

1.

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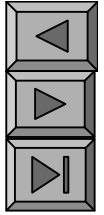
()

4.

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(1)

(2)

(3)

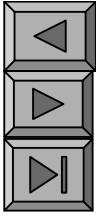
(4)

(5) () ()

(6)

(7)

(8)

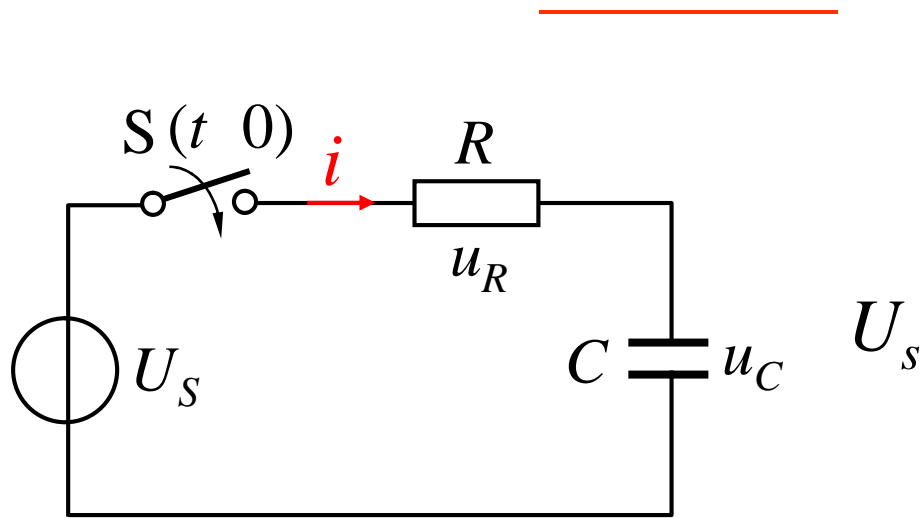
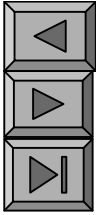


(1)

(2)

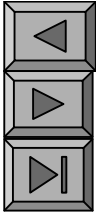
(3)

9



C

C



$(L \ C)$



$L \ C$

3

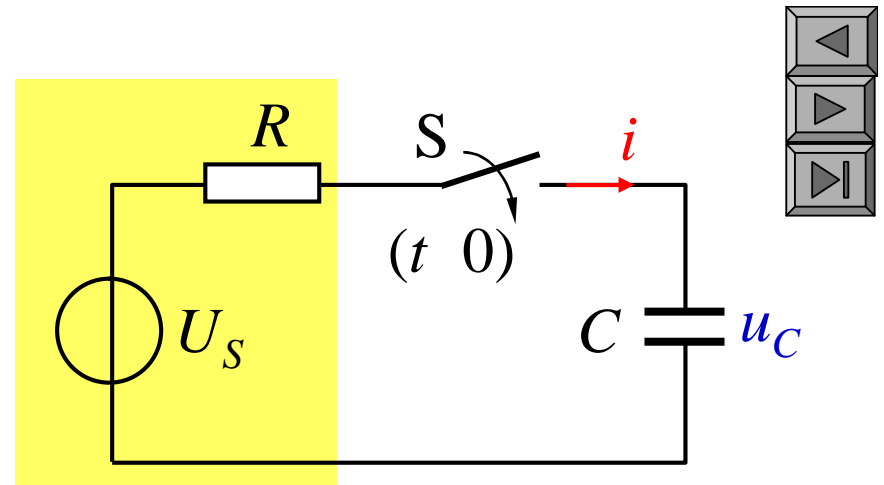
1.



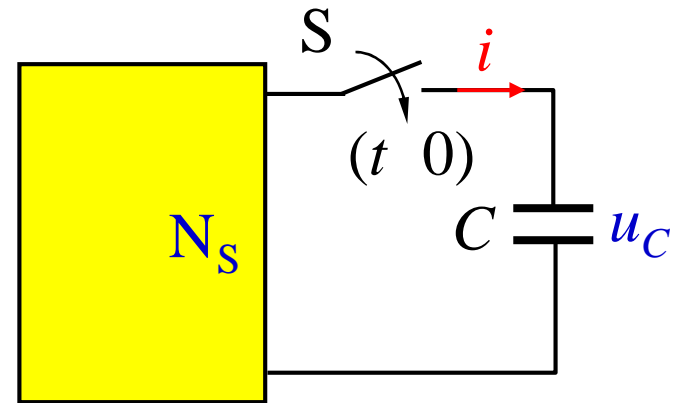
2.

RL RL)

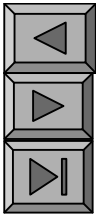
RC $(RC$



3.

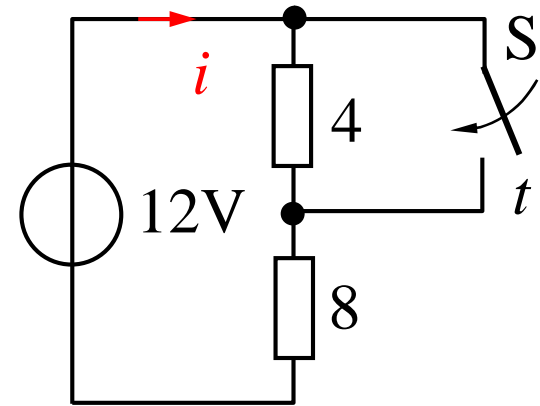


3 1 2

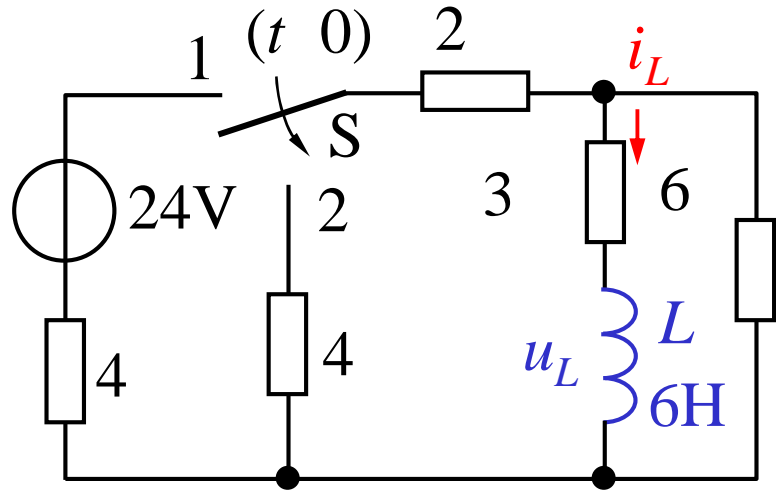


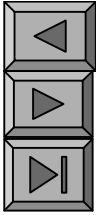
1.

$t = 0^-$ ($t = t_0$)



L C

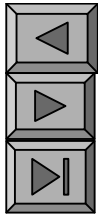




2.

$$\begin{aligned}
 & C \int_{t_0}^t q(t) \, dt - C \int_{t_0}^{t_0} q(t) \, dt = C \int_{t_0}^t q(t) \, dt \\
 & C \int_{t_0}^t i_C(t) \, dt - C \int_{t_0}^{t_0} i_C(t) \, dt = C \int_{t_0}^t i_C(t) \, dt \\
 & C \int_{t_0}^t i_C(t) \, dt = C \int_{t_0}^t i_C(t) \, dt
 \end{aligned}$$

$q(0) = q(0) \quad C$
 $q(t) = C u_C(t) \quad C$
 $u_C(0) = u_C(0) \quad C$



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

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

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

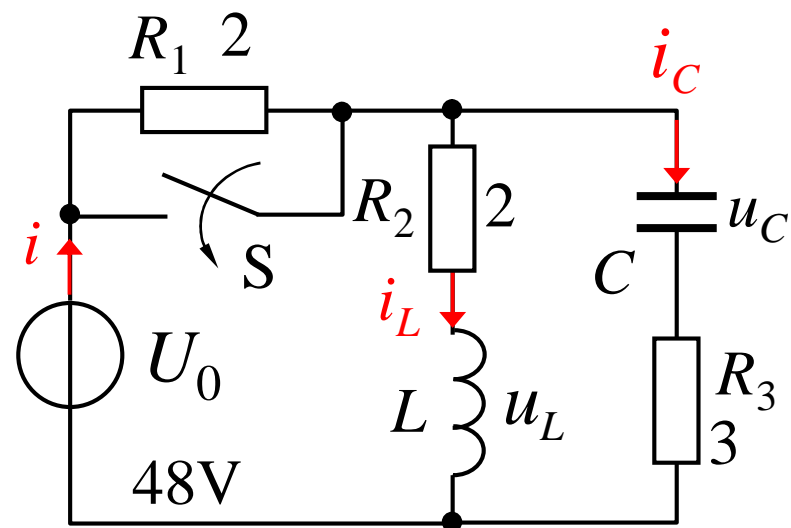


L



L

L



1. “ ”

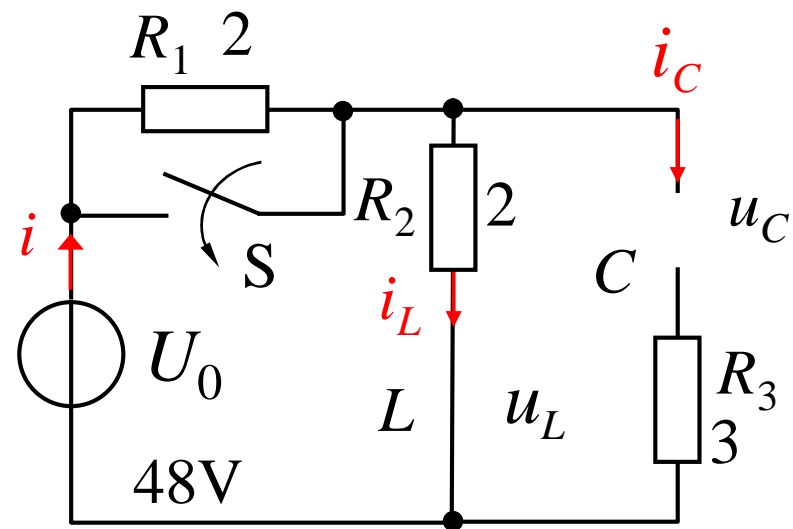
$$u_C(0^-) \quad i_L(0^-)$$

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

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

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

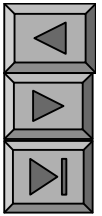
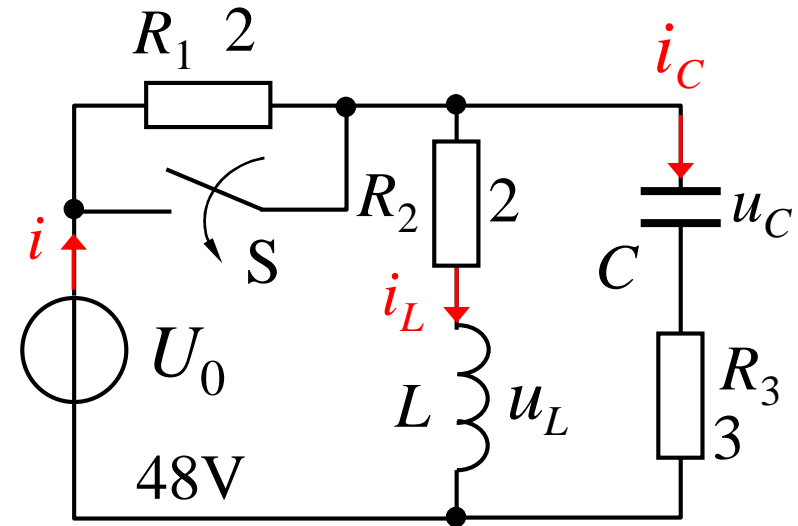
$$u_C(0^-) = 24V \quad u_C(0^-)$$



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

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

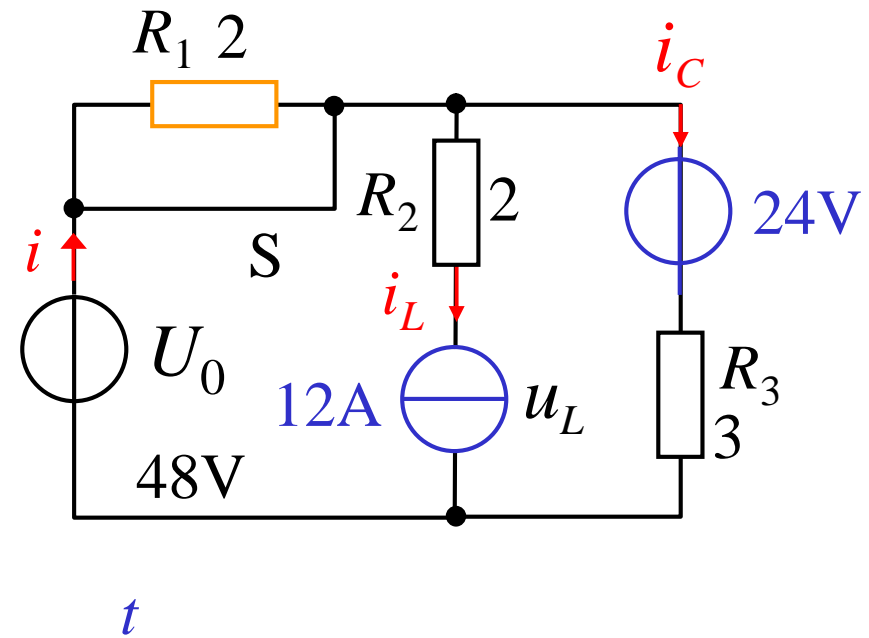
2 t



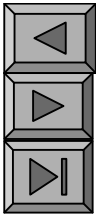
$$i_C(0^+) = \frac{48 - 24}{3}$$

$$u_L(0^+) = 48 - 12 = 36\text{V}$$

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



7 2



(0)

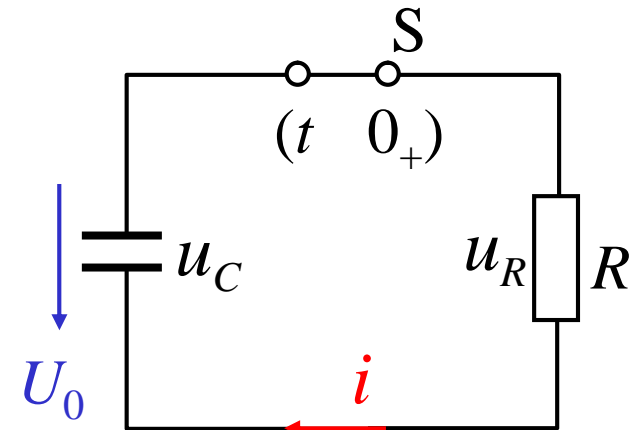
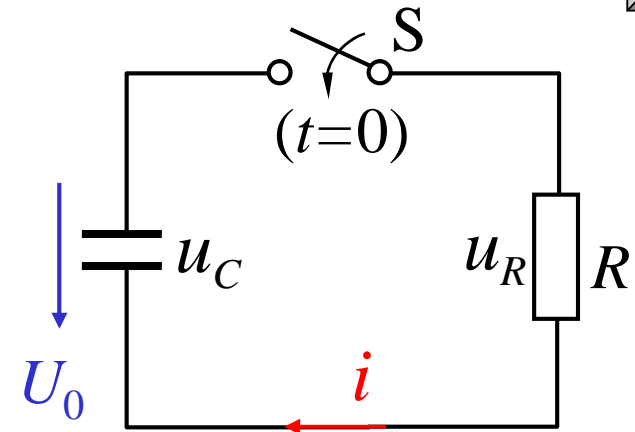
1. RC

RC

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

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

$$RC \frac{du_c}{dt}$$



“ ”

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

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

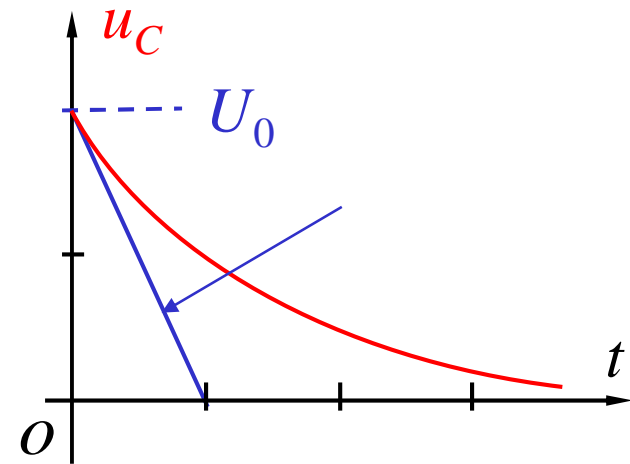
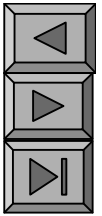
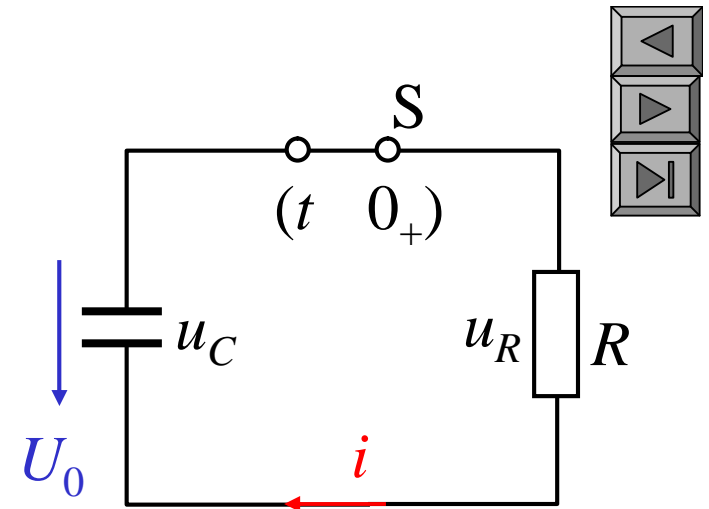
$$u_c = A e^{-\frac{1}{RC}t}$$

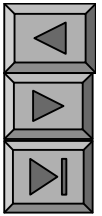
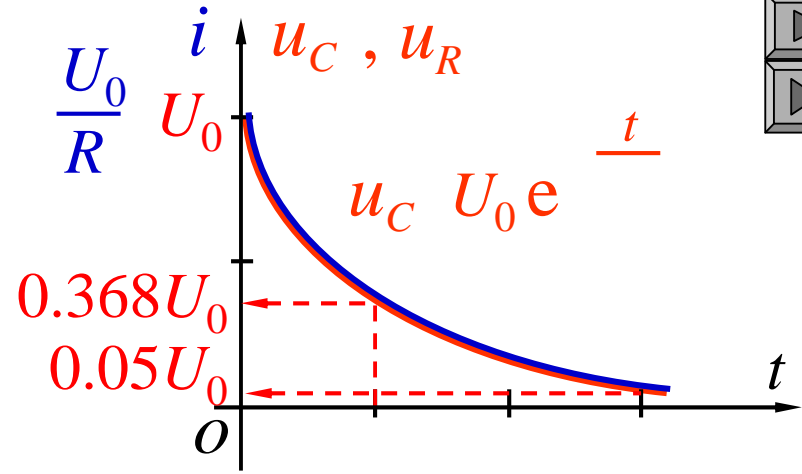
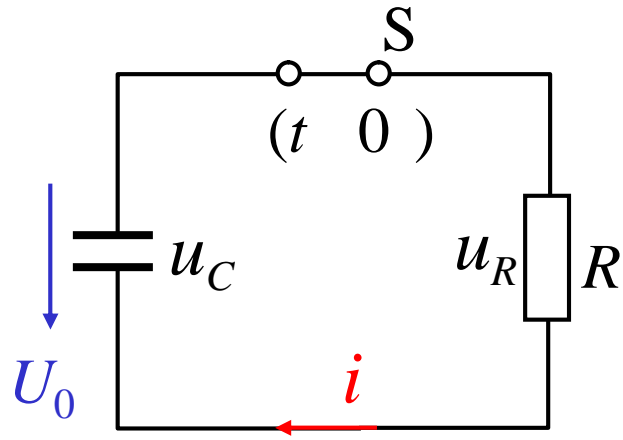
$$u_c(0) = u_c(0) = U_0$$

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

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

$$u_c$$





•

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

•

3 5

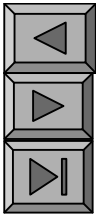
$$u_R = U_0 e^{-\frac{t}{RC}}$$

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

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

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

$$C \quad R$$



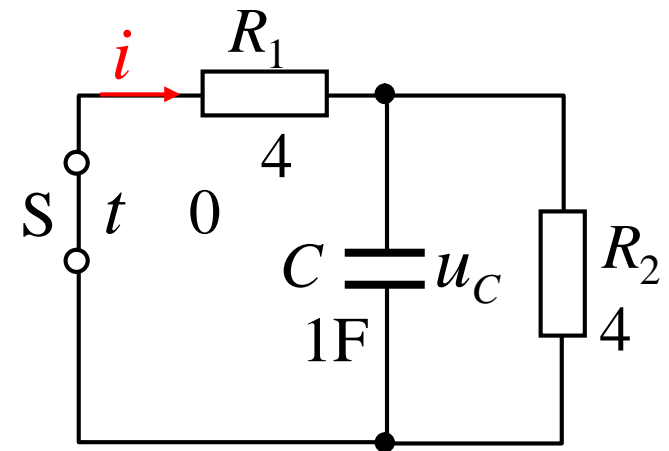
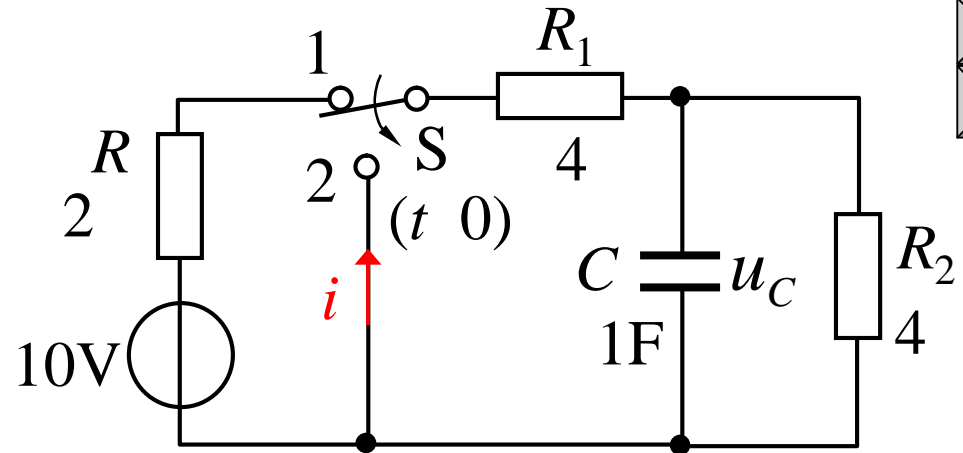
$$u_C(0^-) = \frac{10 \cdot 4}{2+4+4} = 4 \text{ V}$$

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

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

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

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



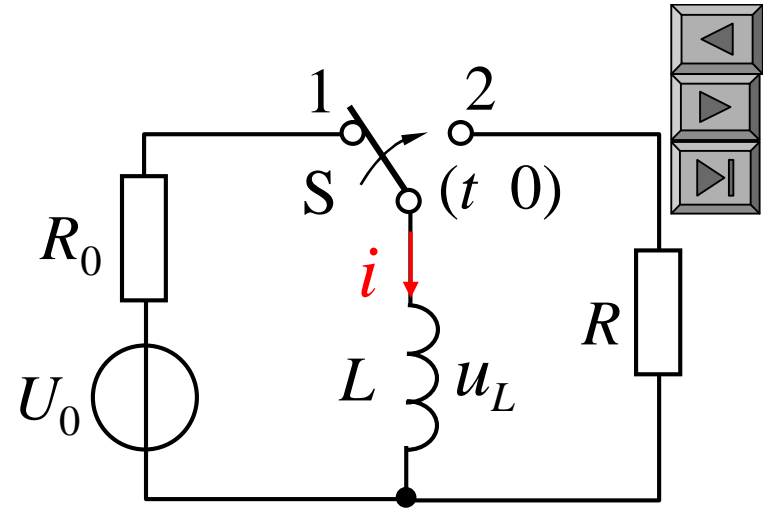
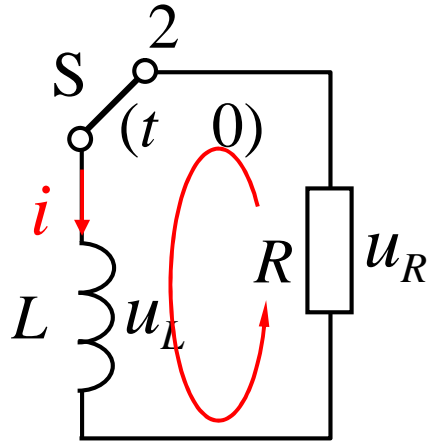
$$i(t) = \frac{1}{2} \frac{u_C}{R_{eq}} e^{-0.5t} \text{ A} \quad (t \geq 0)$$

2. RL

KVL

$$u_L + u_R = 0$$

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



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

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

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

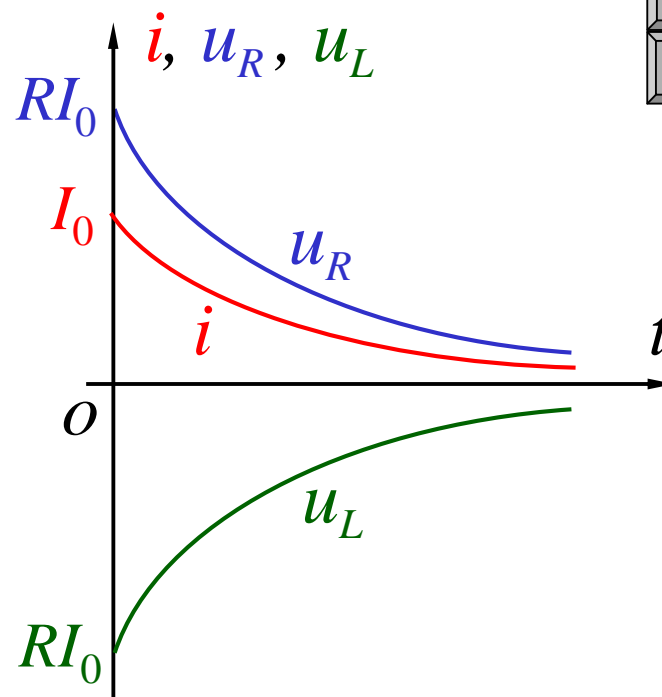
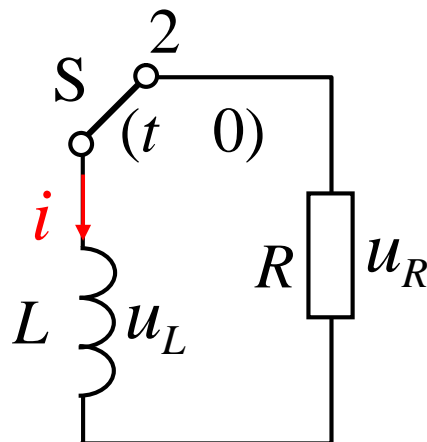
$$i(t) = I_0 e^{-\frac{t}{\tau}} \quad (t \geq 0)$$

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

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



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



$$u_R = Ri$$

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

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

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

3. P144 7 2

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

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

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

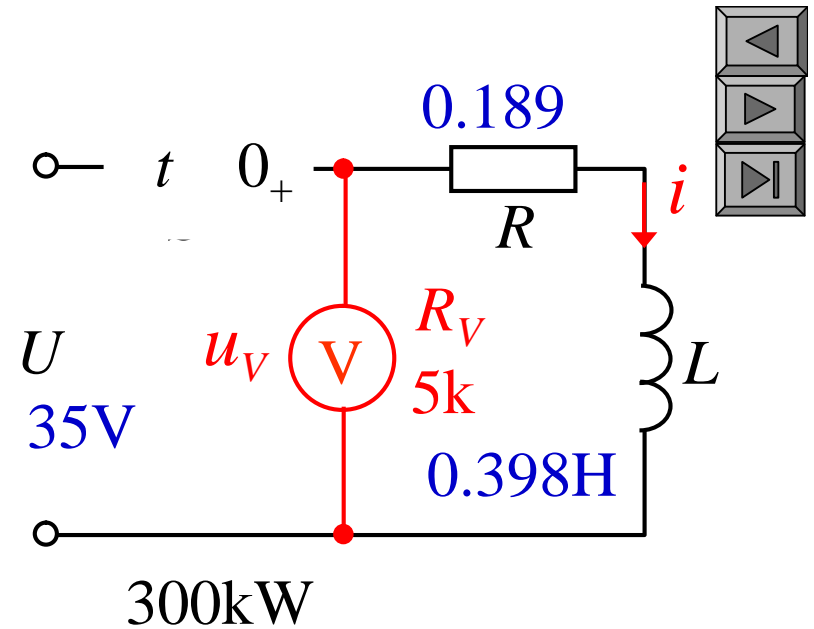
s)

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

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

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

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



7 3

0

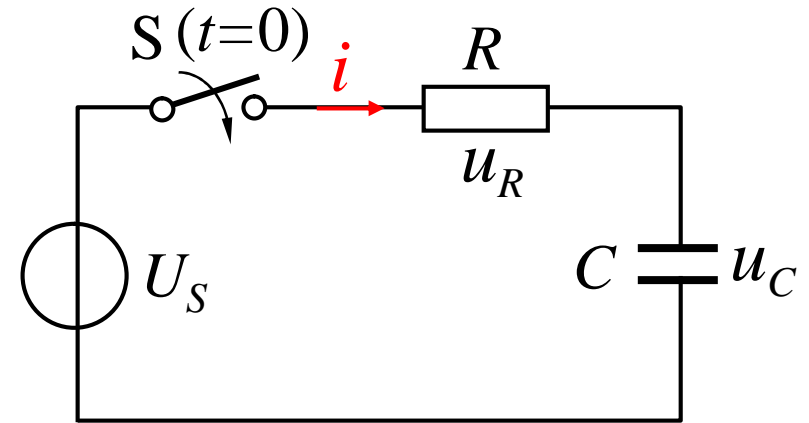
1. RC

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 u'_C u''_C

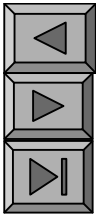


$RC \frac{du_c}{dt}$ u_C 0

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

u'_C U_S

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



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

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

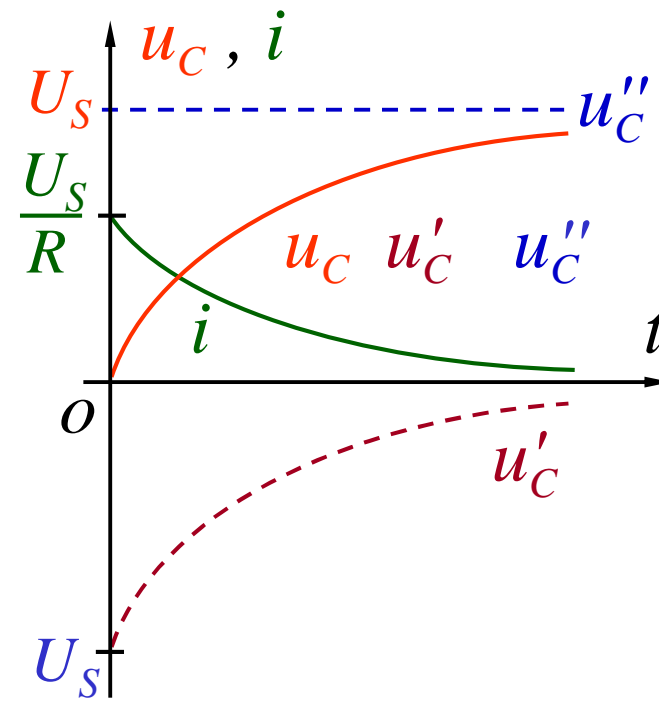
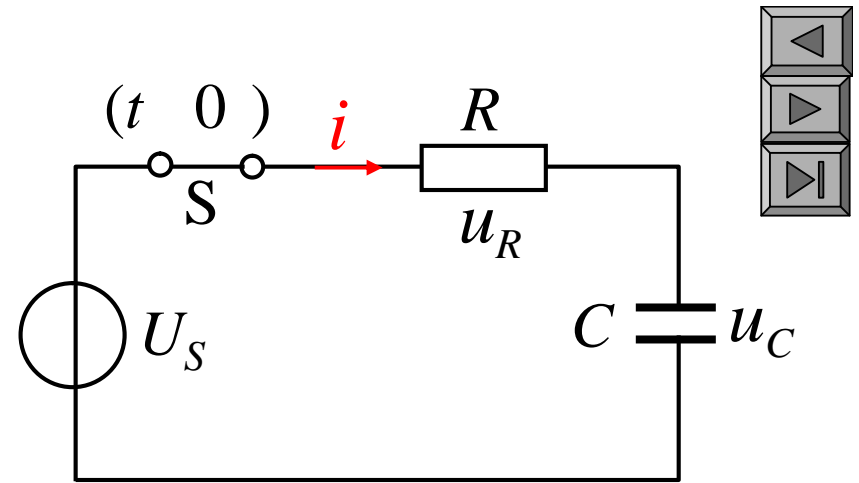
$$u_c(0) = u_c(0) = 0$$

$$A = -U_s$$

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

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

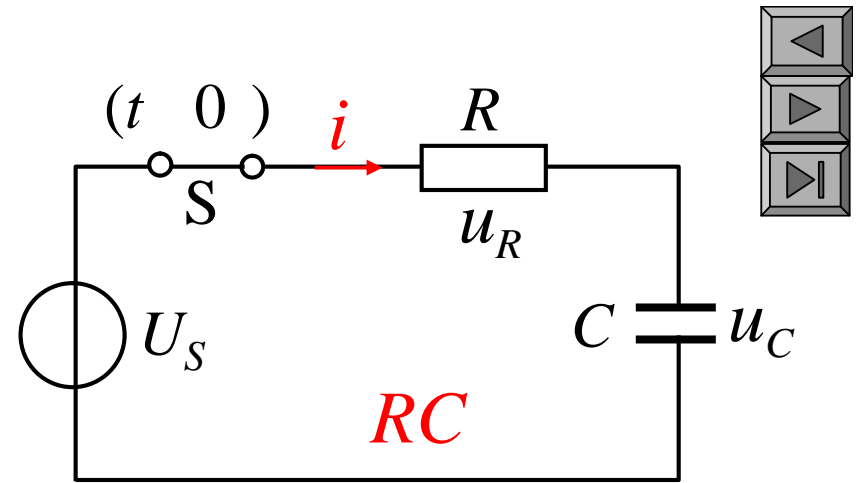
$$u_c = U_s - U_s e^{-\frac{t}{RC}}$$



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

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

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



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

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

50%

2. RL

(1)

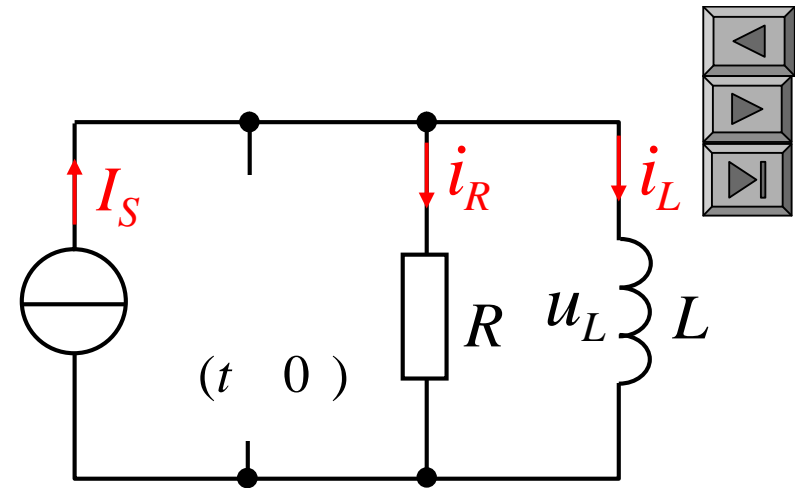
$$i_L(0^-) = i_L(0^+) = 0$$

$$i_R = i_L = I_S$$

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

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

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

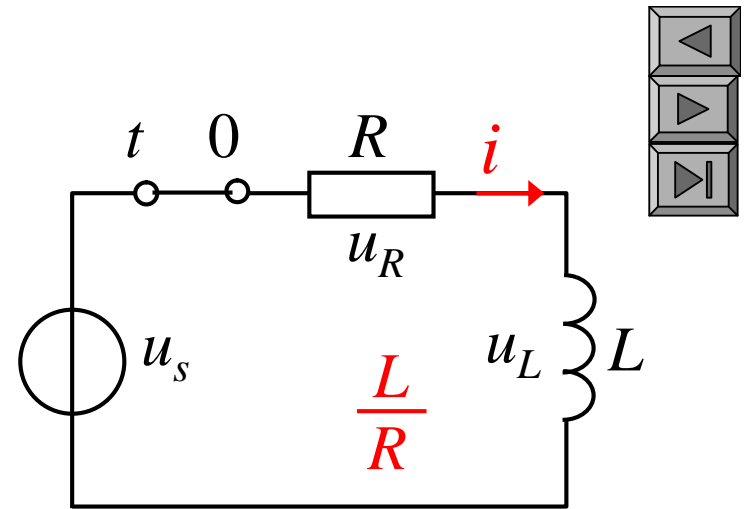


(2)

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

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

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



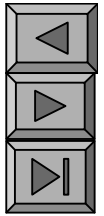
$$i'_L = I_m \cos(\omega t + \varphi_i) \quad I_m$$

i'_L

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

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

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



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

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

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

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

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

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

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

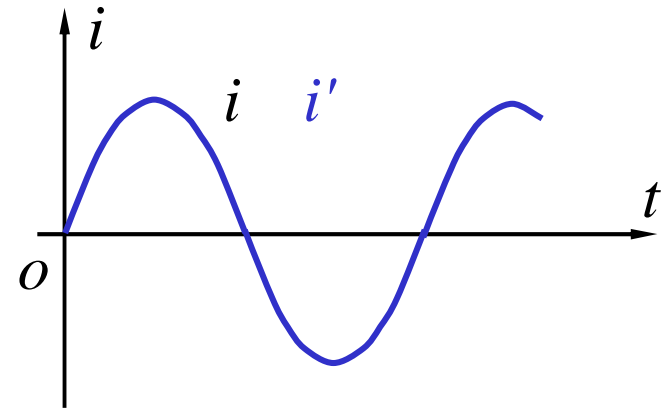


$$i_L = \frac{U_m}{|Z|} \cos(\omega t - \varphi) + \frac{U_m}{|Z|} \cos(\omega t - \varphi) e^{-\frac{t}{\tau}}$$

i'_L
 i''_L

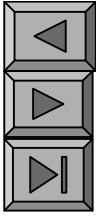
$$R \quad u_R = R i_L \quad L \quad u_L = L \frac{di_L}{dt}$$

(1) S u 90°
 $i''_L = 0$

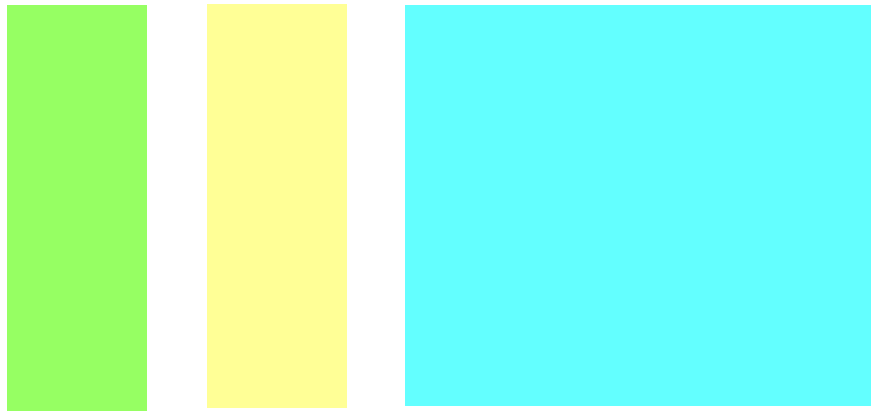
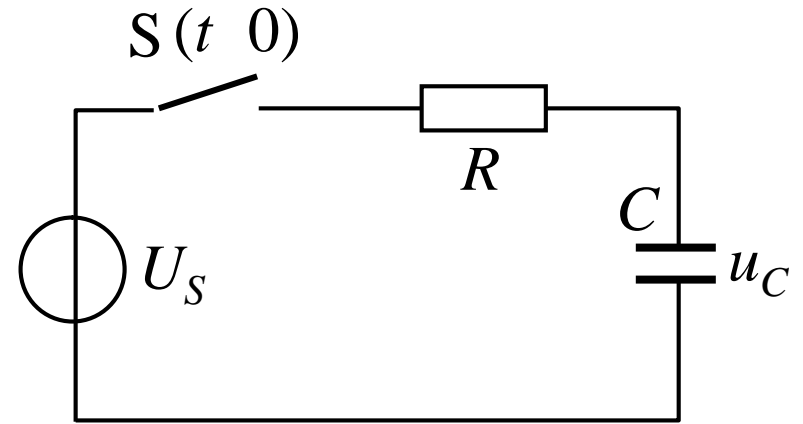


(2) S u $i_L = \frac{U_m}{|Z|} \cos \omega t + \frac{U_m}{|Z|} e^{-\frac{t}{\tau}}$

7 4

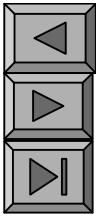
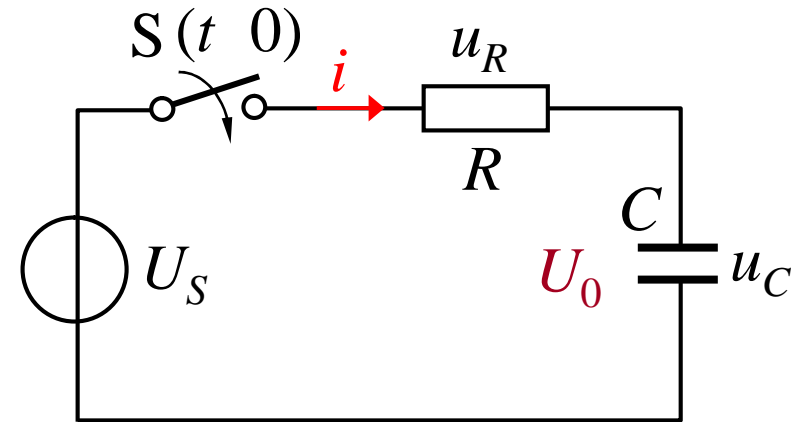
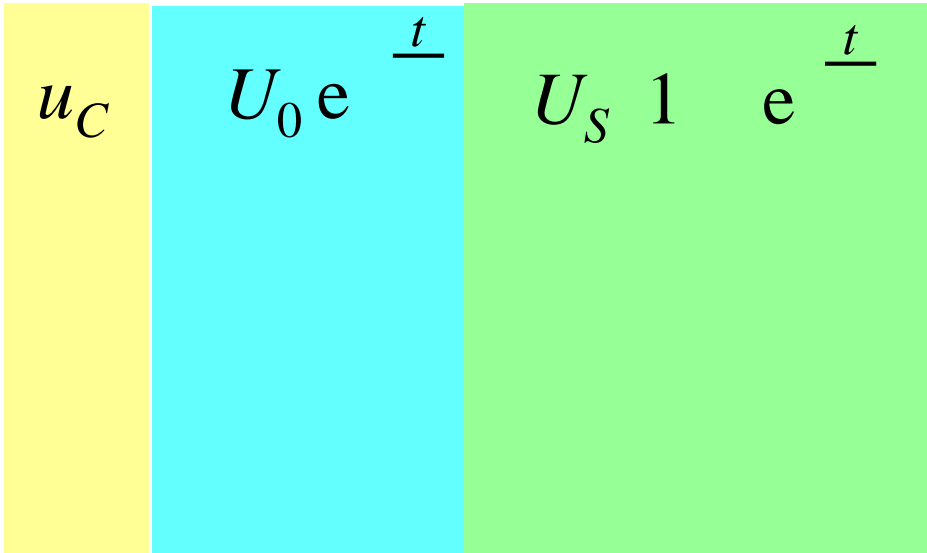


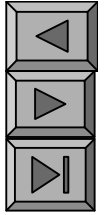
1.



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

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

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

$f(t)$

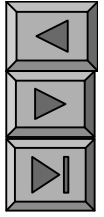
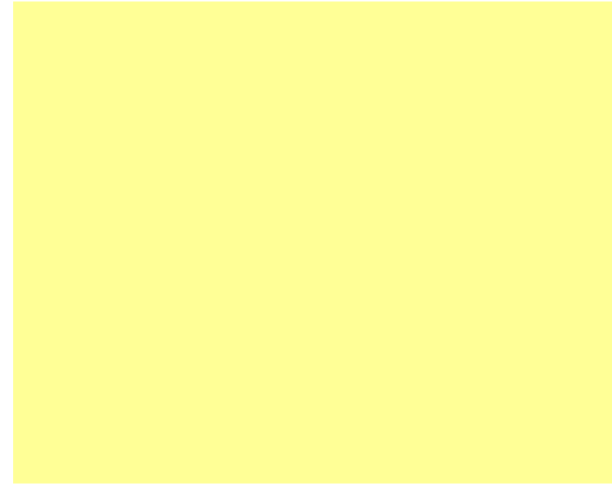
$f(0_+)$

$f(t)$

$f(0_-)$

4.

1

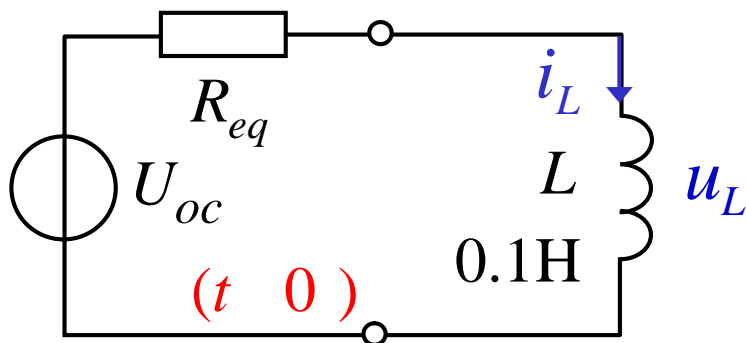


2

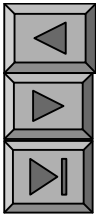
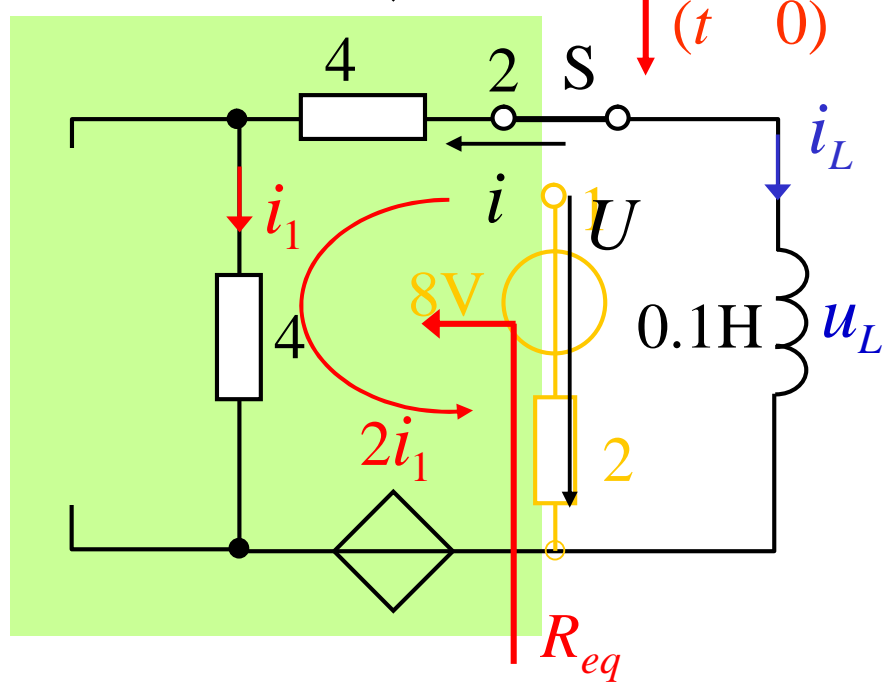
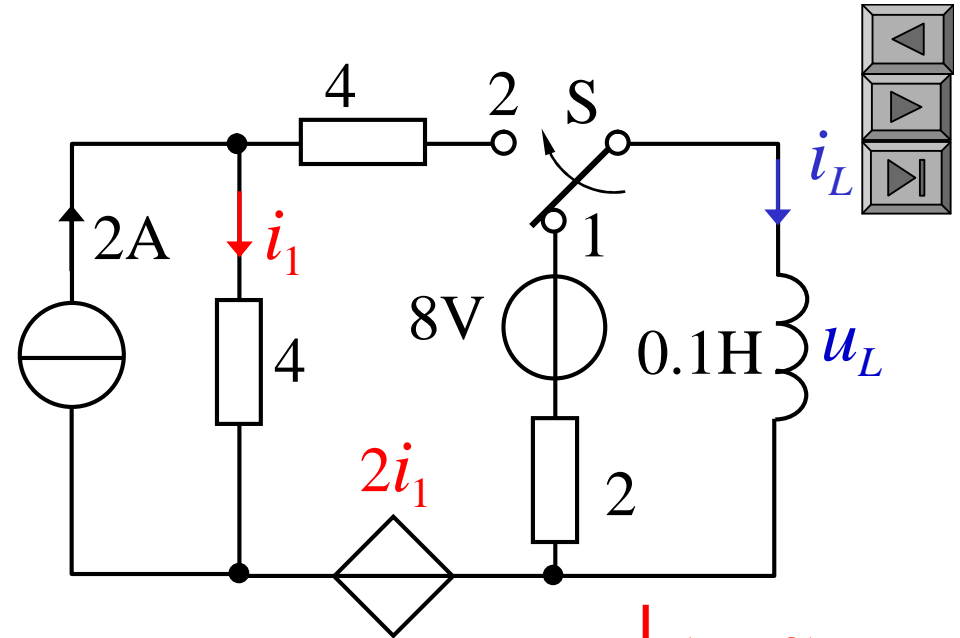
$$i_L(0^-) = 4A \quad u_L(0^-)$$

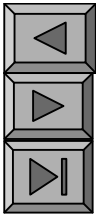
$$U_{oc} = 4i_1 + 2i_1 = 12V$$

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



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



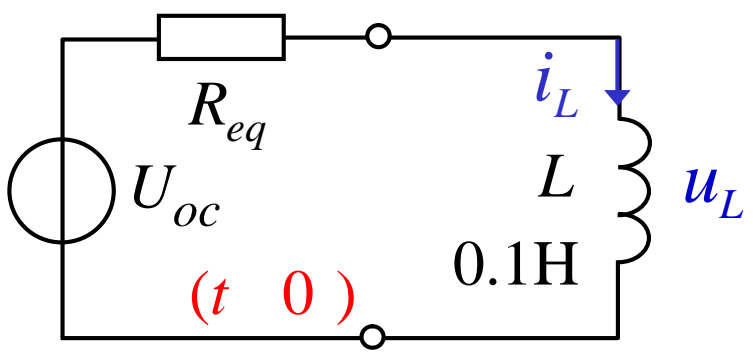


$$2 \quad u_L \quad \frac{L}{R_{eq}} \quad \frac{0.1}{10} \quad 0.01s$$

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

$$U_{oc} \quad 4i_1 \quad 2i_1 \quad 12V \quad f(t) \quad f() \quad [f(0) \quad f()] e^{-\frac{t}{\tau}}$$

$$R_{eq} \quad \frac{U}{i} \quad 10 \quad u_L \quad 52e^{100t} \quad V$$



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

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

$$0.01s$$

$$u_L(0) \quad U_{oc} \quad R_{eq} \quad i_L(0) \quad i_L \quad e^{100t} \quad A$$

$$52V \quad u_L \quad L \quad \frac{di_L}{dt} \quad u_L$$

3

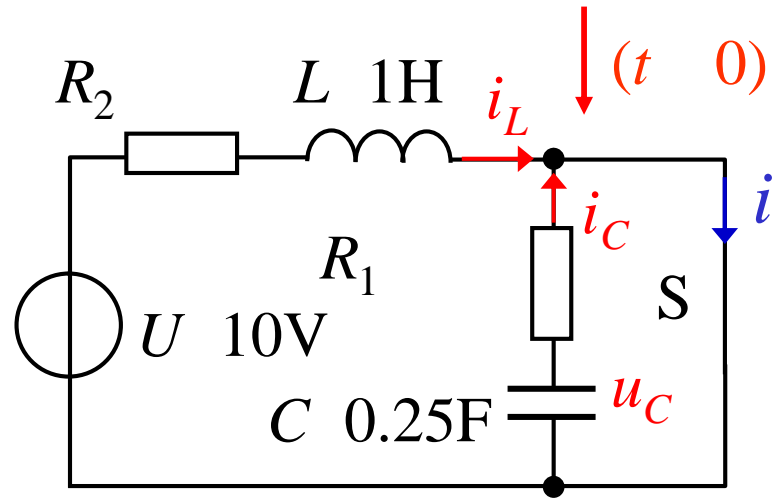
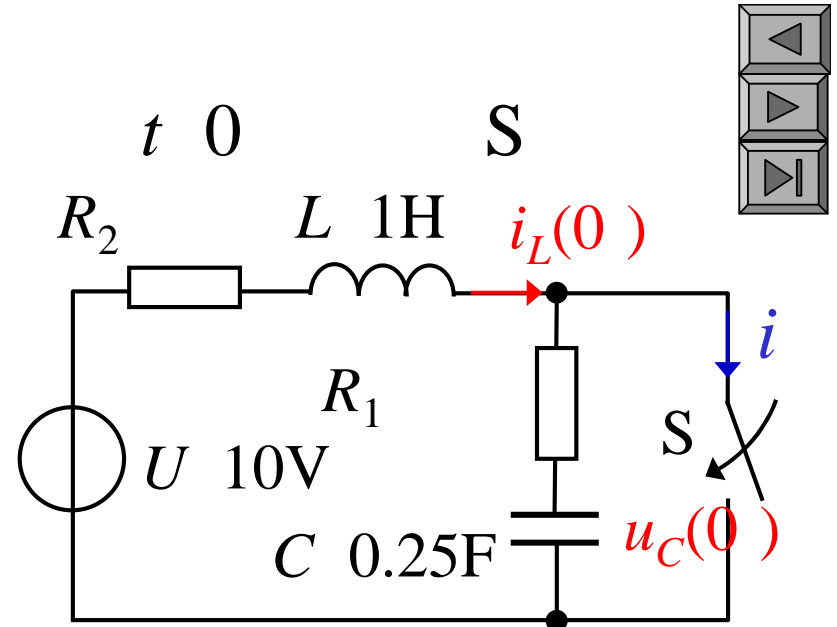
$i_L(0^-)$ 0 $u_C(0^-)$ $10V$
 $i(t)$

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

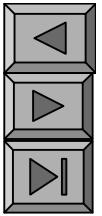
$i_L(0^+)$ $i_L(0^-)$ 0

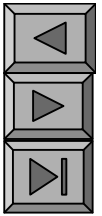
L R_2 $0.2s$,

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

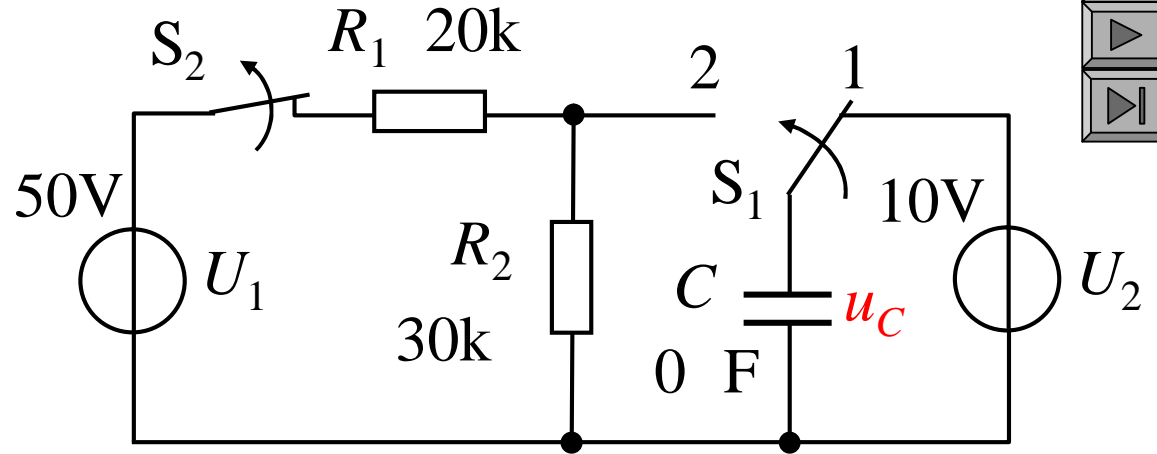


$i_C(t)$ $i_L(t)$
 $i(t)$ $i_L(t)$ $i_C(t)$



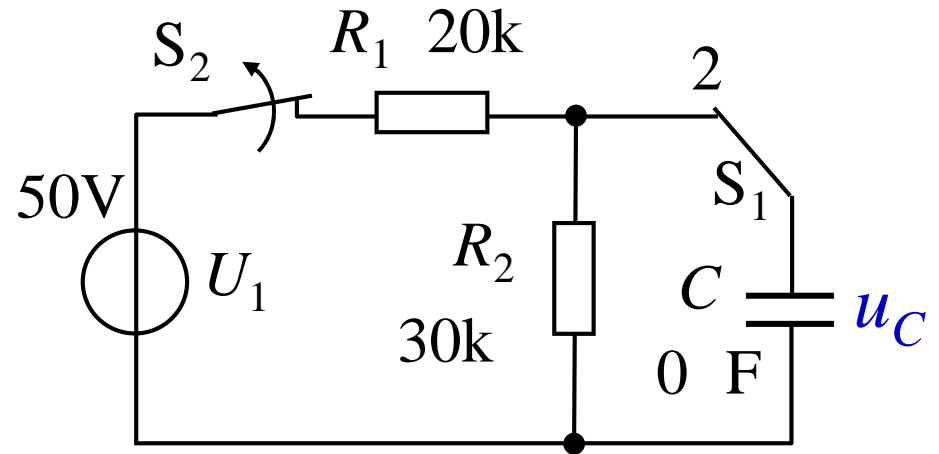


4
 $t = 0$ S_1 1
 2 $0.12s$
 S_2 $u_C(t)$



$u_C(0^-) = 10V$

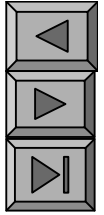
(1) $t = 0.12s$
 $u_C(0^+) = u_C(0^-) = 10V$



$u_C(t) = 30V$

$\tau = (20 // 30) \times 10^3 \times 10^{-6} = 0.12s$

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



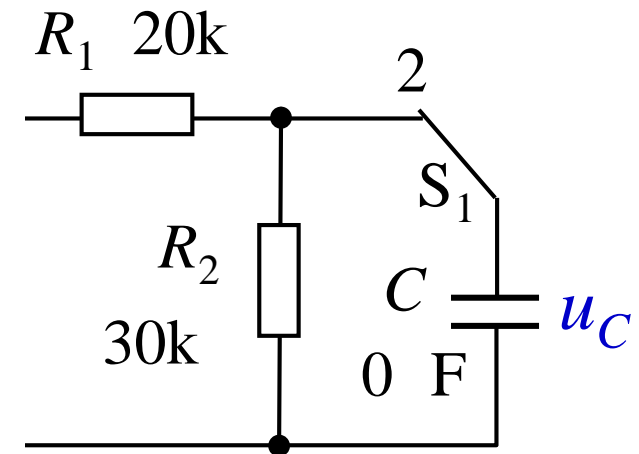
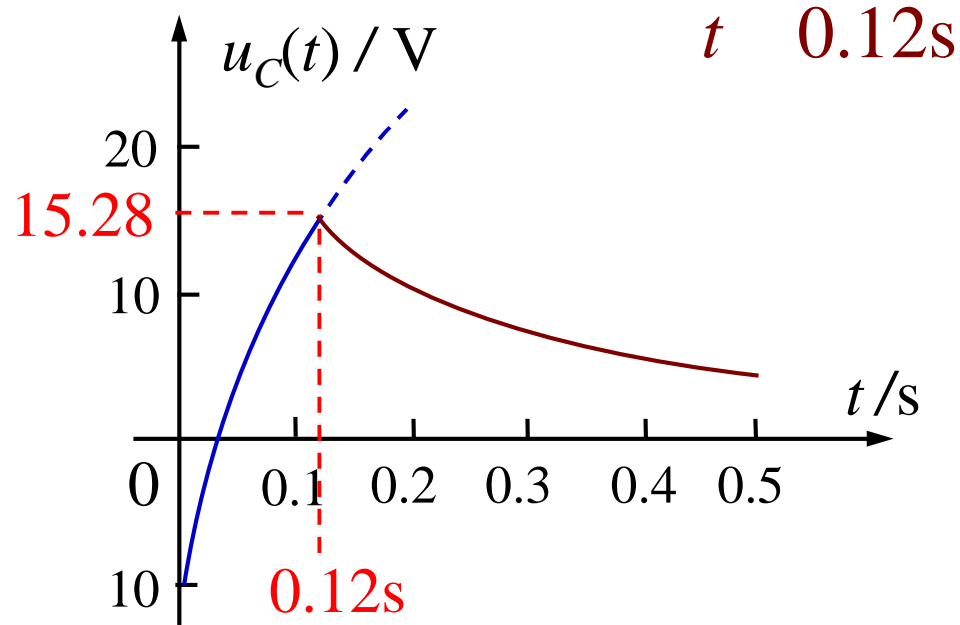
$$u_C(t) = 30 + 40e^{-8.33t} \text{ V} \quad (0 \leq t < 0.12\text{s})$$

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

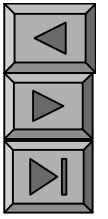
$$(2) \quad t = 0.12\text{s} \quad u_C(0.12) = u_C(0.12) = 15.28\text{V}$$

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

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



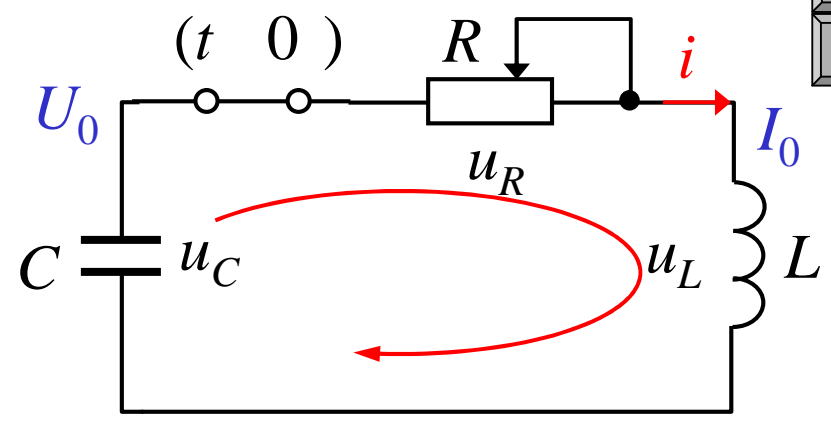
7 5



RLC

1.

KVL u_C Ri u_L 0



$$i \quad C \frac{du_C}{dt} \quad Ri \quad RC \frac{du_C}{dt} \quad u_L \quad L \frac{di}{dt} \quad LC \frac{d^2u_C}{dt^2}$$

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

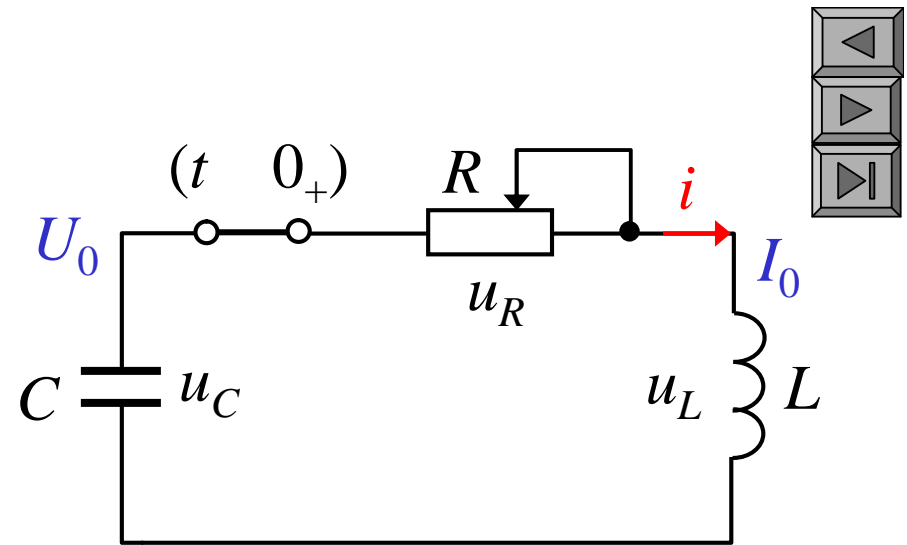
$$u_C(0) = U_0 \quad i(0) = 0 \quad \left. \frac{du_C}{dt} \right|_{t=0} = \frac{i(0)}{C} = 0$$

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

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

2.

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

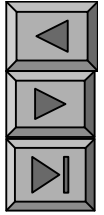


(1)

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

(2) R L C

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



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

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

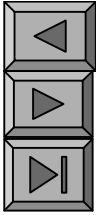
3.

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

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

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

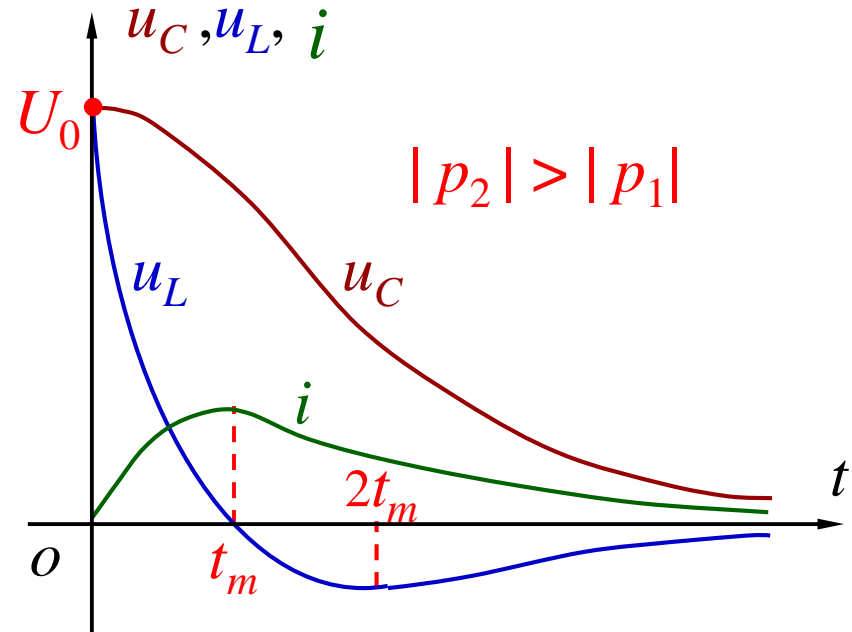
$$u_C = \frac{U_0}{p_2 - p_1} (p_2 e^{p_1 t} - p_1 e^{p_2 t})$$



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

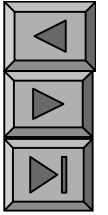
$$i = C \frac{du_C}{dt} = \frac{U_0}{L(p_2 - p_1)} (e^{p_1 t} - e^{p_2 t})$$

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

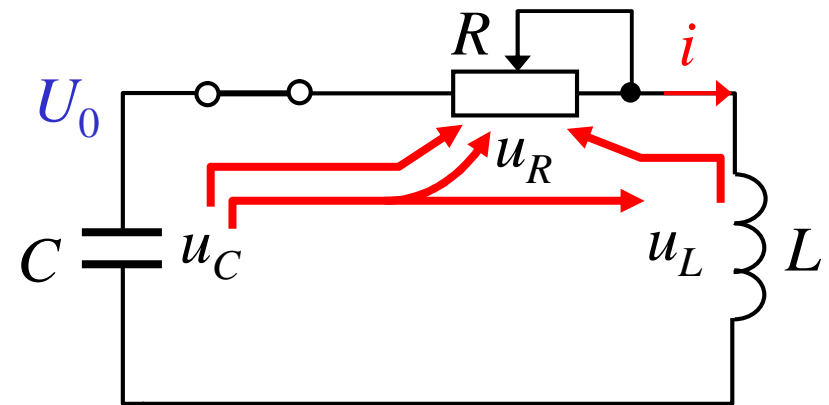
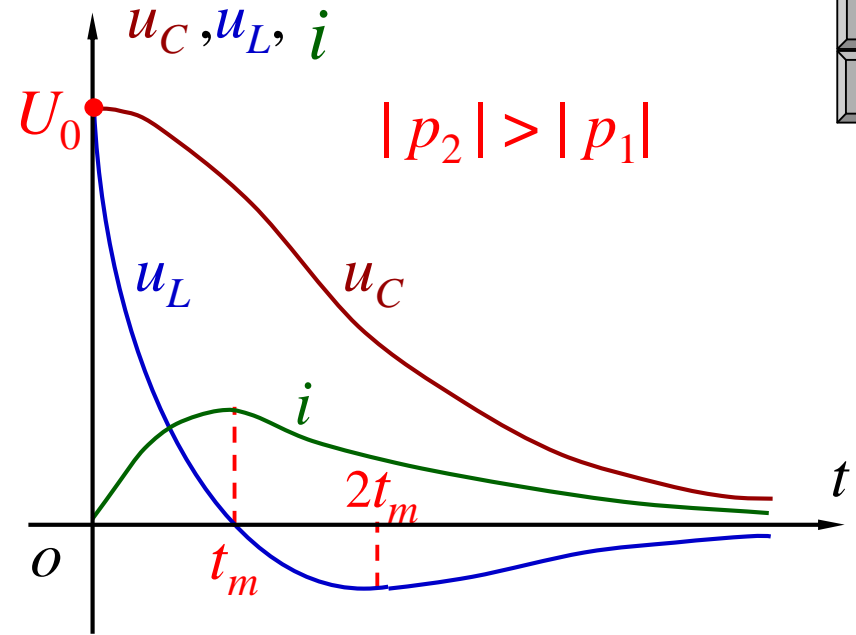


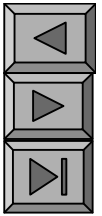
$u_C \quad 0 \quad i \quad 0$

C



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





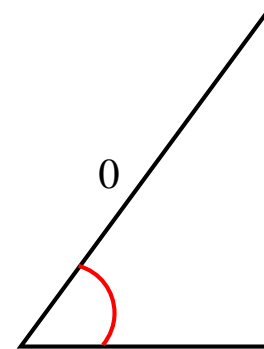
$$(2) \quad R < 2\sqrt{\frac{L}{C}} \quad p_{1,2} = \frac{R}{2L} \pm \sqrt{\left(\frac{R}{2L}\right)^2 - \frac{1}{LC}}$$

$$\frac{R}{2L} < \frac{1}{LC} \left(\frac{R}{2L}\right)^2 \quad p_1 = \frac{R}{2L} + j \quad p_2 = \frac{R}{2L} - j$$

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

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

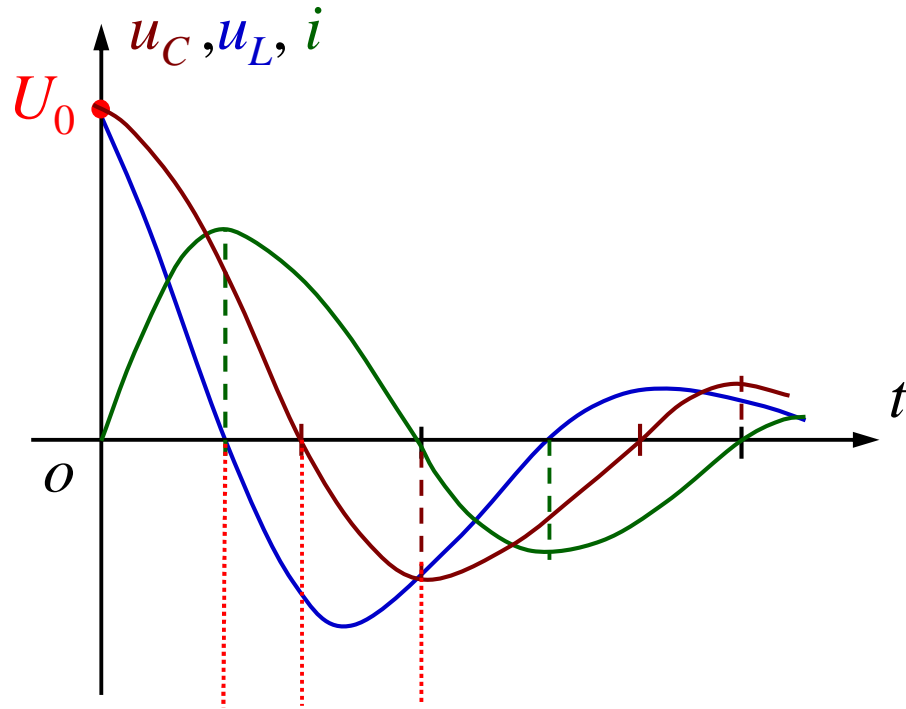
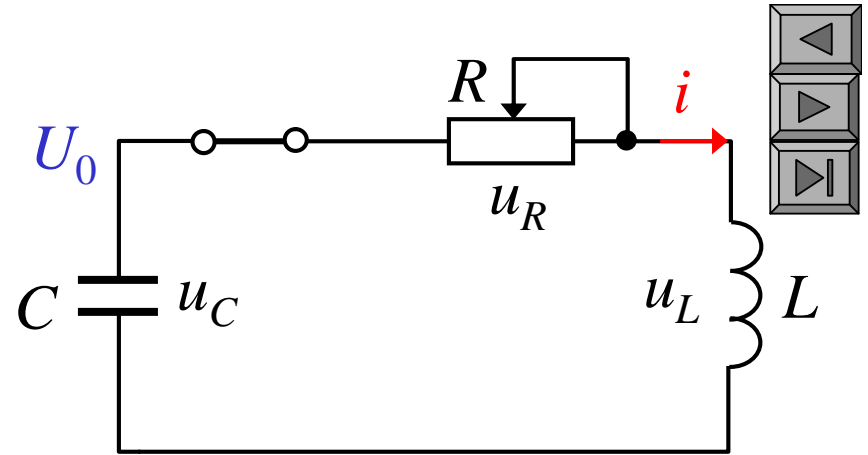
$$B = \frac{U_0}{\sin \theta} \quad \theta = \arctg \frac{B \cos \theta}{B \sin \theta} = \arctg \frac{\cos \theta}{\sin \theta} = \arctg \frac{1}{\omega} = \arctg \frac{1}{\frac{R}{2L} \sqrt{LC}}$$



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

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

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



C		L	R
C	L		R
L		C	R

$R \ 0$

$R \ 0$

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

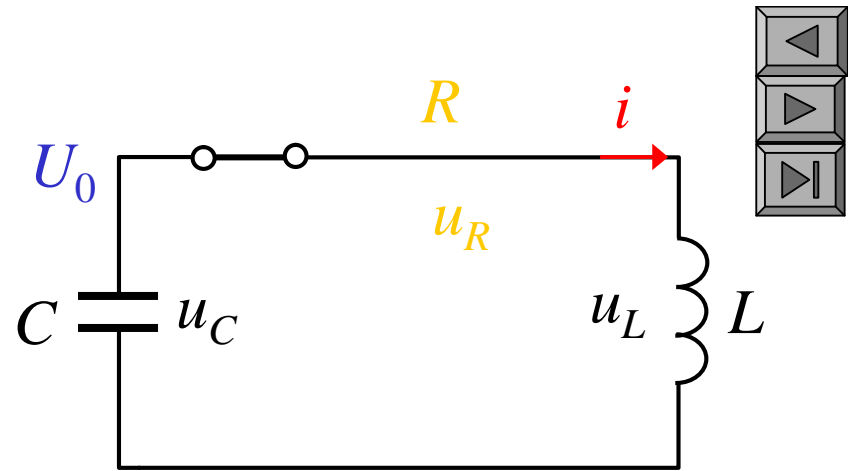
$$\sqrt{\left(\frac{R}{2L}\right)^2 + \frac{1}{LC}} = \frac{1}{\sqrt{LC}}$$

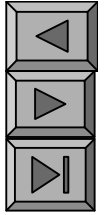
$$\arctg \frac{R}{2L} = 90^\circ$$

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

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

$$u_L = u_C$$





P161 7 7 RLC

U_0 15kV

C 1700 F L $6 \cdot 10^9$ H R $6 \cdot 10^4$

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

RLC

$$\frac{R}{2L} = \frac{6 \cdot 10^4}{2 \cdot 6 \cdot 10^9}$$

$$10^4 \text{ s}^{-1}$$

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

$$= 3.09 \cdot 10^5 \text{ rad/s}$$

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

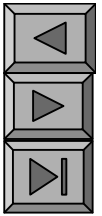
$$10^6 e^{-50000t}$$

$$\sin(3.09 \cdot 10^5 t) \text{ A}$$

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

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

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



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

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

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

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

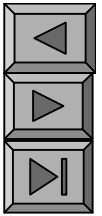
$$u_C(0_+) = U_0 \quad \left. \frac{du_C}{dt} \right|_{t=0} = \begin{matrix} A_1 \\ A_2 \end{matrix} \begin{matrix} U_0 \\ U_0 \end{matrix}$$

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

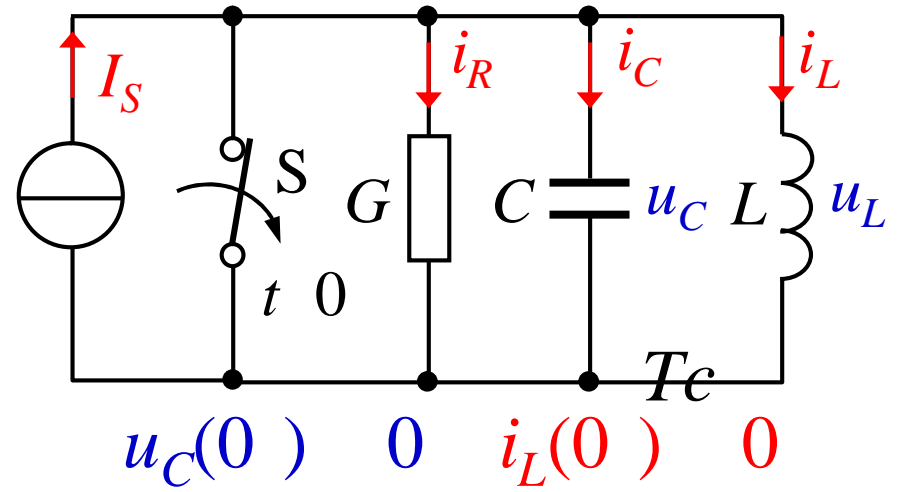
$$i = \frac{U_0}{L} t e^{-t}$$

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

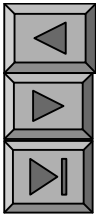
7 6



$$\begin{aligned}
 i_R &= Gu_L - GL \frac{di_L}{dt} \\
 i_C &= C \frac{du_C}{dt} - C \frac{du_C}{dt} - LC \frac{d^2i_L}{dt^2} \\
 &= LC \frac{d^2i_L}{dt^2}
 \end{aligned}$$

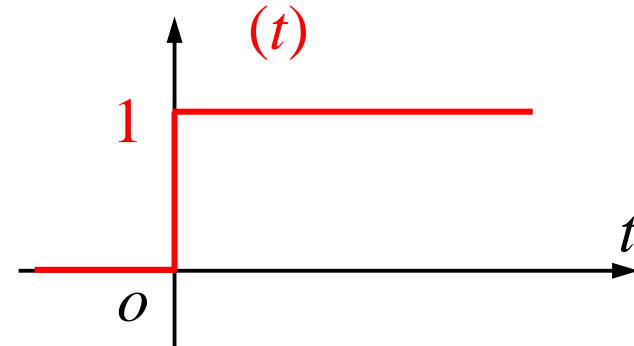


7 7



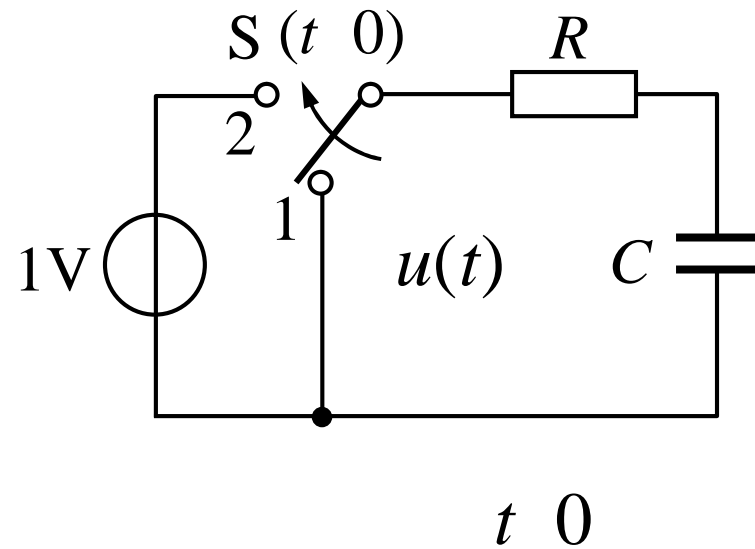
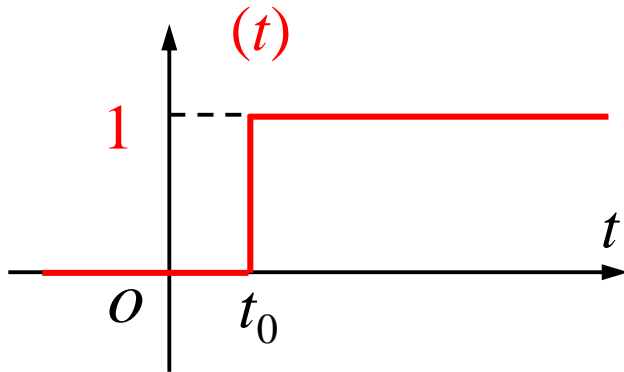
1.

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



(2) 

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

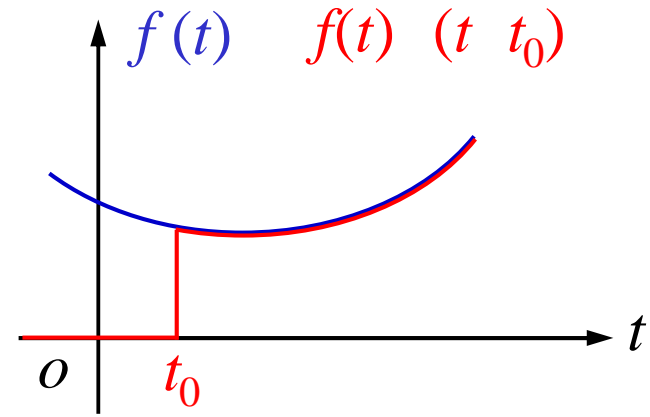




2.

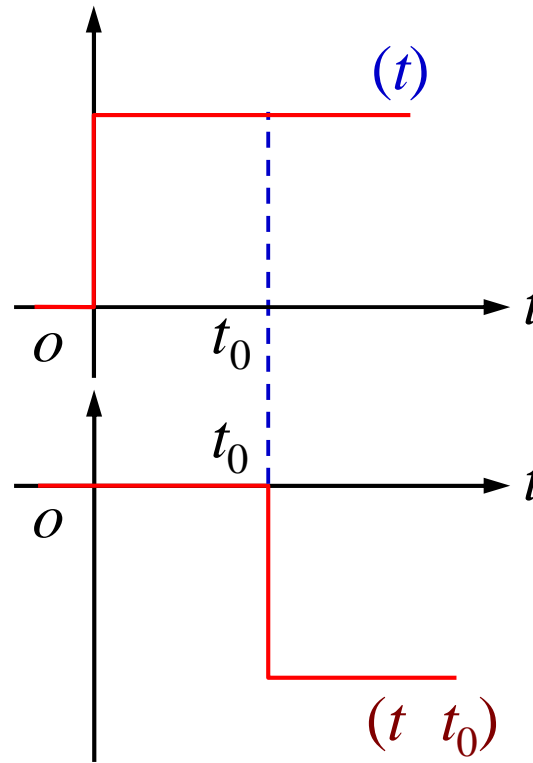
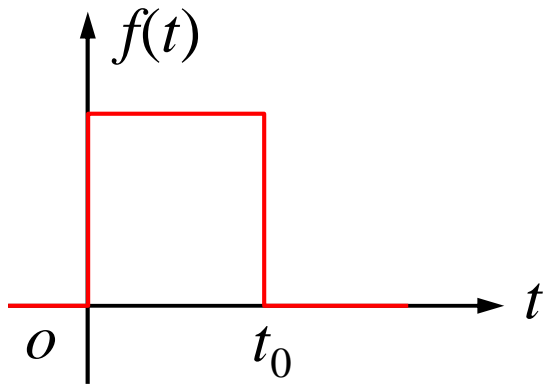
(1)

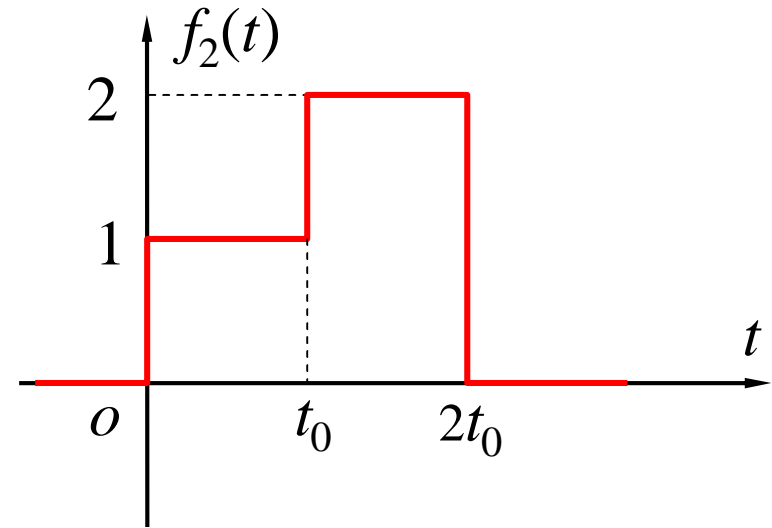
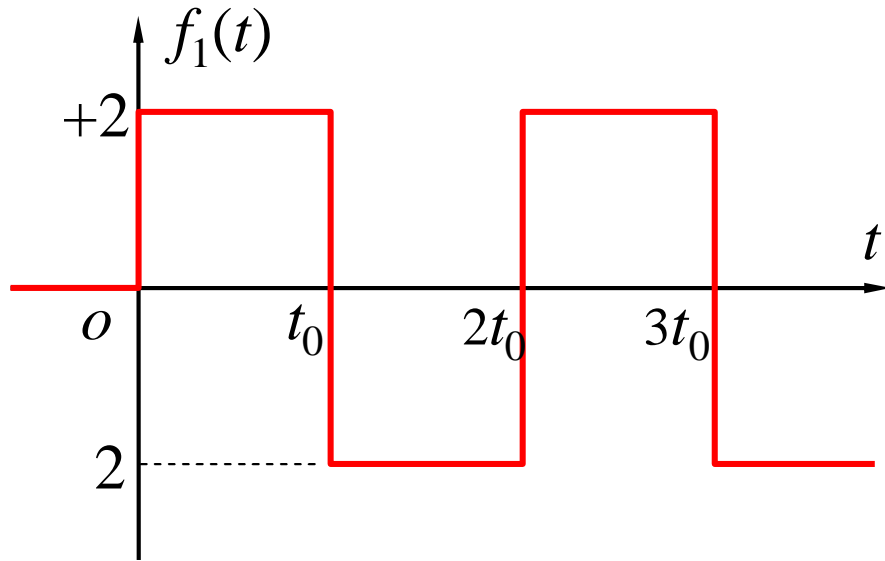
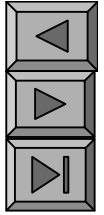
$$f(t) \text{ (} t \text{ } t_0) \begin{cases} 0 & t < t_0 \\ f(t) & t \geq t_0 \end{cases}$$



(2)

$$f(t) \text{ (} t \text{) (} t \text{ } t_0)$$

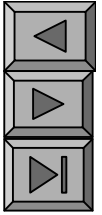




$f_1(t)$ 2 (t) 4 (t t_0) 4 (t $2t_0$) 4 (t $3t_0$)

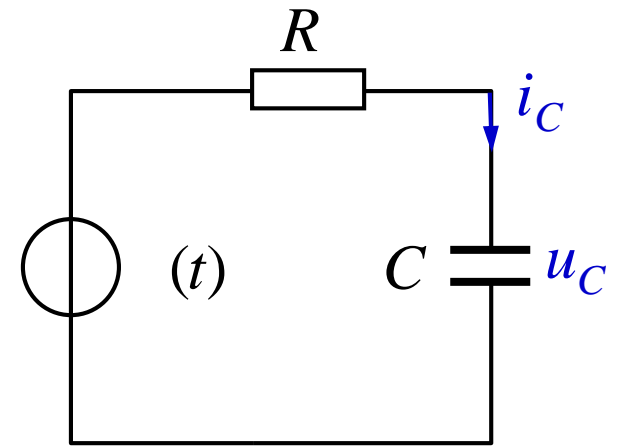
$f_2(t)$ (t) (t t_0) 2 (t $2t_0$)

3.



$$1 \quad \underline{s(t)} \quad \underline{i_C(t)}$$
$$u_C(t) \quad u_C(0) = 0 \quad u_C(\infty) = 1V$$

u_C





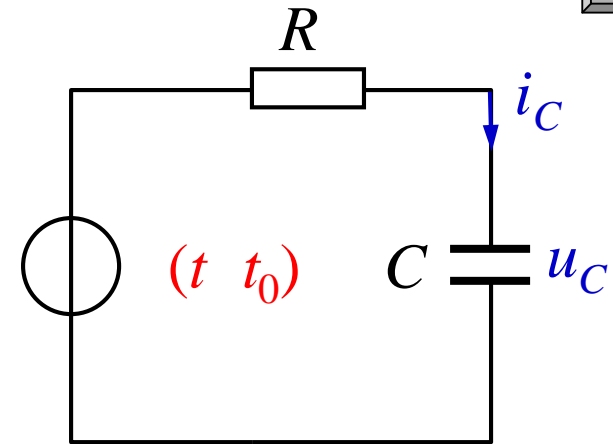
$t - t_0$

$t - t_0$

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

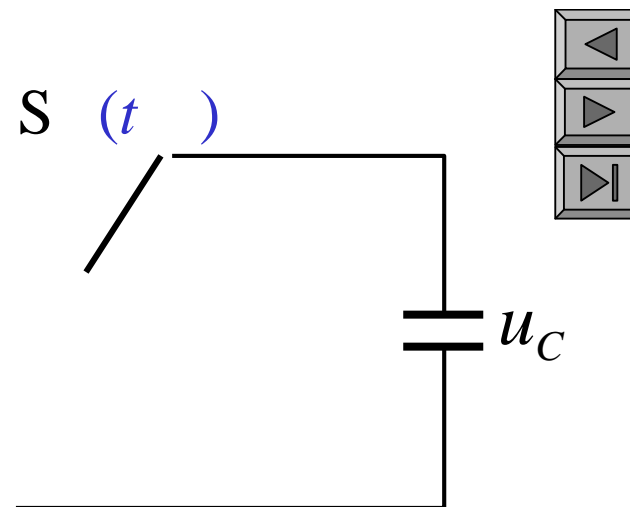
$$i_C = \frac{1}{R} e^{-\frac{t - t_0}{RC}} (t - t_0) \text{ A}$$

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

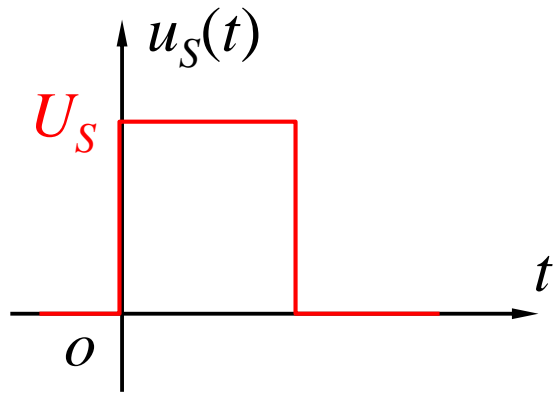


$$f(t) (t - t_0)$$

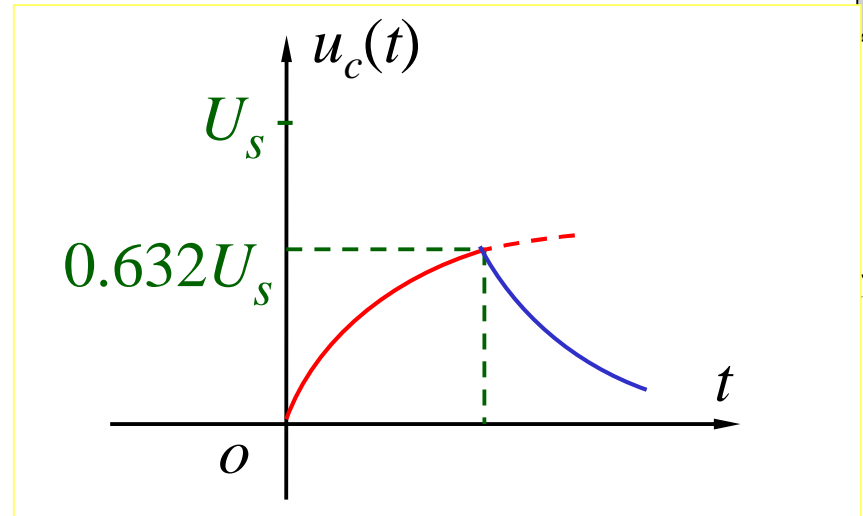
$2 \quad S \quad 1$
 $t \quad 0 \quad S \quad 1 \quad 2$
 $t \quad S \quad 2 \quad 1$
 $t \quad 0 \quad u_C$



2



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



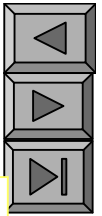
RC

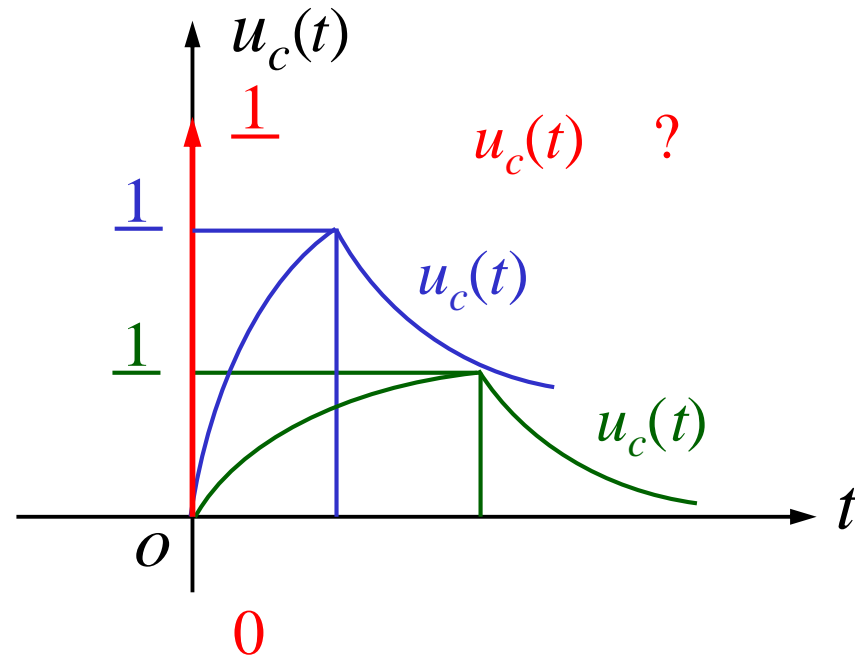
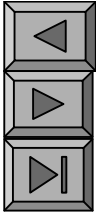
$$s(t) = \begin{cases} 0 & t < 0 \\ 1 - e^{-\frac{t}{\tau}} & t \geq 0 \end{cases}$$

$$s(t) = \begin{cases} 1 - e^{-\frac{t}{\tau}} & t < 0 \\ 0 & t \geq 0 \end{cases}$$

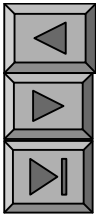
$$u_C(t) = \begin{cases} 0 & t < 0 \\ U_S(1 - e^{-\frac{t}{\tau}}) & t \geq 0 \end{cases}$$

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





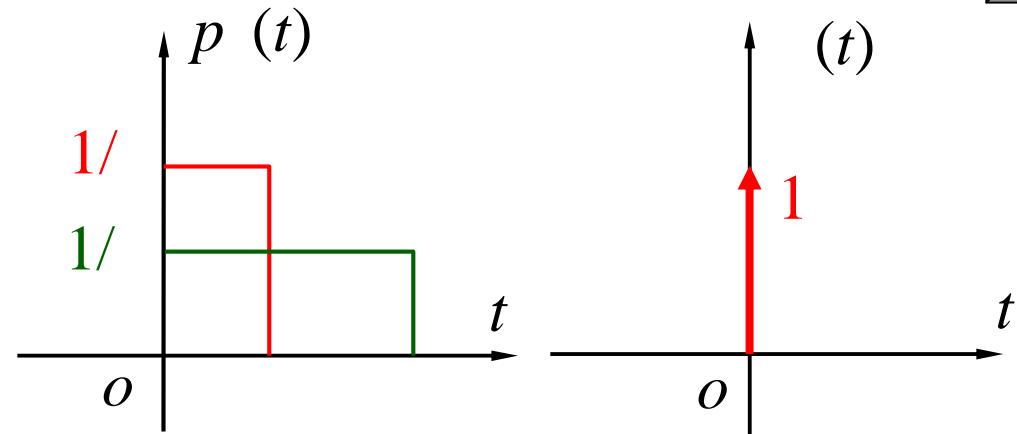
7 8



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)

$k(t)$

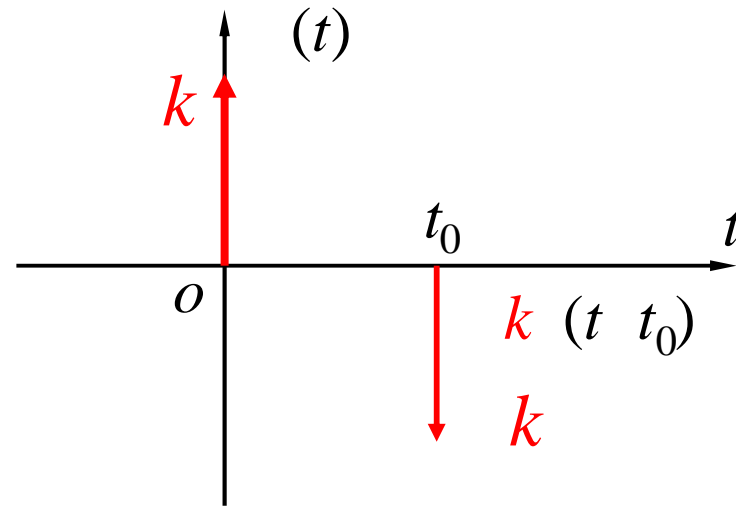
2.

(1) (t) (t)

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

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

k



(2) “ ”

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

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

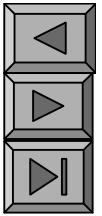
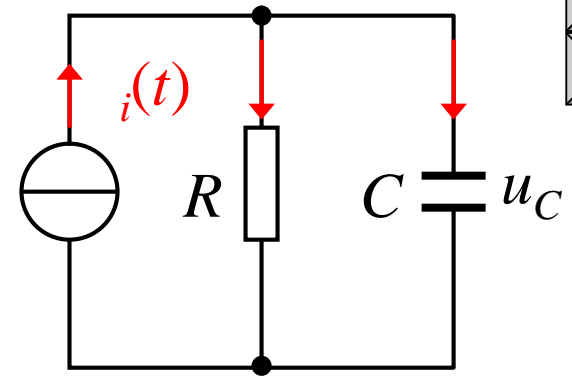
t_0

“ ”

3.

(1)

$h(t)$



RC

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

$$\int_0^t C \frac{du_C}{dt} dt$$

$$\int_0^t \frac{u_C}{R} dt$$

$$\int_0^t i(t) dt$$

$$i(t) \quad 1$$

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

1

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

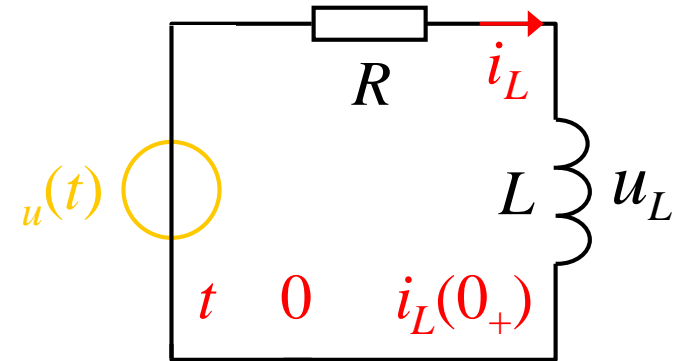
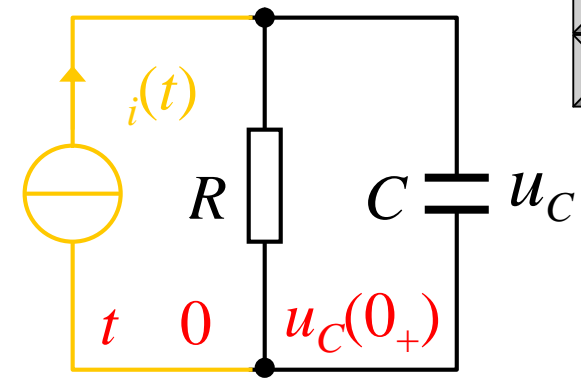
$$(3) \quad t = 0 \quad i(t) = 0$$

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

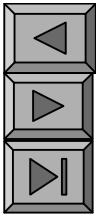
$$\left\{ \begin{array}{l} C \frac{du_C}{dt} = \frac{u_C}{R} \\ u_C(0) = \frac{1}{C} u_C(0) \end{array} \right.$$

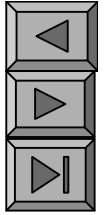
$(t = 0)$

RL



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





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

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

$$u_C \quad i_L$$

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

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

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

4.

1 RC

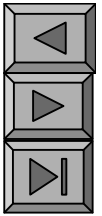
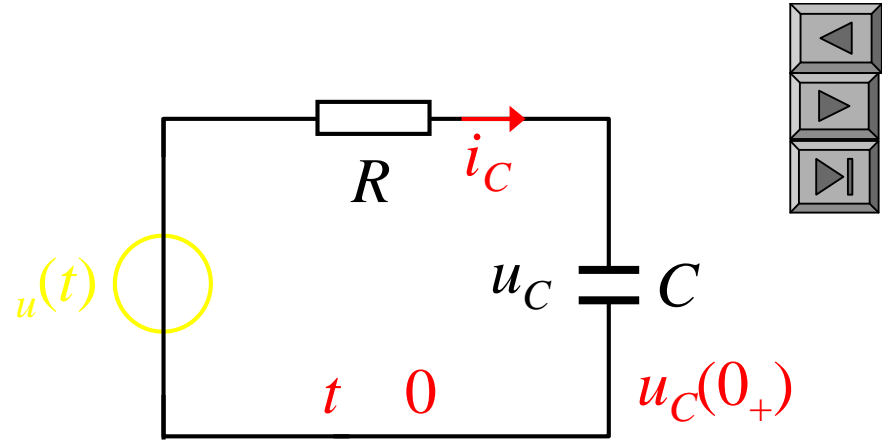
$t = 0$

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

$0 = 0$

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

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



$RC \quad u_C()$

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

(t) “ ”

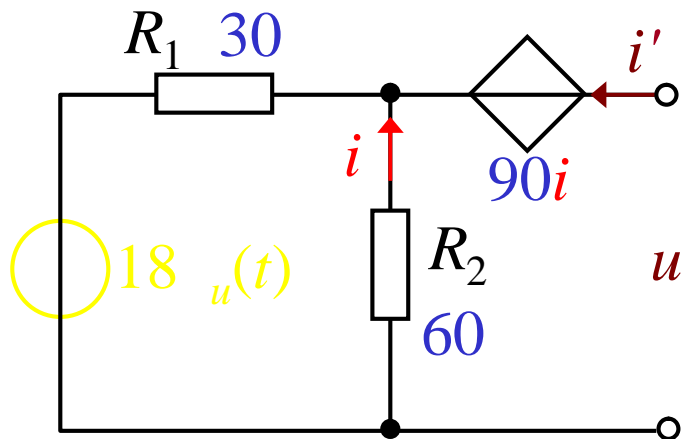
$$u_C(t) \quad t = 0$$

2

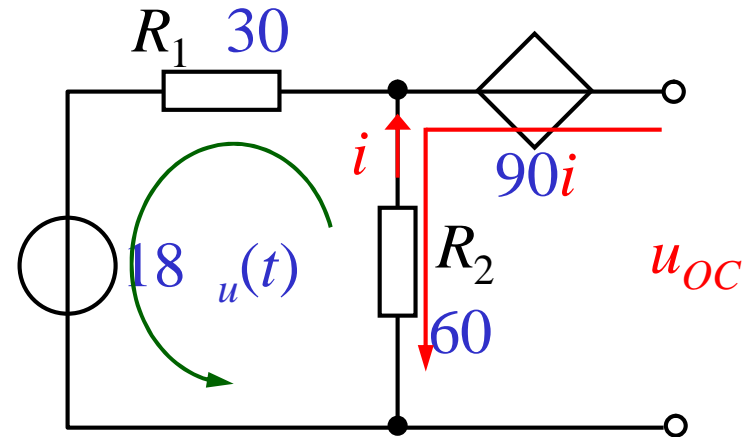
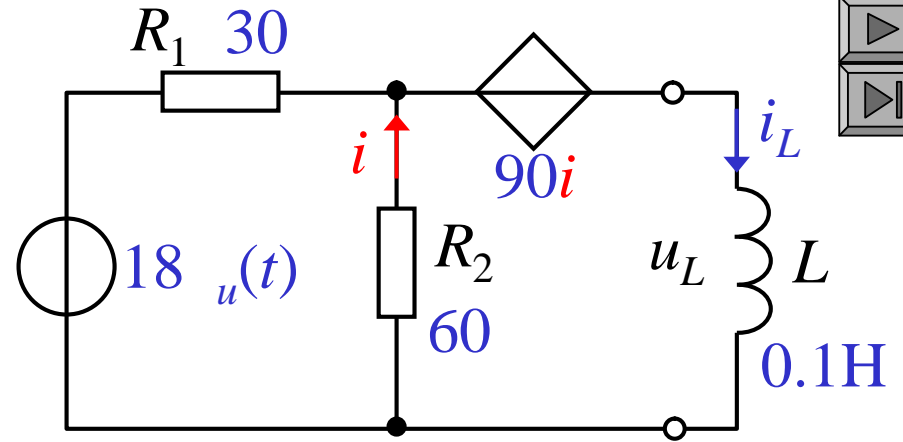
i_L

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

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

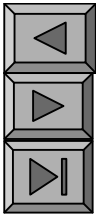


$$i = \frac{30}{30} \frac{i'}{60} = \frac{1}{3} i'$$



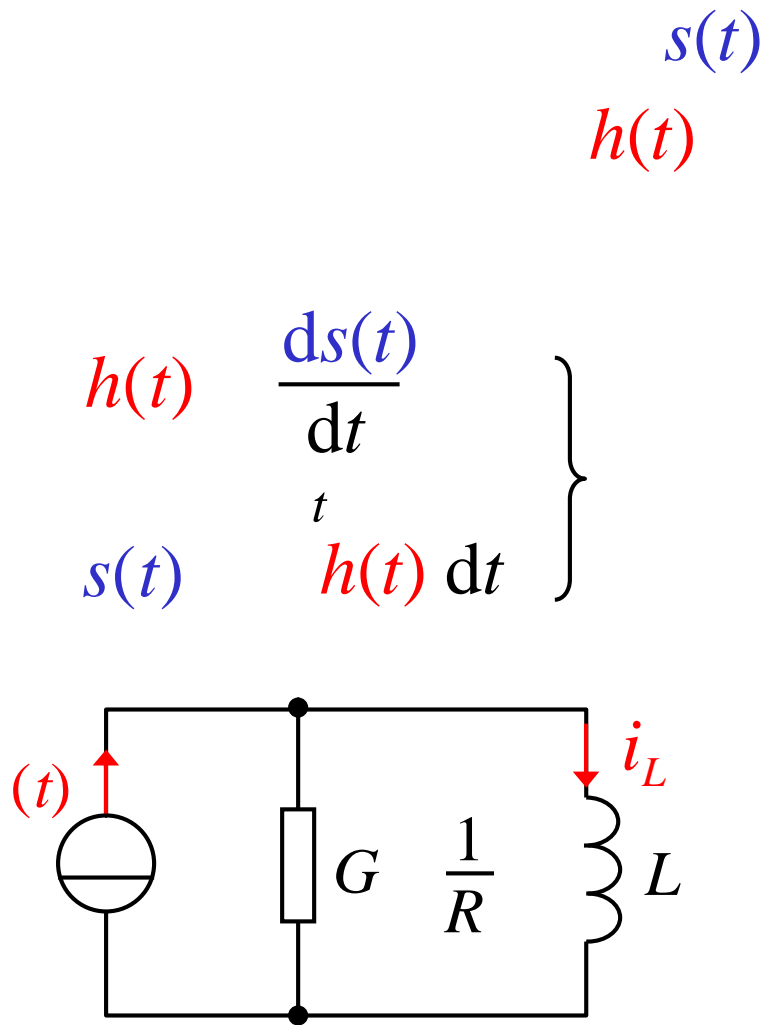
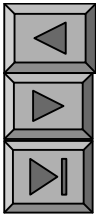
$$R_{eq} = \frac{u}{i'}$$

CCVC



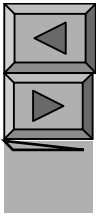


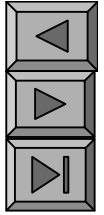
5.



RL

$$i_L(t) = \frac{R}{L} e^{-\frac{t}{L/R}} \int_0^t i_L(\tau) d\tau + e^{-\frac{t}{L/R}} \left[\int_0^t e^{\frac{\tau}{L/R}} \left(\frac{ds(\tau)}{d\tau} + \frac{1}{R} i_L(\tau) \right) d\tau \right]$$

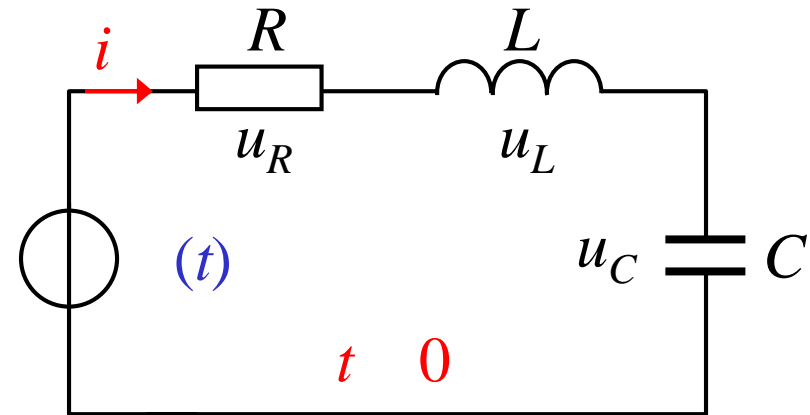




6.

k

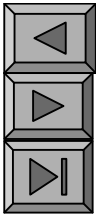
$$\begin{cases} LC \frac{d^2 u_C}{dt^2} & RC \frac{du_C}{dt} & u_C & (t) \\ u_C(0) & 0 & i_L(0) & 0 \end{cases}$$



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

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

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



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

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

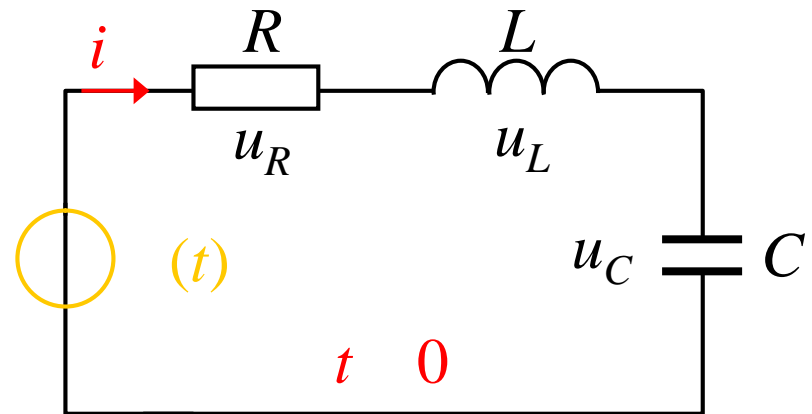
$$u_C(t)$$

$$u_C$$

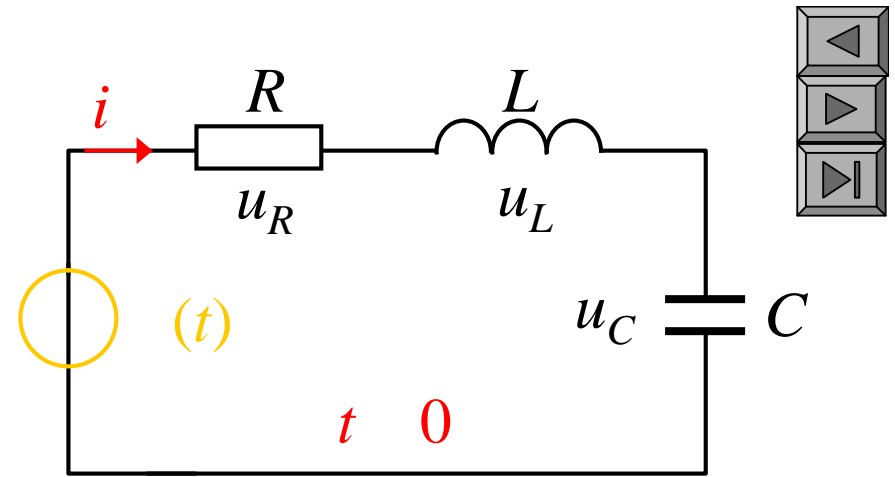
0

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)

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

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

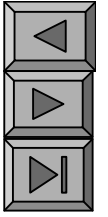
$t = 0$

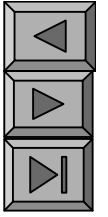
$i_L(0)$

7 5



*7 9





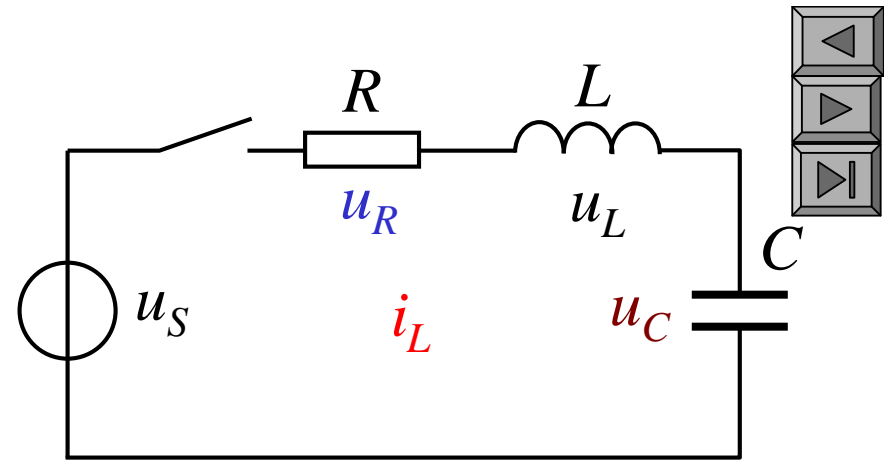
* 7 10

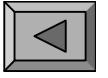
1.



()

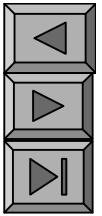
RLC





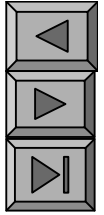
2.

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



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

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



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

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

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

\mathbf{x}

\mathbf{v}

n

m

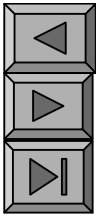
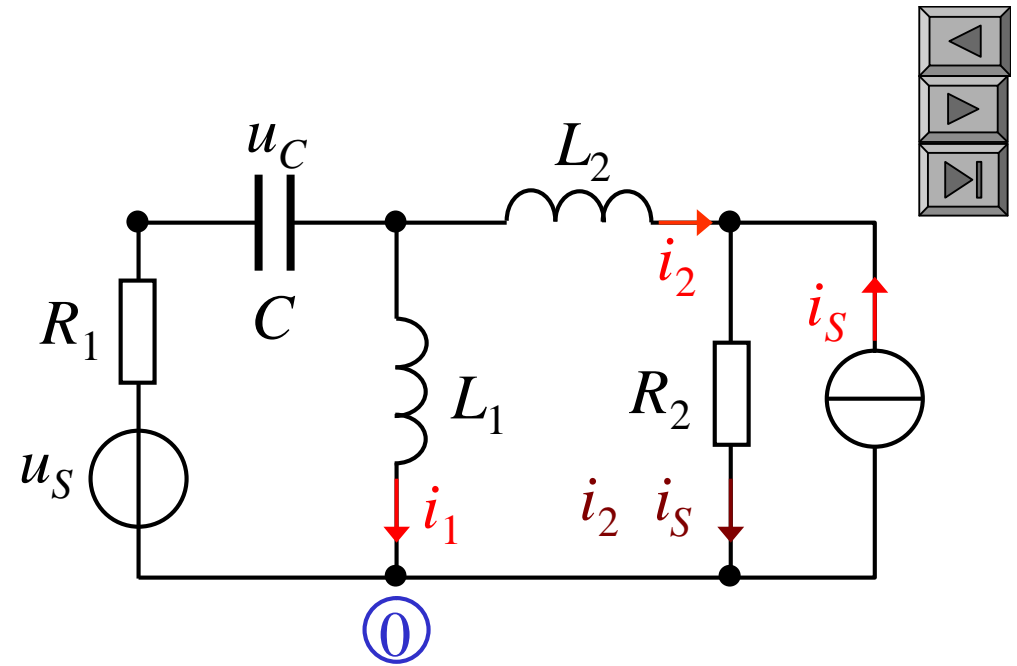
$\dot{\mathbf{x}}$ \mathbf{x} n

\mathbf{A} n n

\mathbf{v} m

\mathbf{B} n m

3.



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

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

u_C i_1 i_2

KCL

C

i_1 i_2

L

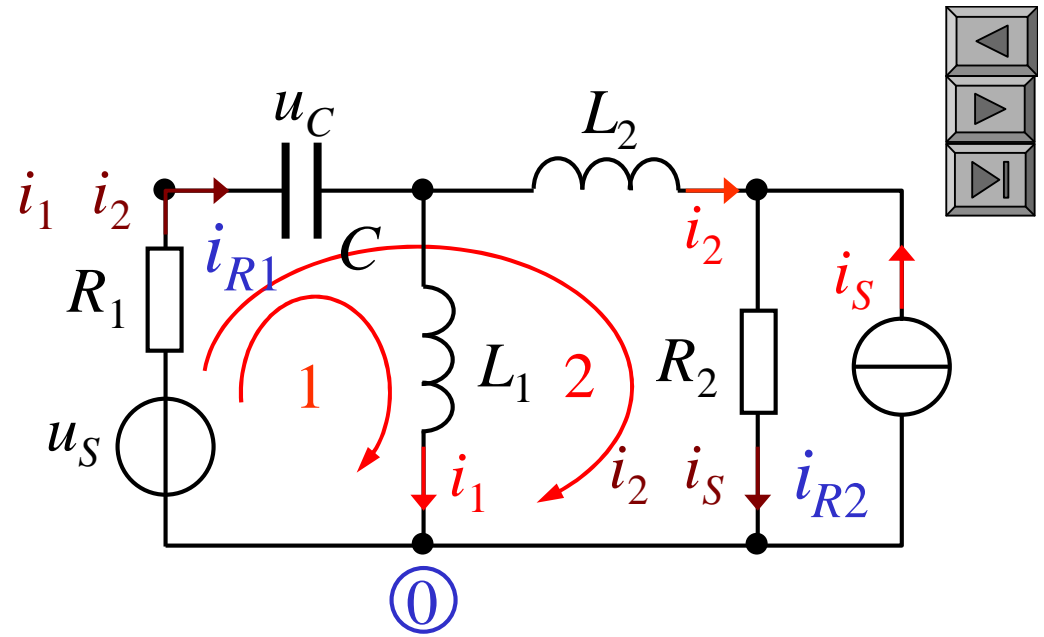
KVL

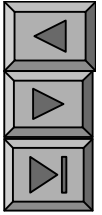
$$L_1 \frac{di_1}{dt}$$

u_C $R_1(i_1+i_2)$ u_S

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

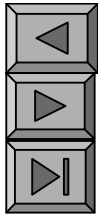
u_C $R_1(i_1+i_2)$ u_S $R_2(i_2+i_S)$





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

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



4. ()

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

$$y = Cx + Dv$$

n , m , h

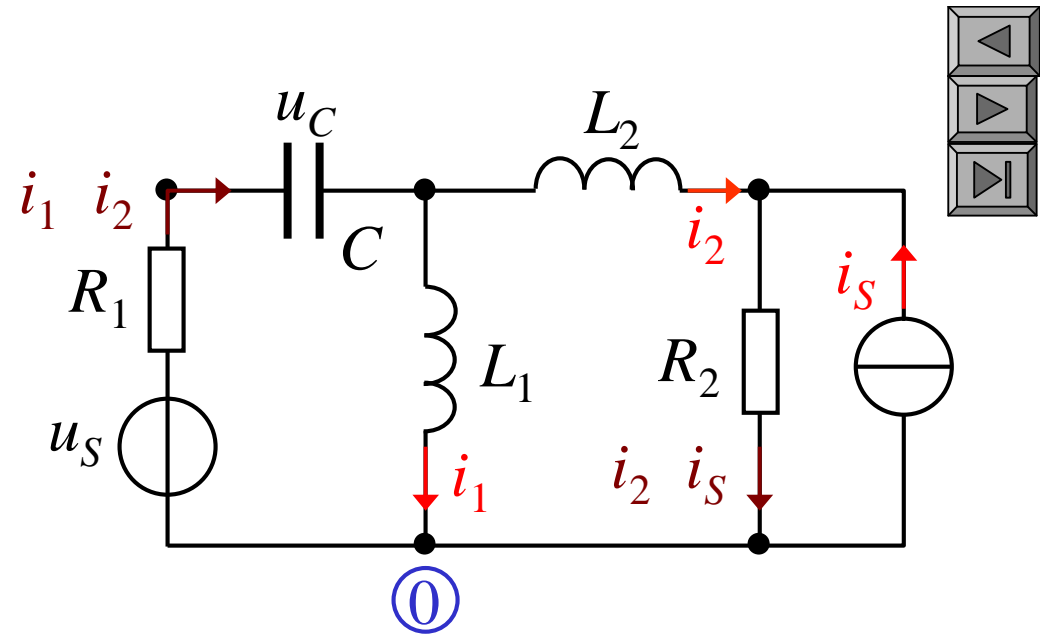
$$y \quad h$$

$$C \quad h \quad n$$

$$D \quad h \quad m$$

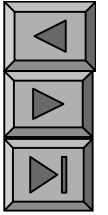
$$C \quad D$$

$y \quad Cx \quad Dv$



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

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



*7 11

1.

(1)

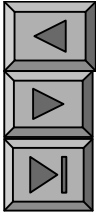
) () (

=

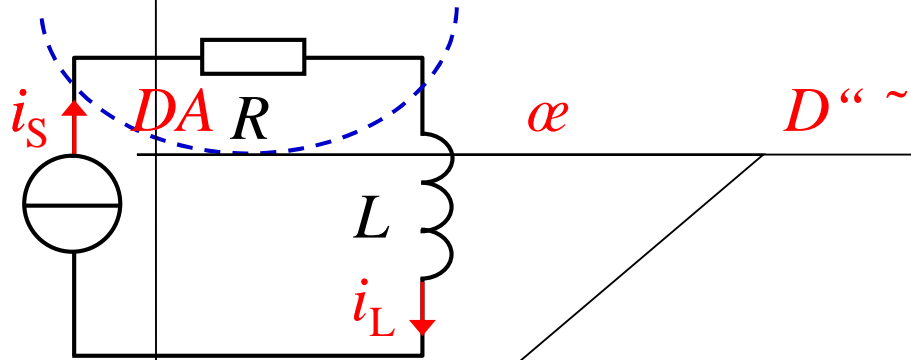
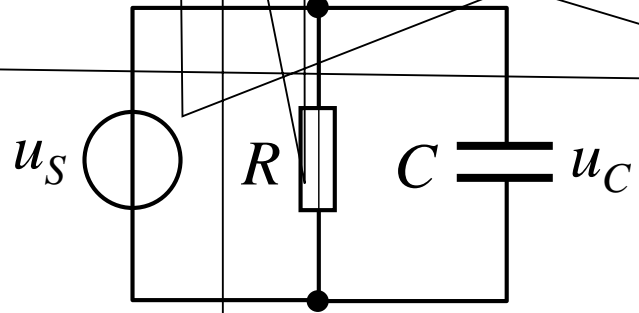
(C

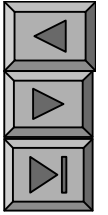
L)

RLC

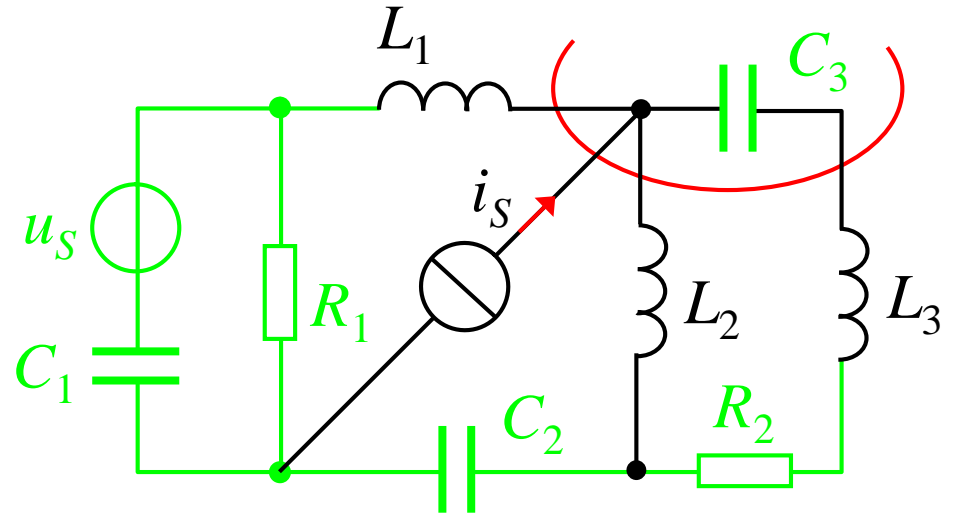
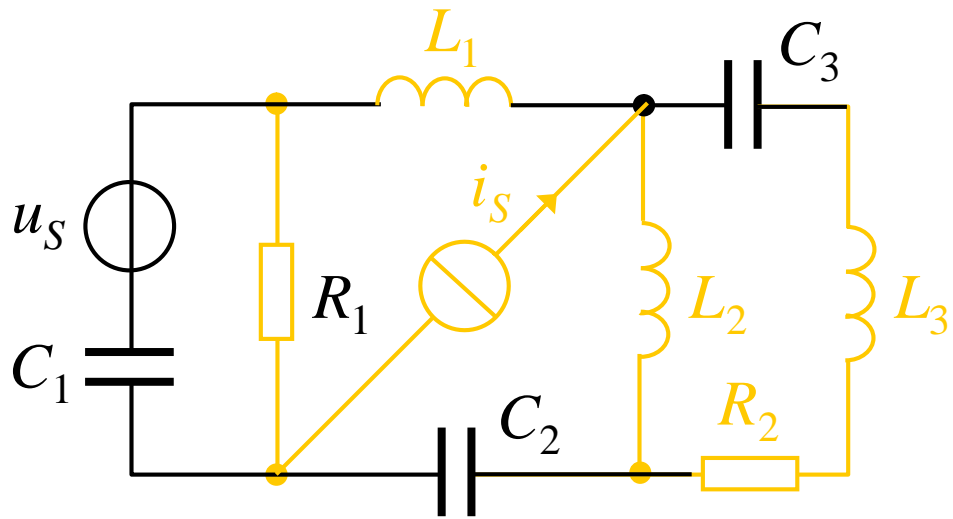
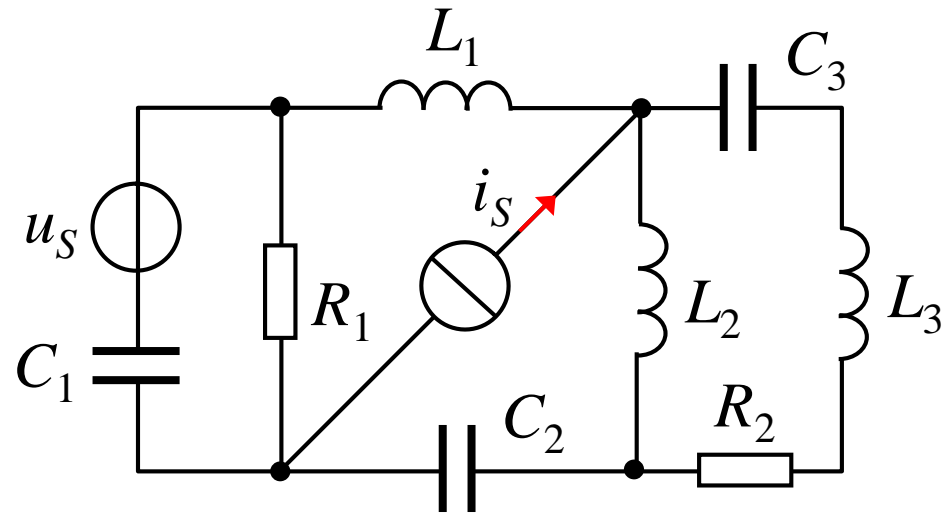


(2)





6 1 5



1



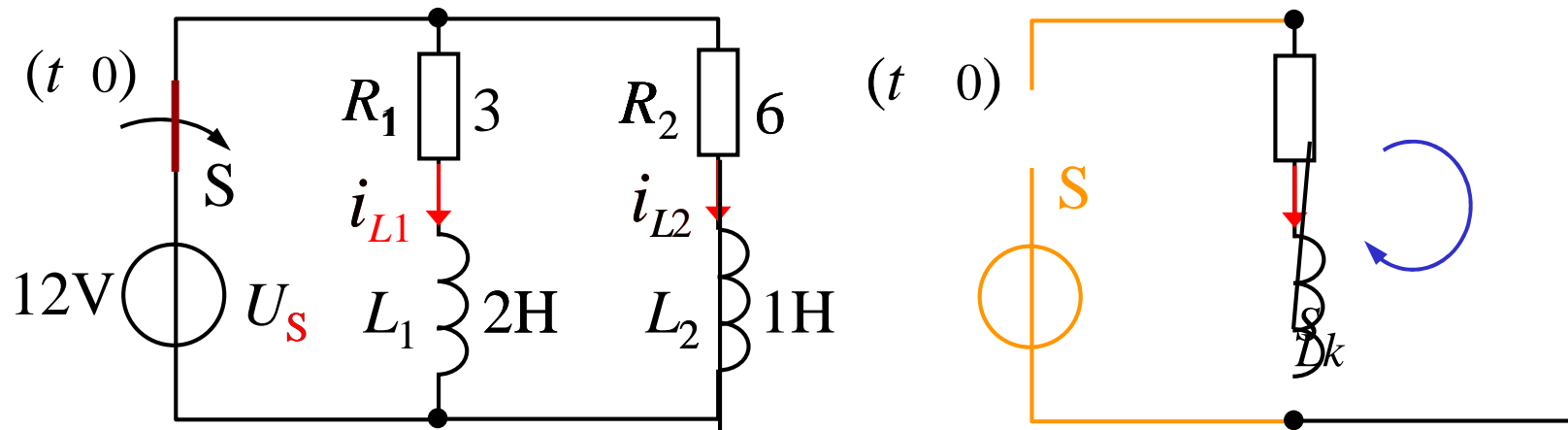
2.

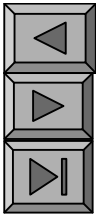
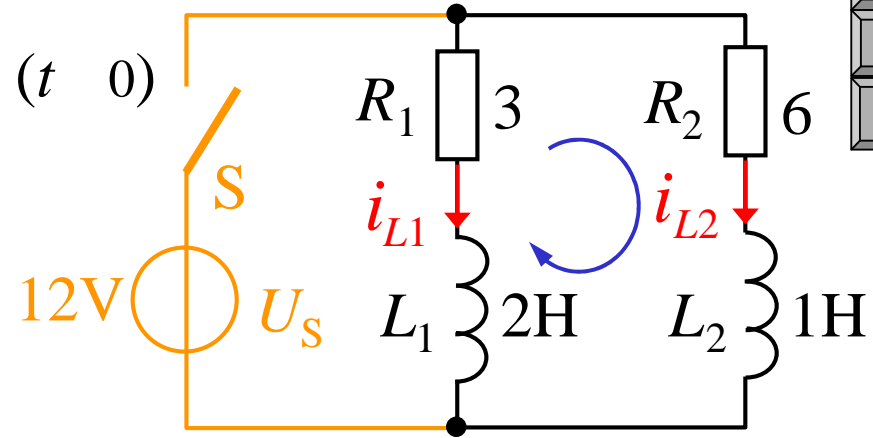
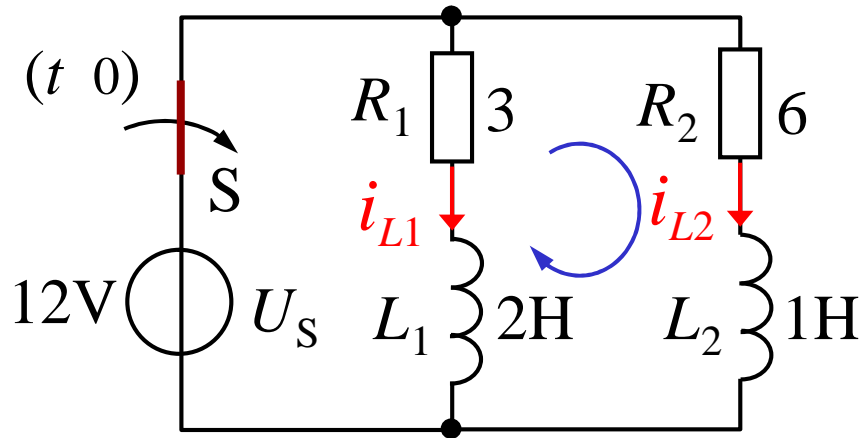
$$q_k(0^-) \quad q_k(0^+)$$

$$i_k(0^-) \quad i_k(0^+)$$

$$C_k u_{Ck}(0^+) \quad C_k u_{Ck}(0^-)$$

$$L_k i_{Lk}(0^+) \quad L_k i_{Lk}(0^-)$$





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

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

$$L_2 i_{L2}(0) = L_1 i_{L1}(0) - L_1 i_L(0)$$

$$i_{L2}(0_+) = \frac{L_2 i_{L2}(0) - L_1 i_{L1}(0)}{L_1 - L_2} \quad A$$

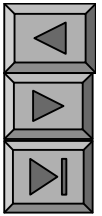
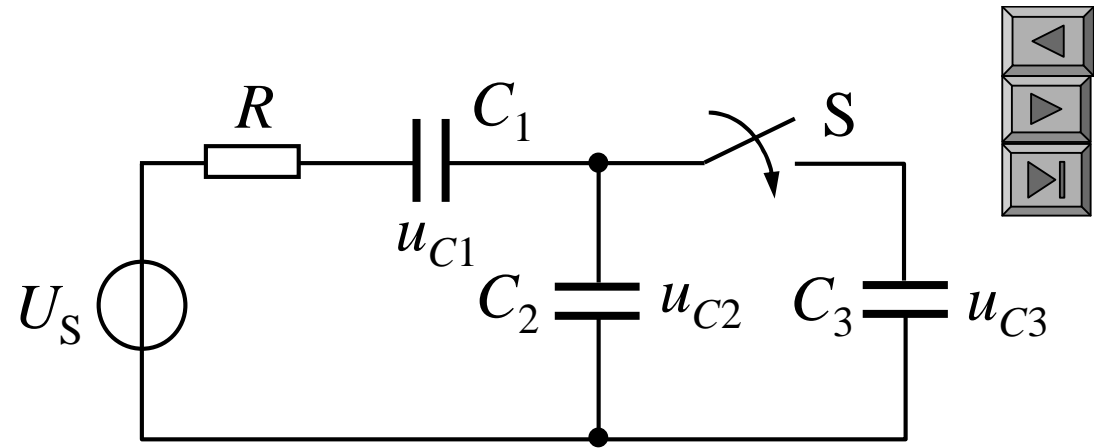
$$i_{L1}(0_+) = 2A$$

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

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

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)

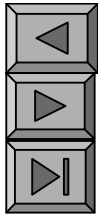
S $u_{C1}(0)$ $u_{C2}(0)$ 3V $u_{C3}(0)$ 0

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

$$P_0 + P_1 t + (P_0 + 0)$$

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

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

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

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

y^*

Q

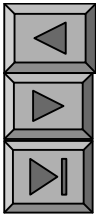
$$Q_0 + Q_1 t$$

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

$$Q e^{mt}$$

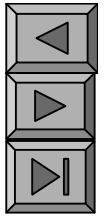
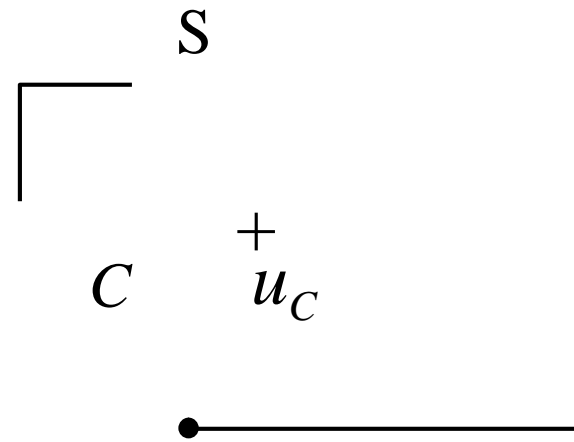
$$Q t e^{mt}$$

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



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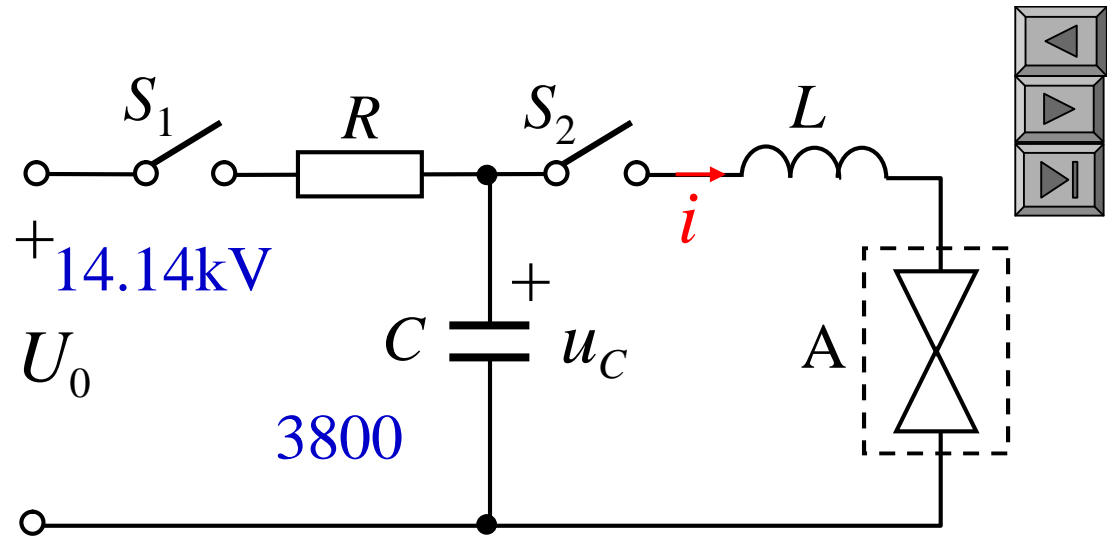
u_C u_R i u_L i_{\max}



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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

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

$$u_C(t) = i(t)$$

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

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i_L u_C i_C

S

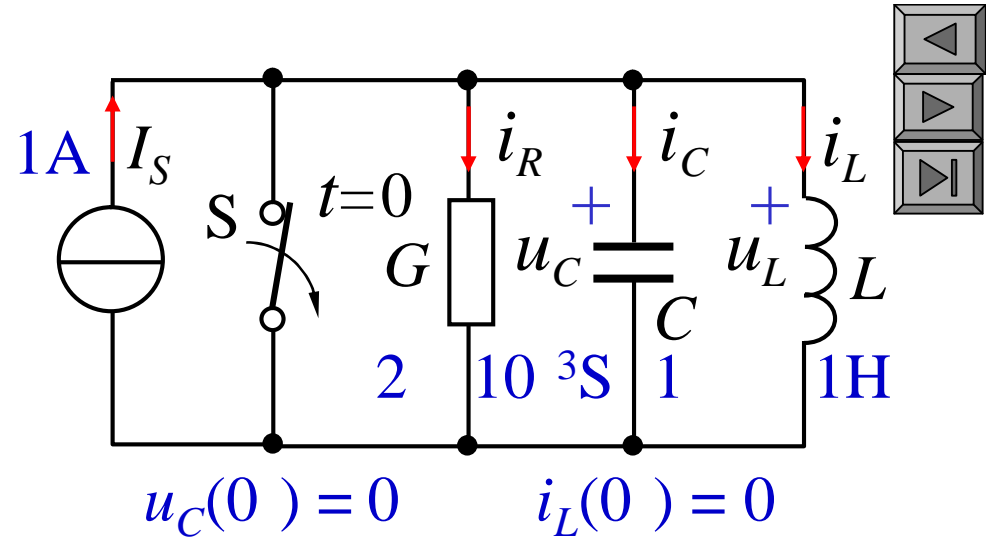
$i_s = (t) \text{ A}$

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

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

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

p_1 p_2 p



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

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

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

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