

1.

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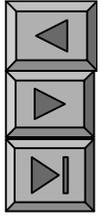
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(1)

(2)

(3)

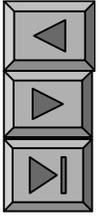
(4)

(5) () ()

(6)

(7)

(8)



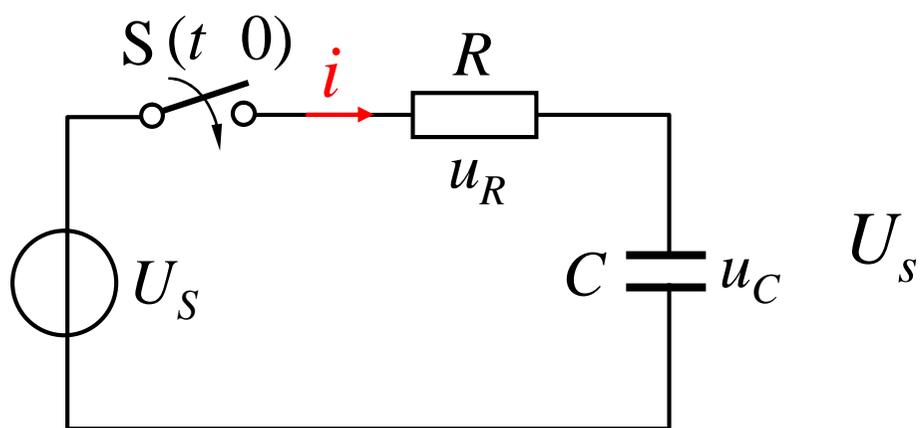
(1)

(2)

(3)

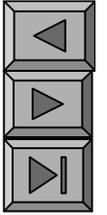
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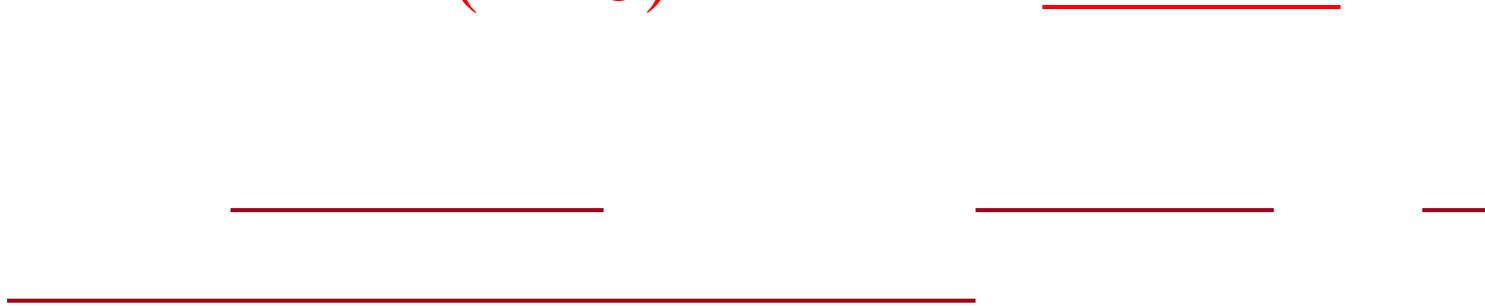


C

C



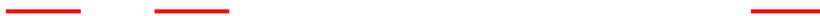
$(L \ C)$



$(L \ C)$

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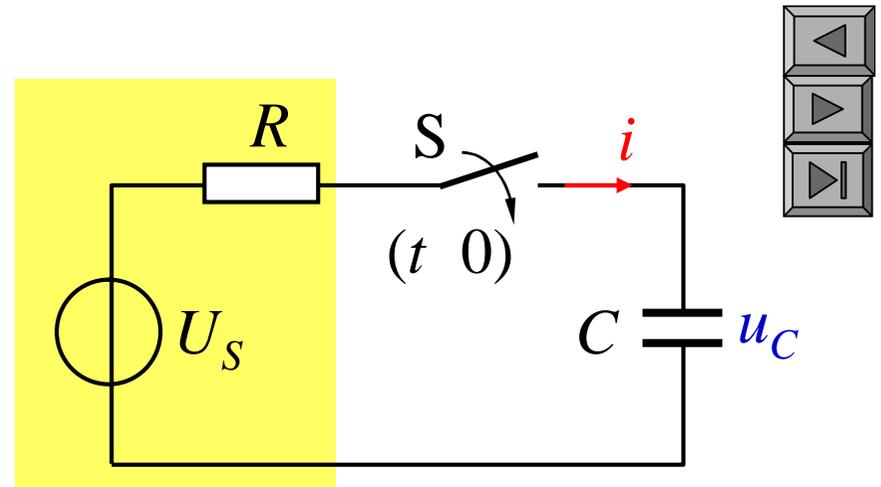
1.



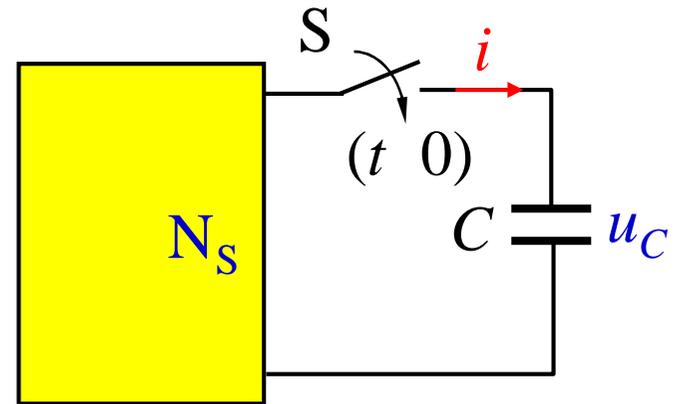
2.

RL RL)

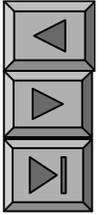
RC (RC



3.

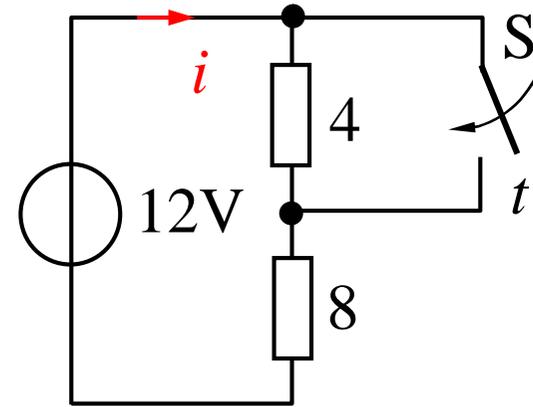


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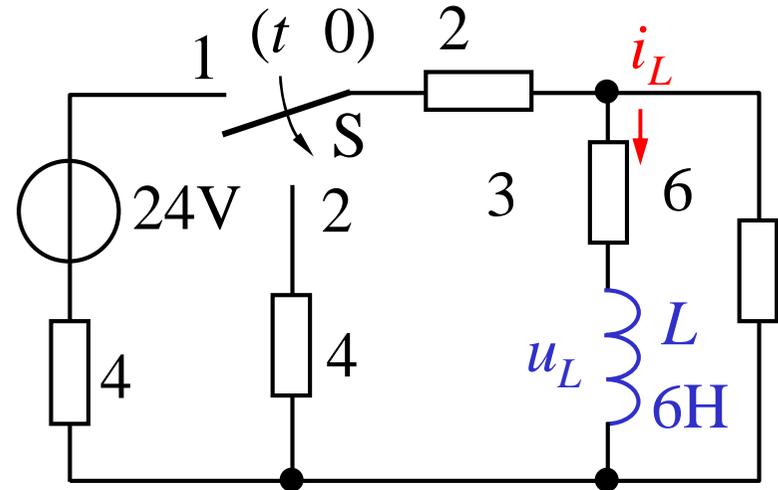


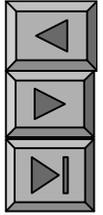
1.

$t = 0$ ($t = t_0$)



L C





$$\begin{pmatrix} 0 \\ \vdots \\ 0 \end{pmatrix} \quad \begin{pmatrix} 0 \\ \vdots \\ 0 \end{pmatrix}$$

$$\begin{pmatrix} \vdots \\ t \end{pmatrix} \quad Li_L(t)$$

$$i_L(0) \quad i_L(0)$$

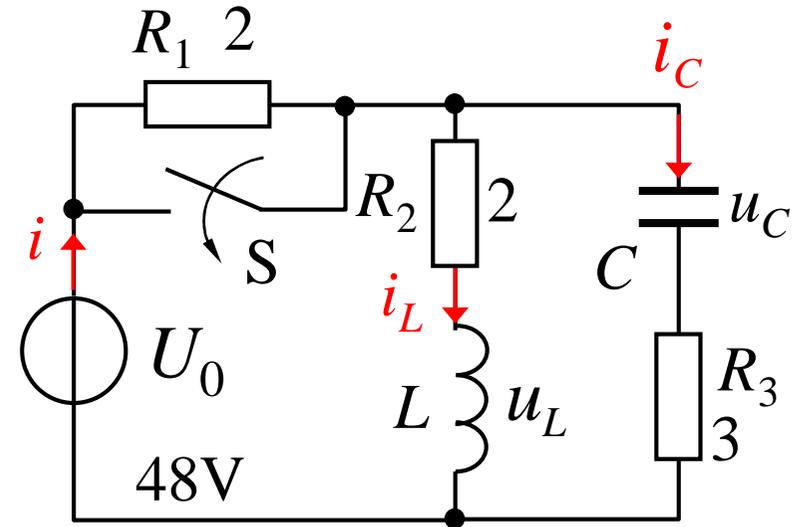
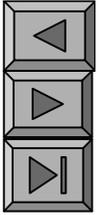


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1. “ ”

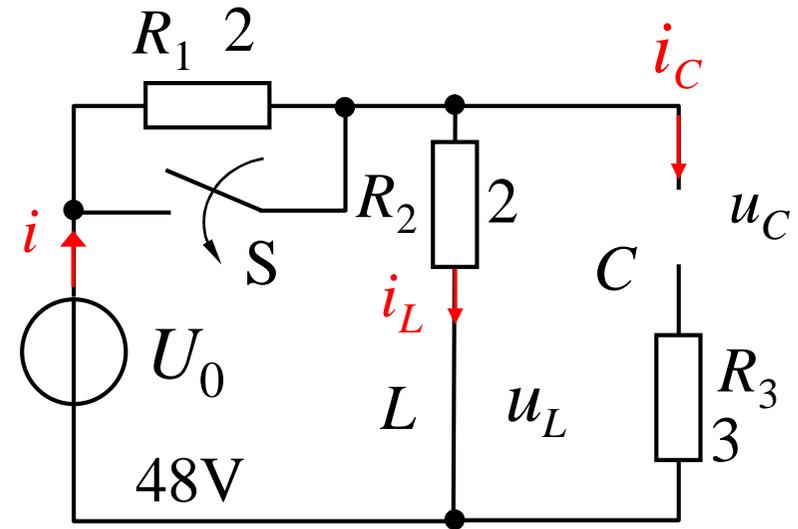
$$u_C(0^-) \quad i_L(0^-)$$

$$i_C(0^-) = 0 \quad C$$

$$u_L(0^-) = 0 \quad L$$

$$i_L(0^-) = 12A \quad i_L(0^-)$$

$$u_C(0^-) = 24V \quad u_C(0^-)$$



$$i_L(0^-) = 12\text{A} \quad i_L(0^+) = 12\text{A}$$

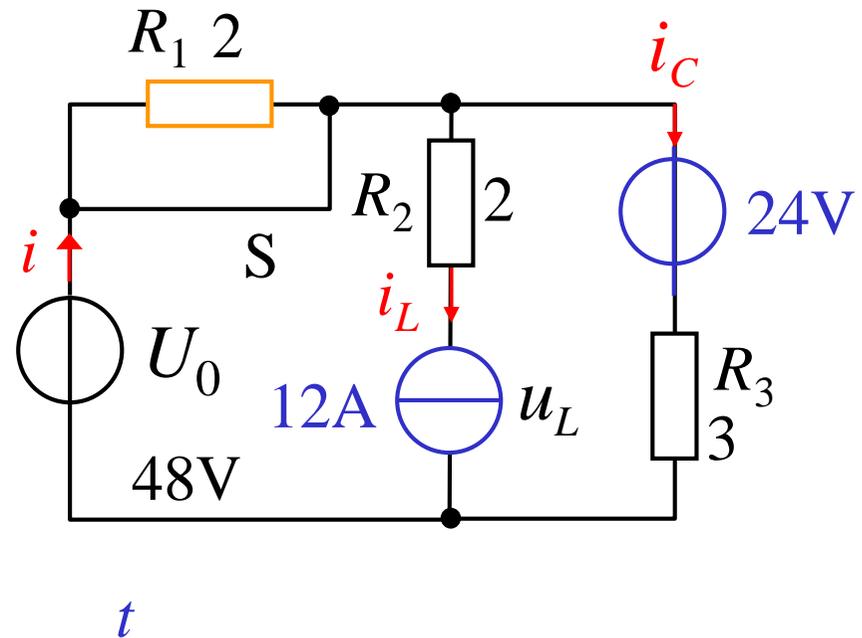
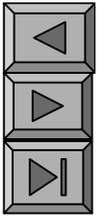
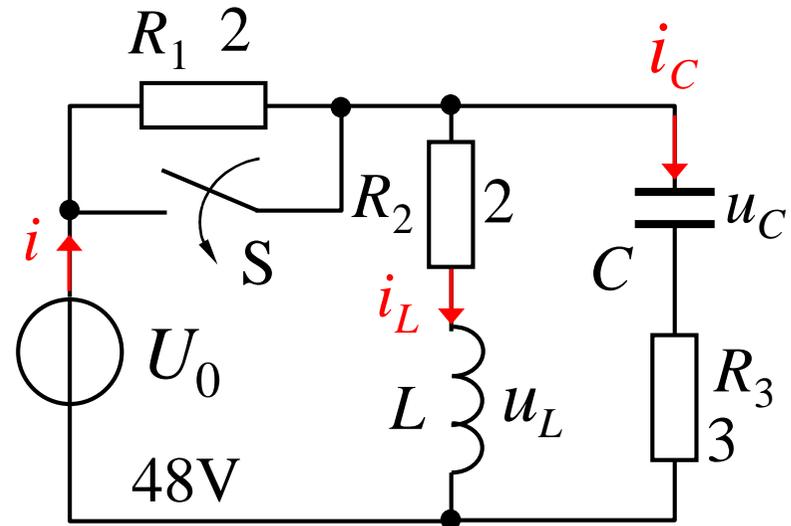
$$u_C(0^-) = 24\text{V} \quad u_C(0^+) = 24\text{V}$$

2. t

$$i_C(0^+) = \frac{48 - 24}{3}$$

$$u_L(0^+) = 48 - 12 \times 2 = 12 \text{ V}$$

$$i(0^+) = i_L(0^+) + i_C(0^+) = 12 + 8 = 20\text{A}$$



§ 7 2



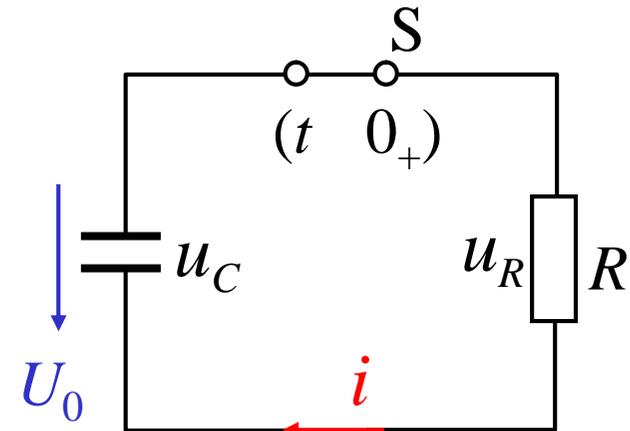
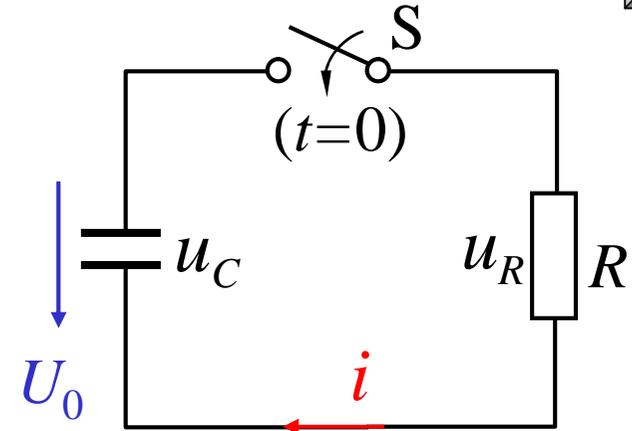
(0)

1. RC

RC

$$i \quad C \frac{du_c}{dt} \quad u_R \quad Ri \quad RC \frac{du_c}{dt}$$

$$\text{KVL} \quad RC \frac{du_c}{dt} \quad u_C \quad 0$$



“ ”

$$RC \frac{du_c}{dt} + u_c = 0$$

$$RCp + 1 = 0 \quad p = -\frac{1}{RC}$$

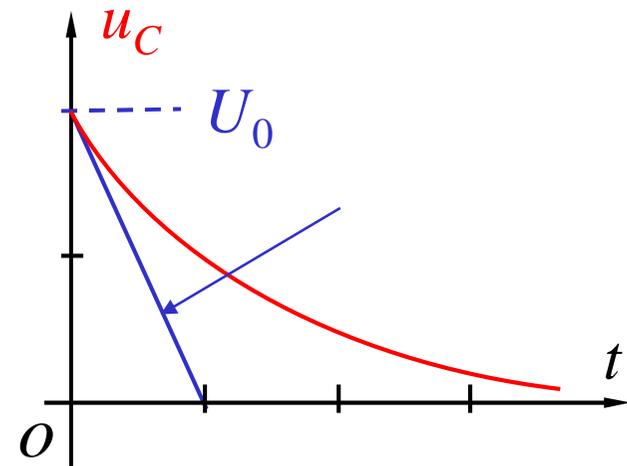
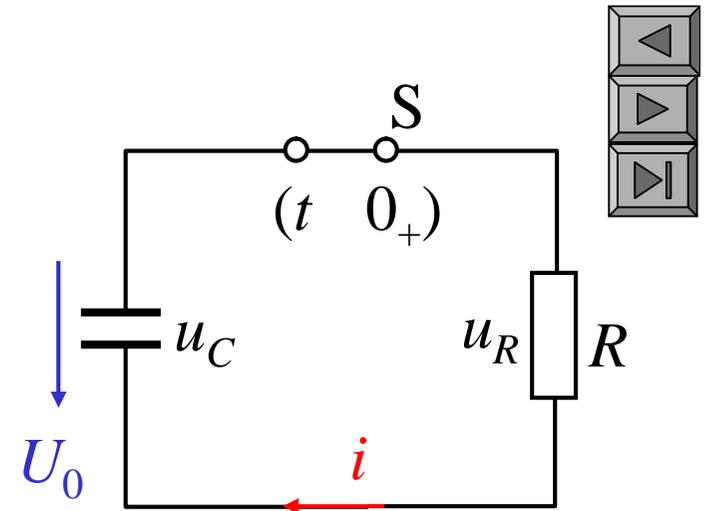
$$u_c = A e^{-\frac{1}{RC}t}$$

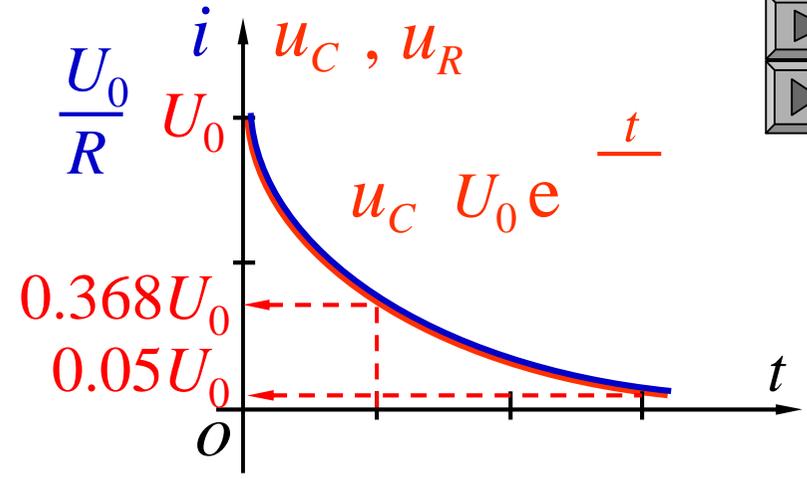
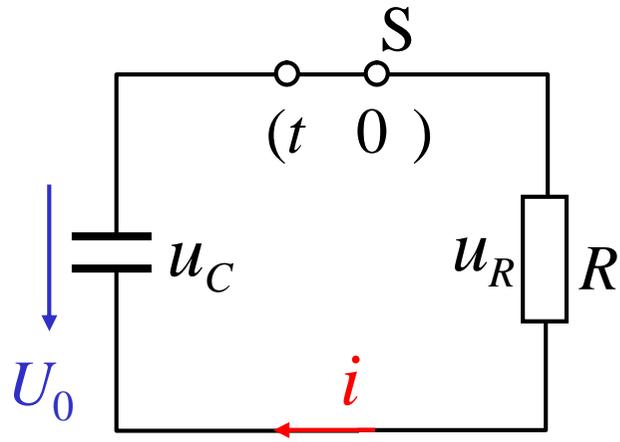
$$u_c(0) = u_c(0) = U_0$$

$$u_c = U_0 e^{-\frac{1}{RC}t} = U_0 e^{-\frac{t}{RC}}$$

$$\frac{RC}{R} = \frac{RC}{C} = R$$

$$u_c$$





•

$$u_C = U_0 e^{-\frac{t}{RC}}$$

•

3 5

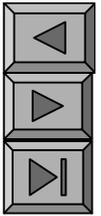
$$u_R = U_0 e^{-\frac{t}{RC}}$$

$$i = \frac{U_0}{R} e^{-\frac{t}{RC}}$$

$$W_R = \int_0^{\infty} i^2(t) R dt$$

$$= \frac{U_0^2}{R} \int_0^{\infty} e^{-\frac{2}{RC}t} dt = \frac{1}{2} C U_0^2$$

$$C \quad R$$



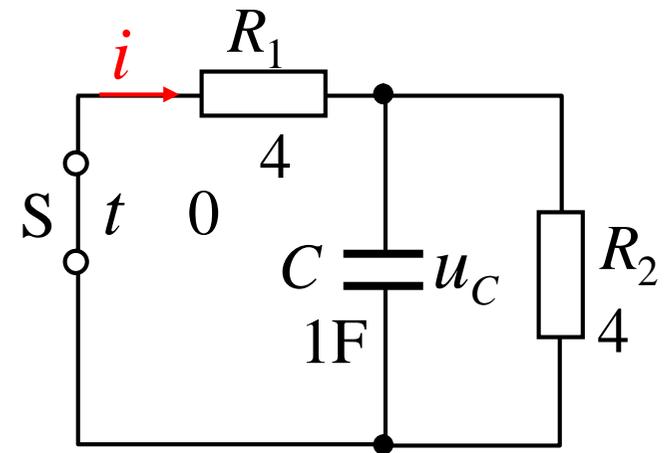
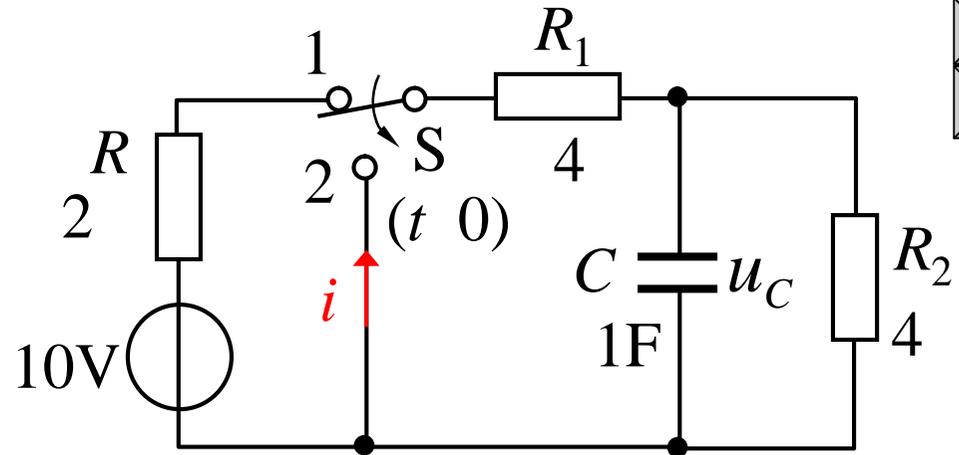
$$u_C(0^-) = \frac{10 \times 4}{2+4+4} = 4 \text{ V}$$

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

$$R_{eq} = R_1 // R_2 = 2 \Omega$$

$$\tau = R_{eq} C = 2 \text{ s}$$

$$u_C(t) = u_C(0^+) e^{-\frac{t}{\tau}} = 4 e^{-0.5t} \text{ V} \quad (t \geq 0)$$



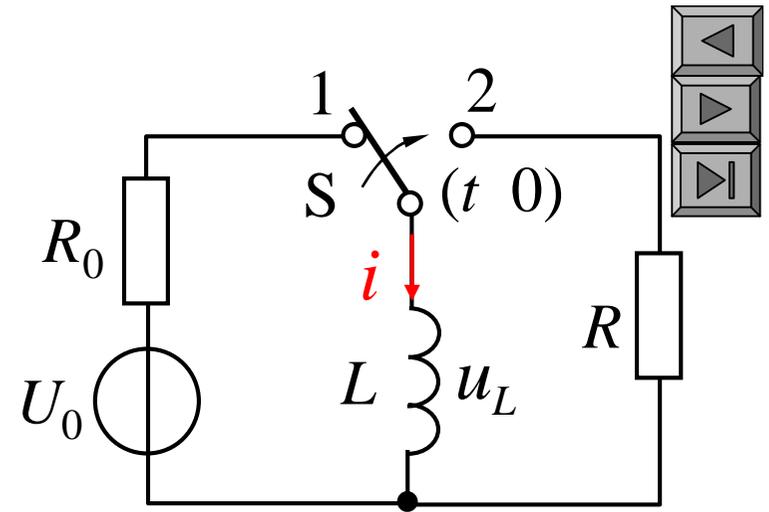
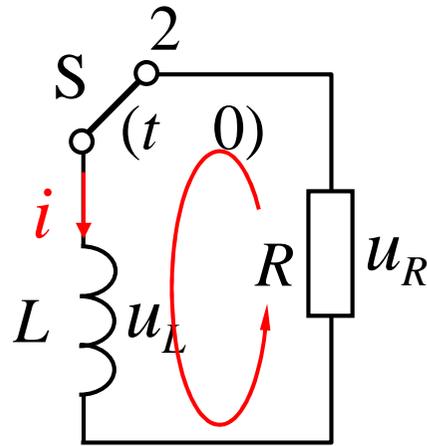
$$i(t) = \frac{1}{2} \frac{u_C}{R_{eq}} e^{-0.5t} \text{ A} \quad (t \geq 0)$$

2. RL

KVL

$$u_L + u_R = 0$$

$$L \frac{di}{dt} + Ri = 0$$



$$\frac{L}{R} \frac{di}{dt} + i = 0 \longrightarrow i(t) = i(0) e^{-\frac{t}{\tau}}$$

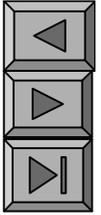
$$i(0) = i(0) = \frac{U_0}{R_0}$$

$$i(t) = \frac{U_0}{R_0} e^{-\frac{t}{\tau}}$$

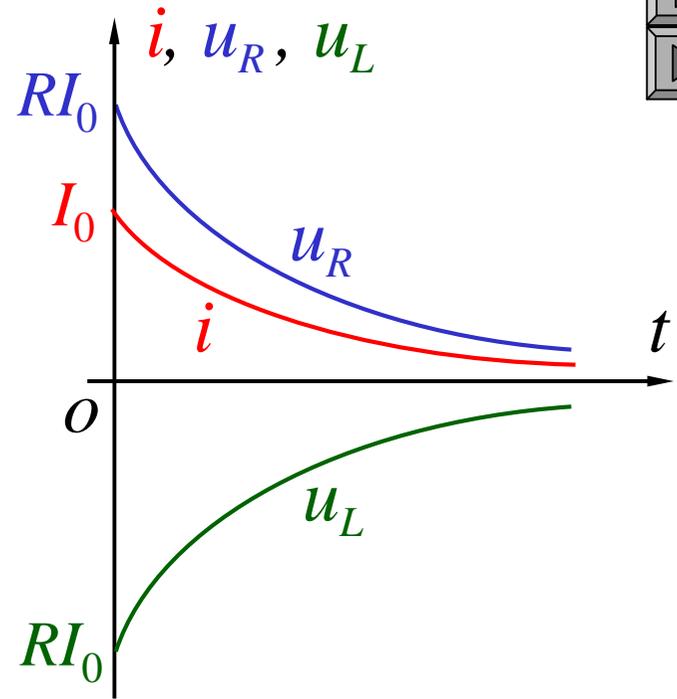
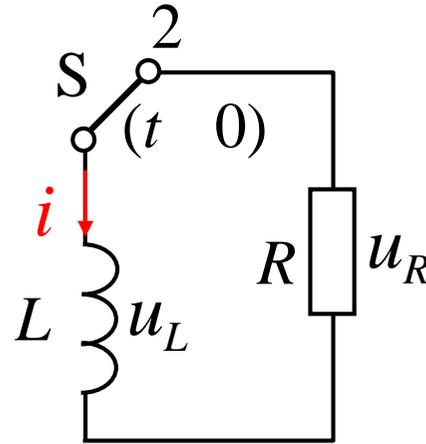
$$i(t) = I_0 e^{-\frac{t}{\tau}} \quad (t \geq 0)$$

$$\frac{L}{R} \quad RL$$

$$[s] \quad \underline{[H]}$$



$$i(t) = I_0 e^{-\frac{t}{\tau}}$$



$$u_R = Ri$$

$$u_R = RI_0 e^{-\frac{t}{\tau}} \quad (t \geq 0)$$

$$u_L = u_R - RI_0 e^{-\frac{t}{\tau}} \quad (t \geq 0)$$

$$u_L = L \frac{di}{dt} = RI_0 e^{-\frac{t}{\tau}} \quad (t \geq 0)$$

3. P144 7 2

$i(0^-)$ $i(0^+)$

$i(t)$ $u_V(t)$ $u_V(0^+)$

$$\frac{L}{R+R_V} \quad \frac{0.398}{0.189 \cdot 5 \times 10^3}$$

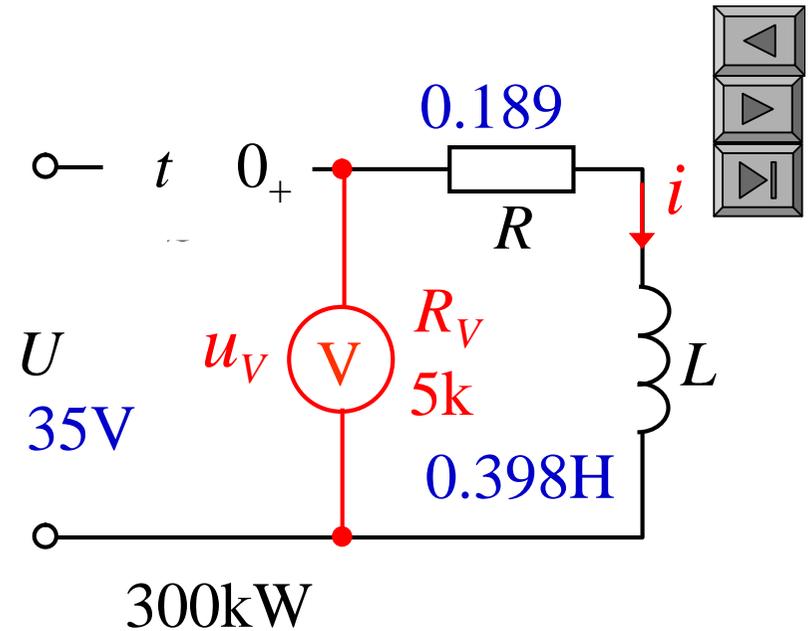
s)

$$i(0^+) = \frac{U}{R} = \frac{35}{0.189} = 185.2 \text{ A} \quad i(0^-)$$

$$i(t) = 185.2 e^{-12560t} \text{ A}$$

$$u_V(t) = R_V i(t) = 926 e^{-12560t} \text{ kV}$$

$$u_V(0^+) = 926 \text{ kV} ! \quad 50\text{V}$$



§ 7-3

0

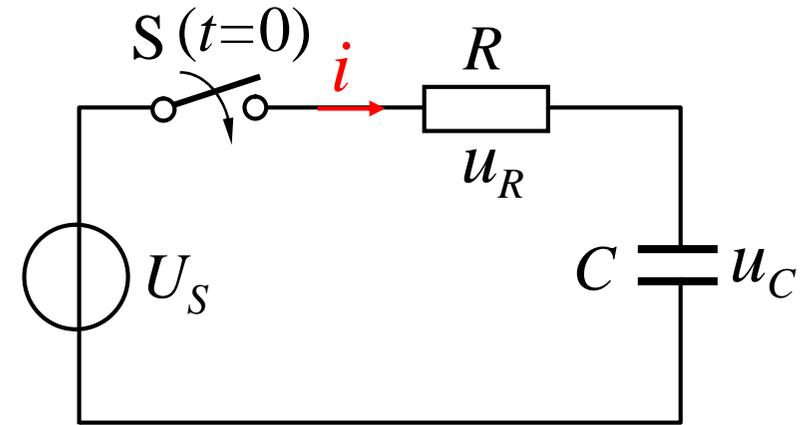
1. RC

KVL $u_R + u_C = U_S$

$u_R = Ri = RC \frac{du_C}{dt}$

$RC \frac{du_C}{dt} + u_C = U_S$

$u_C \quad u'_C \quad u''_C$



$RC \frac{du_C}{dt} + u_C = 0$

$u''_C = A e^{-\frac{1}{RC}t}$

$u'_C = U_S$

$u_C = U_S + A e^{-\frac{1}{RC}t}$



$$RC \frac{du_c}{dt} + u_c = U_s$$

$$u_c = U_s + A e^{-\frac{t}{RC}}$$

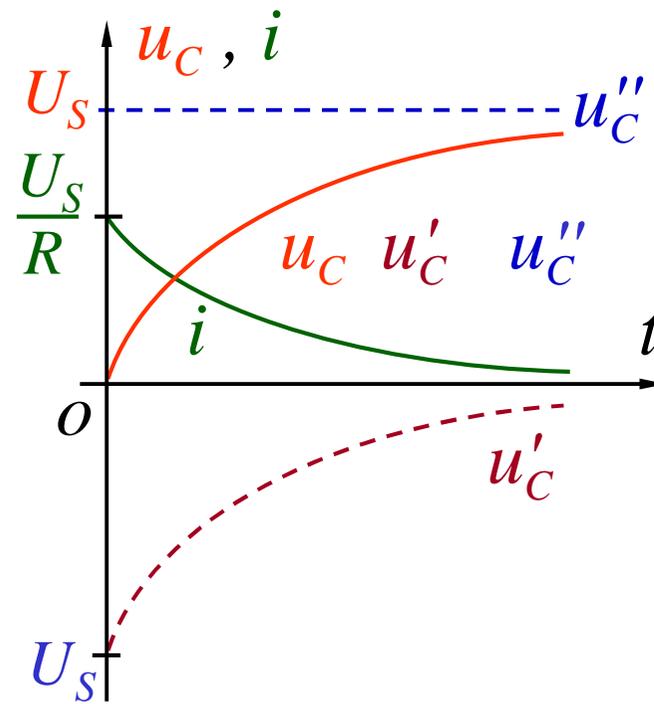
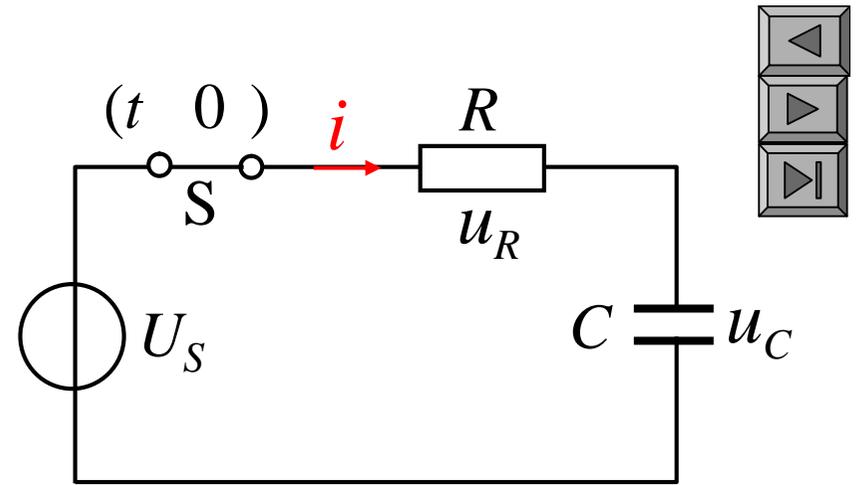
$$u_c(0) = u_c(0) = 0$$

$$A = -U_s$$

$$u_c = U_s (1 - e^{-\frac{t}{RC}})$$

$$i = C \frac{du_c}{dt} = \frac{U_s}{R} e^{-\frac{t}{RC}}$$

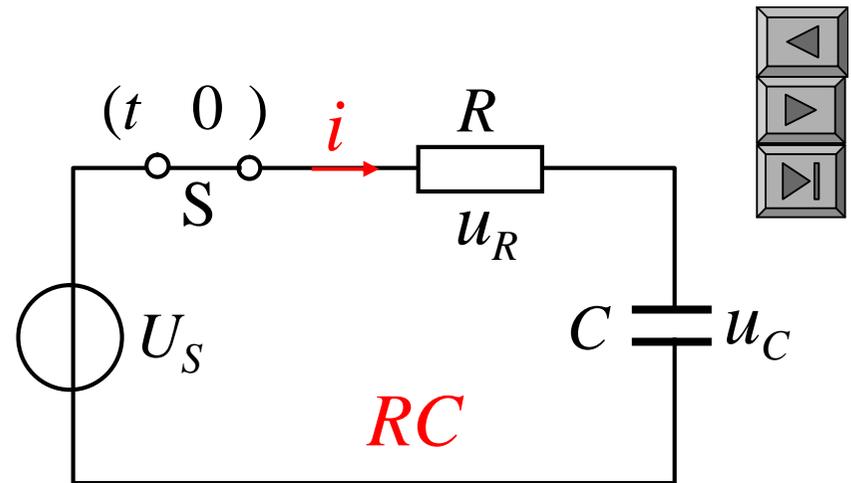
$$u_c = U_s - U_s e^{-\frac{t}{RC}}$$



$$RC \frac{du_c}{dt} + u_c = U_S$$

$$u_c = U_S + A e^{-\frac{t}{RC}}$$

$$i = C \frac{du_c}{dt} = \frac{U_S}{R} e^{-\frac{t}{RC}}$$



$$W = \int_0^{\infty} U_S i(t) dt = CU_S^2$$

$$W_R = \int_0^{\infty} i^2(t) R dt = \frac{1}{2} CU_S^2$$

C

R

RC

50%

2. RL

(1)

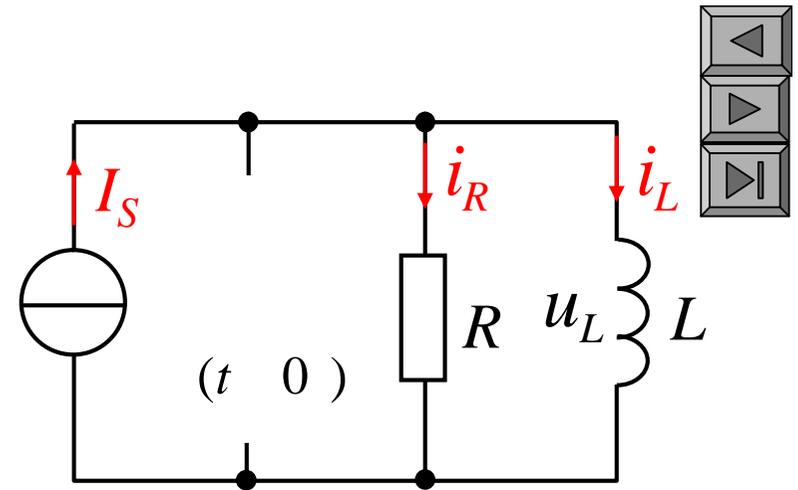
$$i_L(0^-) = i_L(0^+) = 0$$

$$i_R = i_L = I_S$$

$$i_R = \frac{u_L}{R} = \frac{L}{R} \frac{di_L}{dt}$$

$$\underline{\underline{\frac{L}{R} \frac{di_L}{dt} = i_L = I_S}}$$

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

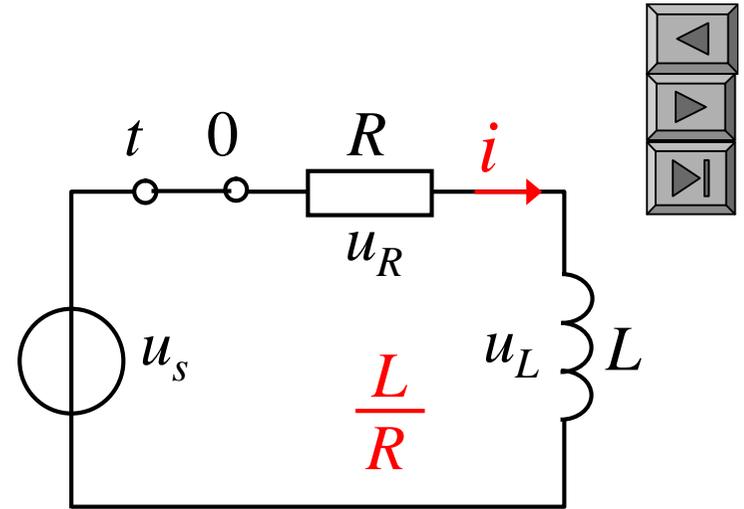


(2)

$$u_s = U_m \cos(\omega t + \varphi_u)$$

$$L \frac{di_L}{dt} + Ri_L = U_m \cos(\omega t + \varphi_u)$$

$$i''_L + A e^{-\frac{t}{\tau}}$$



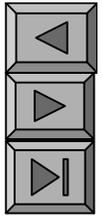
$$i'_L = I_m \cos(\omega t + \varphi_i) \quad I_m$$

$$i'_L$$

$$RI_m \cos(\omega t + \varphi_i) - LI_m \sin(\omega t + \varphi_i) = U_m \cos(\omega t + \varphi_u)$$

$$I_m |Z| \cos(\omega t + \varphi_i) = U_m \cos(\omega t + \varphi_u)$$

$$|Z| = \sqrt{R^2 + (\omega L)^2} \quad \text{tg} \varphi = \frac{\omega L}{R}$$



$$I_m |Z| \cos(t - \varphi) = U_m \cos(t - \varphi)$$

$$|Z| = \sqrt{R^2 + (\omega L)^2} \quad \varphi = \operatorname{tg}^{-1} \frac{\omega L}{R}$$

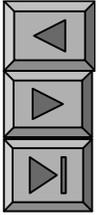
$$I_m = \frac{U_m}{|Z|}$$

$$i'_L = I_m \cos(t - \varphi) = \frac{U_m}{|Z|} \cos(t - \varphi)$$

$$i_L = \frac{U_m}{|Z|} \cos(t - \varphi) + A e^{-\frac{t}{\tau}}$$

$$i_L(0) = i_L(0) = 0 \quad A = \frac{U_m}{|Z|} \cos \varphi$$

$$i_L = \frac{U_m}{|Z|} \cos(t - \varphi) + \frac{U_m}{|Z|} \cos \varphi e^{-\frac{t}{\tau}}$$

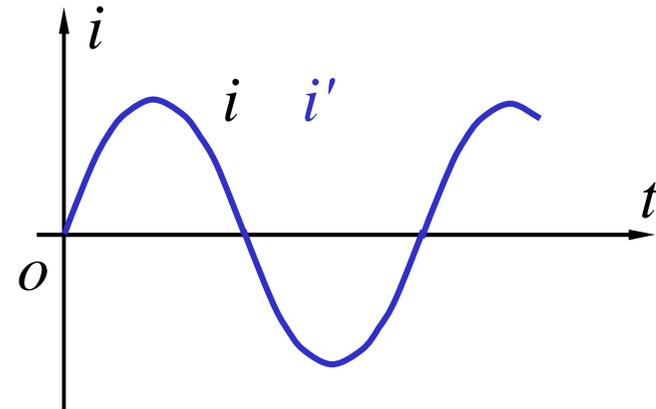


$$i_L = \frac{U_m}{|Z|} \cos(\omega t - \varphi) + \frac{U_m}{|Z|} \cos(\omega t - \varphi) e^{-\frac{t}{\tau}}$$

i'_L
 i''_L

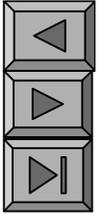
$$R \quad u_R = R i_L \quad L \quad u_L = L \frac{di_L}{dt}$$

(1) $\varphi = \pm 90^\circ$
 $i''_L = 0$

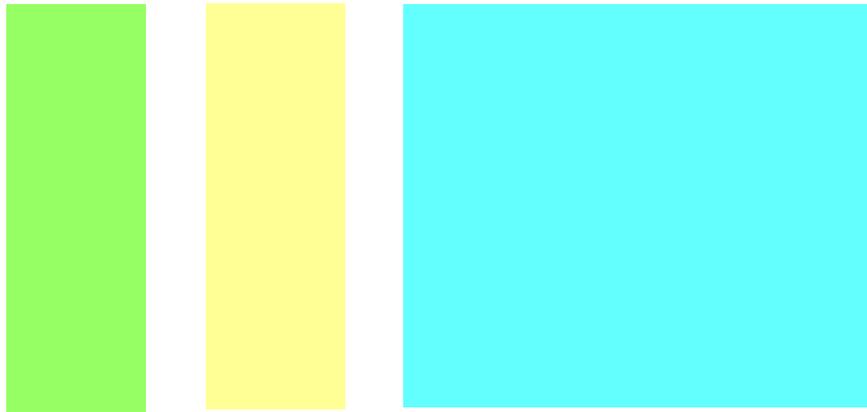
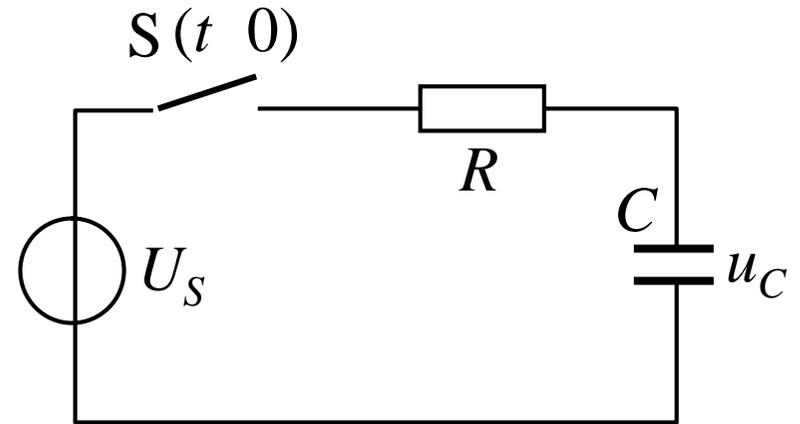


(2) $\varphi = 0$
 $i_L = \frac{U_m}{|Z|} \cos \omega t + \frac{U_m}{|Z|} e^{-\frac{t}{\tau}}$

§ 7 4

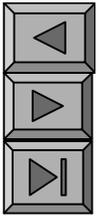
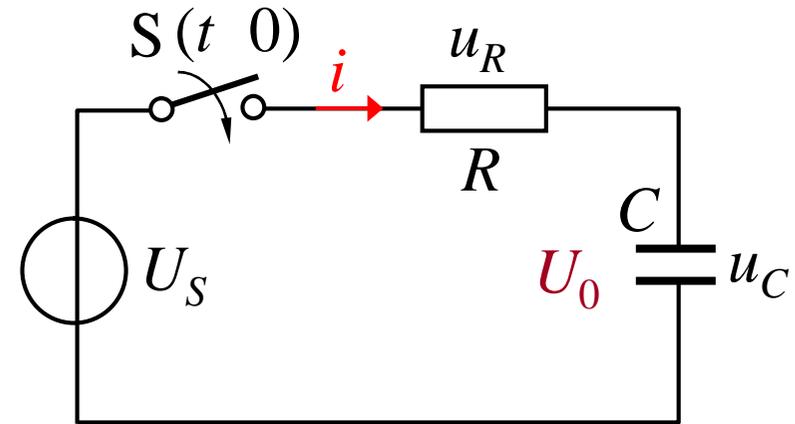
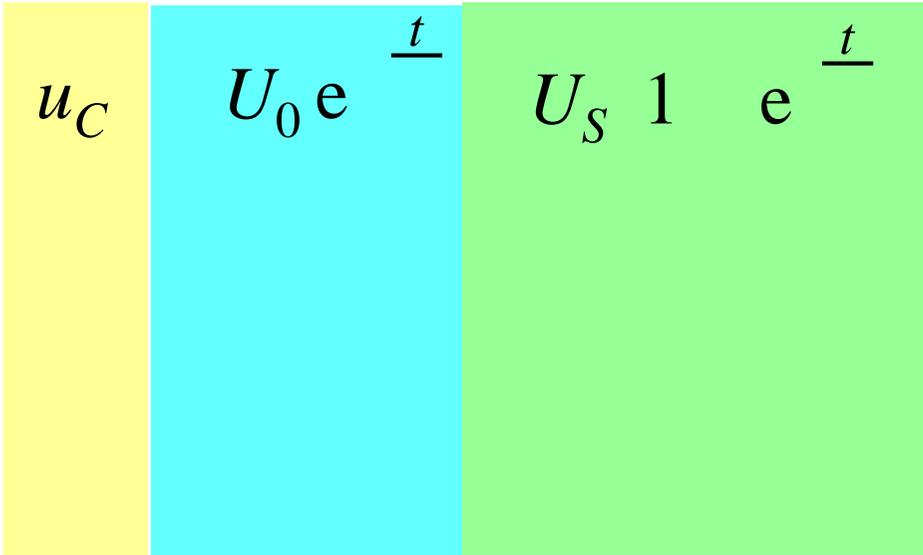


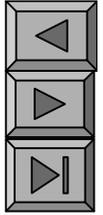
1.



$$u_C = U_S - U_0 e^{-\frac{t}{\tau}}$$

(2)





3.

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

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

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

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

$f(t)$

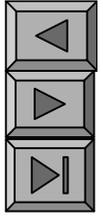
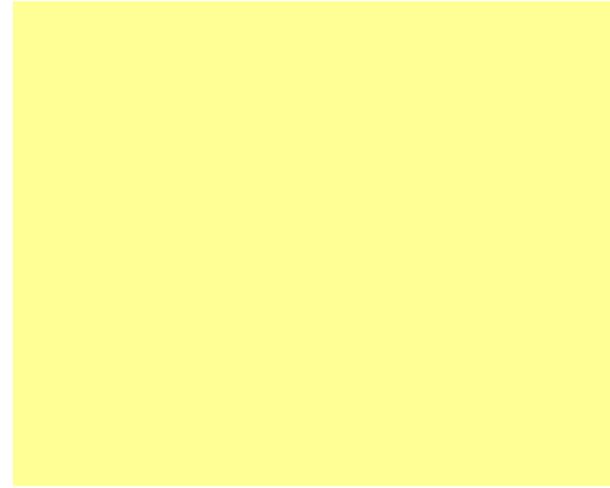
$f(0_+)$

$f(t)$

$f(0_-)$

4.

1

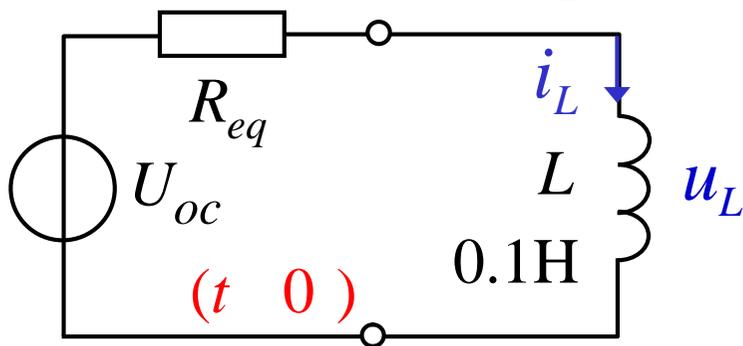


2

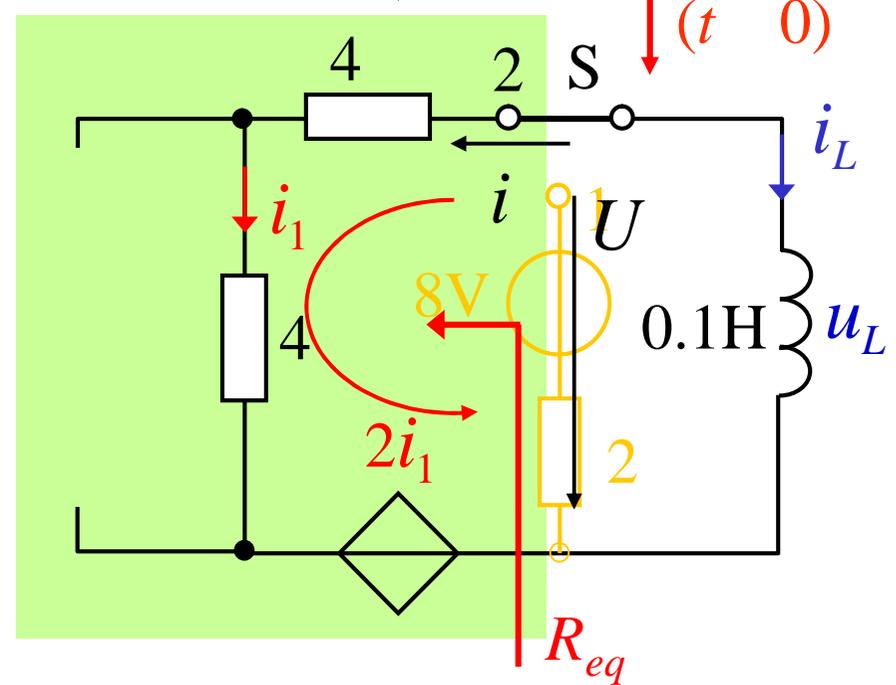
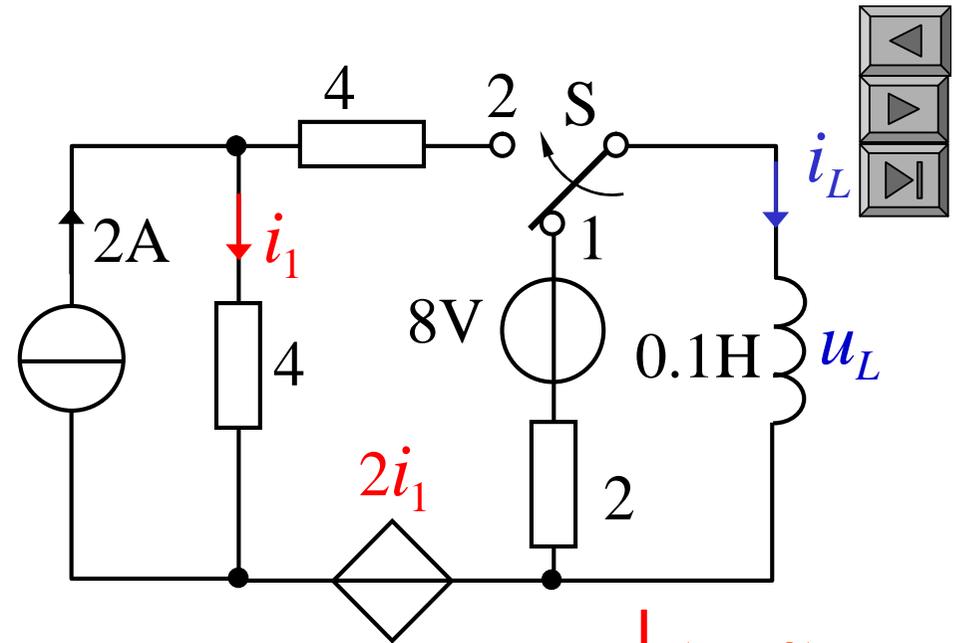
$$i_L(0^-) = 4A \quad u_L(0^-)$$

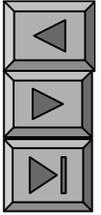
$$U_{oc} = 4i_1 + 2i_1 = 12V$$

$$R_{eq} = \frac{U}{i} = \frac{(4+4)i_1 + 2i_1}{i_1} = 10$$



$$u_L(0^+) = U_{oc} - R_{eq} i_L(0^+) = 12 - 10 \times (4) = -52V$$





$$2 \quad u_L \quad \frac{L}{R_{eq}} \quad \frac{0.1}{10} \quad 0.01s$$

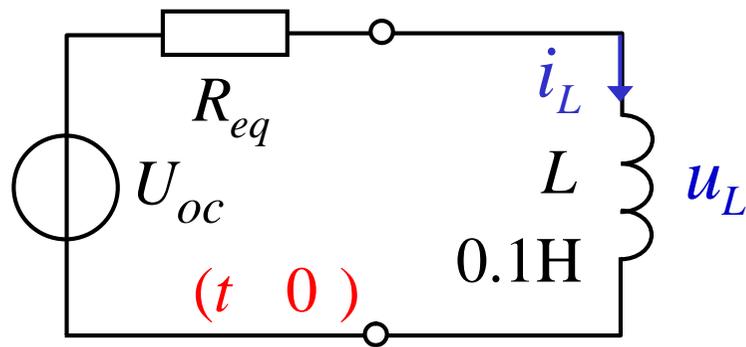
$$i_L(0) \quad 4A \quad i_L(0) \quad u_L() \quad 0$$

$$U_{oc} \quad 4i_1 \quad 2i_1 \quad 12V$$

$$f(t) \quad f() \quad [f(0) \quad f()] e^{-\frac{t}{\tau}}$$

$$R_{eq} \quad \frac{U}{i} \quad 10$$

$$u_L \quad 52e^{-100t} \quad V$$



$$i_L(0) \quad 4A \quad i_L(0)$$

$$i_L() \quad U_{oc} / R_{eq}$$

$$0.01s$$

$$u_L(0) \quad U_{oc} \quad R_{eq} i_L(0)$$

$$52V$$

$$i_L \quad e^{-100t} \quad A$$

$$u_L \quad L \frac{di_L}{dt} \quad u_L$$

3

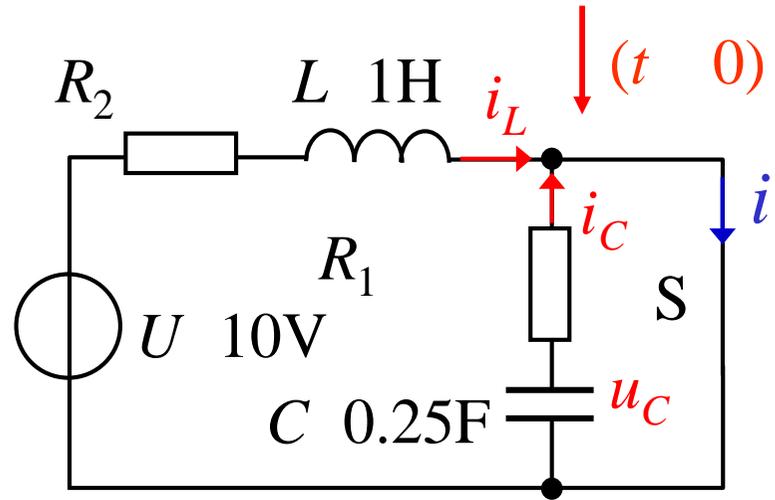
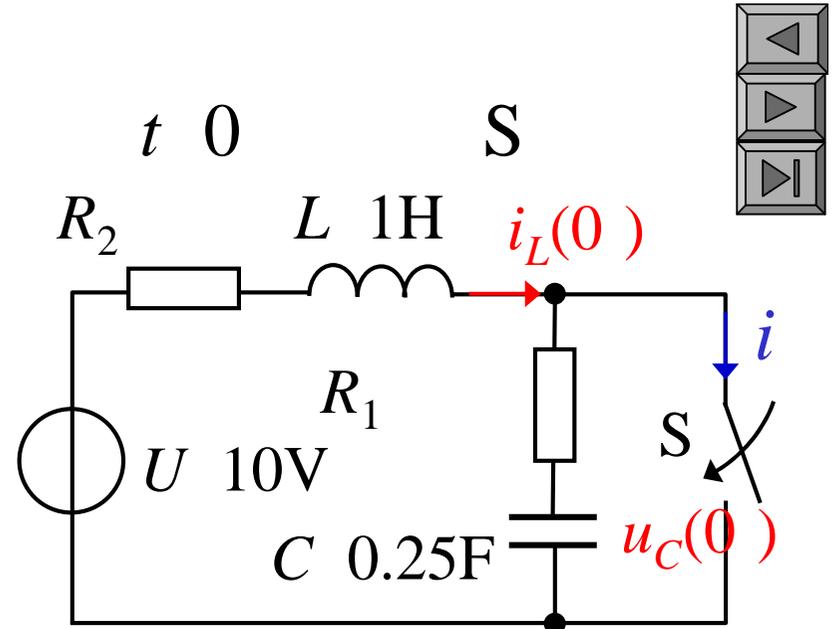
$i_L(0^-)$ 0 $u_C(0^-)$ $10V$
 $i(t)$

$i_C(0^-)$ $u_C(0^-)$ R_1 $5A$
 $R_1 C$ $0.5s$, $i_C(0^-)$ 0

$i_L(0^+)$ $i_L(0^-)$ 0

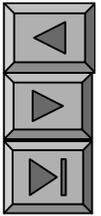
L R_2 $0.2s$,

$i_L(0^+)$ U R_2 10 5 $2A$

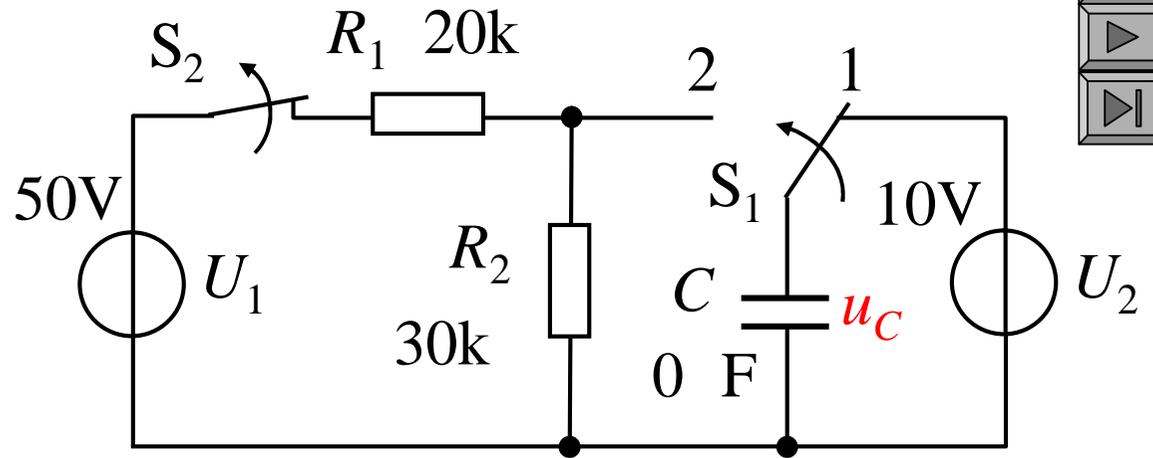


$i_C(t)$ $i_L(t)$

$i(t)$ $i_L(t)$ $i_C(t)$

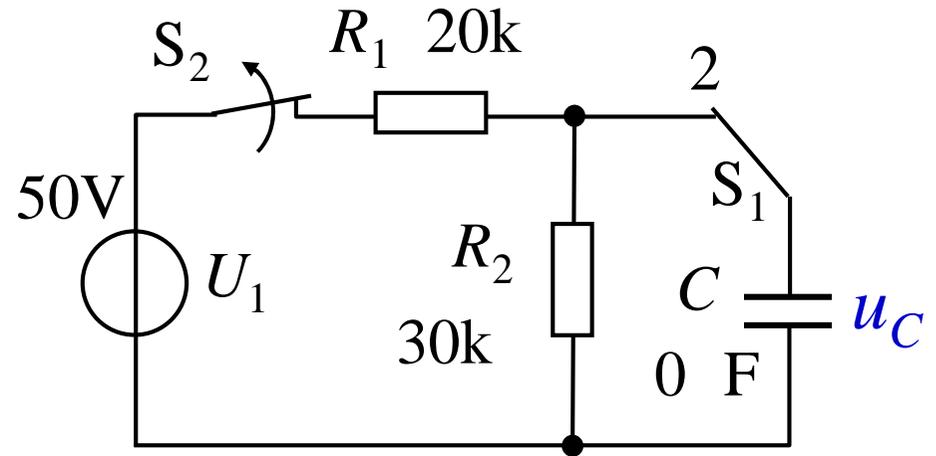


4
 $t = 0$ S_1 1
 2 0.12s
 S_2 $u_C(t)$



$u_C(0^-) = 10V$

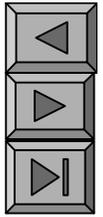
(1) $t = 0.12s$
 $u_C(0^+) = u_C(0^-) = 10V$



$u_C(t) = \frac{30}{20+30} \times 50 = 30V$

$\tau = (20 \parallel 30) \times 10 \times 10^{-6} = 0.12s$

$u_C(t) = 30 + 40e^{-8.33t} V \quad (0 < t < 0.12s)$



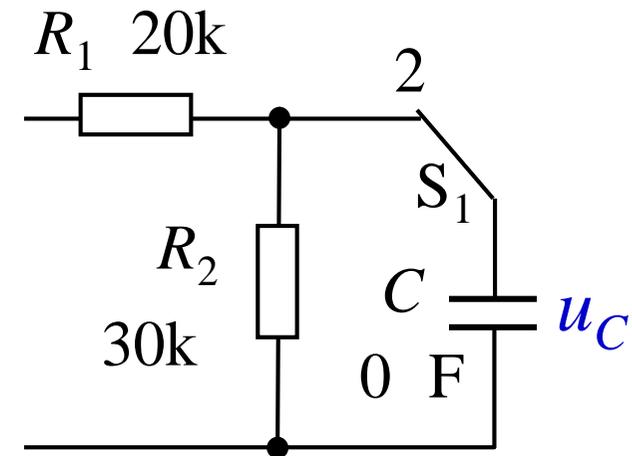
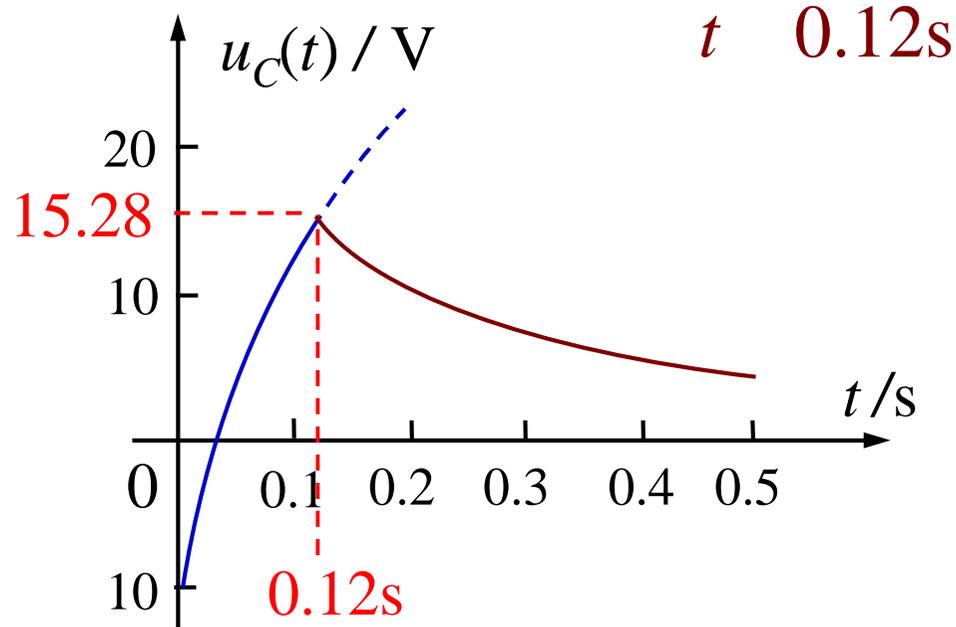
$$u_C(t) = 30 + 40e^{-8.33t} \text{ V} \quad (0 \leq t < 0.12\text{s})$$

$$u_C(0.12) = 30 + 40e^{-8.33 \times 0.12} = 15.28\text{V}$$

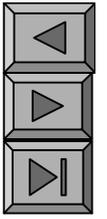
$$(2) \quad t \geq 0.12\text{s} \quad u_C(0.12) = u_C(0.12) = 15.28\text{V}$$

$$\tau = R_2 C = 30 \times 10^3 \times 10 \times 10^{-6} = 0.3\text{s}, \quad u_C(\infty) = 0$$

$$u_C(t) = 15.28e^{-3.33(t - 0.12)} \text{ V} \quad t \geq 0.12\text{s}$$



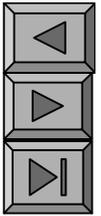
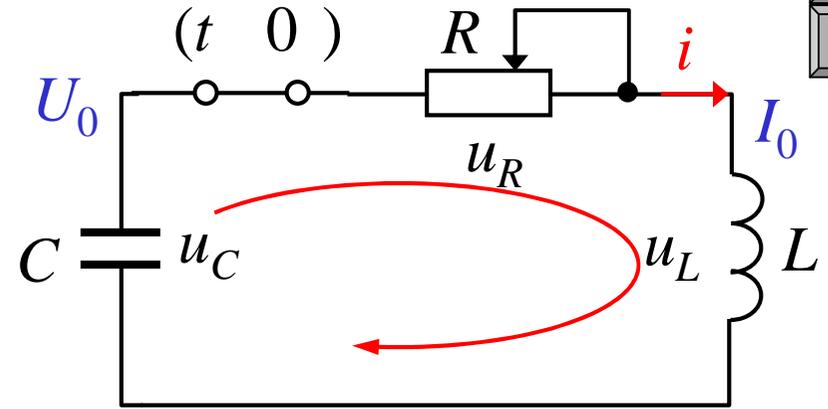
§ 7 5



(RLC)

1.

KVL $u_C + Ri + u_L = 0$



$i = C \frac{du_C}{dt} + Ri + L \frac{di}{dt} = 0$

$LC \frac{d^2u_C}{dt^2} + RC \frac{du_C}{dt} + u_C = 0$

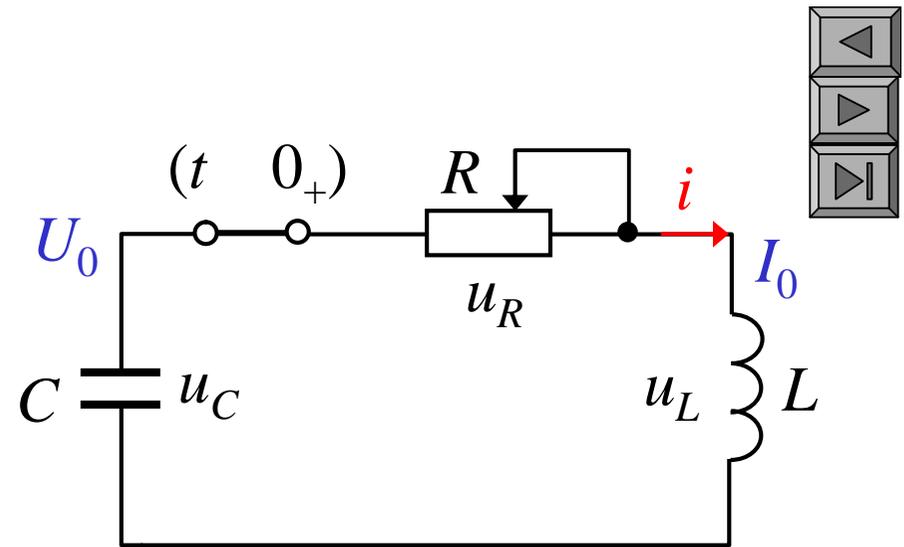
$u_C(0) = U_0, \quad i(0) = 0, \quad \left. \frac{du_C}{dt} \right|_{t=0} = \frac{i(0)}{C} = 0$

$$LC \frac{d^2 u_C}{dt^2} + RC \frac{du_C}{dt} + u_C = 0$$

$$u_C(0) = U_0 \quad \left. \frac{du_C}{dt} \right|_{t=0} = 0$$

2.

$$LCp^2 + RCp + 1 = 0$$

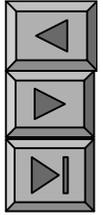


(1)

$$p_1 = \frac{R}{2L} \pm \sqrt{\left(\frac{R}{2L}\right)^2 - \frac{1}{LC}}$$

(2) R L C

$$p_2 = \frac{R}{2L} \pm \sqrt{\left(\frac{R}{2L}\right)^2 - \frac{1}{LC}}$$



$$LC \frac{d^2 u_C}{dt^2} + RC \frac{du_C}{dt} + u_C = 0 \quad p_{1,2} = \frac{R}{2L} \pm \sqrt{\left(\frac{R}{2L}\right)^2 - \frac{1}{LC}}$$

$$u_C(0) = U_0 \quad \left. \frac{du_C}{dt} \right|_{t=0} = 0$$

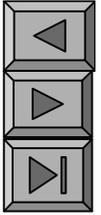
3.

$$(1) R < 2\sqrt{\frac{L}{C}} \quad p_1 \neq p_2$$

$$u_C = A_1 e^{p_1 t} + A_2 e^{p_2 t}$$

$$A_1 = \frac{p_2 U_0}{p_2 - p_1} \quad A_2 = \frac{p_1 U_0}{p_2 - p_1}$$

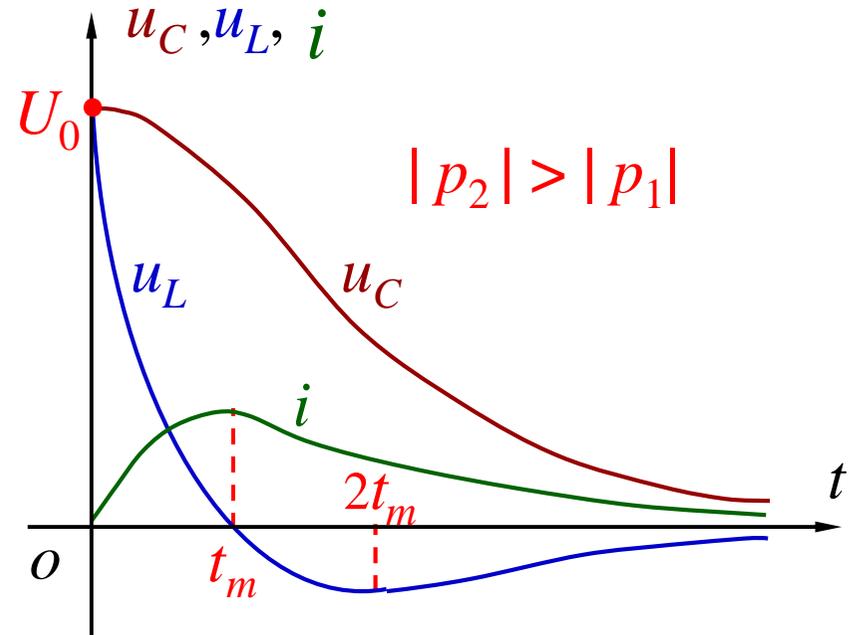
$$u_C = \frac{U_0}{p_2 - p_1} (p_2 e^{p_1 t} - p_1 e^{p_2 t})$$



$$u_C = \frac{U_0}{p_2 - p_1} (p_2 e^{p_1 t} - p_1 e^{p_2 t}) \quad p_1 p_2 = \frac{1}{LC}$$

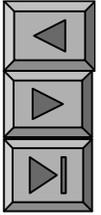
$$i = C \frac{du_C}{dt} = \frac{U_0}{L(p_2 - p_1)} (e^{p_1 t} - e^{p_2 t})$$

$$u_L = L \frac{di}{dt} = \frac{U_0}{(p_2 - p_1)} (p_1 e^{p_1 t} - p_2 e^{p_2 t})$$

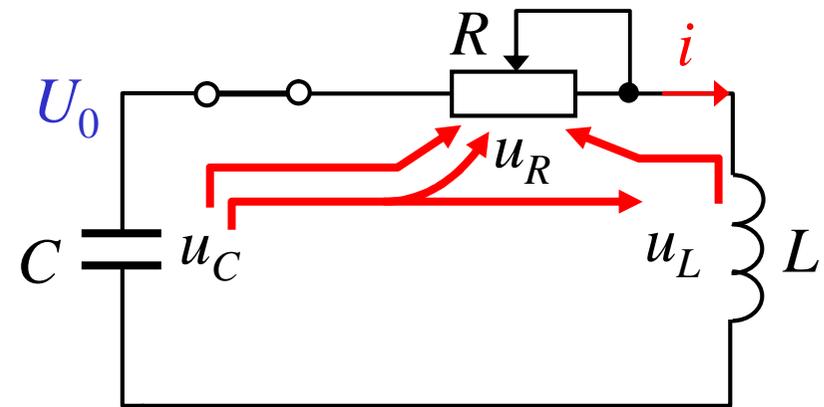
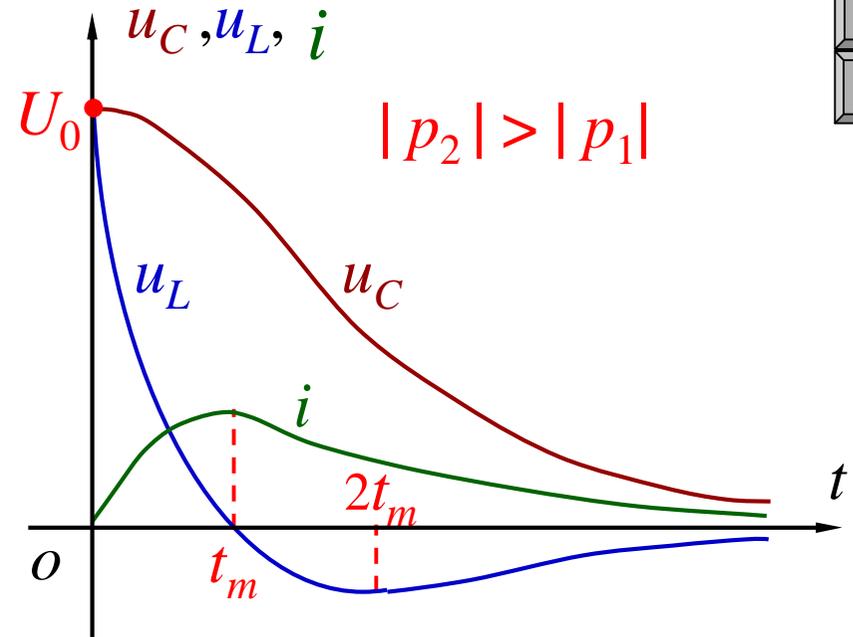


$u_C \quad 0 \quad i \quad 0$

C



i 0 0
 (di/dt) 0
 i i_{\max}
 t_m $\frac{\ln p_2 / p_1}{p_1 p_2}$
 0 t_m C
 L R
 t_m L u_L C
 R



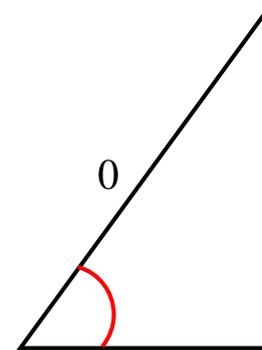


$$(2) \quad R < 2\sqrt{\frac{L}{C}} \quad p_{1,2} = \frac{R}{2L} \pm \sqrt{\left(\frac{R}{2L}\right)^2 - \frac{1}{LC}}$$

$$u_C = e^{-\frac{R}{2L}t} (A_1 \cos \omega t + A_2 \sin \omega t) \quad u_C = e^{-\frac{R}{2L}t} B \sin(\omega t - \theta)$$

$$\begin{cases} u_C(0_+) = U_0 \\ \left. \frac{du_C}{dt} \right|_{t=0} = 0 \end{cases} \quad \begin{cases} B \sin \theta = U_0 \\ B(\omega \cos \theta - \frac{R}{2L} \sin \theta) = 0 \end{cases}$$

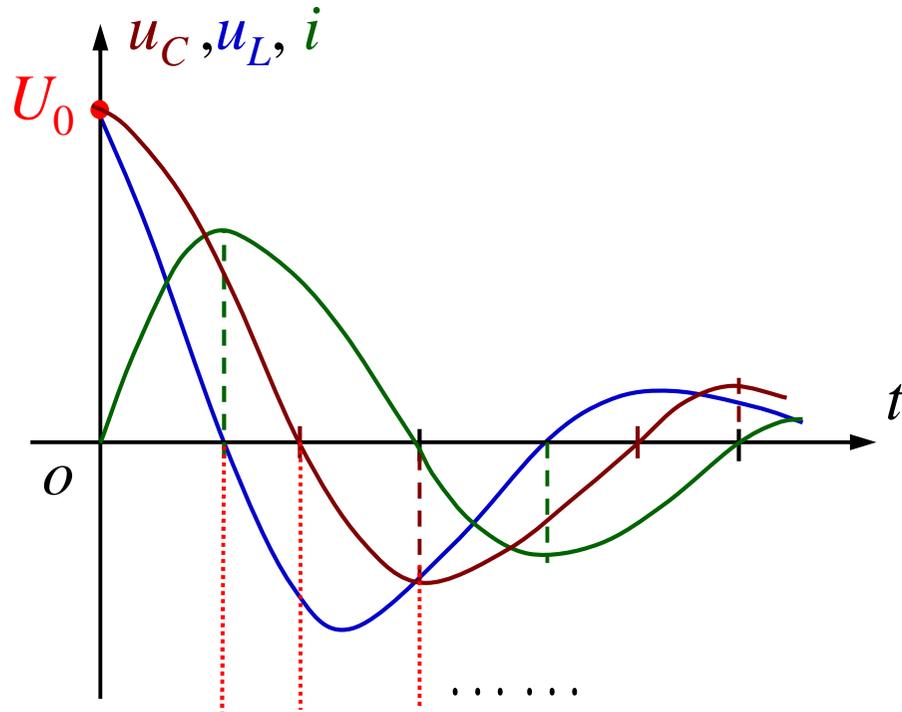
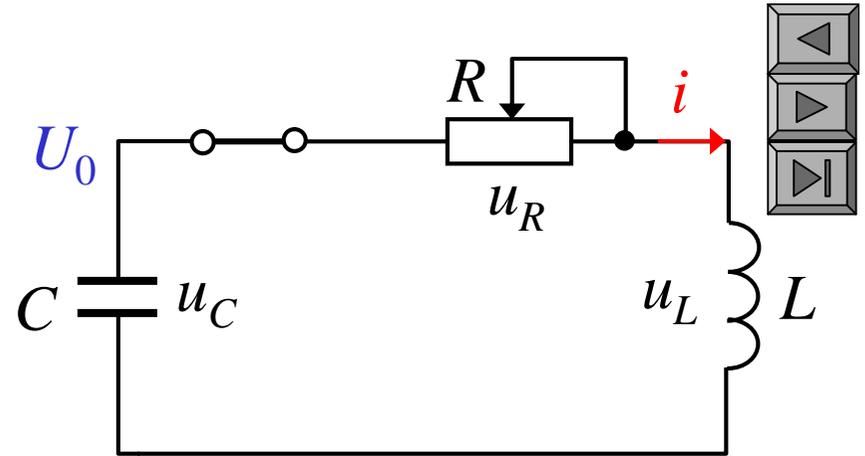
$$B = \frac{U_0}{\sin \theta} \quad \theta = \arctg \frac{B \omega \cos \theta - \frac{R}{2L} \sin \theta}{B \sin \theta} = \arctg \frac{0}{U_0}$$



$$u_C = \frac{U_0}{\omega} e^{-\alpha t} \sin(\omega t)$$

$$i = C \frac{du_C}{dt} = \frac{U_0}{L} e^{-\alpha t} \sin(\omega t)$$

$$u_L = L \frac{di}{dt} = \frac{U_0}{\omega} e^{-\alpha t} \sin(\omega t)$$



C		L	R
C	L		R
L		C	R

$R \ 0$

$R \ 0$

$$R = 0 \quad \frac{R}{2L} = 0$$

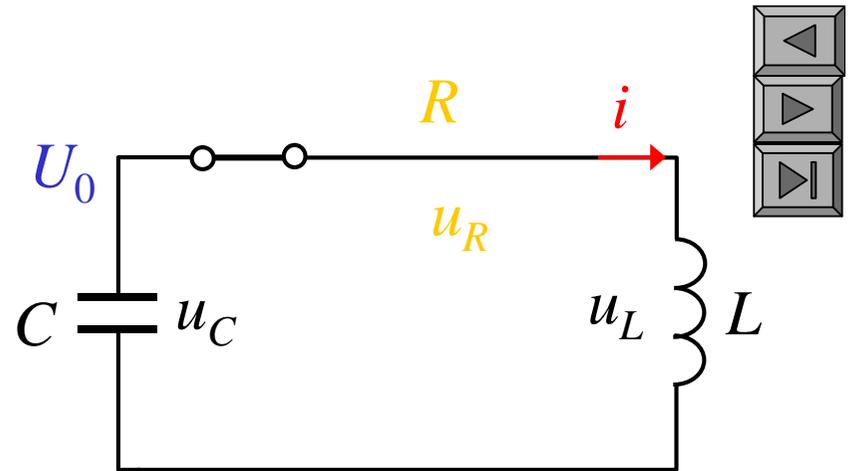
$$\sqrt{\left(\frac{R}{2L}\right)^2 + \frac{1}{LC}} = \frac{1}{\sqrt{LC}}$$

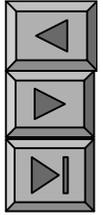
$$\arctg \frac{R}{2L} = 90^\circ$$

$$u_C = \frac{U_0}{\sqrt{LC}} e^{-\frac{R}{2L}t} \sin\left(\frac{1}{\sqrt{LC}}t - 90^\circ\right) = U_0 \sin\left(\frac{1}{\sqrt{LC}}t - 90^\circ\right)$$

$$i = \frac{U_0}{L} e^{-\frac{R}{2L}t} \sin\left(\frac{1}{\sqrt{LC}}t\right) = \frac{U_0}{\sqrt{\frac{L}{C}}} \sin\left(\frac{1}{\sqrt{LC}}t\right)$$

$$u_L = u_C$$





P161 7-7 RLC

U_0 15kV

C 1700 F L 6×10^9 H R 6×10^4

$i(t)$ i i_{\max} i_{\max}

RLC

$$\frac{R}{2L} = \frac{6 \times 10^4}{2 \times 6 \times 10^9} \times 10^4 \text{ s}^{-1}$$

$$\sqrt{\frac{1}{LC} - \left(\frac{R}{2L}\right)^2} = 3.09 \times 10^5 \text{ rad/s}$$

$$i = \frac{U_0}{L} e^{-t} \sin t \times 10^6 e^{50000t} \times \sin(3.09 \times 10^5 t) \text{ A}$$

$$\arctg \text{ — } 1.41 \text{ rad}$$

$$t = t_m \text{ — } 4.56 \text{ (s)}$$

$$i \times 10^6 \text{ A } i_{\max}$$



$$(3) \quad p_{1,2} = \frac{R}{2L} \pm \sqrt{\left(\frac{R}{2L}\right)^2 - \frac{1}{LC}}$$

$$u_C = (A_1 + A_2 t) e^{-t}$$

$$u_C(0_+) = U_0 \quad \left. \frac{du_C}{dt} \right|_{t=0} = \begin{matrix} A_1 & U_0 \\ A_2 & U_0 \end{matrix}$$

$$u_C = U_0 (1 - t) e^{-t}$$

$$i = \frac{U_0}{L} t e^{-t}$$

$$u_L = U_0 e^{-t} (1 + t) \quad \begin{matrix} R > \\ R < \end{matrix} \quad ,$$

§ 7-6

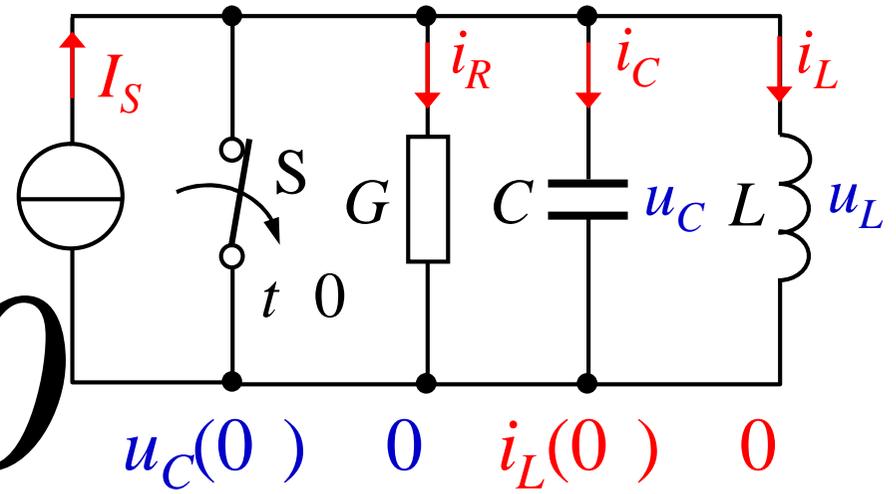


$$i_R \quad Gu_L \quad GL \frac{di_L}{dt}$$

$$i_C \quad C \frac{du_C}{dt} \quad C \frac{du_L}{dt}$$

$$LC \frac{d^2 i_L}{dt^2}$$

$$LC \frac{d^2 \dot{i}_L}{dt^2} \bigcirc$$

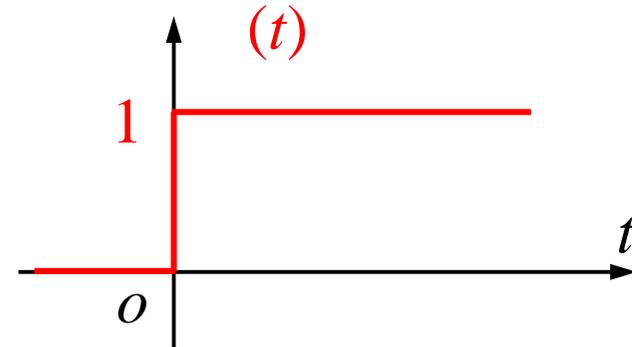


7 7



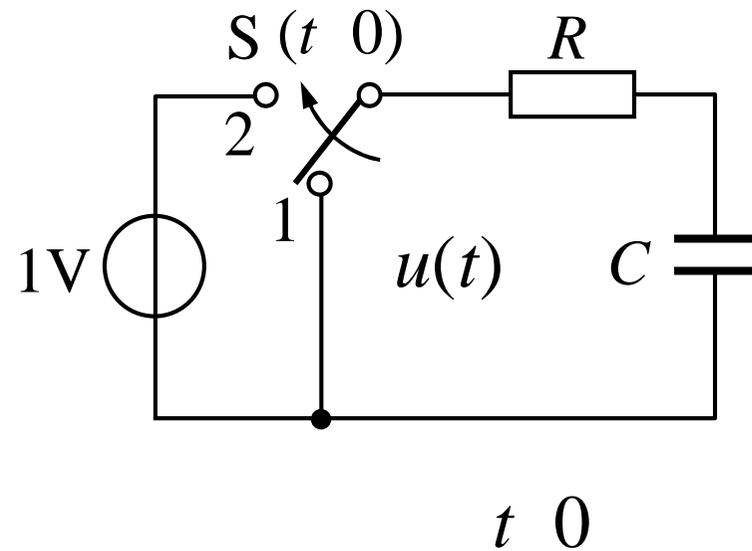
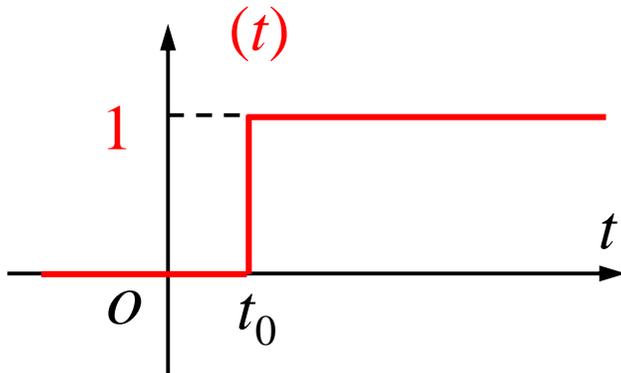
1.

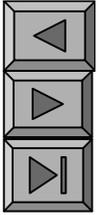
$$(1) \quad (t) \quad \begin{cases} 0 & t & 0 \\ 1 & t & 0 \end{cases}$$



(2) 

$$(t \ t_0) \quad \begin{cases} 0 & t & t_0 \\ 1 & t & t_0 \end{cases}$$

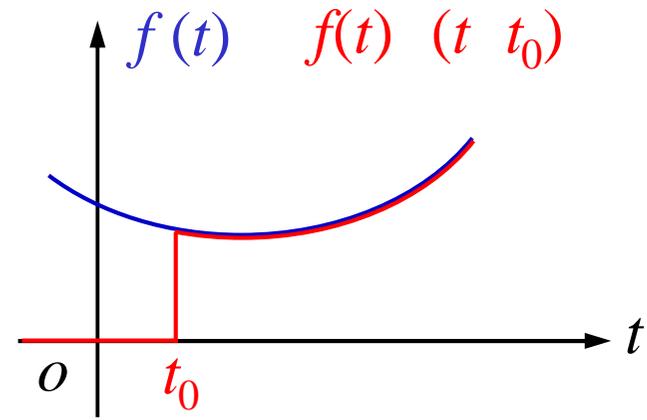




2.

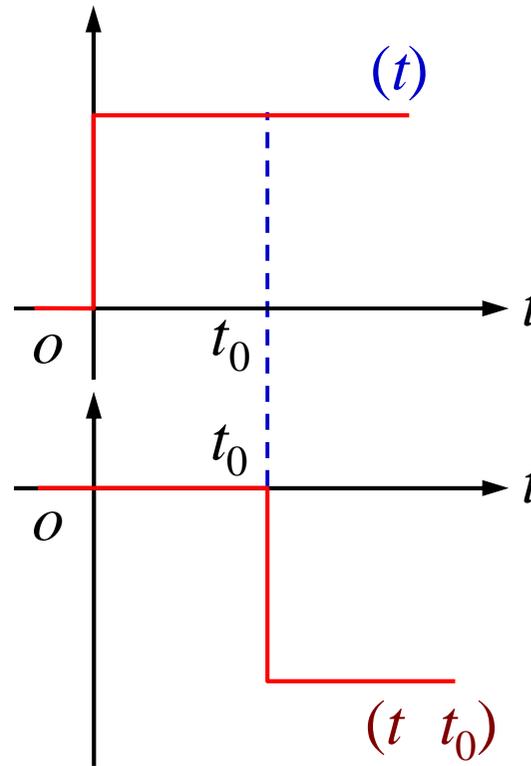
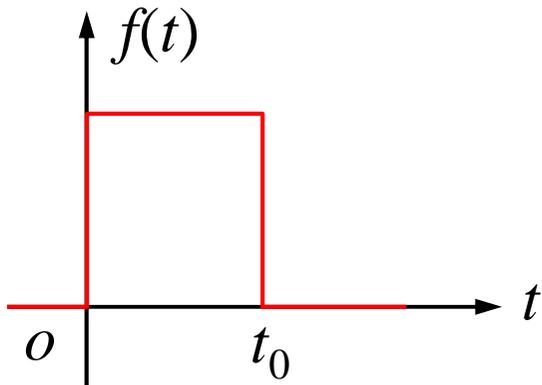
(1)

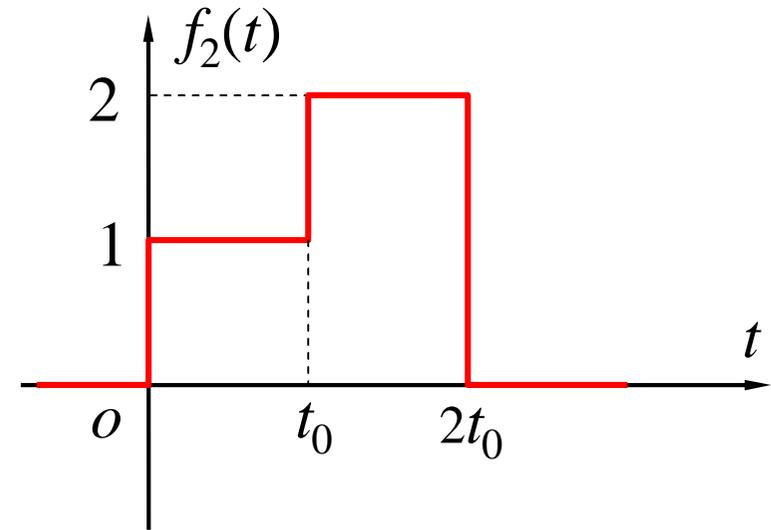
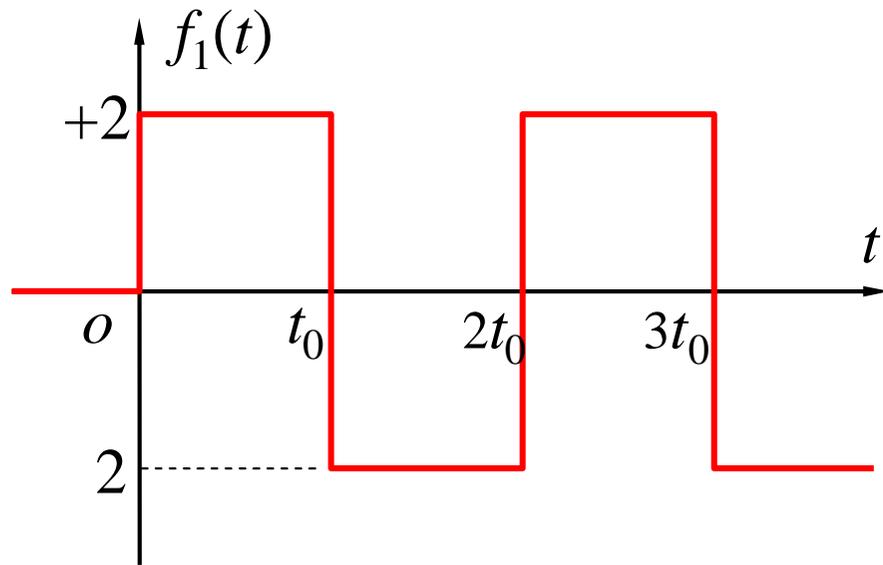
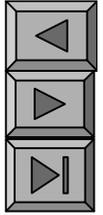
$$f(t) \text{ (t t}_0) \begin{cases} 0 & t < t_0 \\ f(t) & t \geq t_0 \end{cases}$$



(2)

$$f(t) \text{ (t) (t t}_0)$$

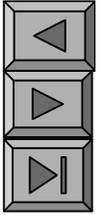




$f_1(t)$ 2 (t) 4 (t t_0) 4 (t $2t_0$) 4 (t $3t_0$) ...

$f_2(t)$ (t) (t t_0) 2 (t $2t_0$)

3.

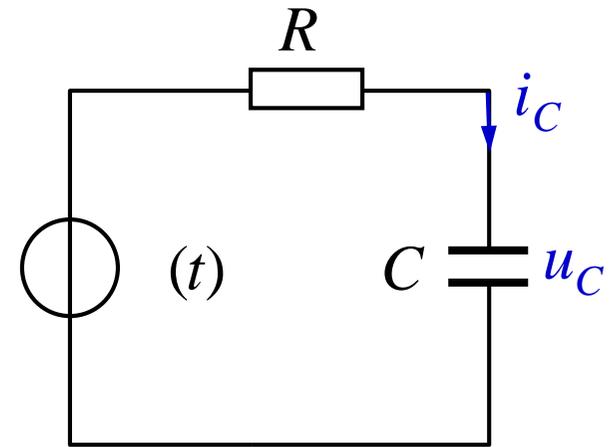


1

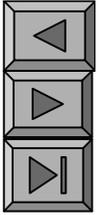
$s(t)$

$u_C(t)$ $i_C(t)$

$u_C(0) = 0$ $u_C(\infty) = 1V$



u_C



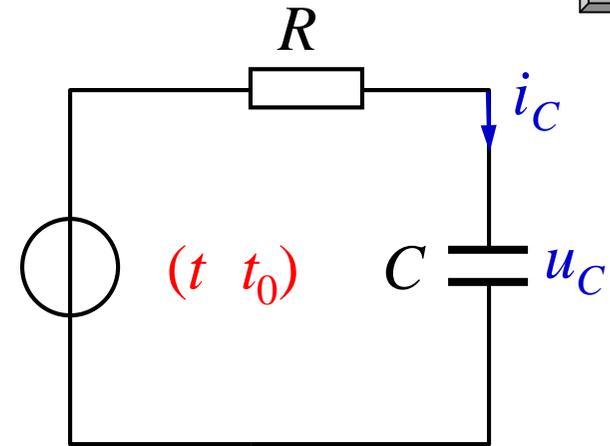
$t - t_0$

$t - t_0$

$$u_C = (1 - e^{-\frac{t - t_0}{RC}}) (t - t_0) \text{ V}$$

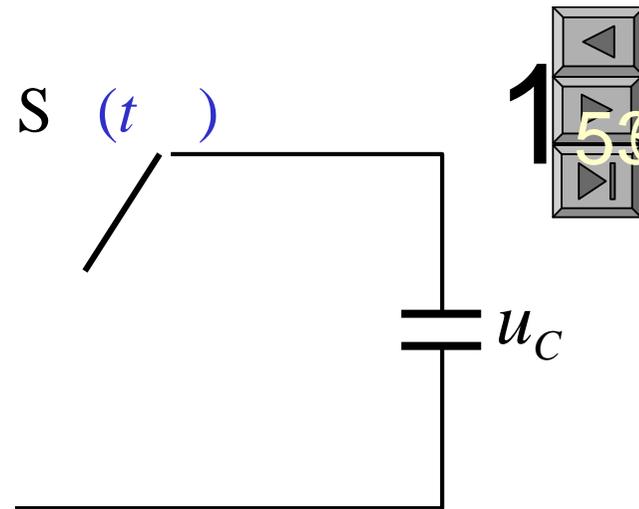
$$i_C = \frac{1}{R} e^{-\frac{t - t_0}{RC}} (t - t_0) \text{ A}$$

$$u_C = (1 - e^{-\frac{t}{RC}}) (t - t_0) \text{ V}$$



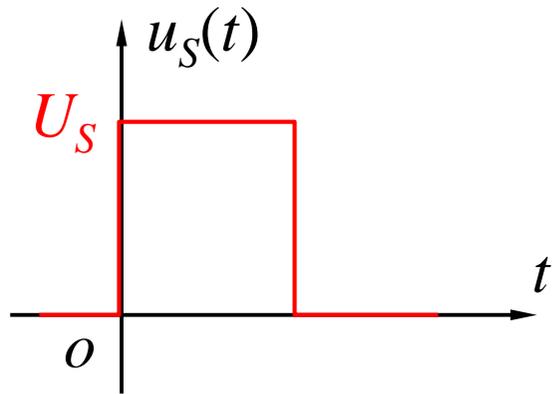
$f(t) (t - t_0)$

2 S 1
 t 0 S 1 2 \ddot{u}
 t S 2 1
 t 0 u_C

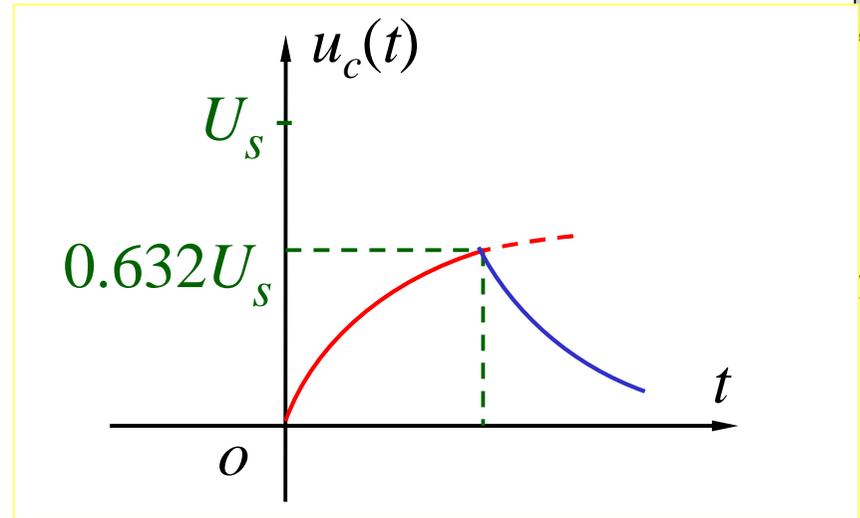


53@žg

2



$$u_S(t) = \begin{cases} 0 & (t < 0) \\ U_S & (0 \leq t \leq \tau) \\ 0 & (t > \tau) \end{cases}$$



RC

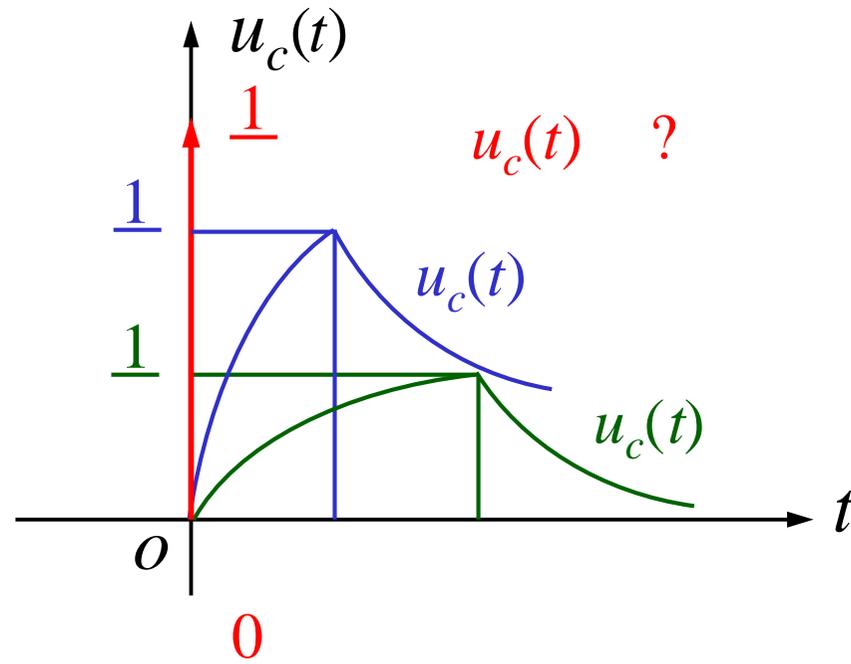
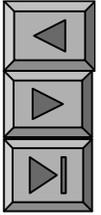
$$s(t) = \begin{cases} 0 & (t < 0) \\ U_S & (0 \leq t \leq \tau) \\ 0 & (t > \tau) \end{cases}$$

$$s(t) = \begin{cases} 0 & (t < 0) \\ U_S & (0 \leq t \leq \tau) \\ 0 & (t > \tau) \end{cases}$$

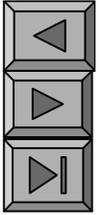
$$u_C(t) = \begin{cases} 0 & (t < 0) \\ U_S(1 - e^{-\frac{t}{\tau}}) & (0 \leq t \leq \tau) \\ U_S e^{-\frac{t-\tau}{\tau}} & (t > \tau) \end{cases}$$

$$u_C(t) = \begin{cases} 0 & (t < 0) \\ U_S(1 - e^{-\frac{t}{\tau}}) & (0 \leq t \leq \tau) \\ U_S e^{-\frac{t-\tau}{\tau}} & (t > \tau) \end{cases}$$





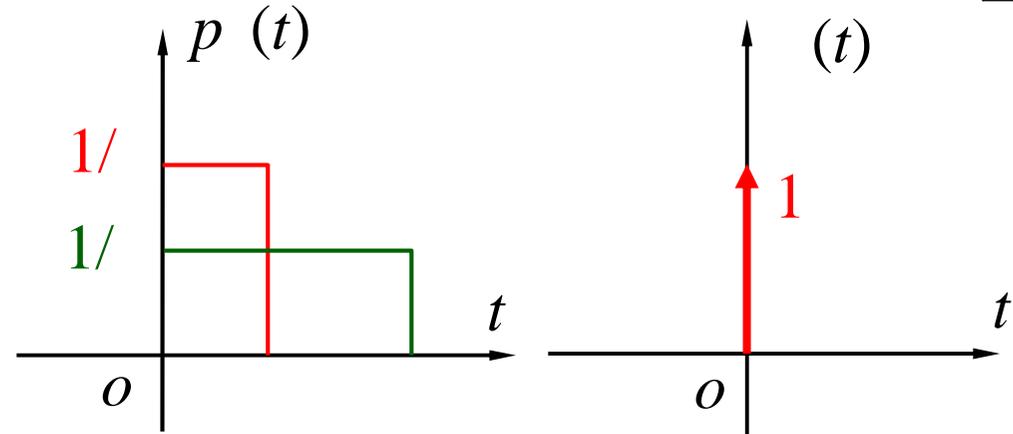
7 8



1.

(1)

$$\left\{ \begin{array}{l} p(t) = 0 \quad t > 0 \\ p(t) = 0 \quad t < 0 \\ \int_{-\infty}^{\infty} p(t) dt = 1 \end{array} \right.$$



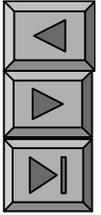
$$\lim_{\epsilon \rightarrow 0} \int_{-\epsilon}^{\epsilon} p(t) dt = 1$$

$$p(t) = 0 \quad t > 0 \quad t < 0$$

$$\int_{-\infty}^{\infty} p(t) dt = 1$$

(2)

$$\left\{ \begin{array}{l} p(t-t_0) = 0 \quad t > t_0 \quad t < t_0 \\ \int_{-\infty}^{\infty} p(t-t_0) dt = 1 \end{array} \right.$$



(3)

$k(t)$

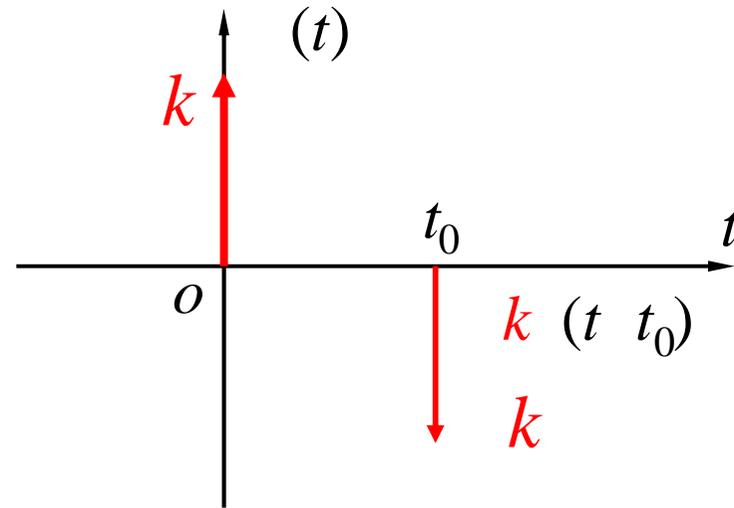
2.

(1) (t) (t)

$$(t) \frac{d(t)}{dt}$$

$$(t) \int_t (x) dx$$

k



(2) “ ”

$$f(t) (t t_0) f(t_0) (t t_0)$$

$$f(t_0) (t t_0) dt f(t_0)$$

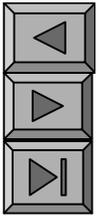
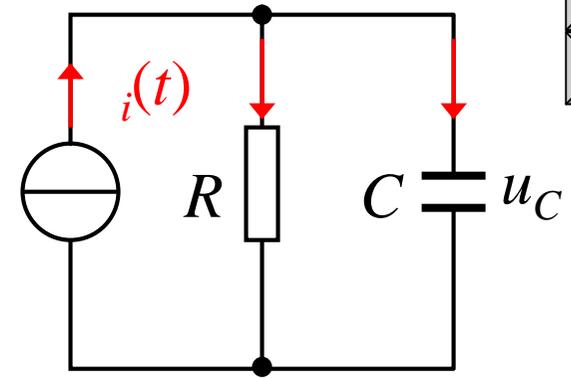
t_0

“ ”

3.

(1)

$h(t)$



RC

$$C \frac{du_C}{dt} + \frac{u_C}{R} = i(t) \quad u_C(0) = 0$$

$$C \frac{du_C}{dt} + \frac{u_C}{R} = i(t) \quad u_C(0_+) = 0$$

$$C \frac{du_C}{dt} + \frac{u_C}{R} = i(t) \quad u_C(0) = 0$$

$$C [u_C(0) \quad u_C(0)] \quad 1 \quad \underline{\underline{u_C(0) \quad \frac{1}{C} \quad u_C(0)}}$$

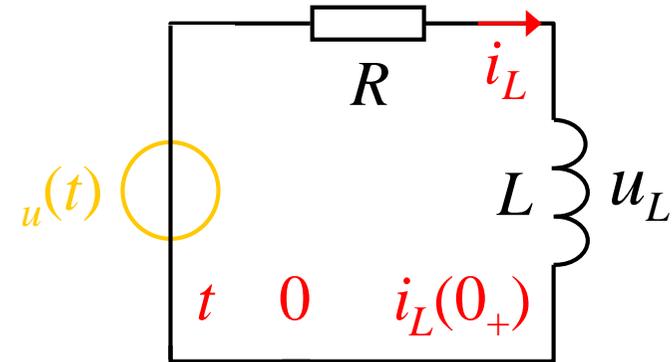
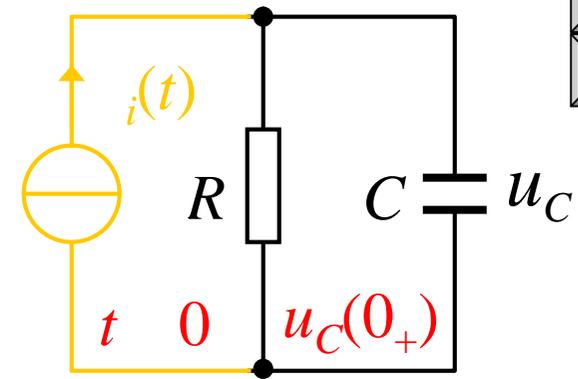
$$(3) \quad t = 0 \quad i(t) = 0$$

$$C \frac{du_C}{dt} = \frac{u_C}{R} \quad i(t)$$

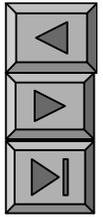
$$\left\{ \begin{array}{l} C \frac{du_C}{dt} = \frac{u_C}{R} \\ u_C(0) = \frac{1}{C} u_C(0) \end{array} \right.$$

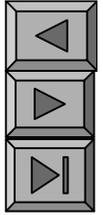
$$(t = 0)$$

RL



$$\left\{ \begin{array}{l} L \frac{di_L}{dt} = Ri_L \\ i_L(0) = \frac{1}{L} i_L(0) \end{array} \right.$$





$$\begin{matrix} 1 & t & 0 & 0 \\ u_C(t) & u_C(0) & u_C(0) \\ i_L(t) & i_L(0) & i_L(0) \end{matrix}$$

$$\begin{matrix} 2 & t & 0 \\ (t) \\ 1 \end{matrix}$$

$$u_C \quad i_L$$

$$u_C(0) [\quad i_L(0)]$$

$$\begin{matrix} (t) & k \\ u_C(0) & \frac{k}{C} & u_C(0) \end{matrix}$$

$$i_L(0) \quad \frac{k}{L} \quad i_L(0)$$

4.

1 RC

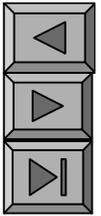
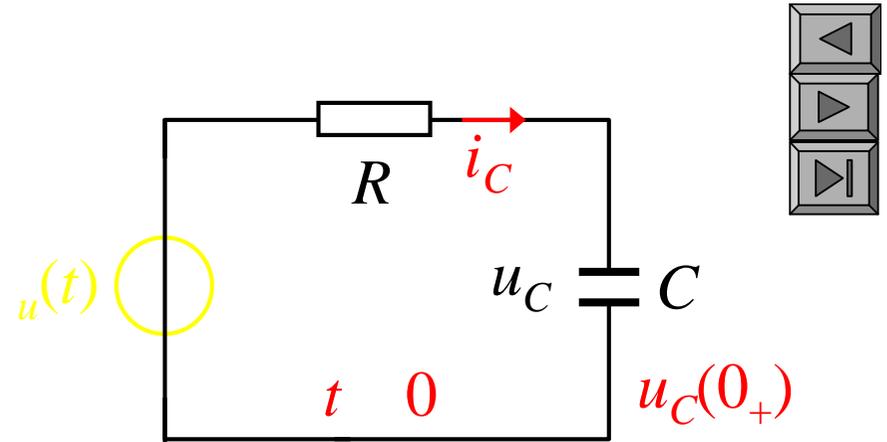
$t = 0$

$$\begin{cases} RC \frac{du_C}{dt} + u_C = i(t) \\ u_C(0^+) = 0 \end{cases}$$

0 0

$$C[u_C(0^+) - u_C(0^-)] = 1$$

$$u_C(0^+) = \frac{1}{RC}$$



RC $u_C()$

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

(t) “ ”

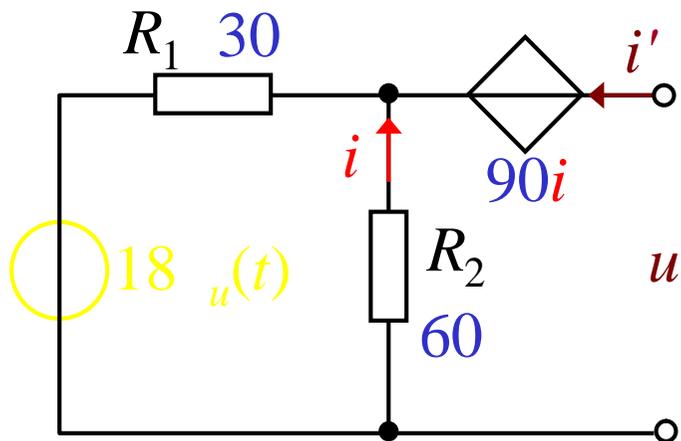
$$u_C(t) = \frac{1}{RC} e^{-\frac{t}{RC}} (t)$$

2

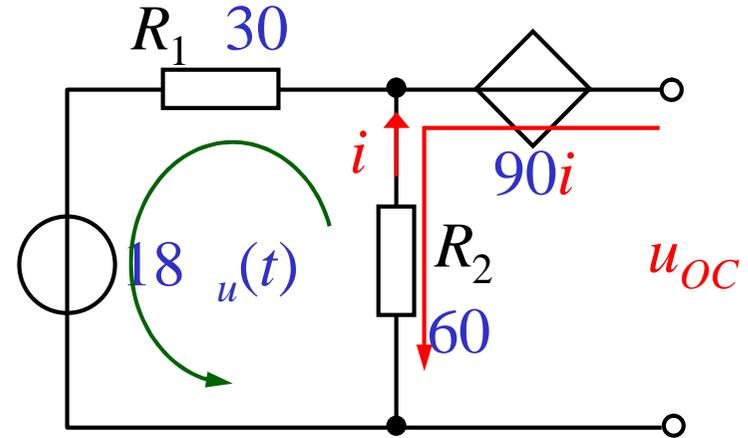
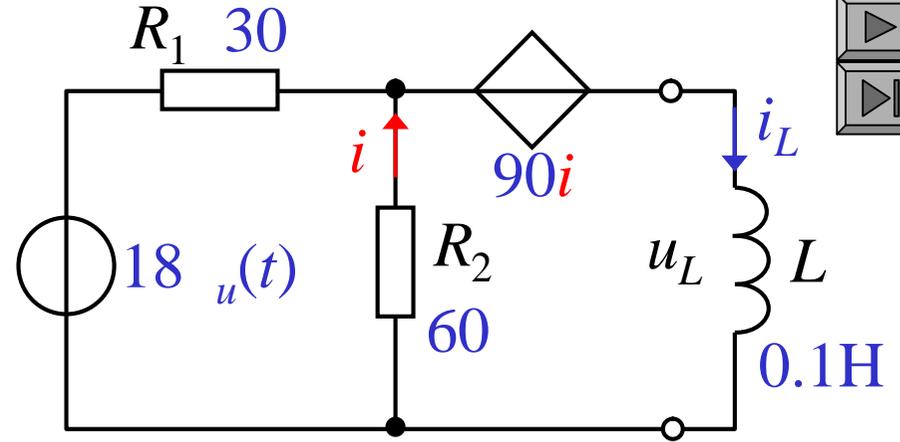
i_L

$$i = \frac{18}{30} \frac{u(t)}{60} = 0.2 u(t)$$

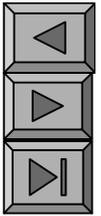
$$u_{oc} = 90i = 6 u(t)$$



$$i = \frac{30}{30} \frac{i'}{60} = \frac{1}{3} i'$$

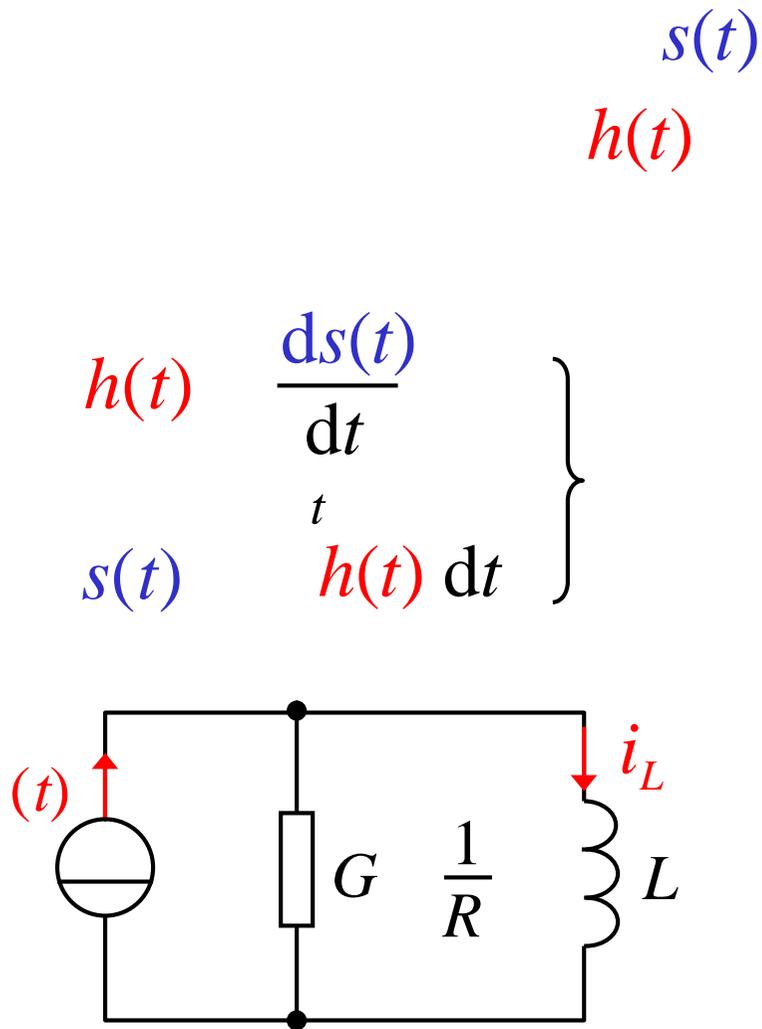


$$R_{eq} = \frac{u}{i'} = \text{CCVC}$$





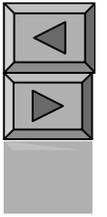
5.

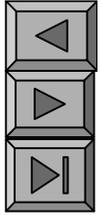


RL

$$i_L(t) = \frac{R}{L} e^{-\frac{t}{L/R}} \int_0^t i_L(\tau) d\tau + e^{-\frac{t}{L/R}} \left[\dots \right]$$

$$e^{-\frac{t}{L/R}} \Big|_0^t \left[e^{\frac{t}{L/R}} \right] (t)$$

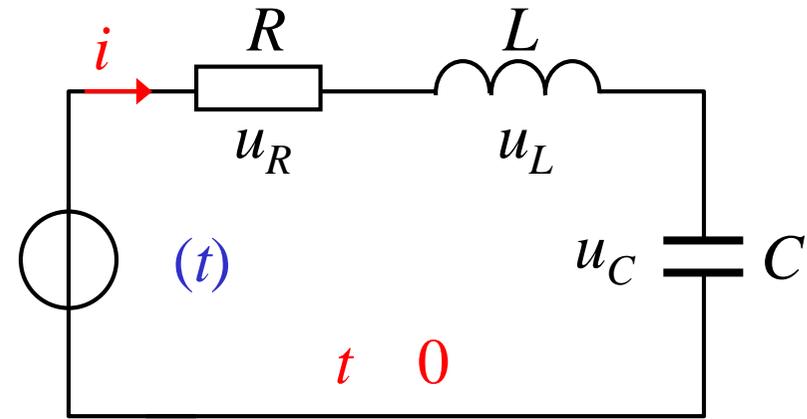




6.

k

$$\begin{cases} LC \frac{d^2 u_C}{dt^2} & RC \frac{du_C}{dt} & u_C & (t) \\ u_C(0) & 0 & i_L(0) & 0 \end{cases}$$



$$LC \frac{d^2 u_C}{dt^2} \quad RC \frac{du_C}{dt} \quad u_C \quad t \quad 0$$

$$\begin{pmatrix} u_C(0) & i_L(0) \\ 0 & 0 \end{pmatrix}$$

$$\begin{cases} LC \frac{d^2 u_C}{dt^2} & RC \frac{du_C}{dt} & u_C & (t) \\ u_C(0) & 0 & i_L(0) & 0 \end{cases}$$



$$LC \left[\frac{du_C}{dt} \Big|_{t=0} \quad \frac{du_C}{dt} \Big|_{t=0} \right]$$

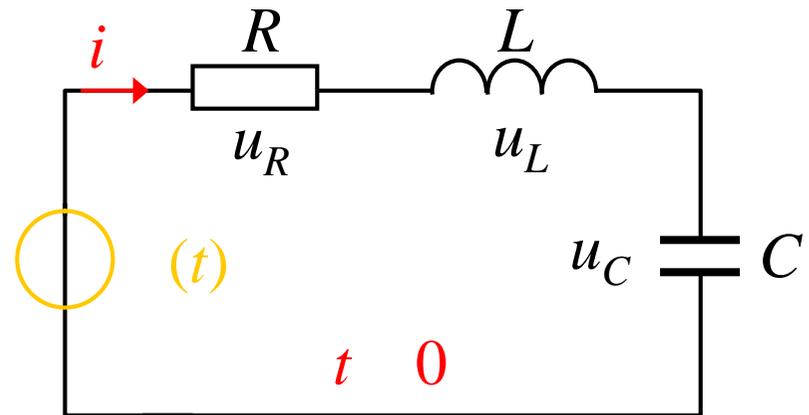
$$RC [u_C(0) \quad u_C(0)] \int_0^{0+} u_C dt \quad 1$$

$$u_C(t)$$

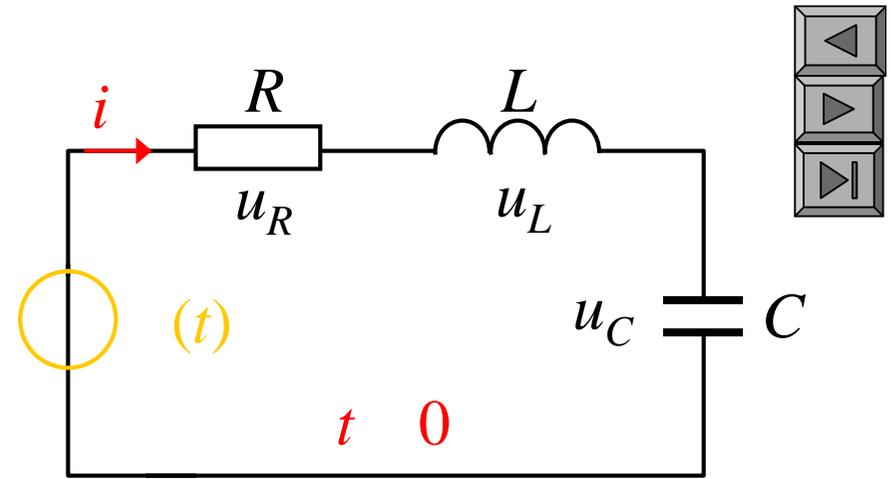
0

0

$$LC \frac{du_C}{dt} \Big|_{t=0} \quad 1$$



$$\begin{cases} LC \frac{d^2 u_C}{dt^2} & RC \frac{du_C}{dt} & u_C \\ u_C(0_+) & 0 & \left. \frac{du_C}{dt} \right|_{t=0_+} \frac{1}{LC} \end{cases}$$



$t = 0$

(t)

$$LC \left. \frac{du_C}{dt} \right|_{t=0} = 1$$

$$\left. \frac{du_C}{dt} \right|_{t=0_+} = \frac{1}{LC}$$

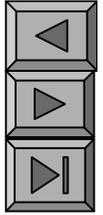
$t = 0$

$i_L(0)$

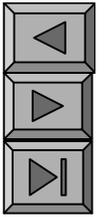
§ 7.5



*7-9



*§ 7 10

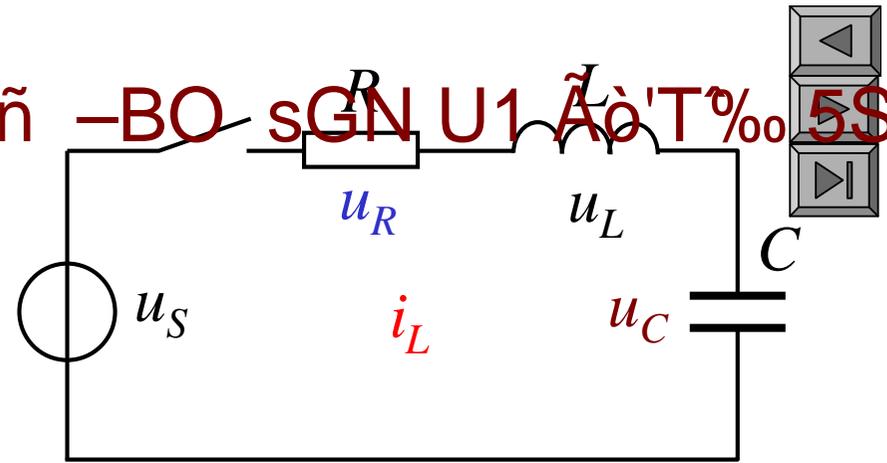


1.

()



RLC circuit analysis





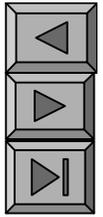
2.

$$\left. \begin{array}{l} \frac{du_C}{dt} \quad \frac{1}{C} i_L \quad 0 \\ \frac{di_L}{dt} \quad \frac{1}{L} u_C \quad \frac{R}{L} i_L + \frac{1}{L} u_S \end{array} \right\}$$



$$\begin{array}{l} x_1 \quad u_C \\ x_2 \quad i_L \\ \dot{x}_1 \quad \frac{du_C}{dt} \end{array} \quad \left[\begin{array}{l} \frac{du_C}{dt} \\ \frac{di_L}{dt} \end{array} \right] \quad \underbrace{\left[\begin{array}{cc} 0 & \frac{1}{C} \\ \frac{1}{L} & \frac{R}{L} \end{array} \right]}_{\mathbf{A}} \underbrace{\left[\begin{array}{l} u_C \\ i_L \end{array} \right]}_{\mathbf{B}} \quad \underbrace{\left[\begin{array}{cc} 0 & 0 \\ 0 & \frac{1}{L} \end{array} \right]}_{\mathbf{B}} \underbrace{\left[\begin{array}{l} i_S \\ u_S \end{array} \right]}_{\mathbf{B}}$$

$$\begin{array}{l} \dot{x}_2 \quad \frac{di_L}{dt} \end{array} \quad \left[\begin{array}{l} \dot{x}_1 \\ \dot{x}_2 \end{array} \right] = \mathbf{A} \left[\begin{array}{l} x_1 \\ x_2 \end{array} \right] + \mathbf{B} \left[\begin{array}{l} i_S \\ u_S \end{array} \right]$$



$$\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \end{bmatrix} = \mathbf{A} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \mathbf{B} \begin{bmatrix} i_S \\ u_S \end{bmatrix}$$

$$\dot{\mathbf{x}} \stackrel{\text{def}}{=} [\dot{x}_1 \quad \dot{x}_2]^T \quad \mathbf{x} = [x_1 \quad x_2]^T \quad \mathbf{v} = [i_S \quad u_S]^T$$

$$\dot{\mathbf{x}} = \mathbf{A} \mathbf{x} + \mathbf{B} \mathbf{v}$$

\mathbf{x}

\mathbf{v}

n

m

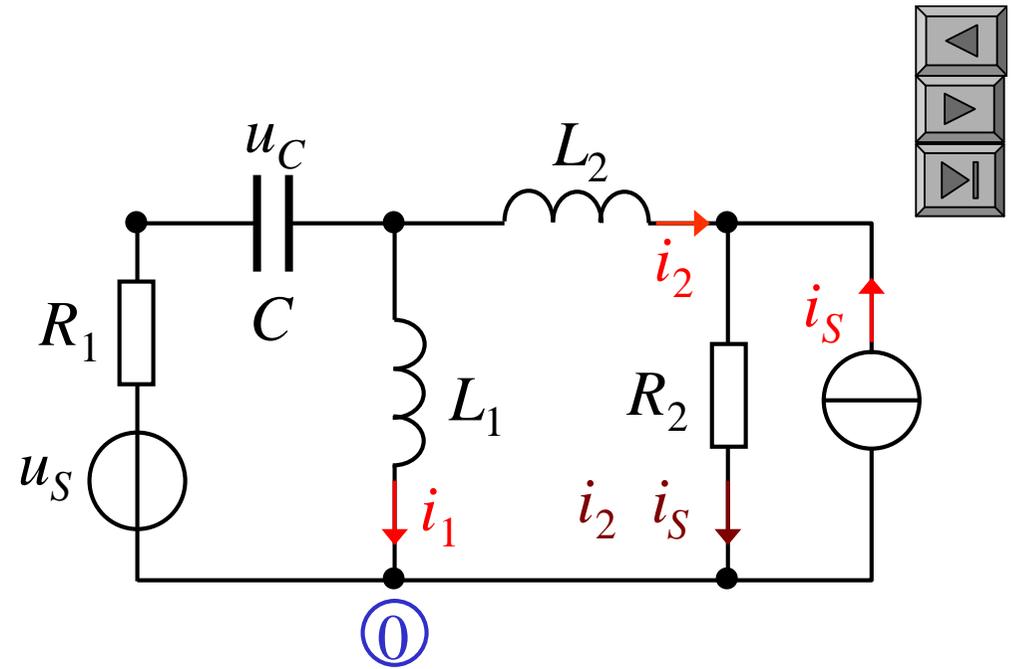
$\dot{\mathbf{x}}$ \mathbf{x} n

\mathbf{A} $n \times n$

\mathbf{v} m

\mathbf{B} $n \times m$

3.



- (1) C KCL
- (2) L KVL
- (3) ()

$$C \frac{du_C}{dt}$$

u_C i_1 i_2

C

KCL

i_1 i_2

L

KVL

$$L_1 \frac{di_1}{dt}$$

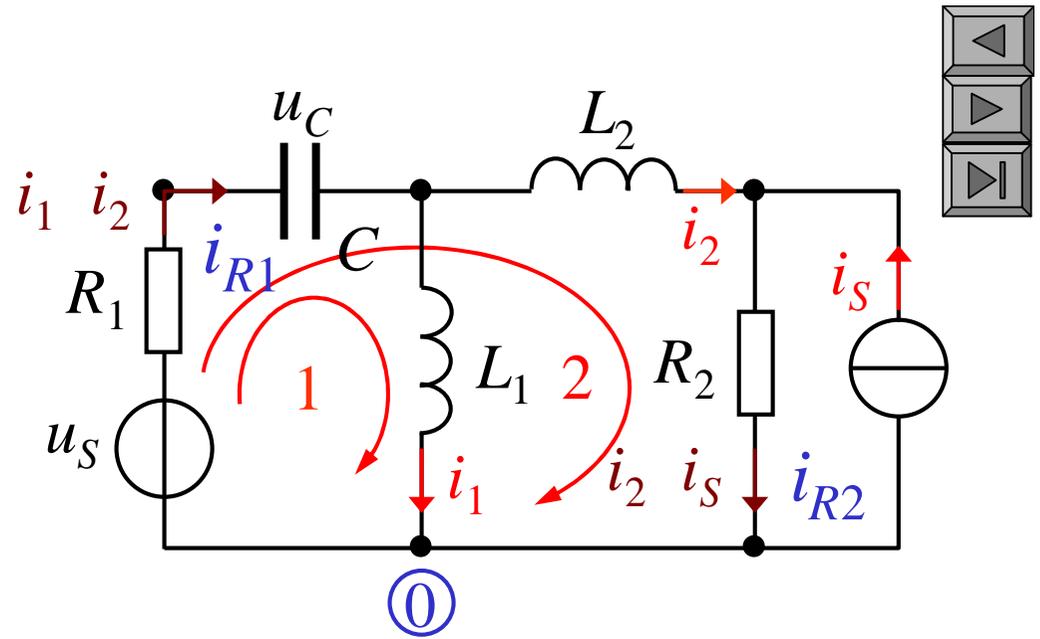
u_C $R_1(i_1+i_2)$ u_S

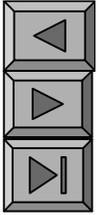
i_{R1}

$$L_2 \frac{di_2}{dt}$$

u_C $R_1(i_1+i_2)$ u_S $R_2(i_2+i_S)$

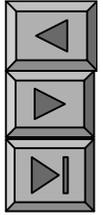
i_{R2}





$$\left. \begin{array}{l} C \frac{du_C}{dt} \quad i_1 \quad i_2 \\ L_1 \frac{di_1}{dt} \quad u_C \quad R_1(i_1+i_2) \quad u_S \\ L_2 \frac{di_2}{dt} \quad u_C \quad R_1(i_1+i_2) \quad u_S \quad R_2(i_2+i_S) \end{array} \right\}$$

$$\begin{bmatrix} \frac{du_C}{dt} \\ \frac{di_1}{dt} \\ \frac{di_2}{dt} \end{bmatrix} \begin{bmatrix} 0 & \frac{1}{C} & \frac{1}{C} \\ \frac{1}{L_1} & \frac{R_1}{L_1} & \frac{R_1}{L_1} \\ \frac{1}{L_2} & \frac{R_1}{L_2} & \frac{R_1+R_2}{L_2} \end{bmatrix} \begin{bmatrix} u_C \\ i_1 \\ i_2 \end{bmatrix} \begin{bmatrix} 0 & 0 \\ \frac{1}{L_1} & 0 \\ \frac{1}{L_2} & \frac{R_2}{L_2} \end{bmatrix} \begin{bmatrix} u_S \\ i_S \end{bmatrix}$$



4. ()

$$\dot{x} = Ax + Bv \quad x(t_0) = x_0$$

$$y = Cx + Dv$$

n , m , h

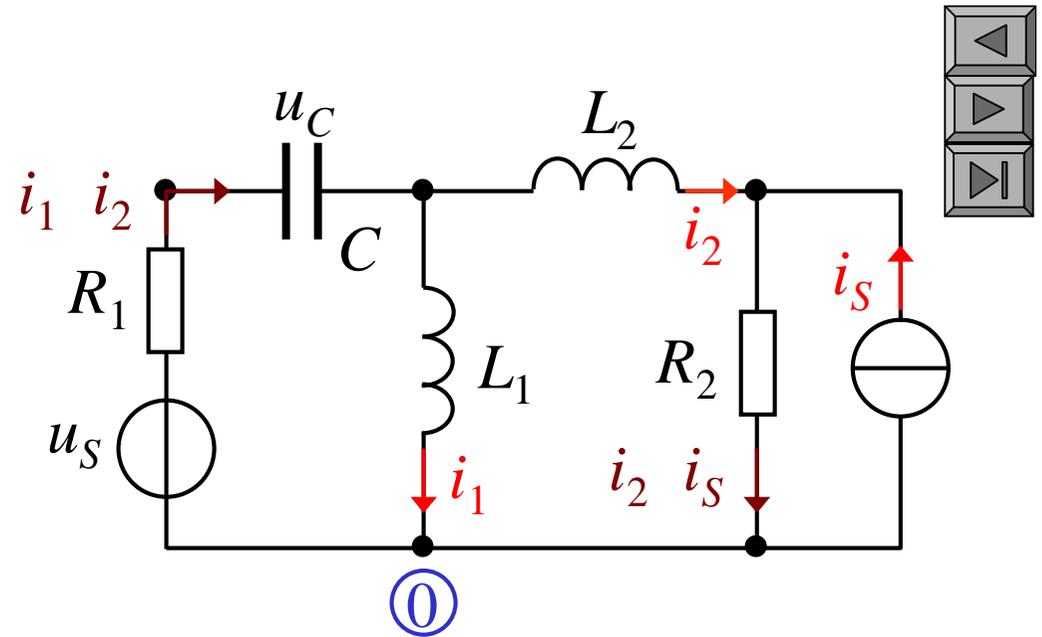
y h

C $h \times n$

D $h \times m$

C D

$y \quad Cx \quad Dv$



$$\left. \begin{array}{l} u_{n1} \quad R_1 \quad i_1 \quad i_2 \quad u_S \\ u_{n2} \quad u_C \quad i_1 \quad i_2 \quad R_1 \quad u_S \\ u_{n3} \quad R_2 \quad i_2 \quad i_S \end{array} \right\}$$

$$\begin{bmatrix} u_{n1} \\ u_{n2} \\ u_{n3} \end{bmatrix} \begin{bmatrix} 0 & R_1 & R_1 \\ 1 & R_1 & R_1 \\ 0 & & R_2 \end{bmatrix} \begin{bmatrix} u_C \\ i_1 \\ i_2 \end{bmatrix} \begin{bmatrix} 1 & 0 \\ 1 & 0 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} u_S \\ i_S \end{bmatrix}$$

*7-11

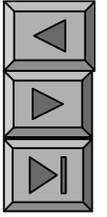


1.

(1)

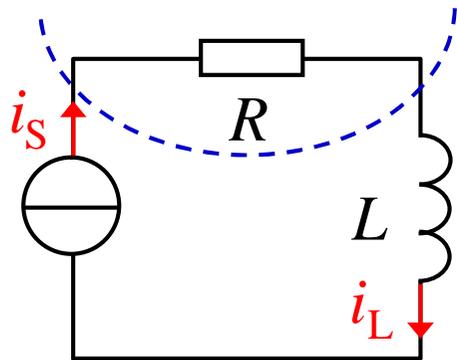
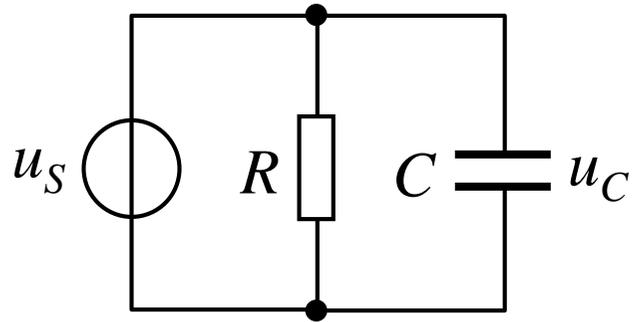
$$\left(\frac{1}{L} \right) = \left(\frac{1}{C} \right)$$

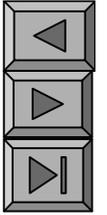
RLC



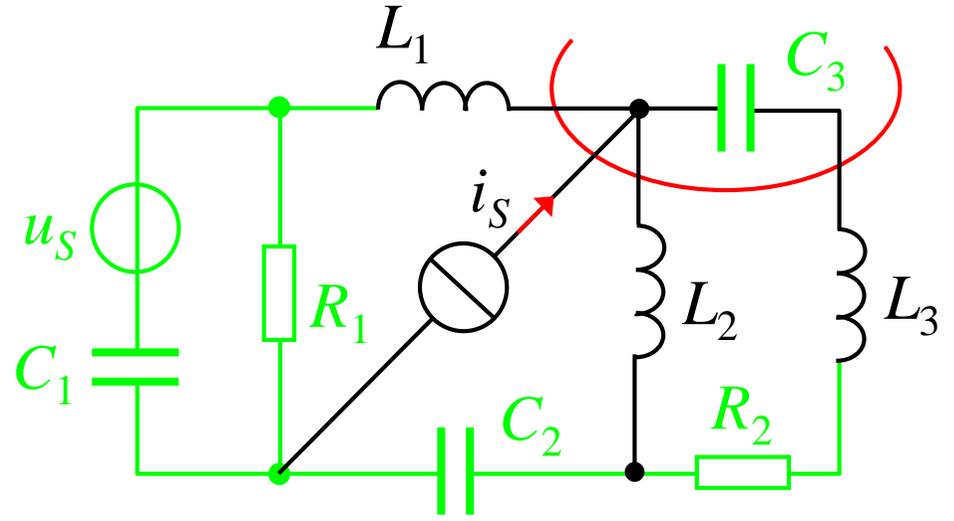
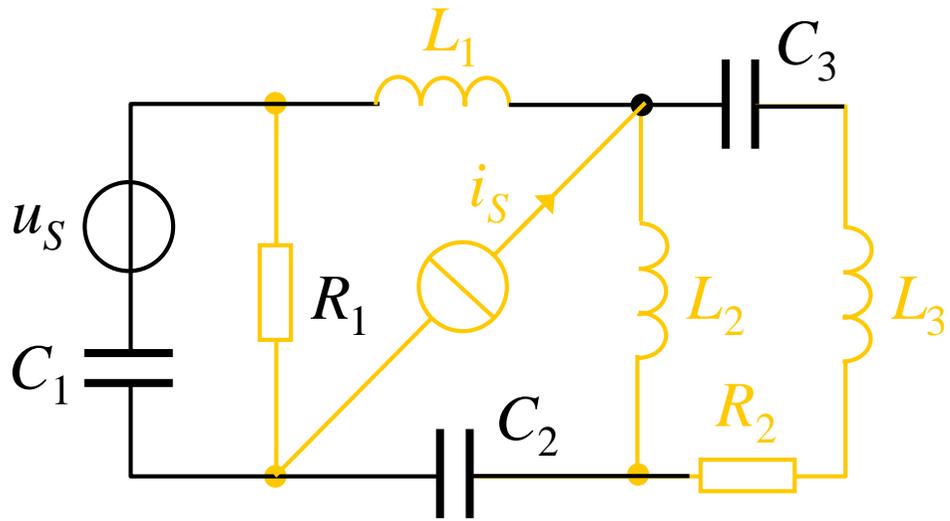
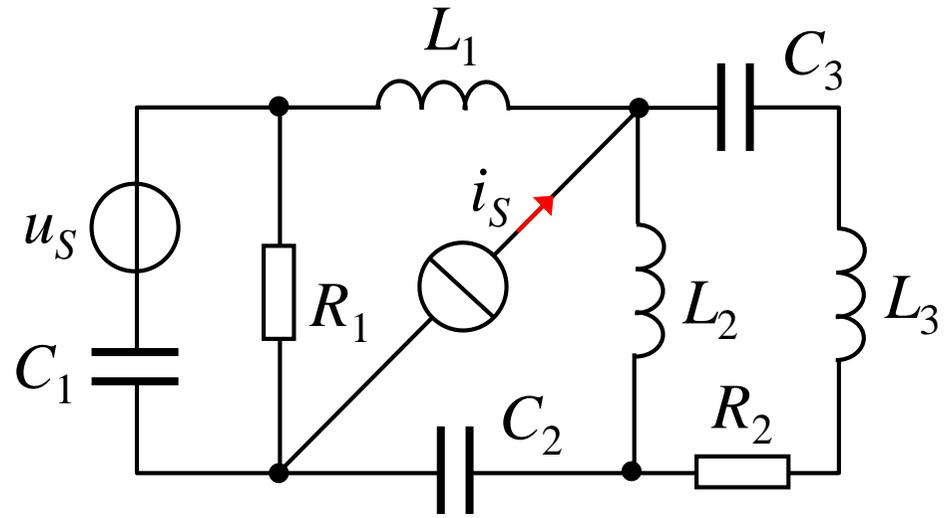
(2)

=

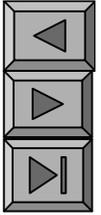




6 1 5



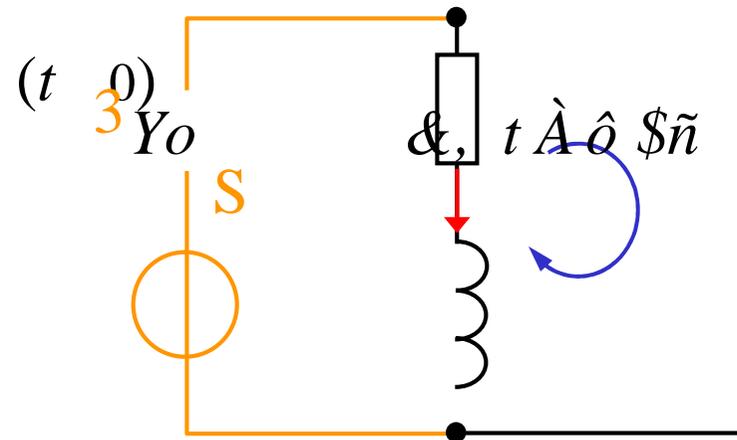
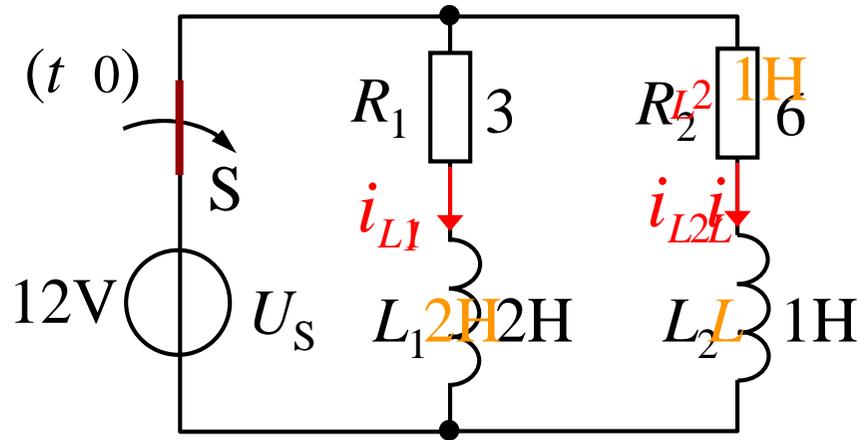
1



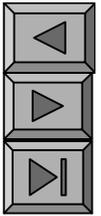
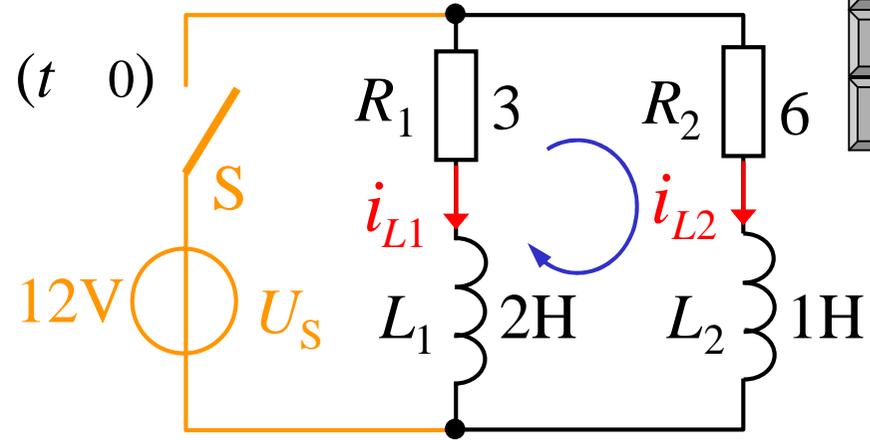
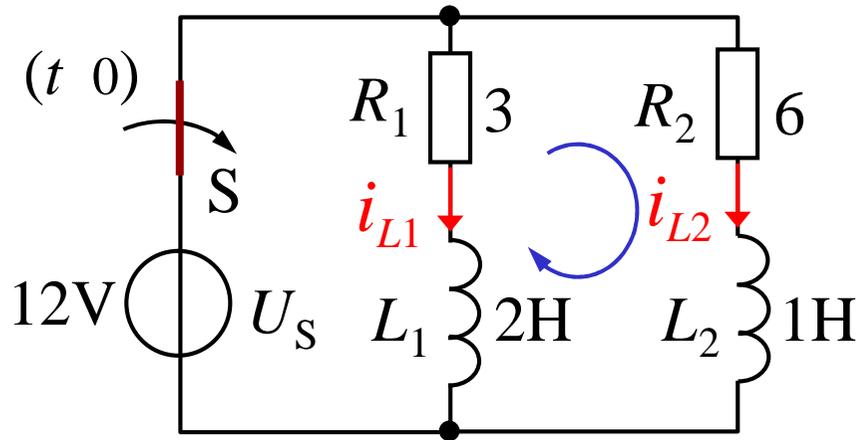
2.

2

$$\begin{array}{cc}
 q_k(0^-) & q_k(0^+) \\
 i_k(0^-) & i_k(0^+)
 \end{array}
 \quad
 \begin{array}{cc}
 C_k u_{Ck}(0^+) & C_k u_{Ck}(0^-) \\
 L_k i_{Lk}(0^+) & L_k i_{Lk}(0^-)
 \end{array}$$



VB•



$$i_{L1}(0) = 4A \quad i_{L2}(0) = 2A$$

KCL $i_{L2}(0) = i_{L1}(0) - i_L(0)$

$$L_2 \frac{di_{L2}(0)}{dt} = L_1 \frac{di_{L1}(0)}{dt} - L_2 \frac{di_L(0)}{dt}$$

$$i_{L2}(0_+) = \frac{L_2 i_{L2}(0) - L_1 i_{L1}(0)}{L_1 - L_2} = \frac{1 \times 2 - 2 \times 4}{1 - 2} = 6A$$

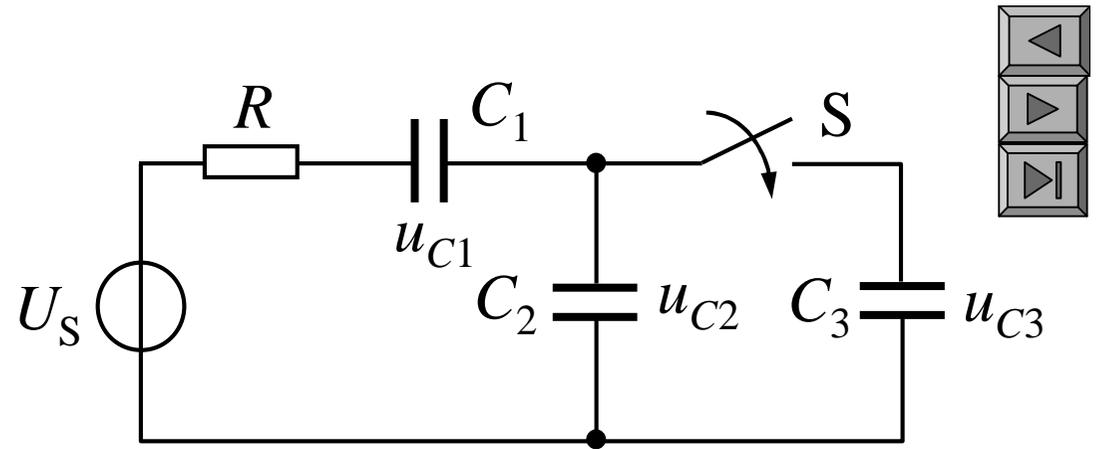
$$i_{L1}(0_+) = 2A$$

$$i_{L2}(\infty) = i_{L1}(\infty)$$

$$(L_1 - L_2) / (R_1 - R_2)$$

KVL

2 S
 $U_S \text{ 6V}$ $C_3 \text{ 2F}$
 $C_1 \text{ 1F}$ $C_2 \text{ 1F}$ $t \text{ 0}$ S



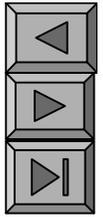
(C_3)

S $u_{C1}(0)$ $u_{C2}(0)$ 3V $u_{C3}(0)$ 0

S $u_{C1}(0)$ $u_{C1}(0)$ 3V $u_{C2}(0)$ $u_{C3}(0)$

$C_2 u_{C2}(0)$ $C_3 u_{C3}(0)$ $C_2 u_{C2}(0)$ $C_3 u_{C3}(0)$
 $u_{C2}(0)$ $2 u_{C3}(0)$ 3 0

KVL $u_{C2}(0)$ $u_{C3}(0)$ $u_{C2}(0)$ $u_{C3}(0)$ V



3.

$$\frac{dy}{dt} = Ay + f(t)$$

$f(t)$

P

$$P_0 + P_1 t + (P_2 t^2 + \dots + 0)$$

$$P_0 + P_1 t + P_2 t^2$$

$$P e^{mt} (m \dots)$$

$$P e^{mt} (m \dots)$$

$$P \sin t + (P \cos t)$$

y^*

Q

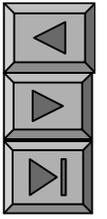
$$Q_0 + Q_1 t$$

$$Q_0 + Q_1 t + Q_2 t^2$$

$$Q e^{mt}$$

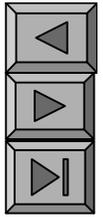
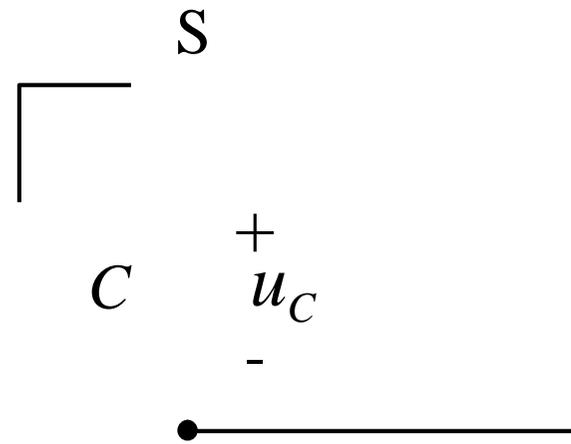
$$Q t e^{mt}$$

$$Q_1 \sin t + Q_2 \cos t$$



P159 7-6

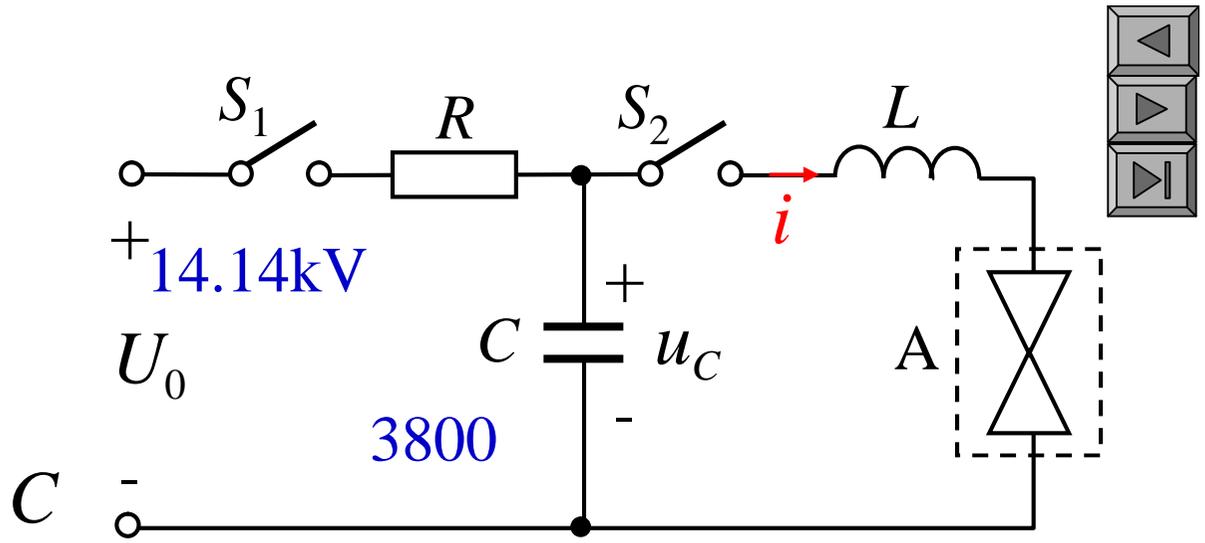
u_C u_R i u_L i_{\max}



P162

7 8

U_0 S_1 C
 S_1 S_2 C



L

$$\frac{1}{\sqrt{LC}} \quad f \quad \text{rad/s}$$

$$L = \frac{1}{\omega^2 C} = 2.67 \text{ (mH)}$$

$$i = \frac{U_0}{\omega L} \sin(\omega t) = 16.9 \sin(\omega t) \text{ (kA)}$$

50Hz

$$u_C \quad u_L = U_0 \sin(\omega t + 90^\circ)$$

$$u_C(t) \quad i(t) = 14.14 \sin(\omega t + 90^\circ) \text{ (kV)}$$

P165 7-9

i_L u_C i_C

S

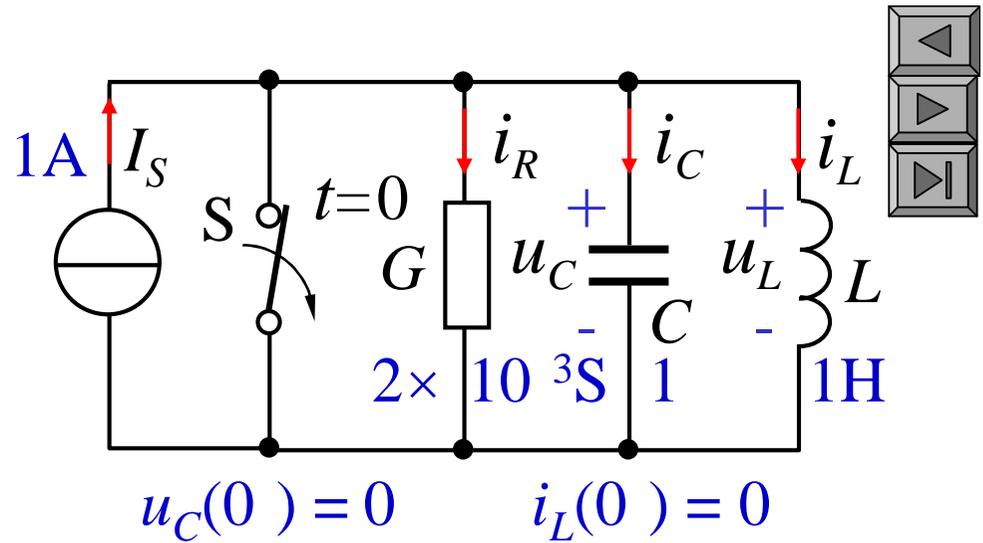
$i_s = (t) \text{ A}$

$$LC \frac{d^2 i_L}{dt^2} + GL \frac{di_L}{dt} + i_L = I_S$$

$$p^2 \frac{G}{C} p + \frac{1}{LC} = 0$$

$$p_{1,2} = \frac{G}{2C} \pm \sqrt{\left(\frac{G}{2C}\right)^2 - \frac{1}{LC}}$$

p_1 p_2 p



$$i''_L = (A_1 + A_2 t) e^{pt} \text{ A}$$

- $i'_L = 1 \text{ A}$

- $i_L = 1 + (A_1 + A_2 t) e^{pt} \text{ A}$

$$\left. \begin{aligned} \left[\frac{di_L}{dt} \right]_0 &= \frac{u_L(0)}{L} = \frac{u_C(0)}{L} = 0 \\ i_L(0) &= i_L(0) = 0 \end{aligned} \right\}$$