第4章　电路定理

4.1叠加定理 Superposition Theorem

4.2替代定理 Substitution Theorem

4.3 戴维宁(诺顿)定理Thevenin(Norton) Theorem

4.4 最大功率传输定理Maximum Power Theorem

4.5 特勒根和互易定理
Tellegen's theorem & Reciprocity theorem

4.6 定理综合运用

第4章　电路定理

目标：

1.熟练应用叠加定理。

2.熟练应用戴维宁/诺顿定理。

3.熟练分析最大功率传输问题。

4.应用互易定理和特勒根定理。

难点：

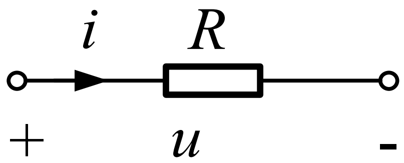
1.电路定理综合应用问题分析。

2.选择合适的分析方法。

讲授学时：6

4.2 线性特性与线性电路

1.线性元件



$u = Ri$

If $i' = \mathrm{k}i$， then $u' = \mathrm{k}u$. **Homogeneity property** 齐次性

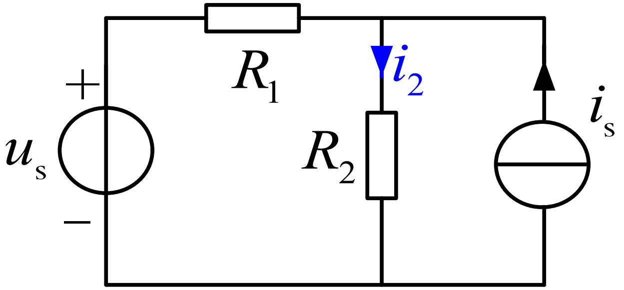
If $i = i_1 + i_2$， then $u = u_1 + u_2$. **Additivity property** 可加性

2. 线性电路

除独立电源外，电路中其他元件均为线性元件。

4.3 叠加定理 Superposition Theorem

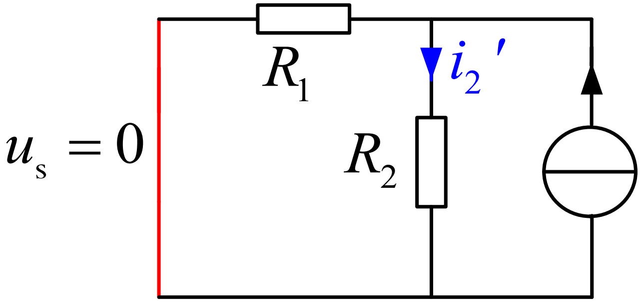
2. 线性电路



$$\left(\frac{1}{R_1}+\frac{1}{R_2}\right)R_2 i_2 = i_s + \frac{1}{R_1}u_s$$

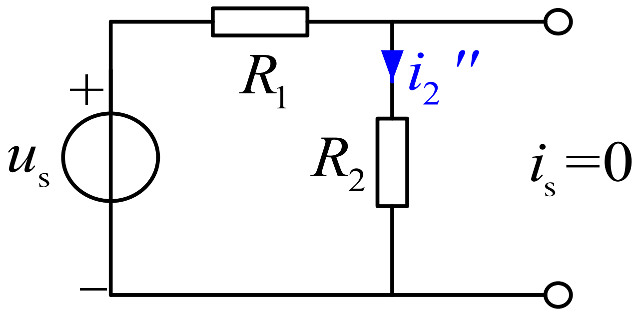
$$i_2 = \frac{R_1}{R_1+R_2}i_s + \frac{1}{R_1+R_2}u_s$$

电流源单独作用



$$i_2' = \frac{R_1}{R_1+R_2}i_s$$

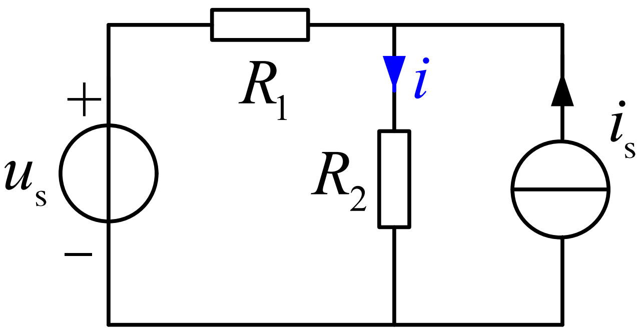
电压源单独作用



$$i_2'' = \frac{1}{R_1+R_2}u_s$$

4.3 叠加定理 Superposition Theorem

2. 线性电路 $i_2 = \dfrac{R_1}{R_1+R_2} i_s + \dfrac{1}{R_1+R_2} u_s$



3. 叠加定理

$\boxed{i_2 = i_2' + i_2''}$ 可加性

$\boxed{i_2' = k_1 i_s}$ $\boxed{i_2'' = k_2 u_s}$

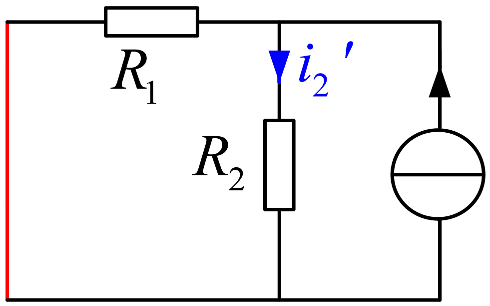
齐次性（单电源作用）

$\boxed{i_2 = k_1 i_s + k_2 u_s}$

线性性（对功率不适用）

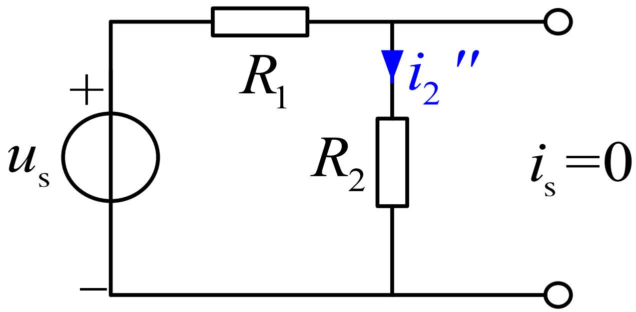
电流源单独作用

$u_s = 0$



$$i_2' = \frac{R_1}{R_1+R_2} i_s$$

电压源单独作用



$$i_2'' = \frac{1}{R_1+R_2} u_s$$

4.3 叠加定理 Superposition Theorem

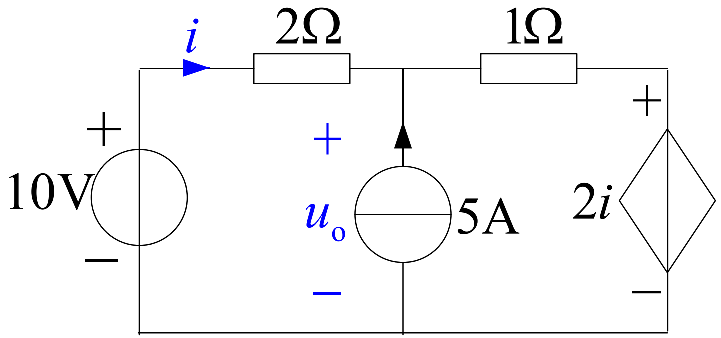
3. 叠加定理

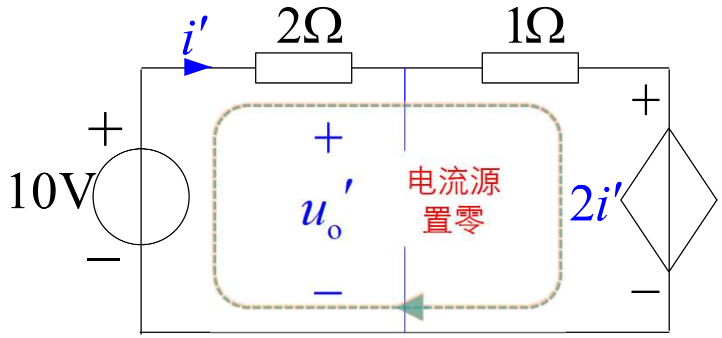
线性电路中，多个独立电源共同激励下的响应（任意电流或电压），等于各独立电源单独（或分组）激励下的响应的代数和。

将多电源电路转化为单电源电路进行计算。

4. 定理应用Applications

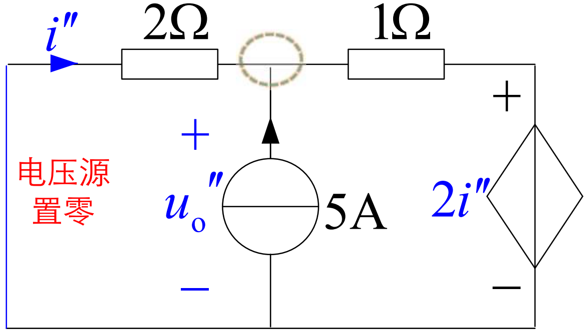
【例 1】 确定电压u_0电流i。





网孔方程：$(2+1)i' = 10 - 2i'$

$$u_o' = 1 \times i' + 2i'$$



结点方程：

$$(\frac{1}{2}+\frac{1}{1})u_o'' = 5 + \frac{2i''}{1}$$

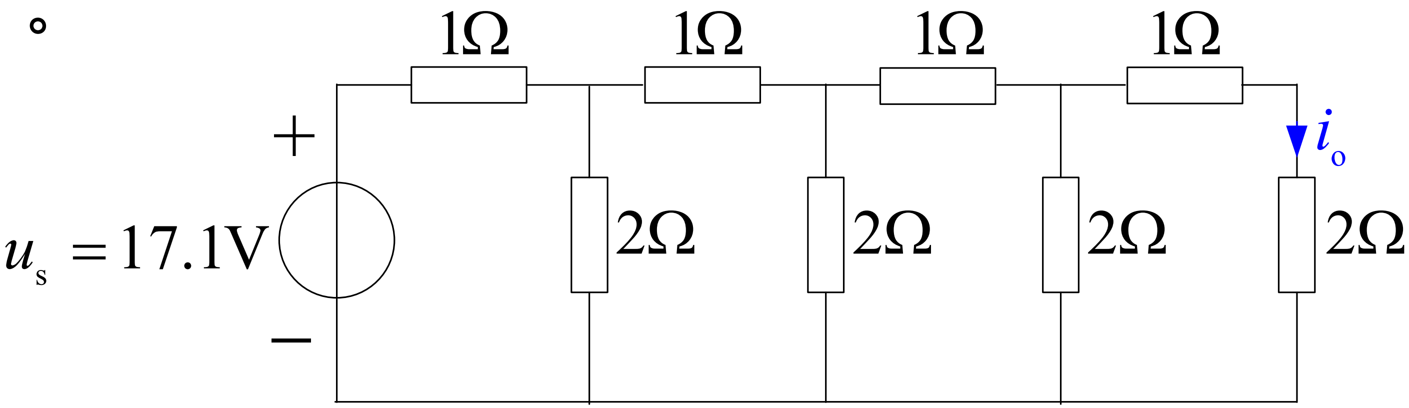
$$u_o'' = -2i''$$

$$u_o = u_o' + u_o'', \quad i = i' + i''$$

$$p_{2\Omega} = i^2 R \neq i'^2 R + i''^2 R$$

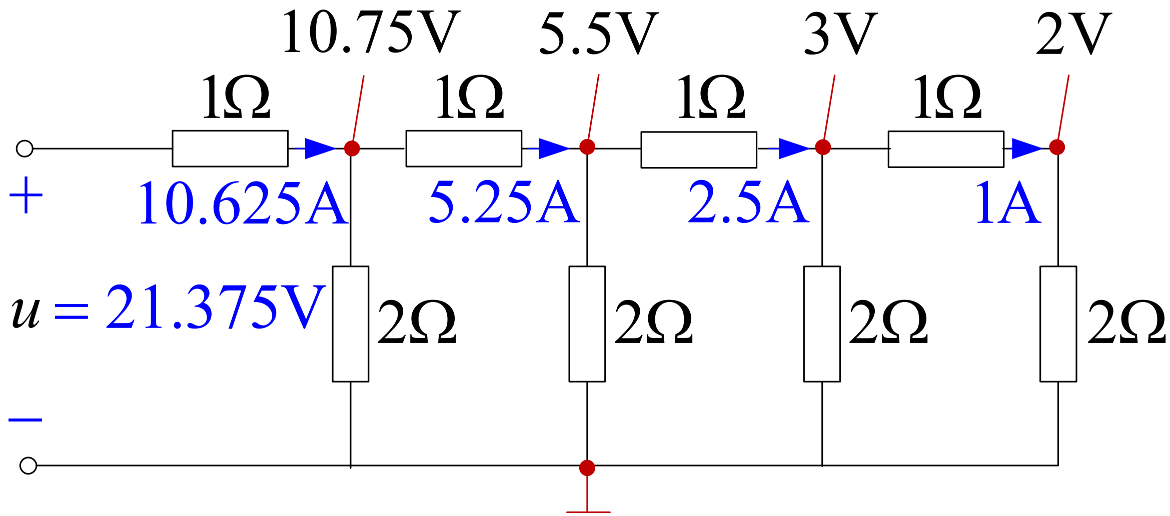
功率不符合叠加关系！

【例 2】确定 i_o 。



由此

$u_s = 21.375\text{V} \rightarrow i_o = 1\text{A}$



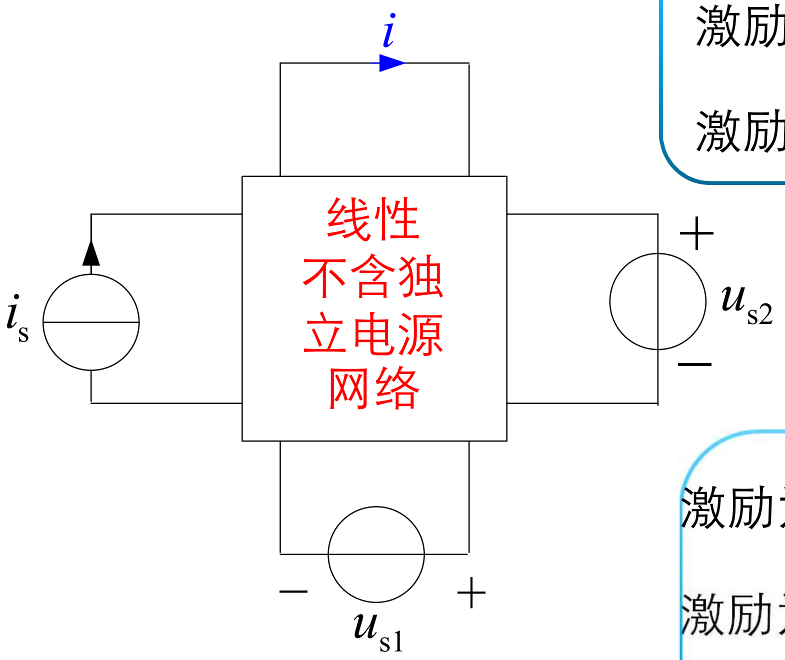
响应与激励的关系为

$$i_o = \frac{1}{21.375} u_s = \frac{8}{171} u_s$$

因此

$$u_s = 17.1\text{V} \rightarrow i_o = \frac{8}{171} \times 17.1 = 0.8\text{A}$$

【例 3】确定电流 i 。



已知条件

激励为 i_s 和 u_{s1} (u_{s2} 置零) → 响应 $i = 2\text{A}$

激励为 i_s 和 u_{s2} (u_{s1} 置零) 响应 $i = -0.5\text{A}$

激励为 i_s 、 u_{s1} 和 u_{s2} 响应 $i = 1.2\text{A}$

确定

激励为 i_s 响应 $i = ?$ → i'

激励为 u_{s1} 响应 $i = ?$ → i''

激励为 u_{s2} 响应 $i = ?$ → i'''

激励为 $0.5i_s$ $2u_{s1}$ 和 $3u_{s2}$ 响应 $i = ?$ → i

$$\begin{cases} i' + i'' = 2 \\ i' + i''' = -0.5 \\ i' + i'' + i''' = 1.2 \end{cases}$$

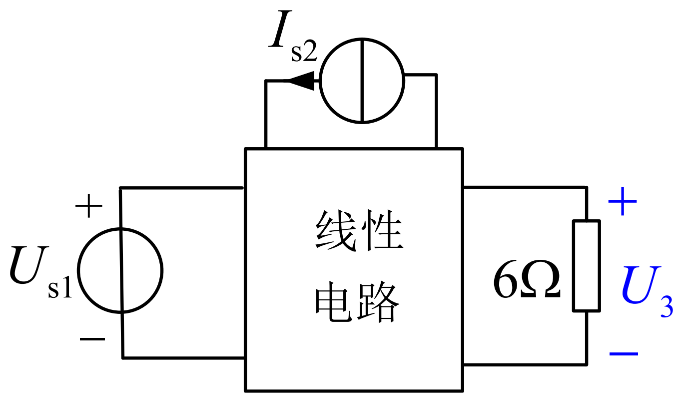
解得 $i'=0.3$、$i''=1.7$、$i'''=-0.8$

$$i = 0.5i' + 2i'' + 3i''' = 1.15\text{A}$$

【练习】一线性电路，U_{S1}=0V，I_{S2}=0A时，有U_3=3V；

U_{S1}=1V，I_{S2}= -1A时，U_3=2V；U_{S1}= -4V，I_{S2}=1A时，U_3=1V。

求当U_{S1}=1V，I_{S2}=2A时，U_3=?



解：由叠加定理

$$U_3 = U_3' + U_3'' + U_3'''$$

$$= k_1 U_{s1} + k_2 I_{s2} + k$$

➢$k_1 U_{S1}$：U_{S1}单独激励产生的电压分量；

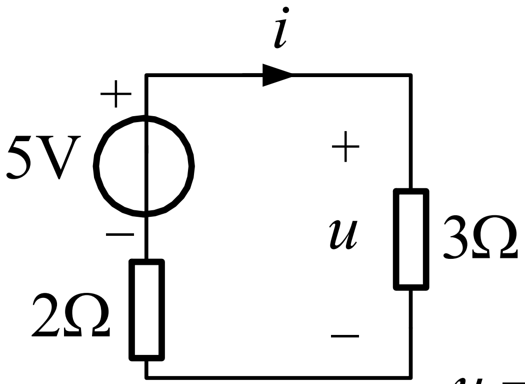
➢$k_2 I_{S2}$：I_{S2}单独作用产生的电压分量；

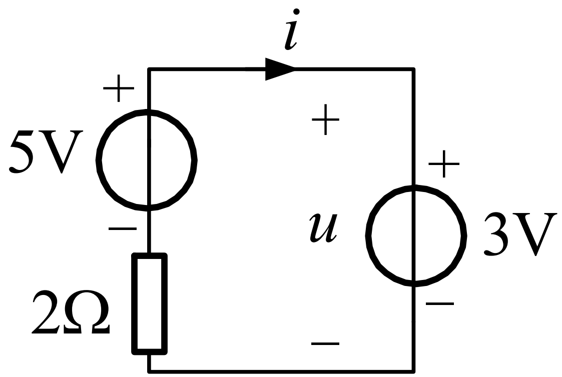
➢k：由电路内的独立源一起激励产生的电压分量；

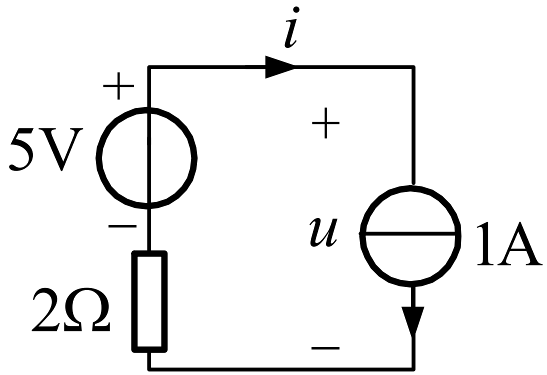
$$\begin{cases} 3 = k_1 \times 0 + k_2 \times 0 + k \\ 2 = k_1 \times 1 + k_2 \times (-1) + k \\ 1 = k_1 \times (-4) + k_2 \times 1 + k \end{cases} \Rightarrow \begin{cases} k_1 = 1 \\ k_2 = 2 \\ k = 3 \end{cases} \Rightarrow U_3 = U_{S1} + 2I_{S2} + 3$$

$$= 8\,\text{V}$$

4.4 替代定理 (Substitution Theorem)



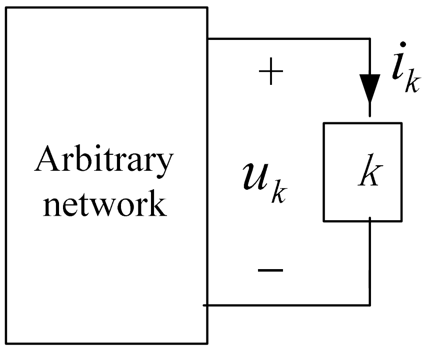




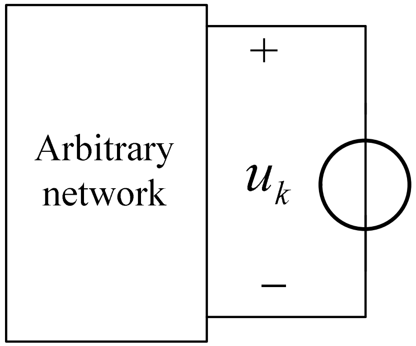
$u = 3\text{V}$

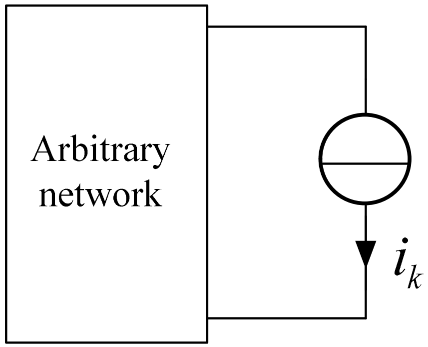
$i = 1\text{A}$

1.定理内容



$\rightarrow$





4.4 替代定理 (Substitution Theorem)

1.定理内容:

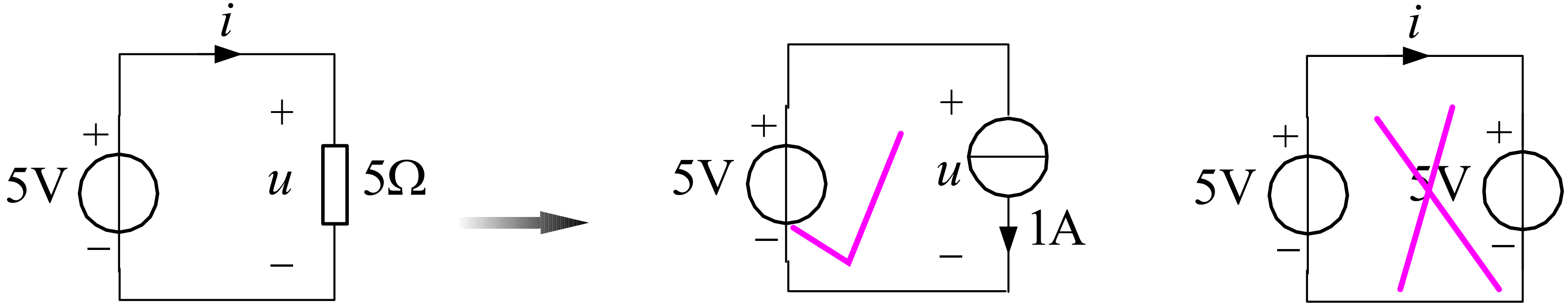
在任意一个电路中，若某支路k电压为u_k、电流为i_k，且该支路与其它支路不存在耦合，那么这条支路

- 可以用一个电压等于u_k的独立电压源替代;
- 或者用一个电流等于i_k的 独立电流源来替代;

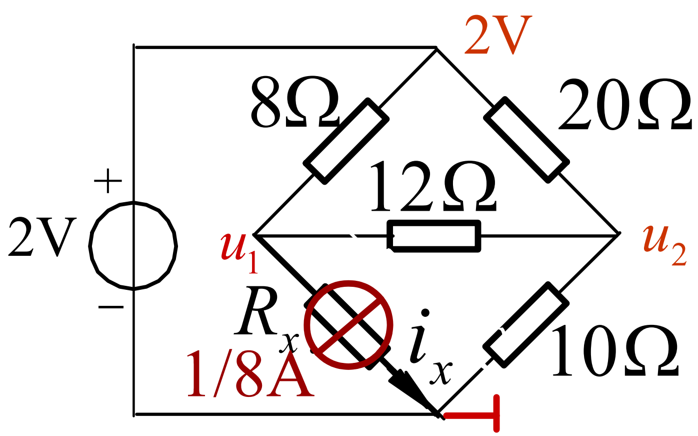
若替代后电路仍具有唯一解，则整个电路的各支路电压和电流保持不变。

2.定理应用 Applications

支路电压、电流具有唯一解



已知 $\boldsymbol{i_x}$ **=1/8 A.** 计算 $\boldsymbol{R_x}$**.**



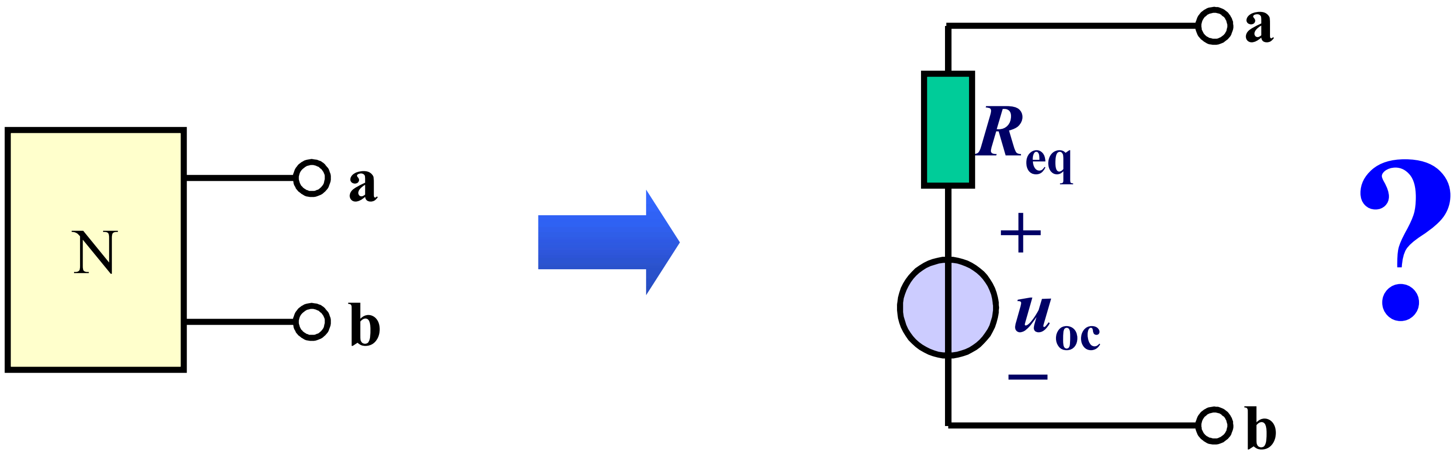
Nodal analysis：

$$\begin{cases} (\frac{1}{8}+\frac{1}{12})u_1-\frac{1}{12}u_2-\frac{1}{8}\times 2=-\frac{1}{8} \\ -\frac{1}{12}u_1(\frac{1}{20}+\frac{1}{12}+\frac{1}{10})u_2-\frac{1}{20}\times 2=0 \end{cases}$$

解方程得出： u_1=0.9V

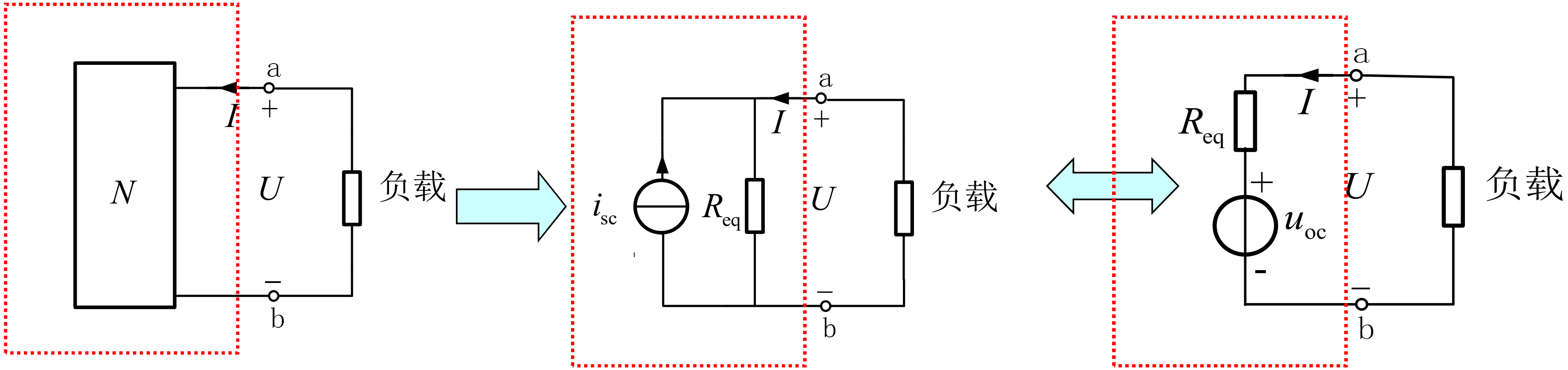
$$R_x=u_1\Big/\frac{1}{8}=0.9\times 8=7.2\Omega$$

4.5 戴维南定理与诺顿定理Thevenin-Norton Theorem



1 定理

戴维南-诺顿定理：一个线性含有独立电源、线性电阻和线性受控源的一端口网络，对外电路来说，可用一个电压源和电阻串联等效，也可用一个电流源和电阻并联等效。



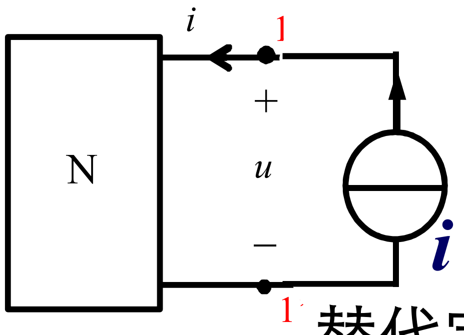
原始电路　　诺顿等效电路　　戴维南等效电路

➢ u_{oc} 是端口的开路电压 （**Open-circuit voltage**）

➢ R_{eq}独立电源置零后的端口等效电阻（**Equivalent resistance**）

➢ i_{sc} 是端口的短路电流（**Short-circuit current**）

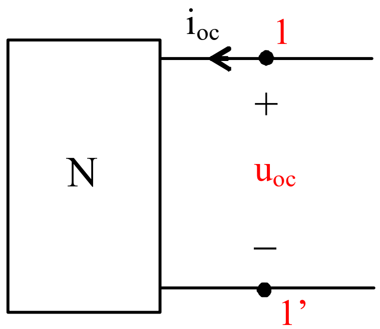
2 定理证明:



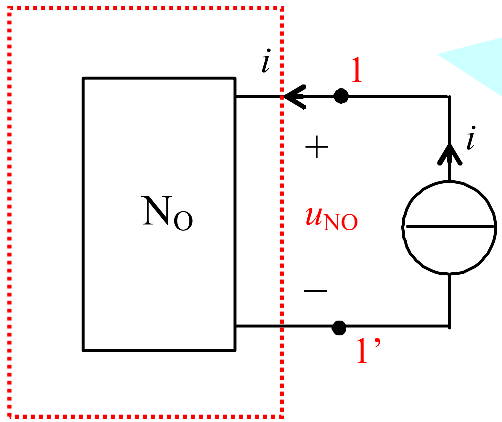
替代定理

利用替代定理，将外部电路用电流源替代，此时***u***, ***i***值不变。计算***u***值。

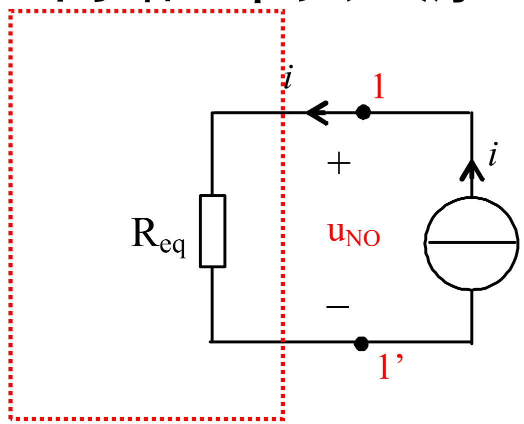
利用叠加定理，让电流源和**N**中电源分别单独作用。计算***u***值。



电流源***i***为零



网络**N**中独立源全部置零

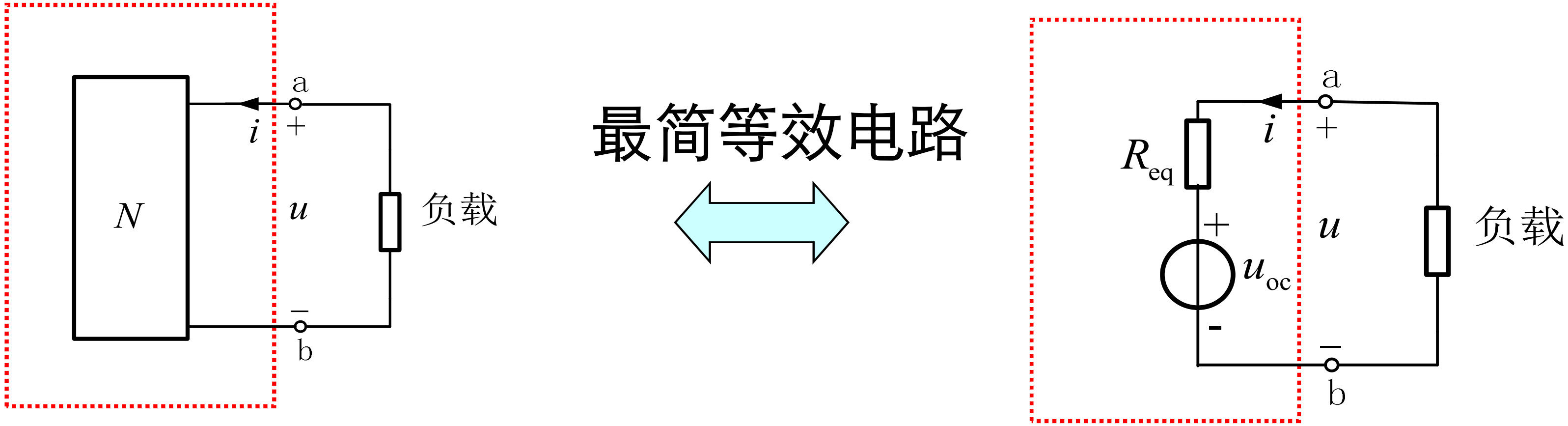


$$u = u' + u''$$

$$= u_{oc} + R_{eq} i$$

2 定理证明:

$$u = u_{oc} + R_{eq} i$$



结论:

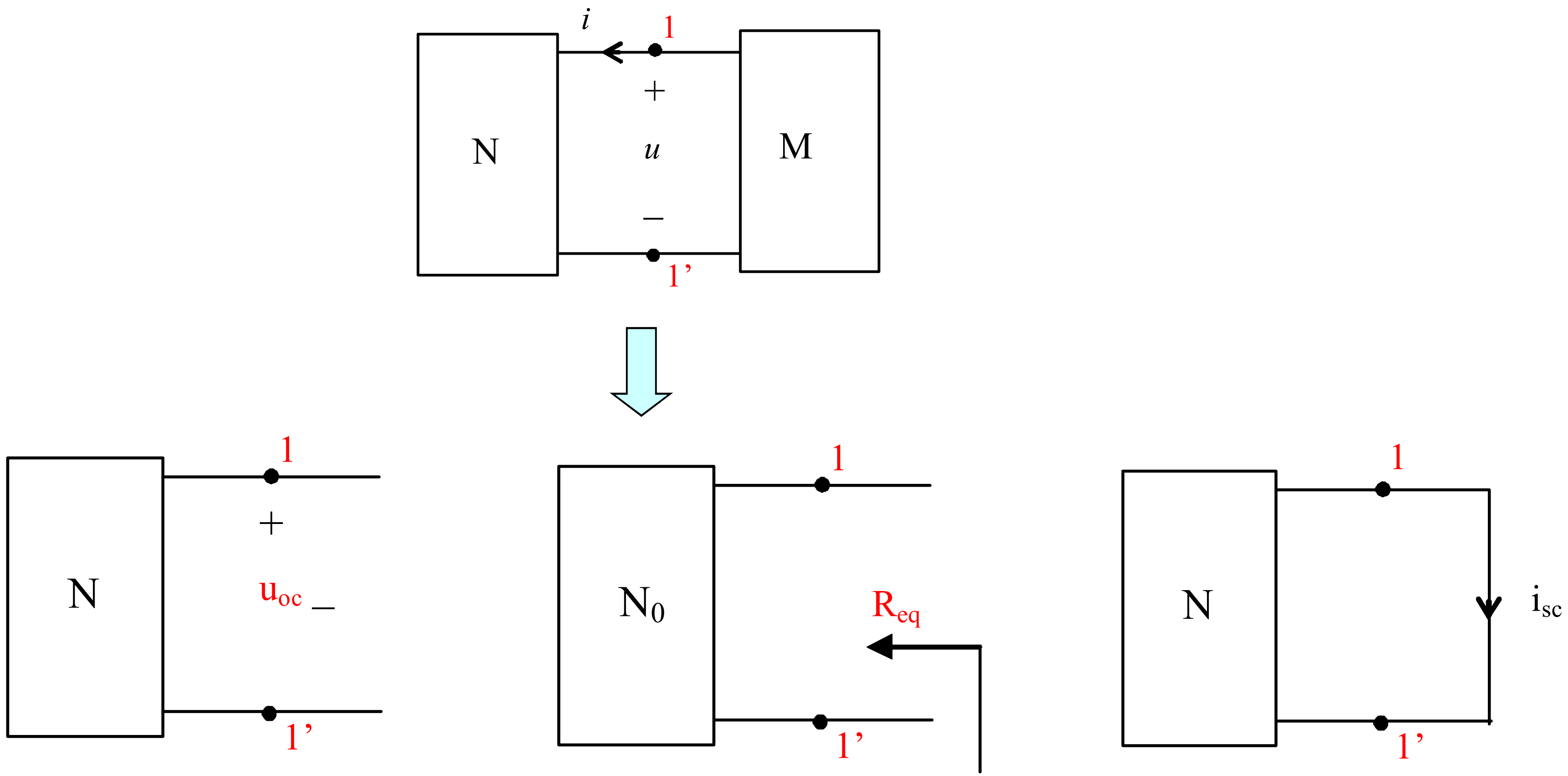
线性有源二端网络N，对外电路而言，可以用一个电压源和电阻元件串联组成的等效电路代替。

$\boldsymbol{u_{oc}}$ 是端口的开路电压；$\boldsymbol{R_{eq}}$一端口中全部独立电源置零后的端口等效电阻。

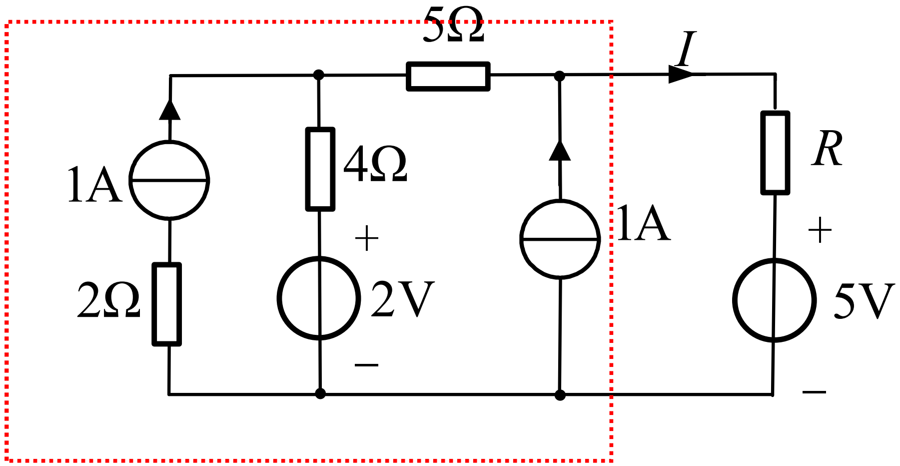
3.定理应用 Applications

确定戴维宁定理参数的方法:

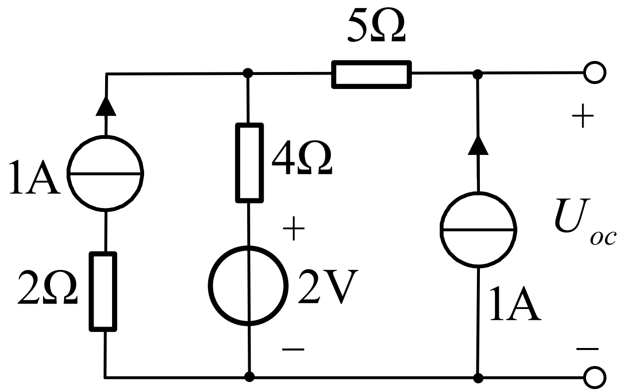
- 将待求支路移走,形成线性有源二端网络,求该网络的短路电流或开路电压或者入端电阻



【例 1】图示电路中，R为可调电阻。问：R为何值时，I=1A?



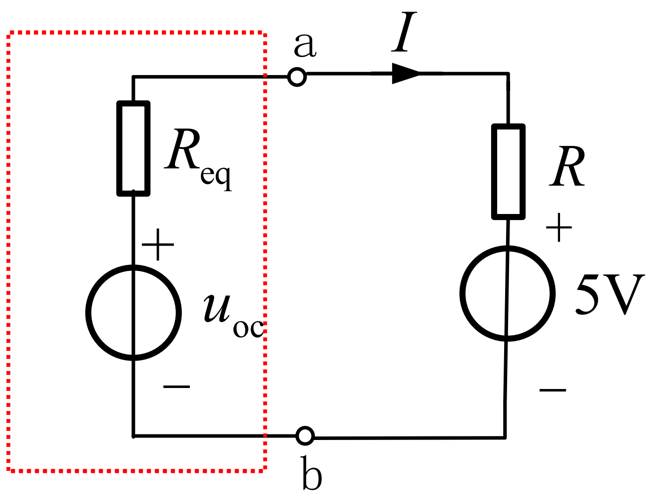
解：求开路电压$\boldsymbol{u}_{\mathbf{oc}}$，：



$$u_{\mathrm{oc}} = 1\times 5+4\times 2+2=15\mathrm{V}$$

求等效电阻R_{eq}：

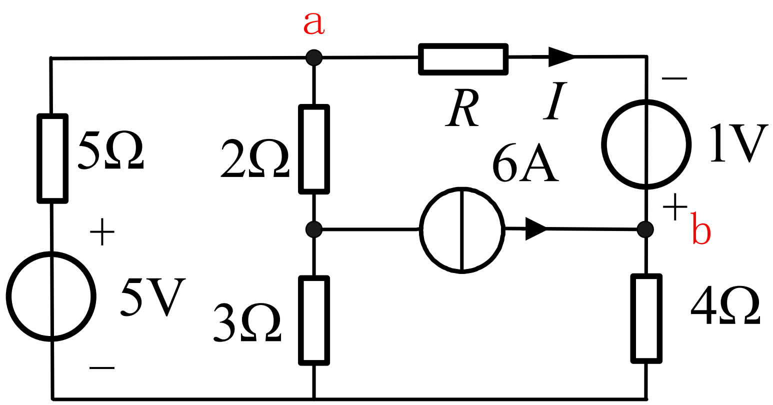
$$R_{\mathrm{eq}} = 9\Omega$$



$$I = \frac{u_{\mathrm{oc}} - 5}{R+9} = 1$$

$$R = 1\Omega$$

【练习】：图示电路中，R为可调电阻。问：R为何值时，I=-1A?

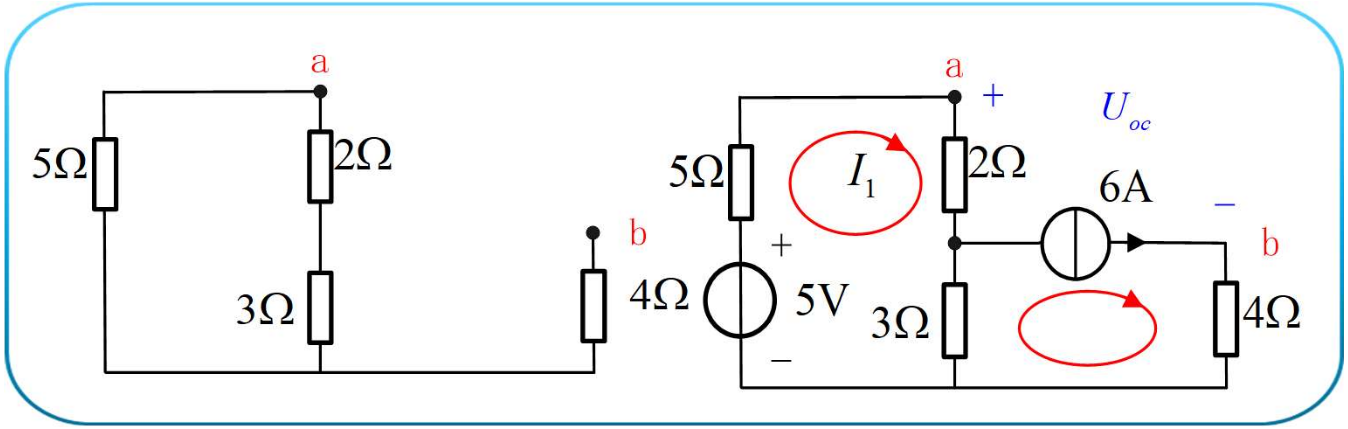


解：求开路电压u_{0C}，：

$$(5+2+3)I_1-3\times 6=5$$

$$I_1=2.3\text{A}$$

$$u_{oc}=-5\times 2.3+5-4\times 6=-30.5\text{V}$$



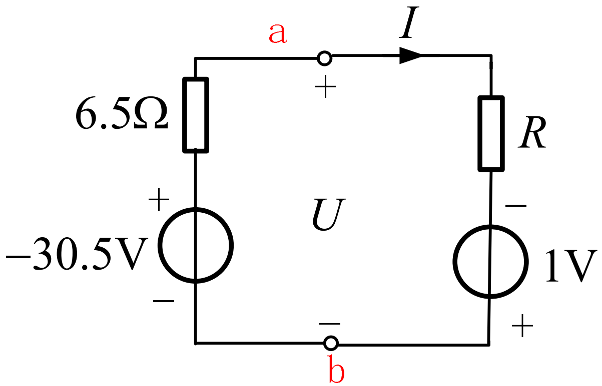
求等效电阻R_{eq}：

$$R_{eq}=6.5\Omega$$

$$I_1=\frac{U_{oc}+1}{R_{eq}+R_1}$$

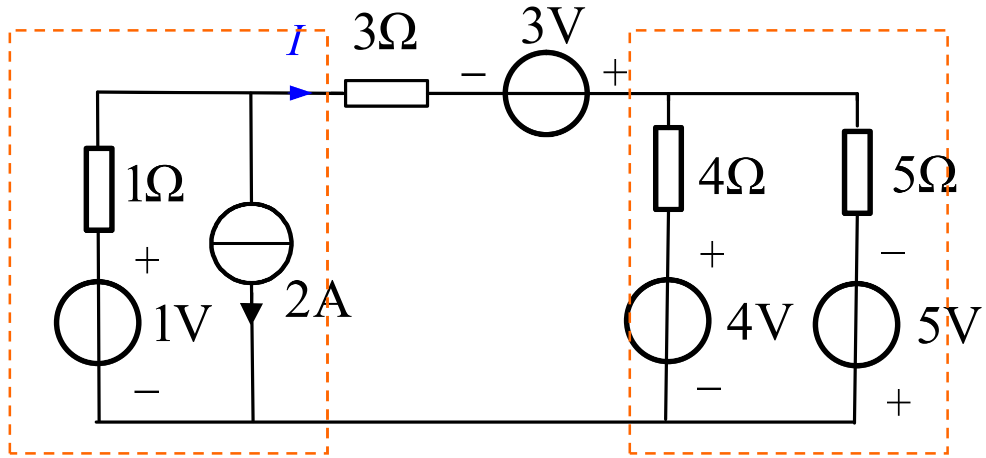
$$\therefore R_1=\frac{U_{oc}+1}{I_1}-R_{eq}$$

$$=23\Omega$$



【例 2】求电流I。

解：求开路电压与等效电阻

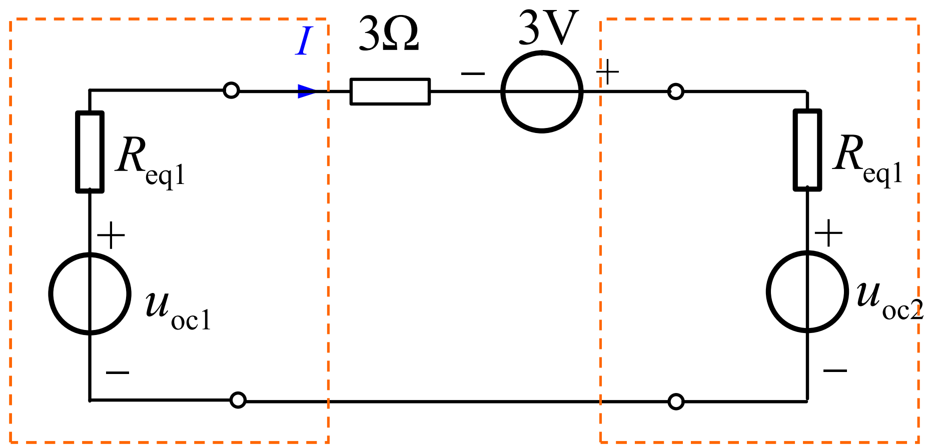


$$u_{oc1} = 1 - 2\times 1 = -1\text{V}$$

$$R_{eq1} = 1\Omega$$

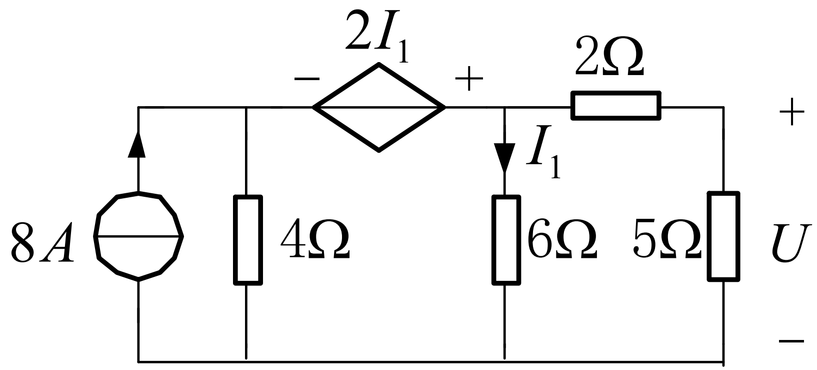
$$u_{oc2} = 0\text{V}$$

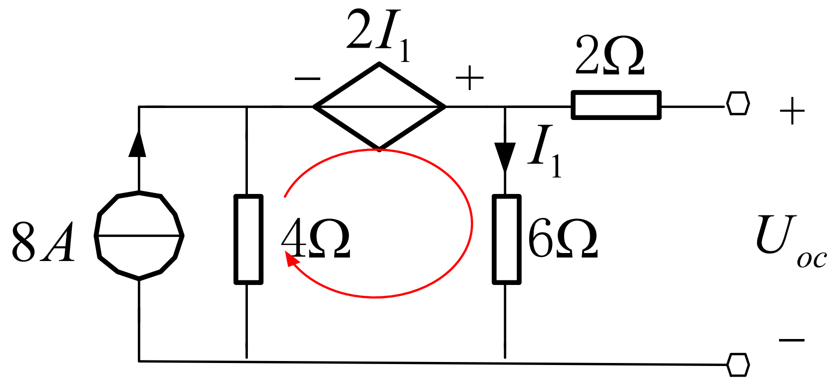
$$R_{eq2} = \frac{20}{9}\Omega$$



$$I = \frac{3+(-1)-0}{3+1+\frac{20}{9}} = \frac{9}{28}\text{A}$$

【例 3】.Find the voltage U.

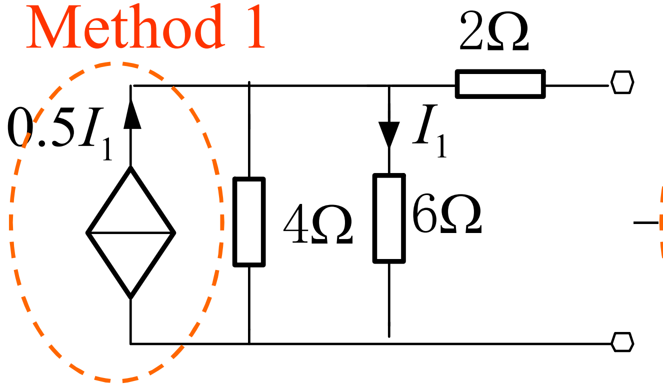


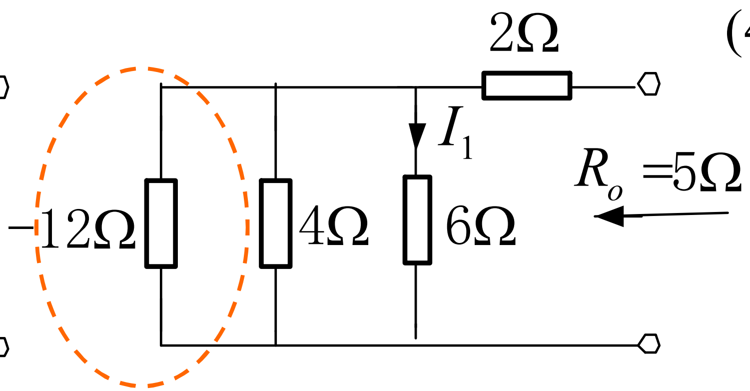


$$(4+6)I_1-8\times 4=2I_1$$

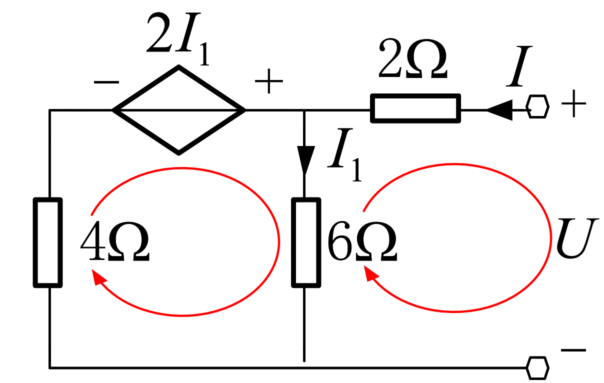
$$\Rightarrow I_1=4\text{A}$$

Method 1





Method 2



$$-6I_1-2I+U=0$$

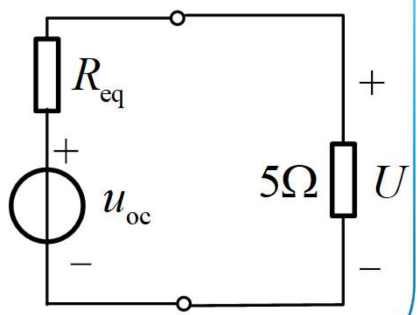
$$-2I_1-4(I-I_1)+6I_1=0$$

$$I_1=0.5I$$

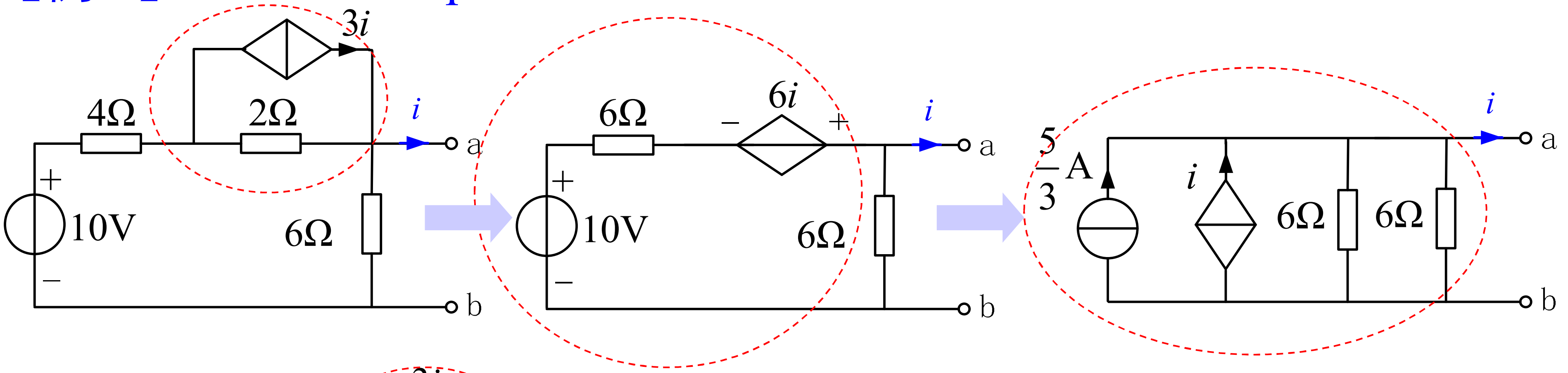
$$R_o=\frac{U}{I}=5\Omega$$

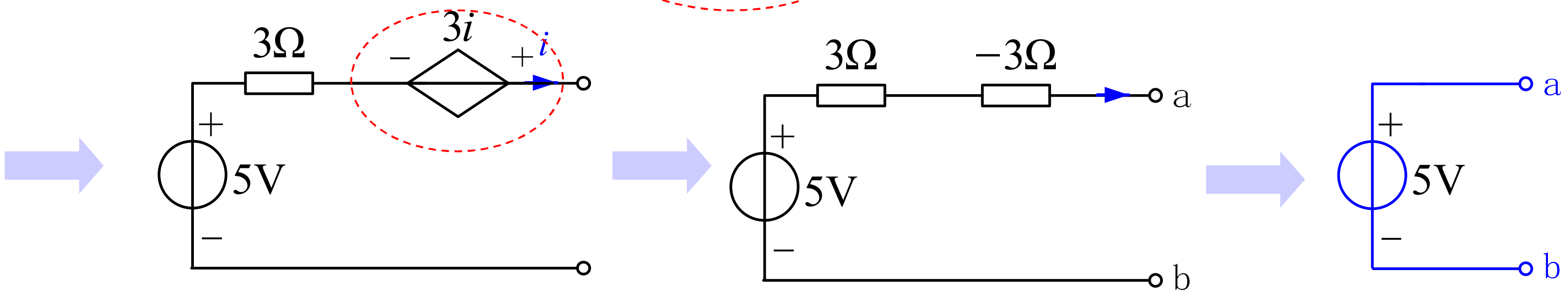
$U_{oc}=24V$

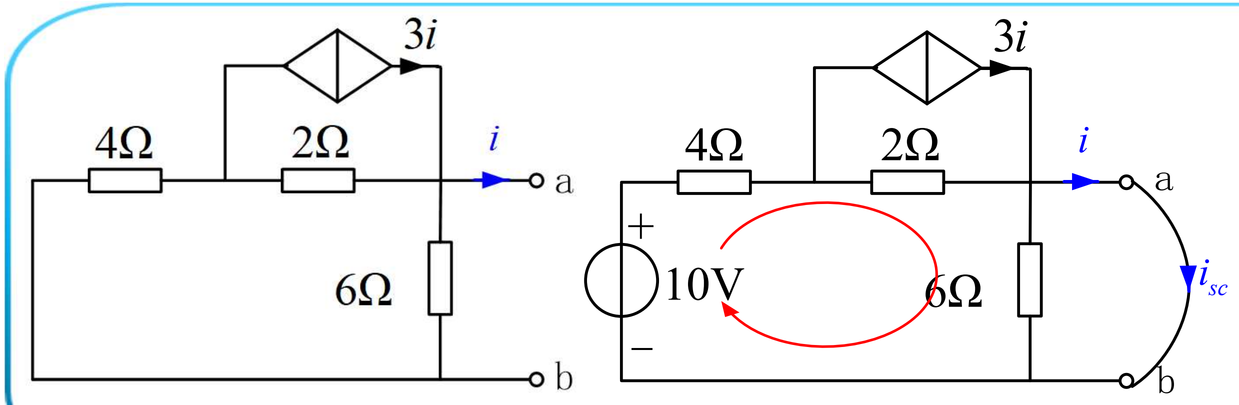
$R_o=5\Omega$



【例 4】. Find the equivalent circuit.







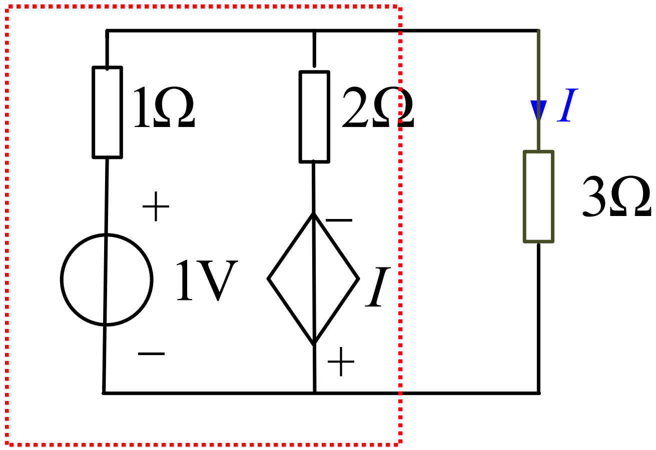
$$u_{oc} = 10 \times \frac{6}{4+2+6} = 5\text{V}$$

$$R_{eq} = 0\Omega$$

$$(4+2)i_{sc} - 2 \times 3i_{sc} = 10$$

$$i_{sc} = \infty$$

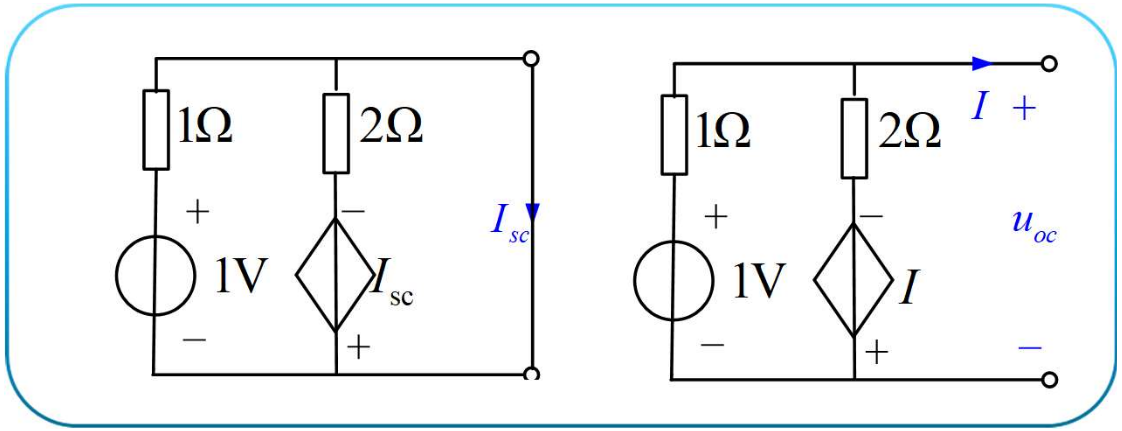
【练习】求电流I。



解：求开路电压u_{oc}：

$$u_{oc}=1\times\frac{2}{1+2}=\frac{2}{3}\text{V}$$

求等效内阻（求短路电流）：

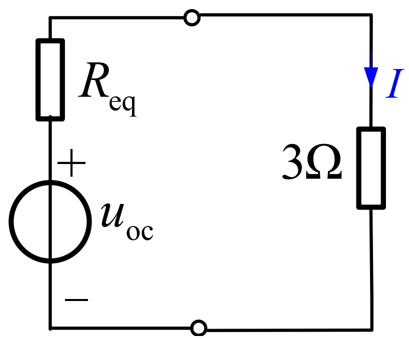


由KCL得：

$$I_{sc}-1+\frac{I_{sc}}{2}=0 \qquad I_{sc}=\frac{2}{3}\text{A}$$

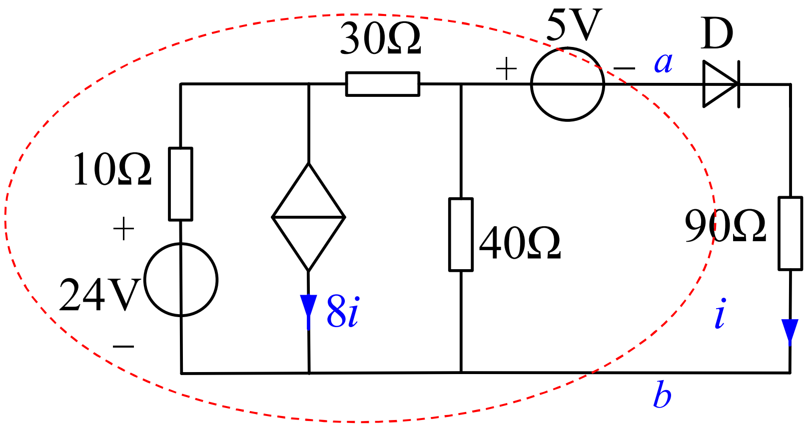
$$R_{eq}=\frac{U_{oc}}{I_{sc}}=1\Omega$$

求 I：

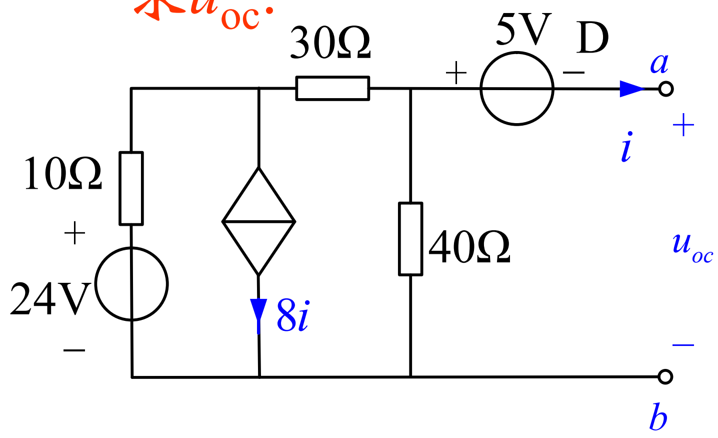


$$I=\frac{u_{oc}}{R_{eq}+3}=\frac{u_{oc}}{4}=\frac{1}{6}\text{A}$$

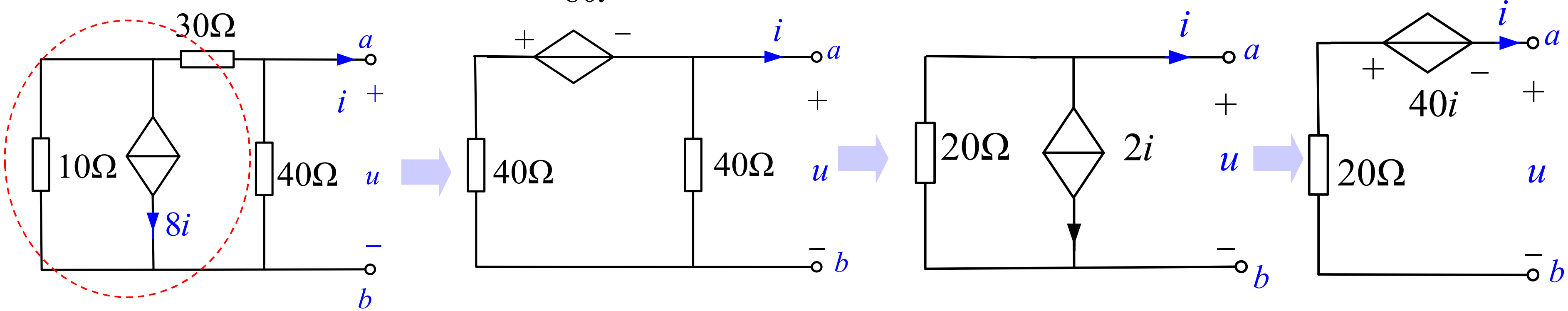
【练习】. 二极管**D**状态？设**D**导通压降为**0.7V**，求$\boldsymbol{i}$。(习题4-25)

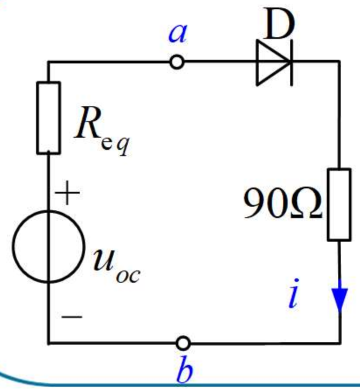


求u_{oc}:



求等效电阻



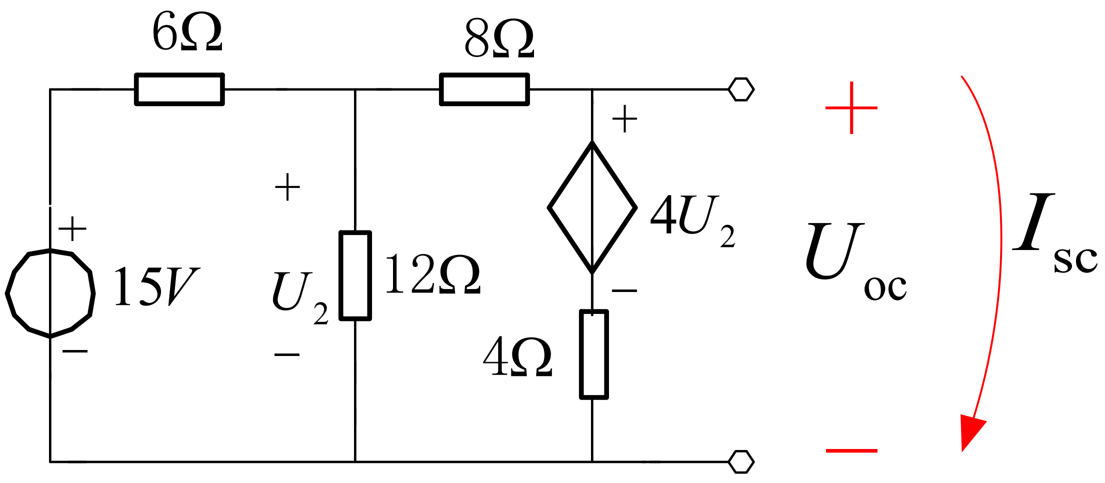


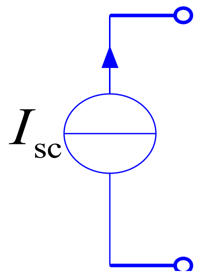
$$u_{oc} = \frac{40}{10+30+40} \times 24 - 5 = 7\text{V}$$

$$R_{eq} = 20+40 = 60\Omega$$

$$i = \frac{7-0.7}{60+90} = 0.042\text{A}$$

【课下练习】求等效电路。





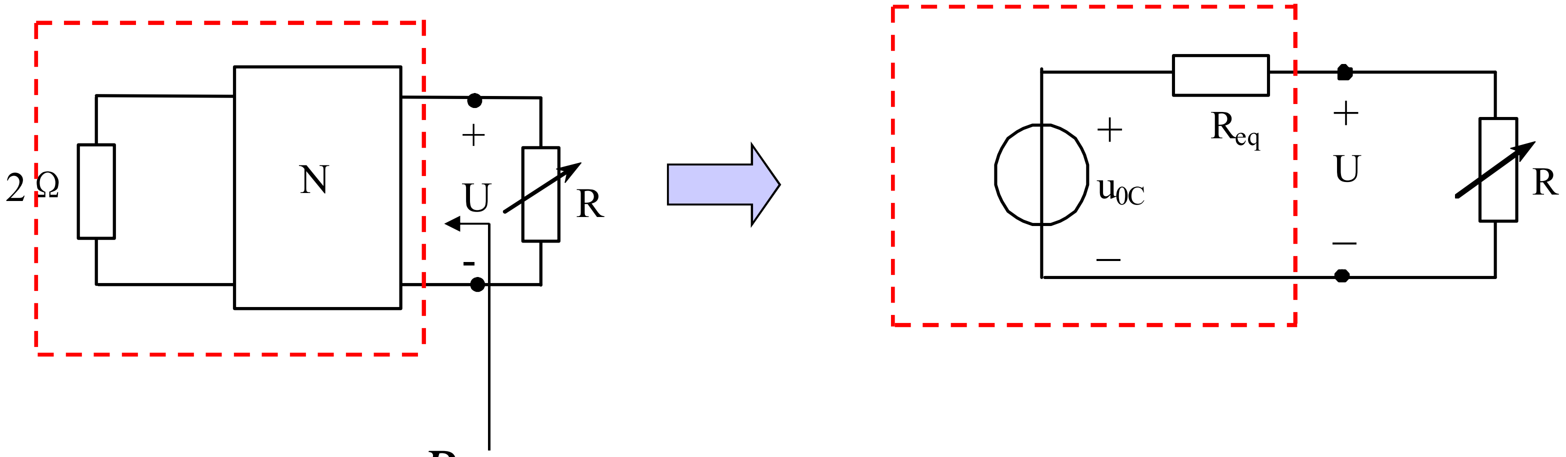
$$\left(\frac{1}{6}+\frac{1}{12}+\frac{1}{12}\right) U_2=\frac{15}{6}+\frac{4U_2}{12} \quad \Rightarrow \quad U_2=\infty,\ \ U_{oc}=\infty$$

$$\left(\frac{1}{6}+\frac{1}{12}+\frac{1}{8}\right) U_2=\frac{15}{6} \quad \Rightarrow \quad U_2=\frac{20}{3}\mathrm{V} \quad \Rightarrow \quad I_{sc}=\frac{U_2}{8}+\frac{4U_2}{4}=\frac{15}{2}\mathrm{A}$$

3.定理应用 Applications

由网络端口伏安关系确定等效模型

【例 5】. N为含独立源的线性电阻网络，确定图中端口左侧的戴维南等效电路。已知当R=4Ω时，U=4V；R=12Ω时，U=6V。

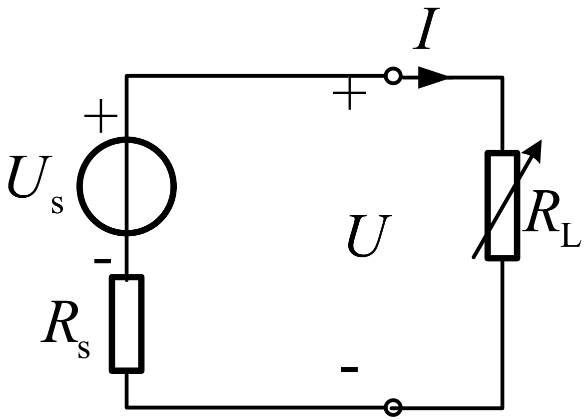


解：
$$\because U=\frac{R}{R+R_{eq}}u_{oc}$$

$$\Rightarrow\begin{cases}4=\dfrac{4}{4+R_{\mathrm{eq}}}u_{oc}\\[2ex]6=\dfrac{12}{12+R_{\mathrm{eq}}}u_{oc}\end{cases}\qquad\Rightarrow\begin{cases}u_{oc}=8\mathrm{V}\\R_{eq}=4\Omega\end{cases}$$

4.6 最大功率传输定理Maximum Power Theorem

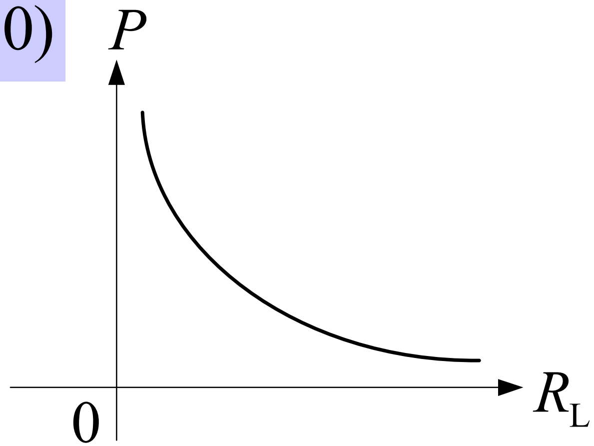
1.负载吸收功率的变化规律



$$P = R_L I^2 = R_L \times \left(\frac{U_s}{R_L + R_s}\right)^2$$

$R_s << R_L$ (或 $R_s \to 0$)

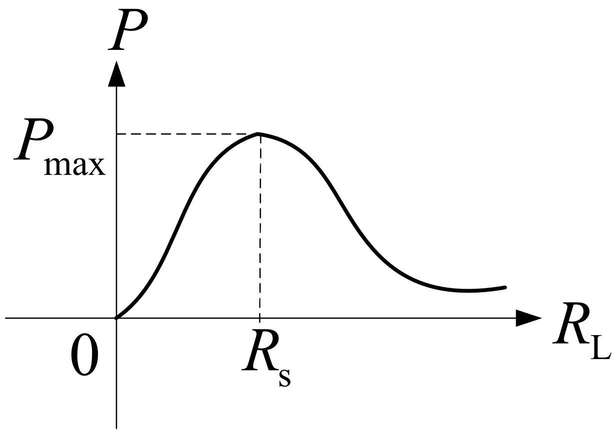
$$P \approx \frac{U_s^{\,2}}{R_L}$$



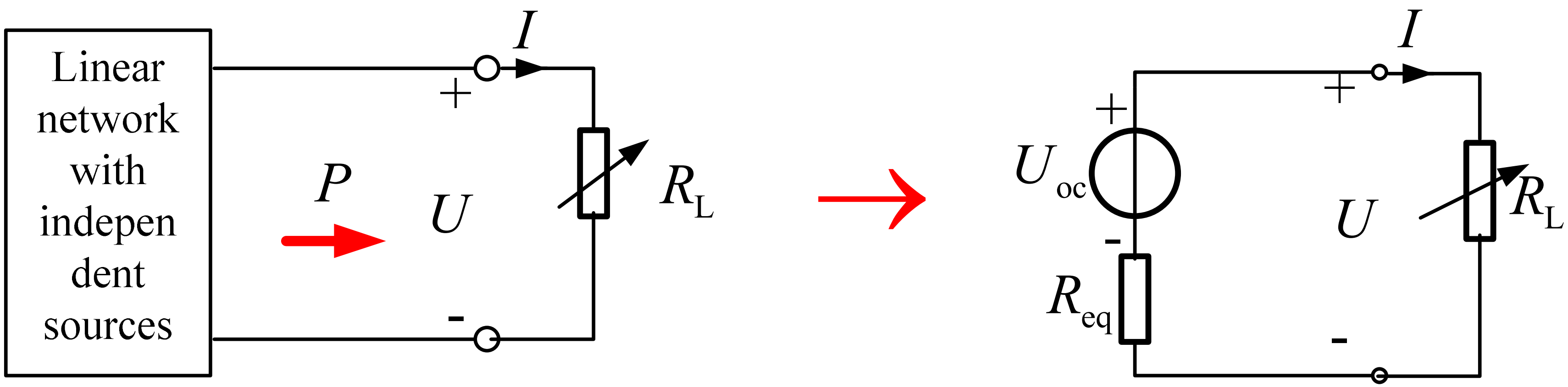
$R_s \neq 0$

$$P_{max} = ?$$

$$P_{max} = \frac{U_s^{\,2}}{4R_s}$$



4.6 最大功率传输定理Maximum Power Theorem



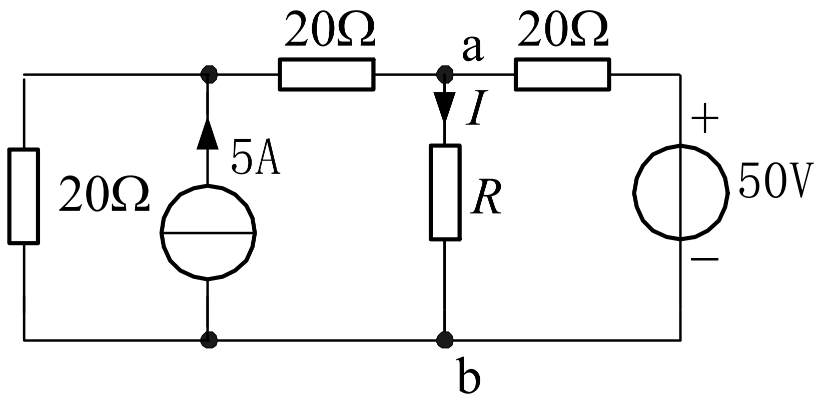
$$R_L = ? \Rightarrow P = \max = ?$$

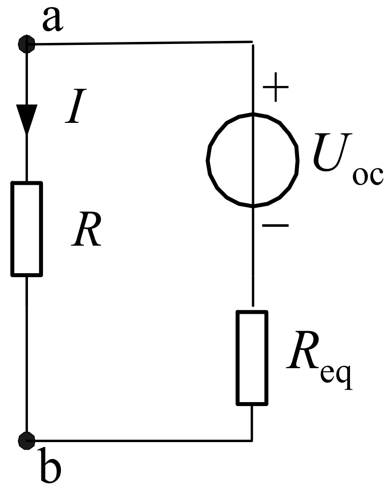
$$\rightarrow P = R_L I^2 = R_L \times \left(\frac{U_{oc}}{R_L + R_{eq}}\right)^2$$

$$\rightarrow \frac{dP}{dR_L} = 0 \quad \rightarrow \quad R_L = R_{eq} \quad \rightarrow \quad P_{max} = \frac{U_{oc}{}^2}{4R_{eq}}$$

讨论 ——目标：最大功率问题分析

【例 1】. Find the value of R for maximum power transfer in the circuit .Find the maximum power absorbed by R.



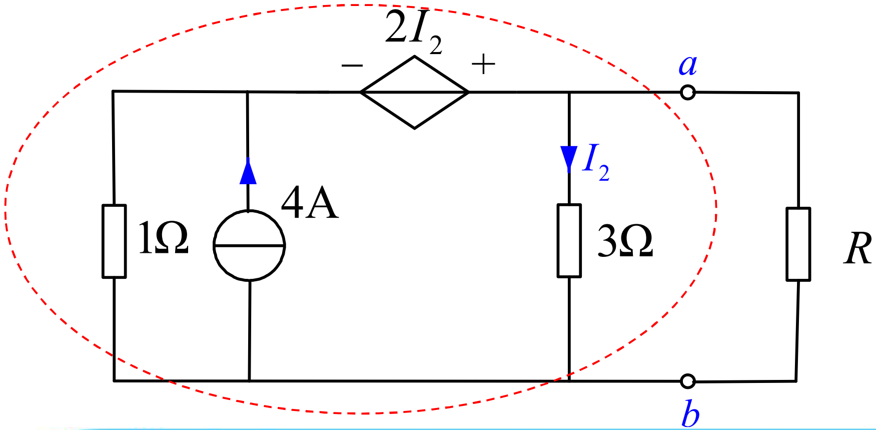


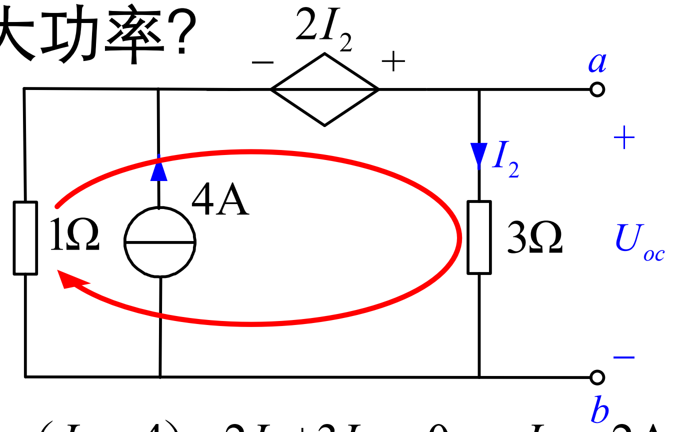
$$U_{oc} = \frac{20 \times 5}{20+40} \times 20 + \frac{40 \times 50}{20+40} = 66.7\text{V}$$

$$R_{eq} = 20 // (20+20) = 13.3\Omega$$

$$R = R_{eq} \qquad P_{max} = \frac{U_{oc}^2}{4R_{eq}} = 83.4\text{W}$$

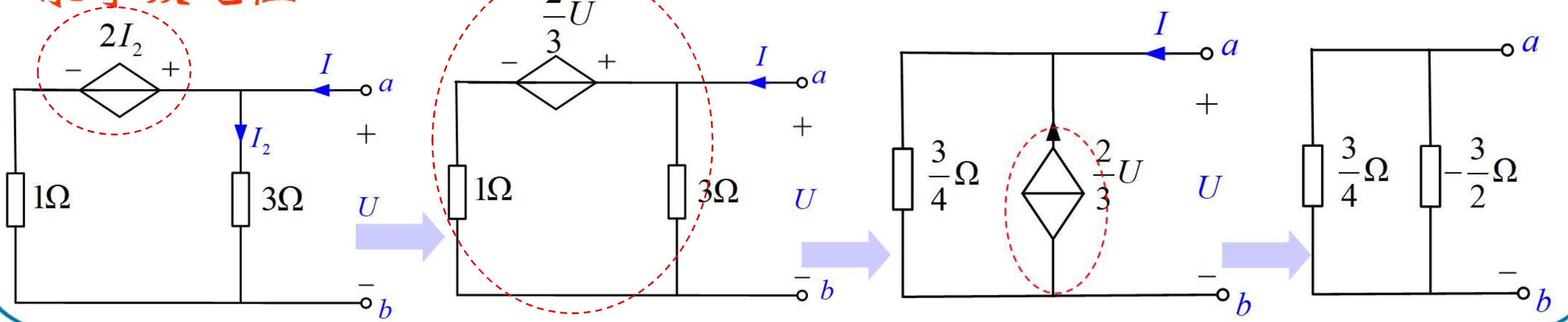
【例 2】. R可变，问R取何值时吸收最大功率?



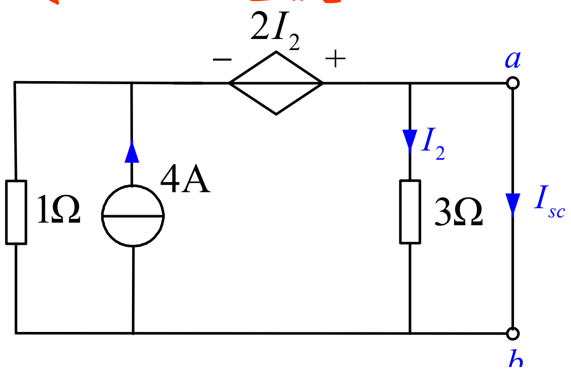


$(I_2-4)-2I_2+3I_2=0 \qquad I_2=2\text{A}$

求等效电阻



求短路电流

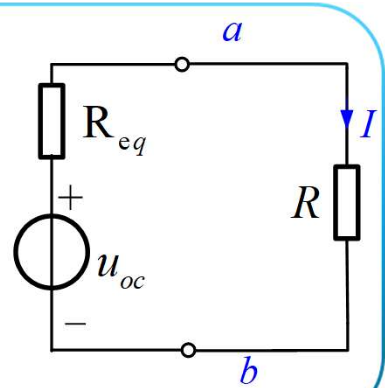


$$u_{oc}=6\text{V}$$

$$P=\frac{u_{oc}^{\ 2}}{4R_{eq}}=6\text{W}$$

$$R_{eq}=\left(\frac{3}{4}//-\frac{3}{2}\right)=1.5\Omega$$

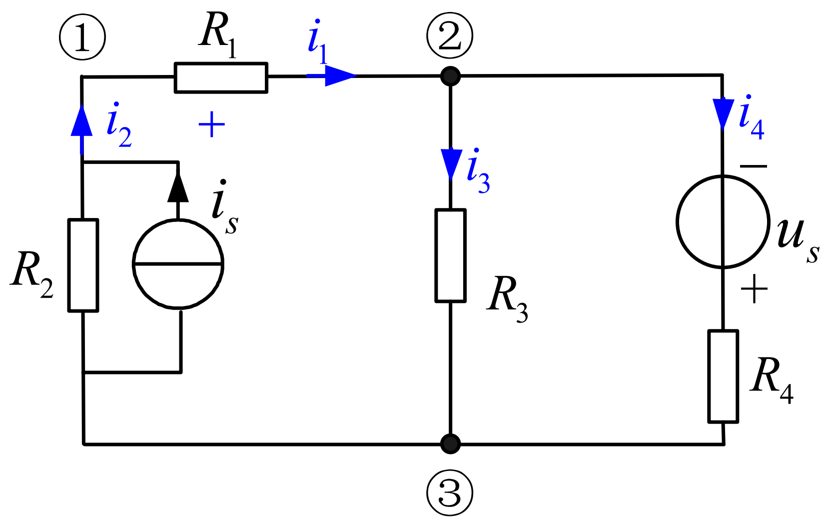
$$i_{sc}=4\text{A}$$



4.7 特勒根定理 与互易定理

Tellegen's Theorem and Reciprocity Theorem

1 特勒根定理之功率守恒



设支路电压、电流为u_1~u_4、i_1~i_4，结点电压分别为u_{n1}、u_{n2}

$$\Sigma P = u_1 i_1 + u_2 i_2 + u_3 i_3 + u_4 i_4$$

$$= (u_{n1} - u_{n2}) i_1 + (-u_{n1}) i_2 + u_{n2} i_3 + u_{n2} i_4$$

$$= u_{n1}(i_1 - i_2) + u_{n2}(-i_1 + i_3 + i_4)$$

$$= 0$$

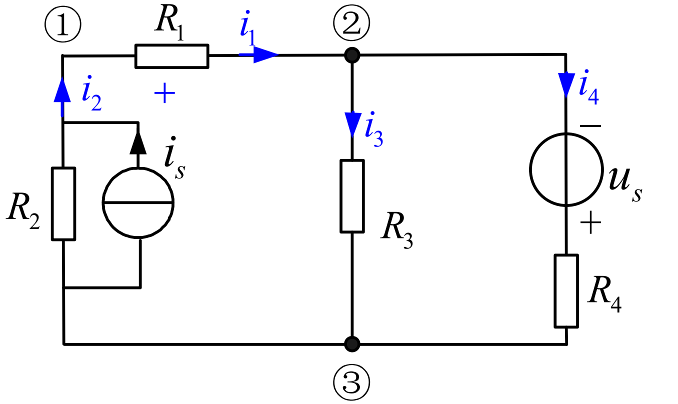
特勒根定理:在集中参数电路中，各支路吸收的功率的代数和等于0。即各独立源提供的功率的总和，等于其余各支路吸收的功率的总和。

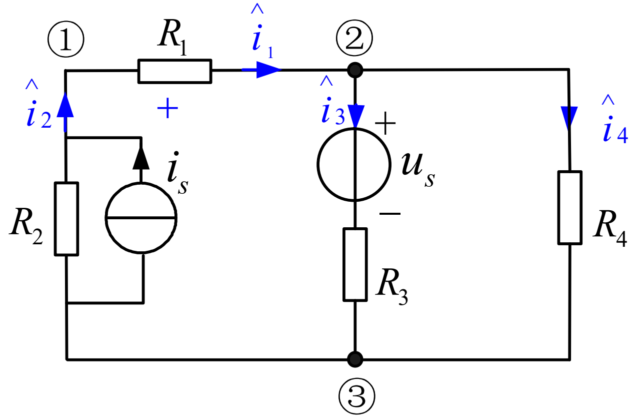
$$u_1 i_1 + u_2 i_2 + u_3 i_3 + u_4 i_4 = 0 \qquad \sum_{k=1}^{b} u_k i_k = 0$$

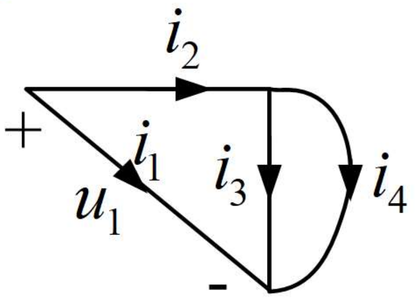
2 特勒根之似功率定理

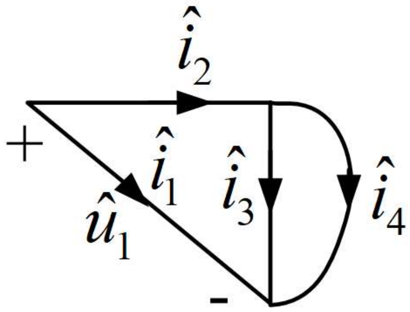
电路N和N’的拓扑图形完全相同，各有4条支路，3个节点，

- 对应支路采用相同编号
- 每一支路电压、电流采用关联参考方向；
- 对应支路电压、电流方向一致。









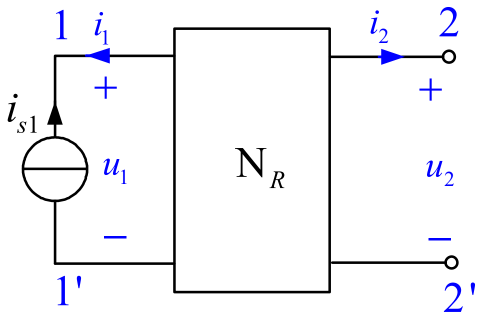
$$u_1\hat{i}_1 + u_2\hat{i}_2 + u_3\hat{i}_3 + u_4\hat{i}_4 = 0$$

$$\hat{u}_1 i_1 + \hat{u}_2 i_2 + \hat{u}_3 i_3 + \hat{u}_4 i_4 = 0$$

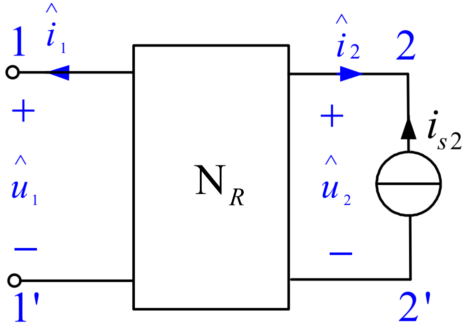
$$\sum_{k=1}^{b} u_k\hat{i}_k = 0, \sum_{k=1}^{b} \hat{u}_k i_k = 0$$

3 线性电阻构成的二端口网络之似功率定理

【例 1】. N_R为无源线性电阻网络，I_{S1}=4A，U_2=10V，I_{S2}=2A，$\hat{U}_1$=?



(a)



(b)

解：设N_R内各支路电压、电流采用关联参考方向

$$u_1\hat{i}_1 + u_2\hat{i}_2 + \sum_{k=3}^{b} u_K\hat{i}_k = 0; \qquad \hat{u}_1 i_1 + \hat{u}_2 i_2 + \sum_{k=3}^{b} \hat{u}_k i_k = 0$$

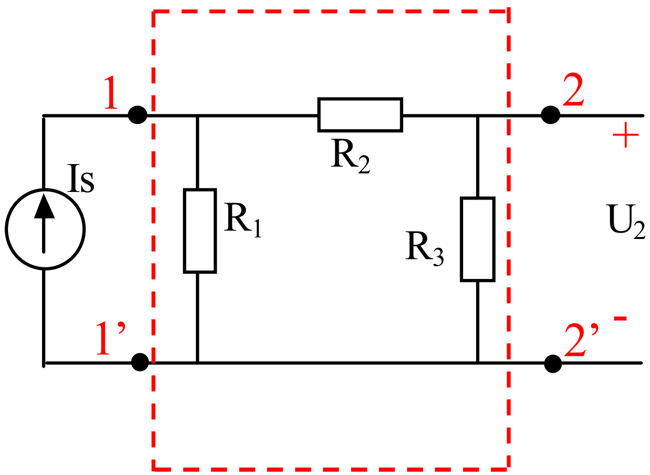
$$\because u_K\hat{i}_k = R_k i_k \hat{i}_k = \hat{u}_k i_k$$

$$\Rightarrow u_1\hat{i}_1 + u_2\hat{i}_2 = \hat{u}_1 i_1 + \hat{u}_2 i_2$$

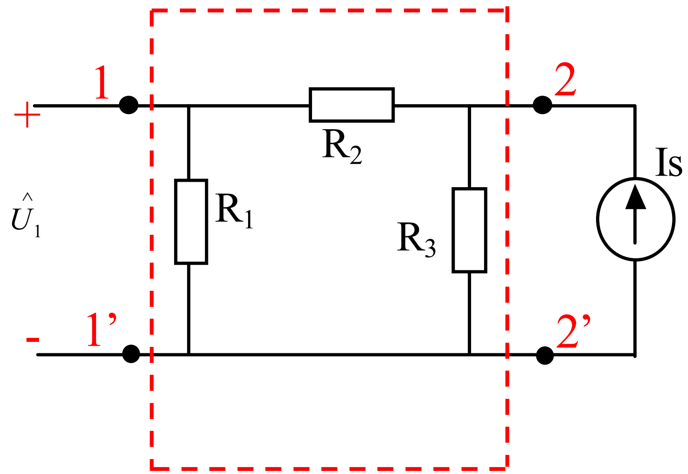
$$u_1 \times 0 + 10 \times (-2) = \hat{u}_1 \times (-4) + \hat{u}_2 \times 0 \qquad \Rightarrow \hat{u}_1 = 5\,\mathrm{V}$$

4 互易定理 （Reciprocity theorem）

互易网络：在单一激励的情况下，若 N_R由线性电阻构成，当激励端口和响应端口互换位置而电路的几何结构不变，同一数值激励所产生的响应在数值上将不会改变。



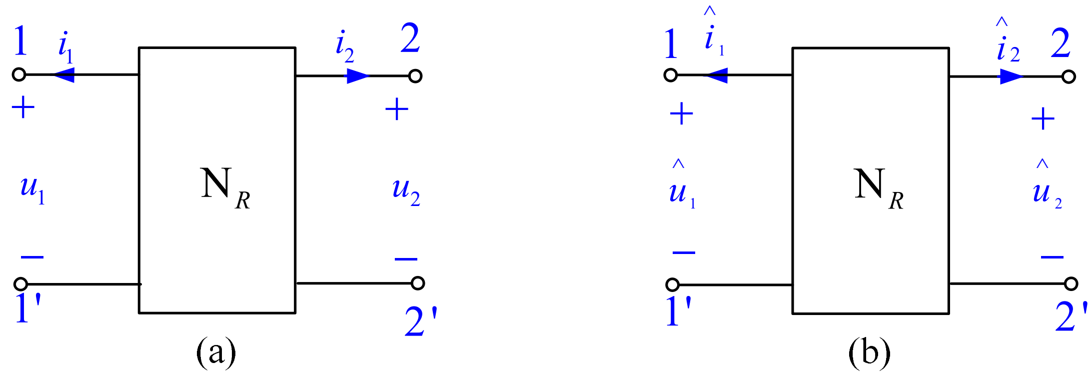
$$U_2 = R_3 \times \frac{R_1}{R_1 + R_2 + R_3} I_S$$



$$\hat{U}_1 = R_1 \times \frac{R_3}{R_1 + R_2 + R_3} I_S$$

$$\hat{U}_1 = U_2$$

4 互易定理 （Reciprocity theorem）

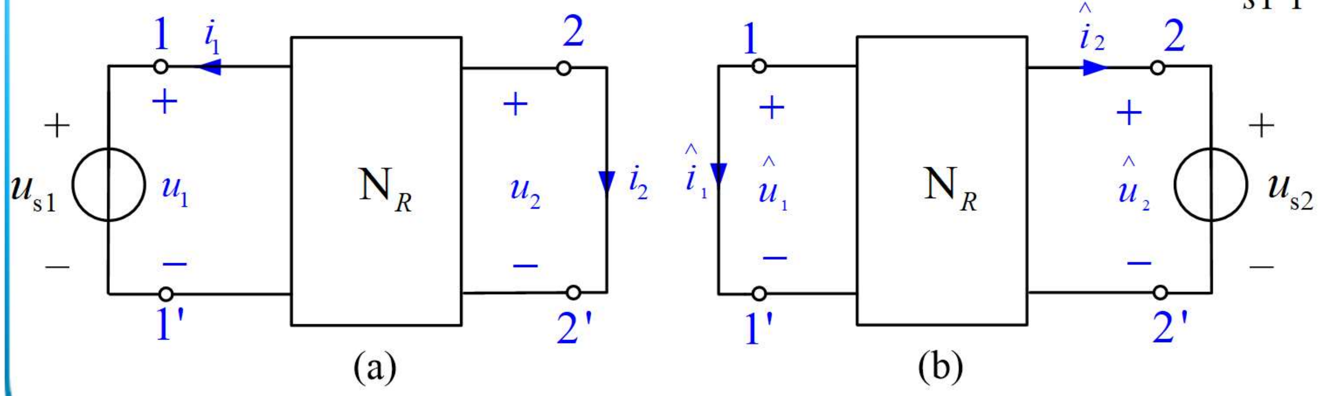


N_R是线性电阻组成的无源网络

应用特勒根定理： $\Rightarrow u_1\hat{i}_1 + u_2\hat{i}_2 = \hat{u}_1 i_1 + \hat{u}_2 i_2$

互易定理的第一种形式：

$$u_{s1}\hat{i}_1 + 0\times\hat{i}_2 = 0\times i_1 + u_{s2} i_2$$



$$u_{s1}\hat{i}_1 = u_{s2} i_2$$

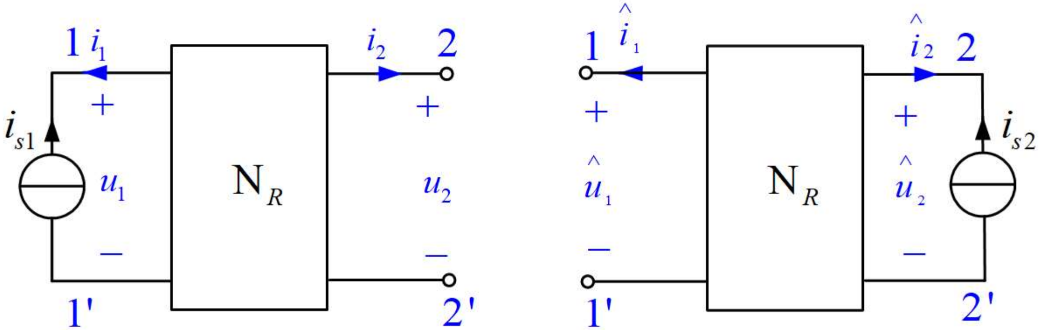
$$\frac{i_2}{u_{s1}} = \frac{\hat{i}_1}{u_{s2}}$$

4 互易定理 （Reciprocity theorem）

$$u_1\hat{i}_1 + u_2\hat{i}_2 = \hat{u}_1 i_1 + \hat{u}_2 i_2$$

互易定理的第二种形式：

$$u_1 \times 0 - u_2 i_{s2} = -\hat{u}_1 \times i_{s1} + \hat{u}_2 \times 0$$



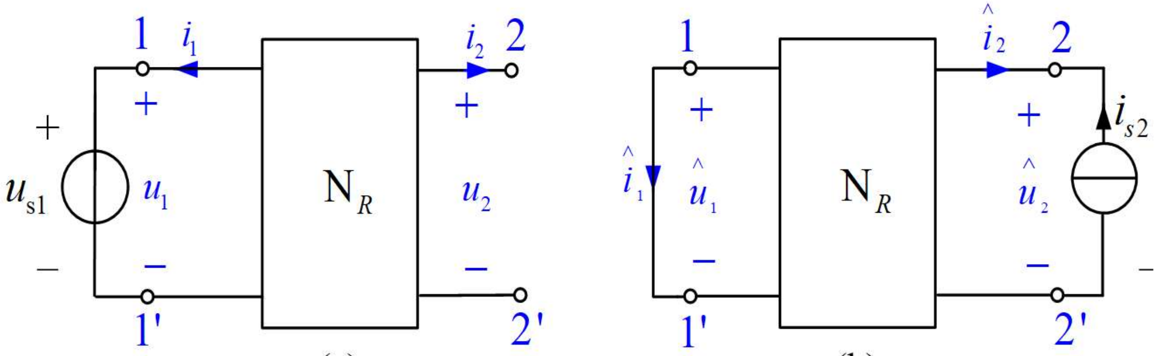
(a) (b)

$$u_2 i_{s2} = \hat{u}_1 i_{s1}$$

$$\frac{u_2}{i_{s1}} = \frac{\hat{u}_1}{i_{s2}}$$

互易定理的第三种形式：

$$u_{s1}\hat{i}_1 + u_2(-i_{s2}) = 0 \times i_1 + \hat{u}_2 \times 0$$



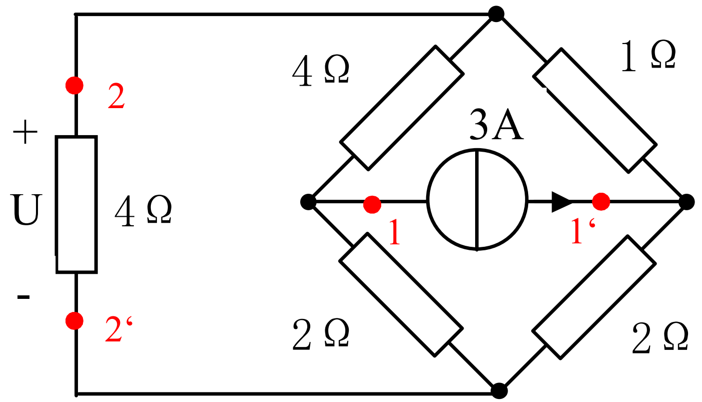
(a) (b)

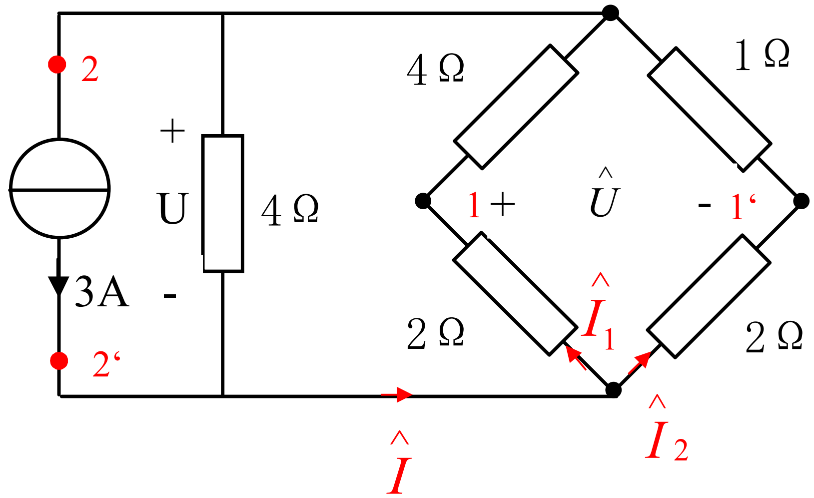
$$u_{s1}\hat{i}_1 = u_2 i_{s2}$$

$$\frac{u_2}{u_{s1}} = \frac{\hat{i}_1}{i_{s2}}$$

5. 应用举例

【例 1】. 求图中电压U。





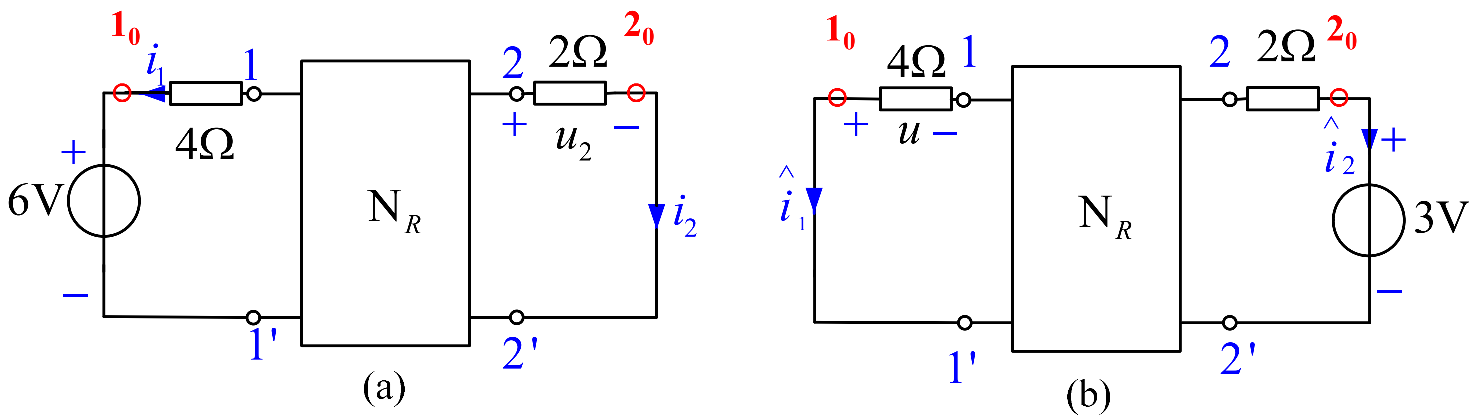
$$\hat{I}=\frac{4}{4+2}\times 3=2\text{A}$$

$$\Rightarrow I_1=\frac{2}{3}\text{A}, I_2=\frac{4}{3}\text{A}$$

$$\Rightarrow \hat{U}=-2\hat{I}_1+2\hat{I}_2 \quad =-2\times\frac{2}{3}+2\times\frac{4}{3}=\frac{4}{3}V$$

由互易定理的第二种形式 $U=\hat{U}=\dfrac{4}{3}V$

【例 2】. 图a中 N_R为无源线性电阻网络，u_2=4V. 求图b中电压u。



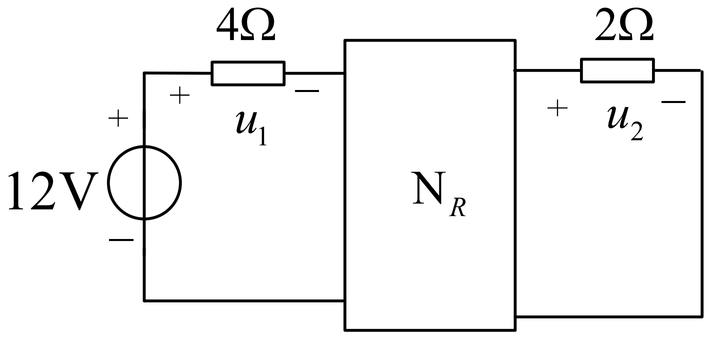
$$i_2 = \frac{u_2}{R_2} = \frac{4}{2} = 2\text{A}$$

由互易定理的第一种形式 $\dfrac{i_2}{u_{s1}} = \dfrac{\hat{i}_1}{\hat{u}_{s2}}$

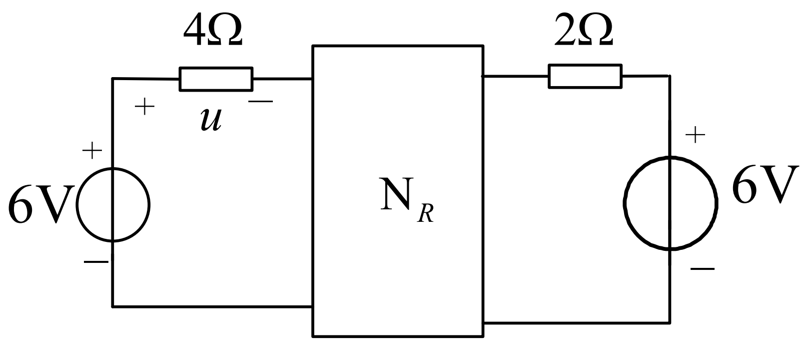
$$\Rightarrow \hat{i}_1 = \frac{i_2 \hat{u}_{s2}}{u_{s1}} = 1\text{A}$$

$$\Rightarrow u = -R_1 \hat{i}_1 = -4\,\text{V}$$

【例 3】. N_R为无源线性电阻网络，已知$u_1=u_2=4V$。求图（b）中的电压u 。

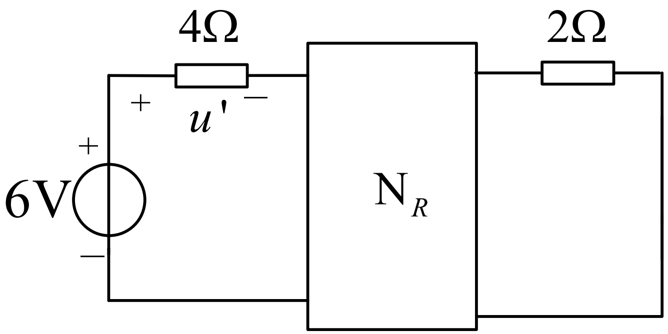


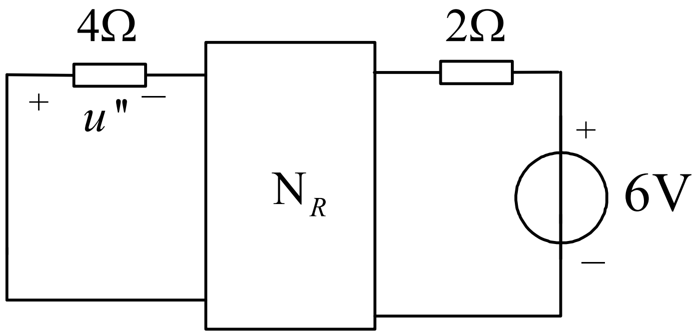
(a)



(b)

Method1:应用叠加及互易性质:





$$u=u'+u''=2+(-4)=-2V$$

Method 2:应用互易性质:

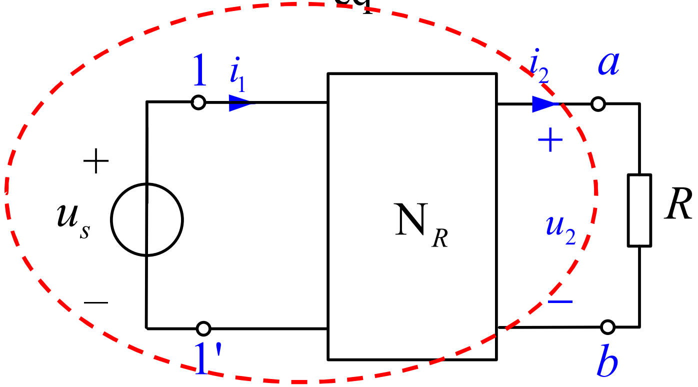
$$u_1\hat{i}_1+u_2\hat{i}_2=\hat{u}_1 i_1+\hat{u}_2 i_2$$

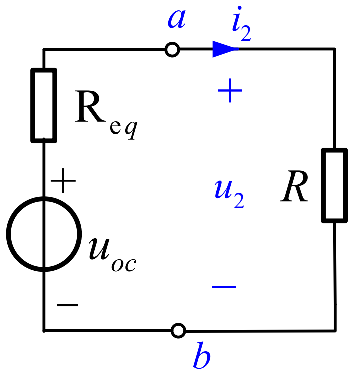
$$12\hat{i}_1+0=6\times(-1)+6\times 2$$

$$\Rightarrow \hat{i}_1=0.5\,\text{A}$$

$$u=-4\hat{i}_1=-2V$$

【例 4】. N_R为无源线性电阻网络，已知ab端的开路电压u_{oc}和入端等效电阻R_{eq}，试问当电阻R为无穷大时，电流i_1将如何变化?



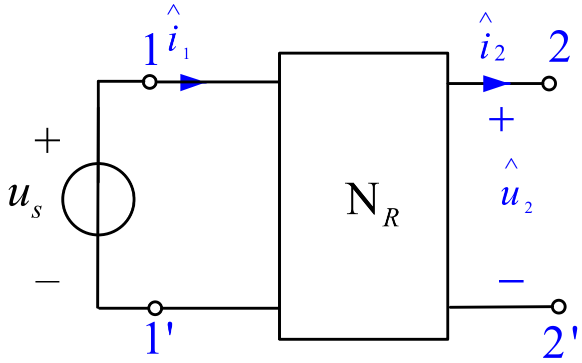


$$u_2 = \frac{R}{R+R_{eq}} u_{oc}$$

$$i_2 = \frac{1}{R+R_{eq}} u_{oc}$$

R为无穷大时的等效电路为:

由特勒根定理得:



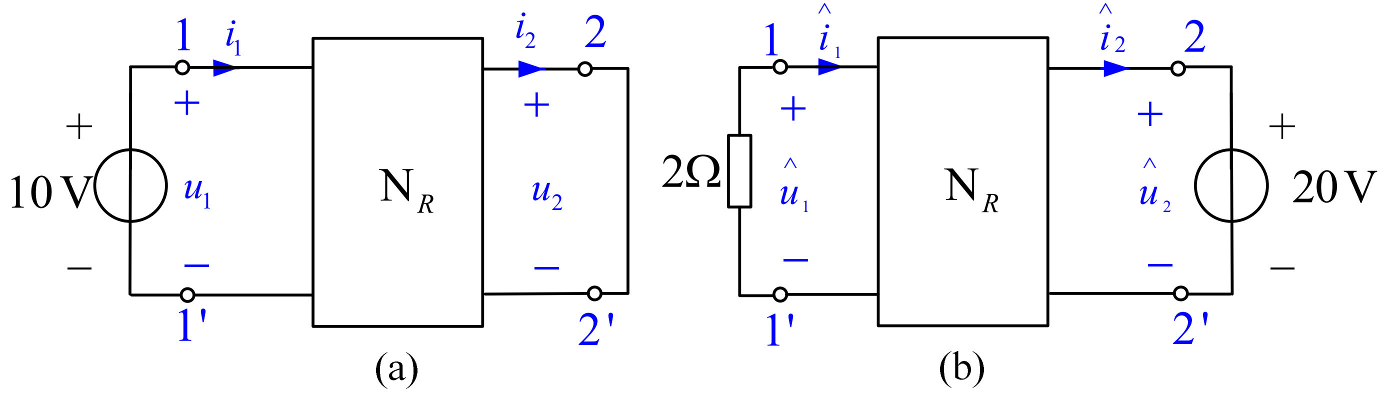
$$-u_1\hat{i}_1 + u_2\hat{i}_2 = -\hat{u}_1 i_1 + \hat{u}_2 i_2$$

$$-u_s\hat{i}_1 + u_2 \times 0 = -u_s i_1 + \hat{u}_2 i_2$$

$$u_s\hat{i}_1 = u_s i_1 - \hat{u}_2 i_2$$

$$\Rightarrow \hat{i}_1 = i_1 - \frac{\hat{u}_2 i_2}{u_S} = i_1 - \frac{u_{oc}{}^2}{(R+R_{eq})u_S}$$

【例5】. N_R为无源线性电阻网络，已知i_1=5A，i_2=1A。求 $\hat{i}_1$ 。



Method1:应用互易性质:

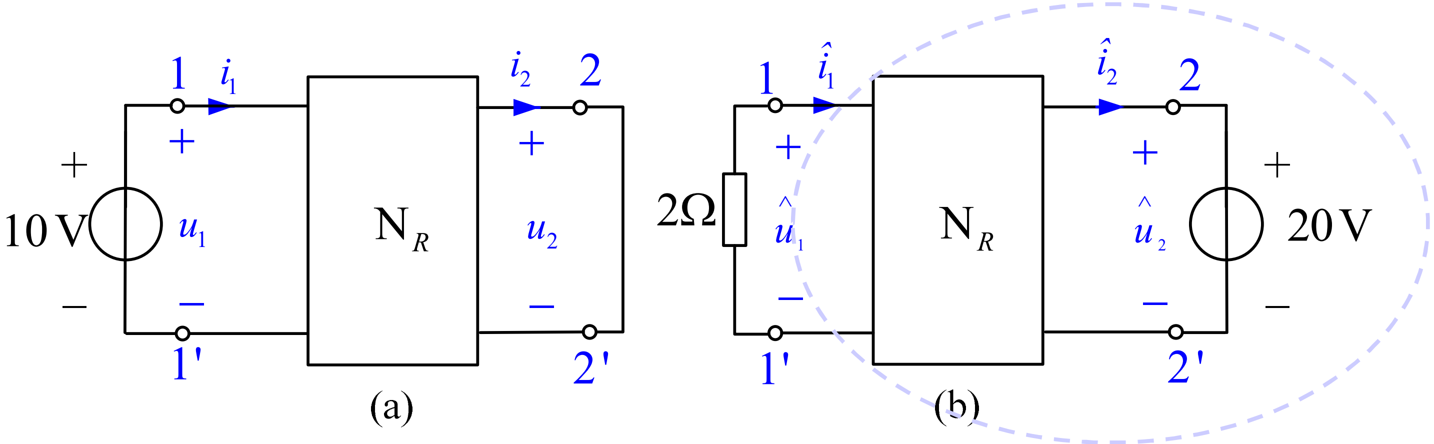
$$-u_1\hat{i}_1 + u_2\hat{i}_2 = -\hat{u}_1 i_1 + \hat{u}_2 i_2$$

将$u_1 = 10\text{V}$、$i_1 = 5\text{A}$、$u_2 = 0$、$i_2 = 1\text{A}$、$\hat{u}_1 = -2\hat{i}_1$、$\hat{u}_2 = 20\text{V}$代入上式

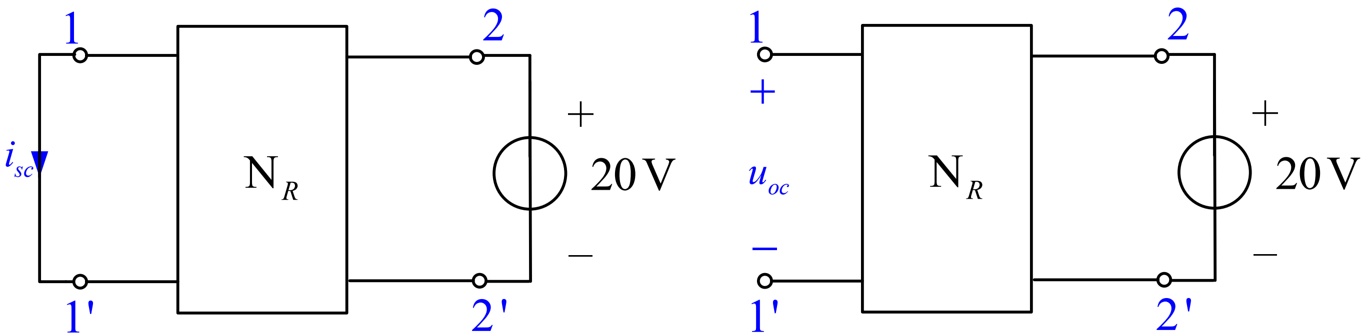
$$-10\times\hat{i} + 0\times\hat{i}_2 = -(-2\hat{i})\times 5 + 20\times 1$$

$$\Rightarrow \hat{i}_1 = -1\,\text{A}$$

【例 5】. N_R为无源线性电阻网络，已知i_1=5A，i_2=1A。求$\hat{i}_1$。



Method2:应用戴维南定理（替代及互易）



$$i_{sc} = \frac{20}{10} \times i_2 = 2\text{A} \qquad u_{oc} = \frac{20}{5} \times i_2 = 4\text{V}$$

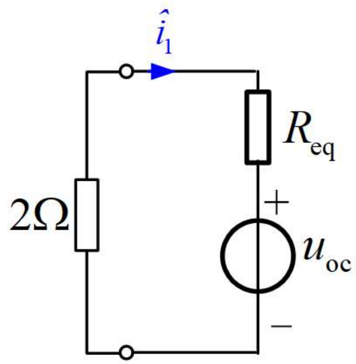
$$\Rightarrow R_{eq} = \frac{u_{oc}}{i_{sc}} = 2\Omega$$

$$\Rightarrow \hat{i}_1 = -1\text{A}$$

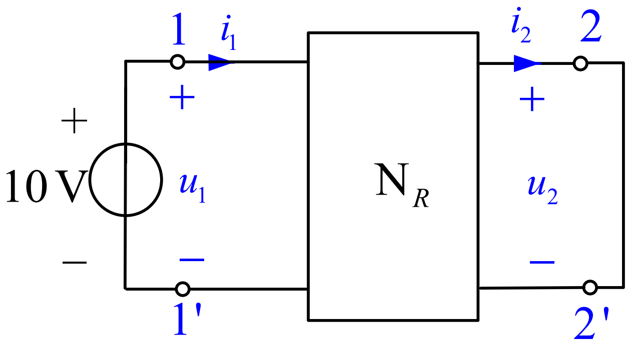
$$\mathrm{R}_{eq} = \frac{10}{5} = 2\Omega$$

$$i_{sc} = 2\text{A}$$

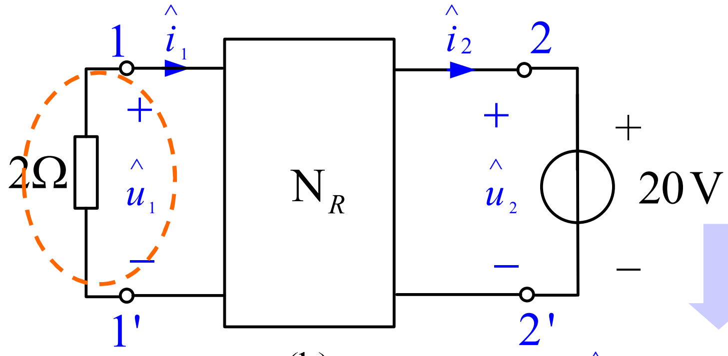
$$u_{oc} = 4\text{V}$$



【例 5】. N_R为无源线性电阻网络，已知i_1=5A，i_2=1A。求$\hat{i}_1$。

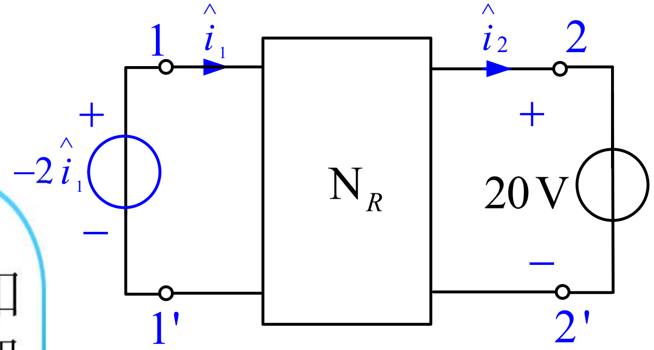


(a)

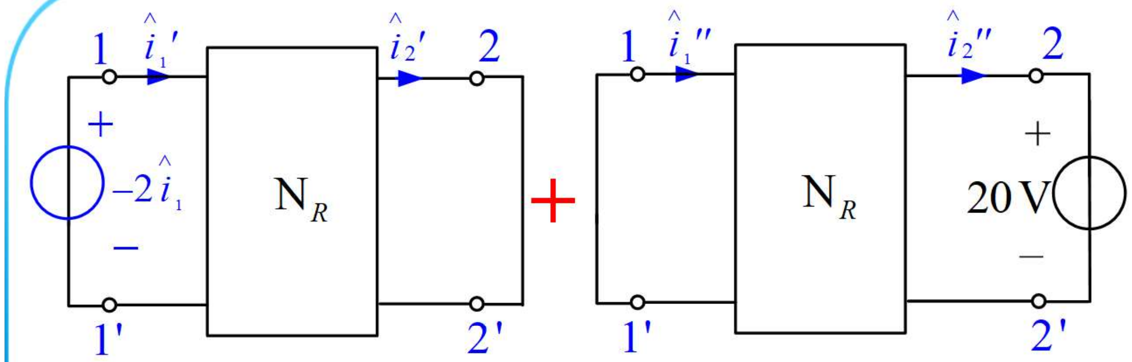


(b)

替代定理



Method3:应用替代定理和叠加定理



叠加定理

由线性性质：

$$\hat{i}_1' = \frac{-2\hat{i}_1}{10}\times 5 = -\hat{i}_1$$

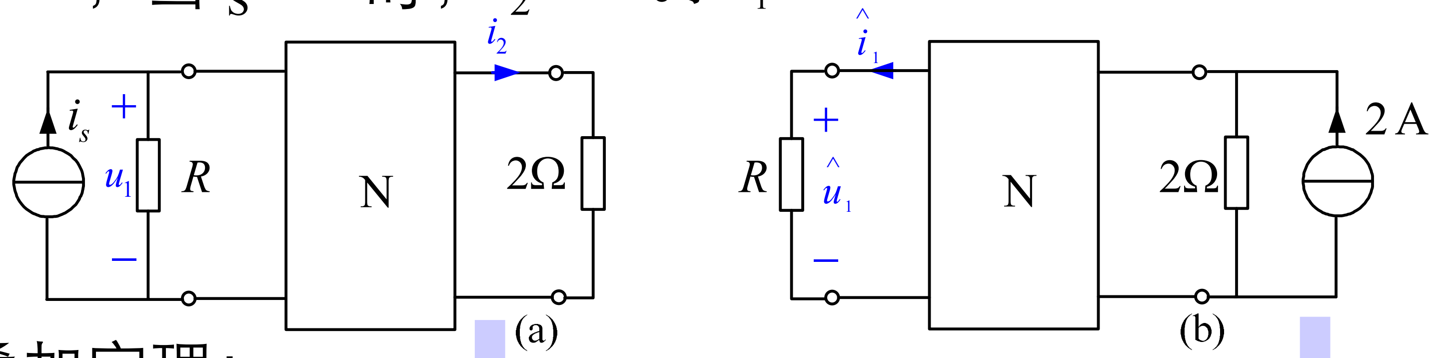
由互易定理的第一种形式

$$\hat{i}_1'' = -2i_2 = -2\text{A}$$

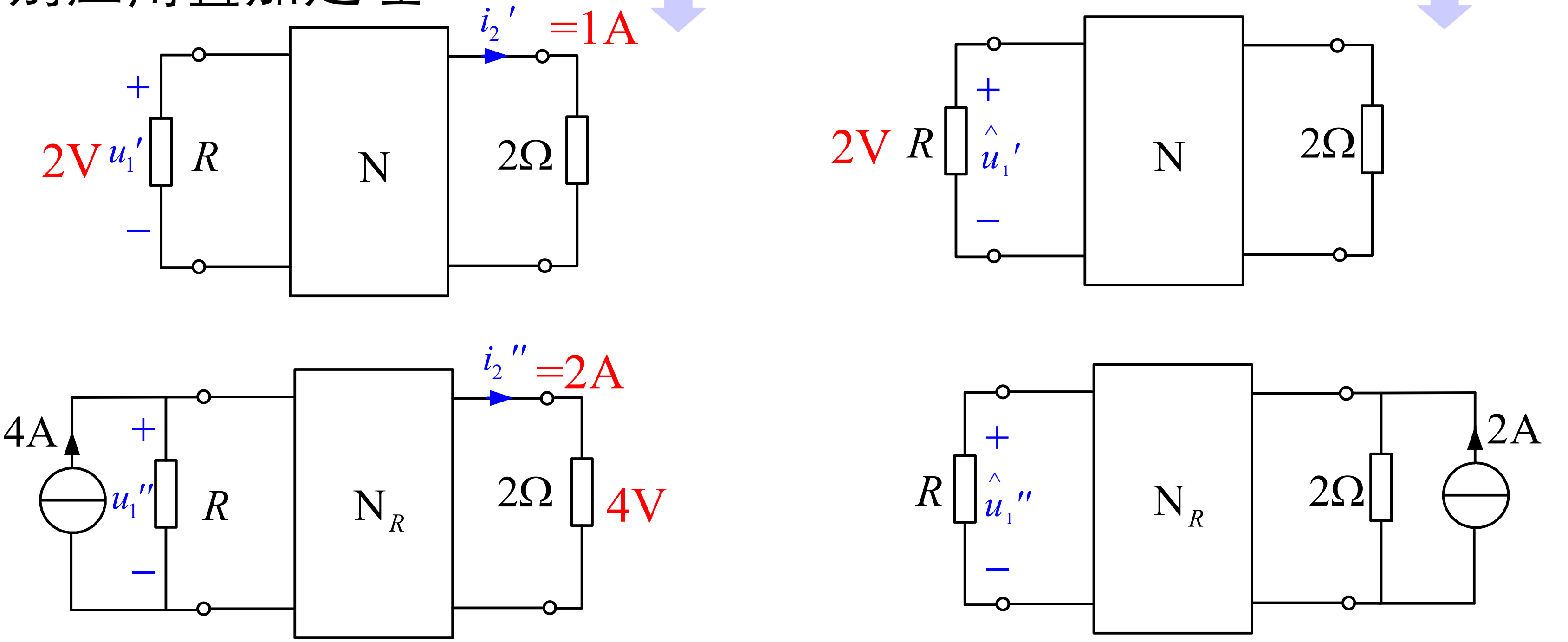
$$\therefore \hat{i}_1 = \hat{i}_1' + \hat{i}_1'' = -2 + (-\hat{i}_1)$$

$$\Rightarrow \hat{i}_1 = -1\,\text{A}$$

【例 6】. N为含独立源的线性电阻网络，已知图（a）当i_S=0A时，u_1=2V，i_2=1A；当i_S=4A时，i_2=3A。求$\hat{u}_1$?

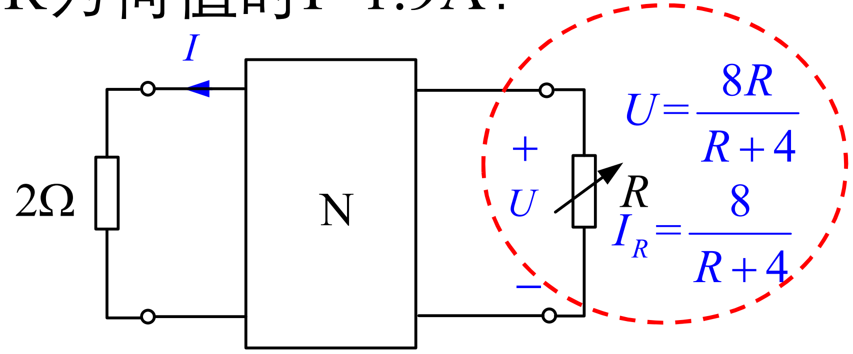


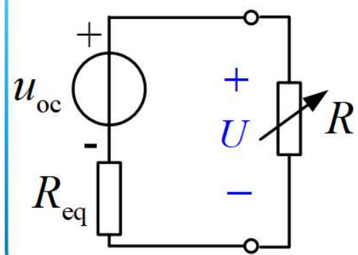
分别应用叠加定理:



由互易定理的第二种形式 $\hat{u}_1'' = \frac{4}{2} \times 4 = 2\,\text{V}$ $\Rightarrow u_1 = \hat{u}_1' + \hat{u}_1'' = 2 + 2 = 4\,\text{V}$

【例 7】. N为含独立源的线性电阻网络，已知当R=4Ω时，U=4V 、I=1.5A；R=12Ω时，U=6V、I=1.75A。求：R为何值时获得最大功率？R为何值时I=1.9A？

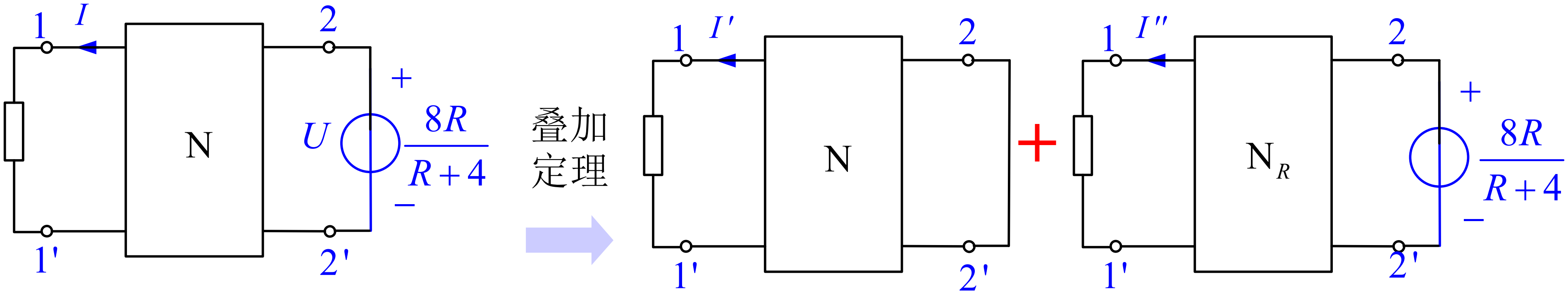




$$\because U=\frac{R}{R+R_{eq}}u_{oc}$$

$$\Rightarrow\begin{cases}u_{oc}=8\text{V}\\ R_{eq}=4\Omega\end{cases}\qquad P_{max}=\frac{u_{oc}^{\ 2}}{4R_{eq}}=4\text{W}$$

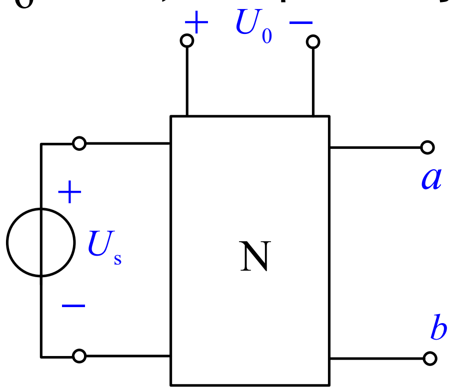
（2）应用替代和叠加定理

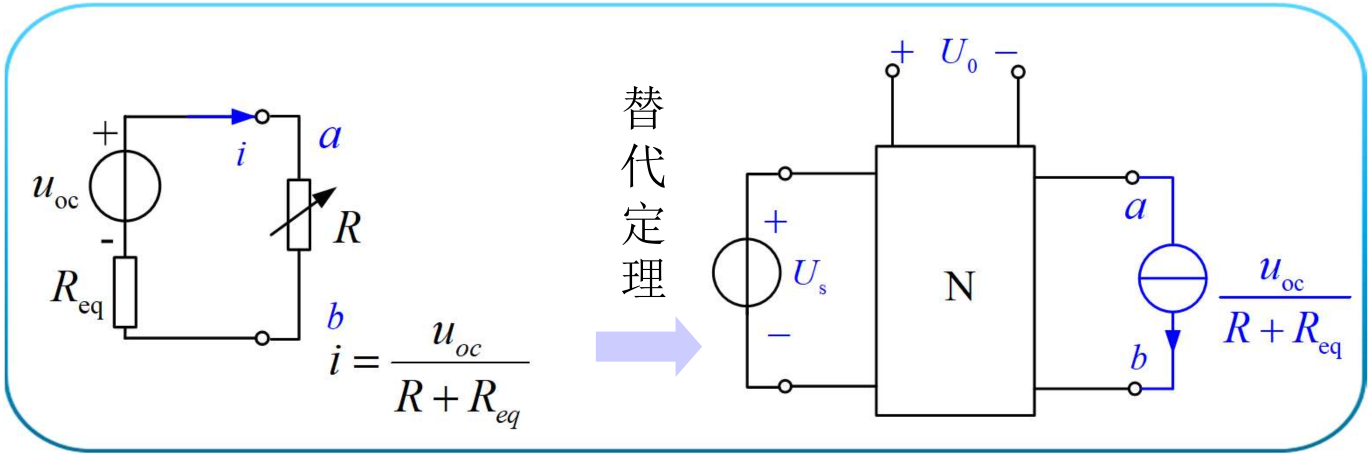


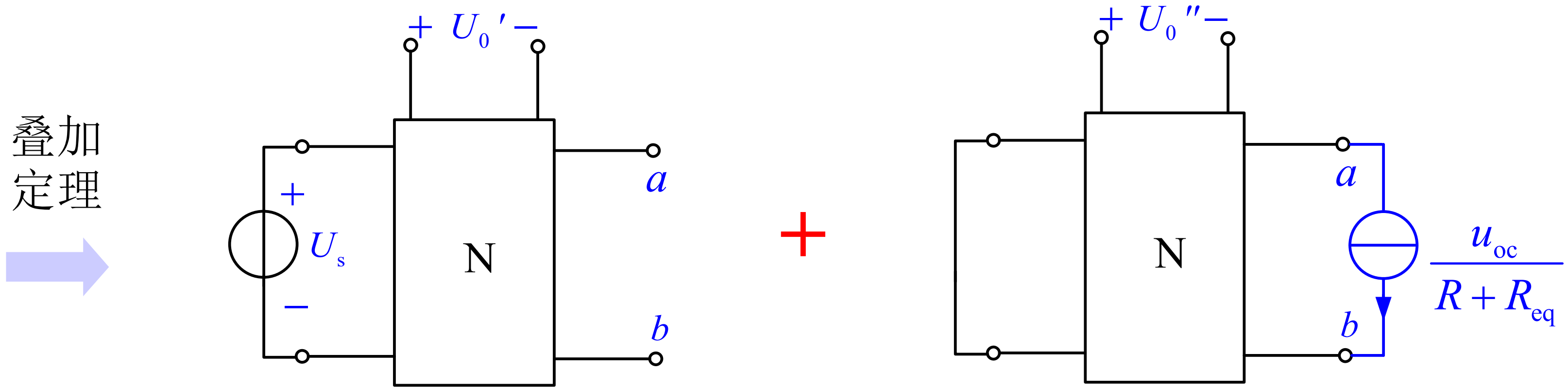
$$\Rightarrow I=I'+I''\ =C\ +K\frac{8R}{R+4}\qquad\Rightarrow\begin{cases}1.5=C+K\dfrac{8\times4}{4+4}\\ 1.75=C+K\dfrac{12\times4}{12+4}\end{cases}\qquad\Rightarrow\begin{cases}C=1\\ K=0.125\end{cases}$$

$$I=1+0.125\frac{8R}{R+4}\qquad\therefore 1.9=1+0.125\frac{8R}{R+4}\qquad\therefore R=36\Omega$$

【练习】. N为电阻网络，已知a、b开路时，U_o=6V；a、b短路时，U_o=8V， 当a、b 接可变电阻R，求 R获得最大功率时 U_o的值。







$$\Rightarrow U_0=U_0'+U_0''=C+K\frac{u_{oc}}{R+R_{eq}} \Rightarrow \begin{cases} U_0=C+K\times 0=6 \\ U_0=C+K\times\dfrac{u_{oc}}{R_{eq}}=8 \end{cases} \Rightarrow \begin{cases} C=6 \\ K\times\dfrac{u_{oc}}{R_{eq}}=2 \end{cases}$$

R获得最大功率时 $\Rightarrow U_0=C+K\times\dfrac{u_{oc}}{R_{eq}+R_{eq}}=6+\dfrac{1}{2}\times K\times\dfrac{u_{oc}}{R_{eq}}=7\text{V}$

计划学时：6学时；课后学习18学时

作业：

4-10，4-15，4-17 /替代、叠加定理

4-25 /戴维南

4-33 /最大功率

4-37，4-39 /互易

4-45 / 综合应用