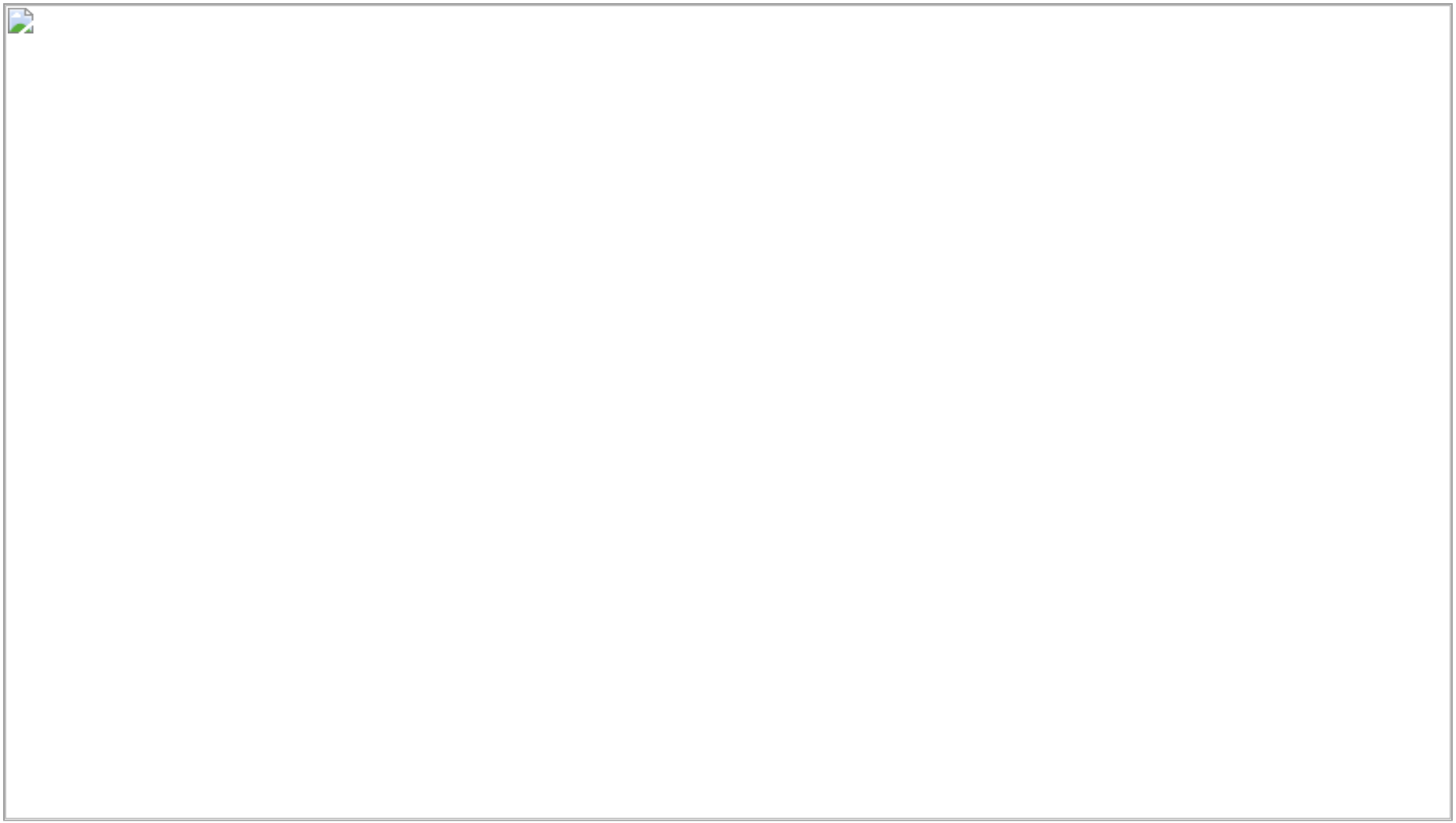
如果在4月8日期中考试时无法现场参加

请课后及早与于老师联系



电路原理

第7讲

电路的定理

纸笔计算器准备好

内容提要

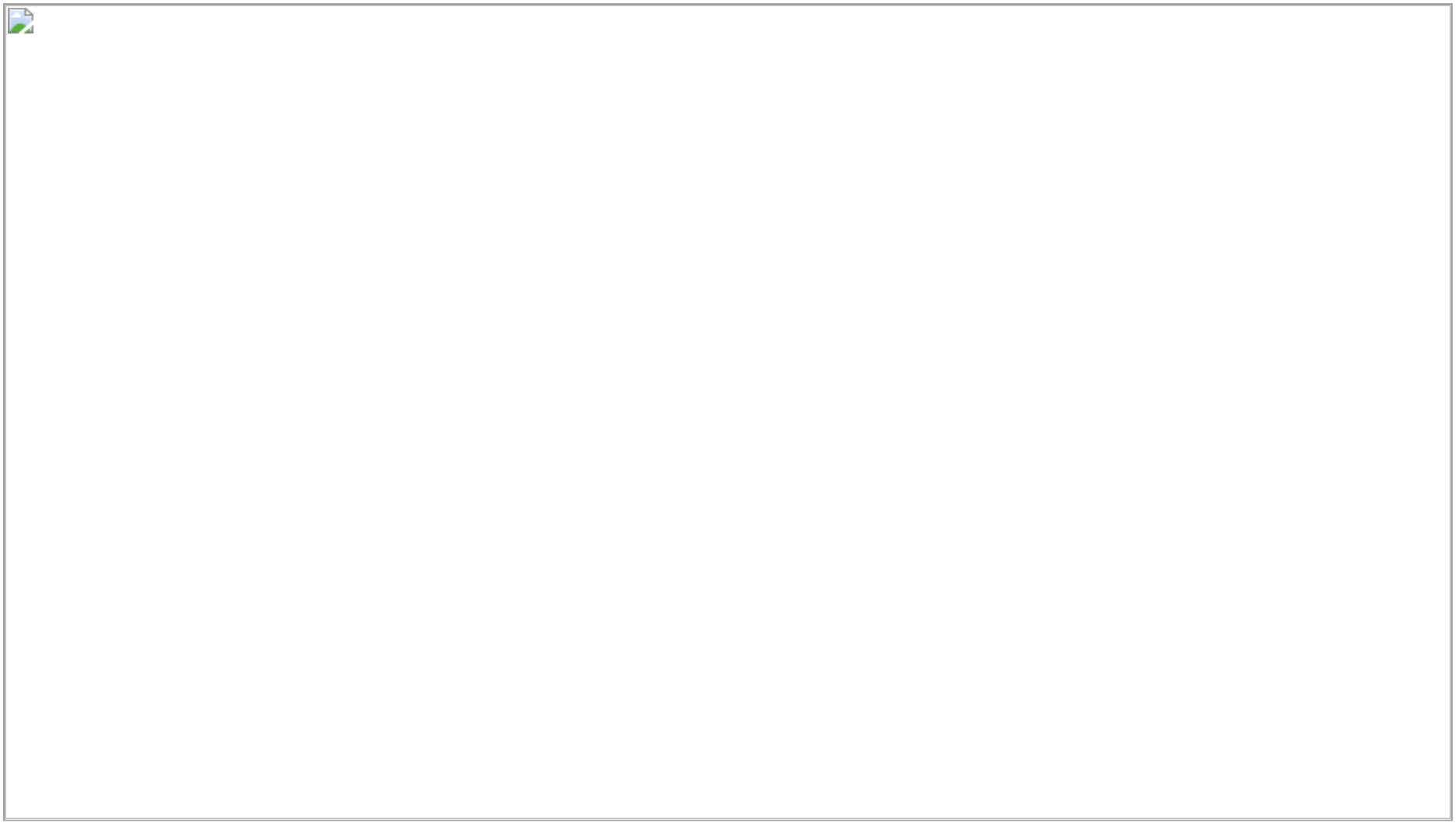
1 叠加定理（对整个电路）

2 戴维南定理和诺顿定理（对一端口网络）

3 替代定理(课后推送学习)

本讲重难点

- 世界观（理念）
  - 分而治之的世界观（叠加）
  - 等效的世界观（戴维南）
- 戴维南定理（实操）
  - 开路电压求法
  - 入端电阻求法
  - 什么时候用
- 替代定理（课后自学）
  - 何时替代
  - 替代为何



1 叠加定理 (*Superposition Theorem*)

叠加定理：

在线性电路中，任一支路电流(或电压)都是电路中各个独立电源单独作用时，在该支路产生的电流(或电压)的代数和。

单独作用：一个电源作用，其余电源不作用。

单选题 1分

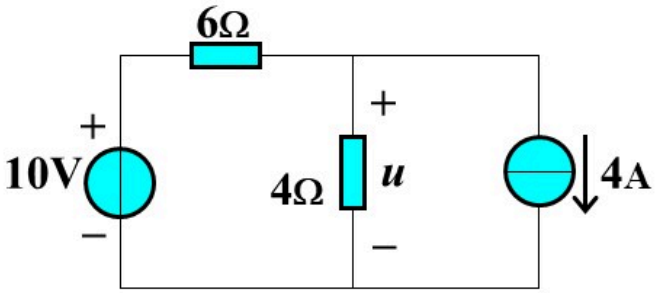
在应用叠加定理过程中，
不作用的电流源应该理解为：

A 短路

B 开路

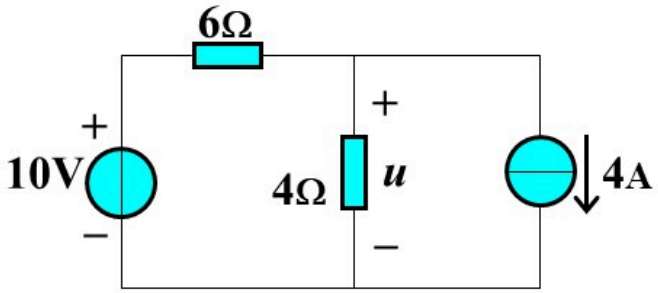
C 保留

例1. 用叠加定理求图中电压u。

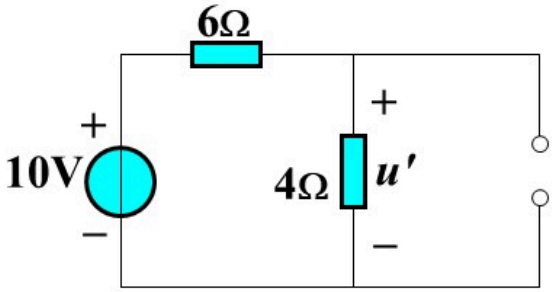


解： (1) 10V电压源单独作用

例1. 用叠加定理求图中电压u。



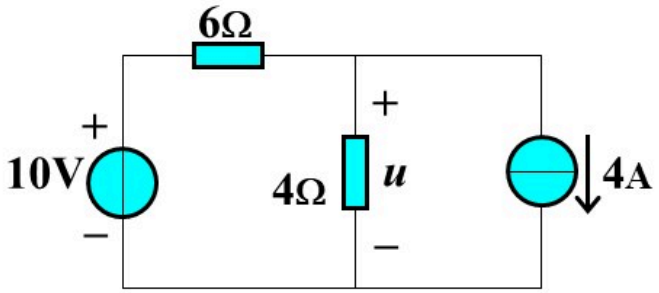
解：(1) 10V电压源单独作用，4A电流源开路



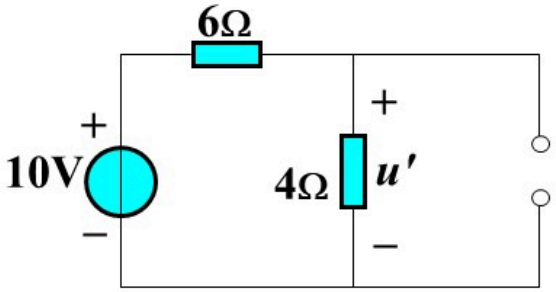
$u'=4V$

(2) 4A电流源单独作用，10V电压源短路

例1. 用叠加定理求图中电压u。

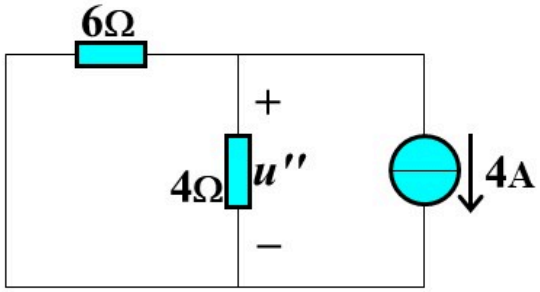


解：(1) 10V电压源单独作用，4A电流源开路

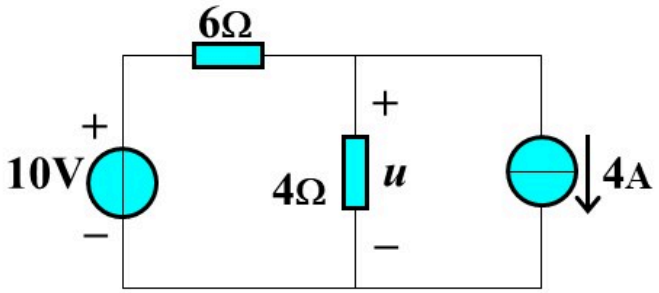


$u'=4V$

(2) 4A电流源单独作用，10V电压源短路

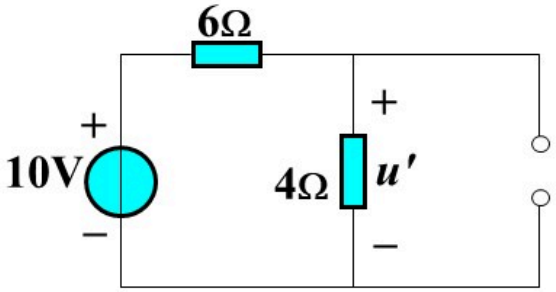


例1. 用叠加定理求图中电压u。



解：(1) 10V电压源单独作用，

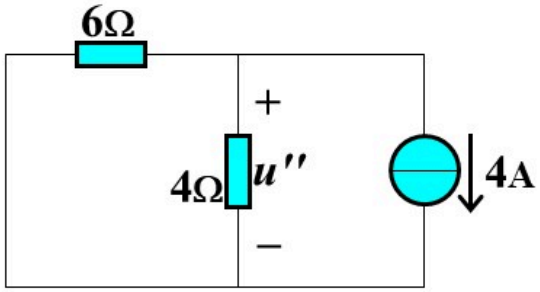
4A电流源开路



$u'=4\text{V}$

(2) 4A电流源单独作用，

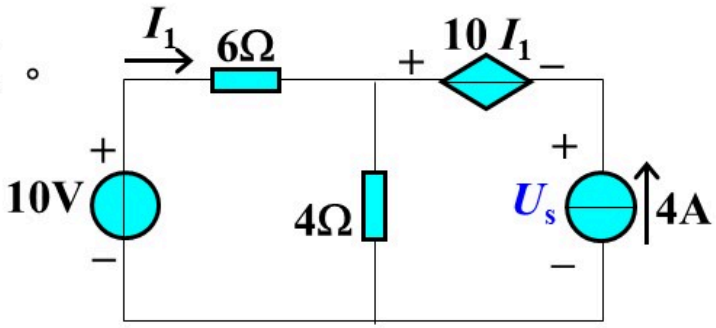
10V电压源短路



$u''=4\times(-2.4)=-9.6\text{V}$

共同作用：$u=u'+u''=4+(-9.6)=-5.6\text{V}$

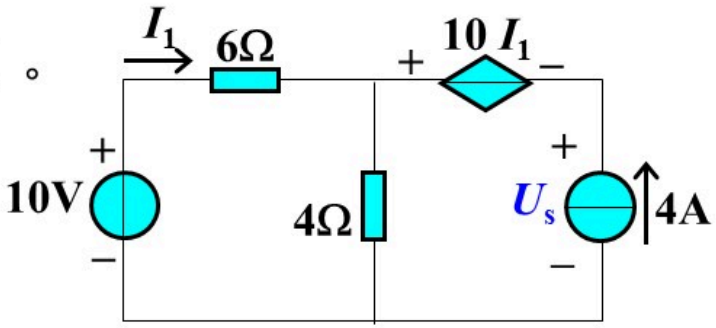
例2　用叠加定理求电压U_s。



可以将CCVS看作独立源进行叠加吗?

此处可以有弹幕
(简要说明理由)

例2　用叠加定理求电压U_s。



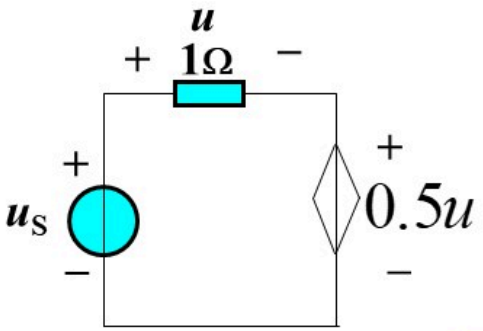
可以将CCVS看作独立源进行叠加吗?

不行

受控源不是能量和信号的“源”

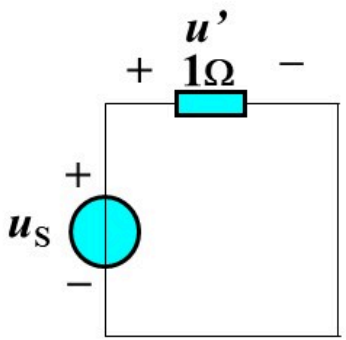
支路量无法表示为受控源的参数和独立源参数的线性组合(本周作业)

如果一意孤行用受控源叠加求：u

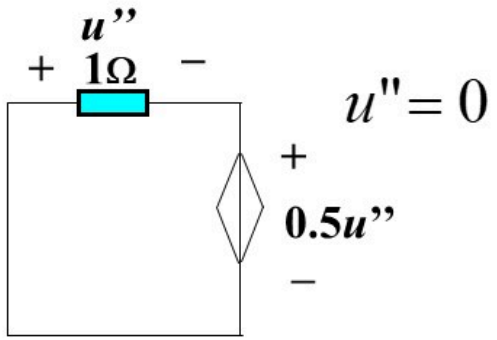


$$u + 0.5u = u_S \Rightarrow u = 0.667u_S$$

受控源不参与叠加



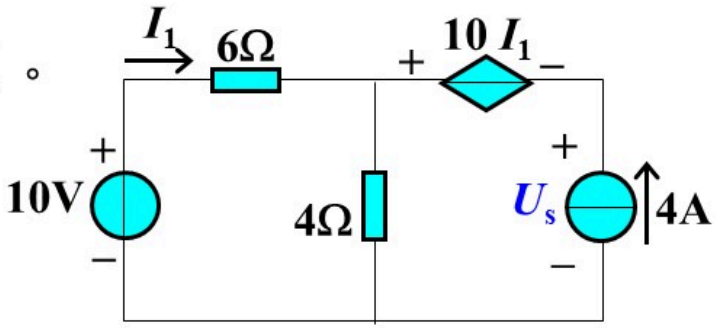
$$u' = u_S$$



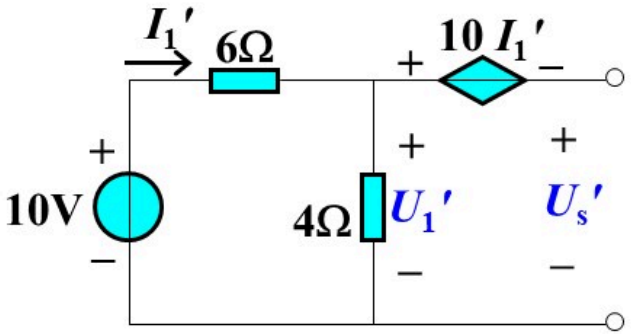
$$u'' = 0$$

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

例2　用叠加定理求电压U_s。

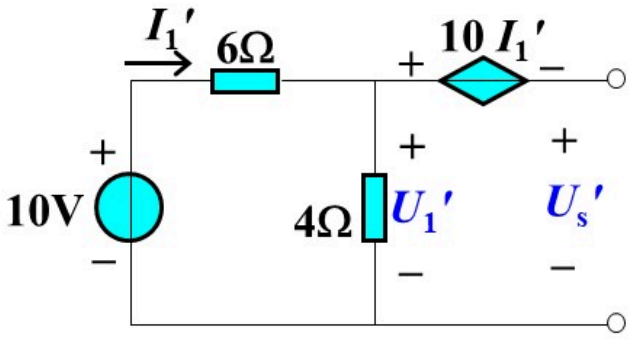


解：　(1) 10V电压源单独作用：



单选题 1分

U_S'=___V



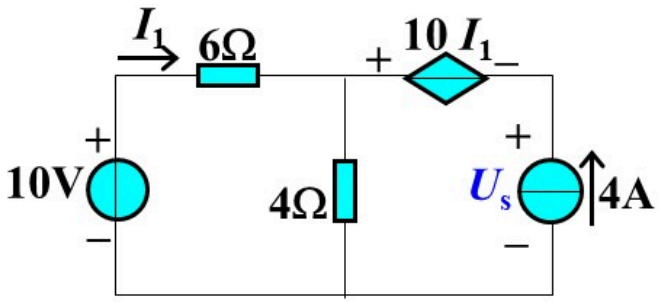
A 4

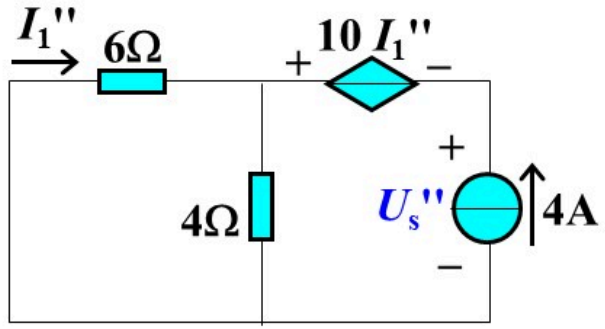
B −4

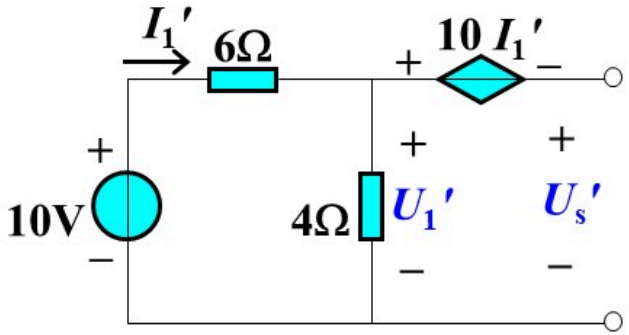
14

−6

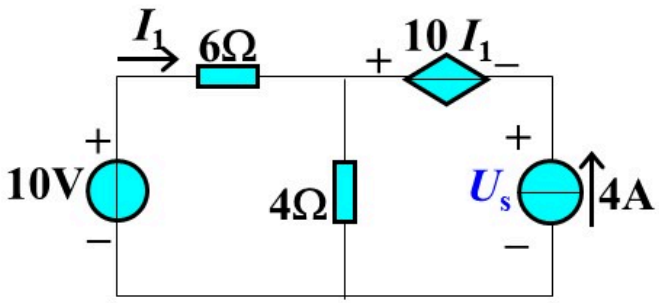
17

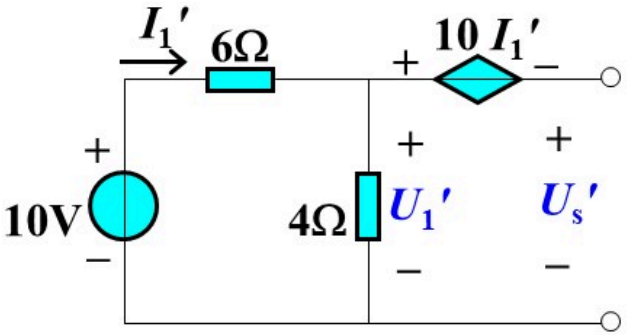




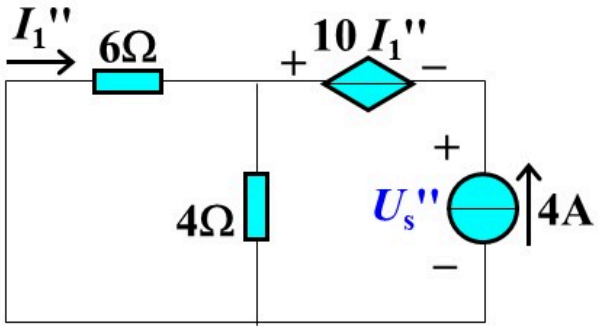


$U_s' = -6\text{V}$





$U_s' = -6\text{V}$



$$U_s'' = -10I_1'' - 6I_1''$$

$$I_1'' = -\frac{4}{4+6} \times 4 = -1.6\text{A}$$

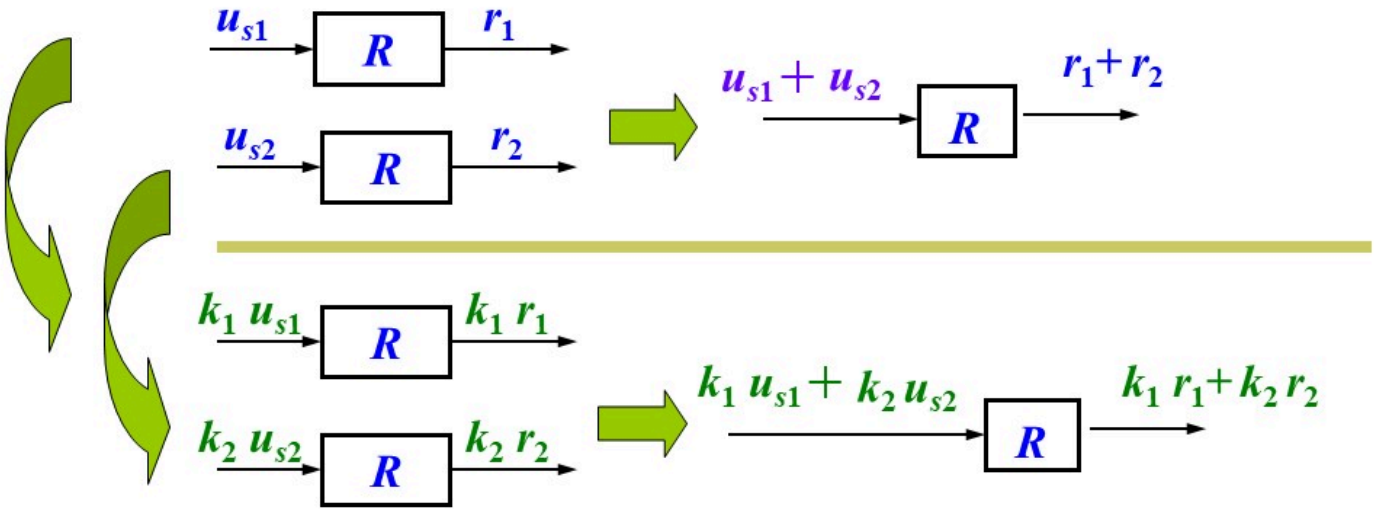
$$U_s'' = -10I_1'' - 6I_1'' = 25.6\text{V}$$

共同作用： $U_s = U_s' + U_s'' = -6 + 25.6 = 19.6\text{V}$

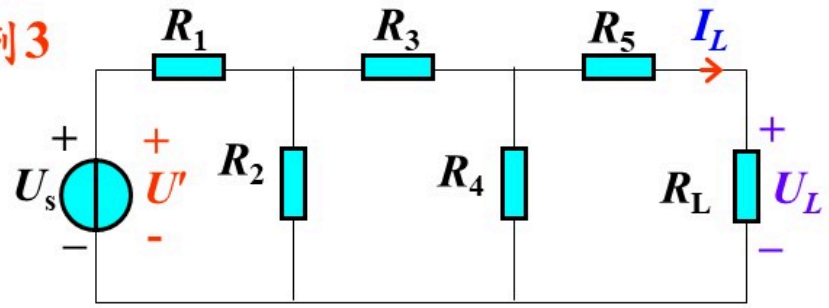
齐性原理（*homogeneity property*）

当线性电路中只有一个激励(独立源)时，则响应(电压或电流)与激励成正比。

可加性 (additivity property)



例3



已知：如图

求：电流 I_L

解

法一：分压、分流

法二：电源变换

法三：节点/回路

法四：齐性原理（单位电流法）

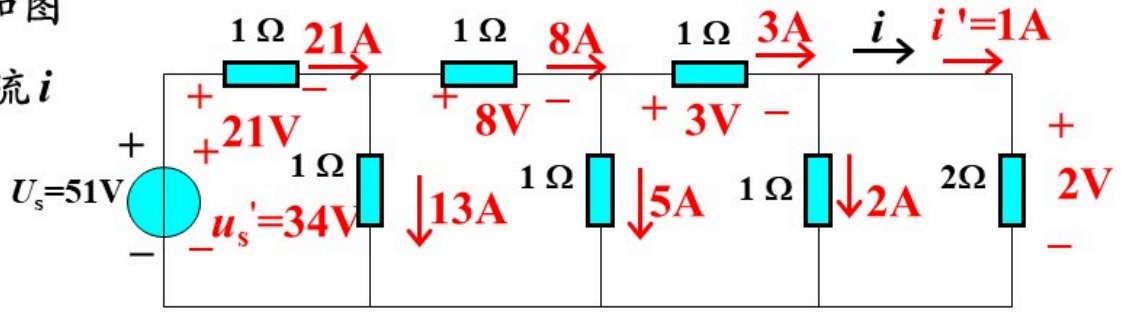
设 $I'_L = 1\text{A}$ ⟹ U'

U_S ⟹ I_L

$$\frac{I_L}{1\text{A}} = \frac{U_s}{U'}$$

已知：如图

求：电流 i



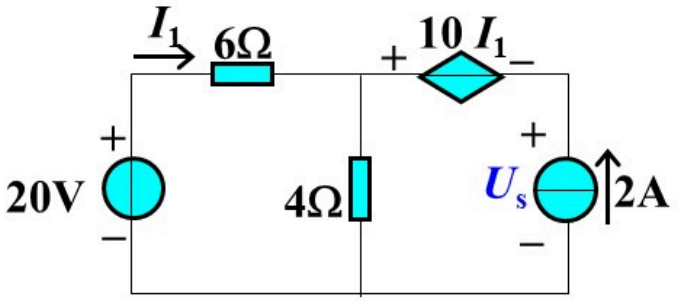
设 $i'=1\text{A}$

$$\frac{i}{i'}=\frac{u_s}{u_s'}$$

$$i=\frac{u_s}{u_s'}i'=\frac{51}{34}\times 1=1.5\text{A}$$

单选题 1分

U_S=___V

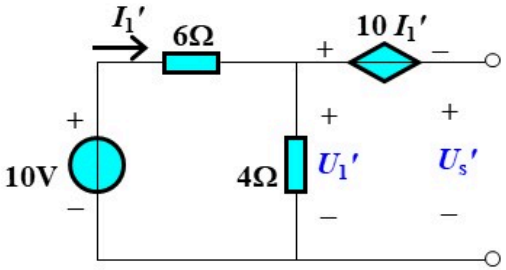


A -12

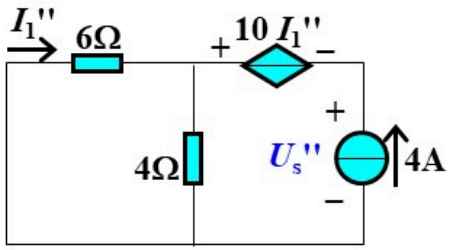
B 39.2

C 9.8

D 0.8



U_s'= −6V

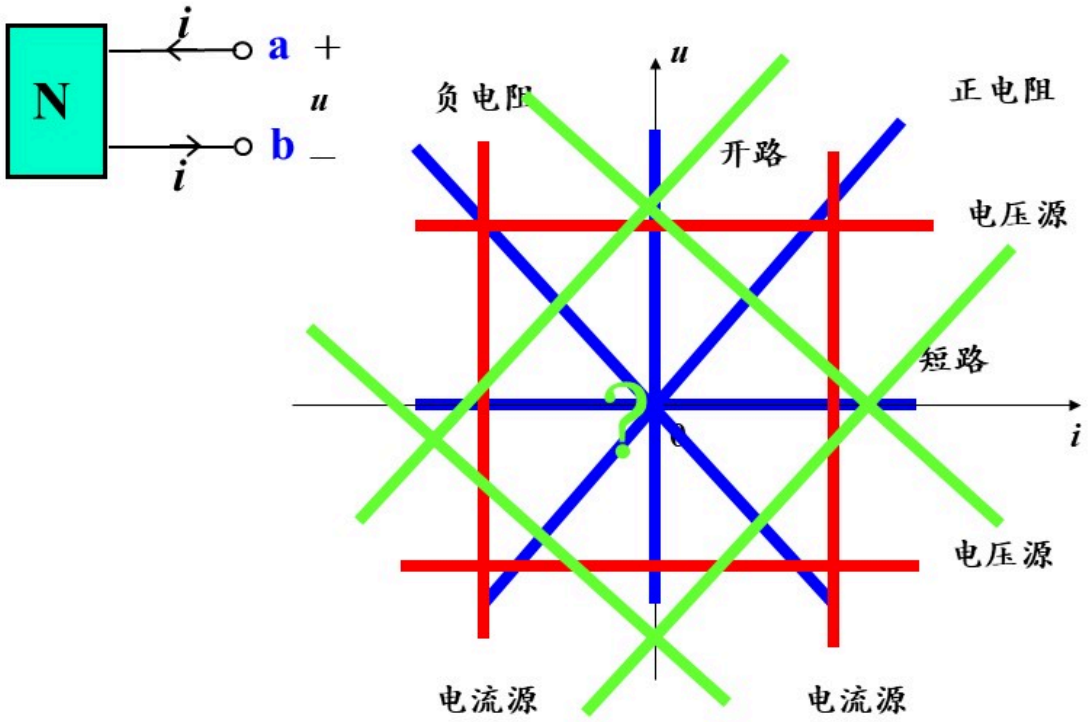


U_s''= 25.6V

24

讨论

u-i平面的任一直线应该对应怎样的等效电路?（投稿）



2 戴维南定理和诺顿定理 (*Thevenin-Norton Theorem*)

戴维南定理

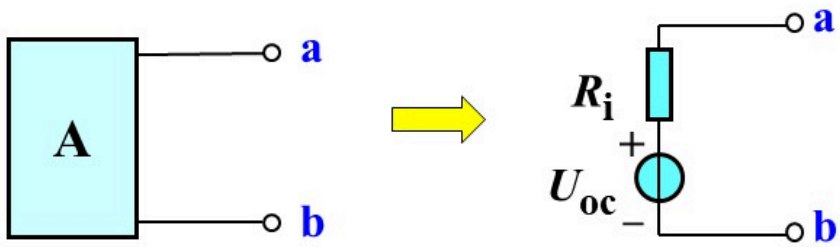
赫姆霍茨(Helmholtz)，1853，德国科学家
戴维南(Thevenin)，1883，法国工程师

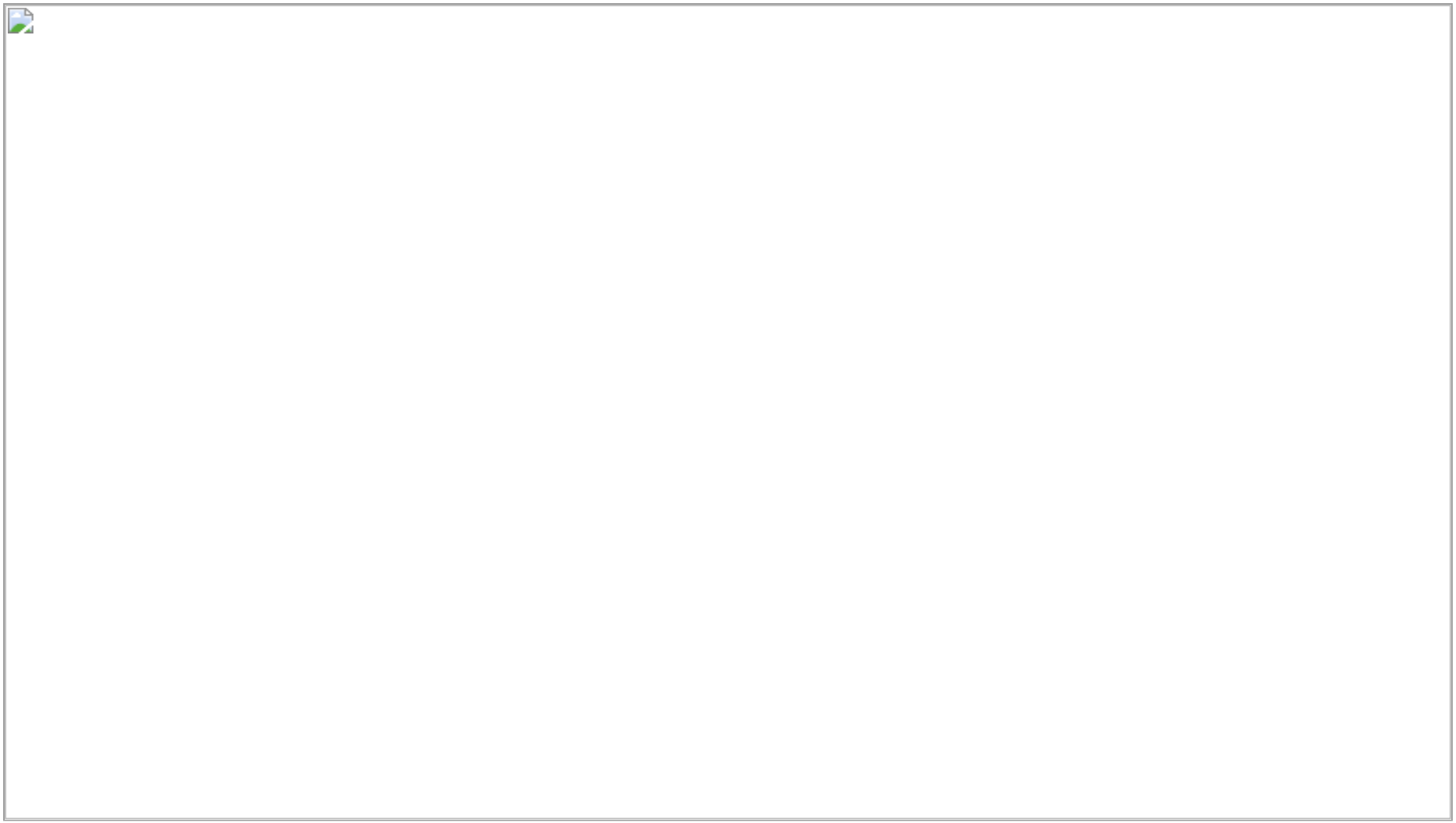
物理领域里的
希尔伯特

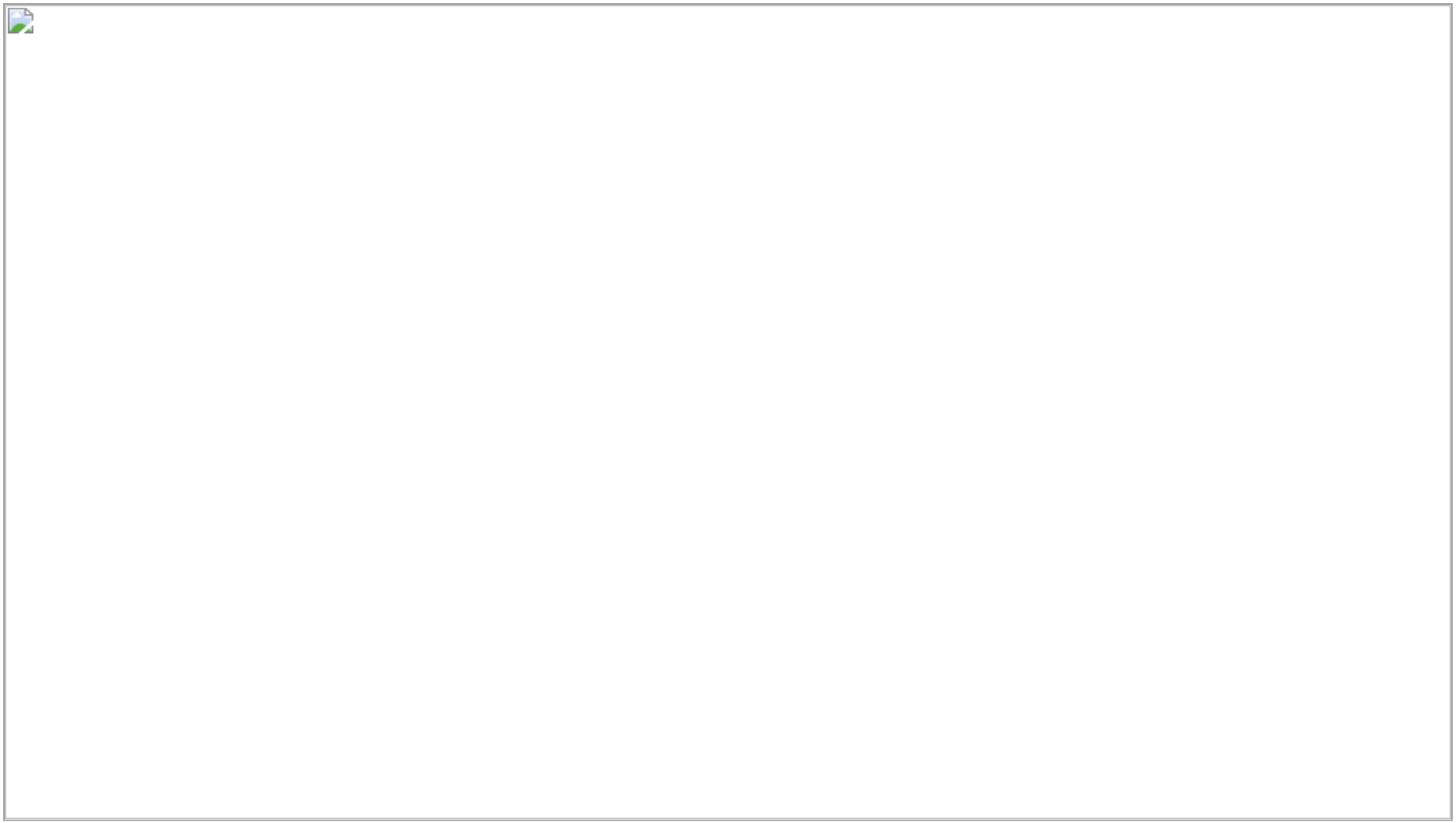
任何一个含有独立电源、线性电阻和线性受控源的一端口网络，

可以用一个独立电压源U_{oc}和电阻R_i的串联组合来等效替代，

其中电压U_{oc}等于端口开路电压，
电阻R_i等于端口中所有独立电源置零后端口的入端等效电阻。







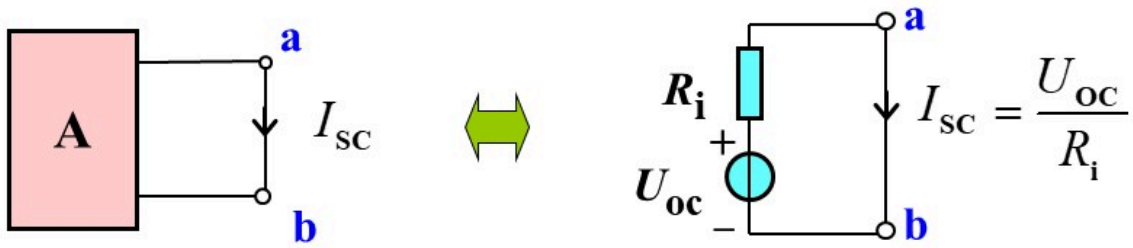
求入端等效电阻的方法:

② ③ 可用于含受控源的线性电路.

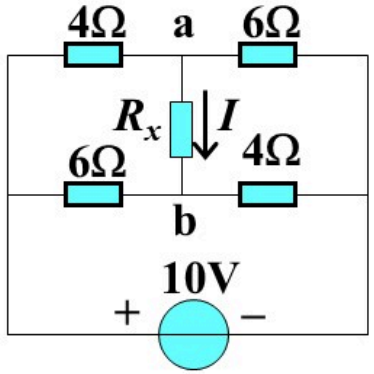
① 无受控源时电阻等效变换(独立源置零)

② 加压求流或加流求压(独立源置零)

③ 开路电压/短路电流(内含独立源) $R_i = \dfrac{U_{OC}}{I_{SC}}$



例1.

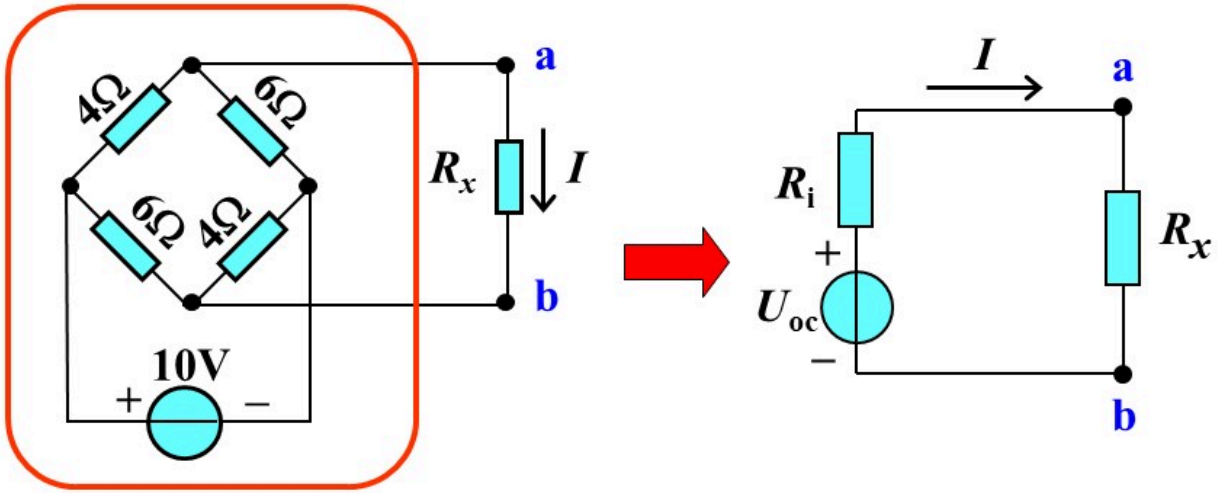


当 R_x=1.2Ω 或 5.2Ω 时计算 I;

Y-Δ变换/节点法/回路法?

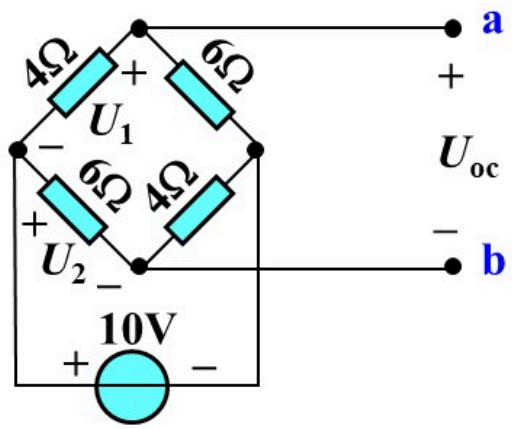
解：

求从 R_x 看进去的戴维南等效电路:



单选题 1分

U_{oc}=_____V



A 10

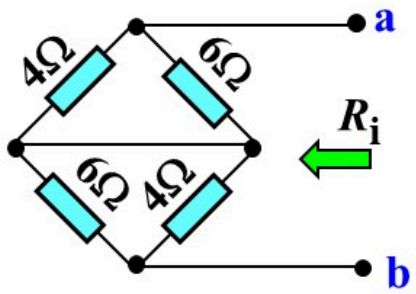
B −10

C −2

D 2

单选题 1分

R_i=_____Ω



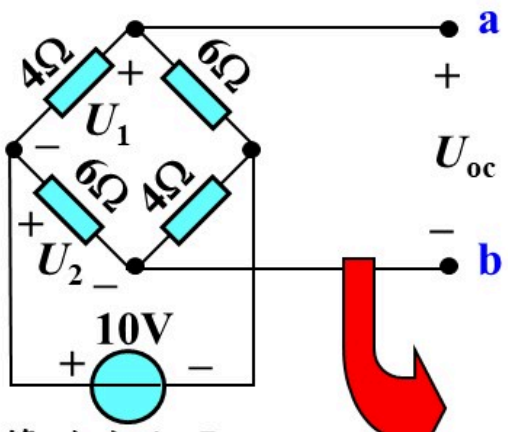
A 4.8

B 10

C 2.4

D 5

(1) 开路电压

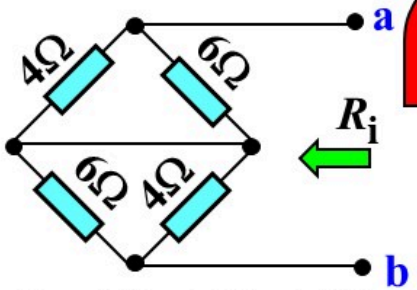


$U_{oc} = U_1 + U_2$

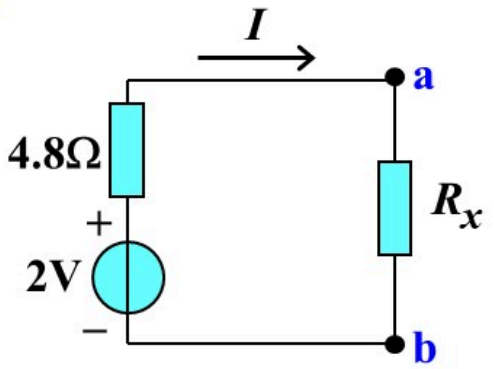
$= -10\times4/(4+6)+10\times6/(4+6)$

$= -4+6=2V$

(2) 等效电阻 R_i



$R_i=4//6+6//4=4.8\Omega$



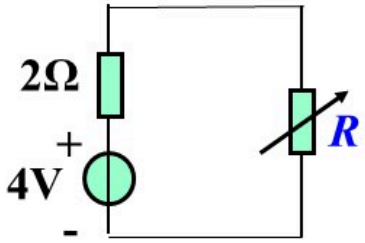
(3) R_x =1.2Ω 时，I= U_{oc} /(R_i + R_x) =0.33A

R_x =5.2Ω 时，I= U_{oc} /(R_i + R_x) =0.2A

总结戴维南定理适用的题型

单选题 1分

可变电阻R为___Ω时，其上获得最大功率___W。



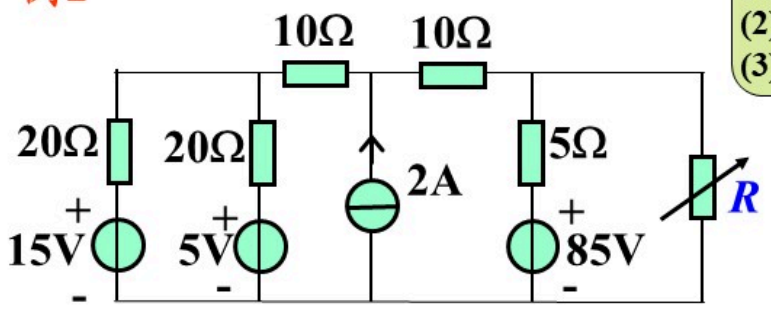
A 2，8

B 2，2

C 0，∞

D ∞，∞

例2



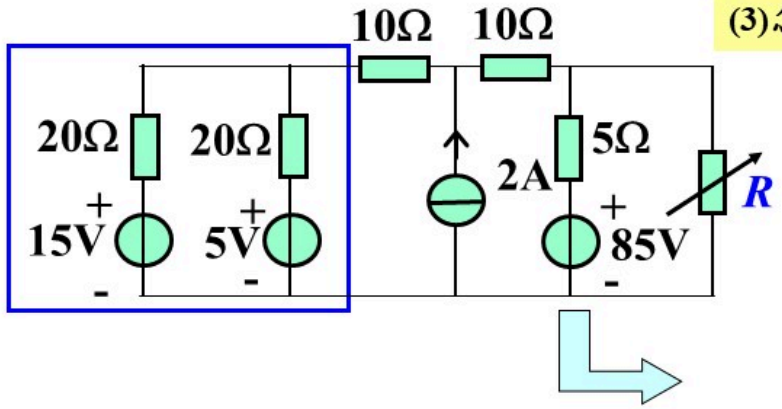
3种方法：
(1)写P与R的函数关系，求导。
(2)电源等效变换。
(3)戴维南定理。

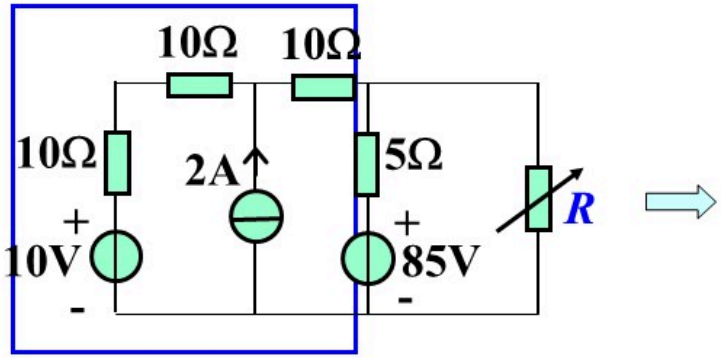
R多大时能从电路中获得最大功率，并求此最大功率。

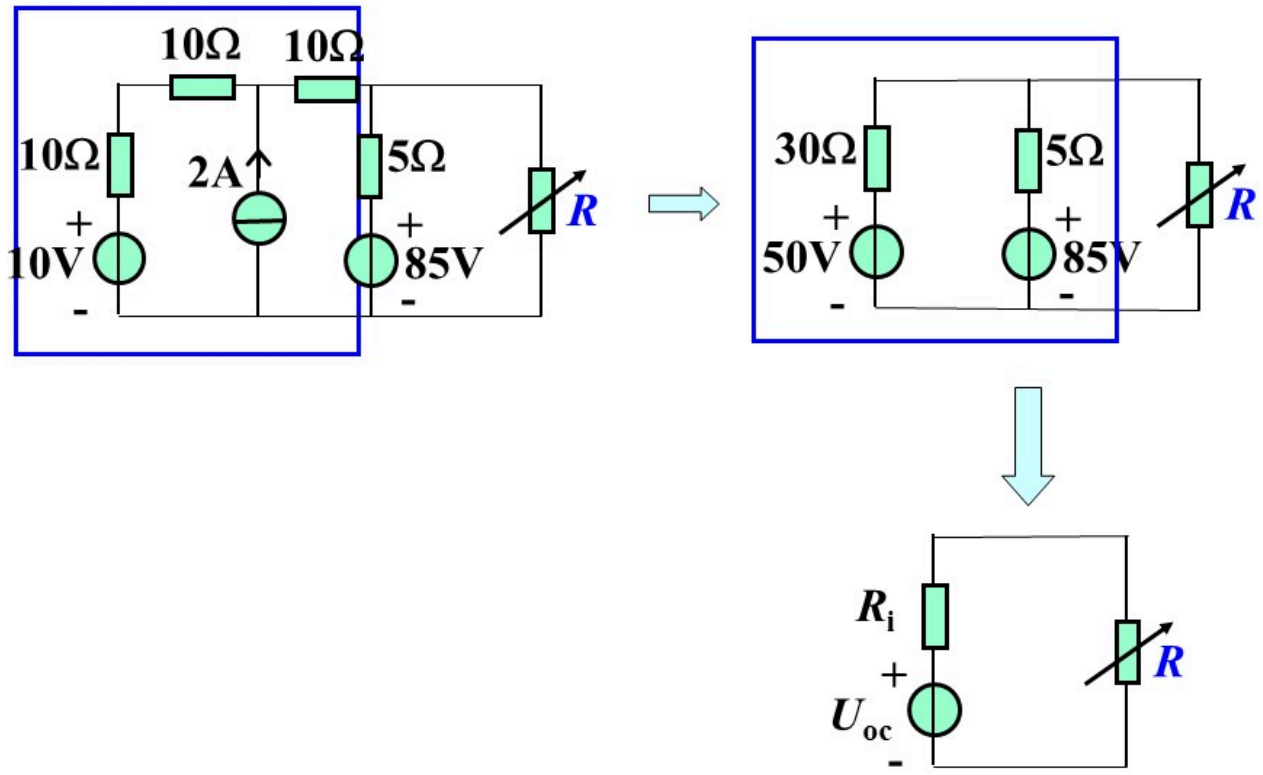
解：

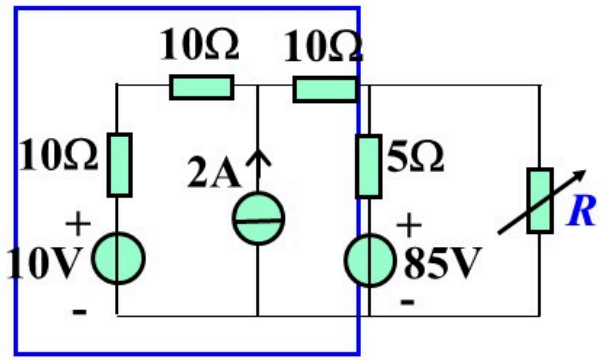
与戴维南定理相关的几个问题

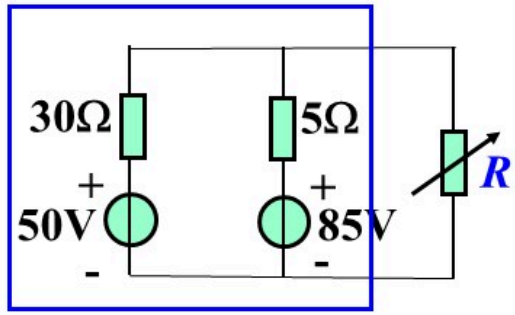
(1)何时用
(2)从哪看
(3)怎么求









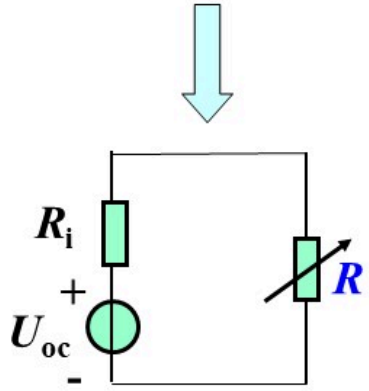


$$U_{oc} = \frac{5}{35} \times 50 + \frac{30}{35} \times 85 = 80\text{V}$$

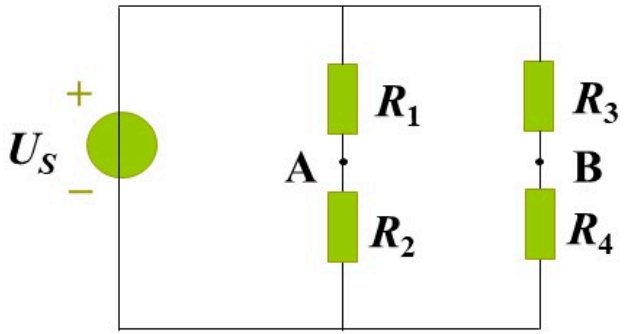
$$R_i = \frac{30 \times 5}{35} = 4.29\,\Omega$$

R =4.29Ω获最大功率。

$$P_{max} = \frac{80^2}{4 \times 4.29} = 373\,\text{W}$$



戴维南定理的应用1：平衡电桥



$$U_{\mathrm{A}} = \frac{R_2}{R_1 + R_2} U_s \qquad U_{\mathrm{B}} = \frac{R_4}{R_3 + R_4} U_s$$

如果

$$R_1 R_4 = R_2 R_3$$

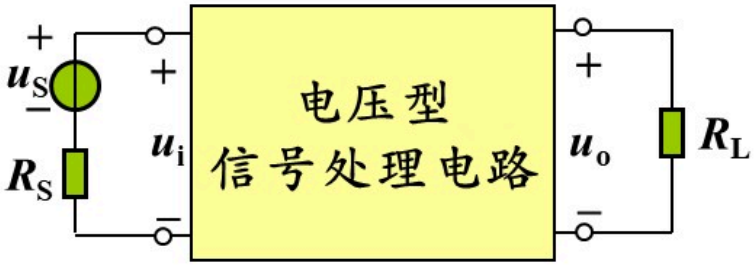
A-B等电位点 ⇒ 电桥平衡

此处可以有弹幕

等电位点间接任意电阻(含开短路)不影响电路的电压电流分布。为什么？

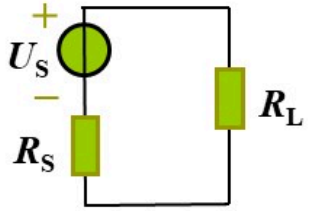
戴维南定理的应用2:

电压型信号处理电路3个最重要的性质



R_L和R_S不满足

得有处理电路



从信号传输的角度:
R_L大好，R_S小好

电压放大倍数 $A_u = \dfrac{u_o}{u_i}$ 两边的性能

输入电阻R_i 从u_i两端向输出端方向看，那个一端口网络的等效电阻(接或不接负载)(输入端往右看的性能)

R_i越大越好，获取电压信号的能力强

输出电阻R_o 从u_o两端向输入端方向看，那个一端口网络的戴维南电阻(输出端往左看的性能)

R_o越小越好，提供电压信号的能力强(带载能力)

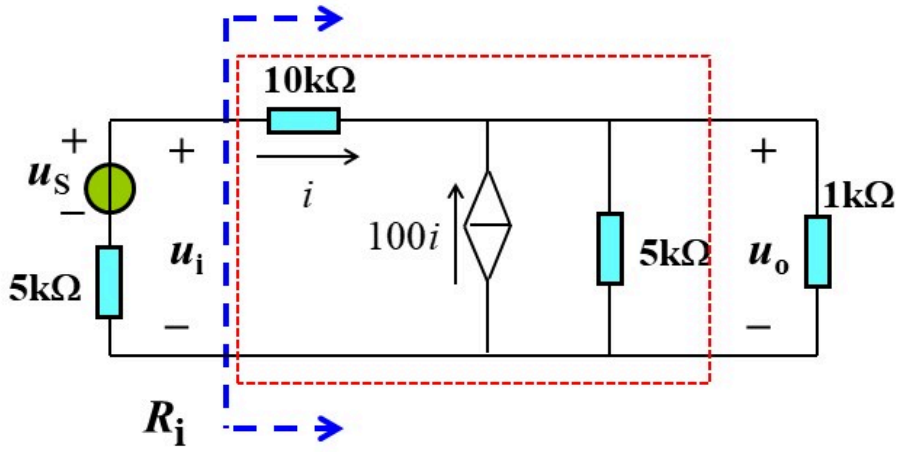
信号源戴维南电路　　负载

只有1/6的电压信号能够传递到负载侧

例3.

双极型晶体管共集放大器
小信号等效电路

求图示放大器的输入电阻和输出电阻



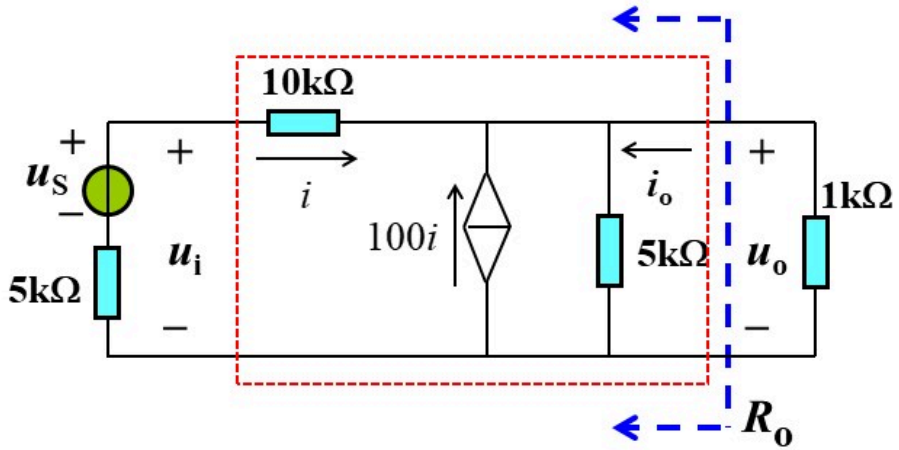
$$10\mathrm{k}i+\left(5\mathrm{k}//1\mathrm{k}\right)\left(100+1\right)i=u_i \quad \Rightarrow \quad R_i=\frac{u_i}{i}=94.2\,\mathrm{k\Omega}$$

获取电压信号的能力强

例3.

双极型晶体管共集放大器
小信号等效电路

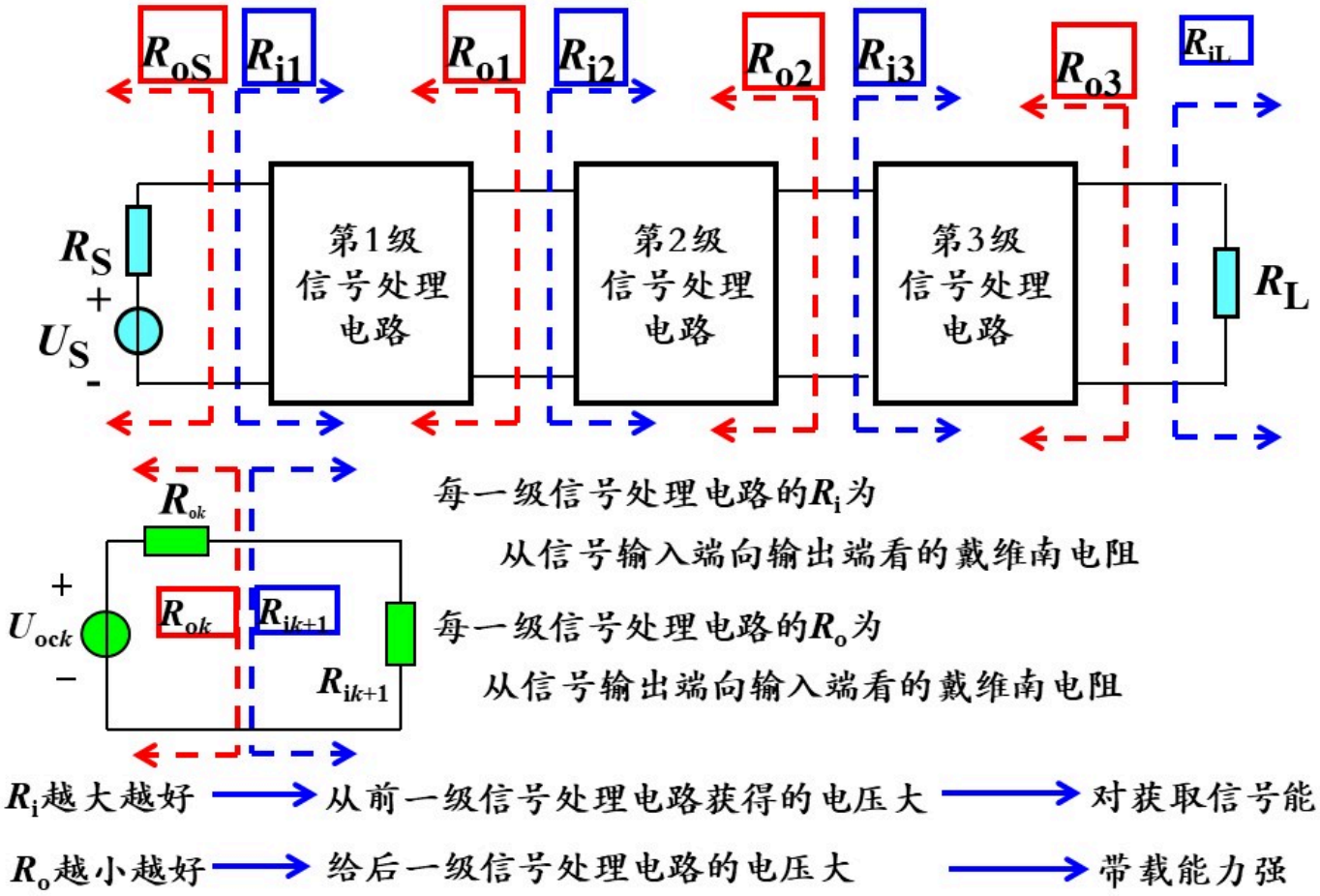
求图示放大器的输入电阻和输出电阻

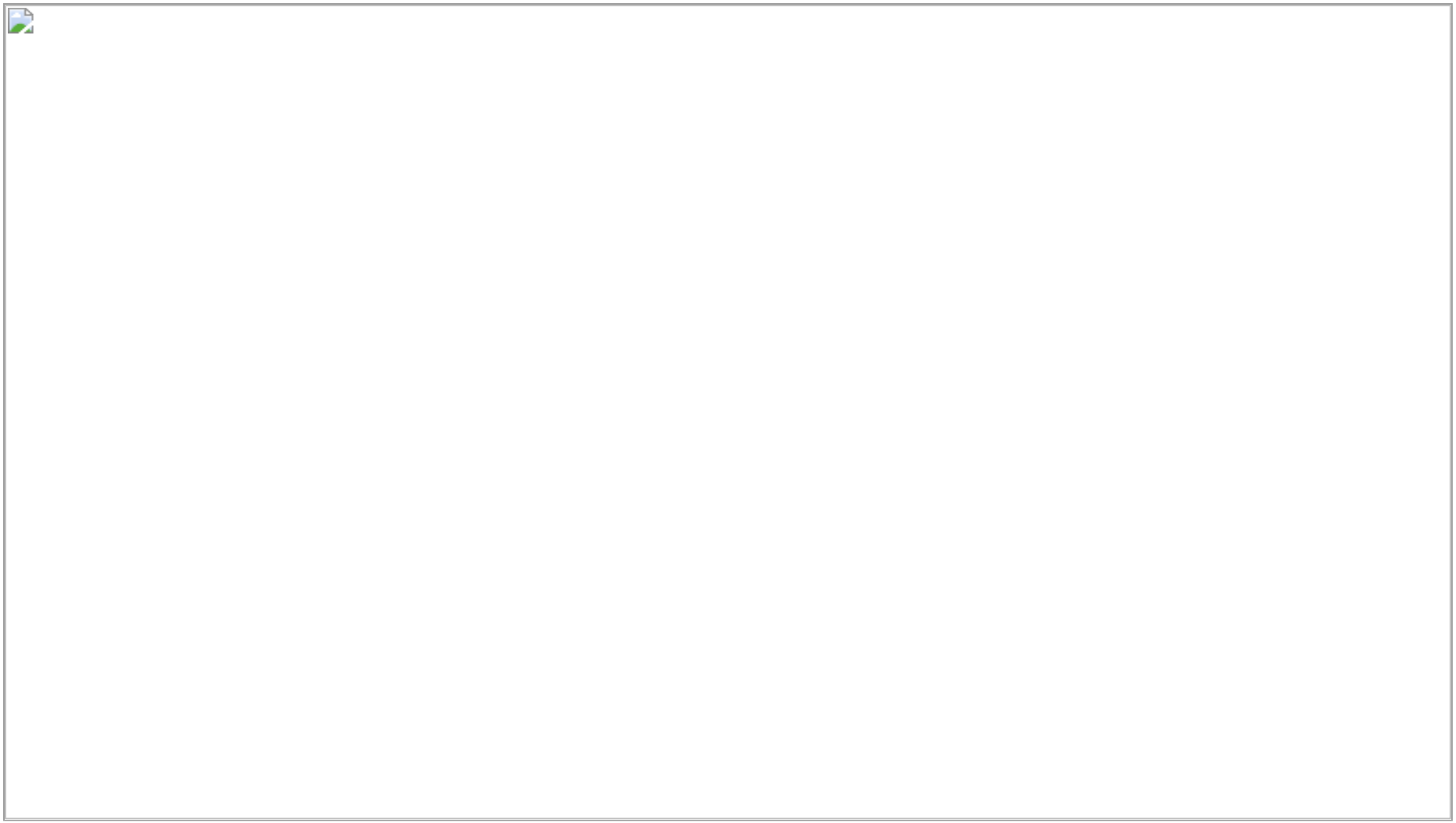


$$\begin{cases} u_o = (i_o + 101i) * 5\text{k} \\ -15\text{k} * i = (i_o + 101i) * 5\text{k} \end{cases} \Rightarrow R_o = \frac{u_o}{i_o} = 144\Omega$$

带载能力强

No free lunch





戴维南定理的细节魔鬼

思考题：每一个含独立源的线性一端口网络对外都能等效为戴维南和诺顿电路吗？