作 业

2-2(b)

2-3(b)

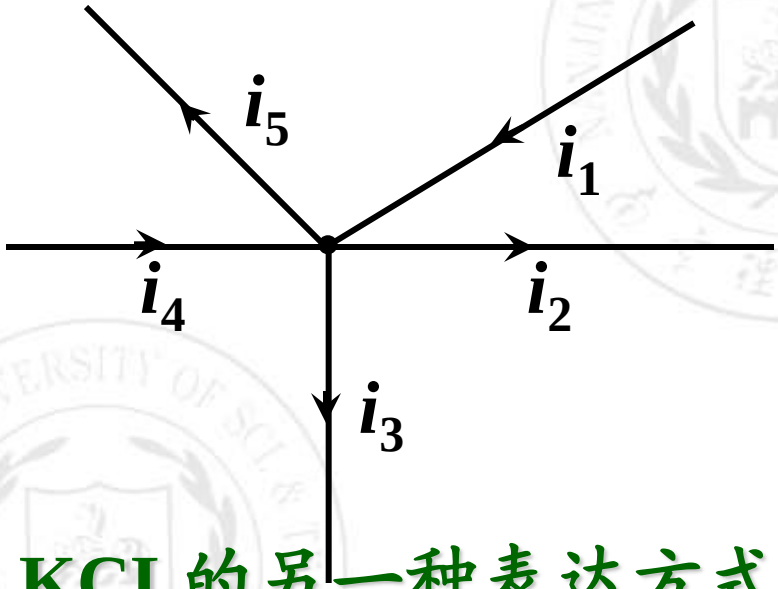
2-11

基尔霍夫电流定律：KCL

- 定律：任一时刻，流入电路中任一节点的电流代数和恒为零：$\sum i_k = 0$

- 约定：流入取负，流出取正.

重点



$$-i_1 + i_2 + i_3 - i_4 + i_5 = 0$$

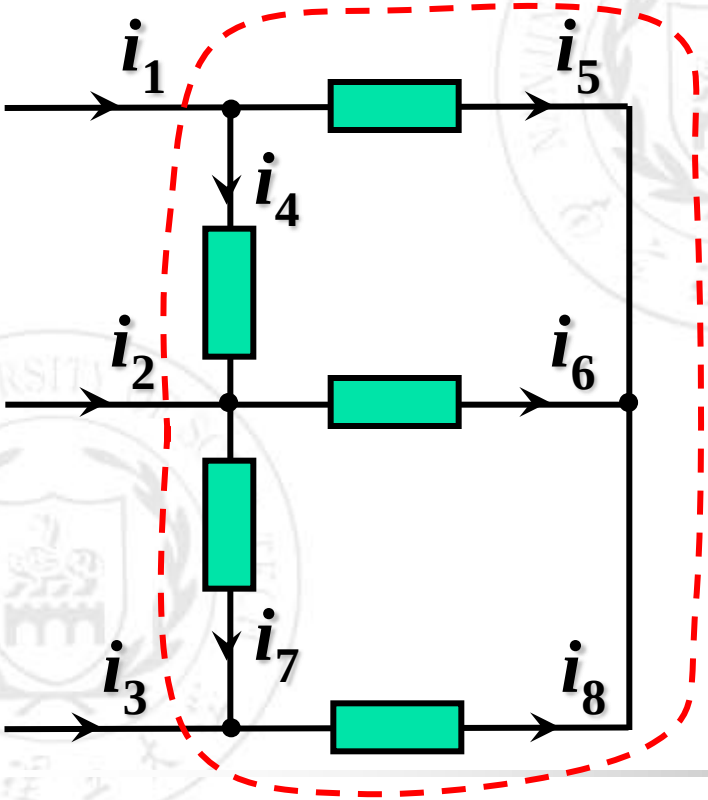
$$\Rightarrow\ i_2 + i_3 + i_5 = i_1 + i_4$$

- KCL的另一种表达方式：

流入节点的电流之和 = 流出该节点的电流之和.

基尔霍夫电流定律

- 物理实质：电荷守恒
- 推广：节点→封闭面（广义节点）
- 例：已知i_1、i_2求i_3

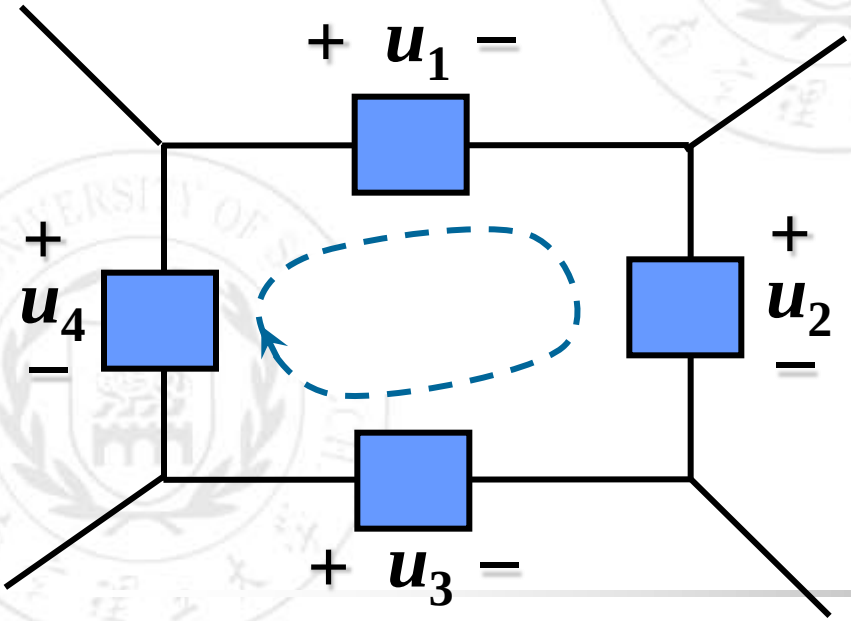


$$\Rightarrow -i_1 - i_2 - i_3 = 0$$

重点

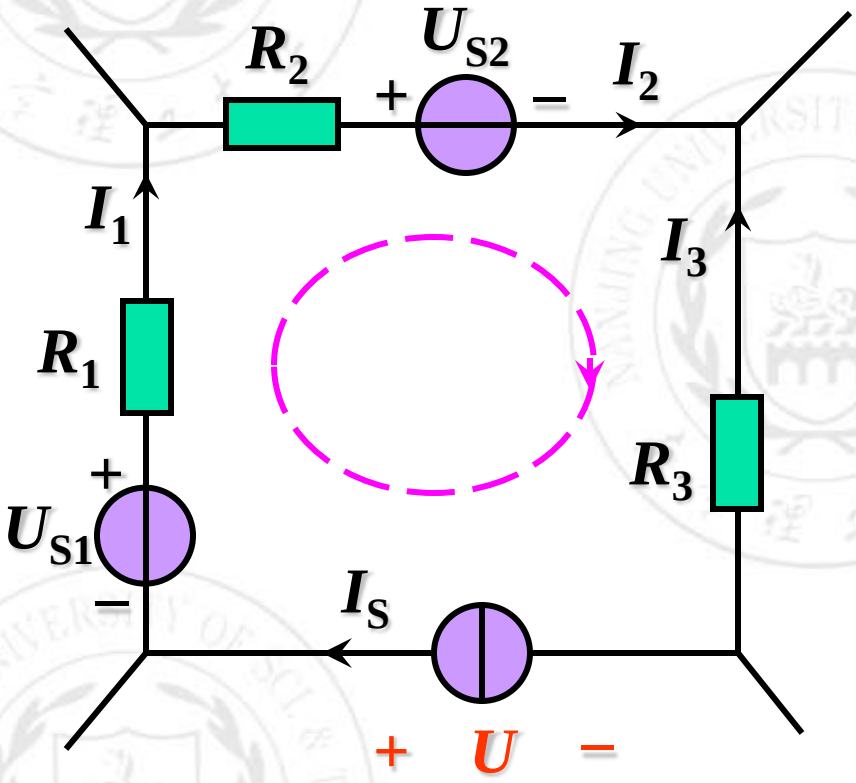
基尔霍夫电压定律：KVL

- 定律：任一时刻，沿任一闭合回路电压降代数和恒为零：$\sum u_k = 0$
- 约定：电压降与回路绕行方向一致取正，反之取负



$$u_1 + u_2 - u_3 - u_4 = 0$$

含电流源的电路



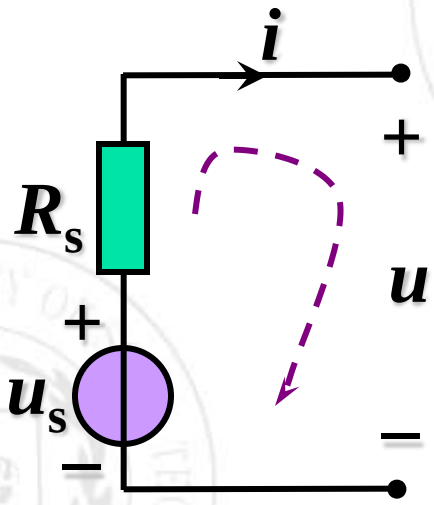
1、在电流源两端任意假设一个电压.

2、暂时把它当作电压源处理，列写方程

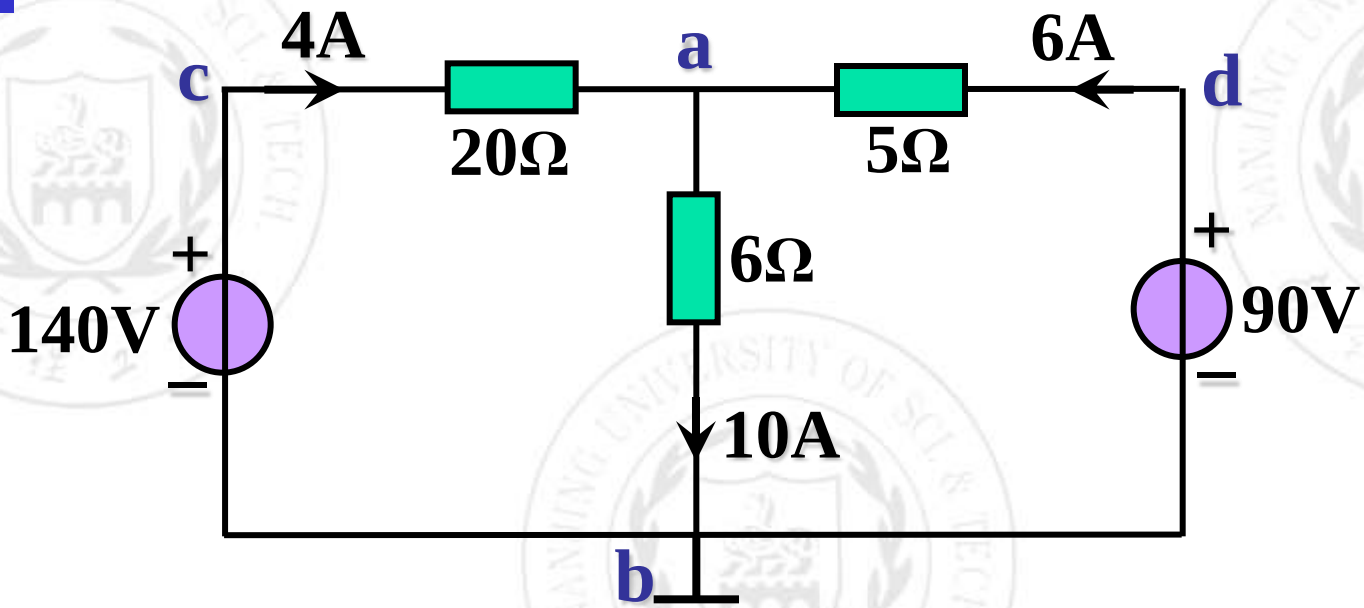
$$R_2 I_2 + U_{S2} - R_3 I_3 - U - U_{S1} + R_1 I_1 = 0$$

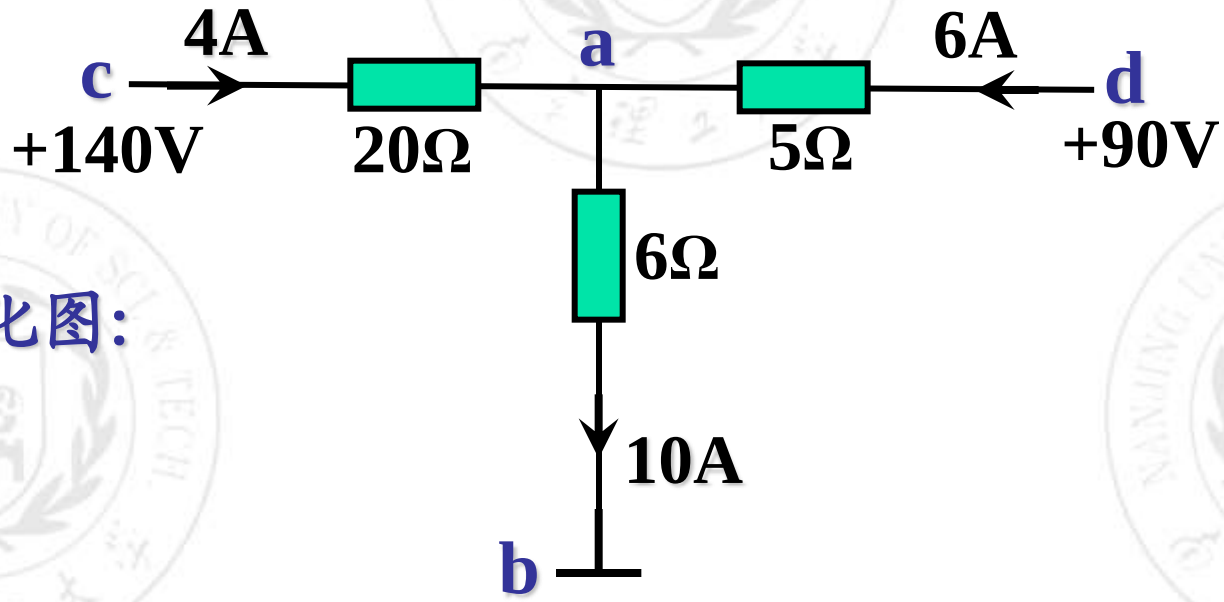
基尔霍夫电压定律

- 物理实质：两点之间电压单值性
- 推广：闭合路径→假想回路

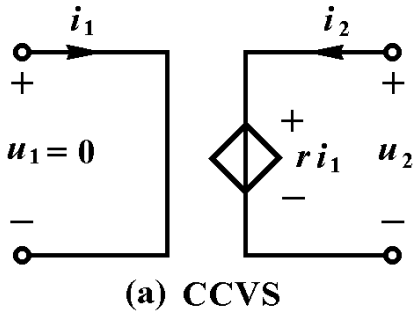


$$u - u_s + R_s i = 0$$

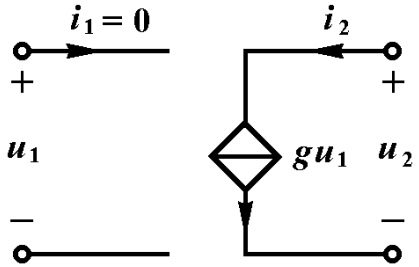

4A
c
a
6A
d
20Ω
5Ω
+
140V
−
6Ω
+
90V
−
10A
b


4A
a
6A
c
d
+140V
20Ω
5Ω
+90V
6Ω
10A
b

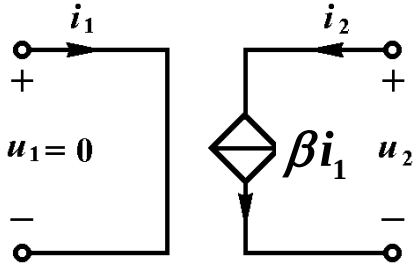
- 简化图:



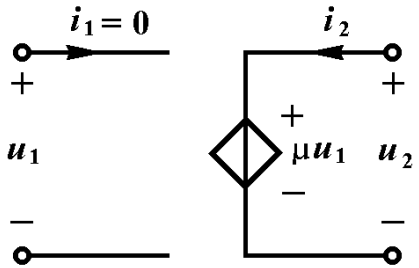
(a) CCVS



(b) VCCS



(c) CCCS



(d) VCVS

CCVS: $\begin{cases} u_1 = 0 \\ u_2 = ri_1 \end{cases}$

r具有电阻量纲，称为转移电阻。

VCCS: $\begin{cases} i_1 = 0 \\ i_2 = gu_1 \end{cases}$

g具有电导量纲，称为转移电导。

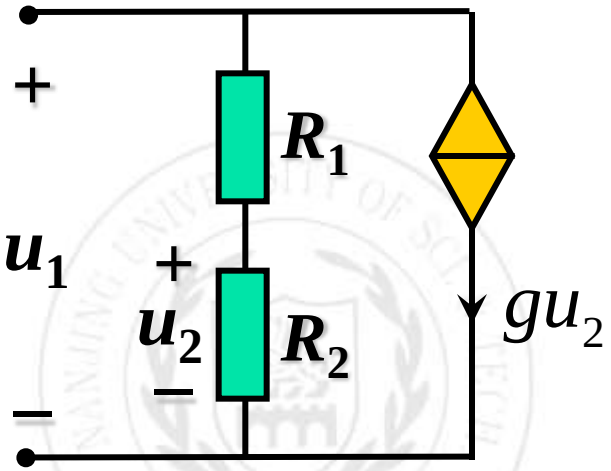
CCCS: $\begin{cases} u_1 = 0 \\ i_2 = \beta i_1 \end{cases}$

α无量纲，称为转移电流比。

VCVS: $\begin{cases} i_1 = 0 \\ u_2 = \mu u_1 \end{cases}$

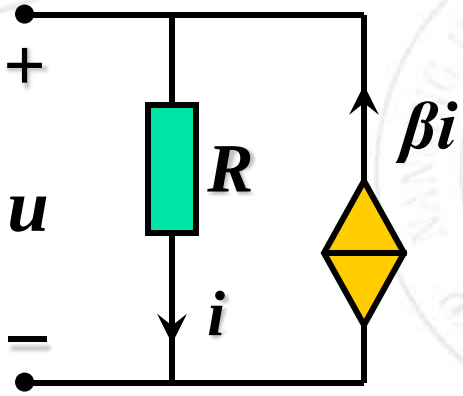
μ亦无量纲，称为转移电压比。

在一定的条件下，受控源可等效成一个电阻



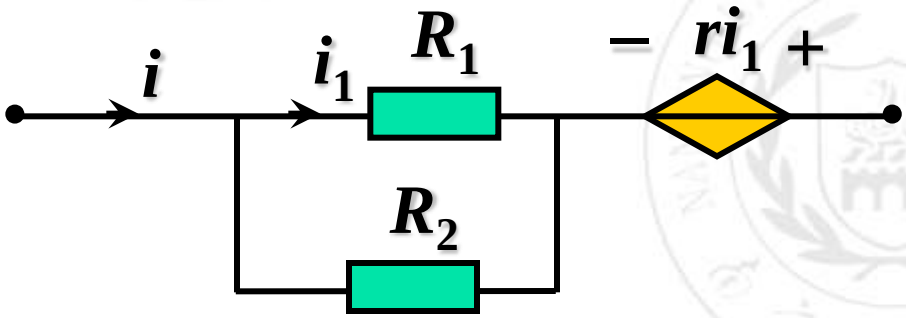
$$u_1 = \frac{u_2}{R_2}(R_1 + R_2)$$

$$\frac{u_1}{gu_2} = \frac{\dfrac{u_2}{R_2}(R_1 + R_2)}{gu_2} = \frac{R_1 + R_2}{gR_2} \overset{\Delta}{=} R$$



$$u = Ri$$

$$\frac{u}{-\beta i} = \frac{Ri}{-\beta i} = -\frac{R}{\beta}$$

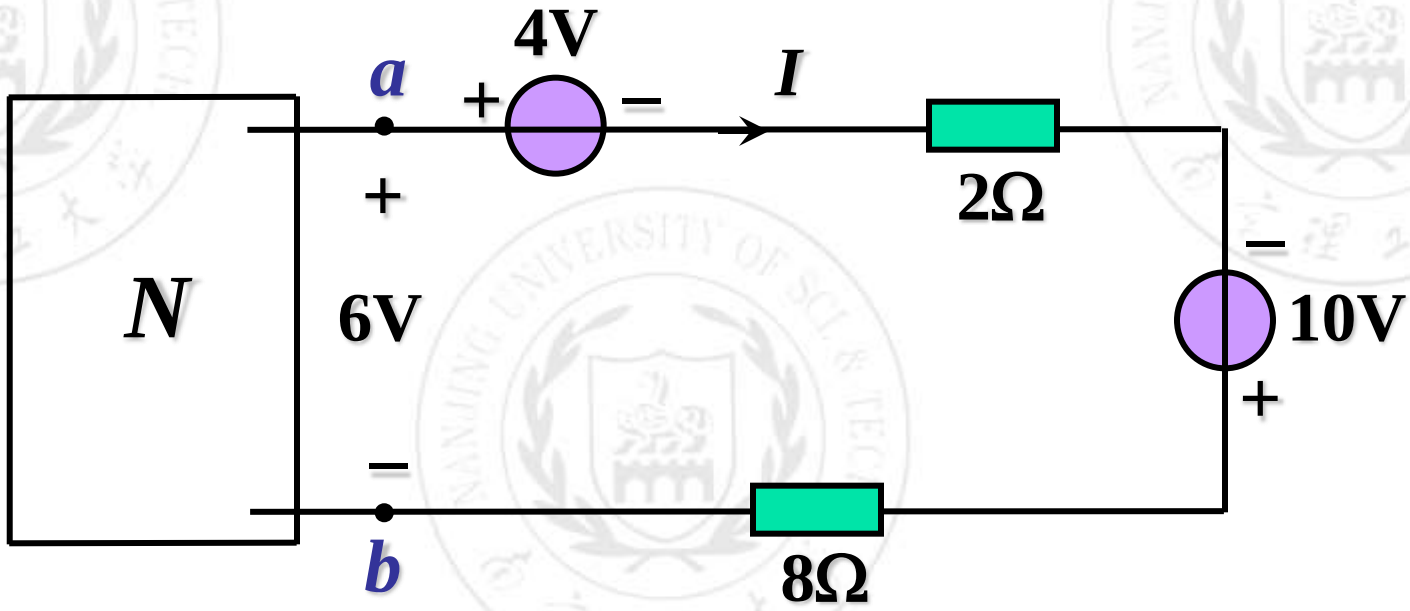


$$i = i_1 + \frac{R_1 i_1}{R_2}$$

$$\frac{-ri_1}{i} = \frac{-ri_1}{i_1 + \frac{R_1 i_1}{R_2}}$$

$$= \frac{-r}{1 + \frac{R_1}{R_2}}$$

例：电路如图所示，求：电流*I*和各电压源吸收的功率.



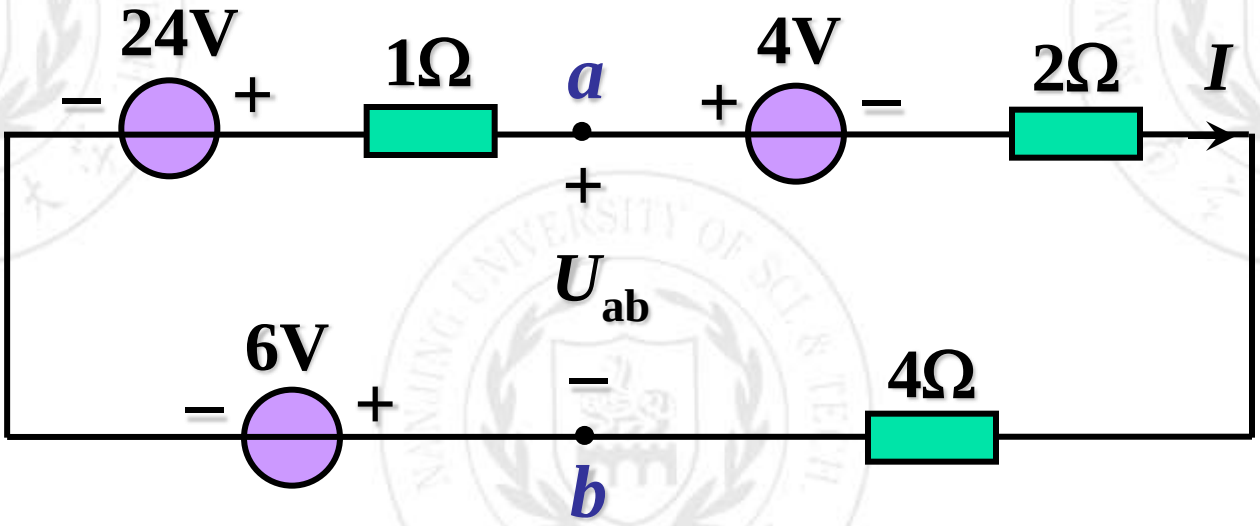
$$I=\frac{6-4+10}{2+8}=1.2\text{A}$$

两个电压源的吸收功率分别为：

$$P_{4\text{V}}=4.8\text{W}$$

$$P_{10\text{V}}=-12\text{W}$$

例：电路如图所示，求：电流I和电压U_{ab}



$$I = 2\text{A}$$

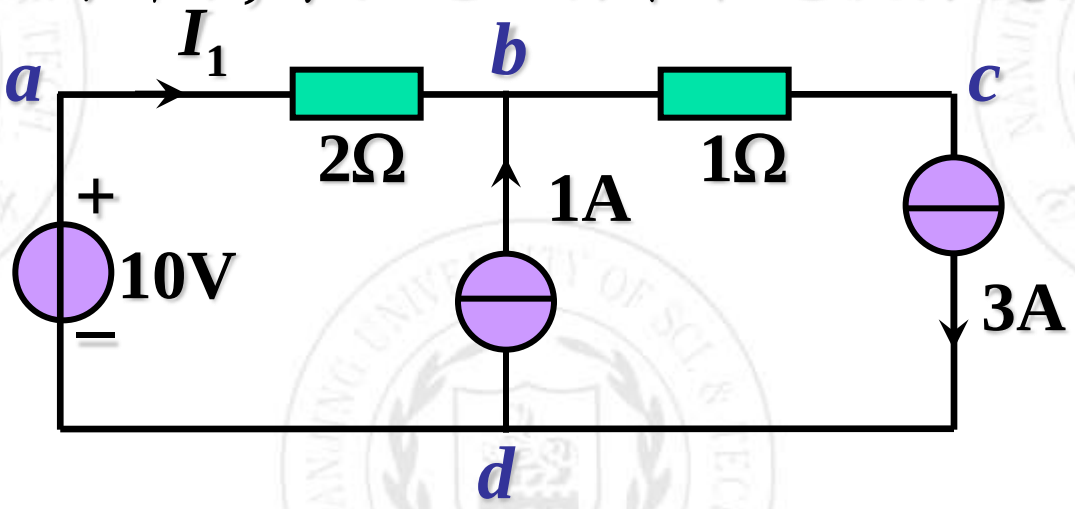
沿右边路径求电压u_{ab}得到：

$$U_{ab} = 4 + 2\times 2 + 4\times 2 = 16\text{V}$$

也可由左边路径求电压u_{ab}得到

$$U_{ab} = -1\times 2 + 24 - 6 = 16\text{V}$$

例：电路如图所示，求：电压源和各电流源发出的功率.



$$I_1 = 3 - 1 = 2\text{A}$$

电压源的吸收功率为

$$P = -10 \times 2 = -20\text{W}(\text{发出}20\text{W})$$

电流源1A和3A吸收的功率分别为：

$$P_{1\text{A}} = -6 \times 1 = -6\text{W}(\text{发出}6\text{W})$$

$$P_{3\text{A}} = 3 \times 3 = 9\text{W}(\text{发出}-9\text{W})$$

目　录

1、线性元件：

端口伏安关系为线性函数的元件。

2、线性电路：

由线性无源元件、线性受控源和独立源组成的电路。

3、线性电阻电路：

如果构成线性电路的无源元件都是线性电阻。

分析线性电阻电路的三个途径

1、运用等效变换法。

2、系统分析法。

3、运用电路定理分析。

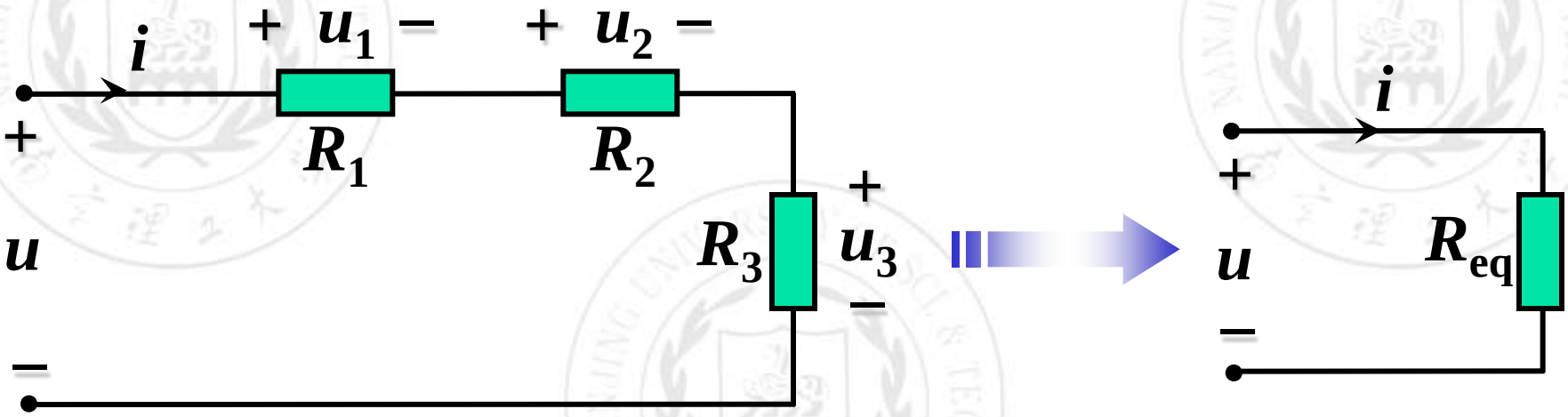
- 若两个二端网络N_1和N_2，当它们与同一个外部电路相接，在相接端点处的电压、电流关系完全相同时，则称N_1和N_2为相互等效的二端网络

$i = i'$

(二端网络)　　(二端网络)

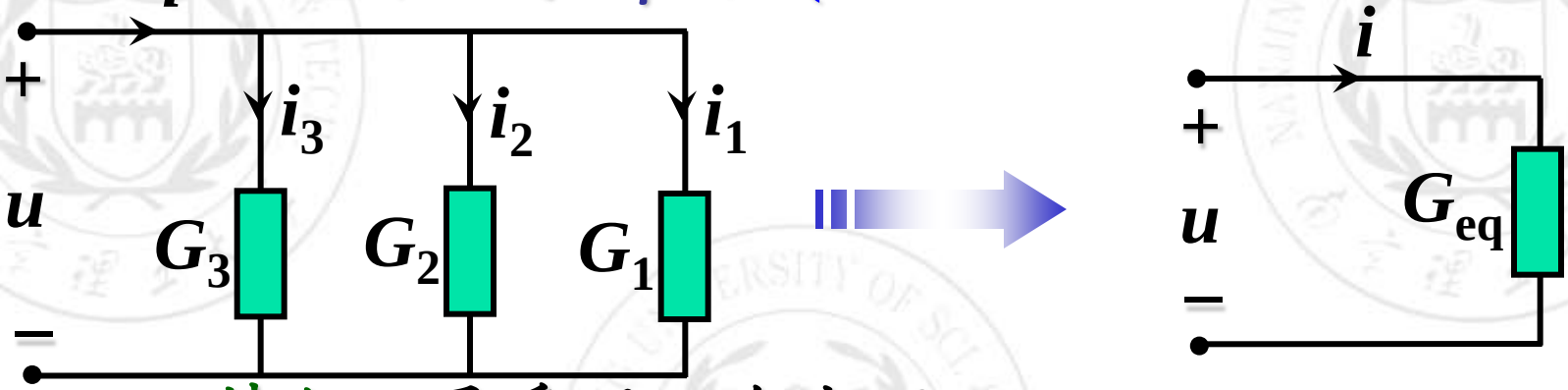
- 等效的两个二端网络相互替代，这种替代称为等效变换
- 目的：简化电路

电阻的串联 (Series connection of resistors)



- 特征: 流过同一电流
- KVL: $u = u_1 + u_2 + u_3 = R_1 i + R_2 i + R_3 i = R_{\text{eq}} i$
- 等效电阻: $R_{\text{eq}} = \sum R_k$
- 分压公式: $u_k = \dfrac{R_k}{R_{\text{eq}}} u$
- 功率: $P_k = R_k i^2;\ P = \sum P_k$

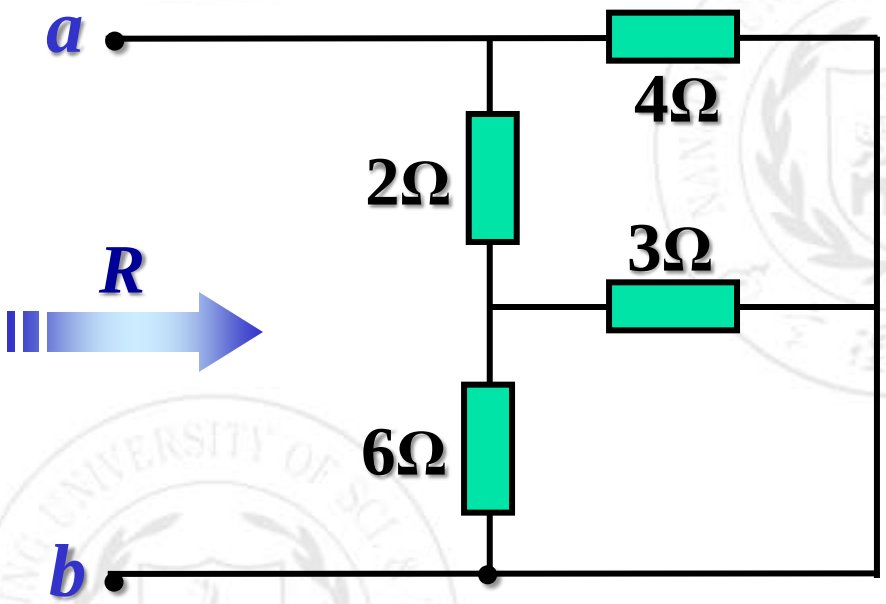
电阻的并联 (Parallel connection of resistors)

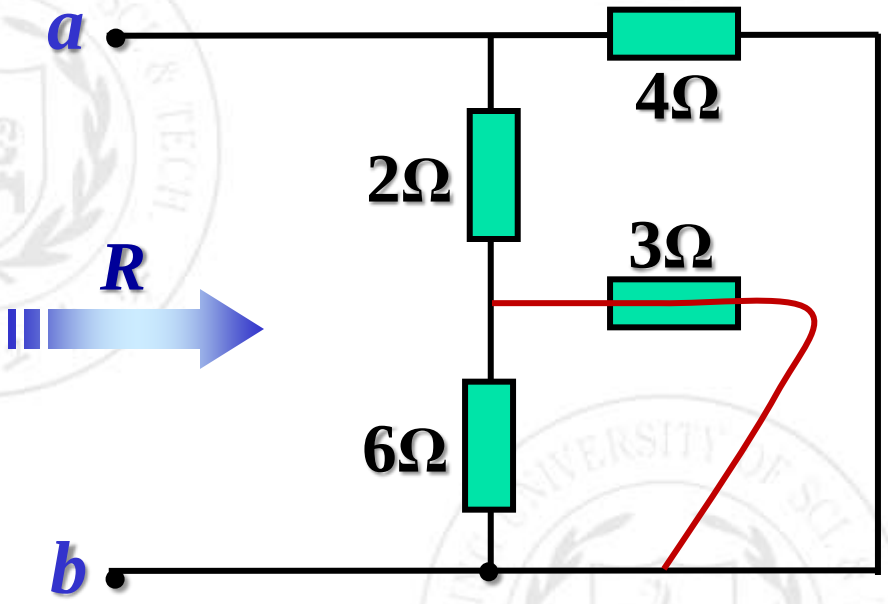


- 特征：承受同一个电压
- KCL: $i = i_1 + i_2 + i_3 = G_1 u + G_2 u + G_3 u = G_{\text{eq}} u$
- 等效电导: $G_{\text{eq}} = \sum G_k$
- 分流公式: $i_k = G_k u = \dfrac{G_k}{G_{\text{eq}}} i$
- 功率: $P_k = G_k u^2;\ P = \sum P_k$

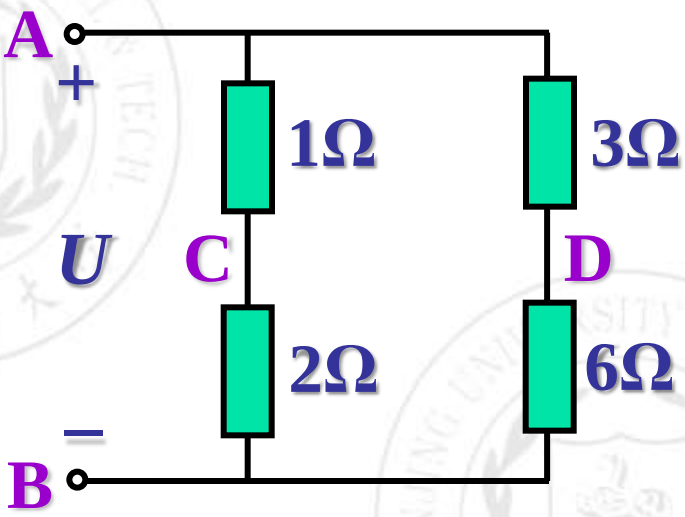
- 如何判断串并联关系？

节点的移动、元件的拉伸

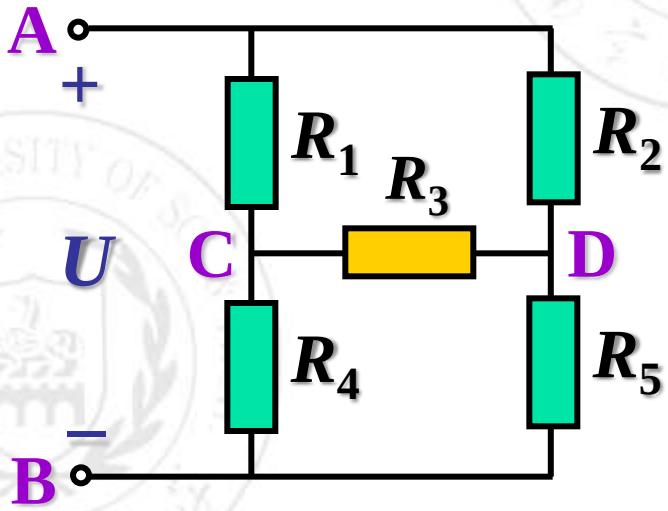




电桥平衡

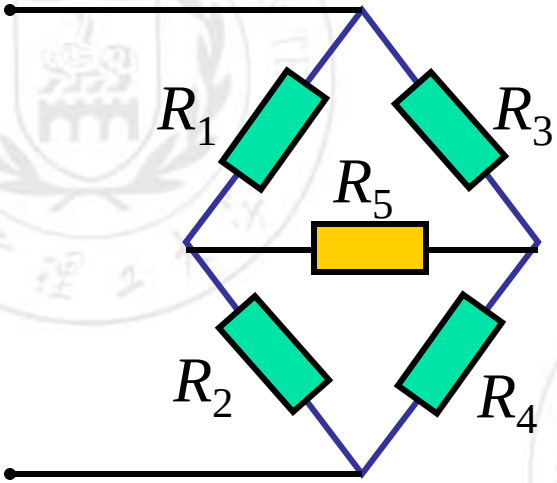


$U_{CD}=?$



$\frac{R_1}{R_4}=\frac{R_2}{R_5}$，$U_{CD}=?$

$U_{CD}=0$



重点

臂支路：R_1、R_2、R_3、R_4

桥支路：R_5

- 每个节点联接3条支路

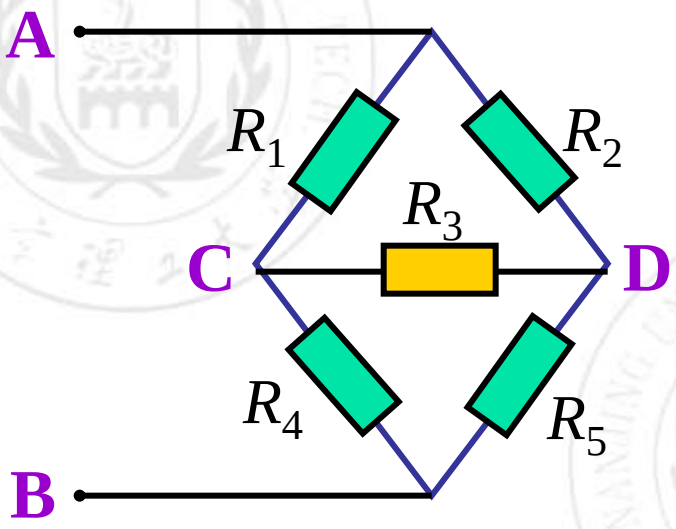
平衡条件：

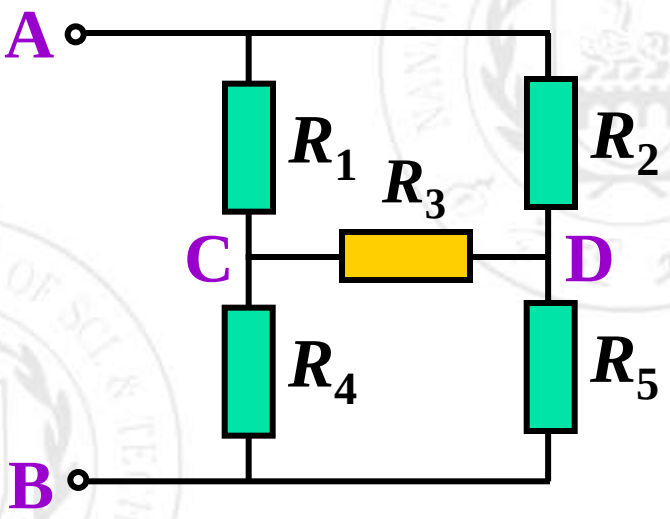
$$\frac{R_1}{R_2}=\frac{R_3}{R_4}$$

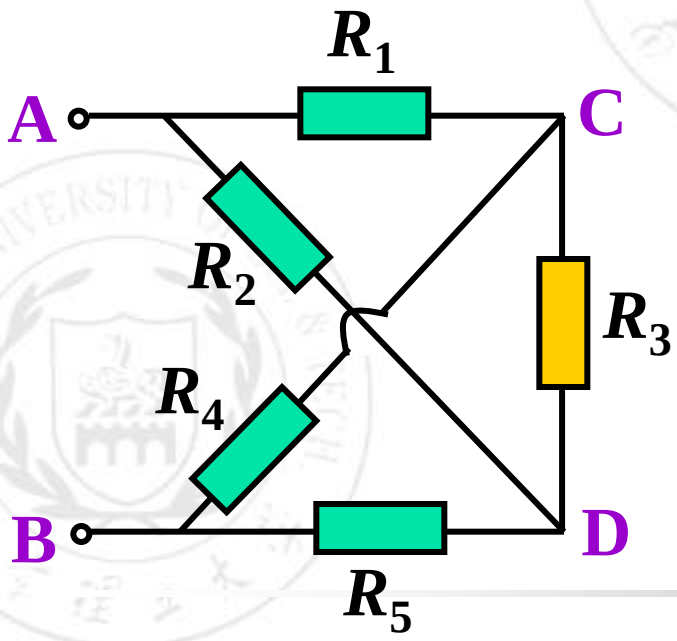
或 $R_1R_4=R_2R_3$

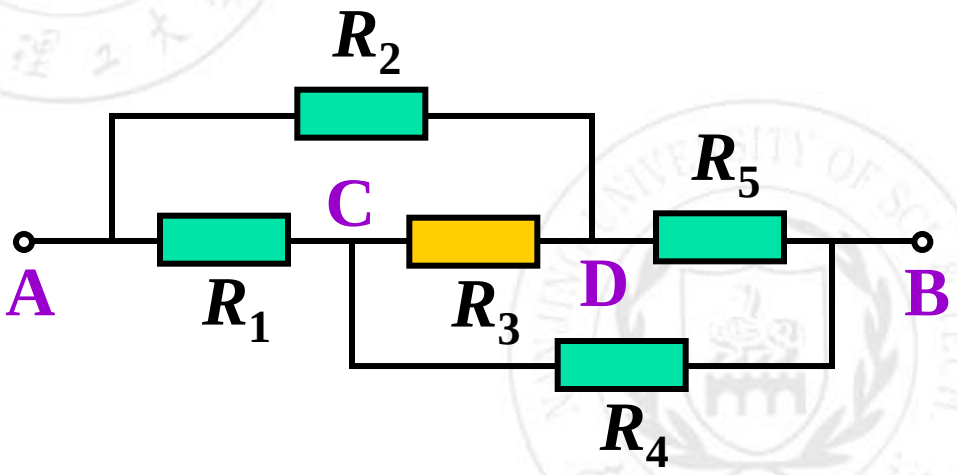
平衡时，R_5所在的支路既可开路又可短路。

电桥电路

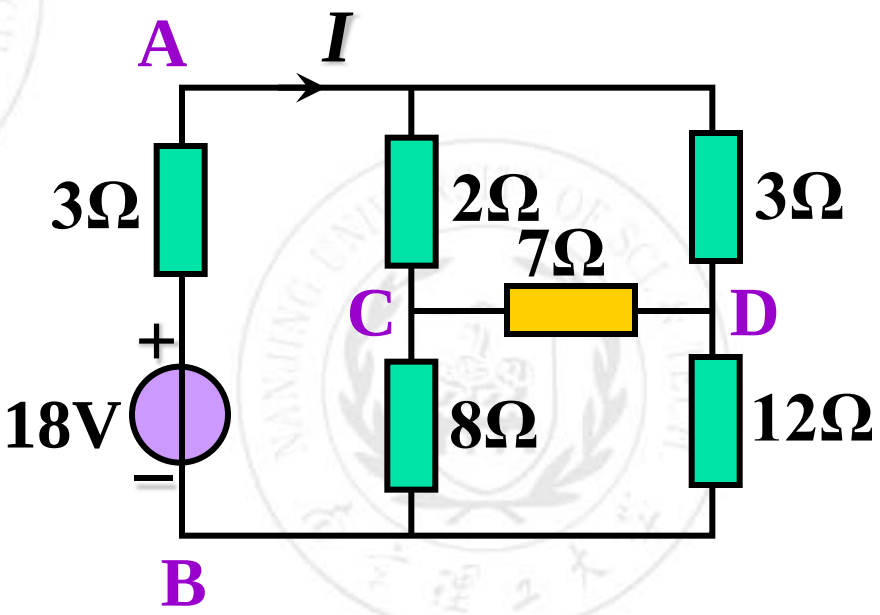

A
R_1
R_2
R_3
C
D
R_4
R_5
B


A
R_1
R_3
R_2
C
D
R_4
R_5
B


R_1
A
C
R_2
R_3
R_4
B
D
R_5


R_2
R_5
C
A
R_1
R_3
D
B
R_4

举例

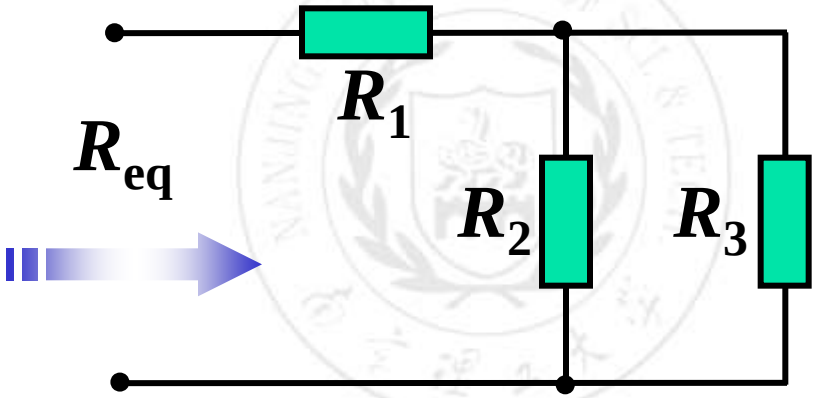


$2\times12=8\times3$ 电桥平衡

$$I=\frac{18}{3+6}=2\text{A}$$

电阻的混联 (Series and parallel connection of resistors)

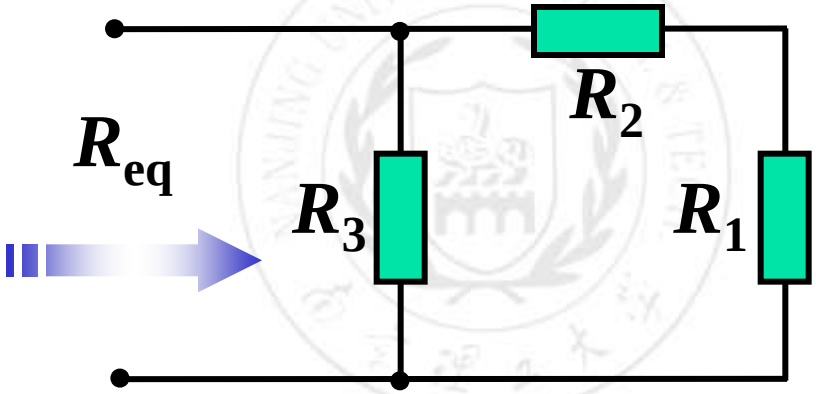
串并联



$$R_{eq} = \frac{R_2 R_3}{R_2 + R_3} + R_1$$

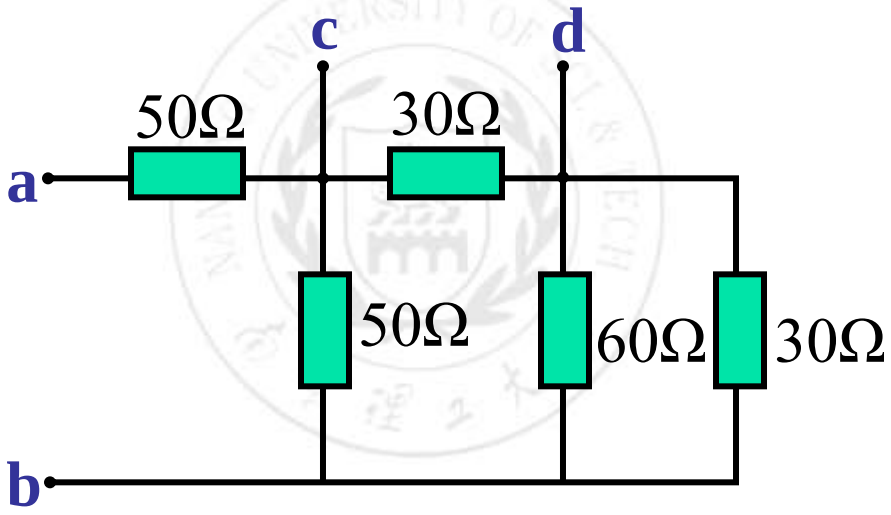
电阻的混联

串并联



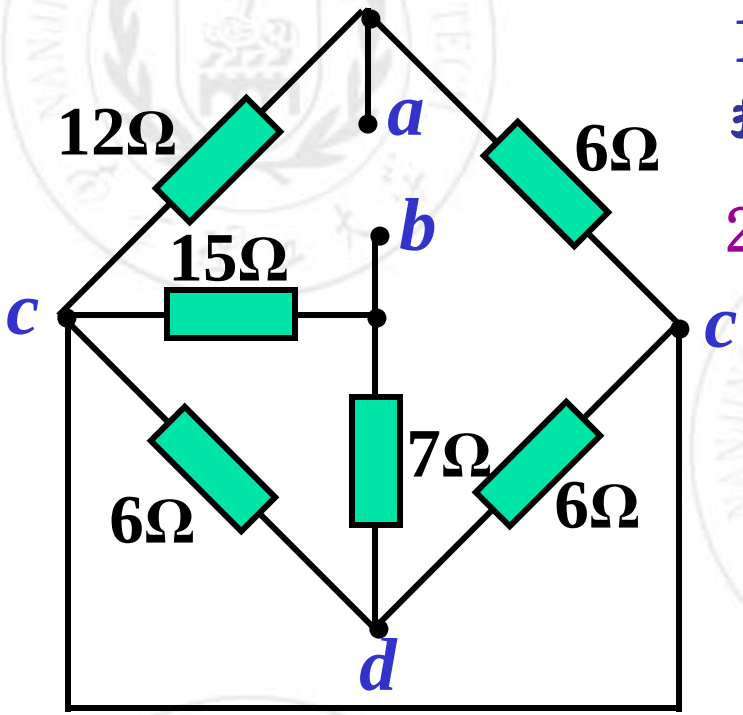
$$R_{eq} = \frac{(R_1 + R_2) \cdot R_3}{R_1 + R_2 + R_3}$$

例：求等效电阻R_{ab}和R_{cd}。



$$R_{ab}=75\Omega,\ R_{cd}=21\Omega$$

例：求R_{ab}



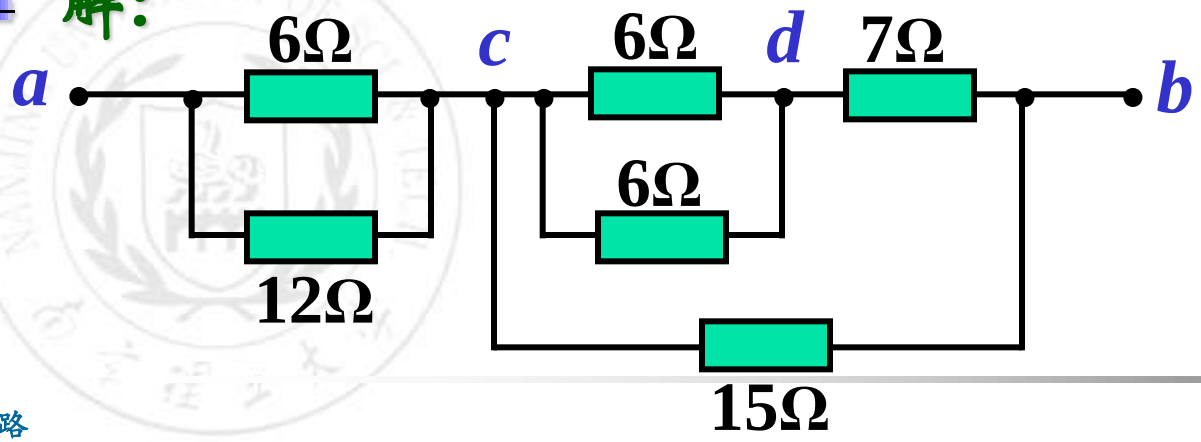
字母标注法

1、在各节点处标上节点字母，短路线联接的点或等位点用同一字母标注；

2、整理并简化电路，求出总的等效电阻。

重点

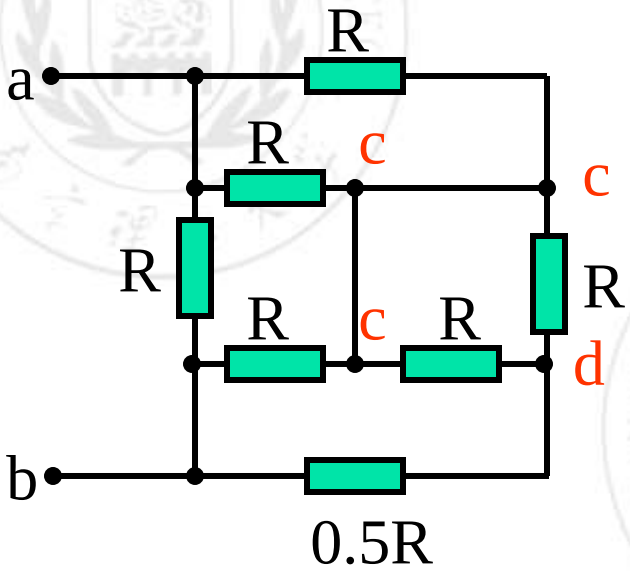
解：



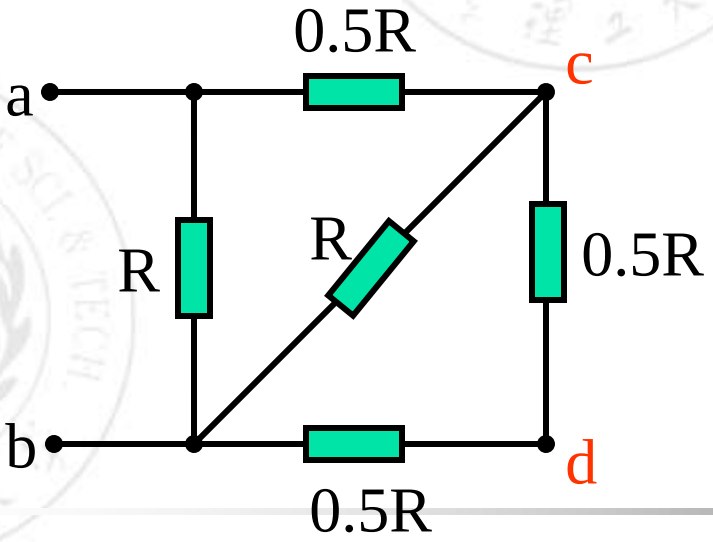
$$R_{ab}=4+6=10\Omega$$

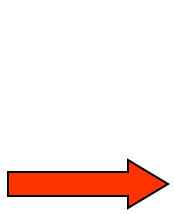
例：求R_{ab}

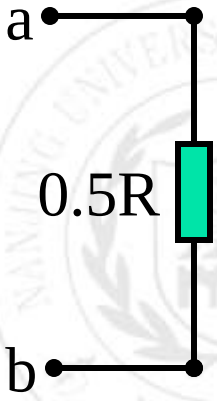
字母标注法



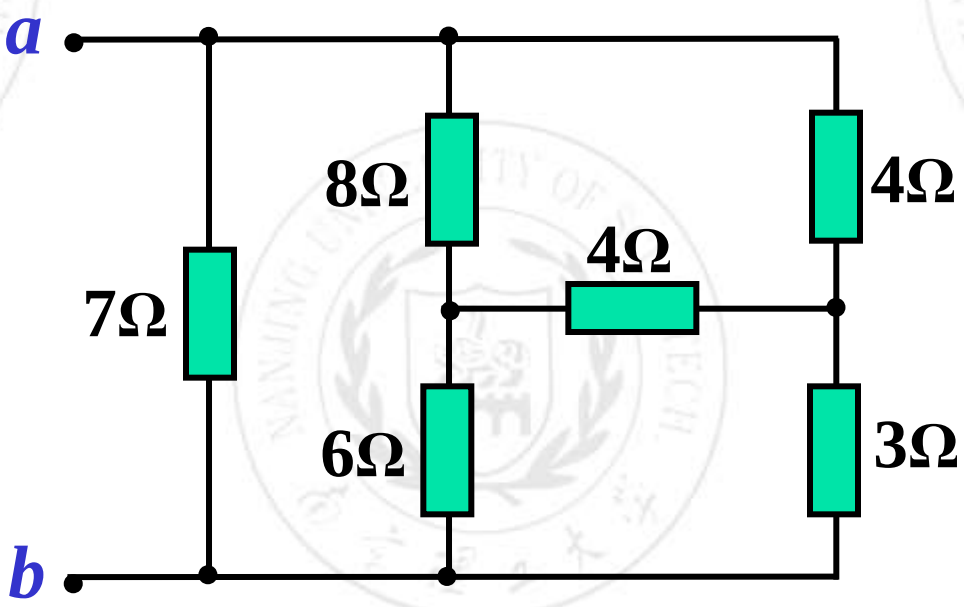
解：







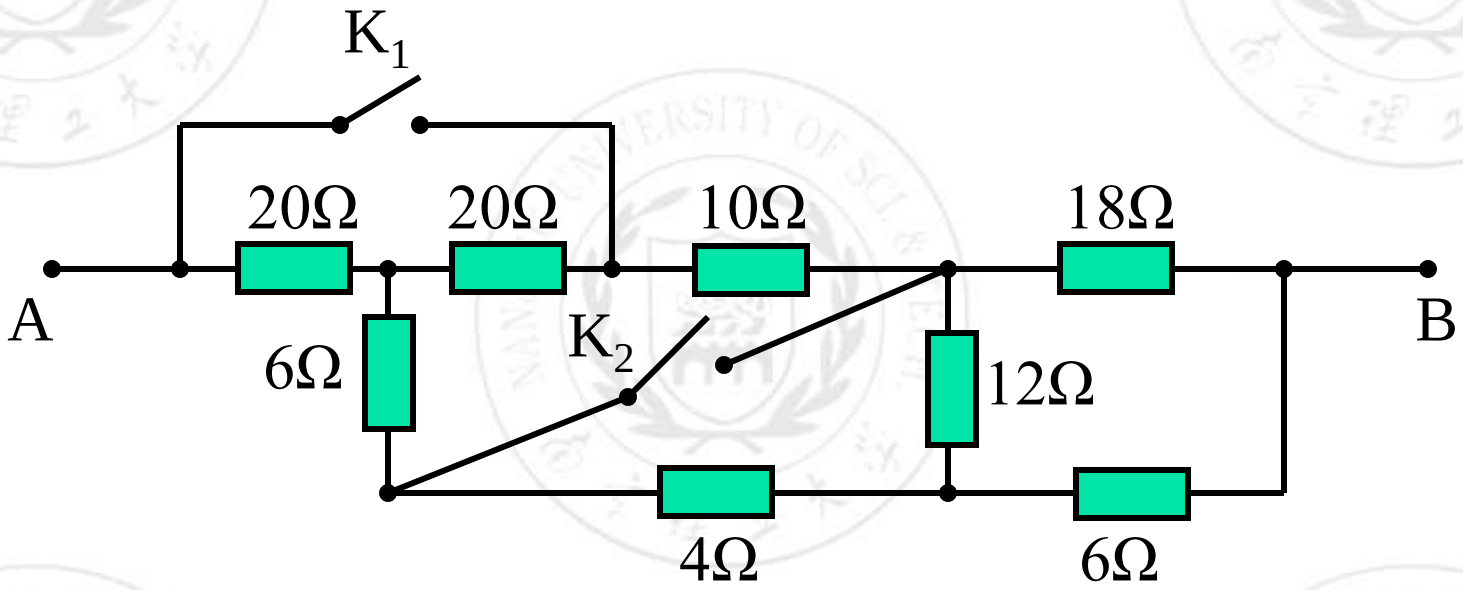
例：求R_{ab}



解：

$$R_{ab}=\frac{1}{\frac{1}{7}+\frac{1}{14}+\frac{1}{7}}=2.8\Omega$$

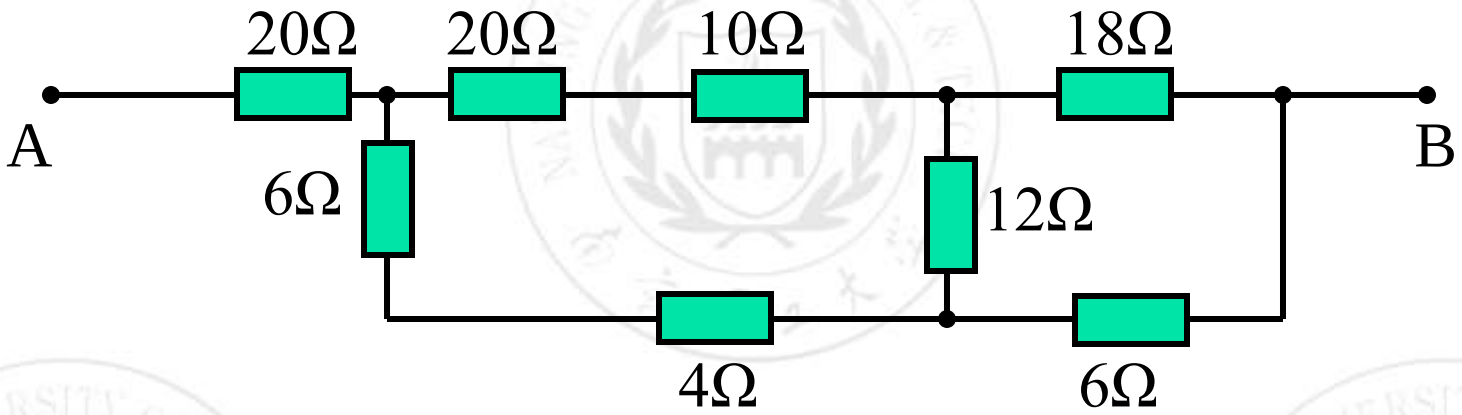
例：求K_1、K_2同时断开或同时闭合时的R_{AB}。



答案：　K_1K_2闭合——12.15 Ω

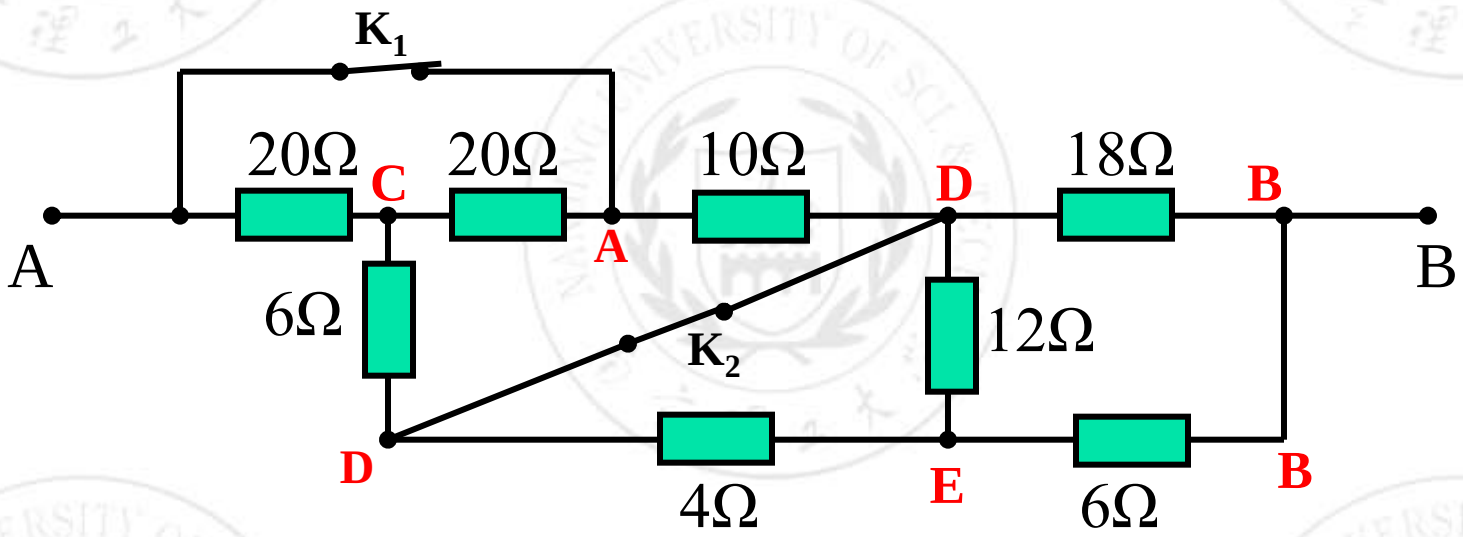
K_1K_2断开——32 Ω

K_1、K_2同时断开：



答案：　K_1、K_2断开——32 Ω

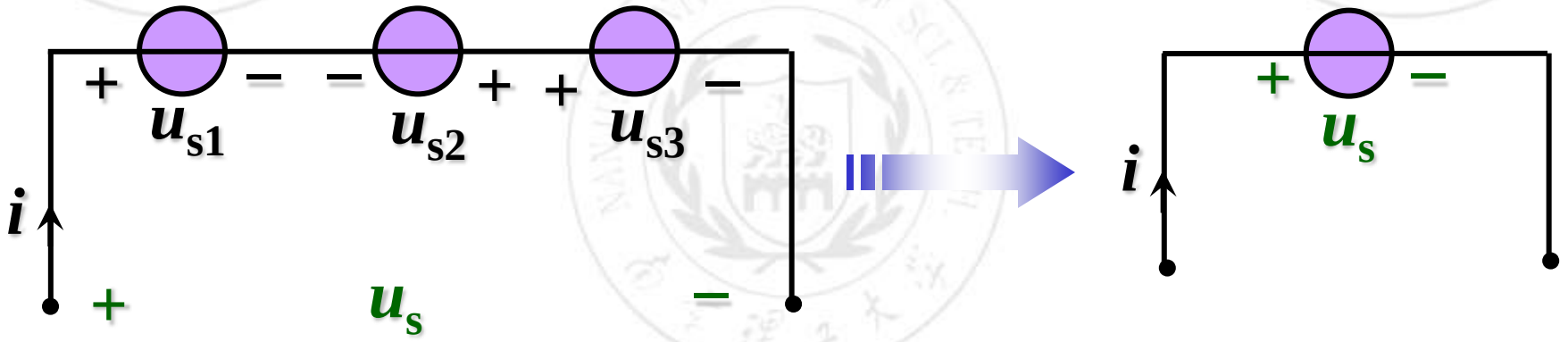
K_1、K_2同时闭合:



答案: K_1K_2闭合——12.15 Ω

目　录

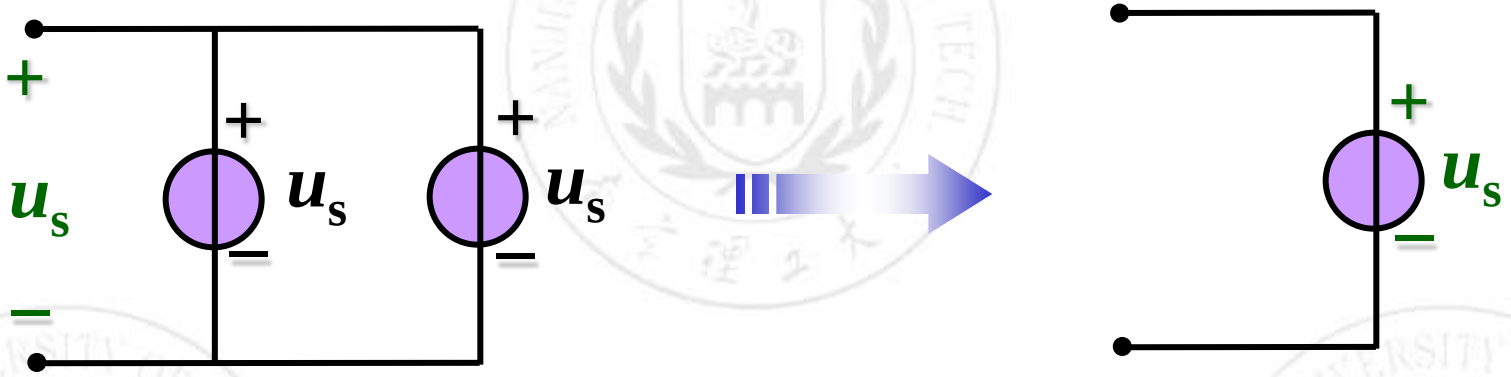
电压源的串联



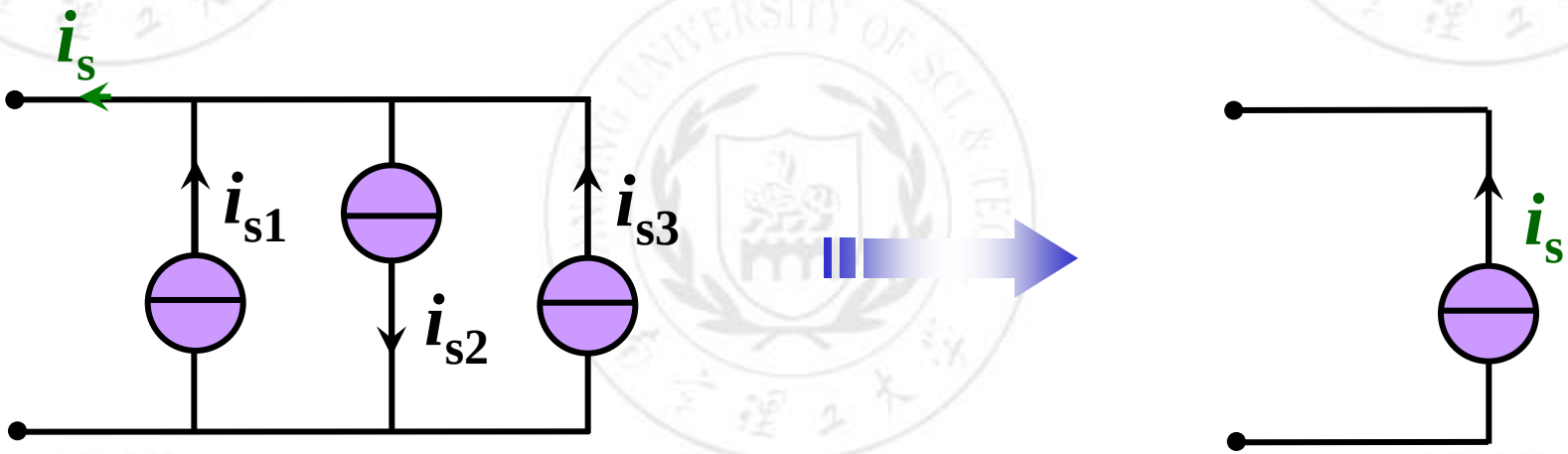
$$u_s = u_{s1} - u_{s2} + u_{s3} = \sum u_{sk}$$

电压源的并联

- 同极性、同数值并联



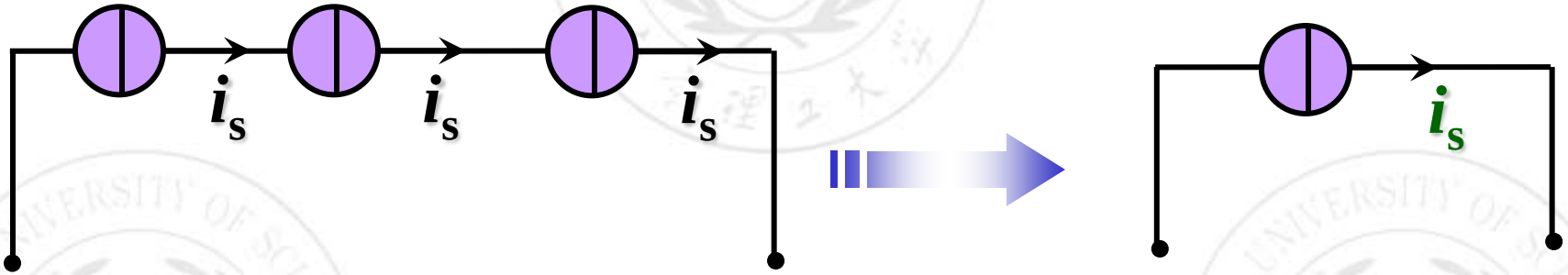
电流源的并联

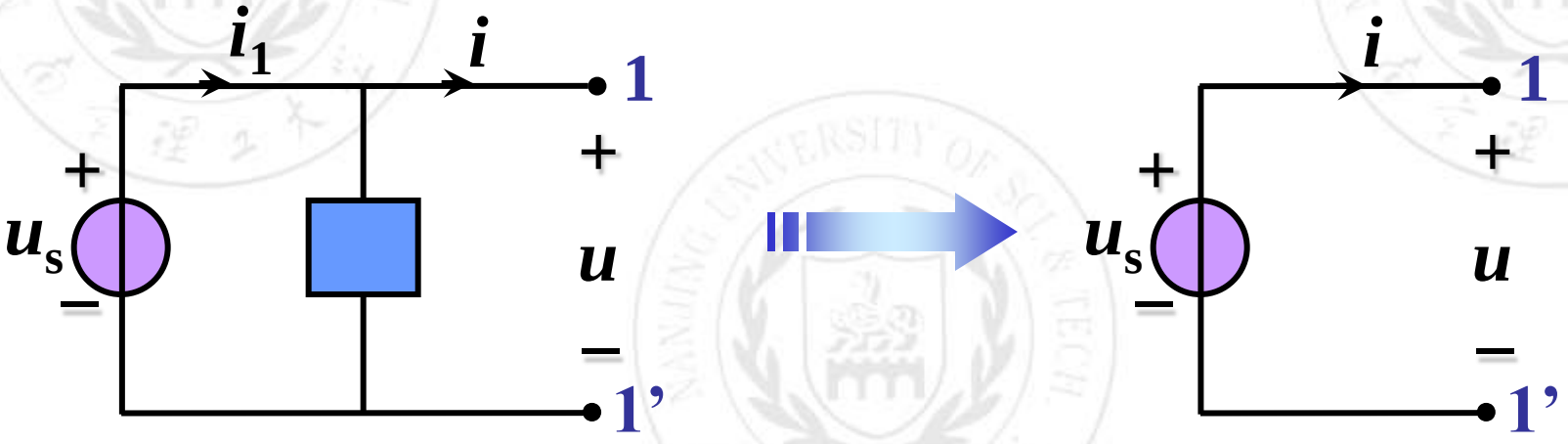


$$i_s = i_{s1} - i_{s2} + i_{s3} = \sum i_{sk}$$

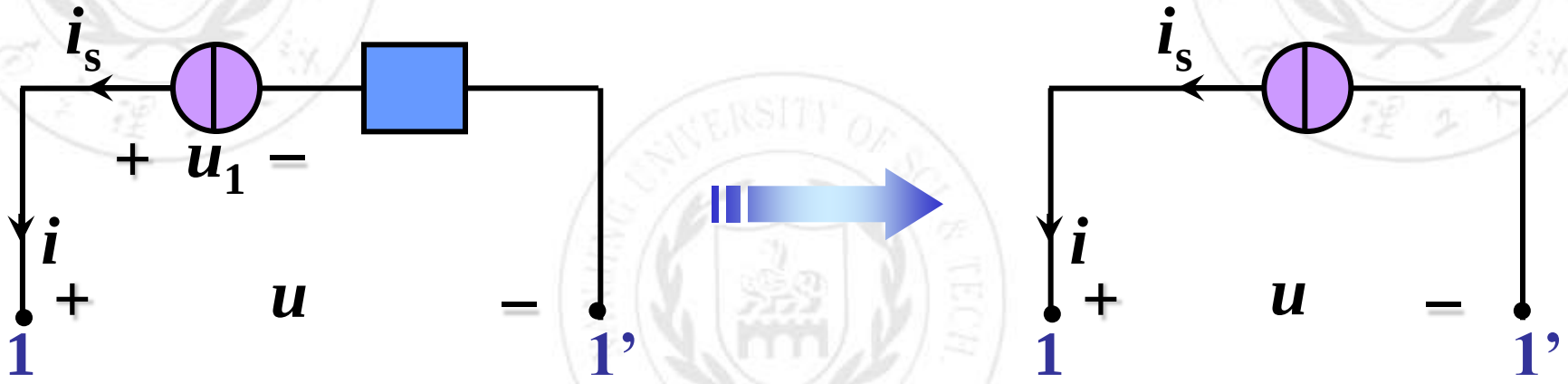
电流源的串联

- 同方向、同数值串联

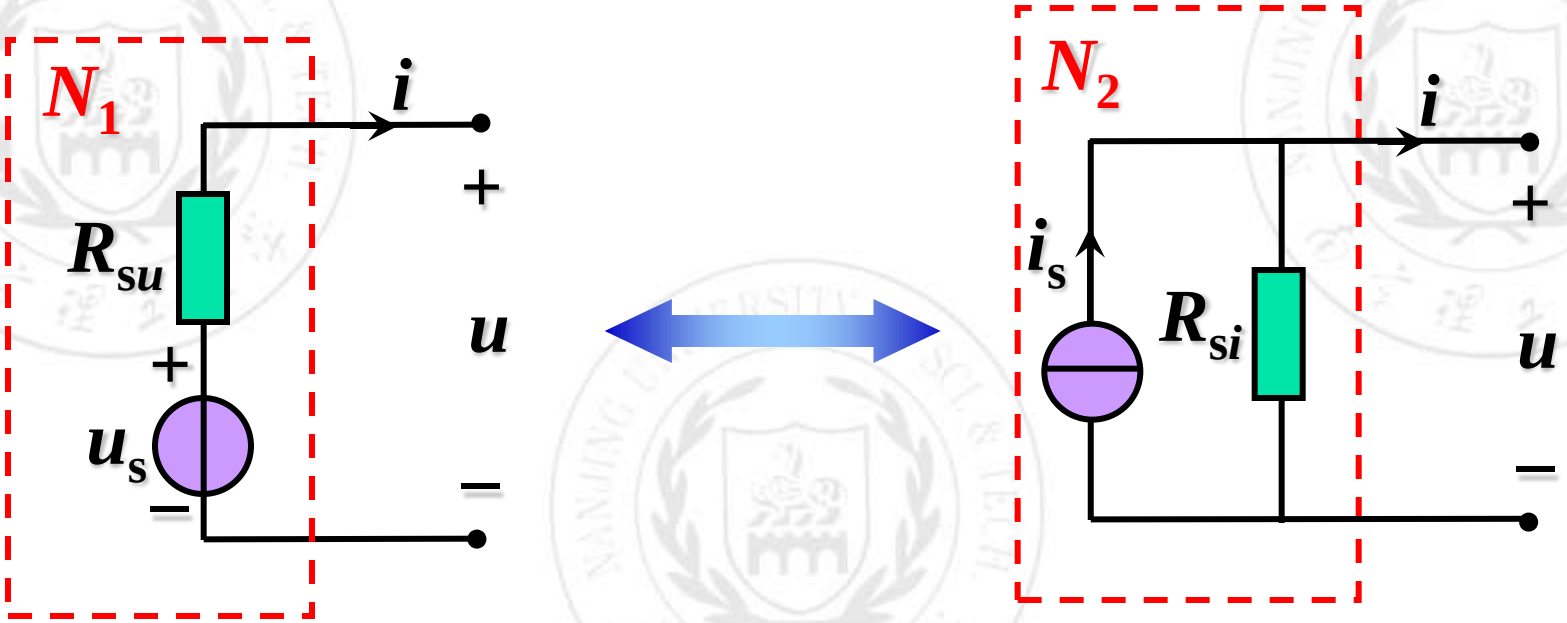




- 电压源与支路并联：可用一个等效电压源替代。



- **电流源与支路串联：** 可用一个等效电流源替代。



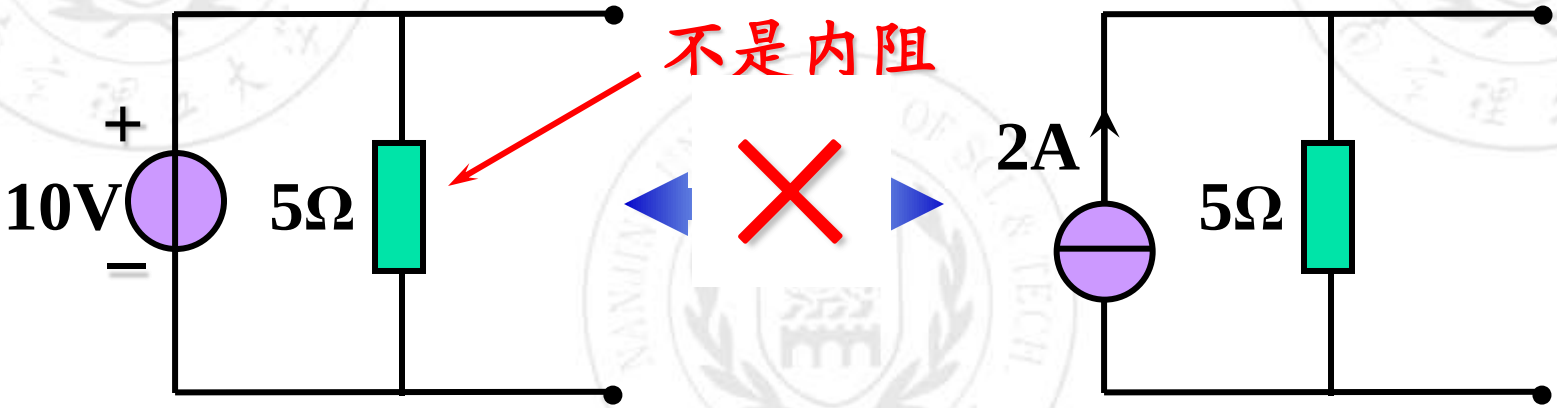
- N_1: $u = u_s - R_{su} i$

- N_2: $i = i_s - \dfrac{u}{R_{si}}$

$u = R_{si} i_s - R_{si} i$

$$\Rightarrow \begin{cases} R_{su} = R_{si} \triangleq R_s \\ u_s = R_s i_s \quad (i_s = \dfrac{u_s}{R_s}) \end{cases}$$

注意！



- 保持变换前后参考方向一致
- 等效是对外部而言，对内不等效
- 理想电压源和理想电流源之间没有等效关系

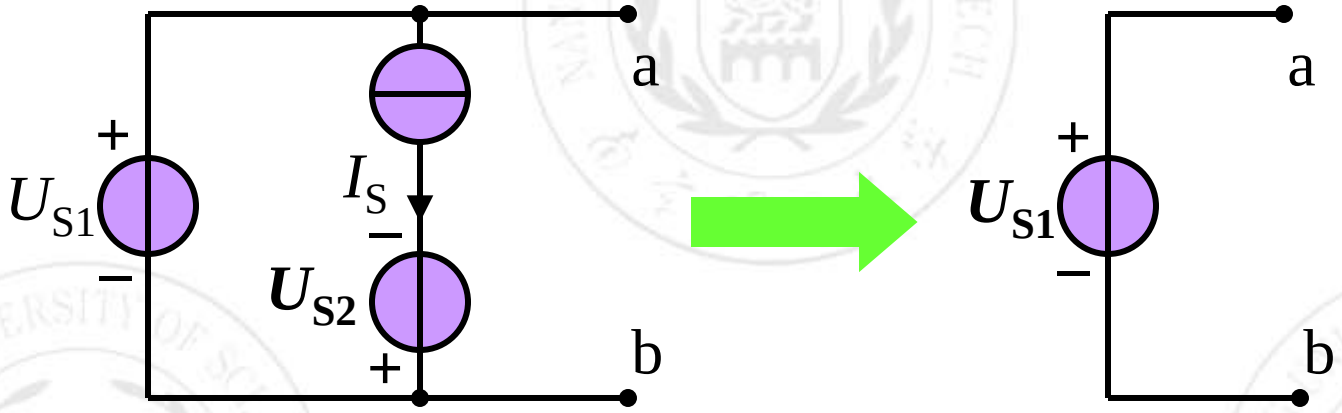
注意！

- 与理想电压源并联的元件（支路）对外电路讨论时可断开

- 与理想电流源串联的元件（支路）对外电路讨论时可短接

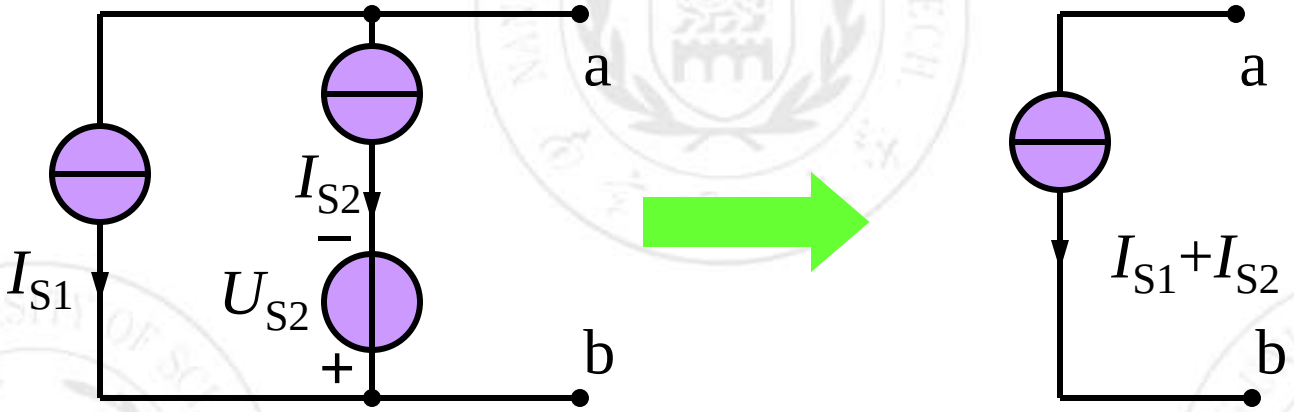
例、将下列电路简化成最简单的电路：

1



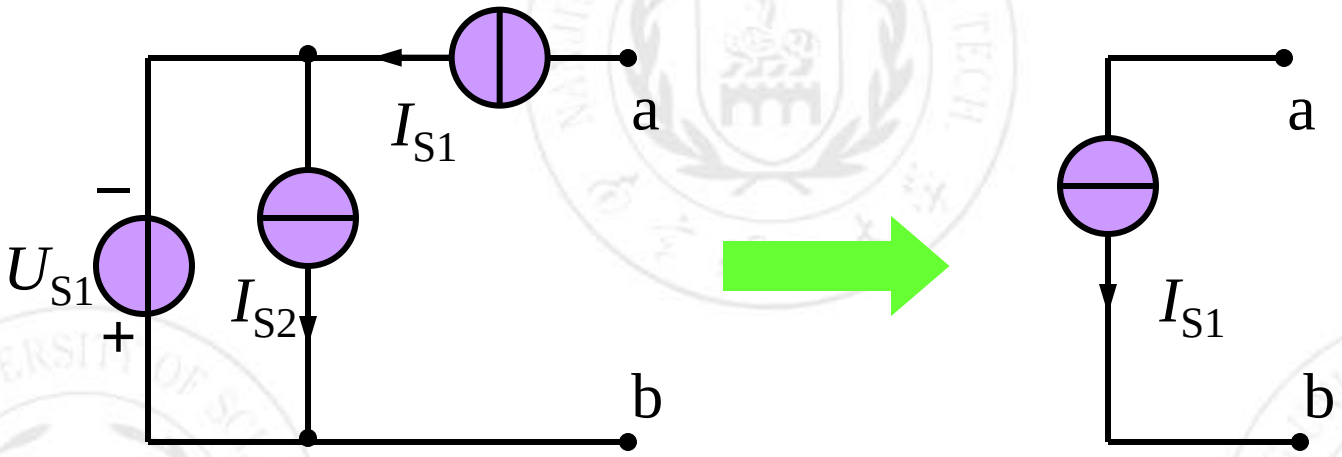
例、将下列电路简化成最简单的电路：

2



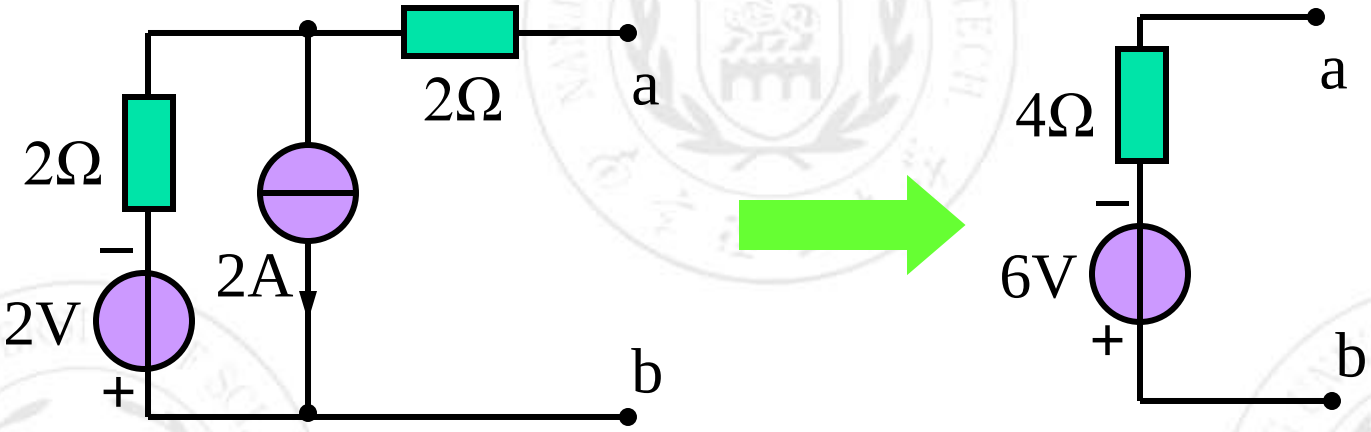
例、将下列电路简化成最简单的电路：

3

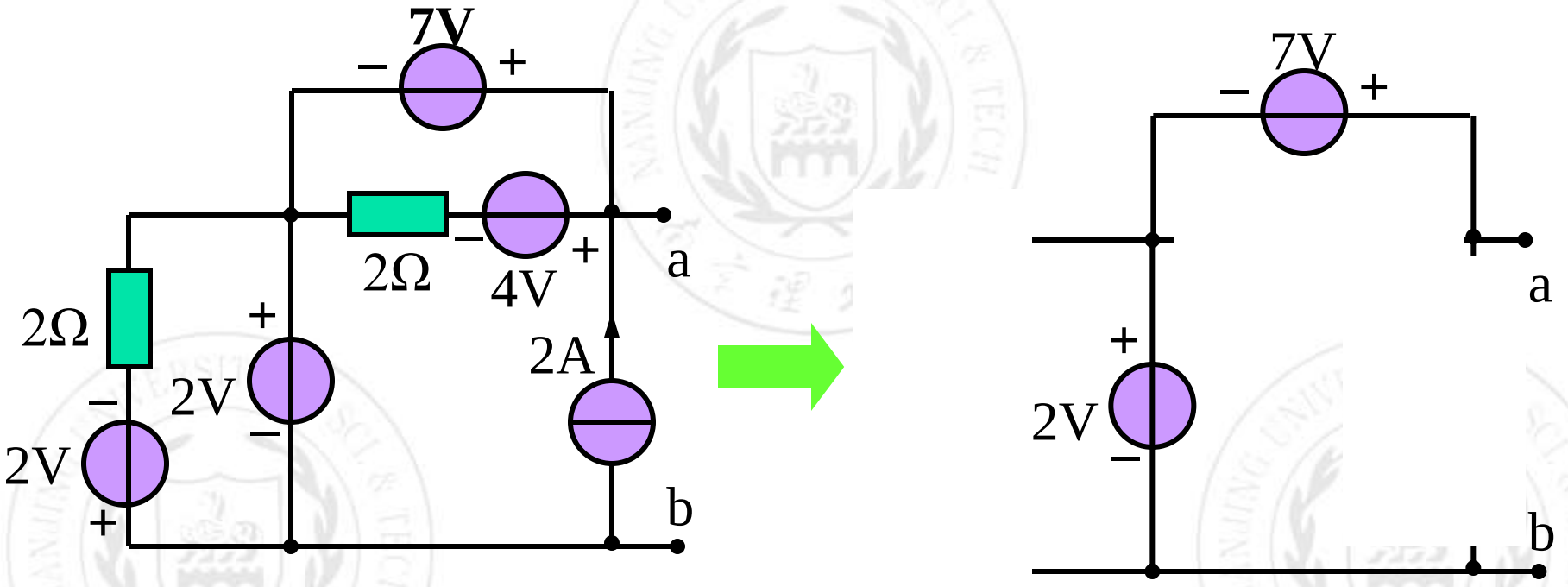


例、将下列电路简化成最简单的电路：

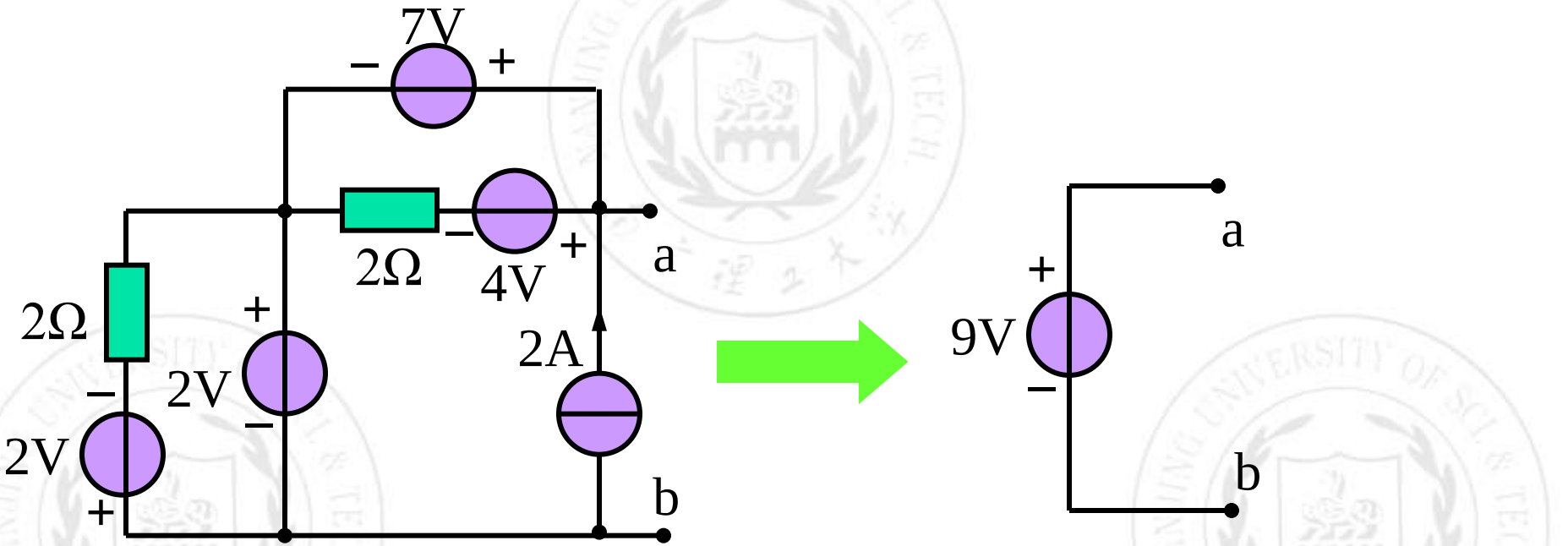
4



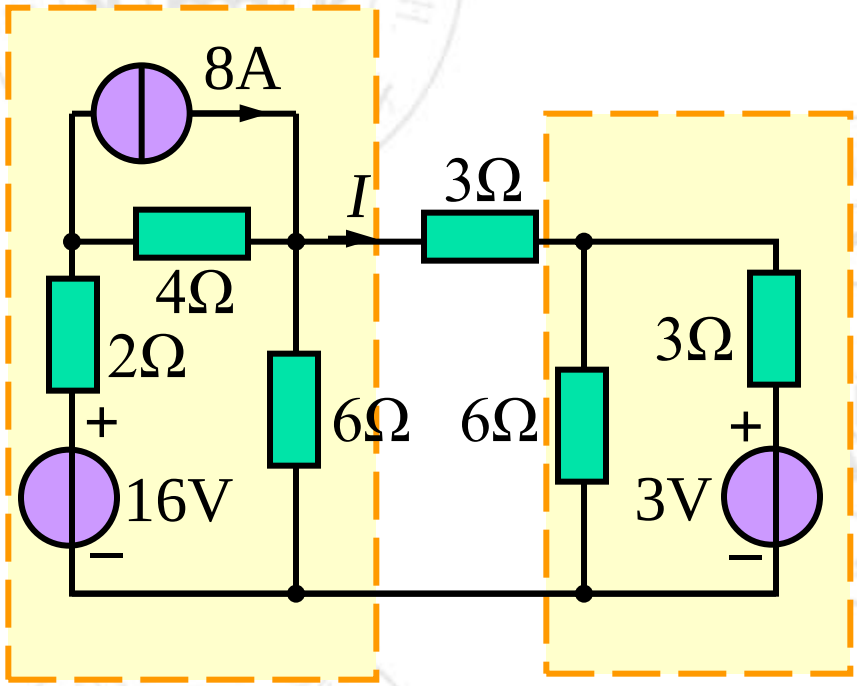
例、将下列电路简化成最简单的电路：

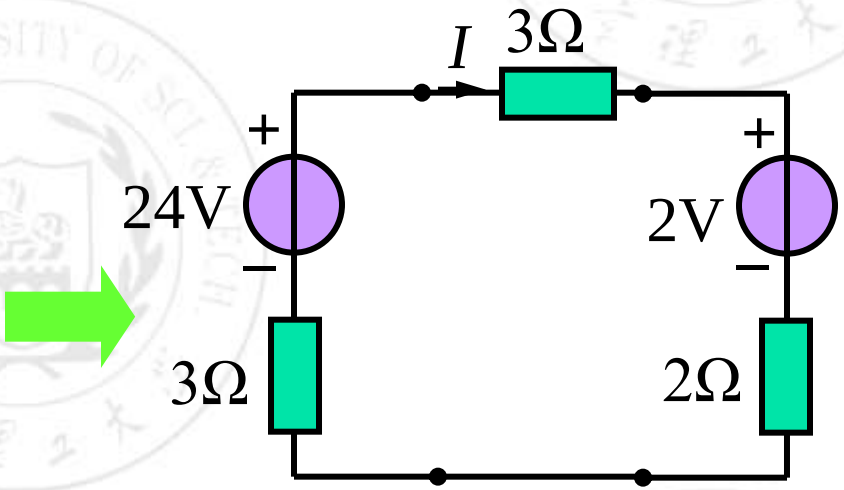


例、将下列电路简化成最简单的电路：



例、求电流I。

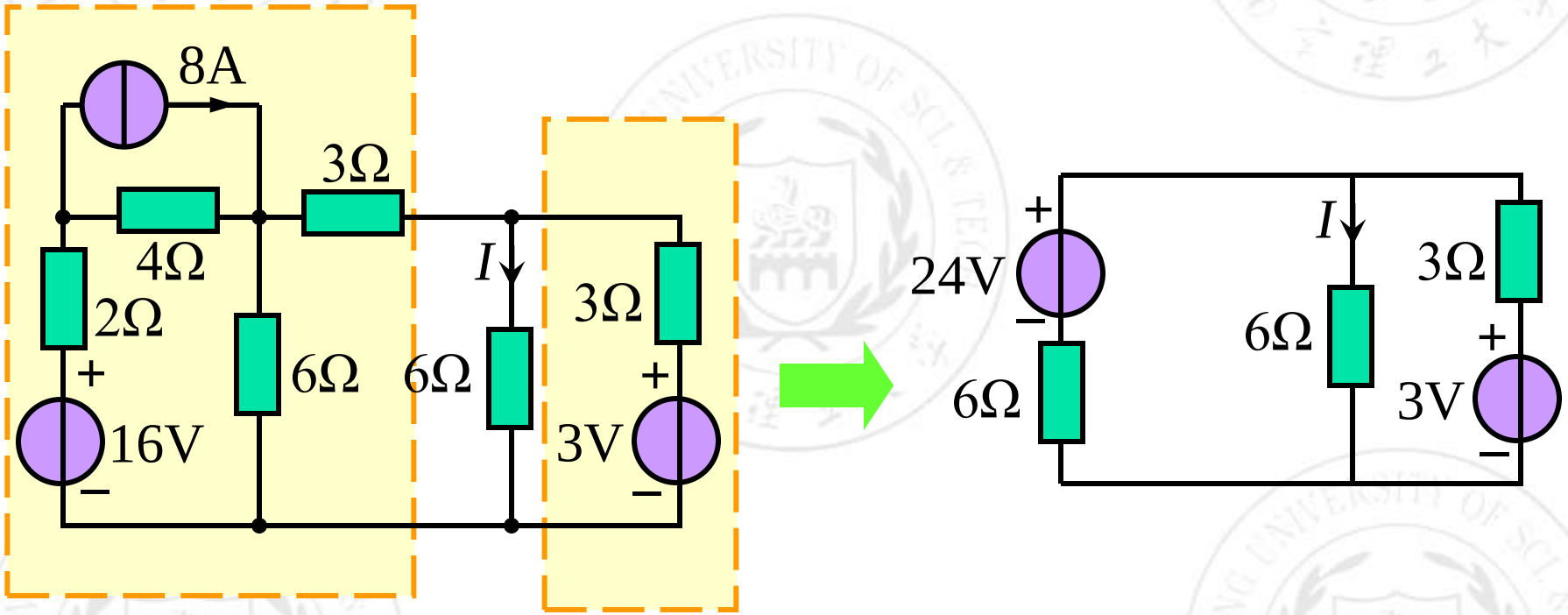




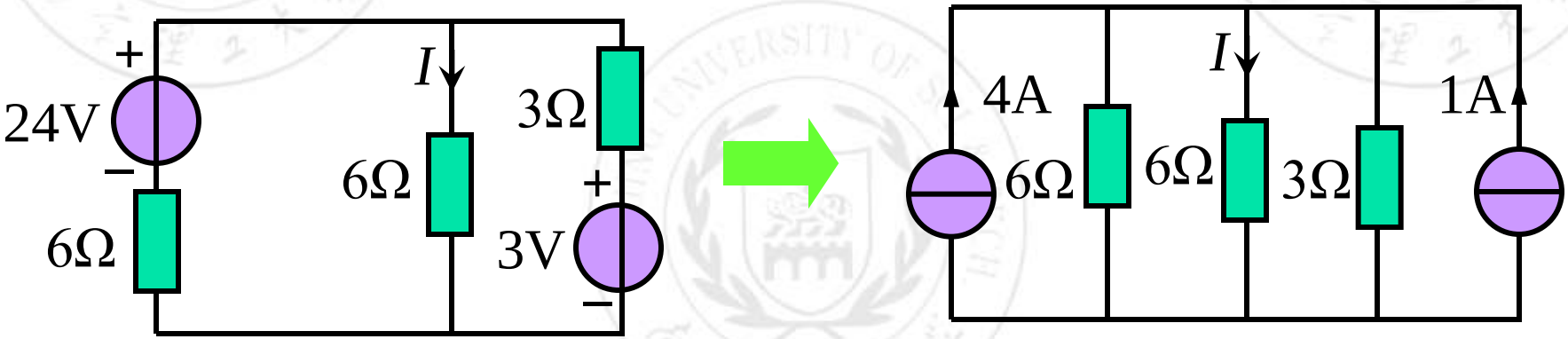
得：

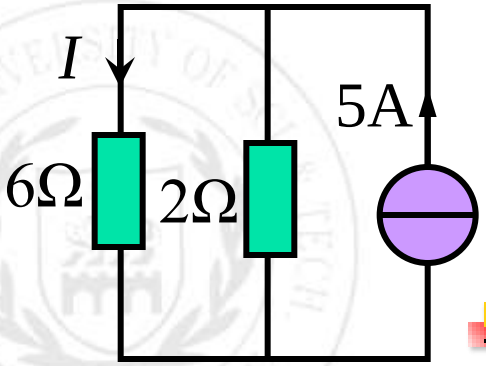
$$I=\frac{24-2}{3+3+2}=2.75\,\mathrm{A}$$

例、求电流I。



例、电流I。

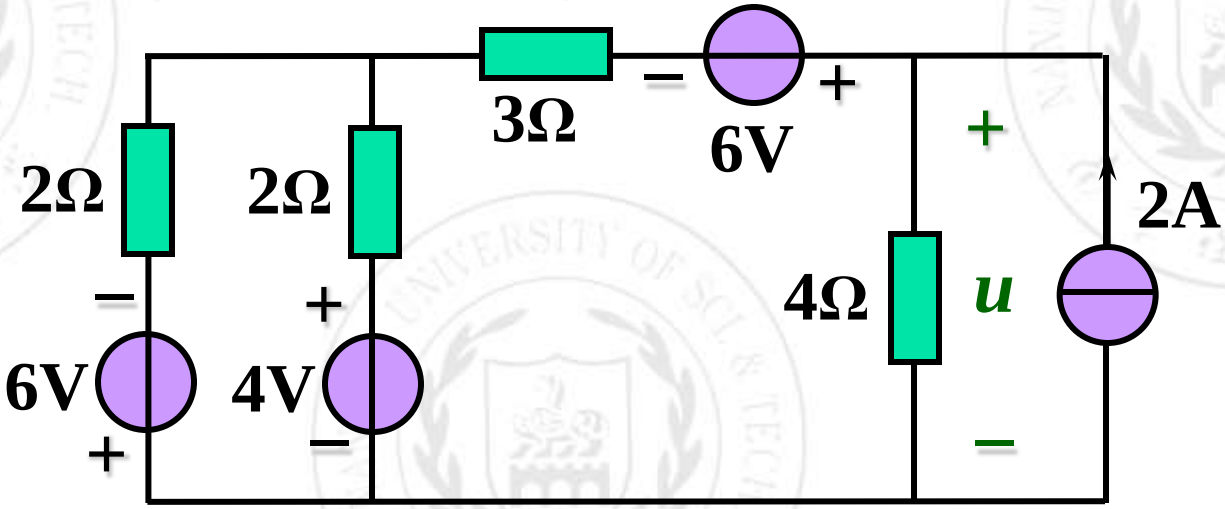




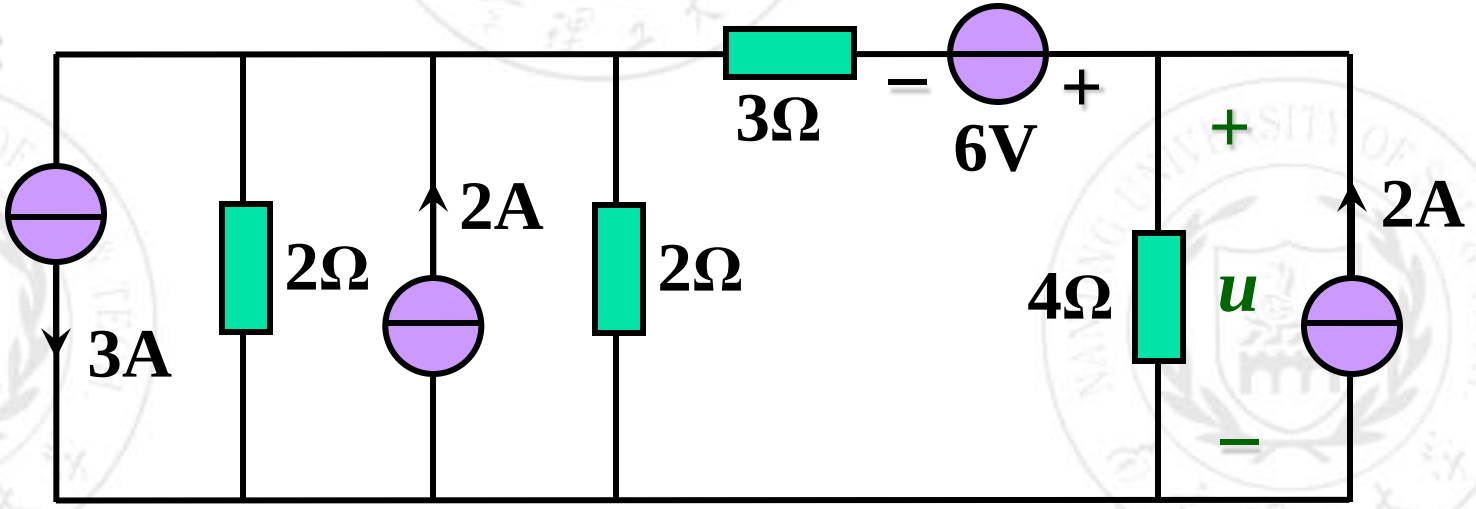
$$I=\frac{2}{2+6}\times 5=1.25\text{A}$$

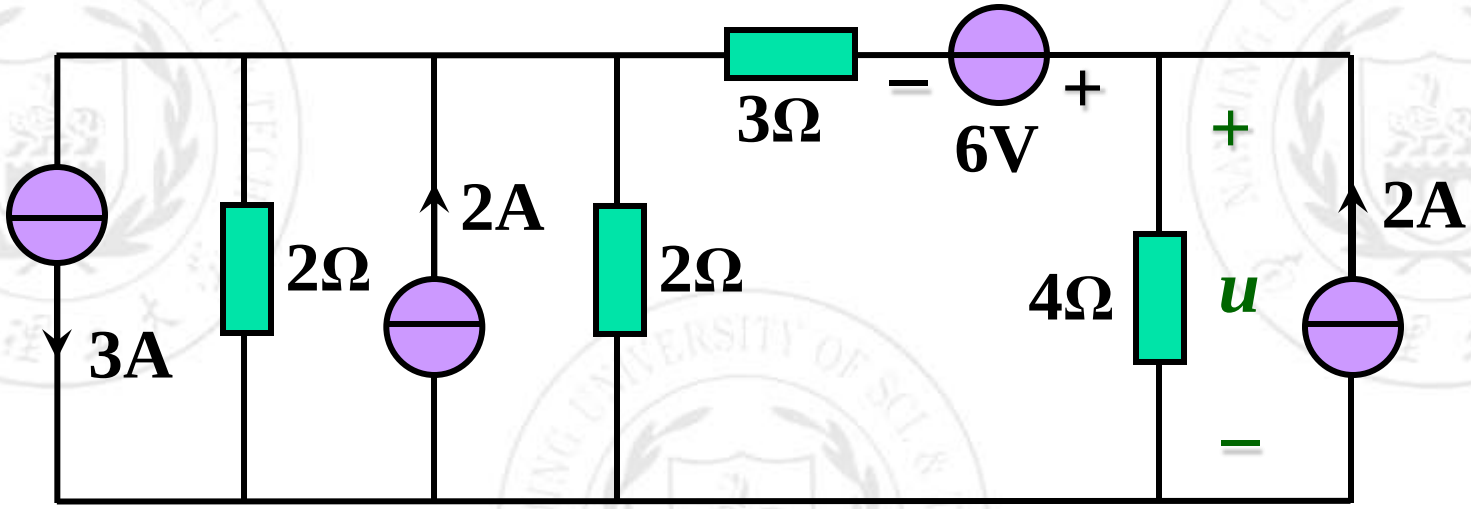
注意：未知量所在的支路一般保持不动

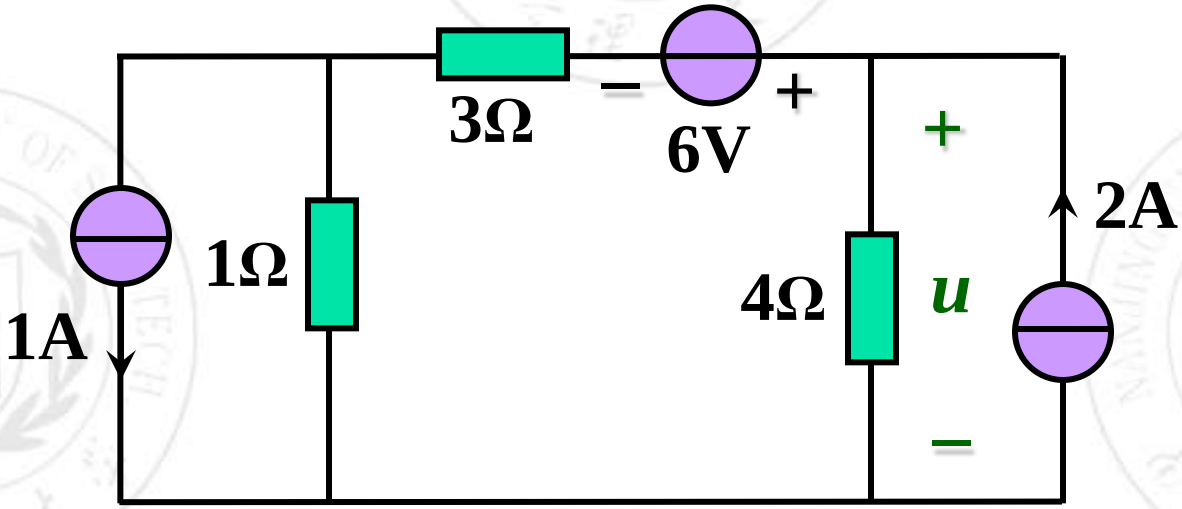
例：运用电源等效变换方法求u

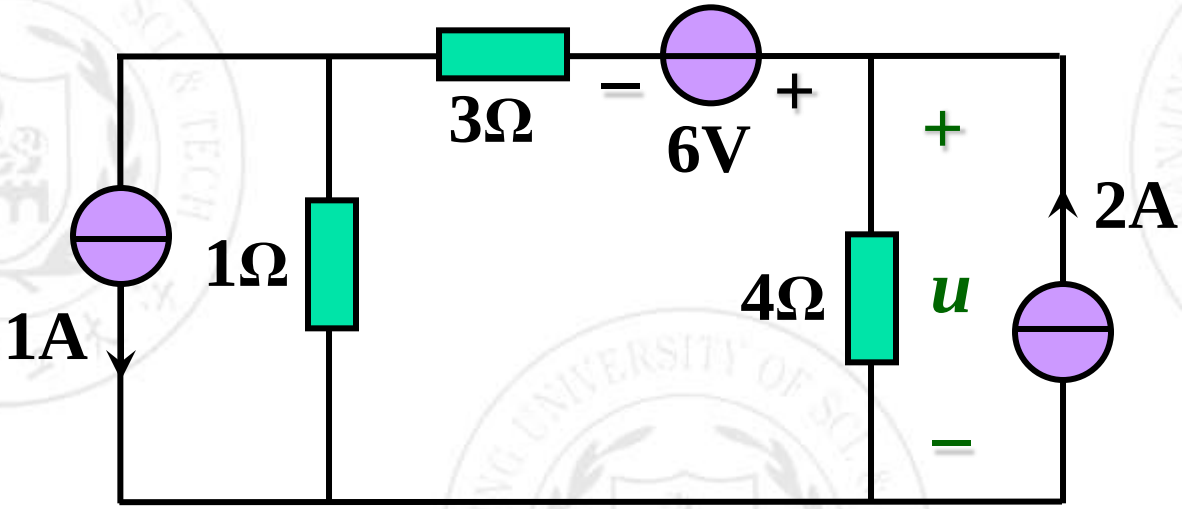


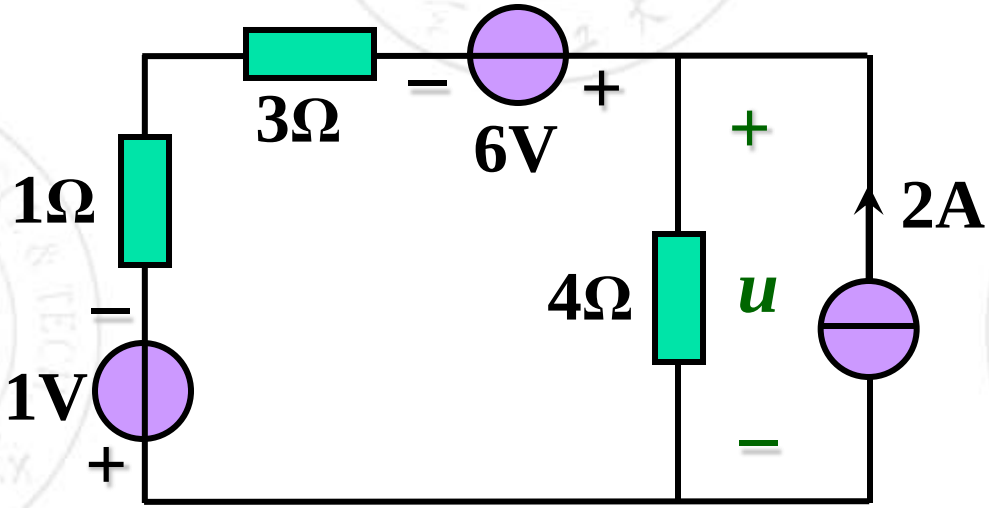
解：

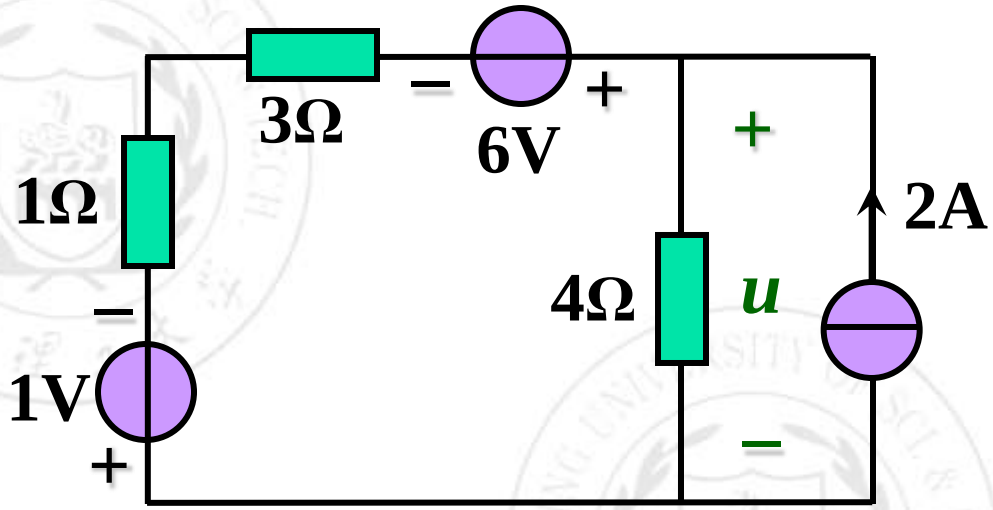



3Ω
−
+
6V
+
u
−
2A
3A
2Ω
2A
2Ω
4Ω
2A

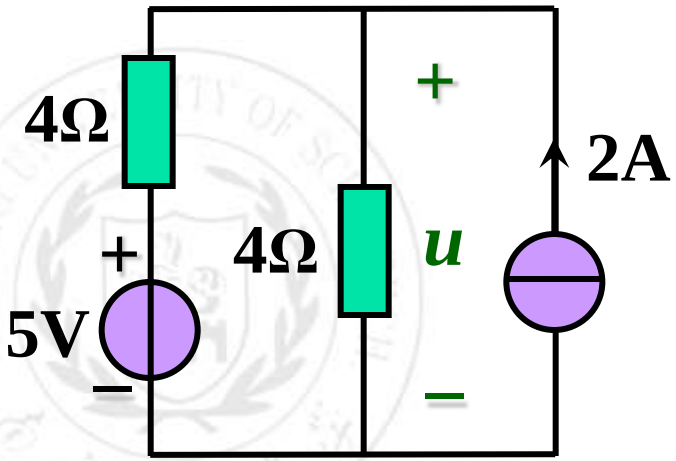

3Ω
−
+
6V
+
u
−
2A
1A
1Ω
4Ω

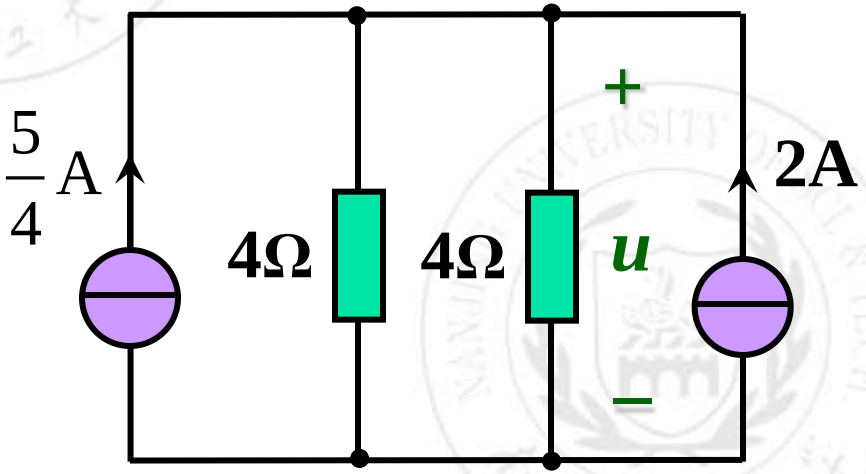

3Ω
–
6V
+
+
2A
1Ω
4Ω
u
1A
–

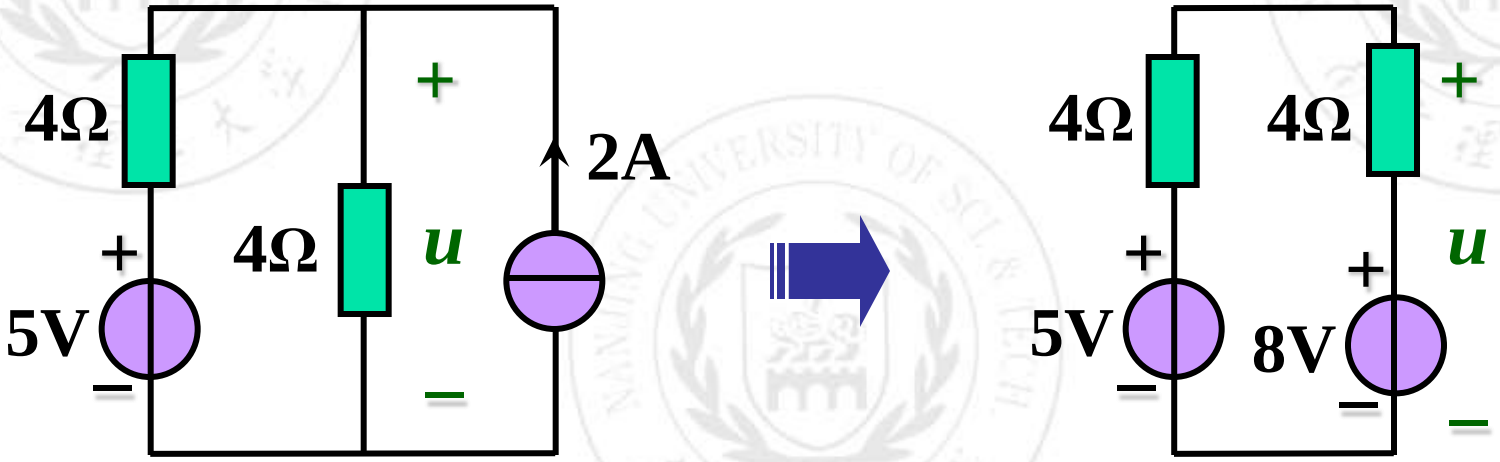

3Ω
–
6V
+
+
2A
1Ω
4Ω
u
–
1V
+



$$u = 4 \times \frac{2 + \frac{5}{4}}{2} = 6.5\text{V}$$







$$u = 6.5\text{V}$$

本次课重点

- 字母标注法.
- 平衡电桥.
- 电源的等效变换.