电工技术与电子技术

第3章 电路的暂态分析

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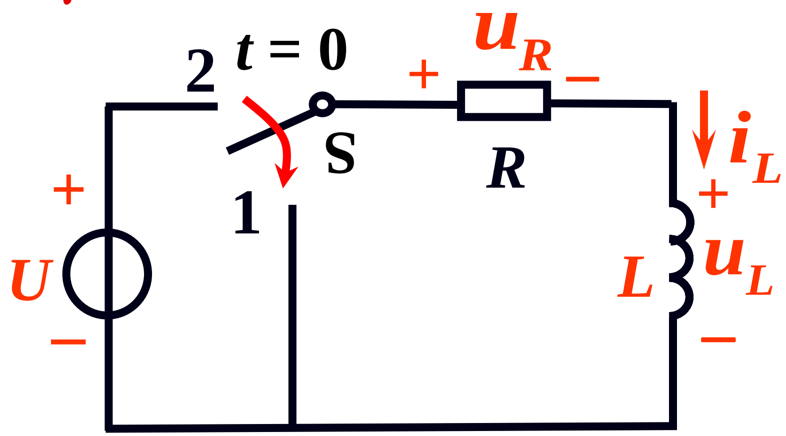
主要内容：

*RL*电路暂态过程中电压、电流的变化规律；时间常数的概念。

重点难点：

利用三要素法求解*RL*电路的暂态过程的方法。

RL 电路的暂态分析



1. *RL* 电路的零输入响应

RL 短接

(1) i_L 的变化规律

$$i_L = i_L(\infty) + [i_L(0_+) - i_L(\infty)]\,\mathrm{e}^{-t/\tau}$$

① 确定初始值 $i_L(0_+)$ $\quad i_L(0_+) = i_L(0_-) = \dfrac{U}{R}$

② 确定稳态值 $i_L(\infty)$ $\quad i_L(\infty) = 0$

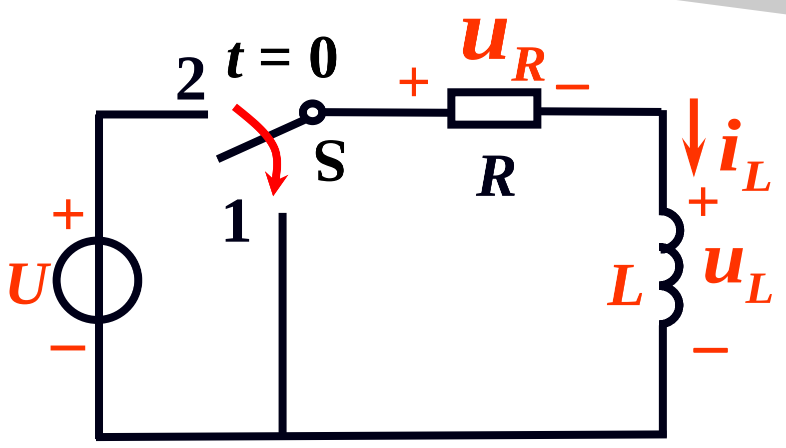
③ 确定电路的时间常数 τ $\quad \tau = \dfrac{L}{R}$

$$\therefore\ i_L = 0 + \left(\frac{U}{R} - 0\right)\mathrm{e}^{-\frac{R}{L}t} = \frac{U}{R}\mathrm{e}^{-\frac{R}{L}t}$$

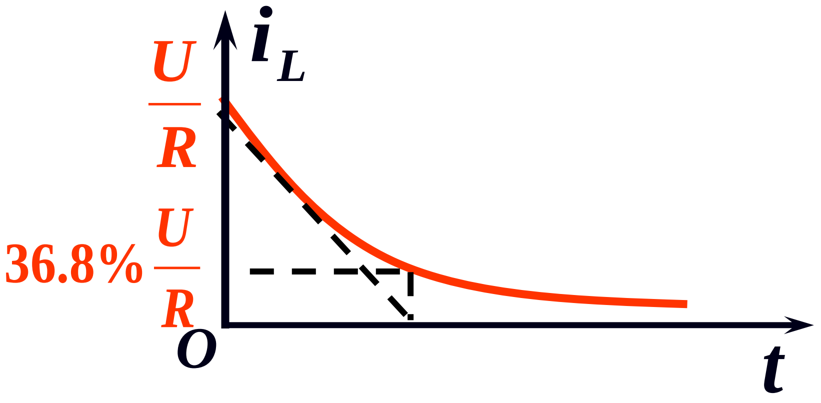
$$i_L = \frac{U}{R} e^{-\frac{R}{L}t}$$

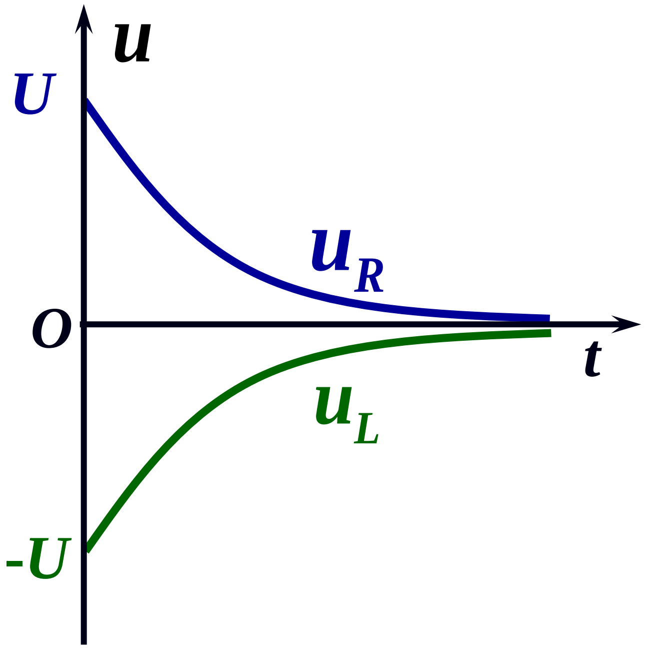
$$u_L = L\frac{\mathrm{d}i}{\mathrm{d}t} = -U e^{-\frac{R}{L}t}$$

$$u_R = i_L R = U e^{-\frac{R}{L}t}$$



(2) 变化曲线

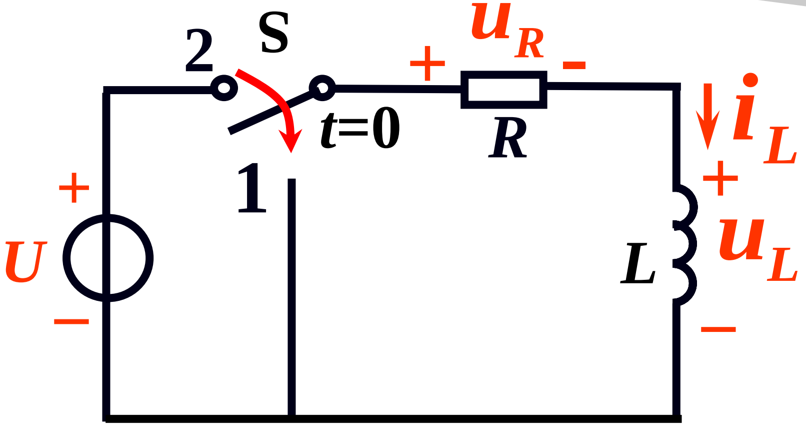




RL直接从直流电源断开

(1) 可能产生的现象

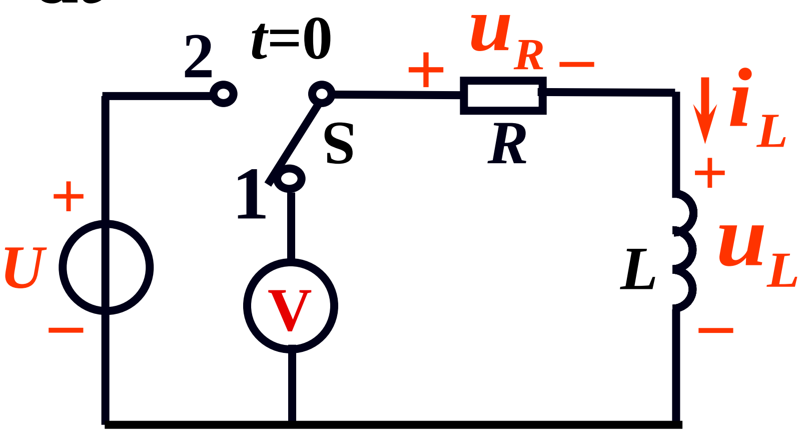
① 刀闸处产生电弧



$$\because \quad i_L(0_-)=\frac{U}{R}$$

$$i_L(0_+)=0 \qquad \therefore \quad u_L=-e_L=L\frac{\mathrm{d}i}{\mathrm{d}t}\rightarrow\infty$$

② 电压表瞬间过电压

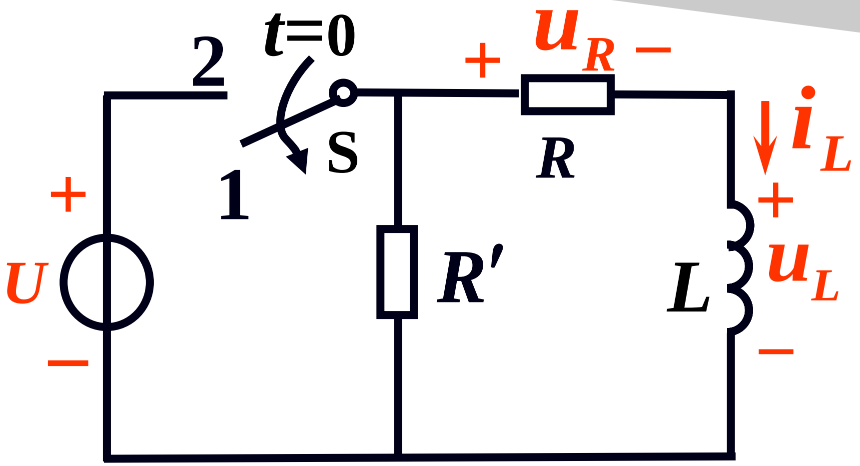


$$\because \quad i_L(0_+)=i_L(0_-)=\frac{U}{R}$$

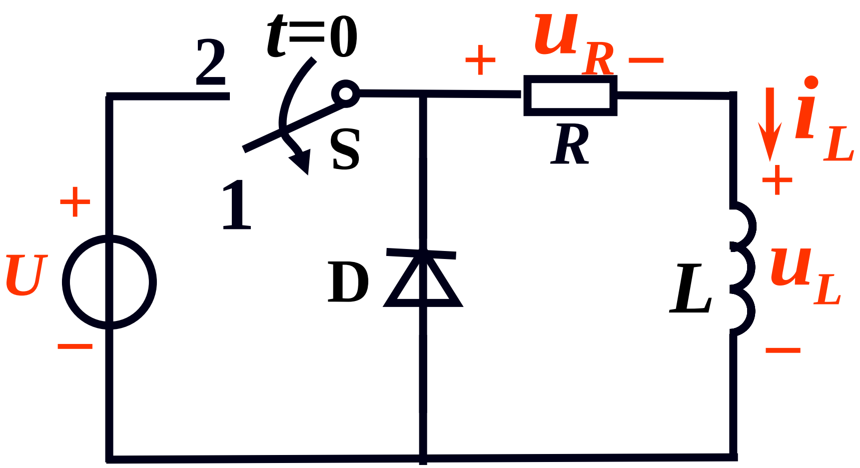
$$V_{表}(0_+)=i_L(0_+)\times R_{表}=\frac{U}{R}\times R_{表}$$

(2) 解决措施

① 接放电电阻 R'



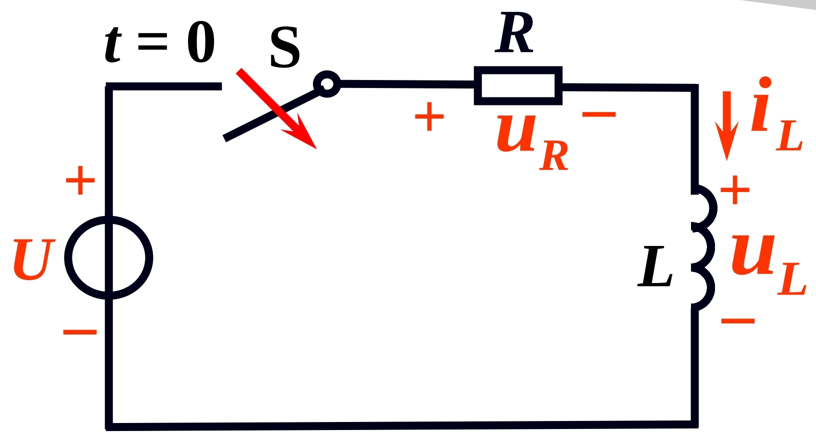
② 接续流二极管D



对此也要一份为二，有时也可利用。

例如在汽车点火上，利用拉开开关时电感线圈产生的高电压击穿火花间隙，产生电火花而将汽缸点燃。

2. RL电路的零状态响应



$(U = 0 \quad i_L(0_-) = 0)$

(1) i_L变化规律

三要素法

$$i_L = i_L(\infty) + [i_L(0_+) - i_L(\infty)]e^{-\frac{t}{\tau}}$$

$$i_L(0_+) = i_L(0_-) = 0 \qquad i_L(\infty) = \frac{U}{R} \qquad \tau = \frac{L}{R}$$

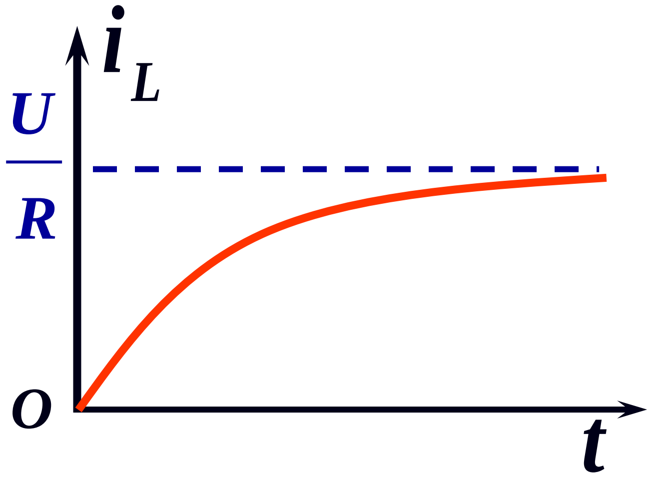
$$i_L = \frac{U}{R} + (0 - \frac{U}{R})e^{-\frac{R}{L}t} = \frac{U}{R}(1 - e^{-\frac{R}{L}t})$$

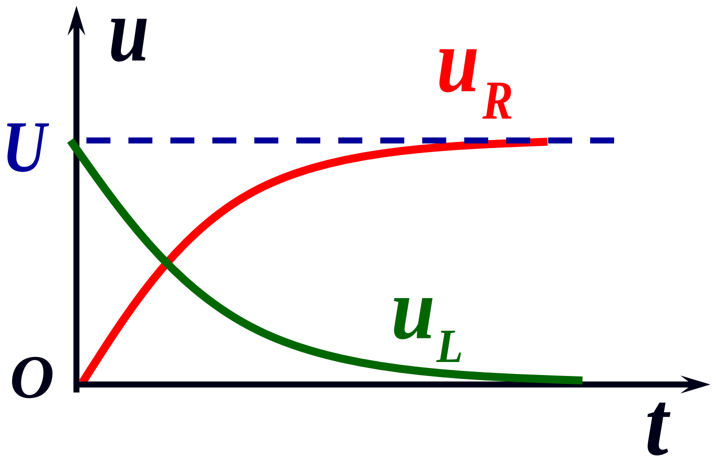
$$i_L = \frac{U}{R}(1 - e^{-\frac{R}{L}t})$$

$$u_L = L\frac{di}{dt} = Ue^{-\frac{t}{\tau}} = Ue^{-\frac{R}{L}t}$$

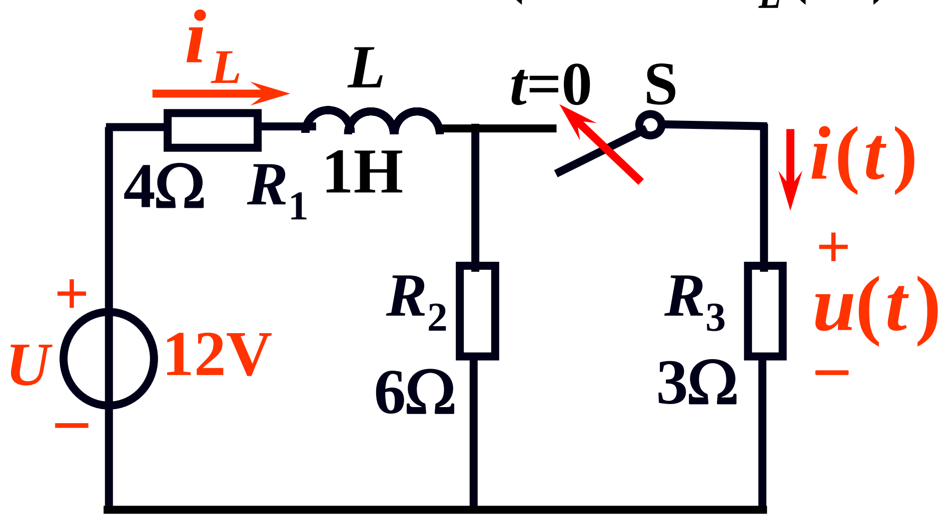
$$u_R = i_L R = U(1 - e^{-\frac{R}{L}t})$$

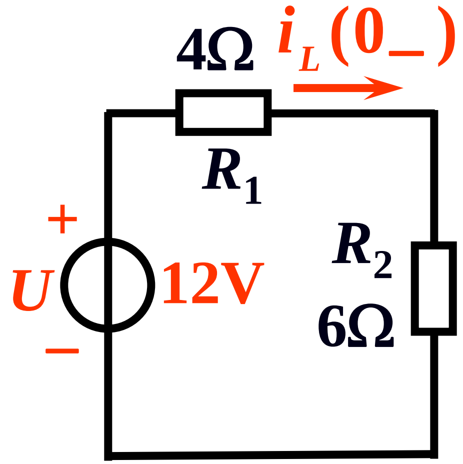
(2) i_L、u_L、u_R 变化曲线





3. RL电路的全响应 $(U \neq 0 \quad i_L(0_-) \neq 0)$





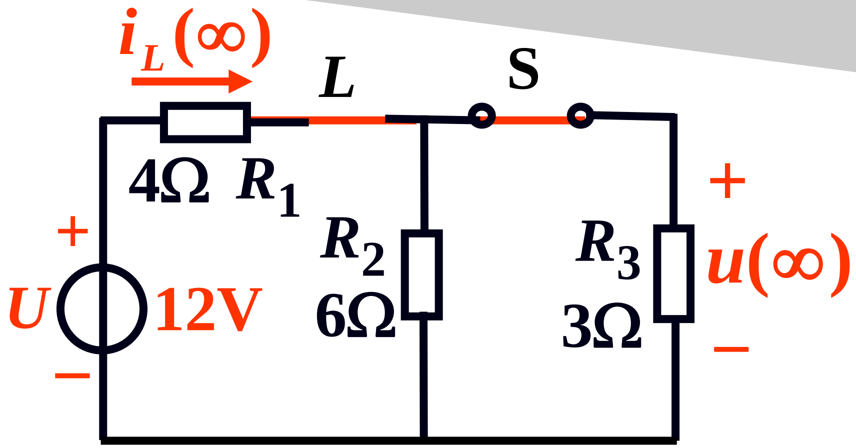
$t = 0_-$时等效电路

(1) i_L变化规律　(三要素法)

$$i_L = i_L(\infty) + [i_L(0_+) - i_L(\infty)]\mathrm{e}^{-\frac{t}{\tau}}$$

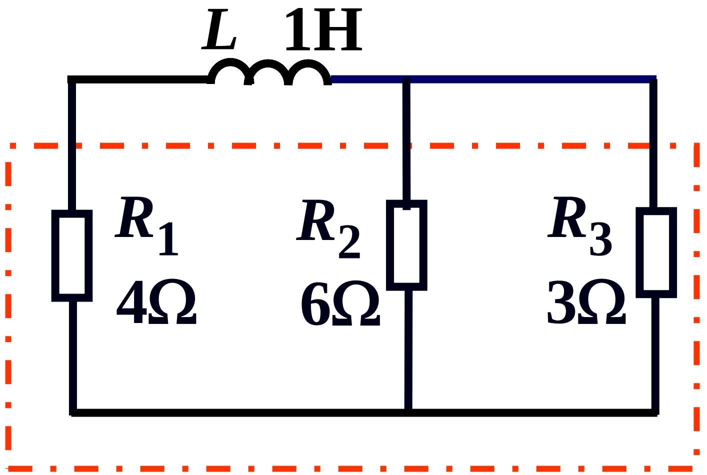
$$i_L(0_+) = i_L(0_-) = \frac{U}{R_1 + R_2} = \frac{12}{4+6} = 1.2\ \mathrm{A}$$

$$i_L(\infty) = \frac{U}{R_1 + \dfrac{R_2 \times R_3}{R_2 + R_3}} = 2\ \text{A}$$



$t = \infty$时等效电路

$$\tau = \frac{L}{R_0} = \frac{L}{R_1 + \dfrac{R_2 \times R_3}{R_2 + R_3}} = \frac{1}{6}\ \text{s}$$



$$\therefore\quad i_L = 2 + (1.2 - 2)e^{-6t} = 2 - 0.8e^{-6t}\ \text{A}\ \ (t \geq 0)$$

(2) $u(t)$变化规律

$$u = iR_3 = \frac{R_2}{R_2+R_3} \times i_L \times R_3$$

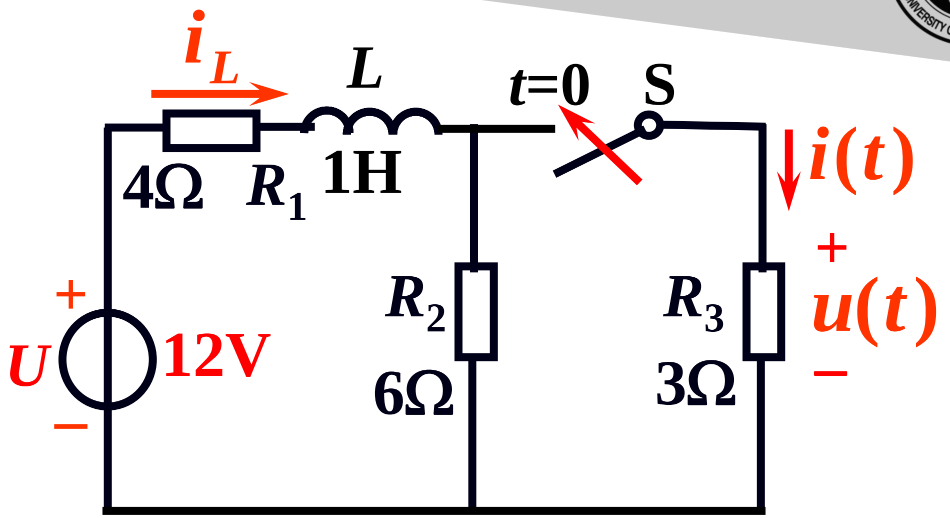
$$u = \frac{6\times 3}{6+3}(2-0.8\mathrm{e}^{-6t}) = 4-1.6\mathrm{e}^{-6t}\ \mathrm{V}$$

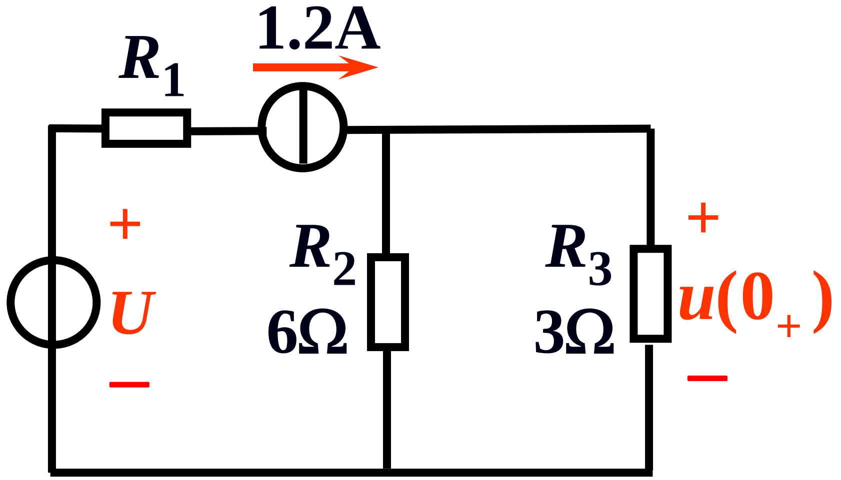
用三要素法求 u

$$u = u(\infty)+[u(0_+)-u(\infty)]\mathrm{e}^{-\frac{t}{\tau}}$$

$$u(0_+) = \frac{6}{6+3}\times 1.2\times R_3$$

$$= \frac{2}{3}\times 1.2\times 3 = 2.4\ \mathrm{V}$$





t=0$_+$等效电路

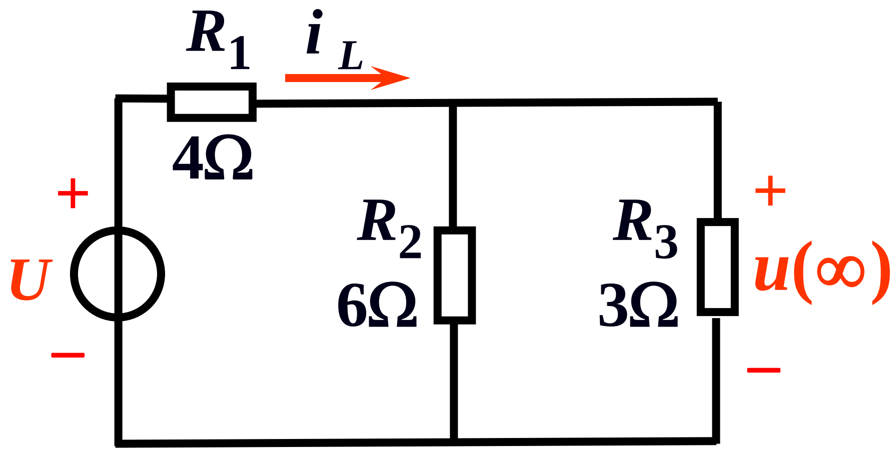
$$u(\infty)=\frac{R_2}{R_2+R_3}i_L(\infty)\times R_3$$

$$=\frac{6}{9}\times 2\times 3=4\ \mathrm{V}$$

$$\tau=\frac{L}{R_0}=\frac{1}{6}\ \mathrm{s}$$

$$u=4+(2.4-4)\mathrm{e}^{-6t}$$

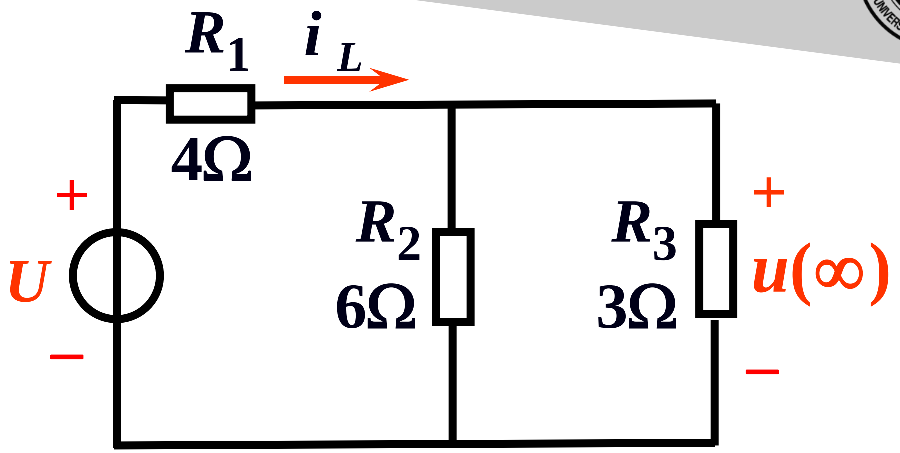
$$=4-1.6\mathrm{e}^{-6t}\ \mathrm{V}\ (t\geq 0)$$



$t=\infty$时等效电路

$$i_L(0_+) = 1.2\ \text{A} \qquad u(0_+) = 2.4\text{V}$$

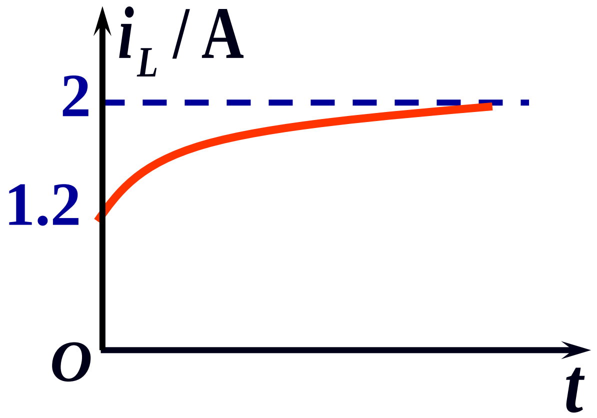
$$i_L(\infty) = 2\ \text{A} \qquad u(\infty) = 4\text{V}$$



$t = \infty$时等效电路

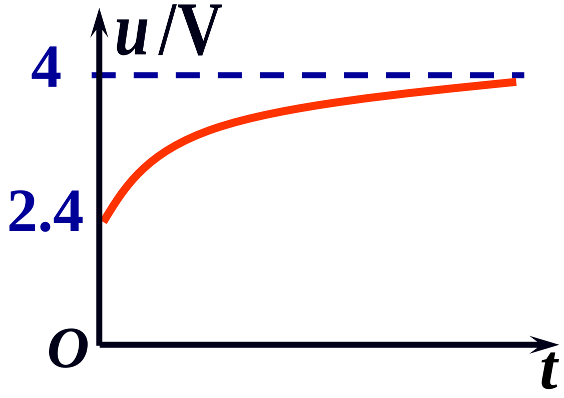
i_L 变化曲线

$$i_L = 2 - 0.8\text{e}^{-6t}\ \text{A}$$



u 变化曲线

$$u = 4 - 1.6\text{e}^{-6t}\ \text{V}$$



小　结

1. RL暂态电路中零输入、零状态以及全响应的变化规律
2. RL暂态电路的求解方法
3. RL暂态电路中时间常数的概念

$$\tau = \frac{L}{R}$$

4. 全响应过程中各电压、电流的变化曲线