6+2//(4+4)=3.6\Omega$

$I=33/(3.6+6.4)=3.3A$

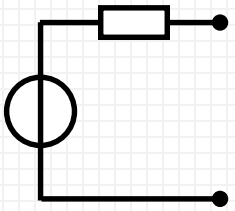
$$T=\begin{bmatrix} 2 & 8\Omega \\ 0.5\,\mathrm{S} & 2.5 \end{bmatrix}$$

七、 如图所示，二端口网络N的传输参数为

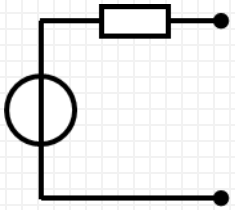
U_S=6V和 R_1=2Ω 的串联支路连接到端口 1。问：**R** 获得**最大功率**时的值，并求此最大功率以及**电源**U_S发出的功率。



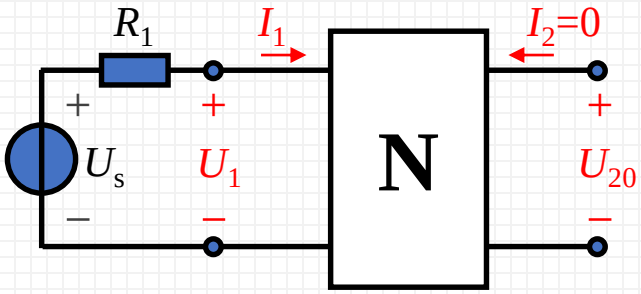
戴维南等效



解:

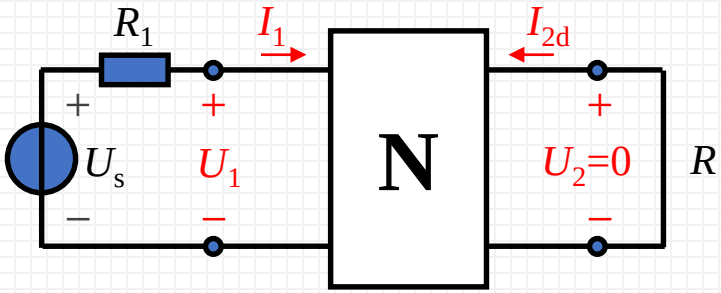


$$P_{U_S}=\frac{U_{20}^2}{2R}$$ ×



$$\begin{bmatrix} U_1=6-2I_1 \\ I_1 \end{bmatrix}=\begin{bmatrix} 2 & 8 \\ 0.5 & 2.5 \end{bmatrix}\begin{bmatrix} U_{20} \\ 0 \end{bmatrix}$$

开路电压: U_{20}= 2V

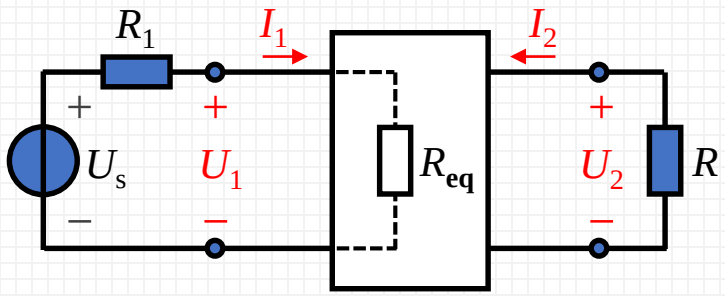


$$\begin{bmatrix} U_1=6-2I_1 \\ I_1 \end{bmatrix}=\begin{bmatrix} 2 & 8 \\ 0.5 & 2.5 \end{bmatrix}\begin{bmatrix} 0 \\ -I_{2d} \end{bmatrix}$$

短路电流: I_{2d}= - 6/13A

$$R_{等}=\frac{U_{20}}{-I_{2d}}=\frac{13}{3}\Omega$$

$$P_{max}=\frac{U_{20}^2}{4R}=0.23\text{W}$$



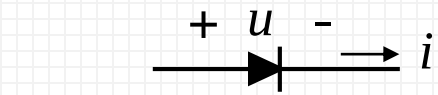
$$T=\begin{bmatrix} 2 & 8\Omega \\ 0.5\,\mathrm{S} & 2.5 \end{bmatrix}$$

$$U_1 = 2U_2 - 8I_2$$
$$I_1 = 0.5U_2 - 2.5I_2$$
$$U_2 = -\frac{13}{3} I_2$$

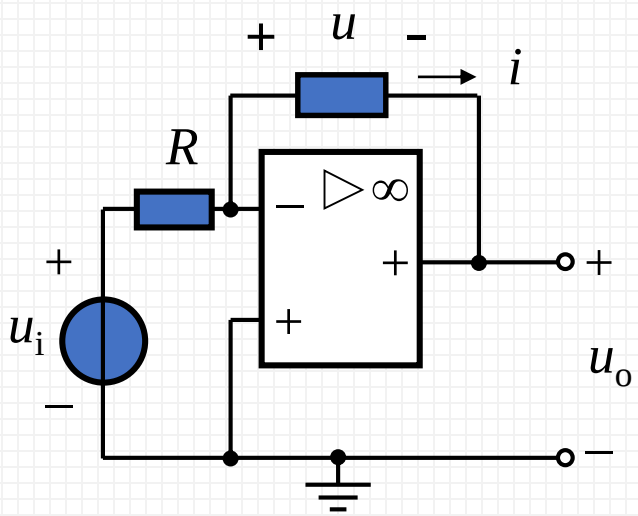
$$\rightarrow \quad U_1 = \frac{25}{7} I_1 \quad \rightarrow \quad R_{eq} = 3.57\Omega$$

$$P = \frac{U_S^2}{R_1 + R_{eq}} = 6.46\mathrm{W}$$

八、用OpAmp实现乘法和除法运算



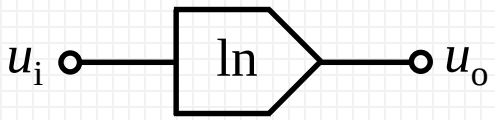
$$i = I_S\left(e^{u/U_{TH}} - 1\right) \approx I_S e^{u/U_{TH}}$$

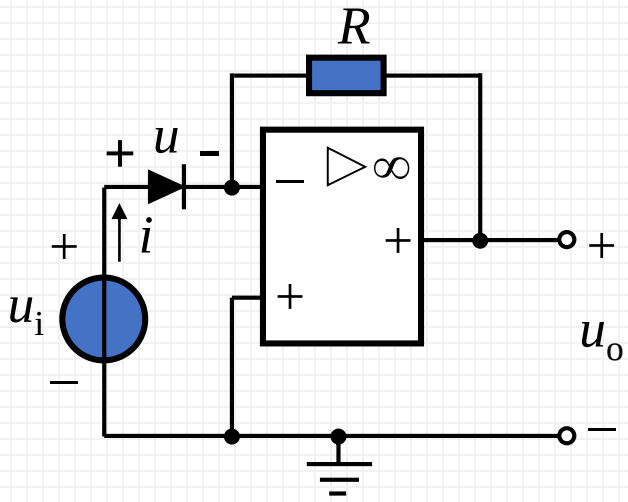


$$\frac{u_i}{R} = i = I_S e^{u/U_{TH}} = I_S e^{-u_0/U_{TH}}$$

$$u_0 = -U_{TH} \ln\left(\frac{u_i}{I_S R}\right)$$

抽象

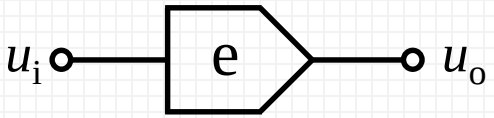




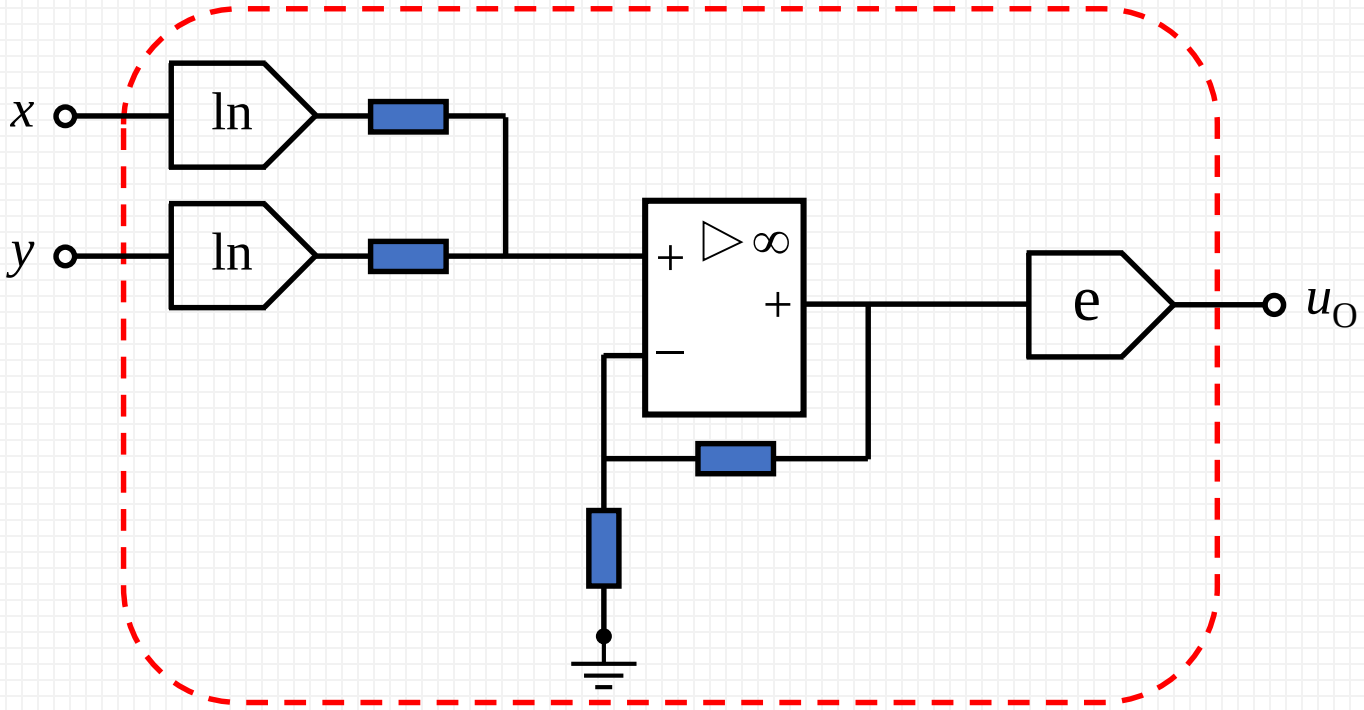
$$i = I_S e^{u_i/U_{TH}} = -\frac{u_0}{R}$$

$$u_0 = -RI_S e^{u_i/U_{TH}}$$

抽象

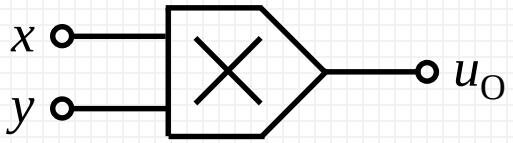


$$xy = e^{(\ln x + \ln y)}$$



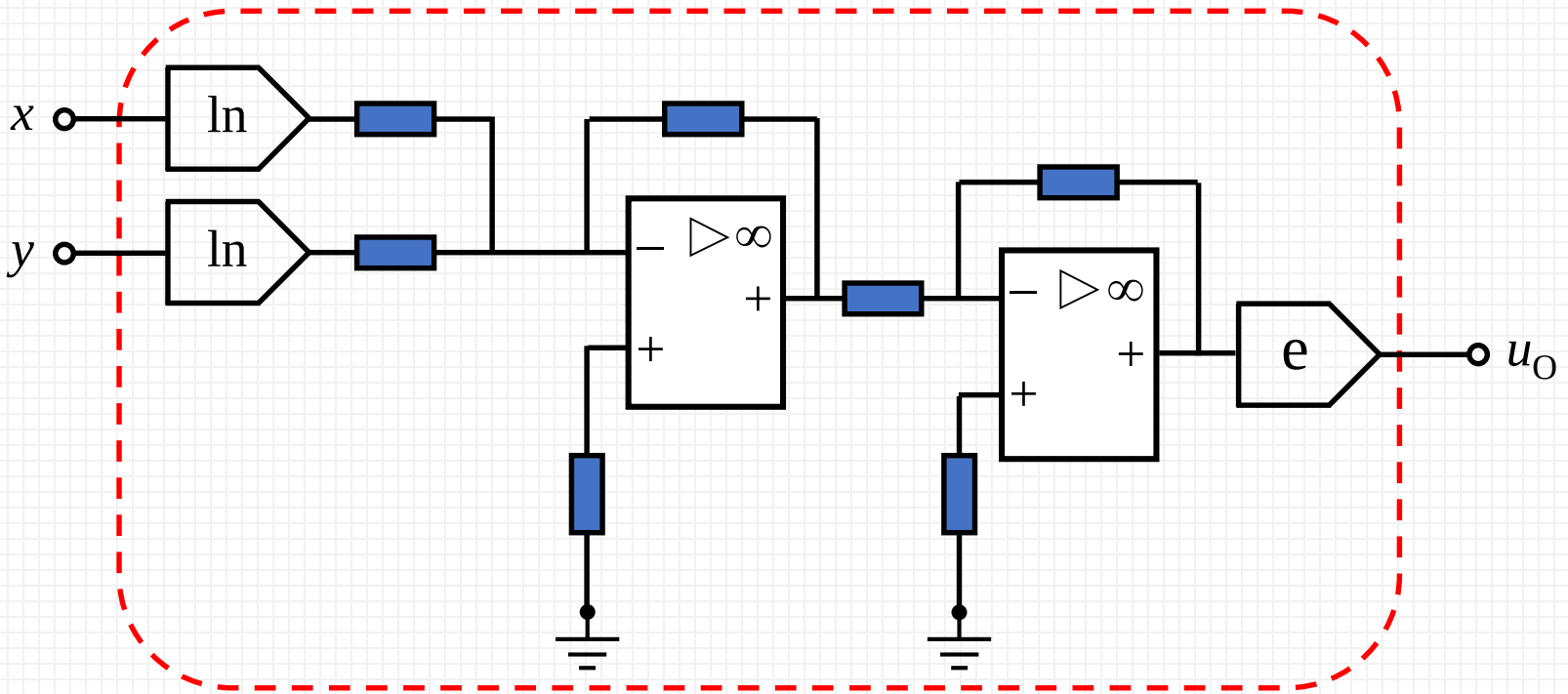
抽象

$$\frac{x}{y} = e^{(\ln x - \ln y)}$$



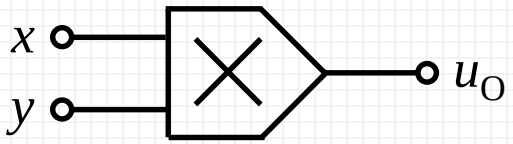
$$u_O = k\,xy$$

$$xy = e^{(\ln x + \ln y)}$$



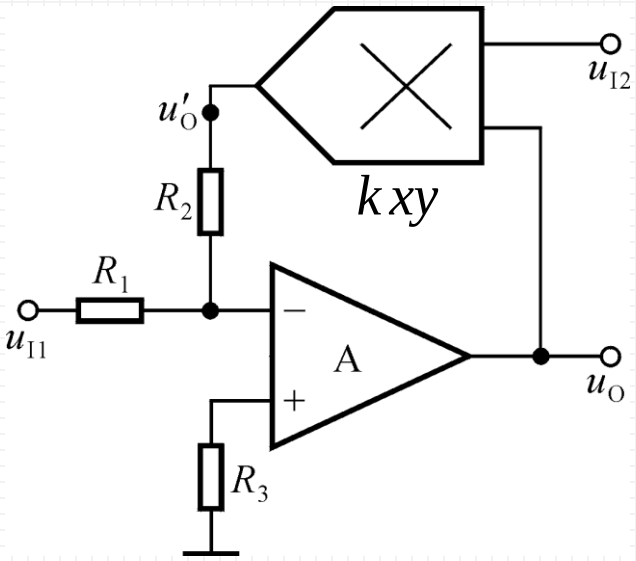
抽象

$$\frac{x}{y} = e^{(\ln x - \ln y)}$$



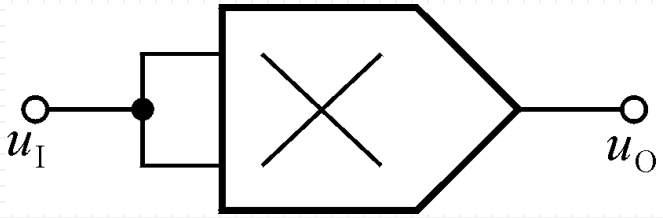
$$u_O = k\,xy$$

除法运算



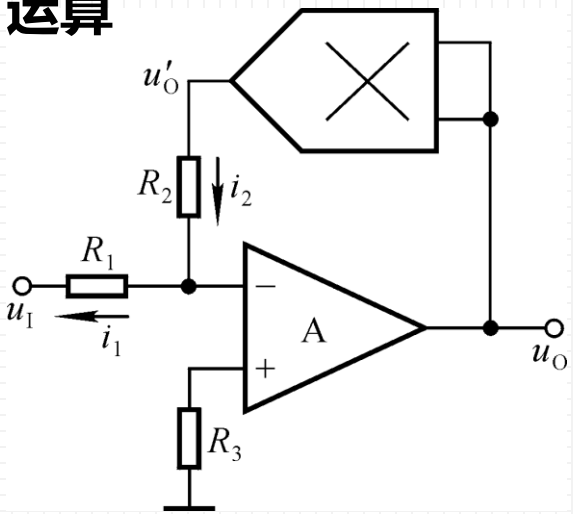
$$u_O = -\frac{R_2}{R_1}\cdot\frac{u_{I1}}{ku_{I2}}$$

乘方运算



$$u_O = ku_I^2$$

开方运算



$$u_O = \sqrt{-\frac{R_2}{kR_1}\cdot u_I}$$

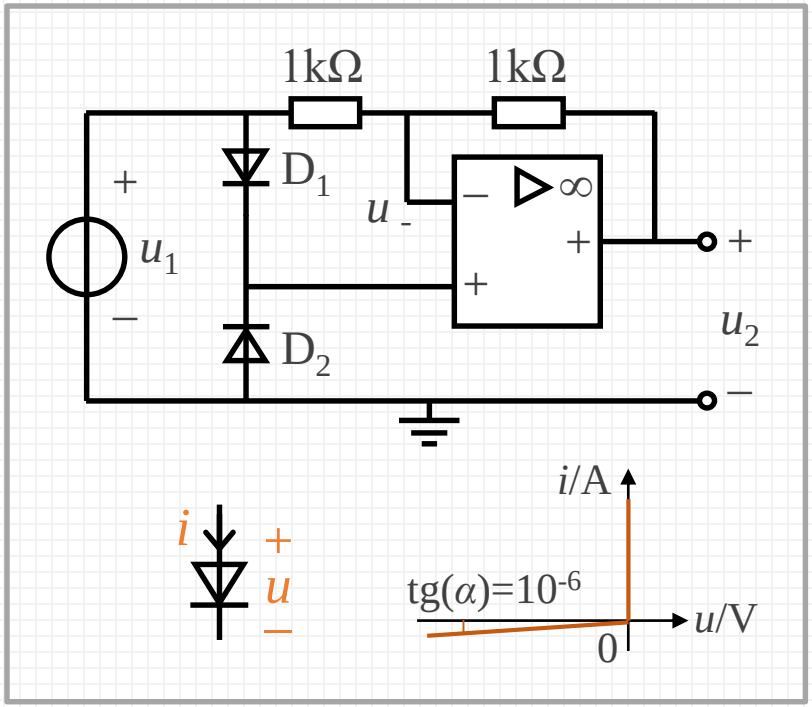
九、 题图所示电路中理想运算放大器工作于线性放大区。二极管的性质如图所示。

(1) 求u_-和u_1、u_2的关系。

(2) 如果$u_1 \geq 0$，求u_2和u_1的关系。

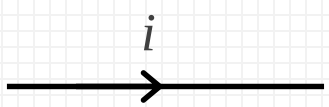
(3) 如果$u_1 < 0$，求u_2和u_1的关系。

(4) 该电路实现了怎样的运算?

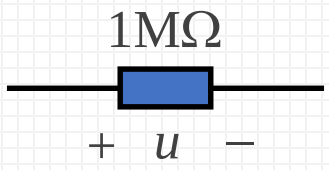


解:

$$u_- = \frac{u_1 + u_2}{2}$$



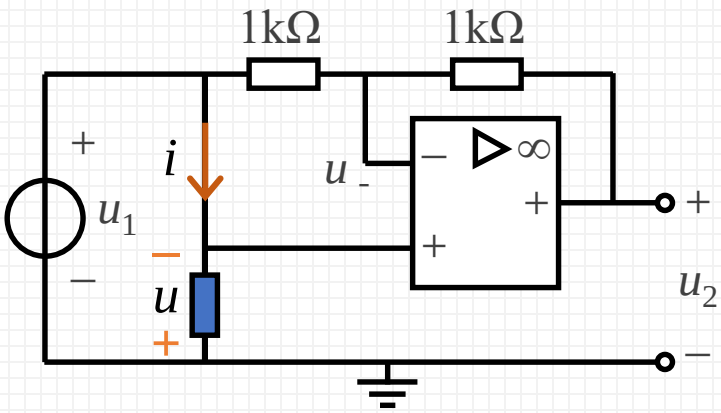
$i > 0$

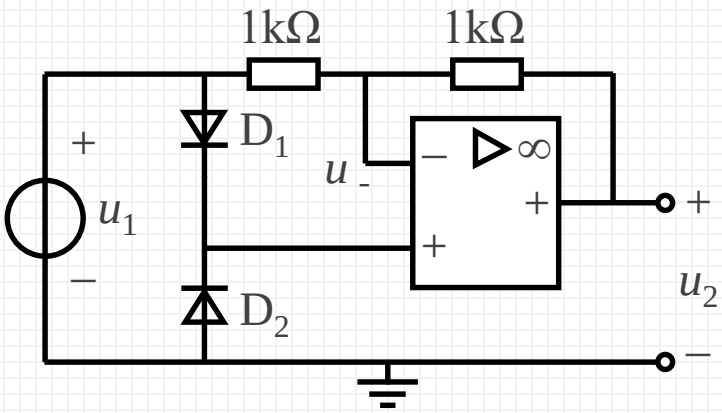


$u < 0$

D_1	D_2
~~短路~~	~~短路~~
~~电阻~~	~~电阻~~
短路	电阻
电阻	短路

D_1**短路**，D_2相当于一个**电阻**





$i > 0$　　$u < 0$

$$u = -u_1$$

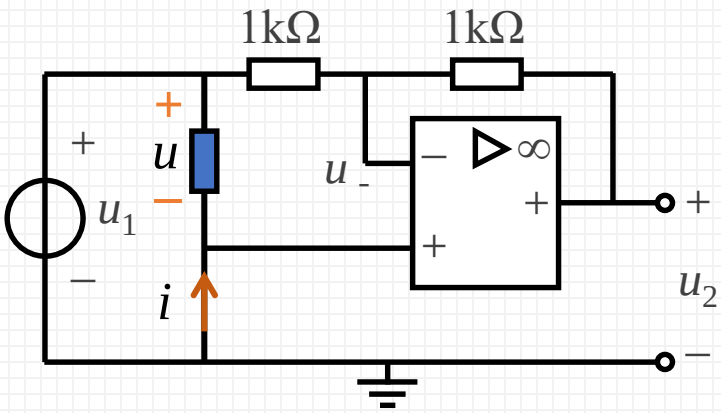
$$u_- = \frac{u_1 + u_2}{2}$$

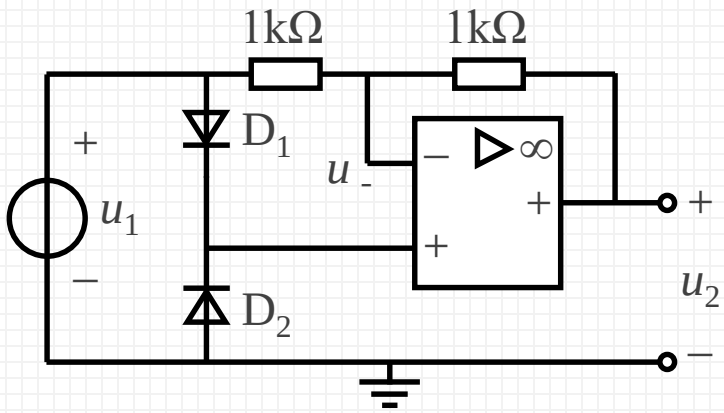
$u_1 > 0$

$i > 0$

$$u_2 = u_1$$

D_1相当于一个**电阻**，D_2**短路**





$i > 0$　　$u < 0$

$u = u_1$

$u_- = \dfrac{u_1 + u_2}{2}$

$\boldsymbol{u_2 = -u_1}$

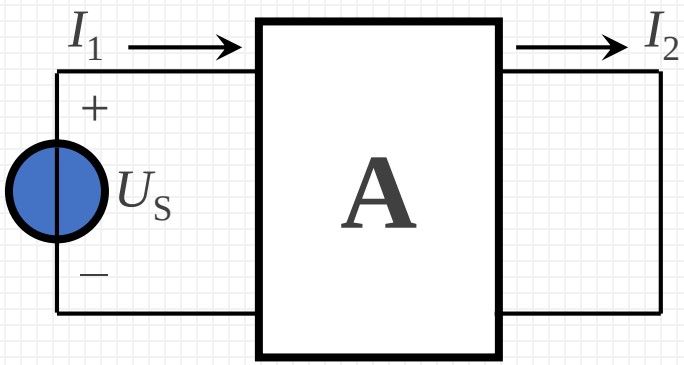
$u_1 < 0$

$\boldsymbol{u_2 = u_1}$　　$u_1 > 0$

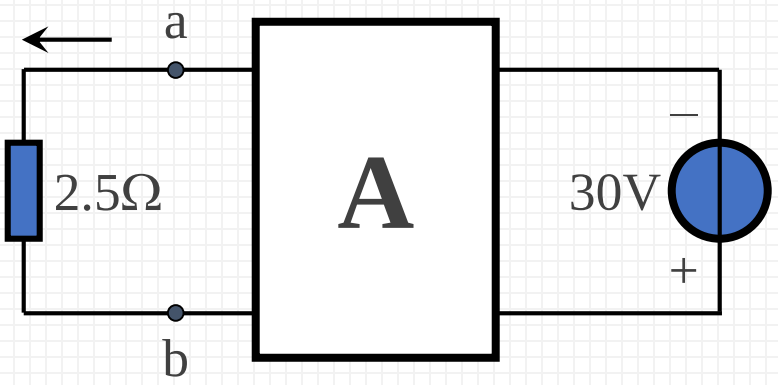
$\boldsymbol{i > 0}$

$\boldsymbol{u_2 = |u_1|}$

十、图示方框为线性含独立源(不含受控源)的电阻网络。已知：图(a)电路当U_S=10V时，I_1=2A，I_2=1A；当U_S=20V时，I_1=6A，I_2=3A。求图(b)电路中ab支路的电流I_{ab}。

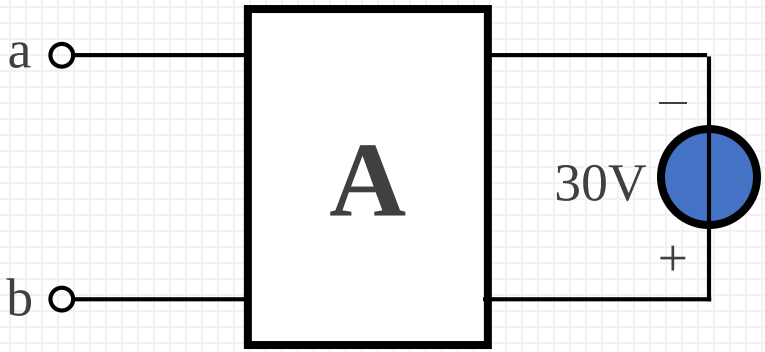


(a)



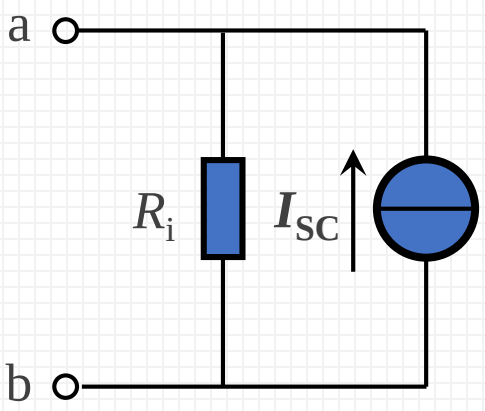
(b)

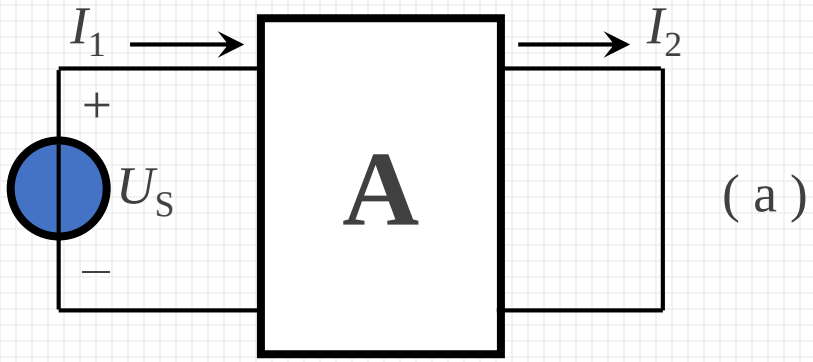
诺顿定理，叠加定理，齐性原理，互易定理



(b)

诺顿等效电路





(a)

设 U_S=10V**单独作用**时在两个支路产生的电流分别为 I_1' 和 I_2'

A中电源单独作用时在两个支路产生的电流分别为 I_1'' 和 I_2''

$$\begin{cases} U_S = 10\text{V} \\ I_1' + I_1'' = 2\text{A} \quad (1) \\ I_2' + I_2'' = 1\text{A} \quad (2) \end{cases}$$

和

$$\begin{cases} U_S = 20\text{V} \\ 2I_1' + I_1'' = 6\text{A} \quad (3) \\ 2I_2' + I_2'' = 3\text{A} \quad (4) \end{cases}$$

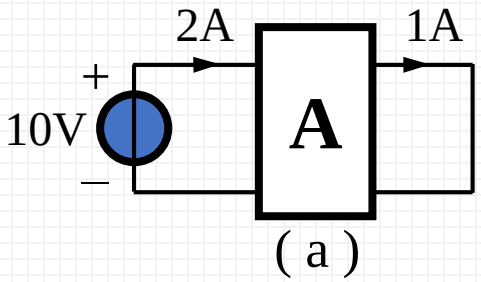
齐性 + 叠加

由式(1)、(3) 得

$$\begin{cases} I_1' = 4\text{A} \\ I_1'' = -2\text{A} \end{cases}$$

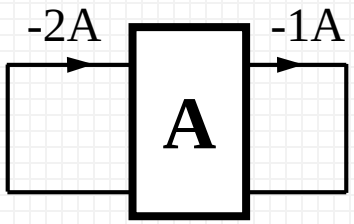
由式(2)、(4) 得

$$\begin{cases} I_2' = 2\text{A} \\ I_2'' = -1\text{A} \end{cases}$$

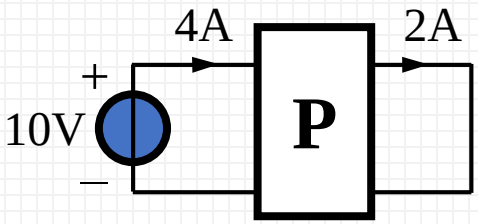


(a)

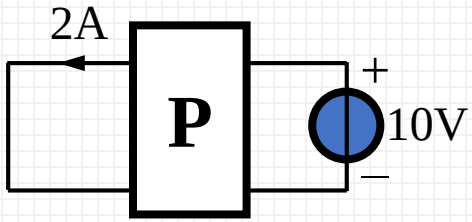
叠加



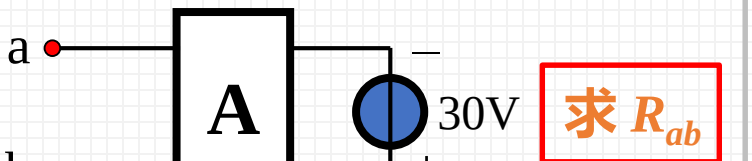
+



互易



齐性

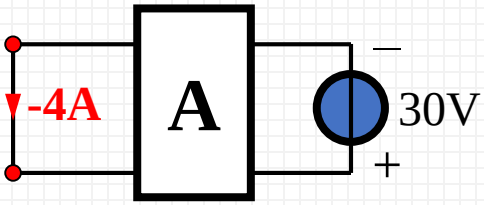


(b)

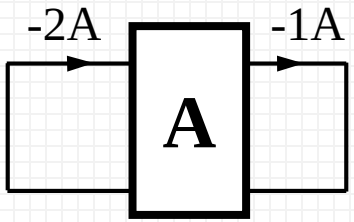
求 R_{ab}

求短路电流

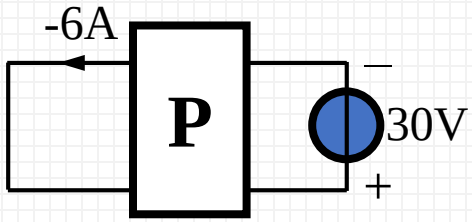
R_{ab}=10/4=2.5Ω



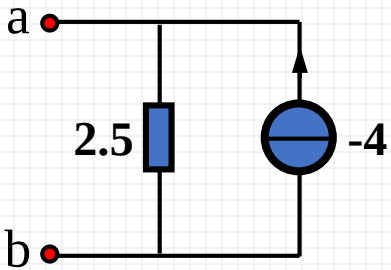
叠加

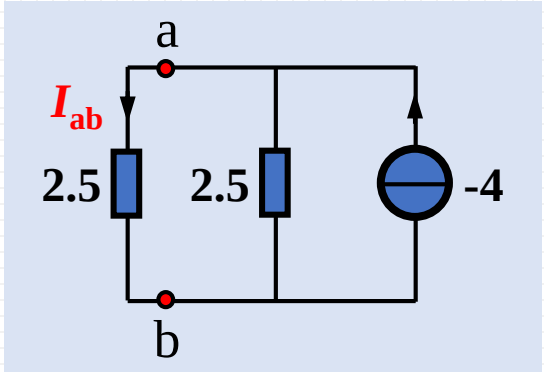


+



诺顿等效电路





I_{ab}= -2A