3

3.1

3.2

3.3

3.4

3.5

3

1.
2.
3.
4.

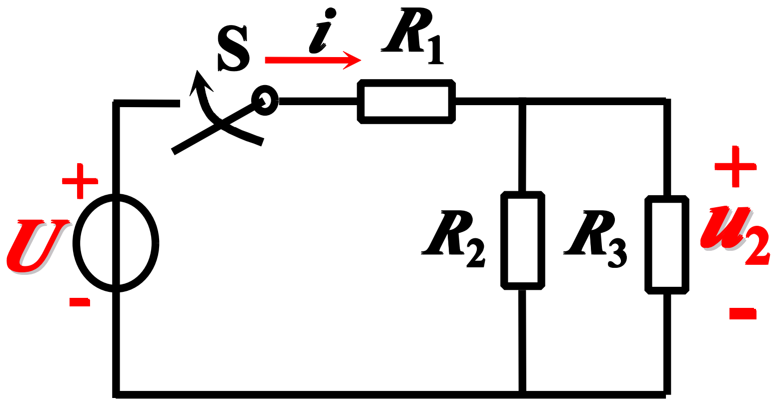
3

1.

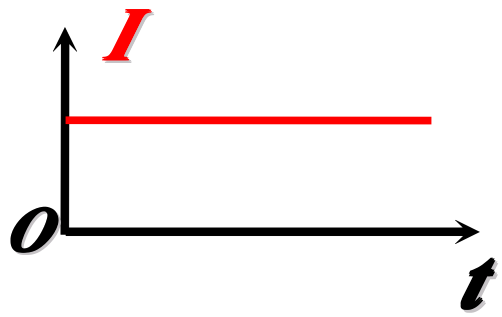
2.

3.1

3.1.1



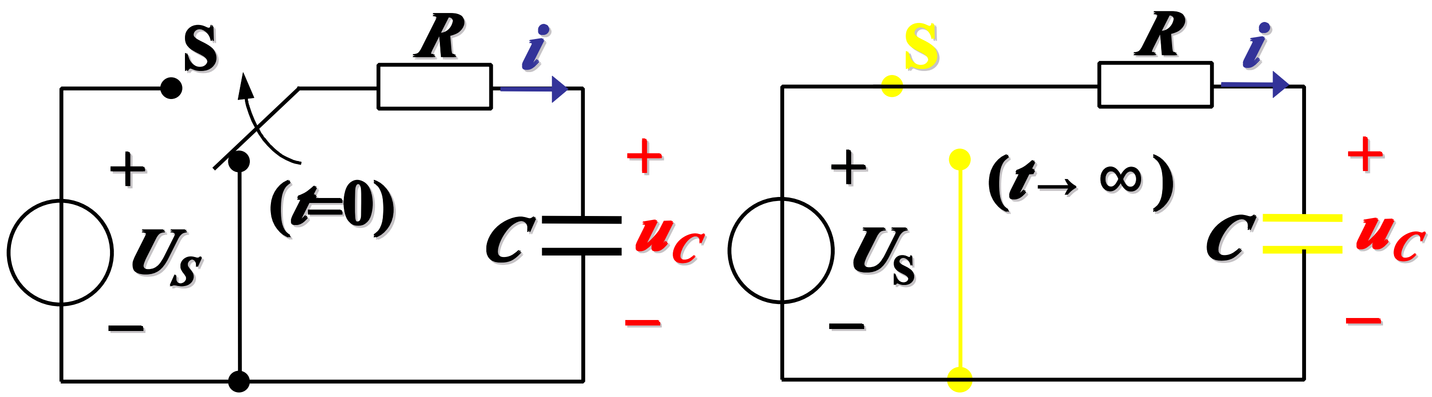
(a)



(a) S $i=0$ $u_{R1}=u_{R2}=u_{R3}=0$

S i u

(R)

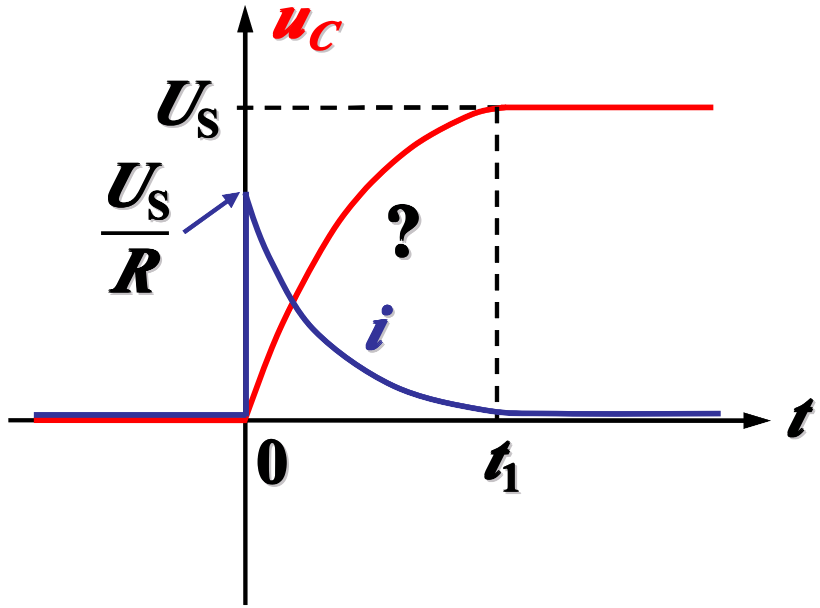


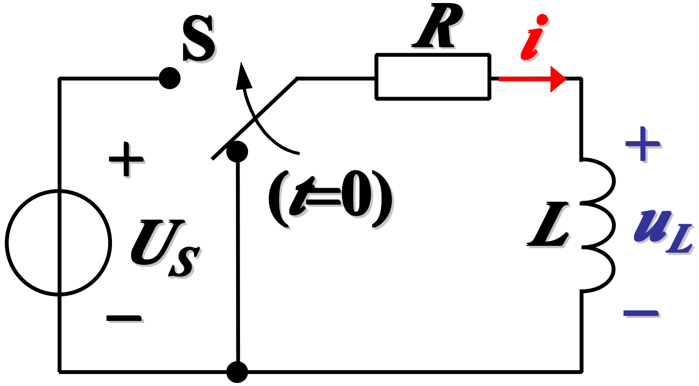
S

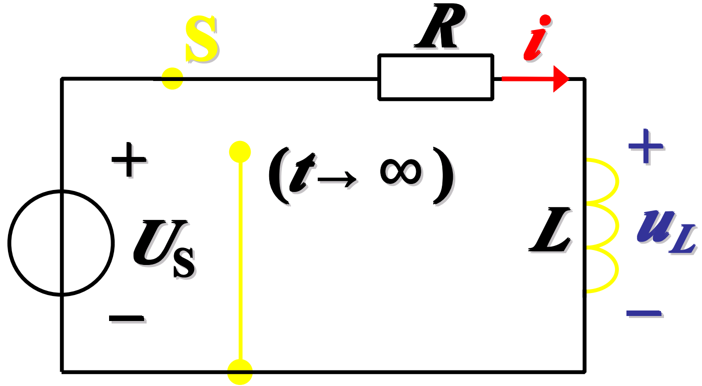
$i=0\ ,\ u_C=0$

S

$i=0\ ,\ u_C=U_S$



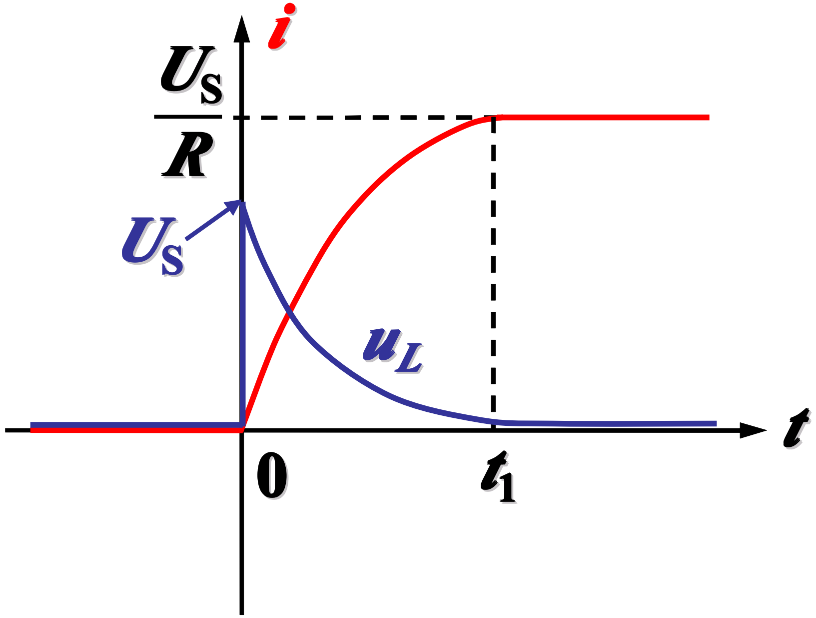




S

$$i=0\ ,\ u_L=0$$

S



$$u_L=0\ ,\ i=\frac{U_S}{R}$$

:

C $$W_C = \frac{1}{2} C u_C^2$$ $\therefore\ u_C$

L $$W_L = \frac{1}{2} L i_L^2$$ $\therefore\ i_L$

3.1.2

t=0 — (　　)

t=0₋ —

t=0₊ —

t=∞ —

$$i_L(0_+) = i_L(0_-)$$

$$u_C(0_+) = u_C(0_-)$$

u_C 　 i_L

3.1.3

u i $t=0_+$

(1) $u_C(0_+)$ $i_L(0_+)$

1) $t=0_-$ $u_C(0_-)$ $i_L(0_-)$

2) $u_C(0_+)$ $i_L(0_+)$

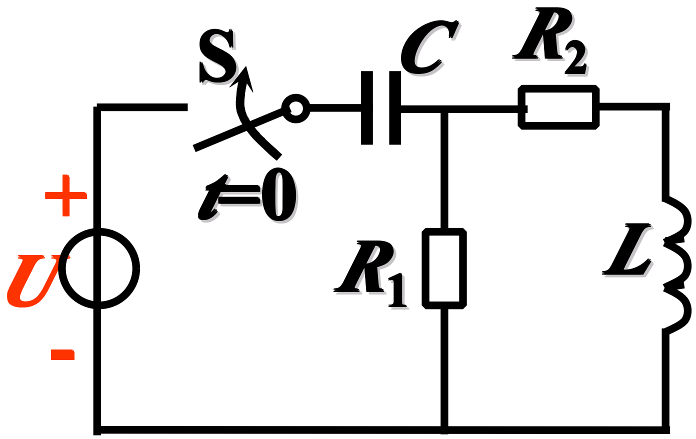
(2)

1) $t=0_+$

2) $t=0_+$ $u_C=u_C(0_+)$

$t=0_+$ $i_L=i_L(0_+)$

1



(a)

C L

(1)

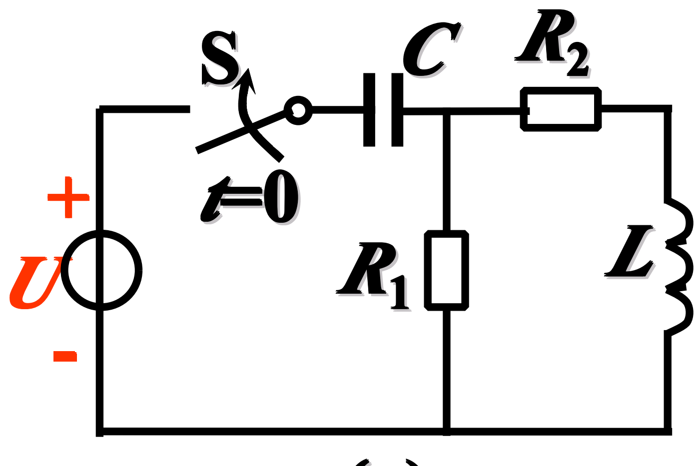
$u_C(0_-),\ i_L(0_-)$

$u_C(0_-) = 0,\ i_L(0_-) = 0$

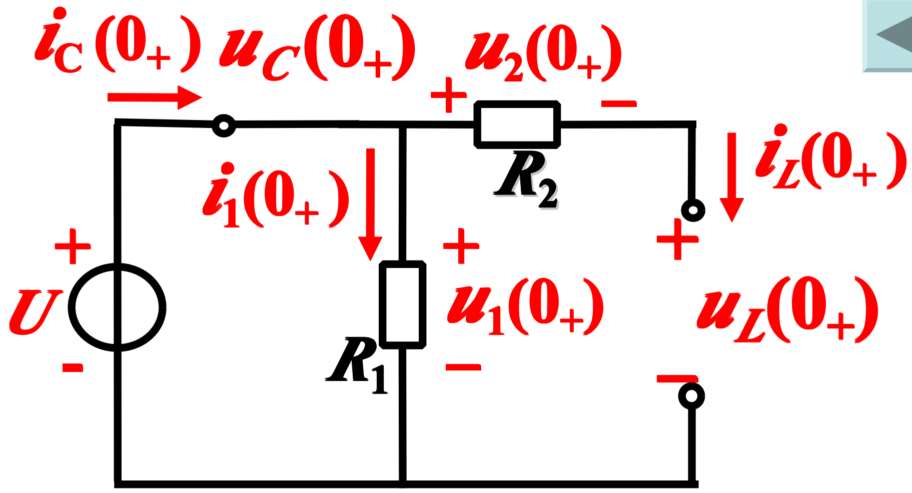
$u_C(0_+) = u_C(0_-) = 0$

$i_L(0_+) = i_L(0_-) = 0$

1:



(a)



(b) $t = 0+$

(2) $t=0_+$

$$u_C(0_-) = 0,$$

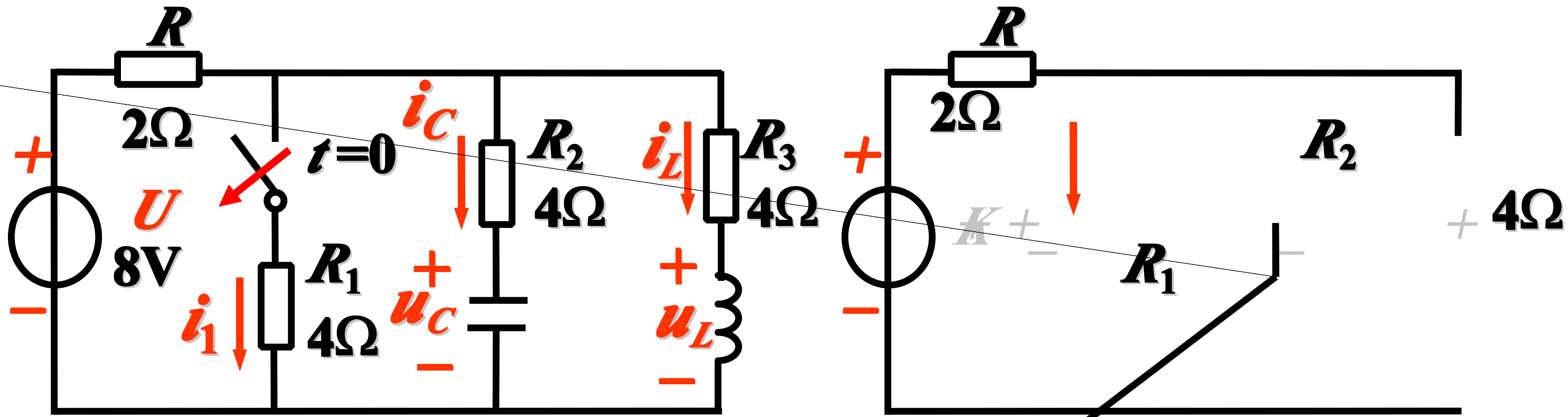
$$i_L(0_-) = 0,$$

$$i_C(0_+) = i_1(0_+) = \frac{U}{R} \qquad (i_C(0_-) = 0)$$

i_C u_L

$$u_L(0_+) = u_1(0_+) = U \qquad (u_L(0_-) = 0) \qquad u_2(0_+) = 0$$

2

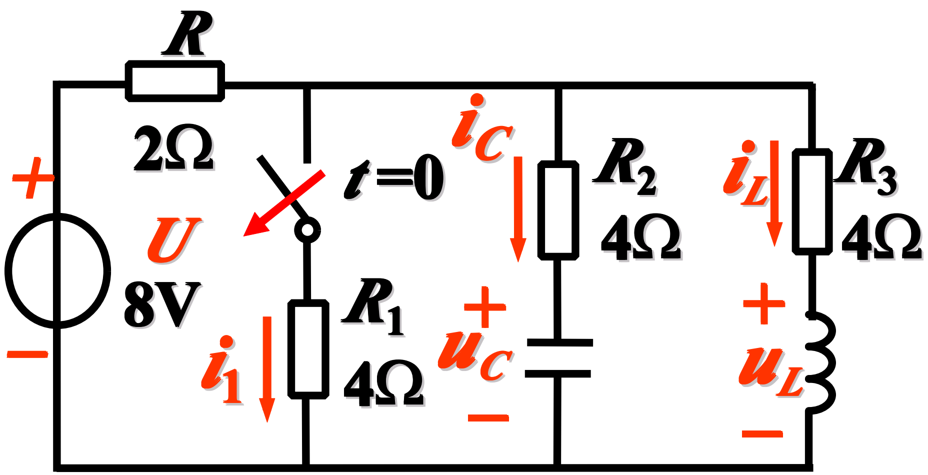


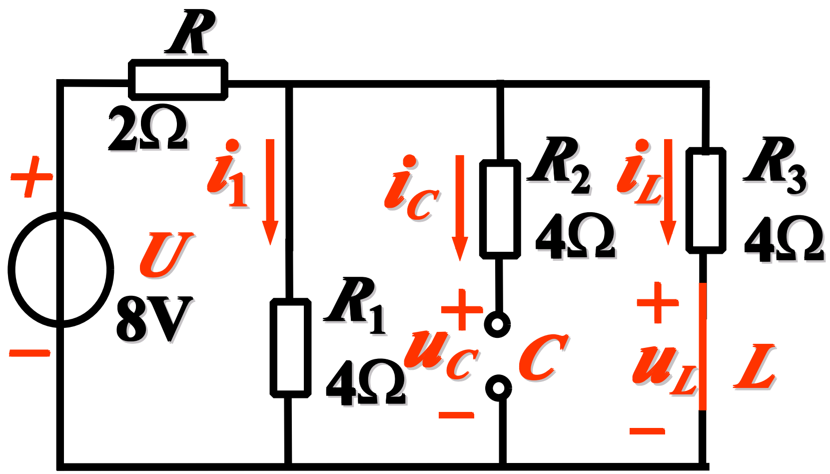
(1) $t=0_-$ $u_C(0_-)$ $i_L(0_-)$

$t=0_-$

$$i_L(0_-)=\frac{R_1}{R_1+R_3}\times\frac{U}{R+\frac{R_1R_3}{R_1+R_3}}=\frac{4}{4+4}\times\frac{U}{2+\frac{4\times4}{4+4}}=1\text{A}$$

2





$t=0_-$

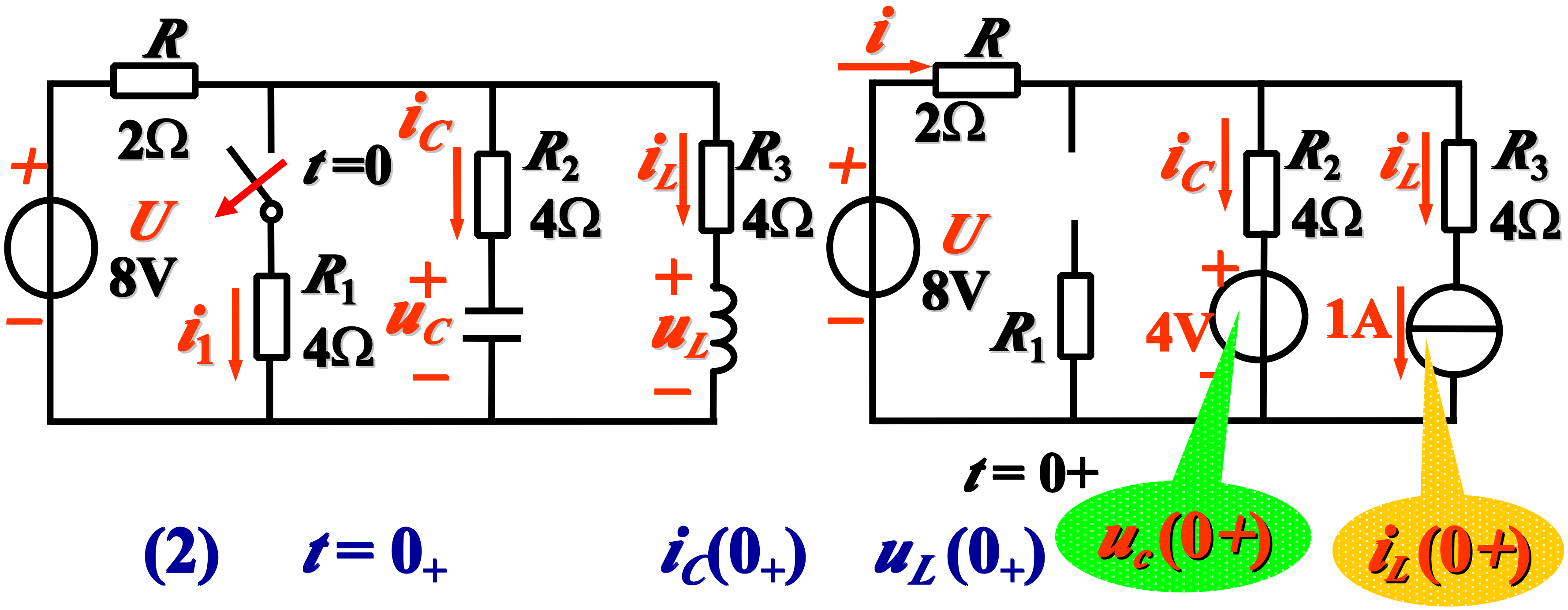
(1) $i_L(0_-)=1\,\text{A}$

$$u_C(0_-)=R_3 i_L(0_-)=4\times1=4\,\text{V}$$

$$i_L(0_+)=i_L(0_-)=1\,\text{A}$$

$$u_C(0_+)=u_C(0_-)=4\,\text{V}$$

2



(2) $t = 0_+$ $i_C(0_+)$ $u_L(0_+)$

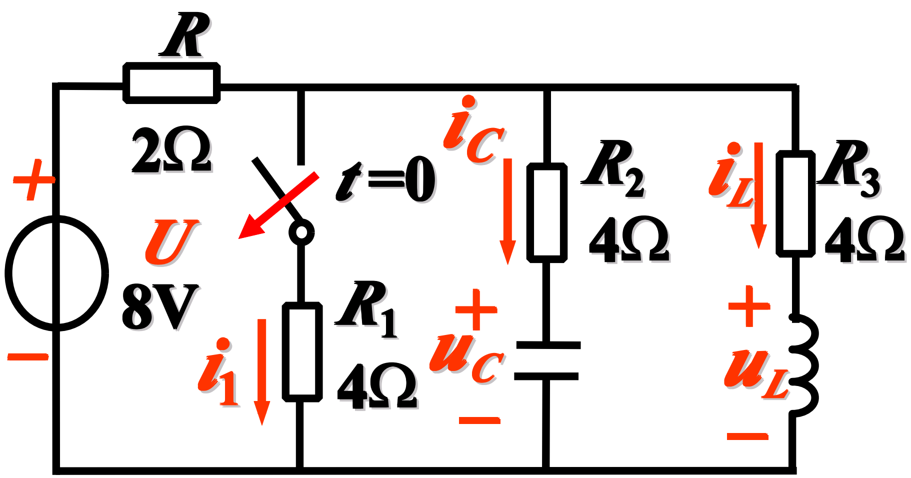
$$U = Ri(0_+) + R_2 i_C(0_+) + u_C(0_+)$$

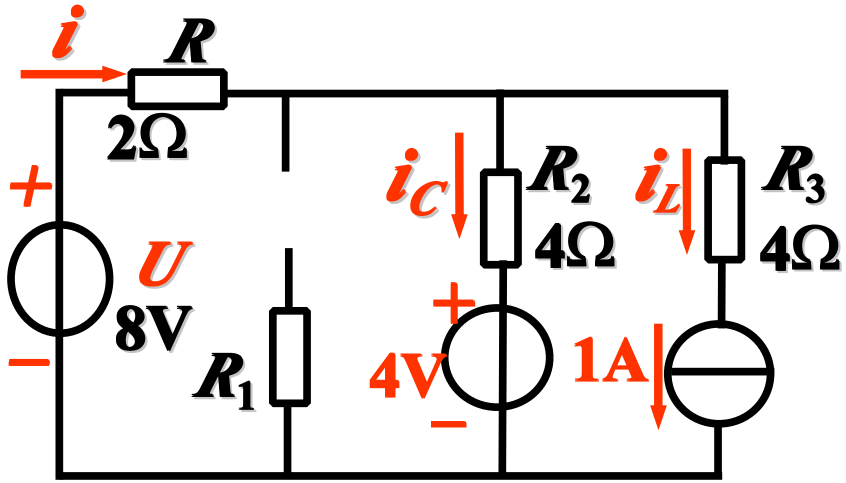
$$i(0_+) = i_C(0_+) + i_L(0_+)$$

$$8 = 2i(0_+) + 4i_C(0_+) + 4$$

$$i(0_+) = i_C(0_+) + 1$$

2

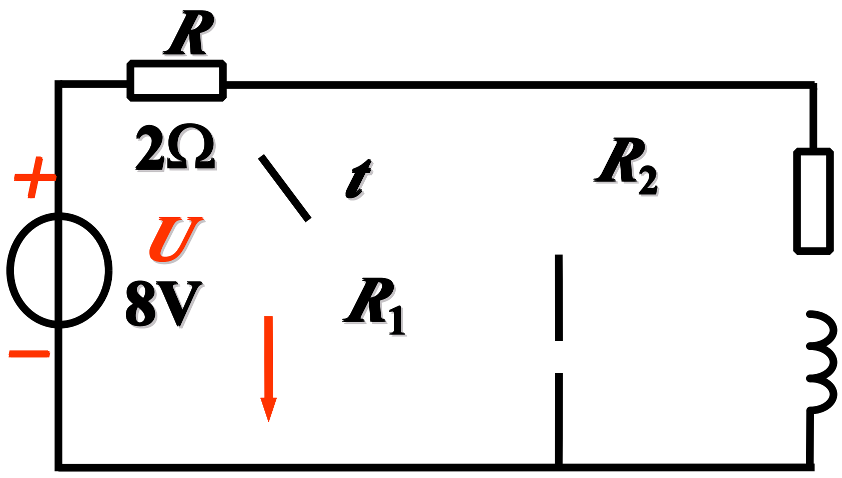




$t = 0+$

$$i_C(0_+) = \frac{1}{3}\,\text{A}$$

$$u_L(0_+) = R_2 i_C(0_+) + u_C(0_+) - R_3 i_L(0_+)$$
$$= 4 \times \frac{1}{3} + 4 - 4 \times 1 = 1\frac{1}{3}\ \text{V}$$



	u_C/V	i_L/A	i_C/A	u_L/V
$t=0_-$	4	1	0	0
$t=0_+$	4	1	$\frac{1}{3}$	$1\frac{1}{3}$

u_C i_L i_C u_L

1. u_C i_L ,

2. , , (t=0_+

)

3. , $u_C(0_-)\neq 0$ $i_L(0_-)\neq 0$ (t=0_+

)

$u_c(0_+)$;

$i_L(0_+)$

3.2

,

1. : ( )

( )

2.

{

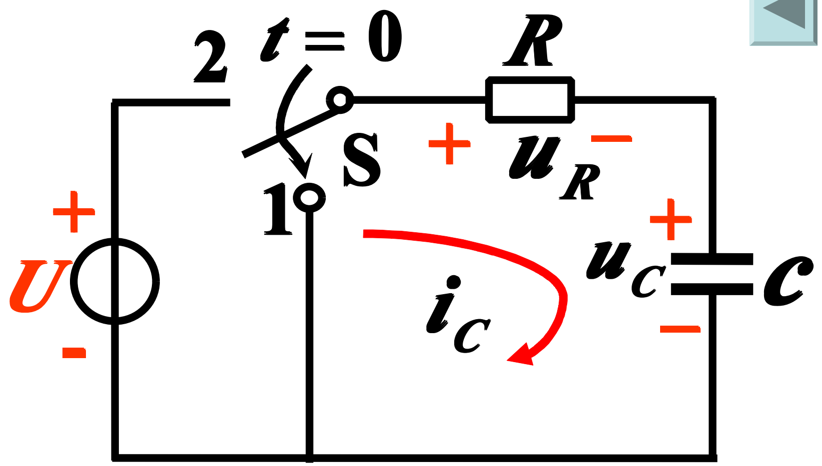
3.2.1 *RC*

:　　,

,

RC

$u_C(0_-)=U$



$u_C(0_-)=U$

$t=0$ $\mathrm{S}\rightarrow 1$, C R

1. u_C $(t\geq 0)$

(1) KVL $\quad + \quad = 0$

$= i \qquad i = \frac{\mathrm{d}}{\mathrm{d}}$

$$\frac{\mathrm{d}}{\mathrm{d}} + \quad = 0$$

(2) $$RC\frac{\mathrm{d}u_C}{\mathrm{d}t}+u_C=0 \qquad : u_C = A\mathrm{e}^{pt}$$

$$+1=0 \qquad \therefore \quad = -\frac{1}{\quad}$$

$$u_C = A\mathrm{e}^{-\frac{t}{RC}}$$

A

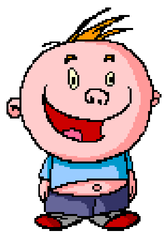
$$t=(0_+) \qquad u_C(0_+)=U\ , \qquad A=U$$

(3) u_C

$$u_C = U\mathrm{e}^{-\frac{t}{RC}} = u_C(0_+)\mathrm{e}^{-\frac{t}{\tau}} \qquad t \geq 0$$

u_C

RC

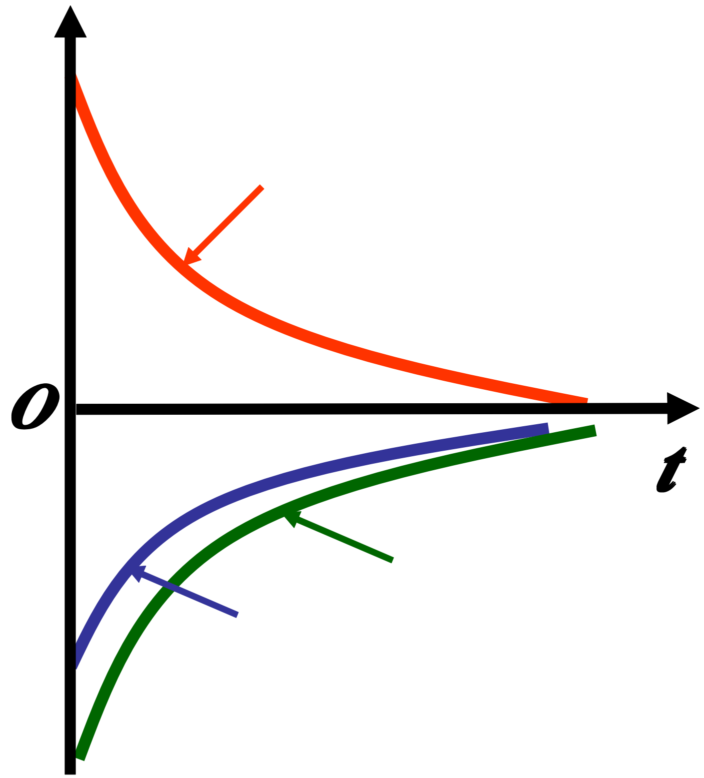


2.

$$u_C = U\mathrm{e}^{-\frac{t}{RC}}$$

$$i_C = C\frac{\mathrm{d}u_C}{\mathrm{d}t} = -\frac{U}{R}\mathrm{e}^{-\frac{t}{RC}}$$

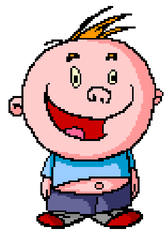
$$u_R = i_C R = -U\mathrm{e}^{-\frac{t}{RC}}$$



3.

4.

: $\boxed{\tau = RC}$: S



(1) $\Omega \dfrac{\text{A}\cdot\text{s}}{\text{V}} = \text{s}$

τ

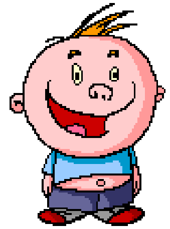
(2)

$$u_C(t) = U\mathrm{e}^{-\frac{t}{RC}}$$

$t=\tau$ $= \quad \mathrm{e}^{-1} = 36.8\%$

$\therefore$ τ u_C U_0 36.8%

(3)



$$t \to \infty \quad u_C \to 0$$

$$t = (3 \sim 5)\tau \quad u_C \to 0$$

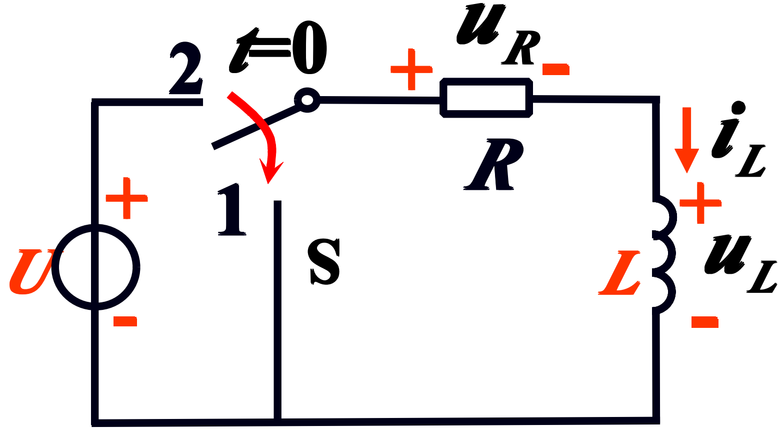
$$e^{-\frac{t}{\tau}}$$

t	τ	2τ	3τ	4τ	5τ	6τ
$e^{-\frac{t}{\tau}}$	e^{-1}	e^{-2}	e^{-3}	e^{-4}	e^{-5}	e^{-6}
u_C	$0.368U$	$0.135U$	$0.050U$	$0.018U$	$0.007U$	$0.002U$

$t=5\tau$ u_C

3.2.2 *RL*

1. *RL*



$(0_-) = —$

t=0 , *L* *R*

(1) i_L

1) KVL $+ \quad = 0$

$= i \qquad = \frac{d}{d}$

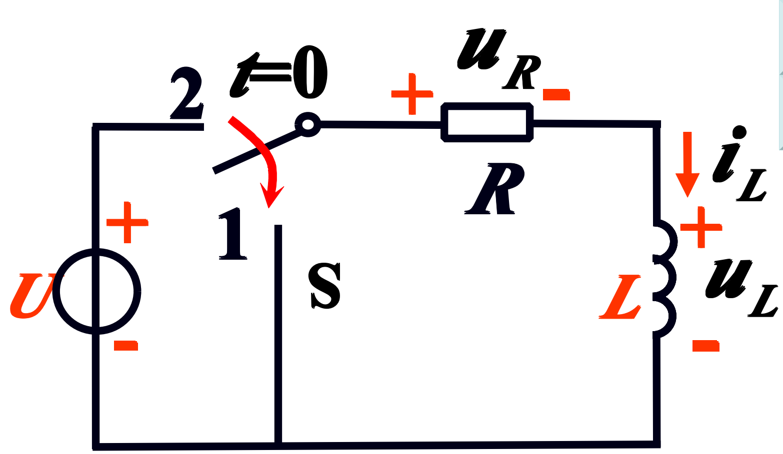
$$— \frac{d}{d} + \quad = 0$$

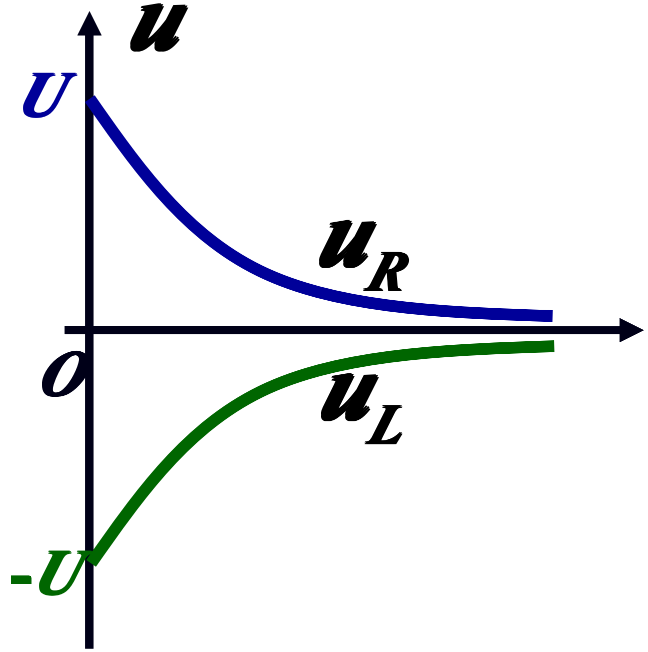
(2)

$$= \frac{}{}\mathrm{e}^{-\frac{}{}}$$

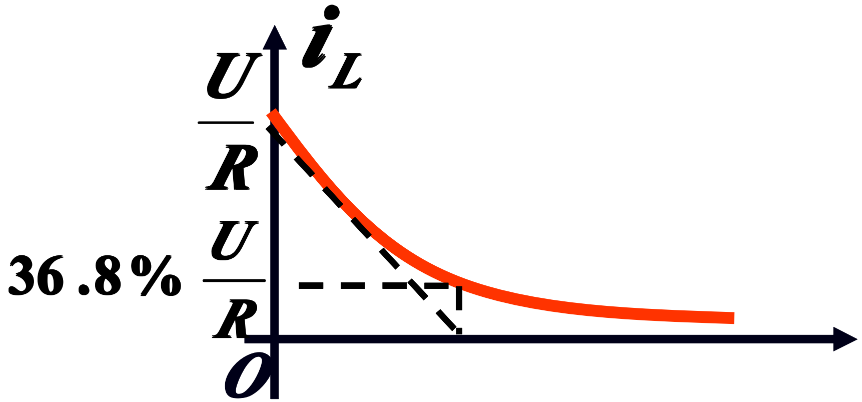
$$= \frac{\mathrm{d}}{\mathrm{d}} = -\ \mathrm{e}^{-\frac{}{}}$$

$$= \quad = \ \mathrm{e}^{-\frac{}{}}$$



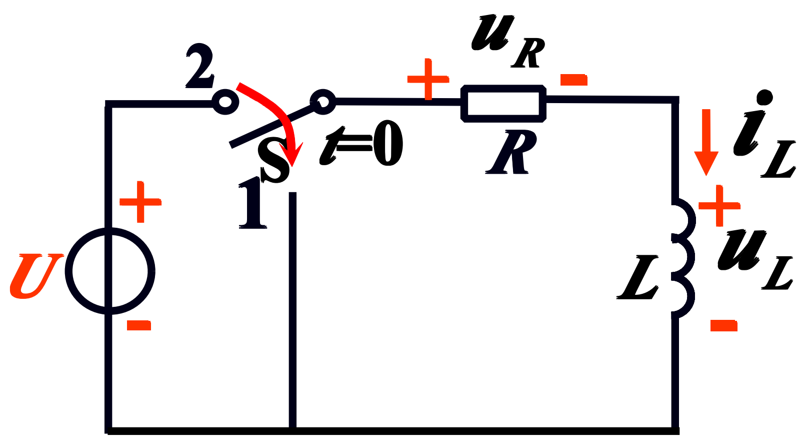


(3)



(4) $\tau = \frac{}{}$

2. *RL*



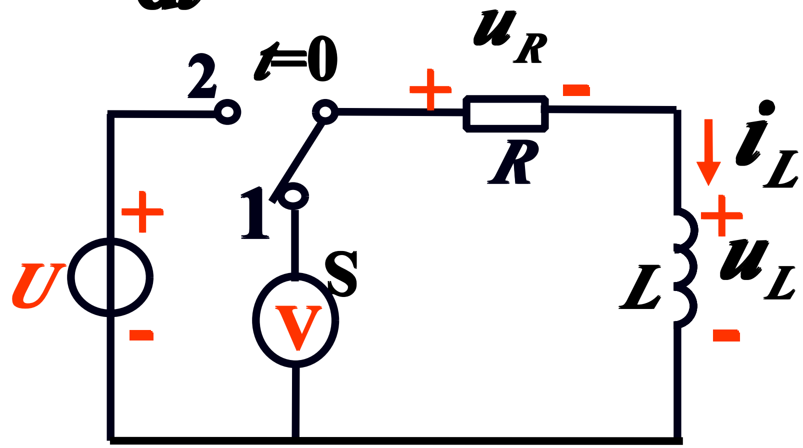
(1)

1)

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

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

2)

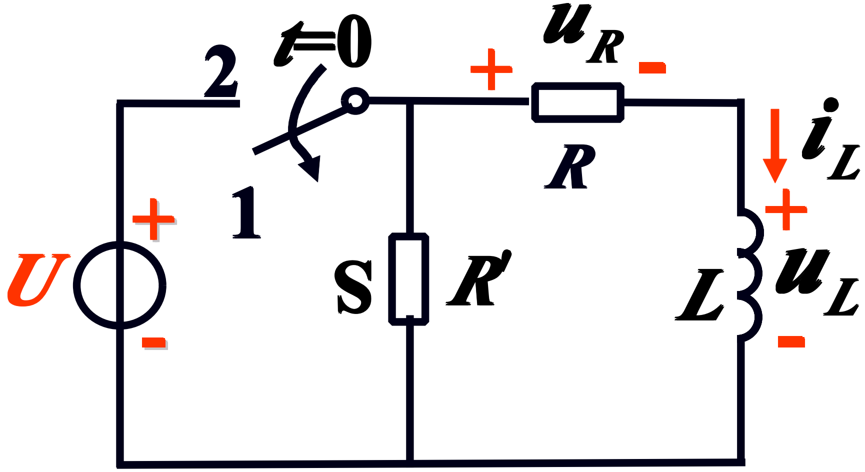


$$\because \quad i_L(0_+) = i_L(0_-) = \frac{U}{R}$$

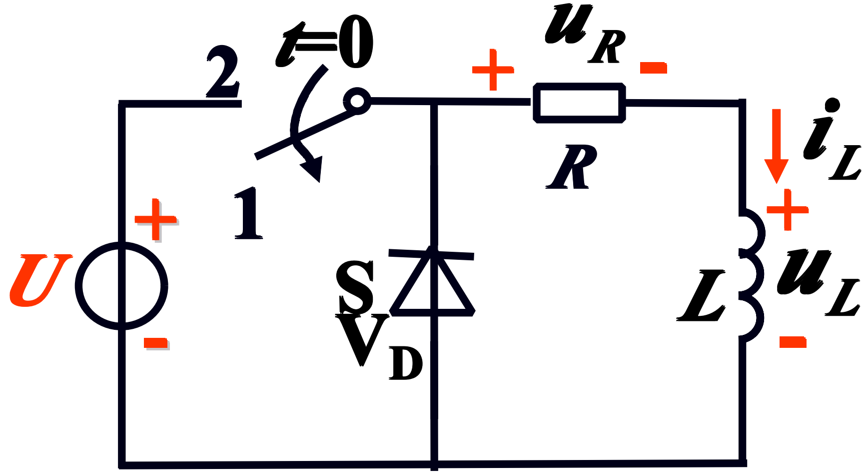
$$V(0_+) = i_L(0_+) \times R = \frac{U}{R} \times R$$

(2)

1) R'



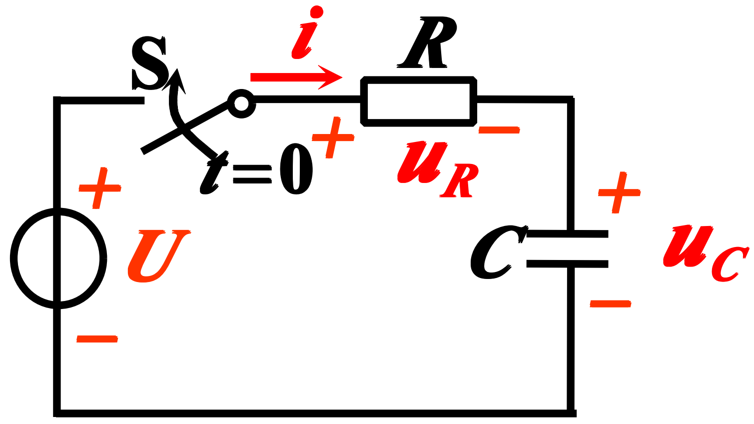
2) V_D



3.3

3.3.1 *RC*

:



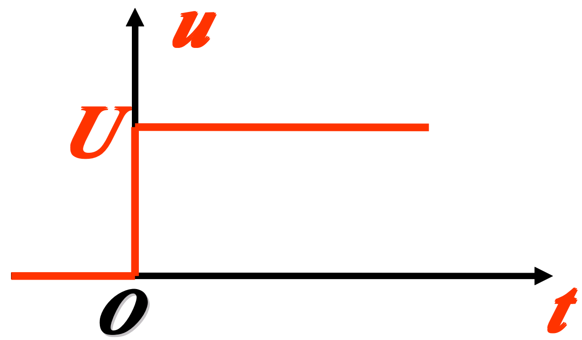
$u_C(0\,-) = 0$

RC

$t = 0$ S

,

u

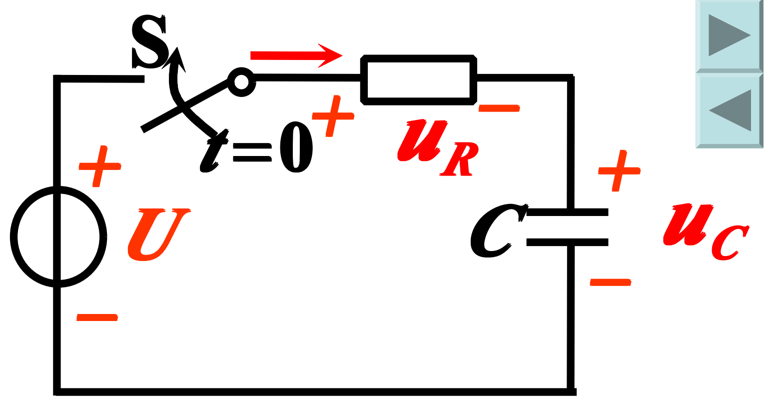


u

$$u = \begin{cases} 0 & t < 0 \\ U & t \geq 0 \end{cases}$$

1. u_C

(1) **KVL** $u_R + u_C = U$



$u_C(0_-) = 0$

$$RC\frac{\mathrm{d}u_C}{\mathrm{d}t} + u_C = U$$

= +

$$u_C(t) = u'_C + u''_C$$

(2)

$$RC\frac{\mathrm{d}u_C}{\mathrm{d}t} + u_C = U$$

$u'_C = K$, $U = RC\frac{dK}{dt} + K$

$K = U$ $u'_C = U$

: $u_C = u'_C + u''_C = U + Ae^{-\frac{t}{RC}}$

---- u'_C

$u'_C(t) = u_C(\infty) = U$

u''_C

$$RC\frac{\mathrm{d}u_C}{\mathrm{d}t} + u_C = 0$$

$$u''_C = A\mathrm{e}^{pt} = A\mathrm{e}^{-\frac{t}{RC}}$$

$$u_C = u'_C + u''_C = U + A\mathrm{e}^{-\frac{t}{\tau}} \qquad \tau = RC$$

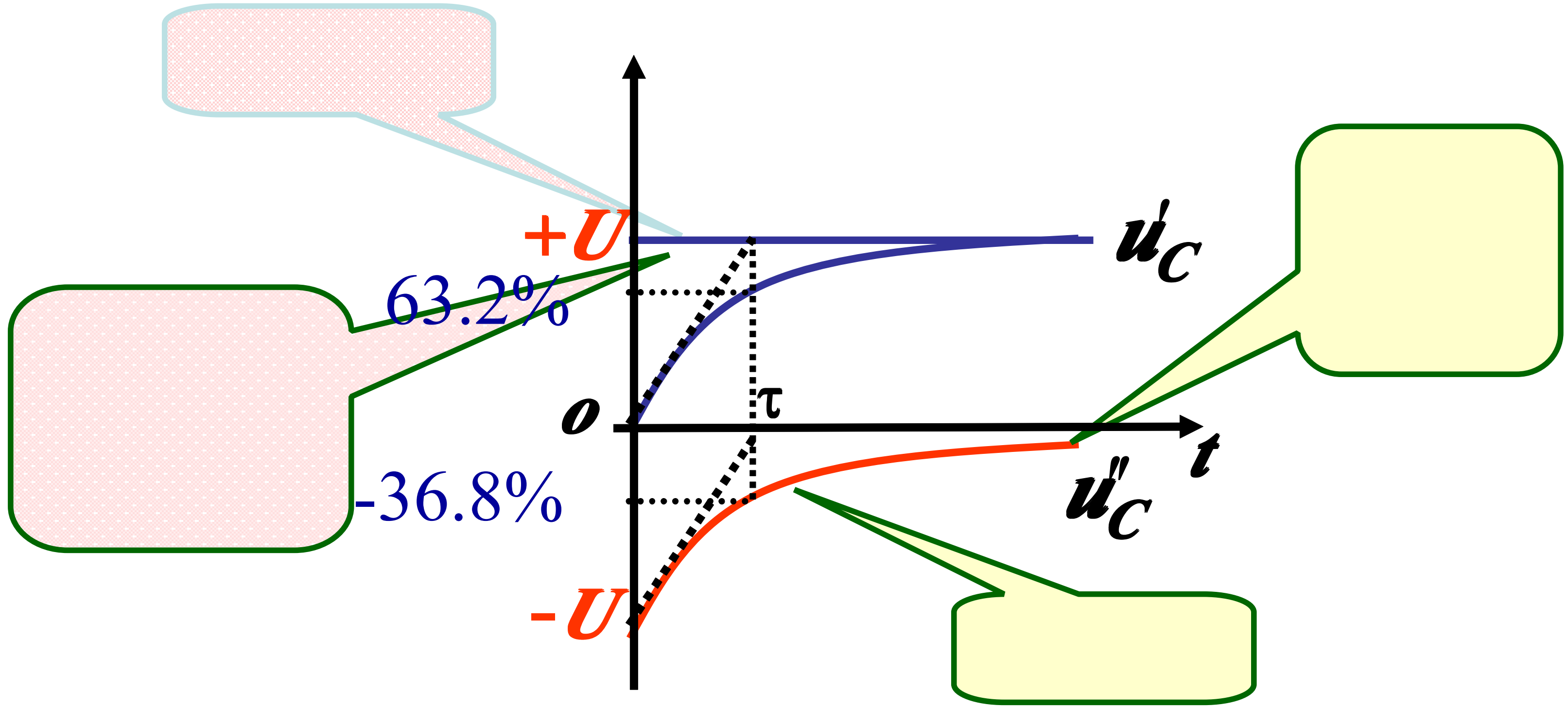
A

t=0_+ $\qquad u_C(0_+) = 0$

$A = -U$

(3) u_C

$$u_C = U - U\mathrm{e}^{-\frac{t}{RC}}$$



[redacted]

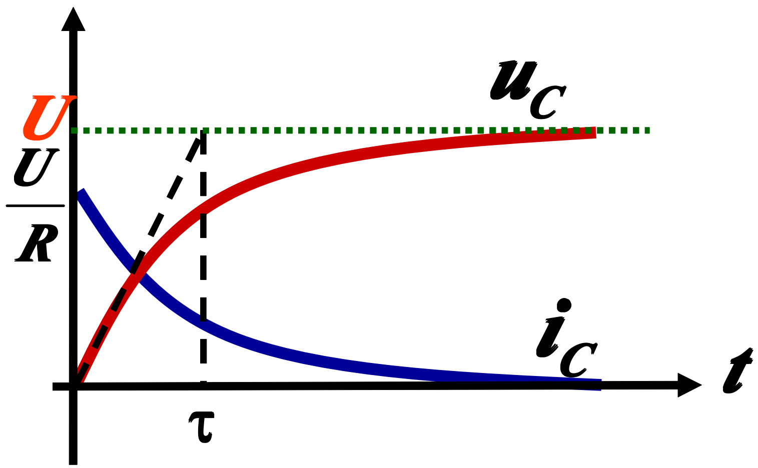
2. i_C

$t=0$

$$i_C = C\frac{\mathrm{d}u_C}{\mathrm{d}t} = \frac{U}{R}\mathrm{e}^{-\frac{t}{\tau}} \quad t \geq 0$$

3. u_C i_C

$$u_C = U(1-\mathrm{e}^{-\frac{t}{RC}})$$



4. τ

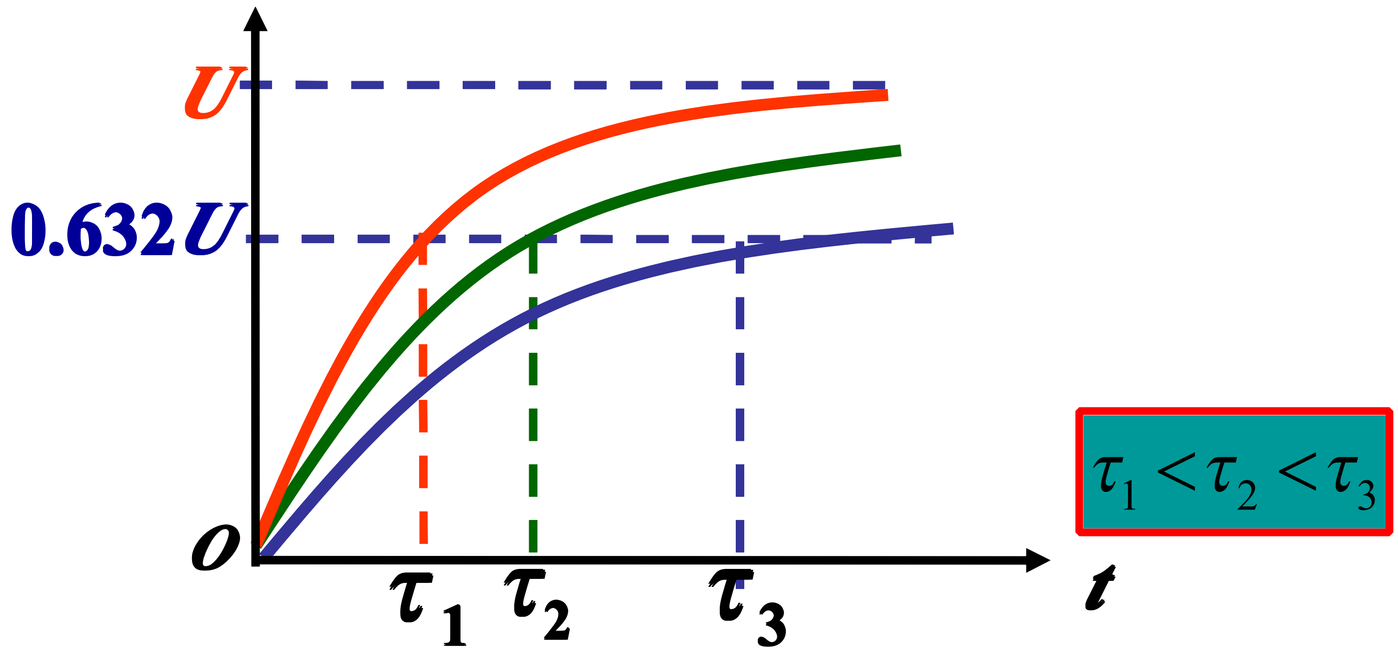
$t=\tau$

$$u_C(\tau) = U(1-e^{-1}) = 63.2\%U$$

τ u_C

63.2%

	0	τ	2τ	3τ	4τ	5τ	6τ
u_C	0	$0.632U$	$0.865U$	$0.950U$	$0.982U$	$0.993U$	$0.998U$



τ u_C

$t = 5\tau$, , u_C

3.3.2 *RL*

1. i_L

(1) KVL $\quad + \quad =$

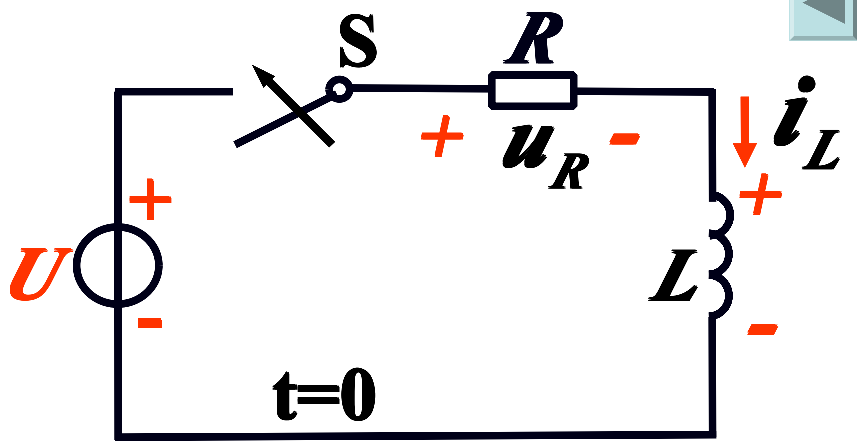
$$— \frac{\mathrm{d}}{\mathrm{d}} + \quad = —$$

$= \qquad +$

$$(\ ) = \ ' + \ ''$$

(2)

$$(\ ) = \quad (\infty) = —$$



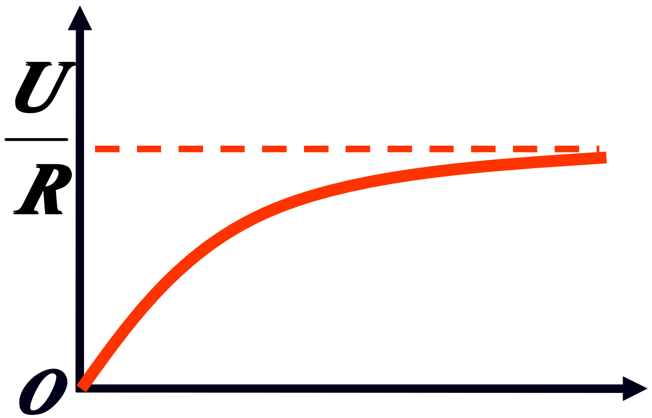
$(U=0 \quad i_L(0_-)=0)$

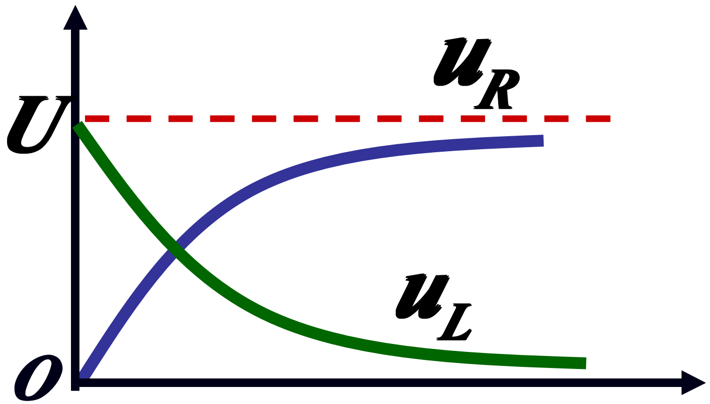
$$i_L = \frac{U}{R}(1 - e^{-\frac{R}{L}t})$$

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

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

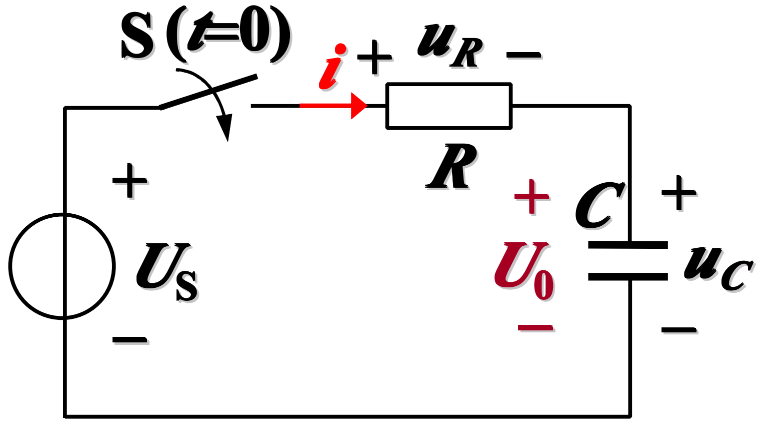
2. i_L　u_L　u_R





3.4

1.



$$RC\frac{\mathrm{d}u_C}{\mathrm{d}t}+u_C=U_S$$

$$u_C(0_+)=u_C(0_-)=U_0$$

2.

$$u_C=U_S+(U_0-U_S)\,\mathrm{e}^{-\frac{t}{\tau}}$$

(1)

$=$ $+$

( )

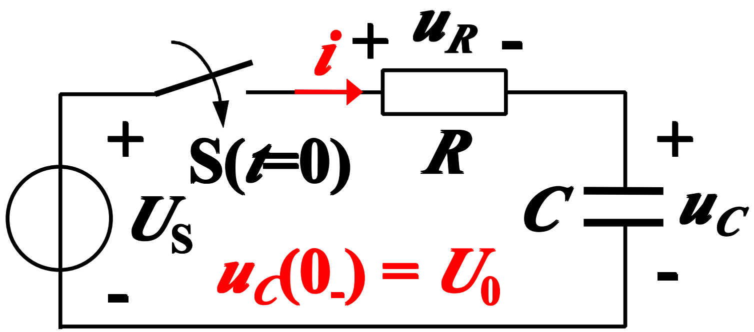
( )

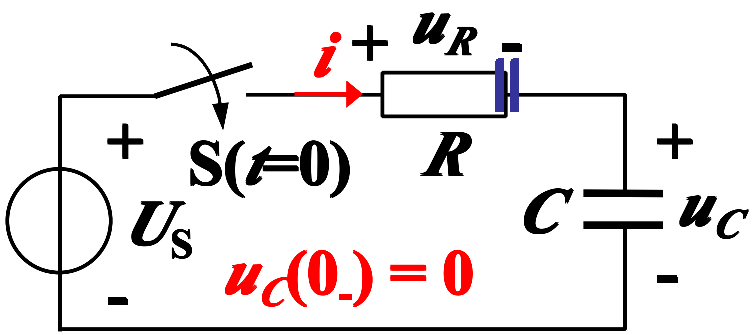
$$u_C = U_S + (U_0 - U_S)\, e^{-\frac{t}{t}}$$

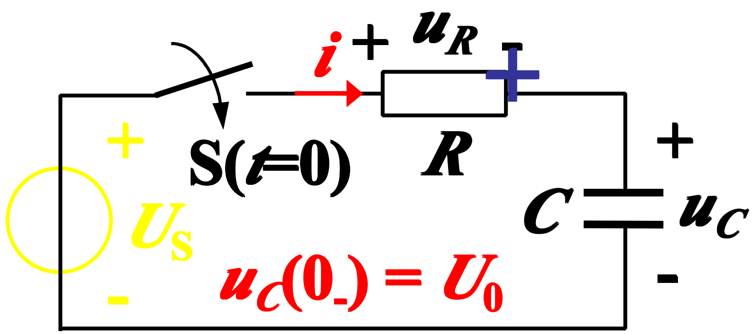
(2)

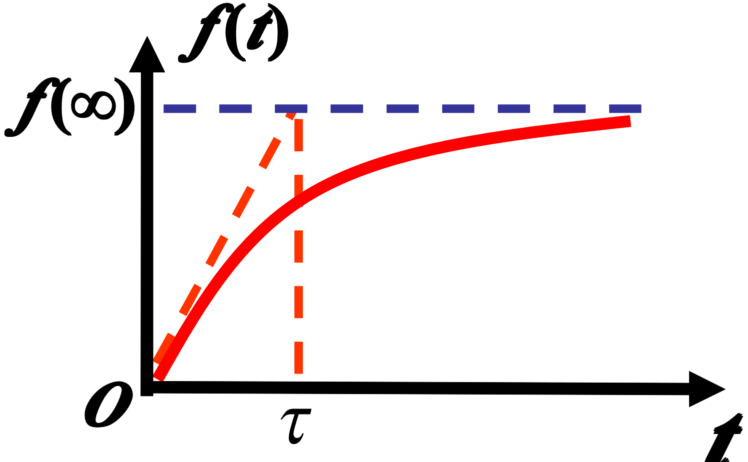
$$u_C = U_S(1 - e^{-\frac{t}{t}}) + U_0 e^{-\frac{t}{t}}$$

$$= \qquad + \qquad$$

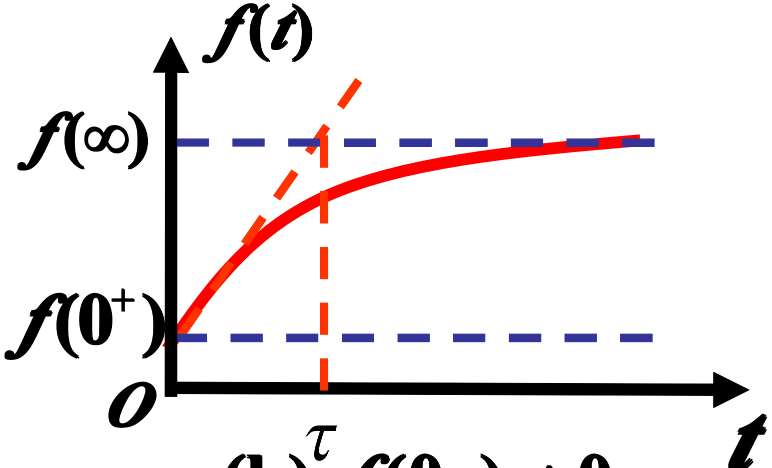




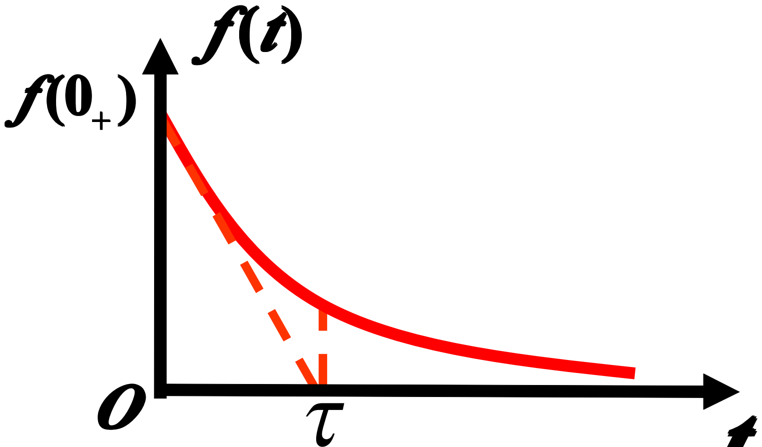




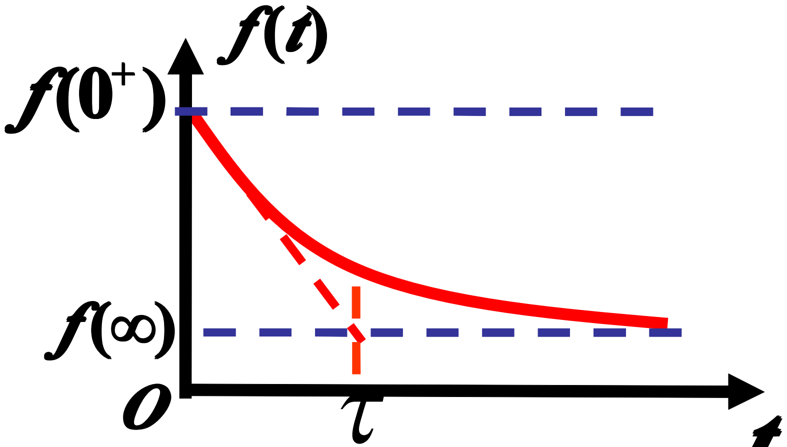
(a) $f(0_+) = 0$



(b) $f(0_+) \neq 0$



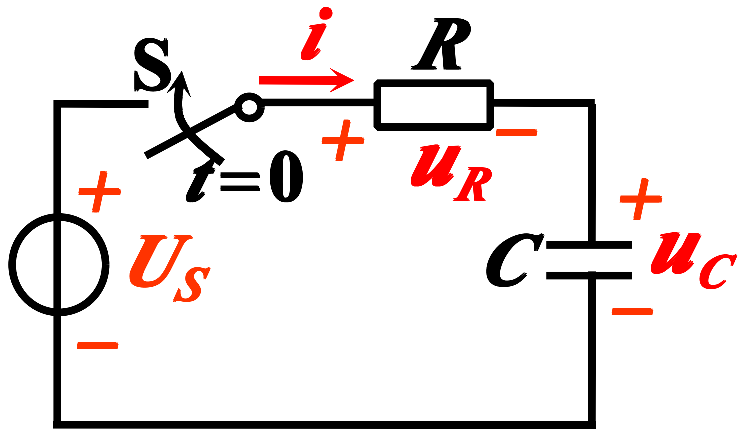
(c) $f(\infty) = 0$



(d) $f(\infty) \neq 0$

3.5

,



$u_C(0_-) = U_0$

$$= \quad + (\quad_0 - \quad)e^{-\frac{\quad}{\tau}}$$

$$(\infty) =$$

$$(0_+) = \quad (0_-) = \quad_0$$

$$u_C = u_C(\infty) + [u_C(0_+) - u_C(\infty)]\,\mathrm{e}^{-\frac{t}{RC}}$$

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

, $f(t)$

$f(0_+)$ --

$f(\infty)$ --

τ --

τ

( )

(2) $f(0_+)$

1) t=0$_-$ $u_C(0_-)$ $i_L(0_-)$

2) $$\begin{cases} u_C(0_+) = u_C(0_-) \\ i_L(0_+) = i_L(0_-) \end{cases}$$

3) t=0$_+$ $u(0_+)$ $i(0_+)$

(3) τ

RC $\tau = R_0 C$ RL $\tau = \dfrac{L}{R_0}$

1) $R_0 = R$;

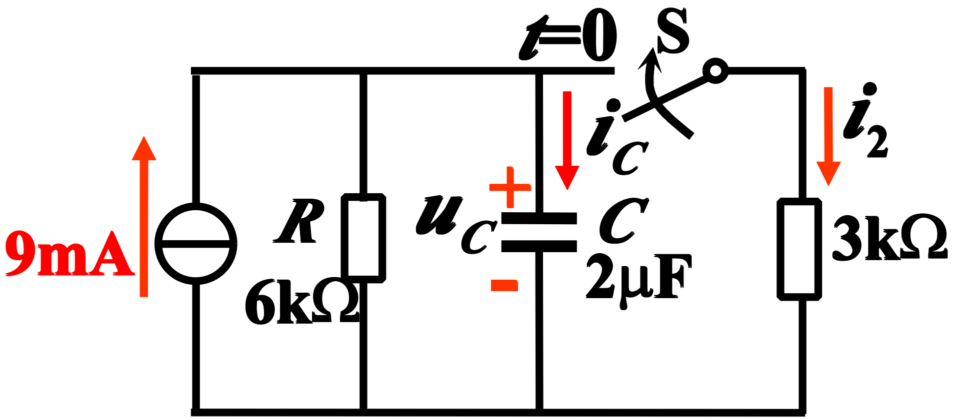
2) R_0

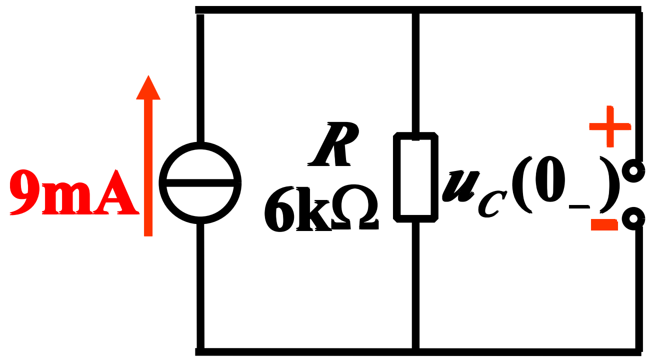
R_0

$$R_0 = (R_1 // R_2) + R_3$$

t=0　　　　S　　S

u_c　　　　i_2　i_C





t=0$_-$

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

(1)　$u_C(0_+)$

t=0$_-$　$u_C(0\_) = 9\times10^{-3}\times6\times10^{3} = 54\,\text{V}$

$$u_C(0_+) = u_C(0\_) = 54\,\text{V}$$

(2) $u_c(\infty)$

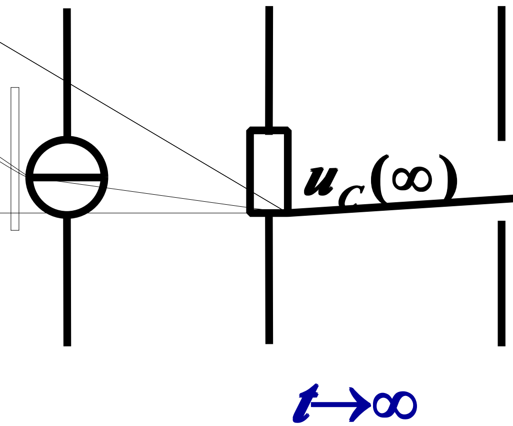
$u_c(\infty)$

$$u_C(\infty) = 9\times 10^{-3} \times \frac{6\times 3}{6+3} \times 10^{3}$$

$$= 18\ \text{V}$$

(3)

τ

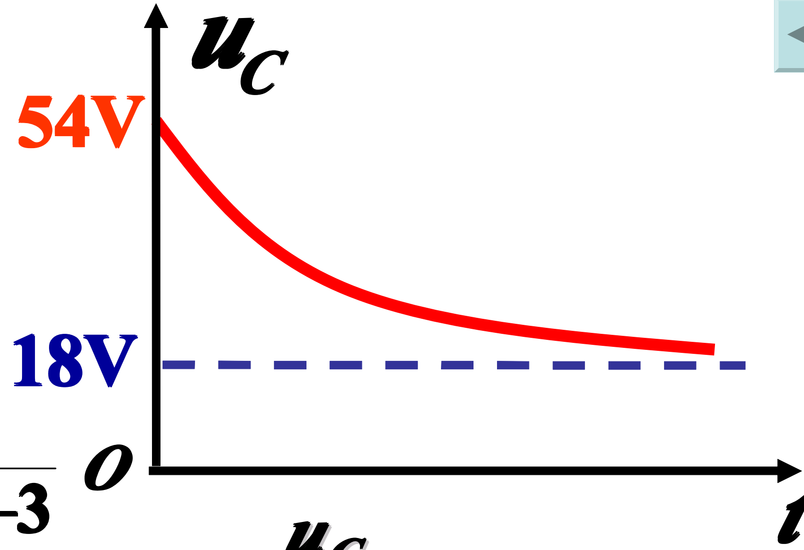


$$\tau = R_0 C$$

$$= \frac{6\times 3}{6+3} \times 10^{3} \times 2\times 10^{-6}$$

$$= 4\times 10^{-3}\ \text{s}$$

$$\begin{cases} u_C(0_+) = 54\ \text{V} \\ u_C(\infty) = 18\ \text{V} \\ \tau = 4\times10^{-3}\ \text{s} \end{cases}$$



u_C

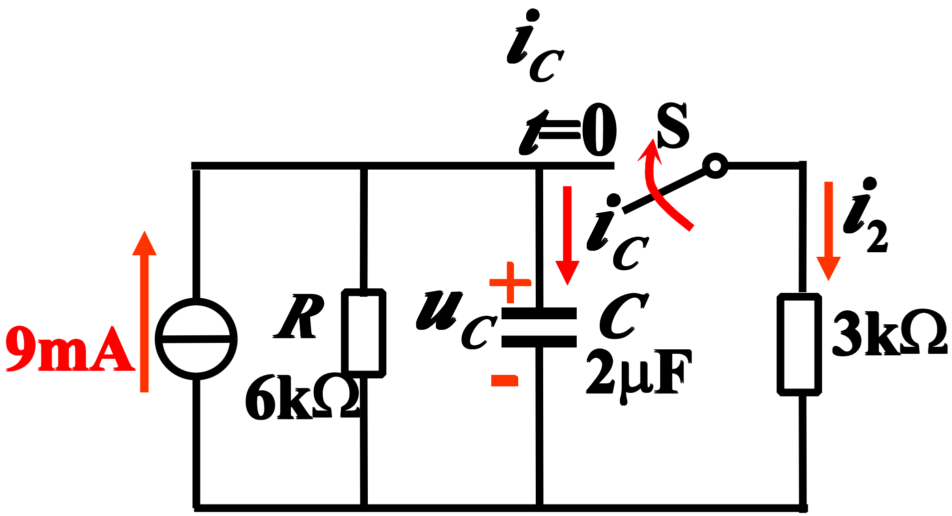
$$\therefore u_C = 18 + (54-18)e^{-\frac{t}{4\times10^{-3}}}$$

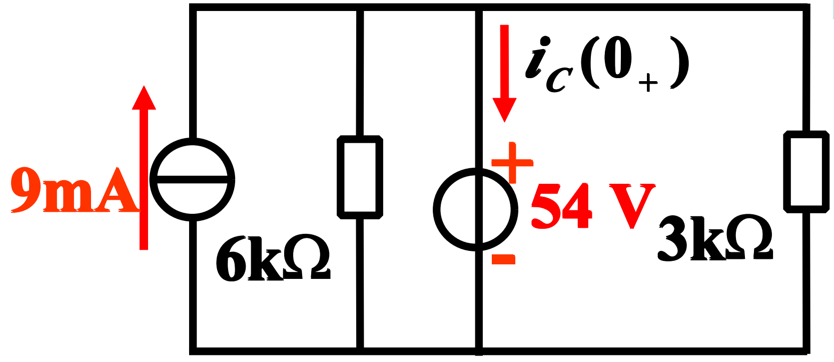
$$= 18 + 36e^{-250t}\ \text{V}$$

u_C

$$i_C = C\frac{du_C}{dt} = 2\times10^{-6}\times36\times(-250)e^{-250t}$$

$$= -0.018e^{-250t}\ \text{A}$$





t=0+

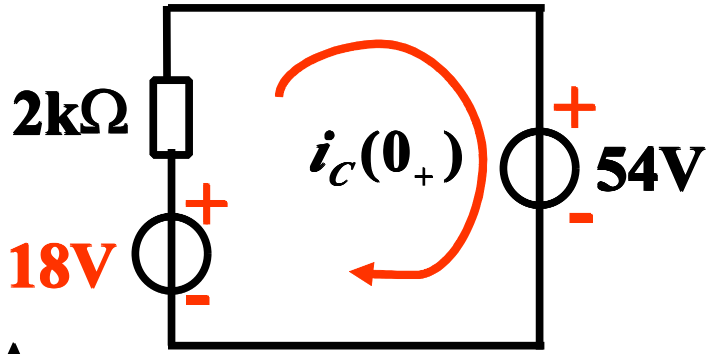
$$i_C = i_C(\infty) + \left[i_C(0_+) - i_C(\infty)\right]e^{-\frac{t}{\tau}}$$

$$i_C(0_+) = \frac{18-54}{2\times10^3} = -18\ \text{mA}$$

$$i_C(\infty) = 0$$

$$i_C(t) = -18e^{-250t}\ \text{mA}$$

$$i_2(t) = \frac{u_C(t)}{3\times10^3} = 6 + 12\,e^{-250\,t}\ \text{mA}$$

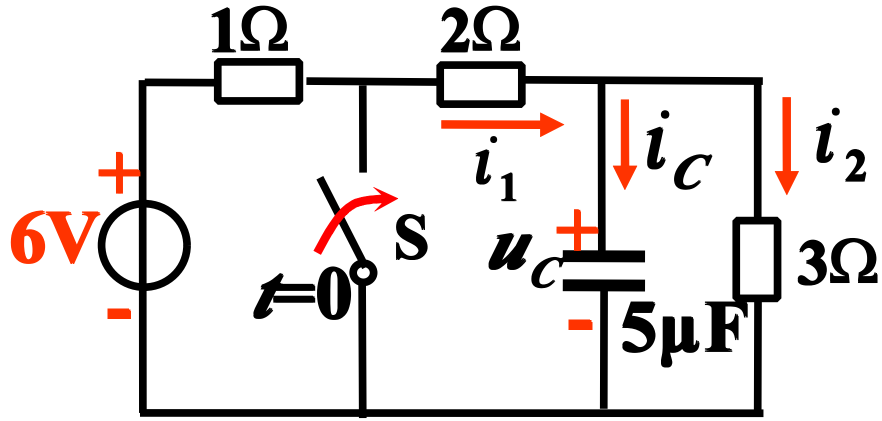


t=0+

2 S

t=0 S t 0 u_C i_C

i_1 i_2

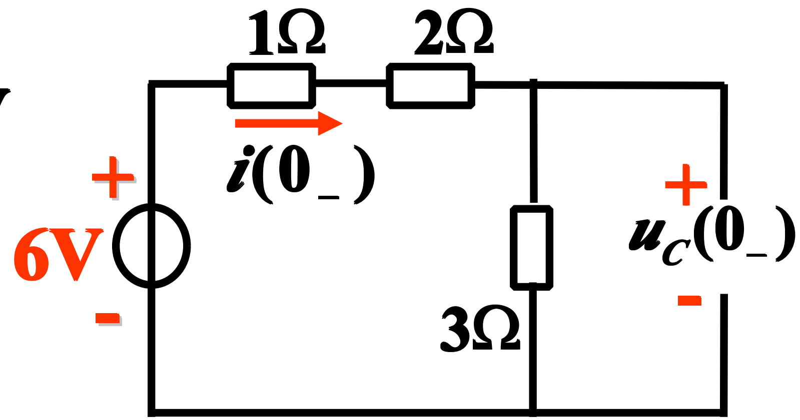


$u_C(0_+)$

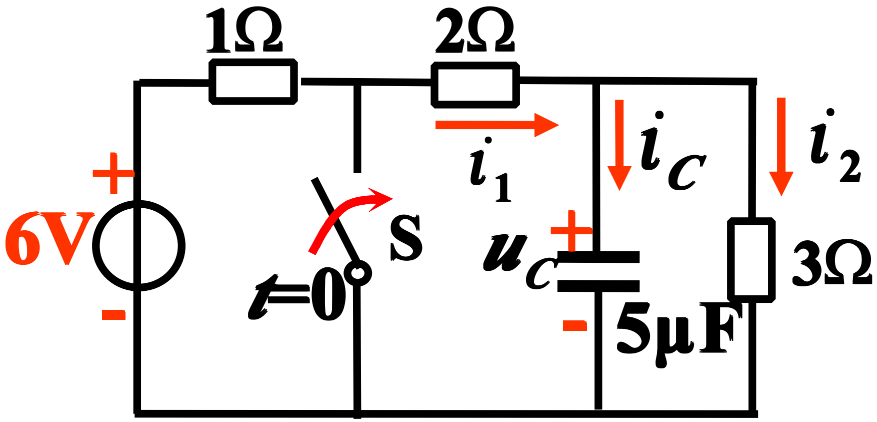
t=0-

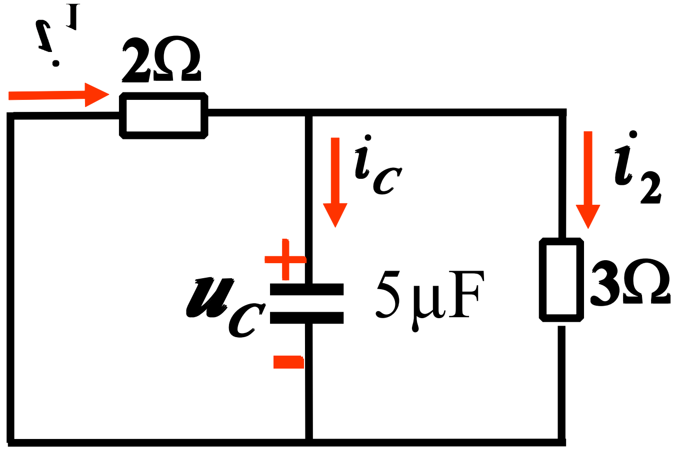
$$u_C(0_-)=\frac{6}{1+2+3}\times 3=3\text{ V}$$

$$u_C(0_+)=u_C(0_-)=3\text{V}$$



$t=0_-$





$u_C(\infty)$ $\quad u_C(\infty)=0$

τ

$$\tau = R_0 C = \frac{2\times 3}{2+3}\times 5\times 10^{-6} = 6\times 10^{-6}\ \text{s}$$

$$\therefore\ u_C(t) = u_C(\infty) + \left[u_C(0_+) - u_C(\infty)\right] U e^{-\frac{t}{\tau}}$$

$$= 0 + 3e^{-\frac{10^6}{6}t} = 3e^{-1.7\times 10^5 t}\ \text{V}$$

$i_C(t$

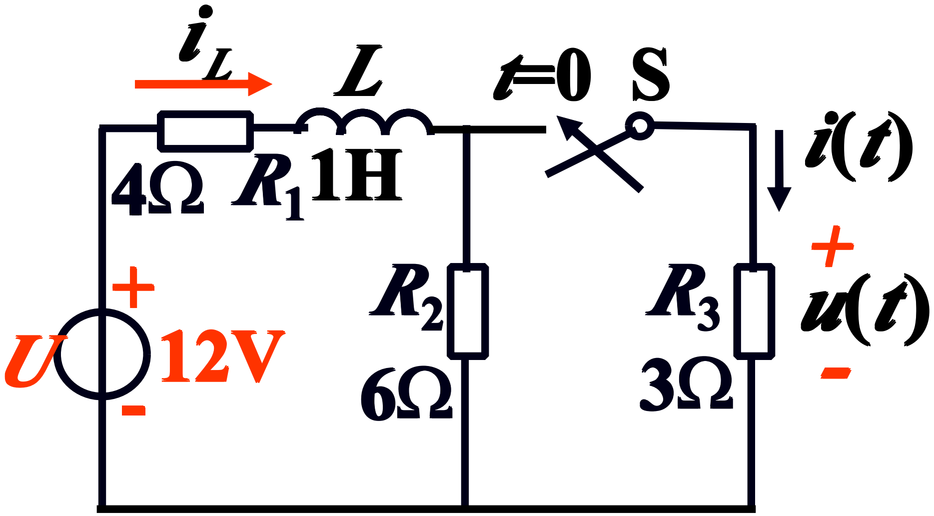
u_C

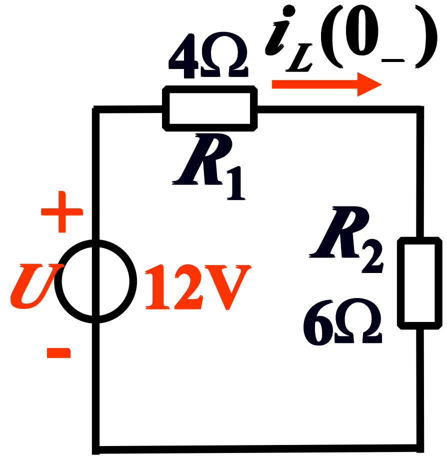
u_C

$= -1.5\,e$ … A

3 t=0

.





t=0_-

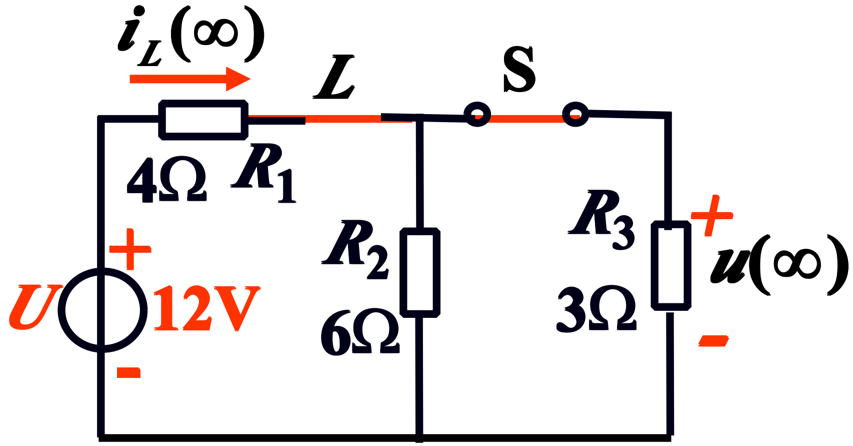
1. i_L ( )

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

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

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

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

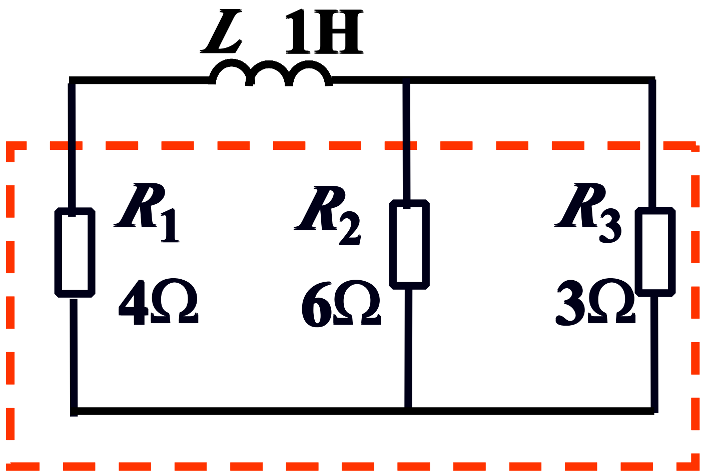


$t=\infty$

$$\tau = \frac{L}{R_0}$$

$$= \frac{L}{R_1 + \dfrac{R_2 \times R_3}{R_2 + R_3}}$$

$$= \frac{1}{6}\ \text{s}$$



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

2. $u(t)$

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

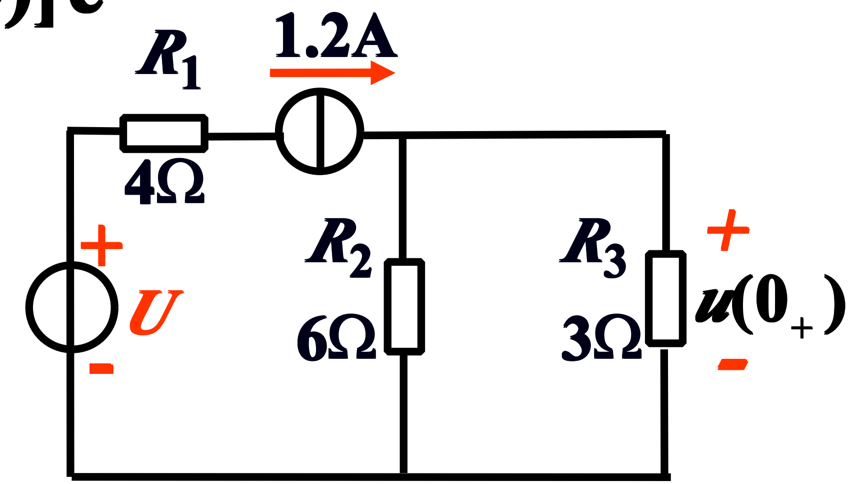
$$u = \frac{6\times3}{6+3}(2-0.8e^{-6t}) = 4-1.6e^{-6t}\,\text{V}\ (t\geq0)$$

u

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

$$u(0_+) = \frac{6}{6+3}\times1.2\times R_3$$

$$= \frac{2}{3}\times1.2\times3 = 2.4\,\text{V}$$



$t=0_+$

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

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

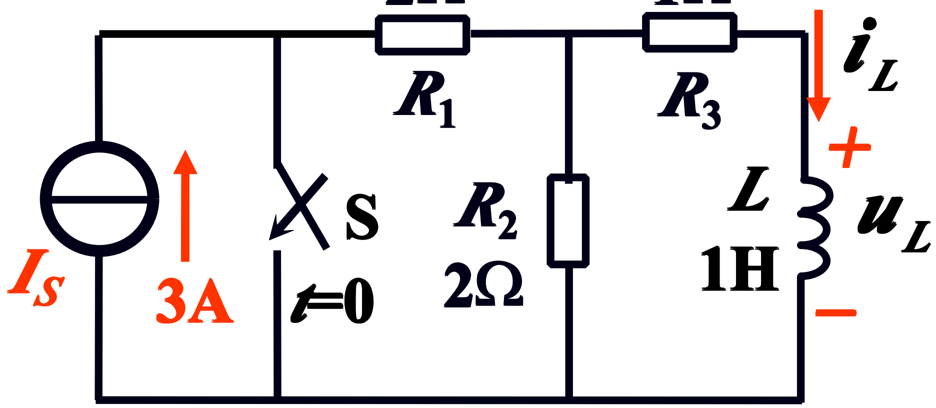
$$\frac{L}{R_0}=\frac{1}{6}\,s$$

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

$$6\mathrm{e}^{-6t}\ \text{V}\ (t\geq 0)$$

4: S t=0

: i_L u_L



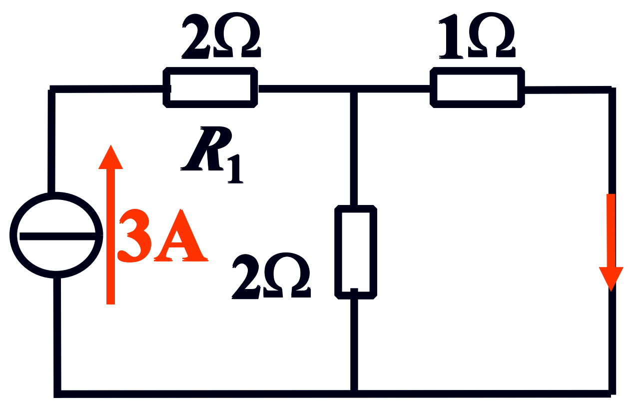
:

(1) $u_L(0_+)$, $i_L(0_+)$

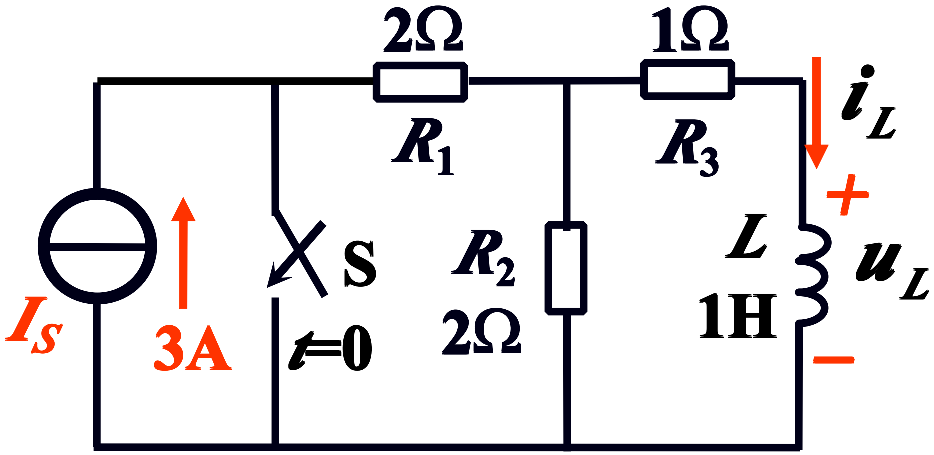
$t = 0_-$

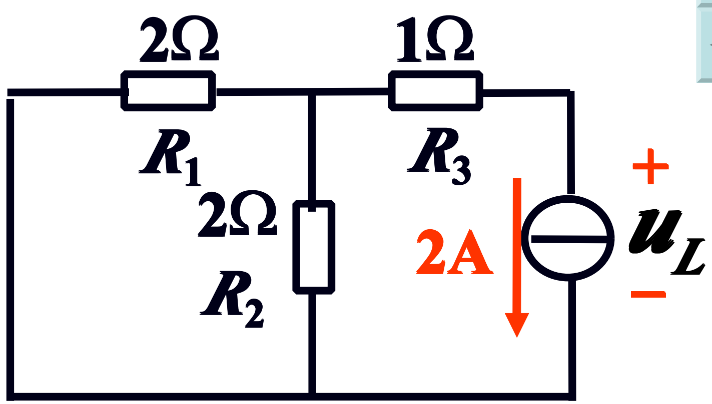
$$i_L(0_-) = \frac{2}{1+2} \times 3 = 2\text{ A}$$

$$i_L(0_+) = i_L(0_-) = 2\text{ A}$$



$t = 0_-$





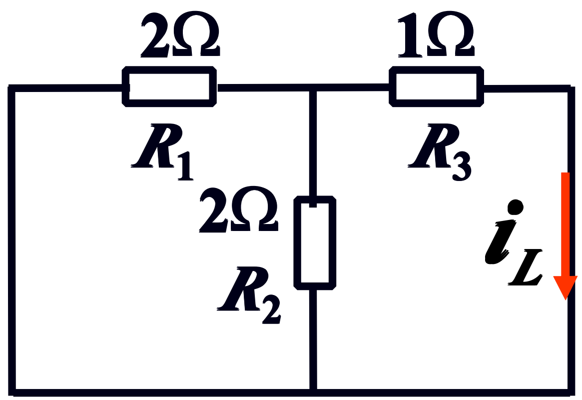
$t=0_+$

$$i_L(0_+)=i_L(0_-)=2\ \text{A}$$

$t=0_+$

$$u_L(0_+)=-i_L(0_+)\times(\frac{2\times2}{2+2}+1)$$

$$=-4\,\text{V}$$



$t=\infty$

(2) $i_L(\infty)$ $u_L(\infty)$

$t=\infty$

$$i_L(\infty)=0\,\text{V} \quad u_L(\infty)=0\,\text{V}$$

(3) τ

$$R_0 = R_1 // R_2 + R_3$$

$$\tau = \frac{L}{R_0} = \frac{1}{2} = 0.5\,\text{s}$$

$$i_L = 0 + (2 - 0)\,e^{-2t} = 2\,e^{-2t}\,\text{A}$$

$$u_L = 0 + (-4 - 0)\,e^{-2t} = -4\,e^{-2t}\,\text{V}$$