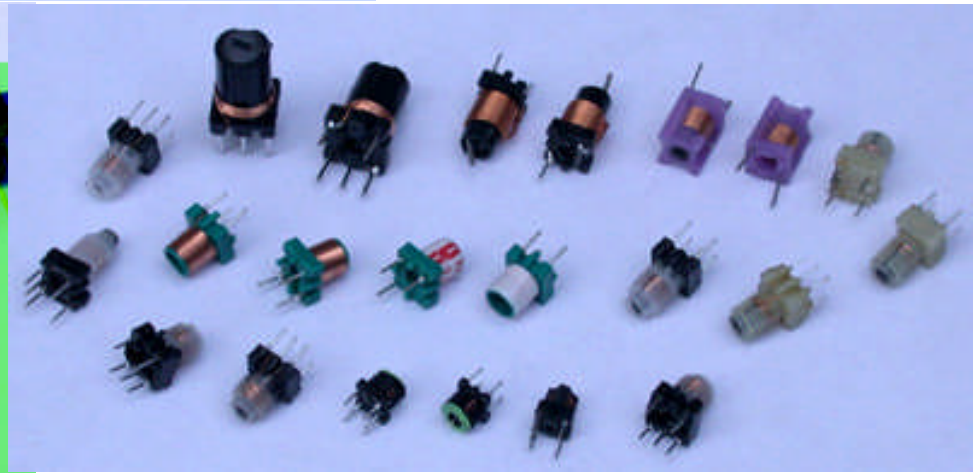
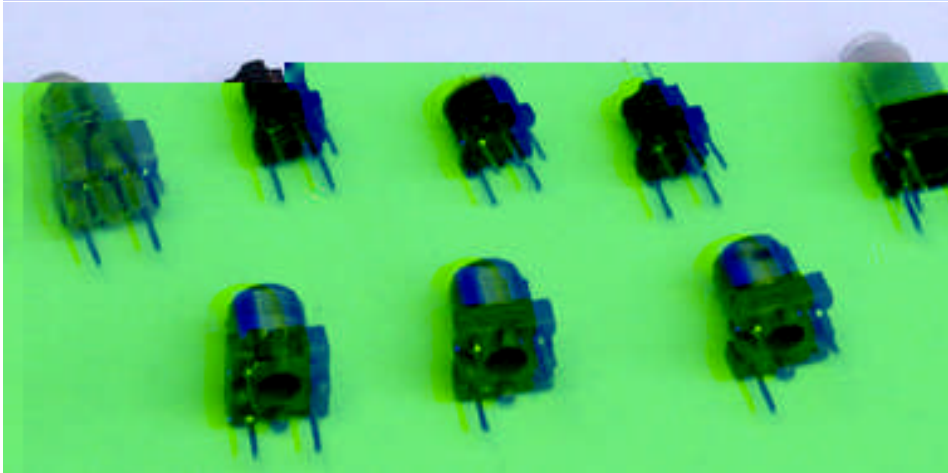
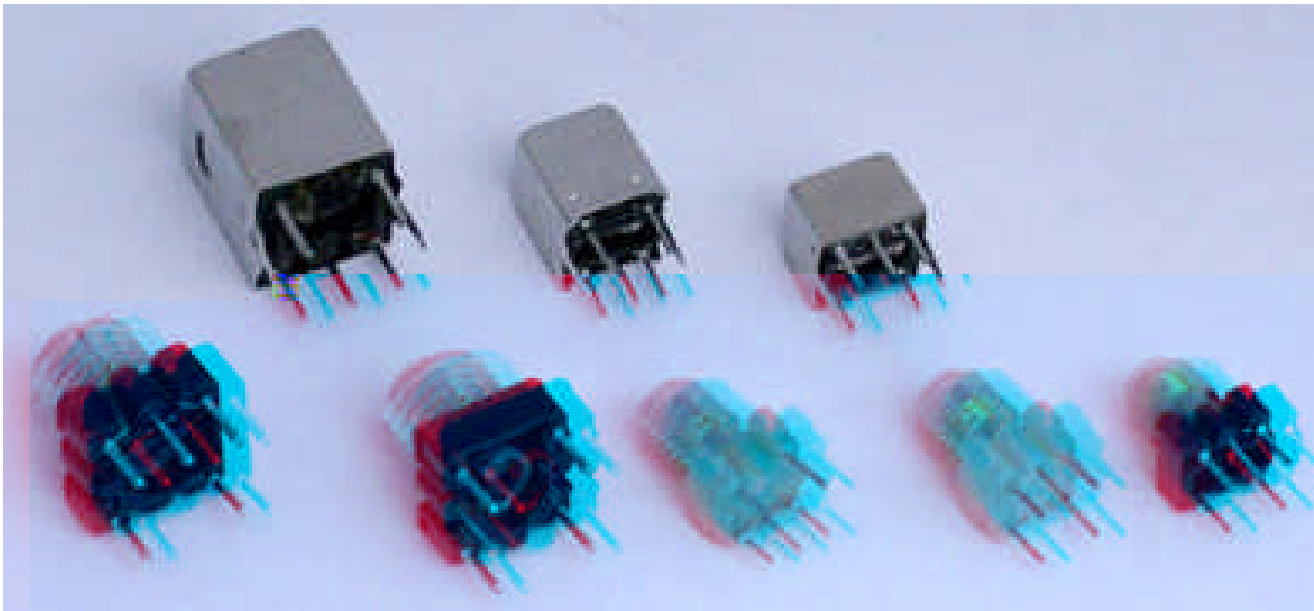
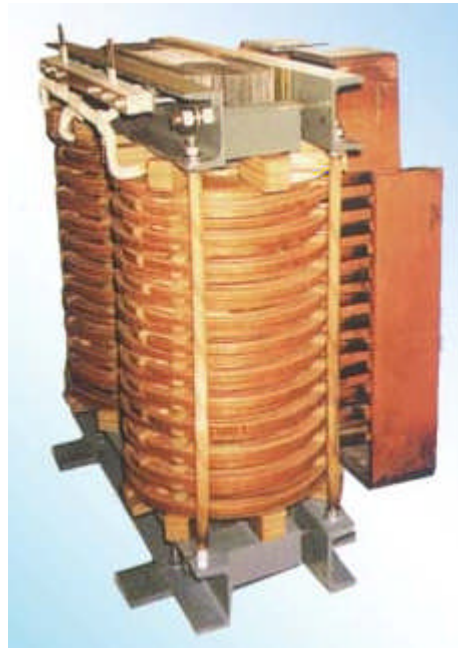


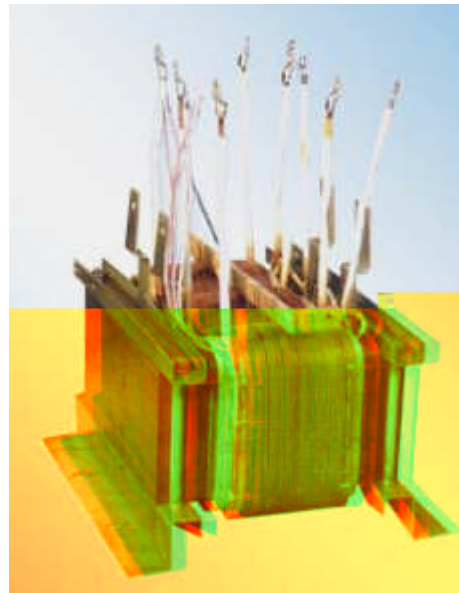
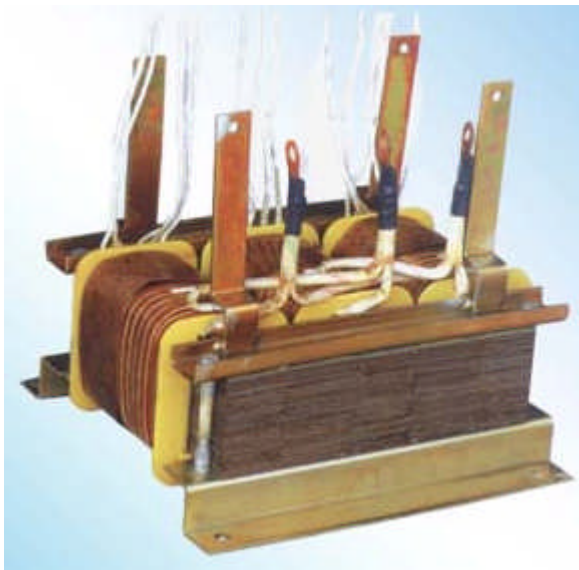
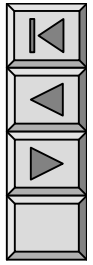
( )

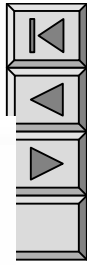
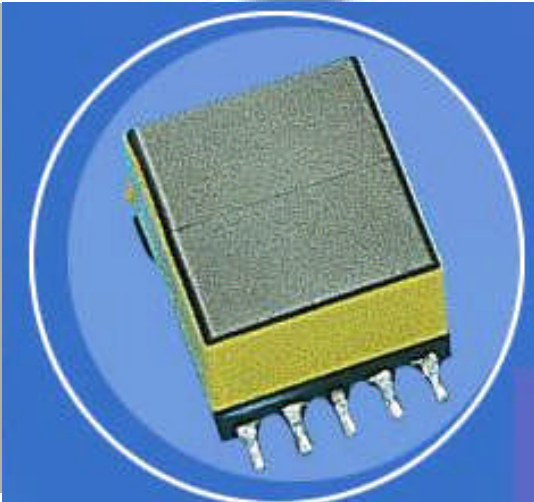


( )

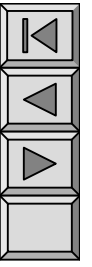


10kVA~300kVA

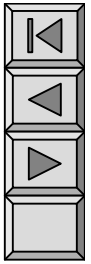




Power Transformer    Telecom Transformer    Audio Transformer



# § 10-1



1.



$i_1$

$i_1$

11

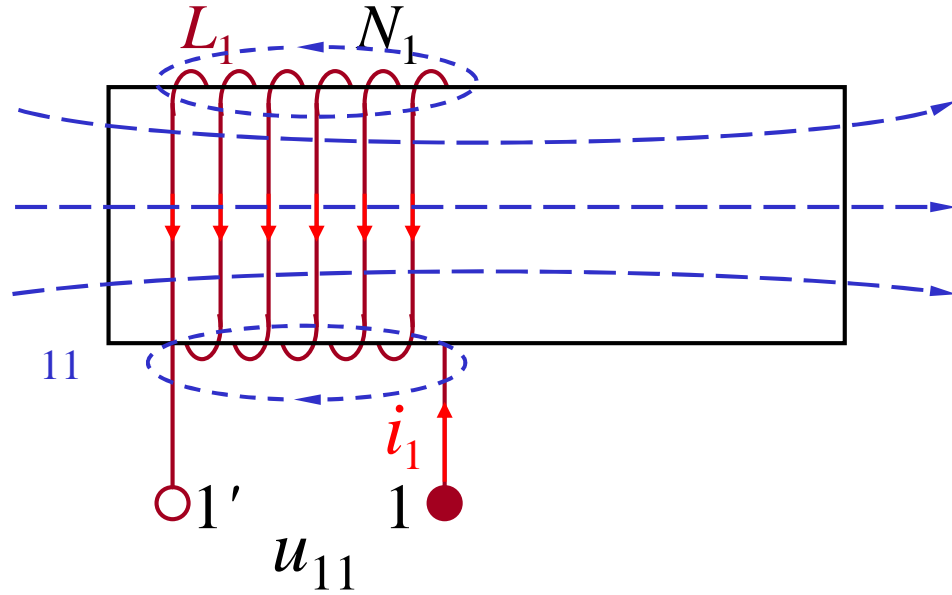
11

11

$i_1$

$u_{11}$

11



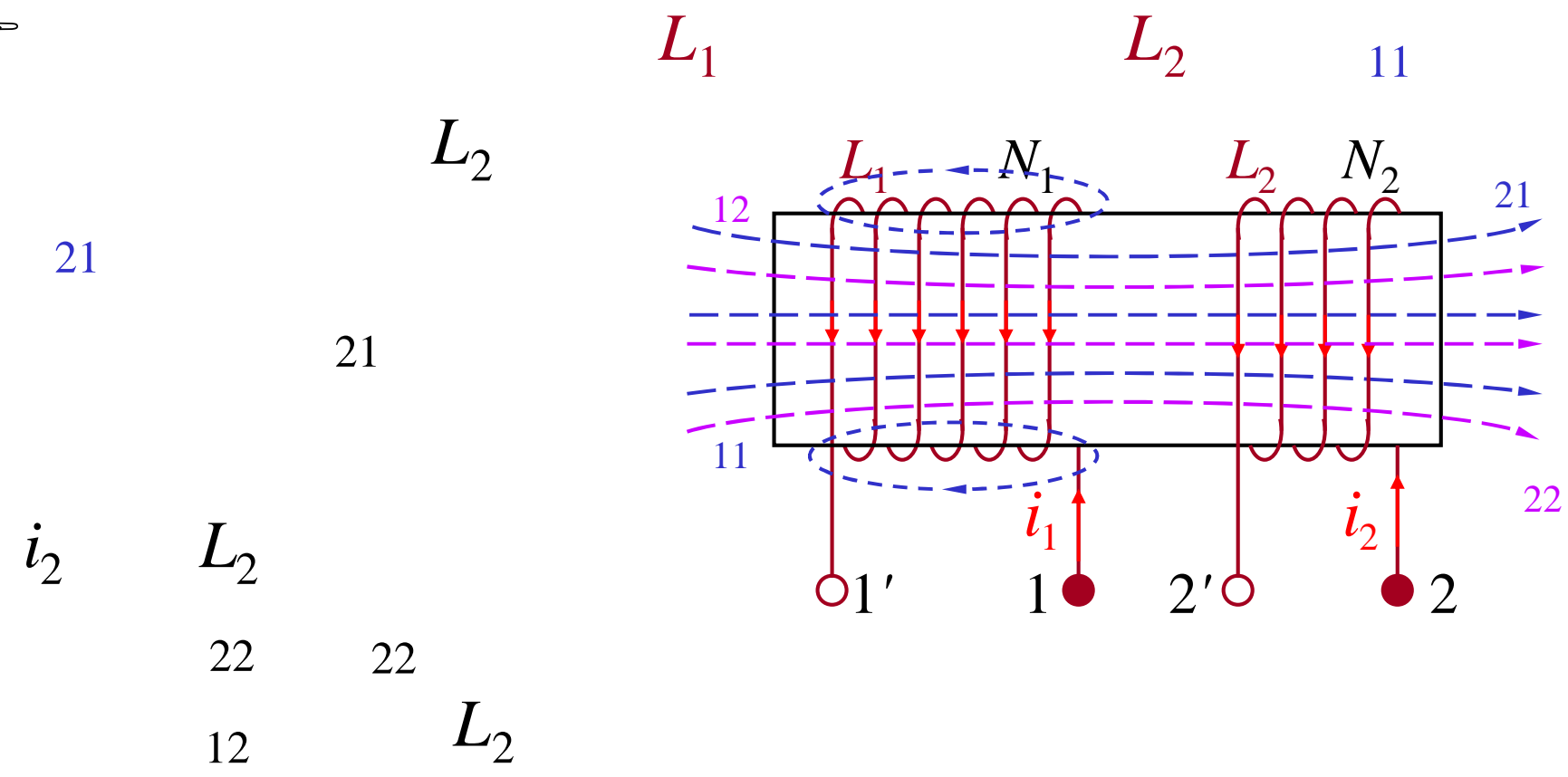
$u_{11} \quad i_1$

$$u_{11} = \frac{d}{dt} \quad 11$$

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

$$L_1 i_1$$





$i_2$

$L_2$

22

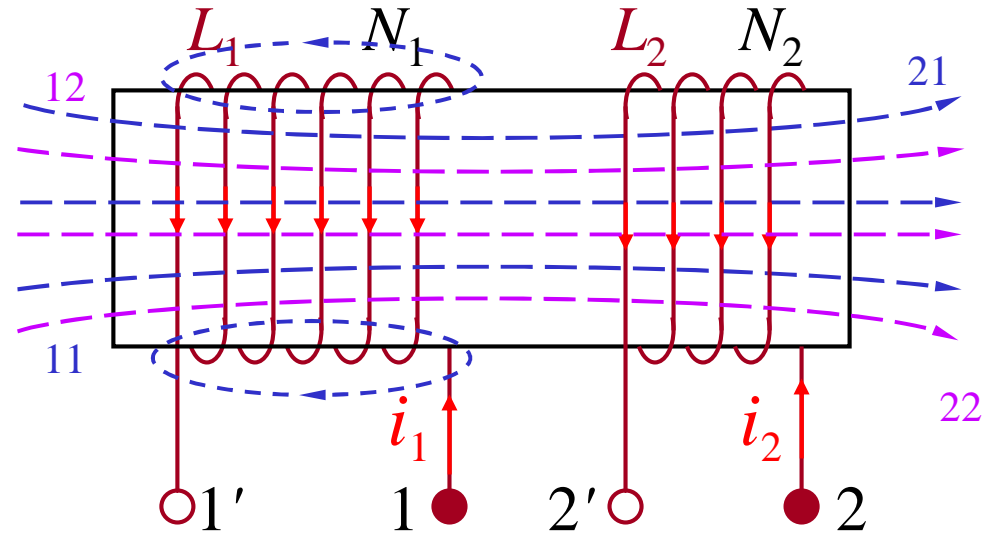
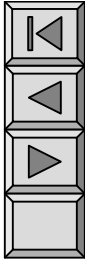
22

12

$L_2$

$$1^{\text{--}} = 11^{\pm} \quad 12$$

$$2^{\text{--}} = 22^{\pm} \quad 21$$



2.

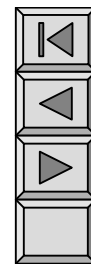
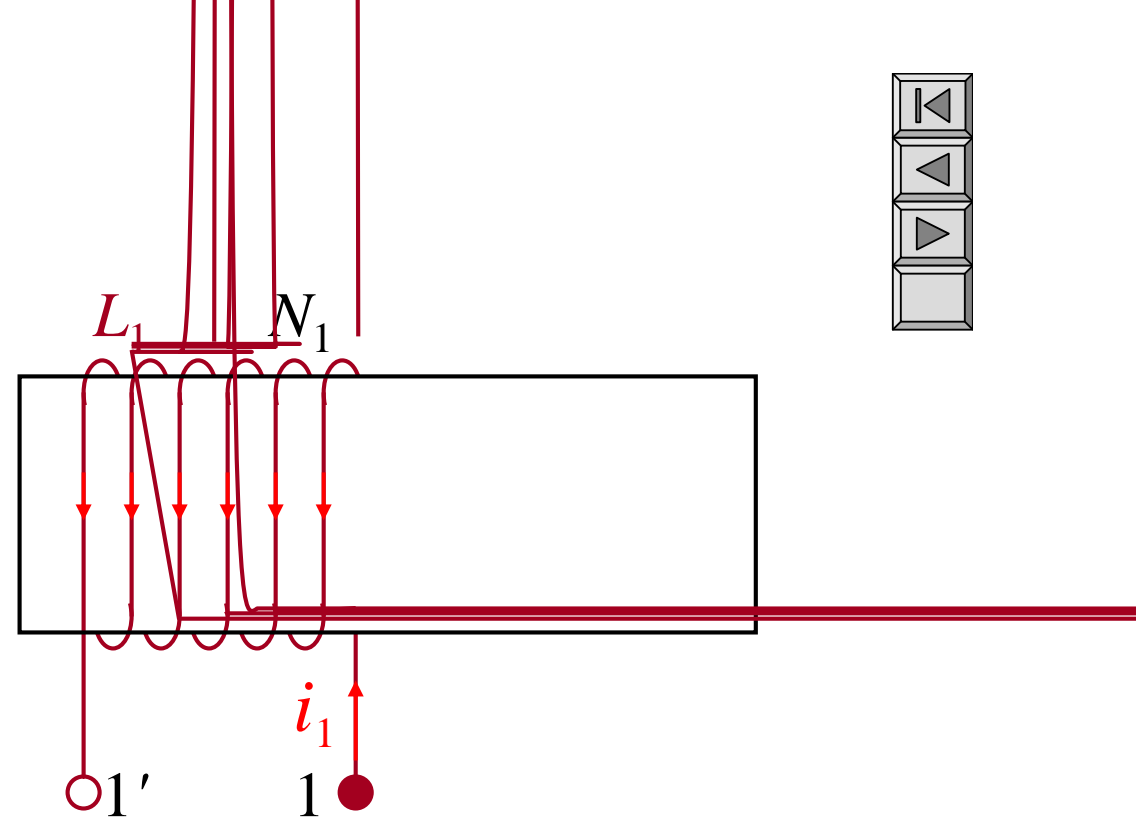
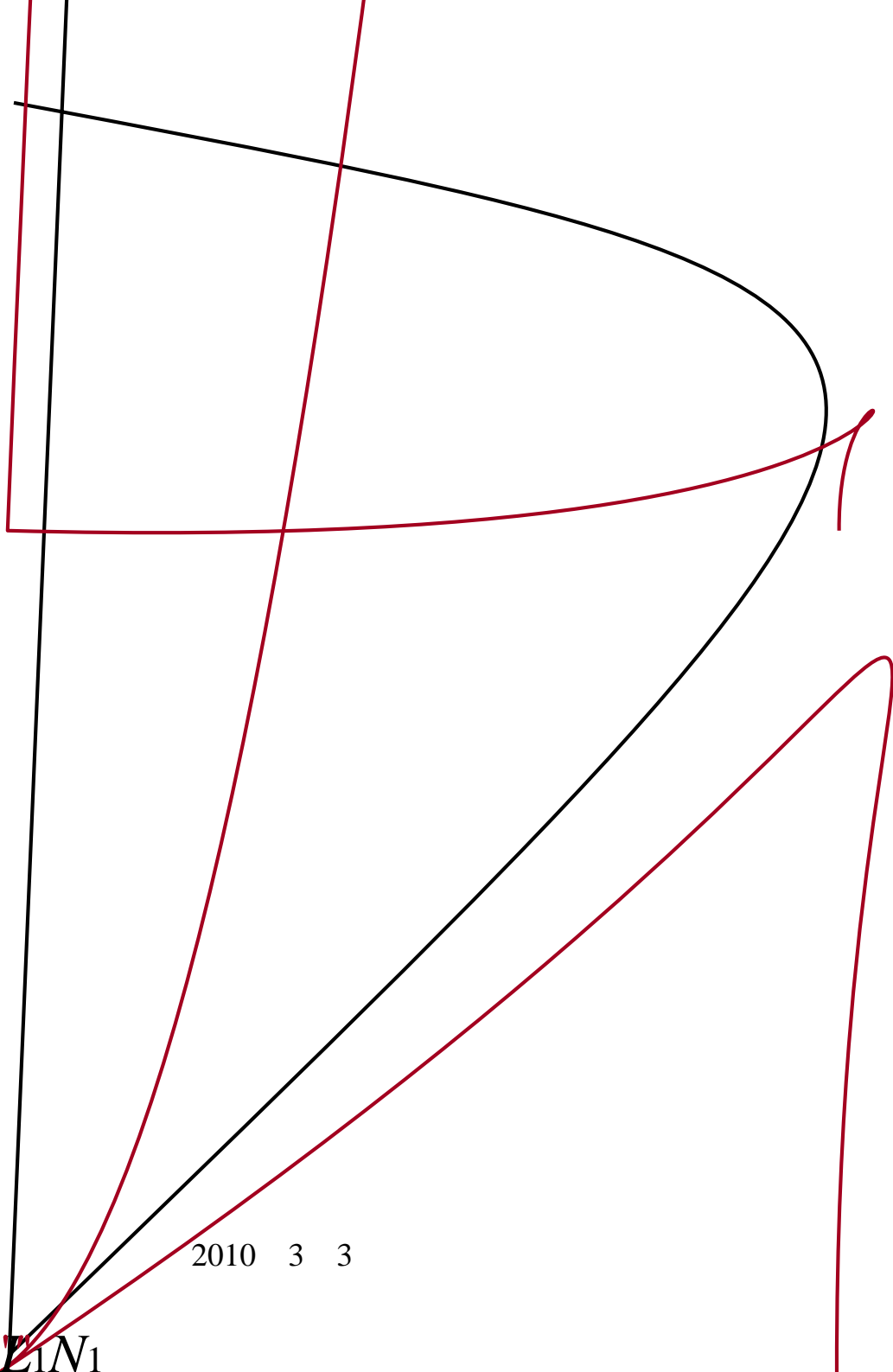
- $_{11} L_1 i_1$        $_{22} L_2 i_2$
- $_{12} M_{12} i_2$        $_{21} M_{21} i_1$
- $M_{12}$        $M_{21}$
- $H_0$



11

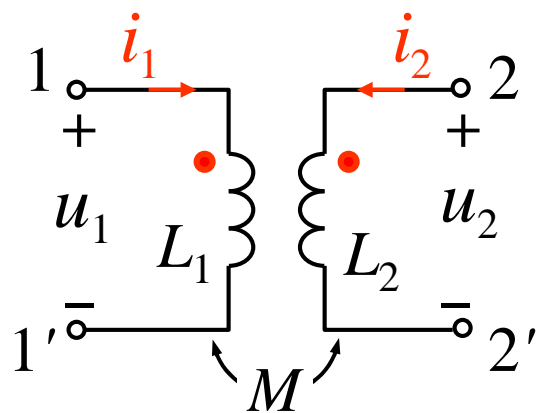
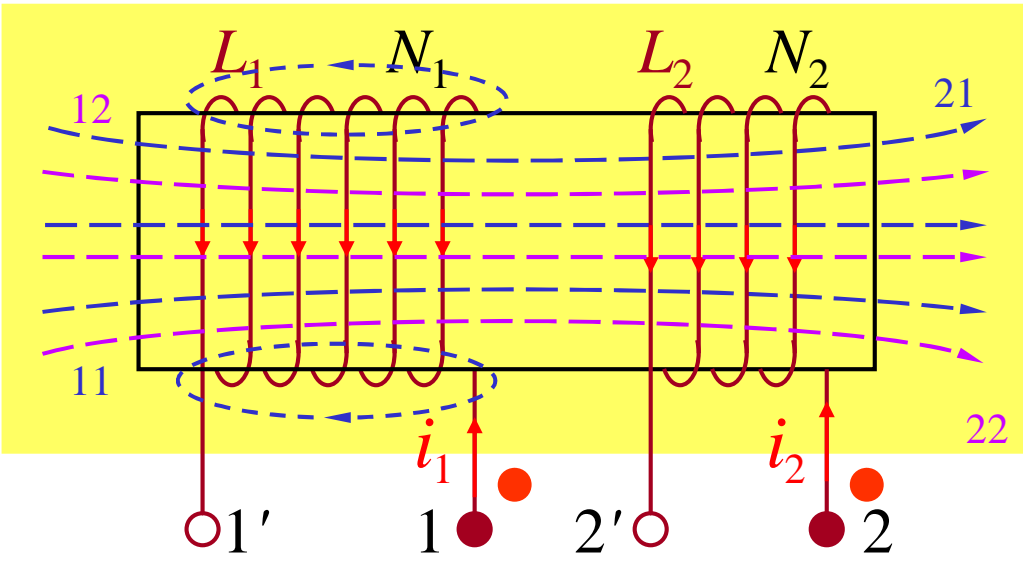
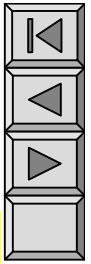
12

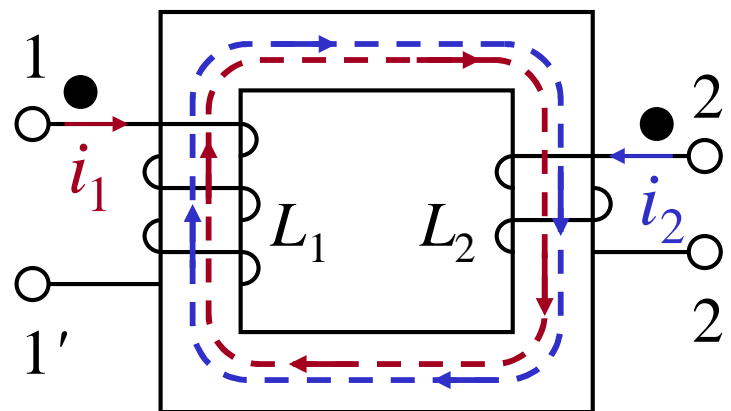
13





“●” “\*”  
“ ”

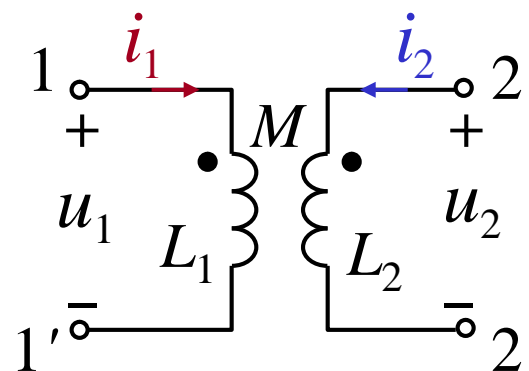




$$i_1 \quad i_2 (>0)$$

$$i_1 \quad i_2$$

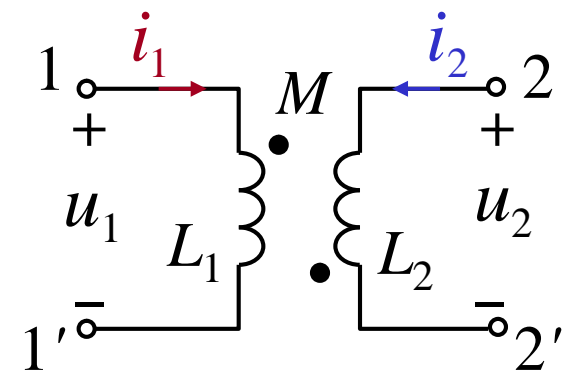
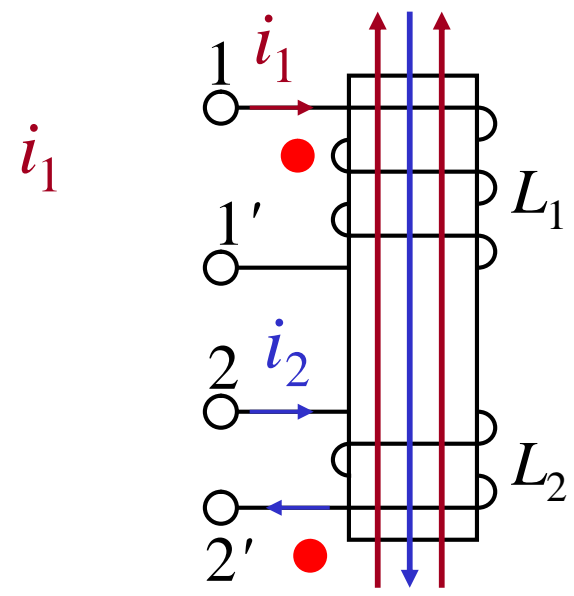
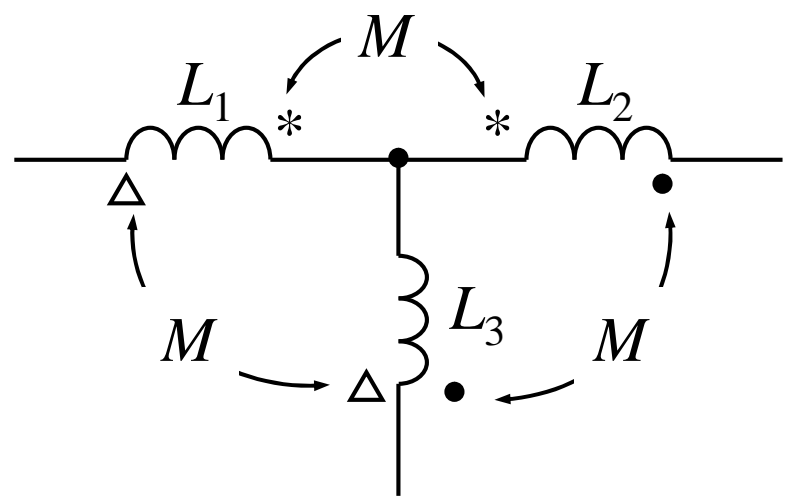
1 2  
1' 2'



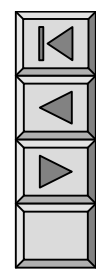
$>0)$

$i_2$

$i_1$   $i_2$



VCR

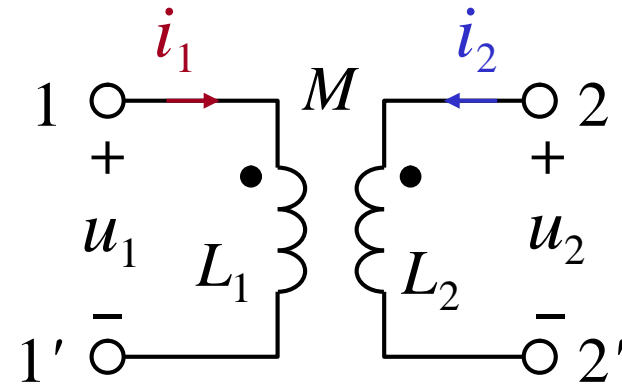




4.



$$\begin{aligned}
 u_1 &= \frac{d}{dt} L_1 i_1 + M \frac{di_2}{dt} \\
 u_2 &= \frac{d}{dt} L_2 i_2 + M \frac{di_1}{dt}
 \end{aligned}$$



$i_1$   $L_1$

“+”

$L_2$

$i_1$   $L_2$

$i_2$   $L_2$

“+”

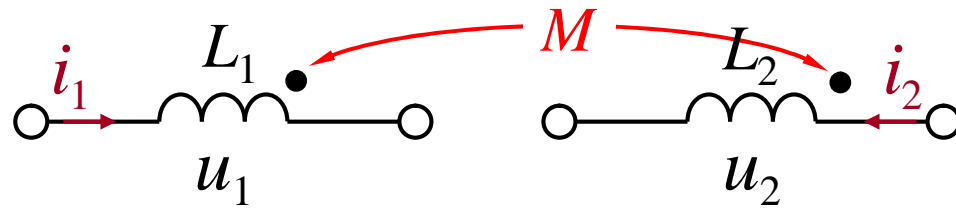
$L_1$

$i_2$   $L_1$





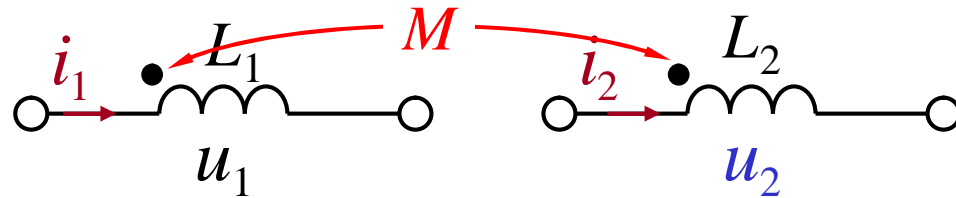
# VCR



$$\begin{aligned}
 u_1 &= L_1 \frac{di_1}{dt} + M \frac{di_2}{dt} \\
 u_2 &= L_2 \frac{di_2}{dt} + M \frac{di_1}{dt}
 \end{aligned}$$

# VCR

$$\begin{aligned}
 \dot{U}_1 &= j L_1 \dot{I}_1 + j M \dot{I}_2 \\
 \dot{U}_2 &= j L_2 \dot{I}_2 + j M \dot{I}_1
 \end{aligned}$$



$$\begin{aligned}
 u_1 &= L_1 \frac{di_1}{dt} - M \frac{di_2}{dt} \\
 u_2 &= L_2 \frac{di_2}{dt} - M \frac{di_1}{dt}
 \end{aligned}$$

$$\begin{aligned}
 \dot{U}_1 &= j L_1 \dot{I}_1 - j M \dot{I}_2 \\
 \dot{U}_2 &= j M \dot{I}_1 - j L_2 \dot{I}_2
 \end{aligned}$$



“ ”

2 3 ( )  
220V

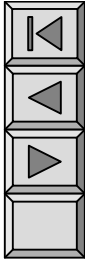
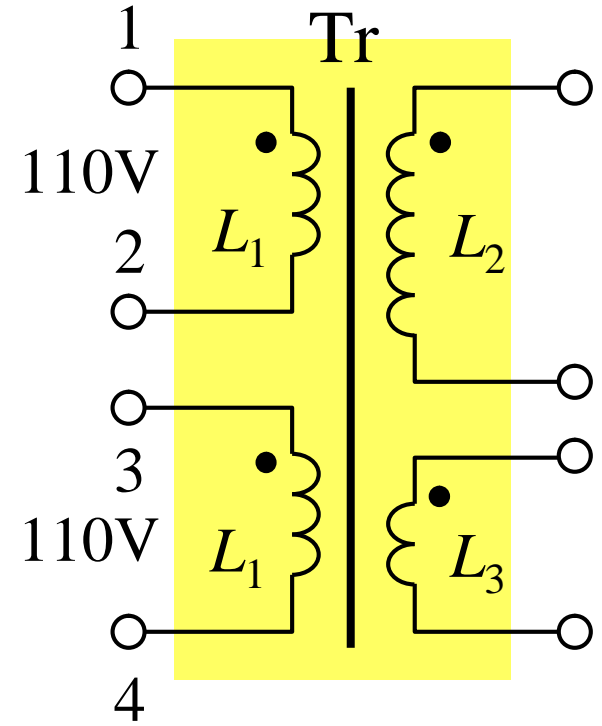
1 4

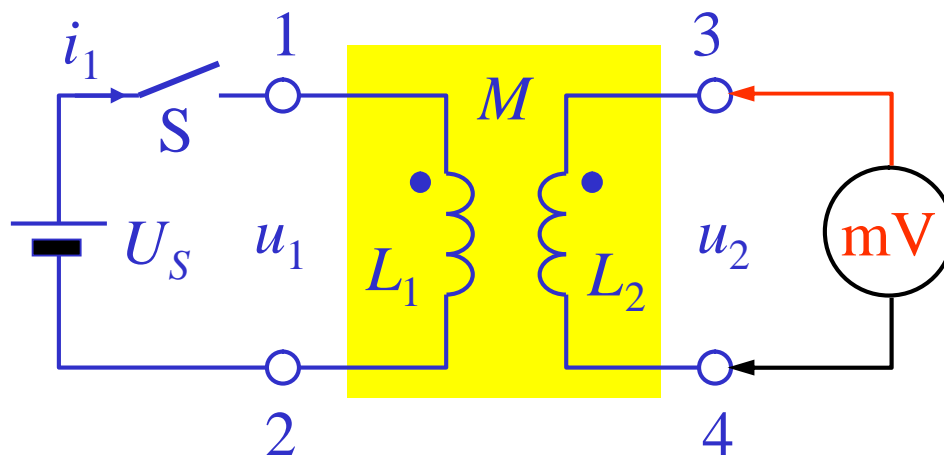
1 3 2 4 ( )

110V



( )





$$u_2 = M \frac{di_1}{dt}$$

$S$   $\frac{di_1}{dt} > 0$   $S$

$u_2 > 0$   $1 \quad 4$

5.

$k$

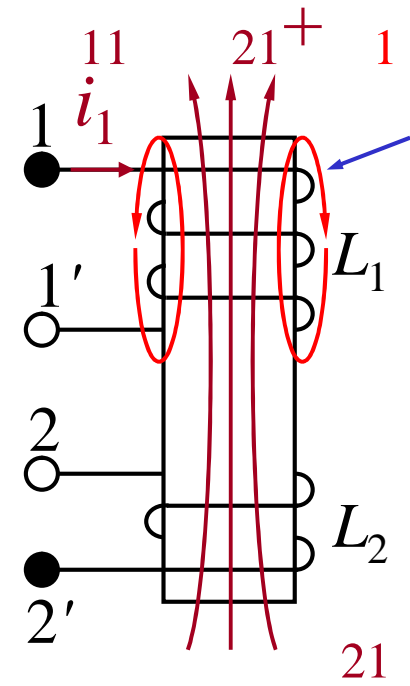
•

•

$$k = \frac{\text{del}}{\sqrt{\frac{12}{11} \cdot \frac{21}{22}}}$$

$$\begin{matrix} 11 & L_1 i_1 & 22 & L_2 i_2 \\ 12 & M i_2 & 21 & M i_1 \end{matrix}$$

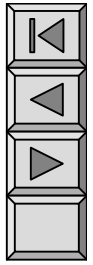
$$0 \quad k \quad \frac{M}{\sqrt{L_1 L_2}} \quad 1$$



1

$k$

$k \quad 1$



§ 10-2



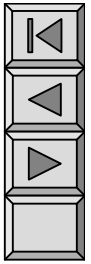
1



2

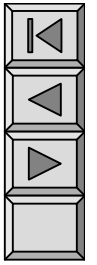
( )

VCR





3



1.

(1)  $L_1$   $L_2$  “ ”

KVL( )

$$u_1 = R_1 i + L_1 \frac{di}{dt} + M \frac{di}{dt}$$

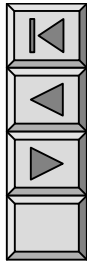
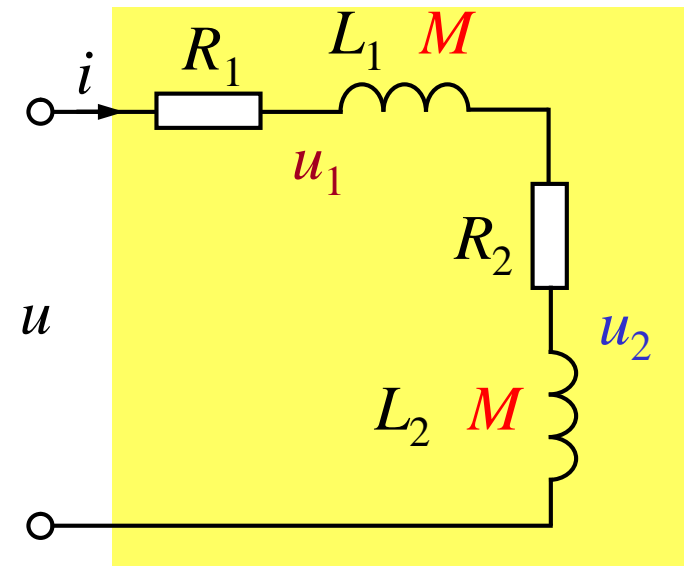
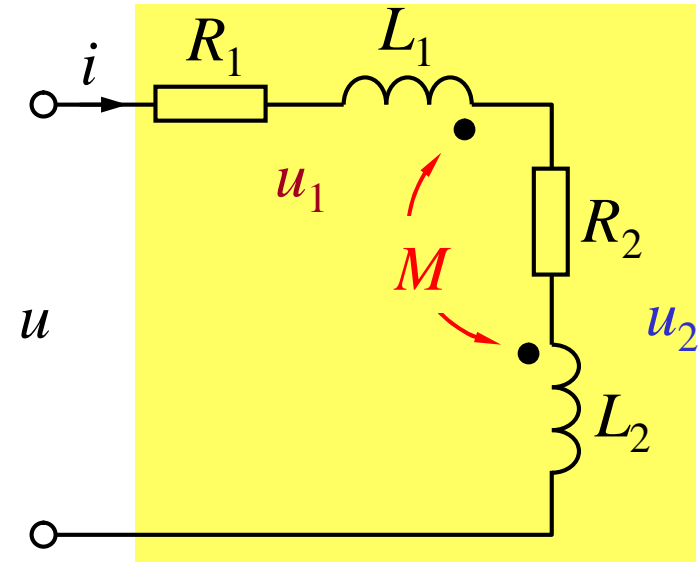
---


$$R_1 i + (L_1 + M) \frac{di}{dt}$$

$$u_2 = R_2 i + L_2 \frac{di}{dt} + M \frac{di}{dt}$$

---


$$R_2 i + (L_2 + M) \frac{di}{dt}$$





$$u_1 = R_1 i + (L_1 - M) \frac{di}{dt} \quad u_2 = R_2 i + (L_2 + M) \frac{di}{dt}$$

$$\dot{U}_1 = R_1 \dot{I} + j(L_1 - M) \dot{I} + Z_1 \dot{I}$$

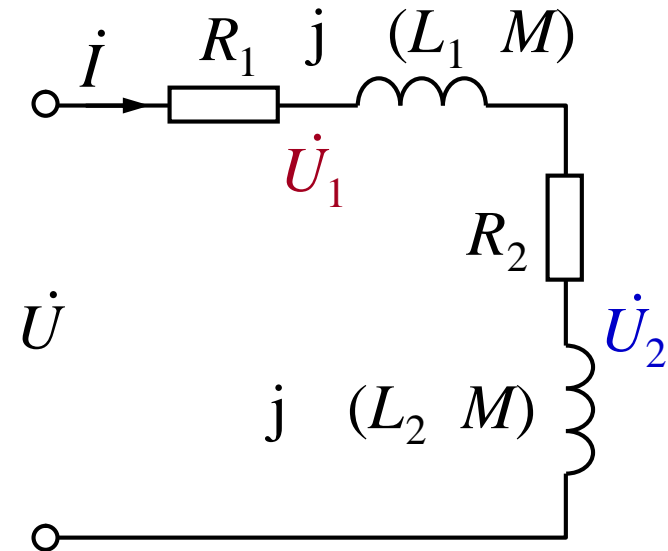
$$Z_1 = R_1 + j(L_1 - M)$$

$$\dot{U}_2 = R_2 \dot{I} + j(L_2 + M) \dot{I} + Z_2 \dot{I}$$

$$Z_2 = R_2 + j(L_2 + M)$$

$$\text{KVL } \dot{U} = \dot{U}_1 + \dot{U}_2 = (Z_1 + Z_2) \dot{I} = Z \dot{I}$$

$$Z = Z_1 + Z_2 = (R_1 + R_2) + j(L_1 + L_2 + 2M)$$



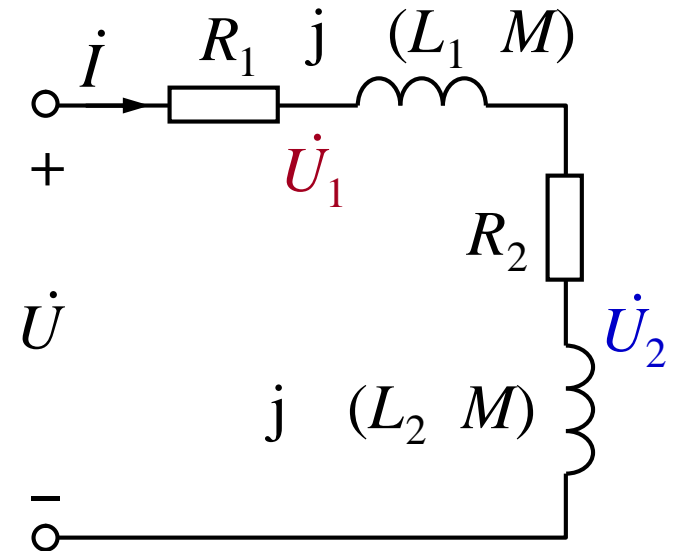




$$Z = Z_1 + Z_2 = (R_1 + R_2) + j(L_1 + L_2 + 2M)$$

“ ”

$$(Z_1 + Z_2) = Z$$



“ ”

“ ”

$$(L_1 + M) + (L_2 + M)$$



$$k = 1$$

$$(L_1 + L_2 + 2M) = 0$$

(2)

$$Z_1 \quad R_1 \quad j \quad (L_1 \quad M)$$

$$Z_2 \quad R_2 \quad j \quad (L_2 \quad M)$$

$$Z \quad (R_1 \quad R_2) \quad j \quad (L_1 \quad L_2 \quad 2M)$$

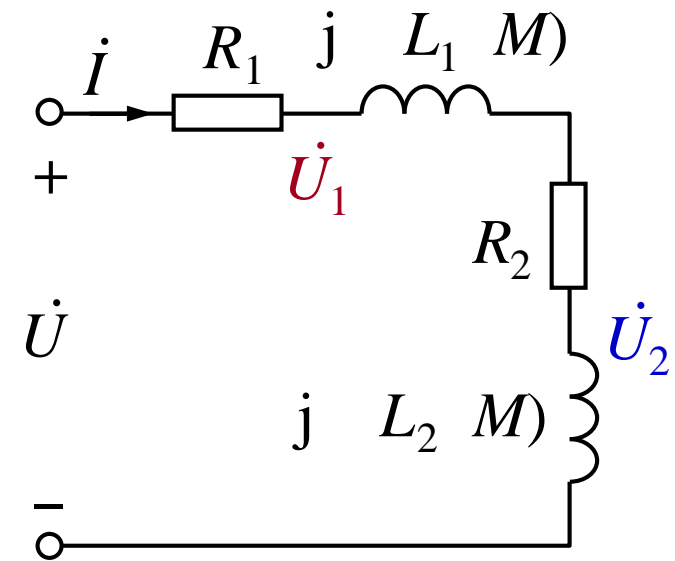
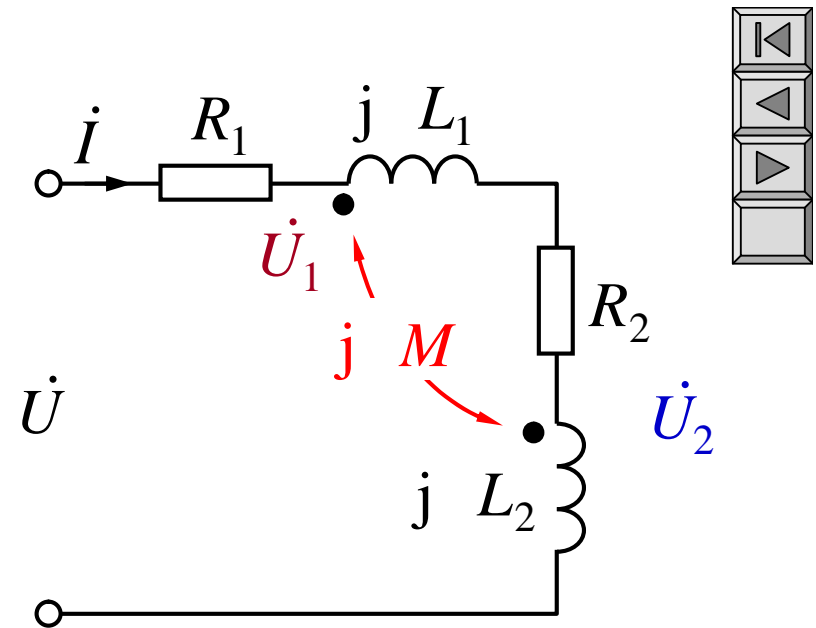


$L$

$$L \quad L_1 \quad L_2 \pm 2M$$

“ ”

“ ”





$$Z = 20 + j40$$

$$44.7 \angle -63.4^\circ$$

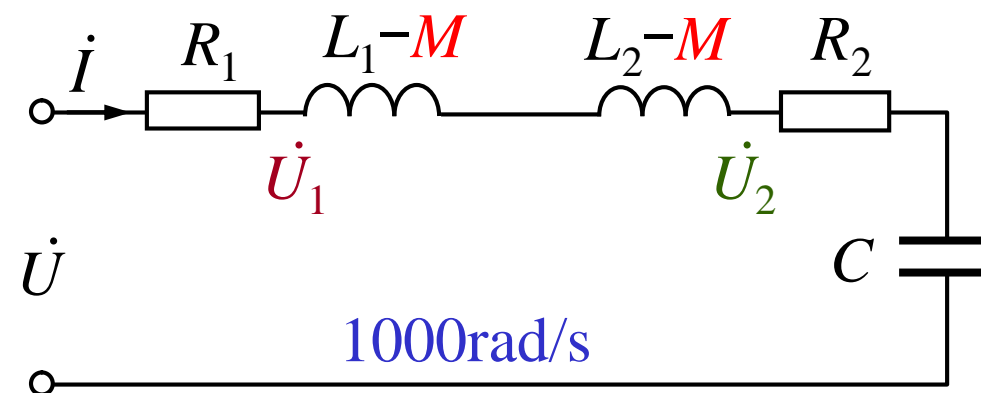
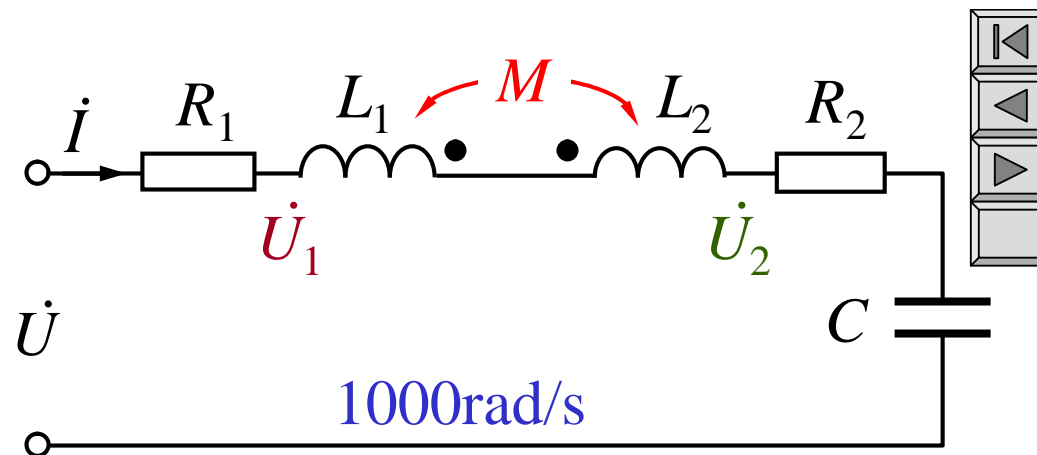
$$\dot{U} = 6 \angle 0^\circ \text{ V}$$

$$\dot{I} = \frac{\dot{U}}{Z} = \frac{6 \angle 0^\circ}{44.7 \angle -63.4^\circ}$$

$$0.134 \angle 63.4^\circ \text{ A}$$

$$\dot{U}_1 = [R_1 + j(L_1 - M)] \dot{I} = 1.34 \angle 63.4^\circ \text{ V}$$

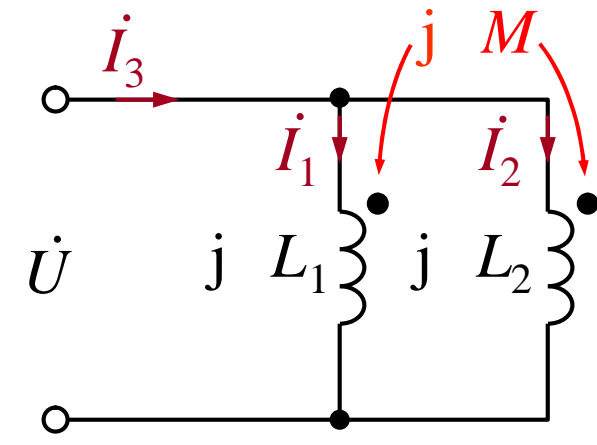
$$\dot{U}_2 = [R_2 + j(L_2 - M)] \dot{I} = 1.90 \angle 108.4^\circ \text{ V}$$





2.

(1)



$$\dot{U} = j L_1 \dot{I}_1 + j M \dot{I}_2 \dots \dots (1)$$

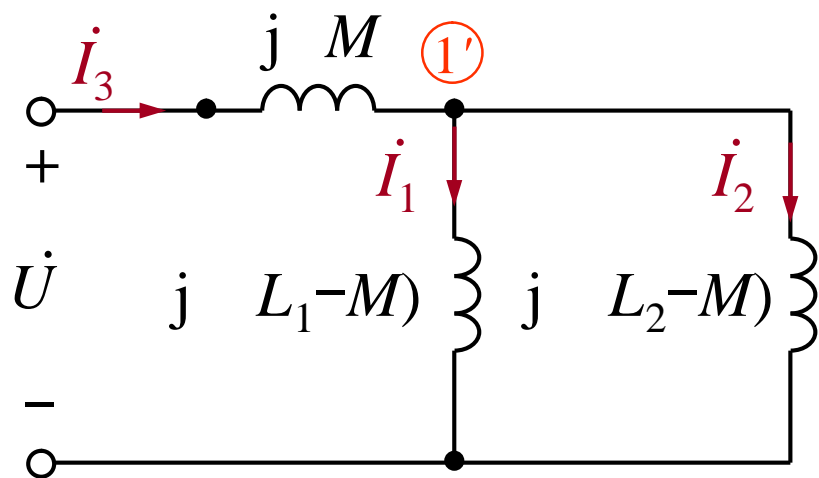
$$\dot{U} = j M \dot{I}_1 + j L_2 \dot{I}_2 \dots \dots (2)$$

$$\dot{I}_3 = \dot{I}_1 + \dot{I}_2 \dots \dots \dots (3)$$

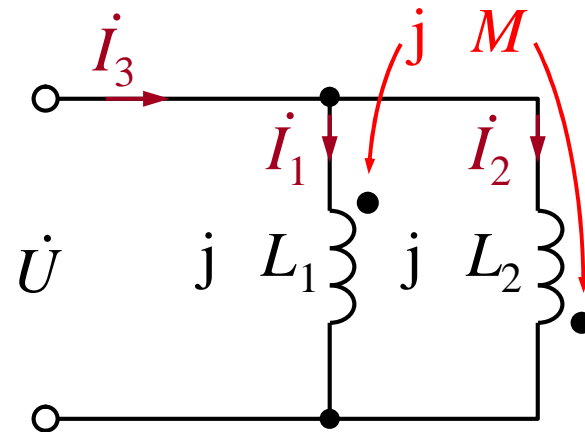
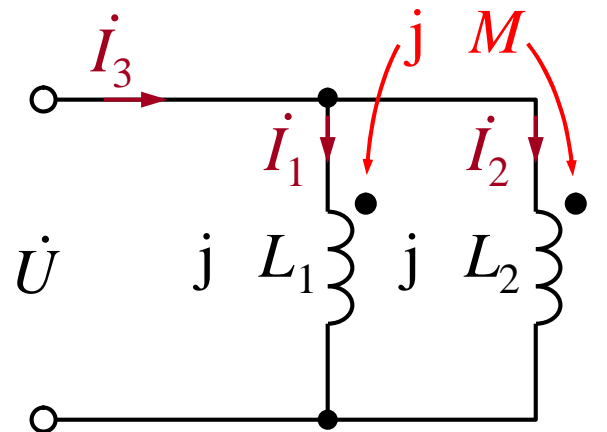
$$(3) \quad (1) \quad \dot{U} = j L_1 \dot{I}_1 + j M (\dot{I}_3 - \dot{I}_1) \\ j (L_1 - M) \dot{I}_1 + j M \dot{I}_3$$

$$(3) \quad (2) \quad \dot{U} = j M (\dot{I}_3 - \dot{I}_2) + j L_2 \dot{I}_2 \\ j M \dot{I}_3 + j (L_2 - M) \dot{I}_2$$

$$\begin{aligned} \dot{U} &= j(L_1 - M)\dot{I}_1 + jM\dot{I}_3 \\ \dot{U} &= jM\dot{I}_3 + j(L_2 - M)\dot{I}_2 \end{aligned}$$

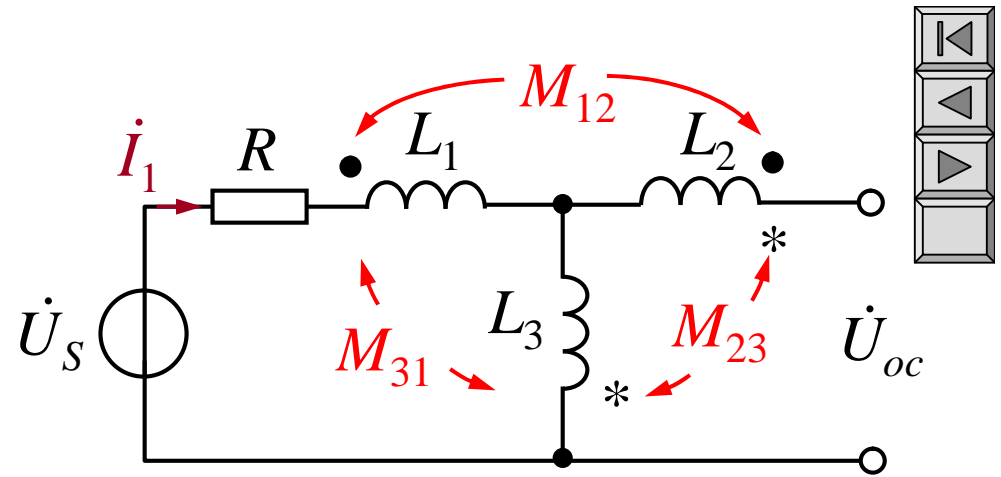


(2)





1  
 $L_2$   
 $L_1$   $L_3$



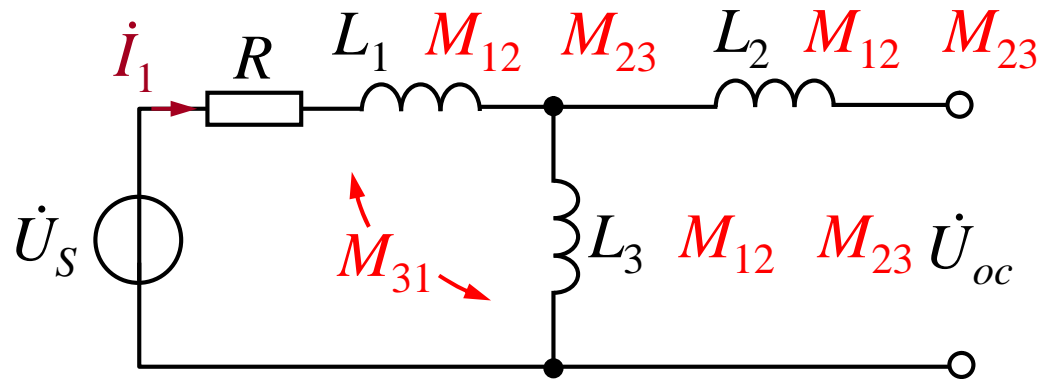
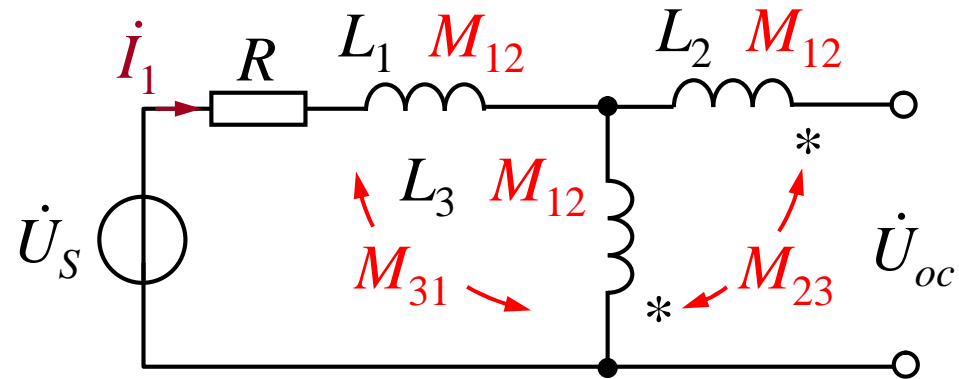
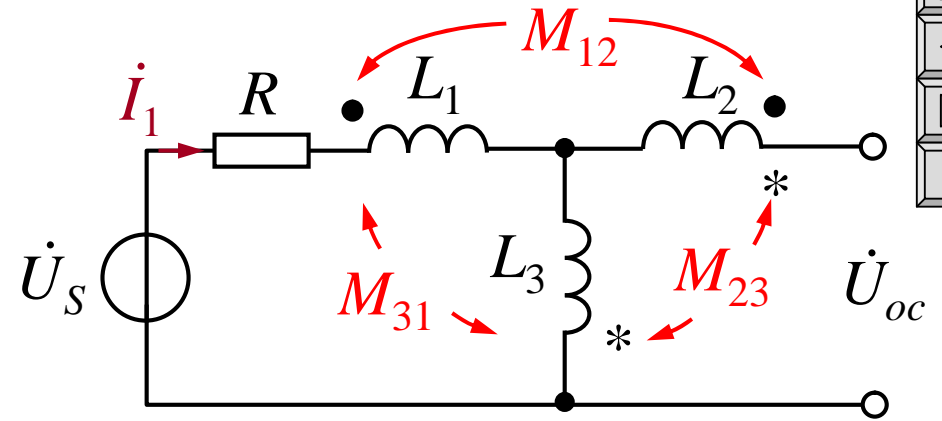
$$\dot{I}_1 = \frac{\dot{U}_S}{R + j(L_1 + L_3 + 2M_{31})}$$

$$\dot{U}_{OC} = jM_{12}\dot{I}_1 + jM_{23}\dot{I}_1 + jM_{31}\dot{I}_1 + jL_3\dot{I}_1$$

$$\dot{U}_{OC} = \frac{j(M_{12} + M_{23} + M_{31} + L_3)\dot{U}_S}{R + j(L_1 + L_3 + 2M_{31})}$$



2



$L$  

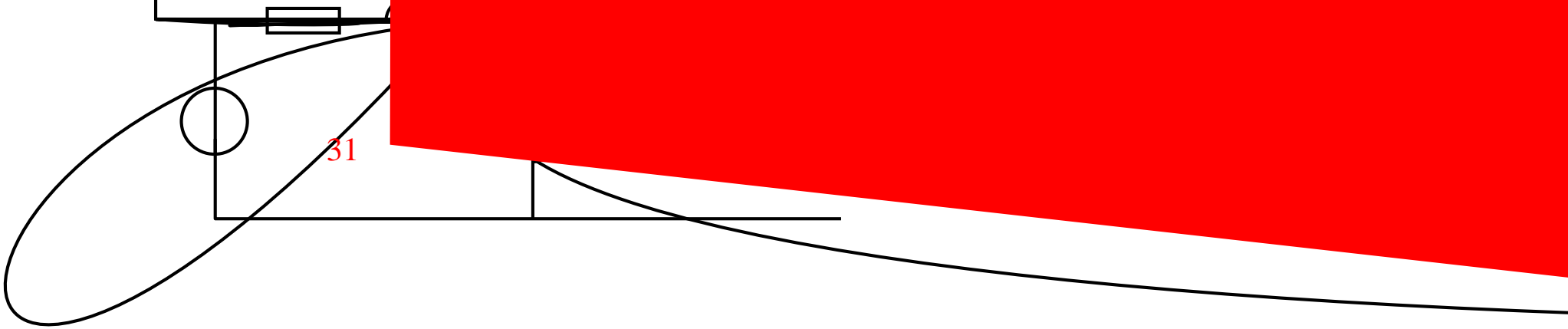
$U(3)TJ$

0 0 0 rg2

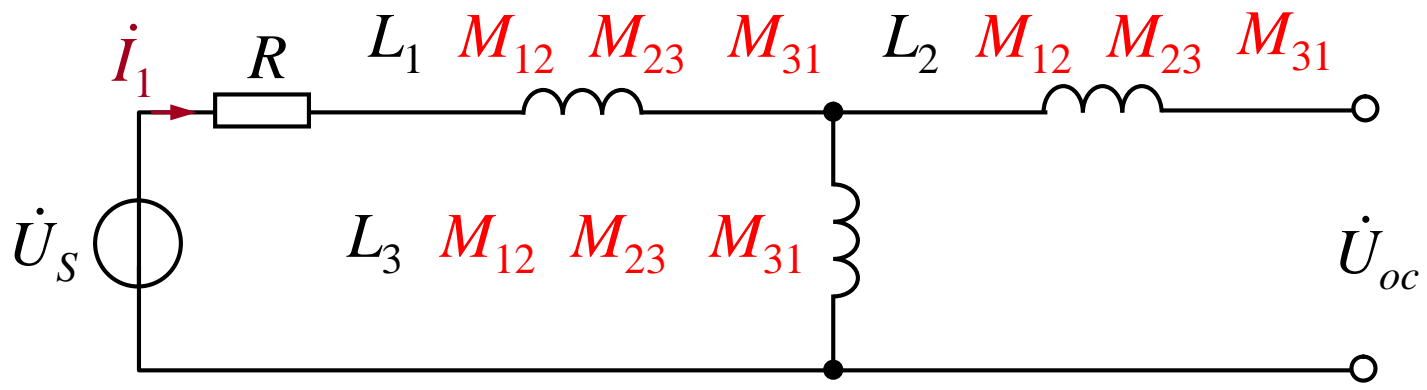
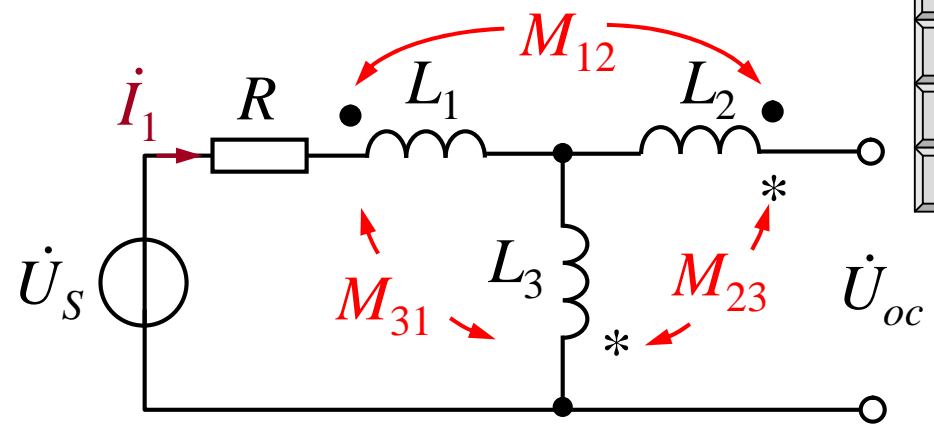
0 Tc

$L$

31

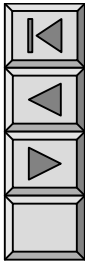


2



$$\dot{U}_{oc} = \frac{j(L_3 + M_{12} + M_{23} + M_{31})\dot{U}_S}{R + j(L_1 + L_3 + 2M_{31})}$$

§ 10-3



( )



*M*

*L C*

*L*

*L*

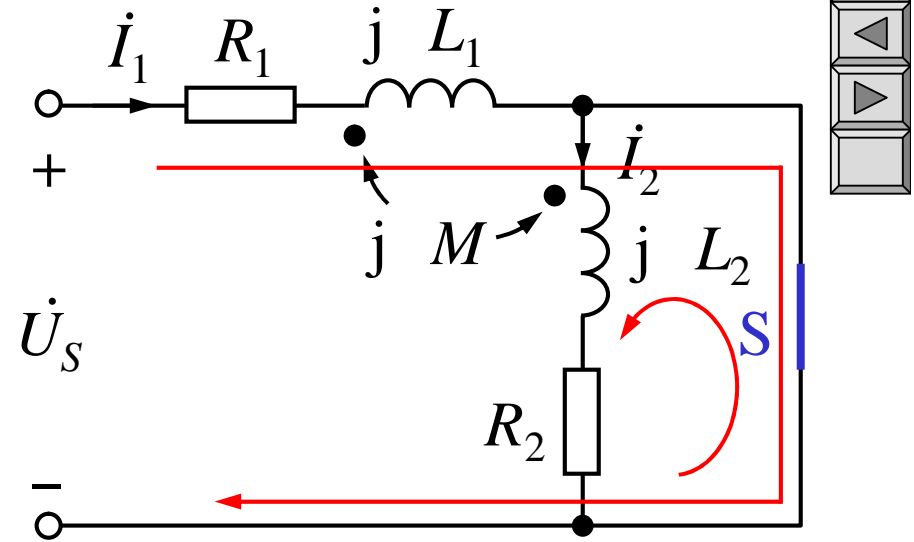
( )

$$\begin{array}{rcl}
 10 & 6 & R_1 \quad 3 \quad R_2 \quad 5 \\
 L_1 & 7.5 & L_2 \quad 12.5 \\
 M & 8 & U_S \quad \text{V}
 \end{array}$$

$$\dot{U}_S = 50 \angle 0^\circ \text{ V}$$

$$\begin{array}{l}
 (R_1 + j L_1) \dot{I}_1 + j M \dot{I}_2 = \dot{U}_S \\
 j M \dot{I}_1 + (R_2 + j L_2) \dot{I}_2 = 0
 \end{array}$$

$$\dot{I}_1 = 8.81 \angle 32.93^\circ \text{ A}$$



$$\dot{I}_2 = 5.24 \angle \quad \text{A}$$

$$\begin{array}{l}
 \overline{S}_S = \dot{U}_S \dot{I}_1^* \\
 233 + j582 \quad 137 + j343 \text{ VA}
 \end{array}$$

$$\begin{array}{l}
 \overline{S}_2 = j M \dot{I}_1 \dot{I}_2^* + (R_2 + j L_2) I_2^2 \\
 37 + j343 \quad j343 \text{ VA}
 \end{array}$$

$$\overline{S}_S = \dot{U}_S \dot{I}_1^* + (R_1 + jL_1) \dot{I}_1^2 + jM \dot{I}_2 \dot{I}_1^*$$

233 + j582 + 137 + j343 VA

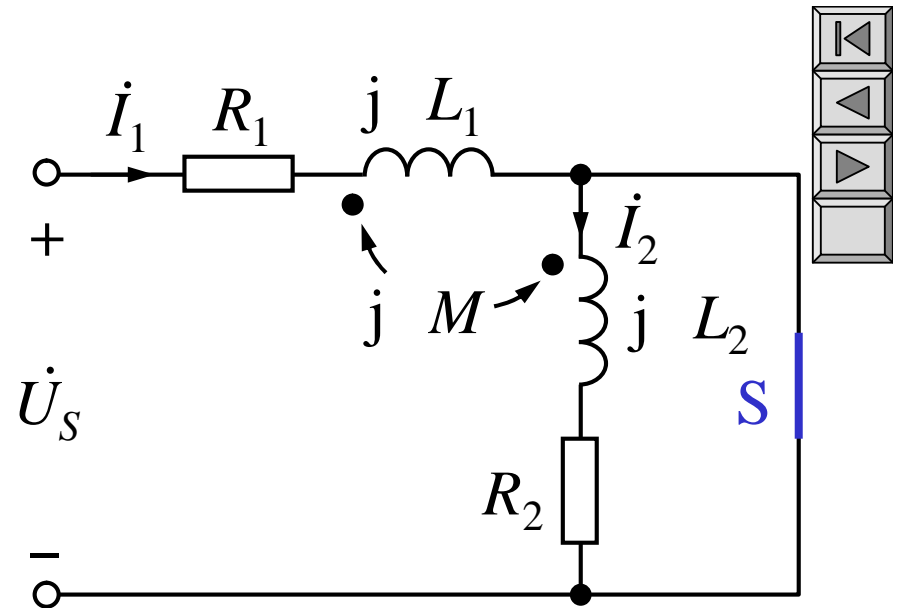
$$\overline{S}_2 = jM \dot{I}_1 \dot{I}_2^* + (R_2 + jL_2) \dot{I}_2^2$$

37 + j343 + 137 + j343 VA

$L_1$

582

239



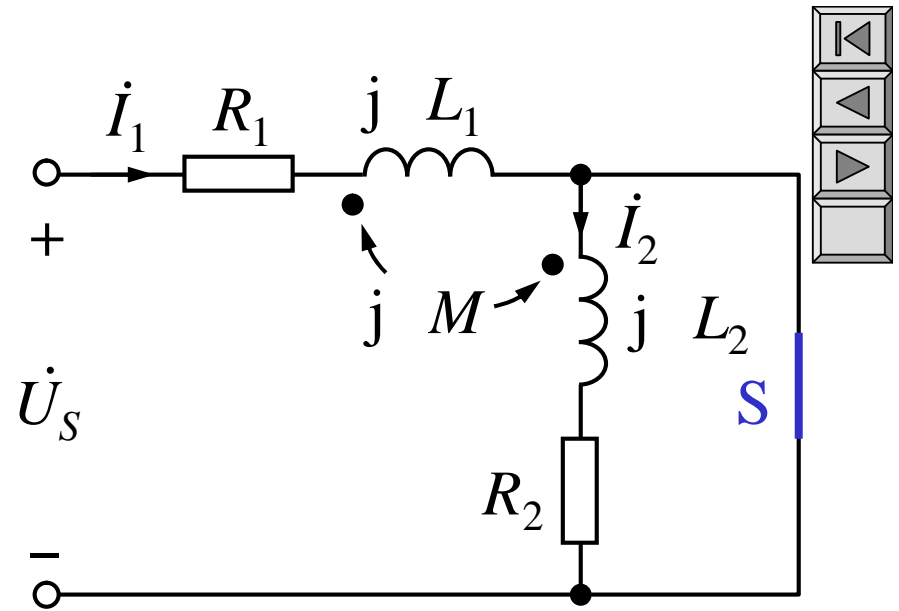
$L_1$   $L_2$



1 137W

2  $R_2$

$$\begin{aligned} \dot{U}_S &= 50 \angle 0^\circ \text{ V} \\ \dot{I}_1 &= 8.81 \angle 32.93^\circ \text{ A} \\ \dot{I}_2 &= 5.24 \angle \quad \quad \quad \text{ A} \\ R_1 &= 3 \quad R_2 = 5 \end{aligned}$$



$$P = U_S I_1 \cos 32.93^\circ = 370 \text{ W}$$

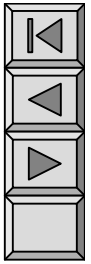
$$R_1 \quad I_1^2 R_1 = 233 \text{ W} \quad R_2 \quad I_2^2 R_2 = 137 \text{ W}$$

$$Q = U_S I_1 \sin 32.93^\circ = 239 \text{ Var}$$

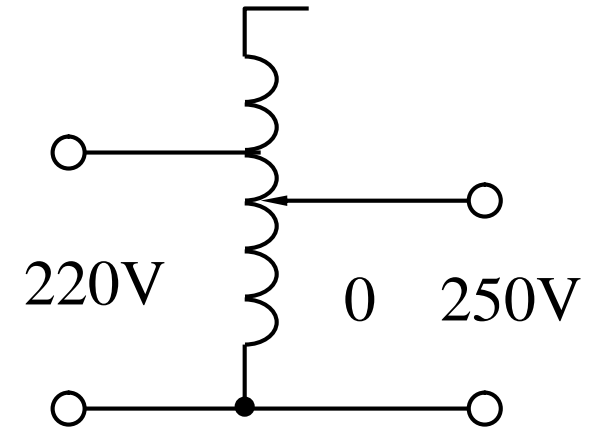
$$343 \text{ Var} \quad L_1$$

$$582 \text{ Var}$$

§ 10-4



1.



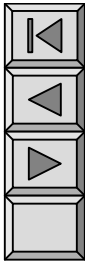
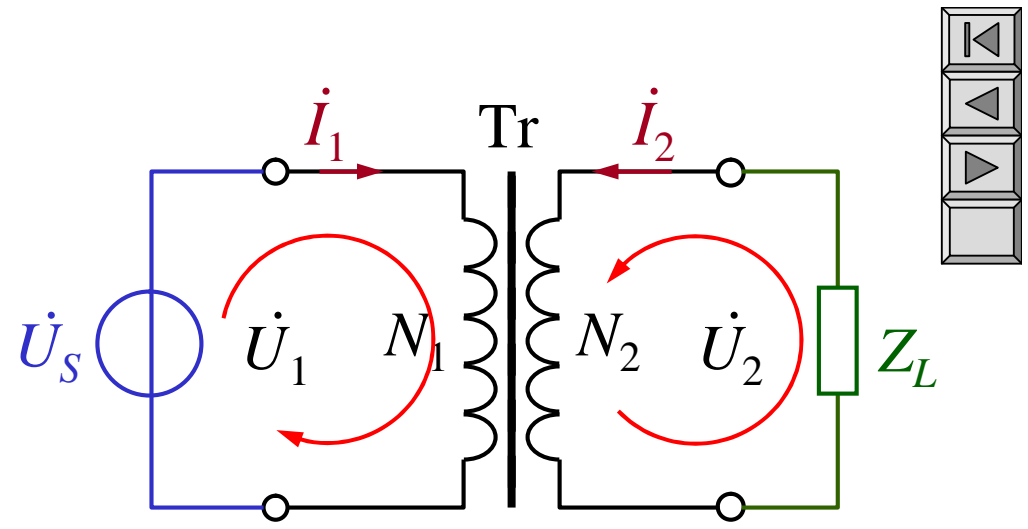
( )

( )



( )

$(N_1)$

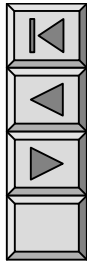
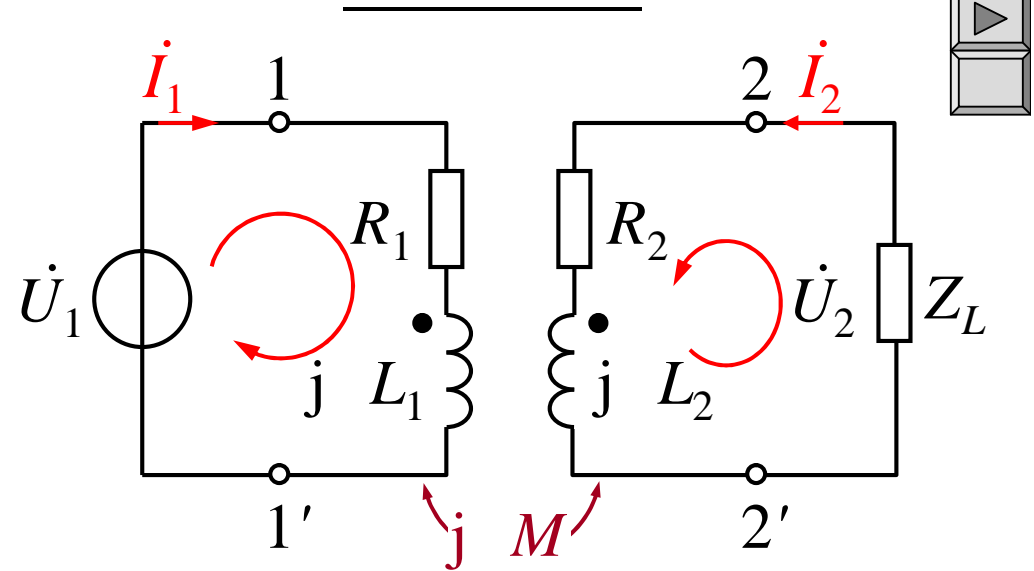


$(N_2)$

2. ( )



$$\begin{pmatrix} (R_1 + j\omega L_1) \dot{I}_1 + j\omega M \dot{I}_2 \\ j\omega M \dot{I}_1 + (R_2 + j\omega L_2 + Z_L) \dot{I}_2 \end{pmatrix} = \begin{pmatrix} \dot{U}_1 \\ 0 \end{pmatrix}$$



$$Z_M = j\omega M$$

$$Z_{11} = R_1 + j\omega L_1$$

$$Z_{22} = R_2 + j\omega L_2 + Z_L$$

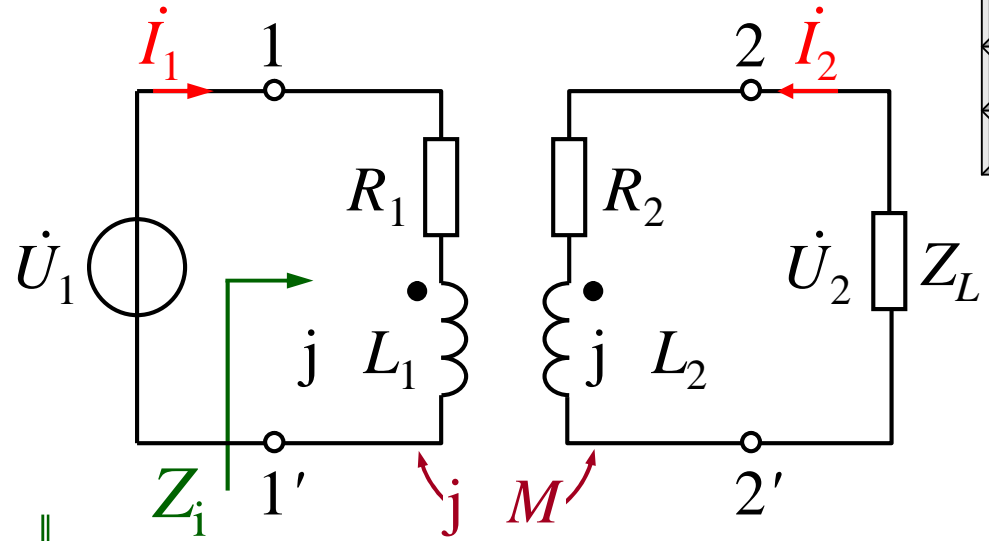
$$\begin{pmatrix} Z_{11} \dot{I}_1 + Z_M \dot{I}_2 \\ Z_M \dot{I}_1 + Z_{22} \dot{I}_2 \end{pmatrix} = \begin{pmatrix} \dot{U}_1 \\ 0 \end{pmatrix}$$

$$\begin{pmatrix} \dot{U}_1 \\ 0 \end{pmatrix} = \begin{pmatrix} Z_{11} \dot{I}_1 + Z_M \dot{I}_2 \\ Z_M \dot{I}_1 + Z_{22} \dot{I}_2 \end{pmatrix}$$

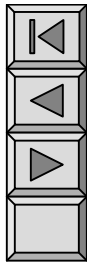
$$\dot{I}_1 = \frac{\dot{U}_1}{Z_{11} + Z_M^2 Y_{22}}$$

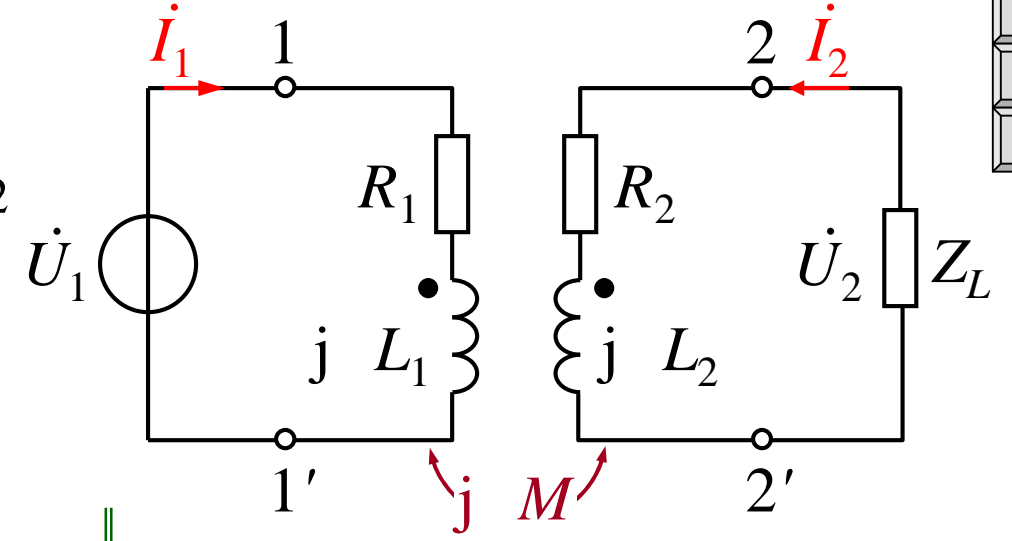
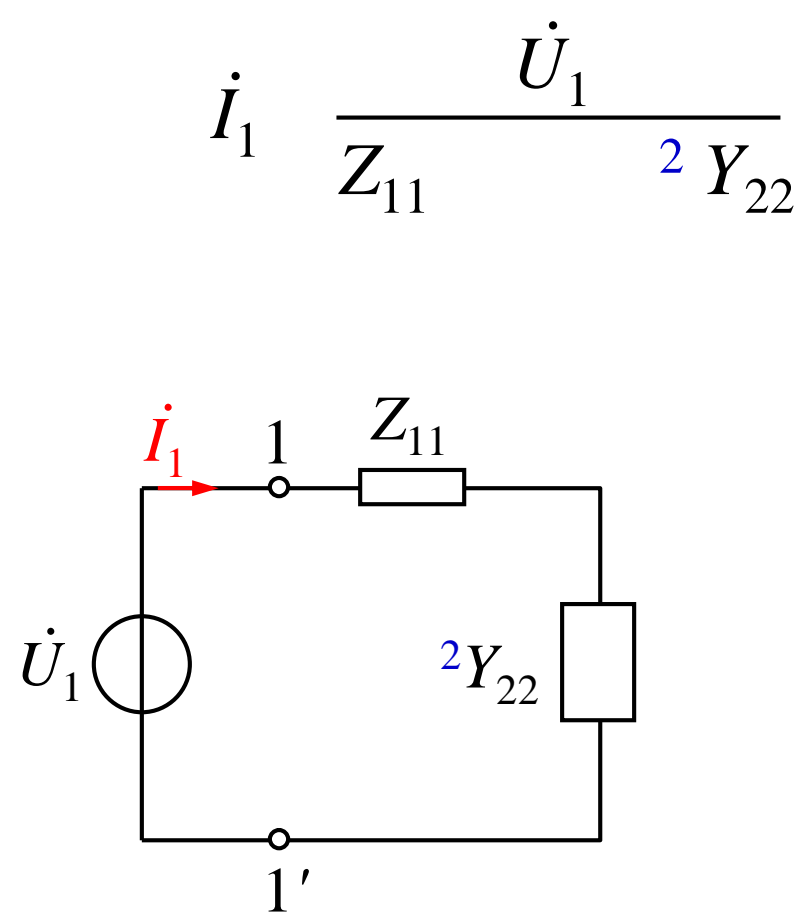
$$Z_i = \frac{\dot{U}_1}{\dot{I}_1} = Z_{11} + (M)^2 Y_{22}$$

$$(M)^2 Y_{22}$$



$$Z_{22} = (M)^2 \frac{1}{|Z_{22}|}$$





$$\begin{aligned} Z_{11}\dot{I}_1 + Z_M\dot{I}_2 &= \dot{U}_1 \\ Z_M\dot{I}_1 + Z_{22}\dot{I}_2 &= 0 \end{aligned}$$

$$\dot{I}_2 = \frac{Z_M}{Z_{22}}\dot{I}_1$$

$$\dot{U}_2 = Z_L\dot{I}_2 + \frac{Z_M Z_L}{Z_{22}}\dot{I}_1$$

$$\dot{I}_1 \quad \dot{U}_2$$





$$\dot{U}_{oc} = j M Y_{11} \dot{U}_1$$

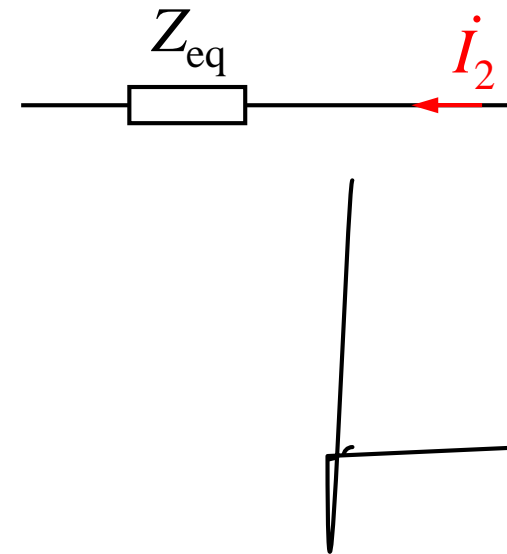
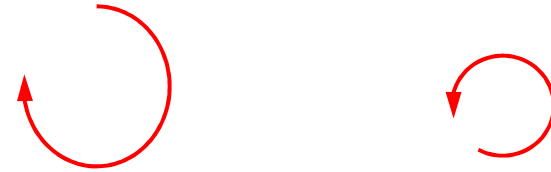
$$Z_{11} \dot{I}_1 + j M \dot{I} = 0$$

$$(R_2 + j L_2) \dot{I} + j M \dot{I}_1 = \dot{U}$$

$$\dot{I}_1$$

$$(R_2 + j L_2) \dot{I} + j M (j M Y_{11} \dot{I}) = \dot{U}$$

$$Z_{eq} = \frac{\dot{U}}{\dot{I}} = (R_2 + j L_2) (1 - M^2 Y_{11})$$

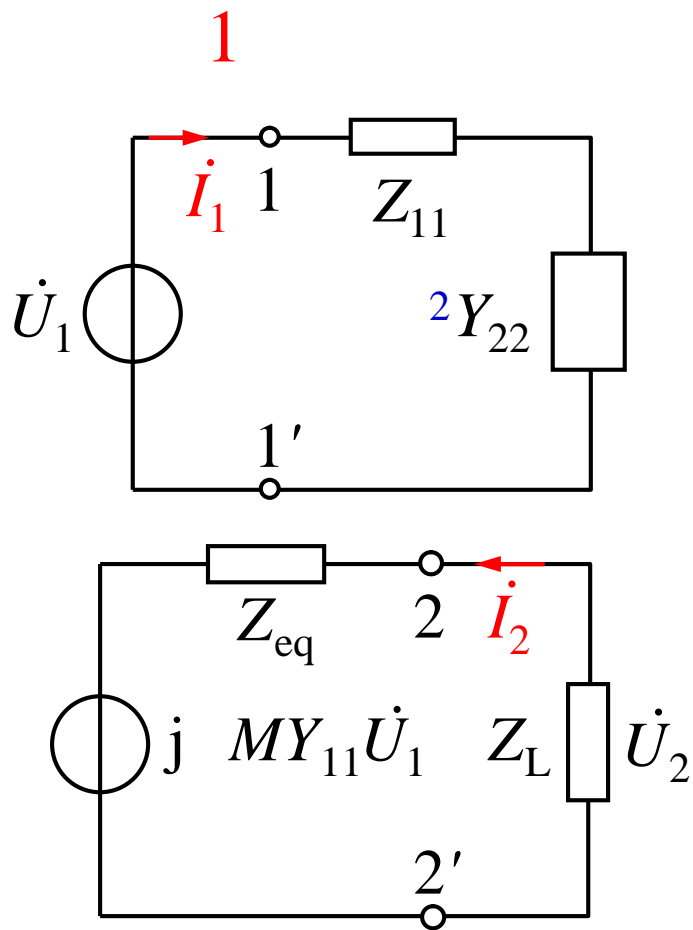
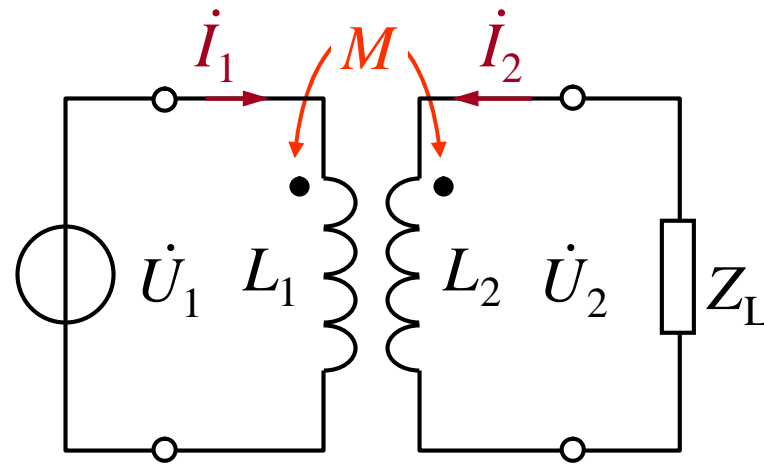




3.  $u_1 = 100\cos(10t) \text{ V}$

$L_1 = 5\text{H}$   $L_2 = 2\text{H}$   $M = 2\text{H}$

$Z_L = 3$   $i_1$   $i_2$



$$Z_{11} = j\omega L_1 = j50$$

$$Z_{22} = j\omega L_2 + Z_L = 3 + j12$$

$$j\omega M = j20 \quad Z_L = 3$$

$$Z_{eq} = j\omega L_2 + (j\omega M)^2 Y_{11} = j28$$

( )

$$i_1 = 4.95\cos(10t - 67.2^\circ) \text{ A}$$

$$i_2 = 8\cos(10t - 126.84^\circ) \text{ A}$$



3.  $u_1 = 100\cos(10t) \text{ V}$

$L_1 = 5\text{H}$     $L_2 = 2\text{H}$     $M = 2\text{H}$

$Z_L = 3$     $i_1$     $i_2$

2

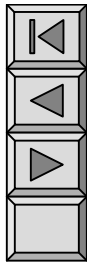
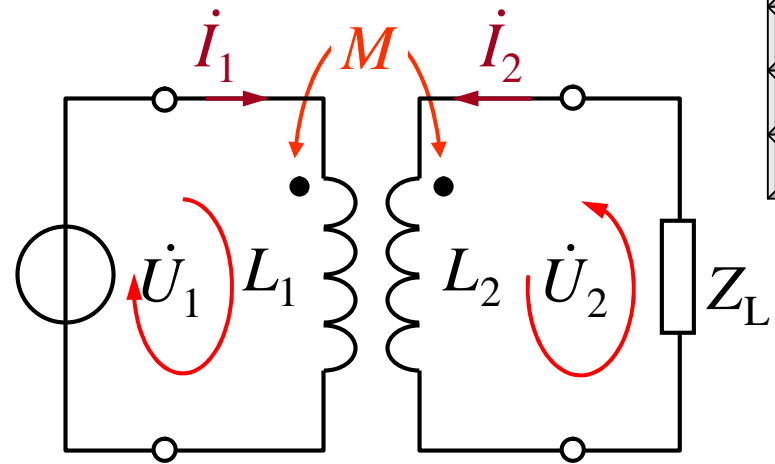
$$\left. \begin{array}{l} Z_{11} \dot{I}_{1m} + j M \dot{I}_{2m} = \dot{U}_1 \\ j M \dot{I}_{1m} + Z_{22} \dot{I}_{2m} = 0 \end{array} \right\}$$

$j M = j20$

$Z_{11} = j L_1 = j50$

$Z_{22} = j L_2 + Z_L = 3 + j12$

$\dot{U}_{1m} = 100 \angle 0^\circ \text{ V}$

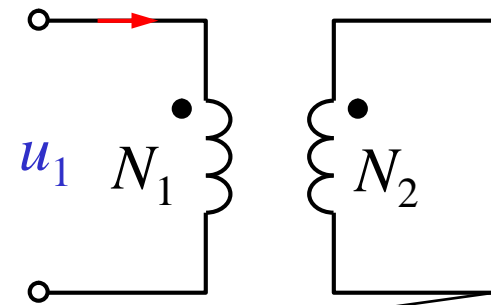
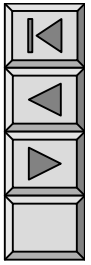


$$\left. \begin{array}{l} j50 \dot{I}_{1m} + j20 \dot{I}_{2m} = 100 \\ j20 \dot{I}_{1m} + (3 + j12) \dot{I}_{2m} = 0 \end{array} \right\}$$

$\dot{I}_{1m} = 4.95 \angle -67.2^\circ \text{ A}$

$\dot{I}_{2m} = 8 \angle 126.84^\circ \text{ A}$

§ 10-5

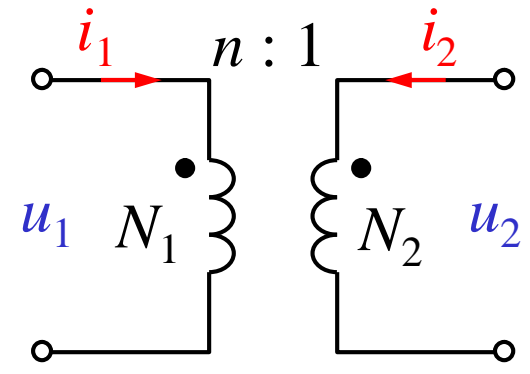




$$u_1 = \frac{N_1}{N_2} u_2 = n u_2$$

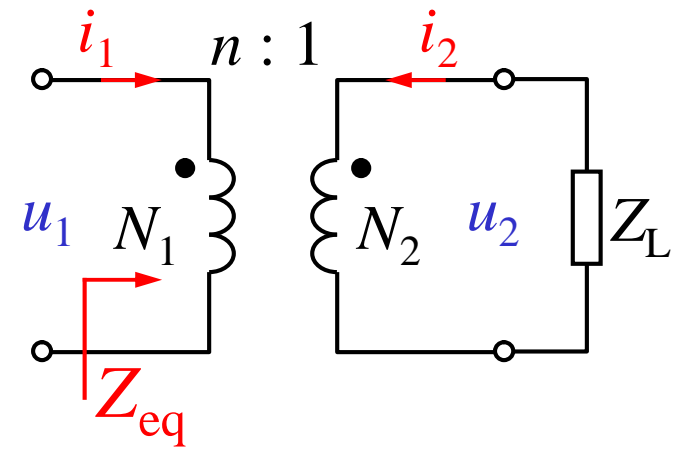
(2)

$$\begin{pmatrix} i_1 \\ i_2 \end{pmatrix} = \begin{pmatrix} \frac{N_2}{N_1} i_2 \\ \frac{1}{n} i_2 \end{pmatrix}$$

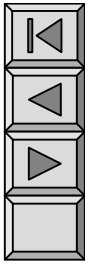
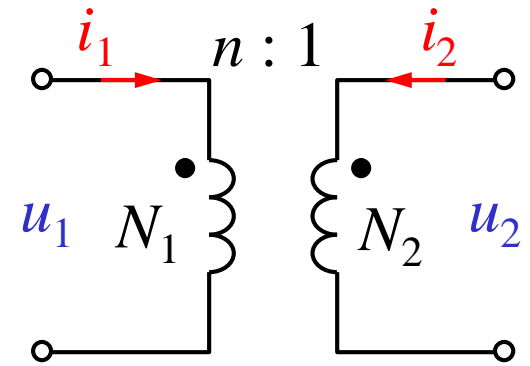


(3)

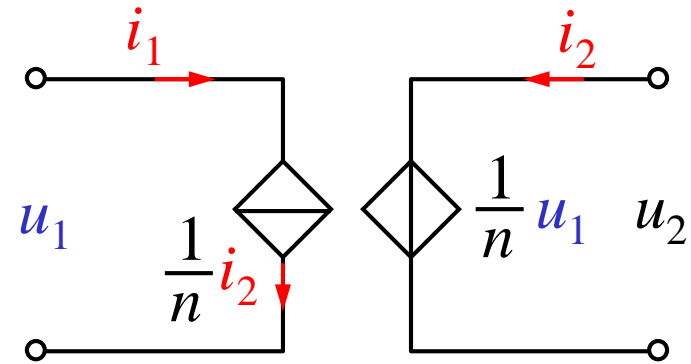
$$Z_{eq} = \frac{\dot{U}_1}{\dot{I}_1} = \frac{n \dot{U}_2}{\frac{1}{n} \dot{I}_2} = n^2 \left( \frac{\dot{U}_2}{\dot{I}_2} \right) = n^2 Z_L$$



3.



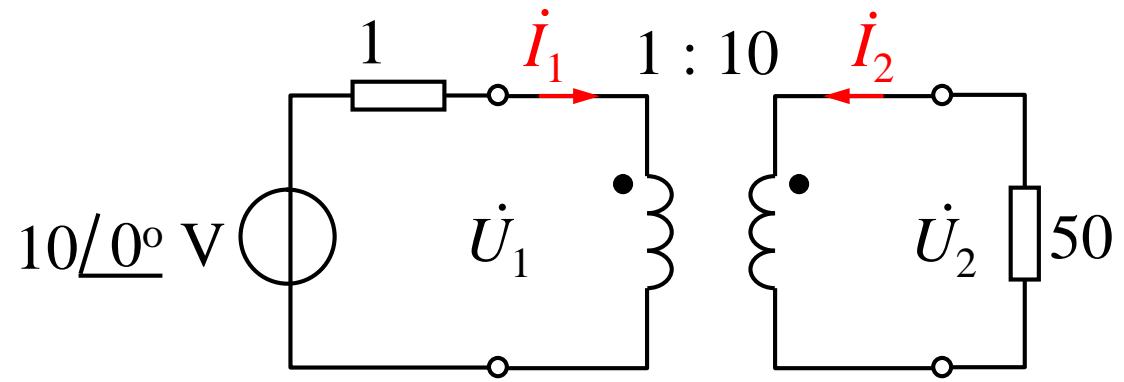
$$u_1 i_1 - u_2 i_2 = u_1 i_1 - \frac{1}{n} u_1 (n i_1) = 0$$



$n$



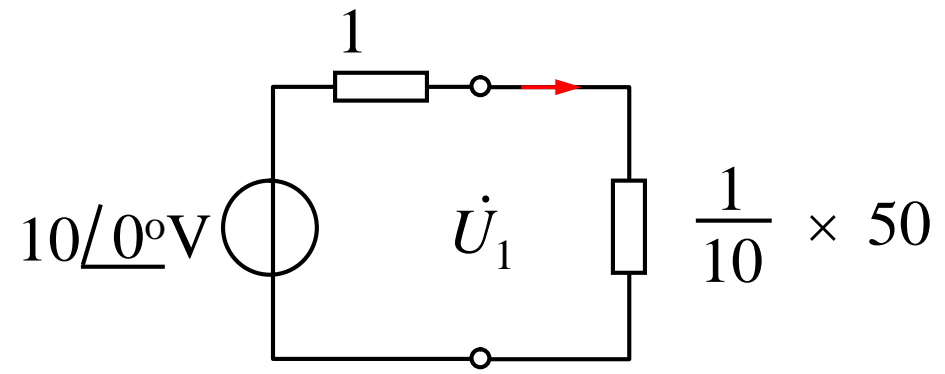
1  $\dot{U}_2$



2

$\dot{I}_1$   $\dot{U}_1$   $\underline{\quad}$

$50\dot{I}_2$   $\dot{U}_2$



$\dot{U}_1$  —  $\dot{U}_2$   $\dot{I}_1$   $\dot{I}_2$

$\dot{U}_1$   $\underline{\quad} \times 0.5$  —  $\underline{\quad}$  V

$\dot{U}_2$  33.33∠0° V

$\dot{U}_2$   $\dot{U}_1$  33.33  $\underline{\quad}$  V

$$\begin{aligned}
 & 3 \\
 & \dot{I}_2 \quad \dot{I}_1 \\
 & \dot{U}_{oc} \quad 10 \dot{U}_1 \quad 100 \angle 0^\circ \text{ V} \\
 & R_{eq} \quad \frac{\dot{U}_2}{\dot{I}_2} \quad 10 \times 1 \quad 100 \\
 & \dot{U}_2 \quad \frac{\dot{U}_{oc}}{50} \times 50 \\
 & \quad \frac{100 \angle 0^\circ}{100} \quad 50 \\
 & \quad 33.33 \angle \quad \text{V}
 \end{aligned}$$

