4

4.1

4.2

4.3

4.4

4.5

4.6

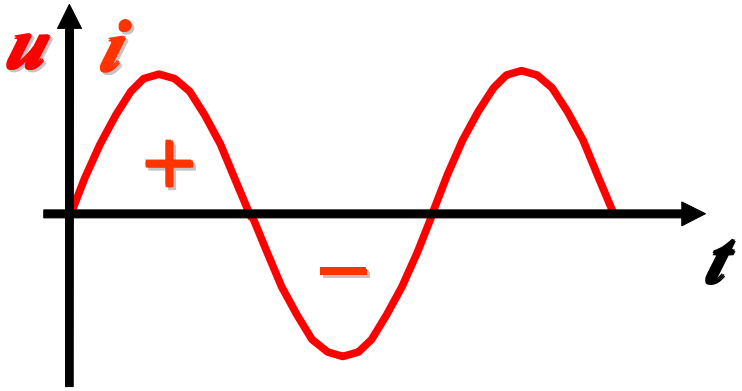
4.7

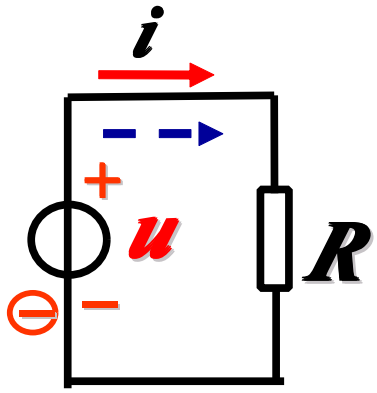
*4.8

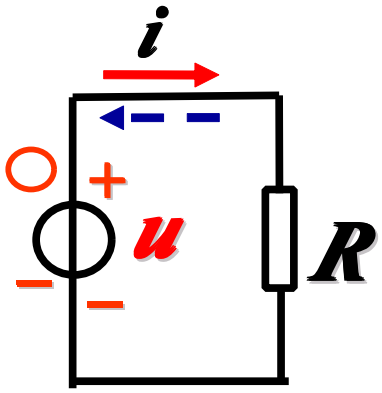
4

1.
2.
3.

4.1







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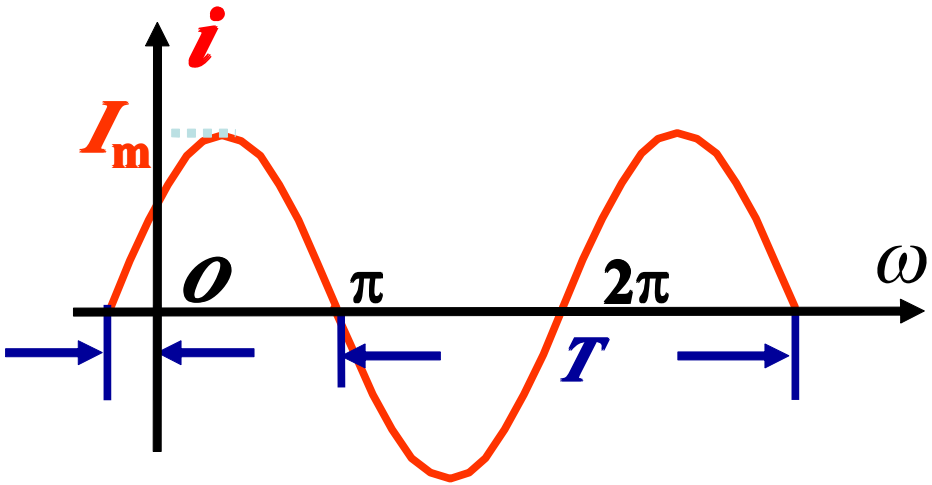
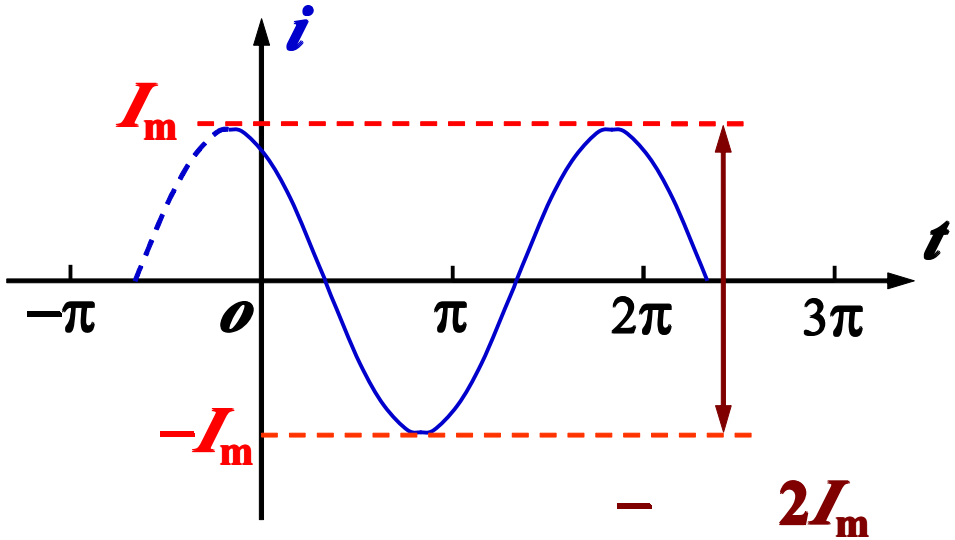


$$= \qquad (\omega \quad + \varphi)$$

4.1.1 ____( ) I_m _____I( )

$$i = I_m \sin(\omega t + \varphi_i) = \sqrt{2} I \sin(\omega t + \varphi_i)$$

☞



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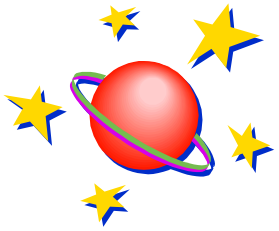
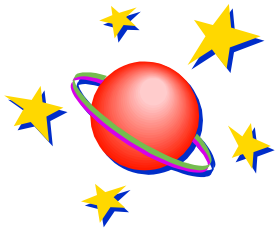


I i

T R

$$I^2RT = \int_0^T i^2R\,\mathrm{d}t \longrightarrow I \xlongequal{\text{def}} \sqrt{\frac{1}{T}\int_0^T i^2\,\mathrm{d}t}$$



$i = I_m \sin(\quad t + \quad _i)$

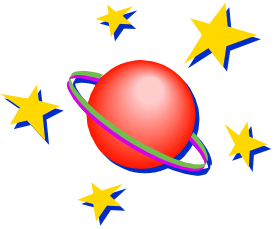
$$I_m = \sqrt{2}\, I$$

$$U_m = \sqrt{2}\, U$$

$U = 220\mathrm{V}$ U_m 311V

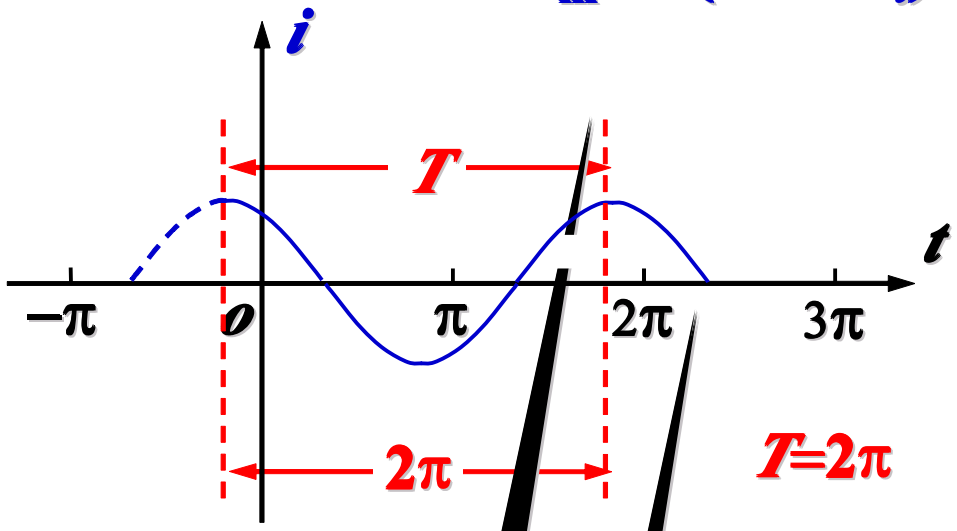
i u I_m U_m I U

$I_M\,(I_{max})$



4.1.2 f T( )

$i = I_m \sin(\quad t + \quad _i)$



$T=2\pi$

Hz

rad/s

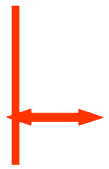
f

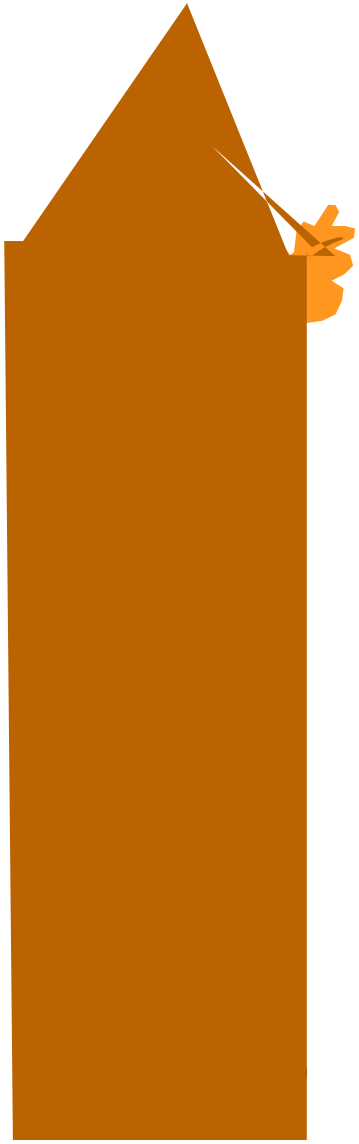
s

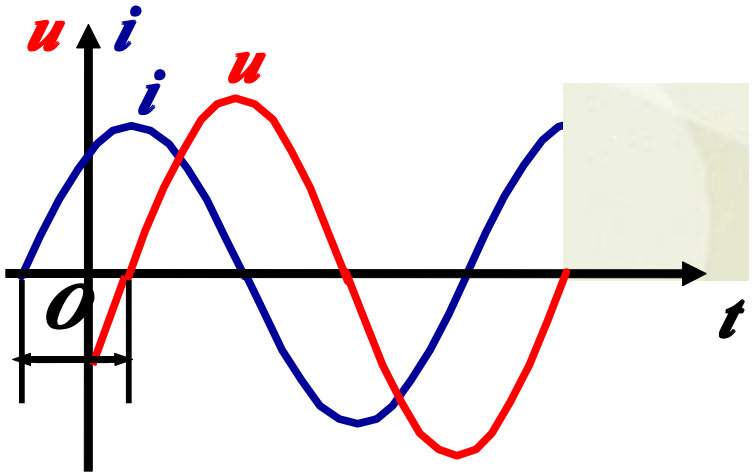
$=2\pi f$ $f=\frac{1}{T}$ $T=\frac{1}{f}$

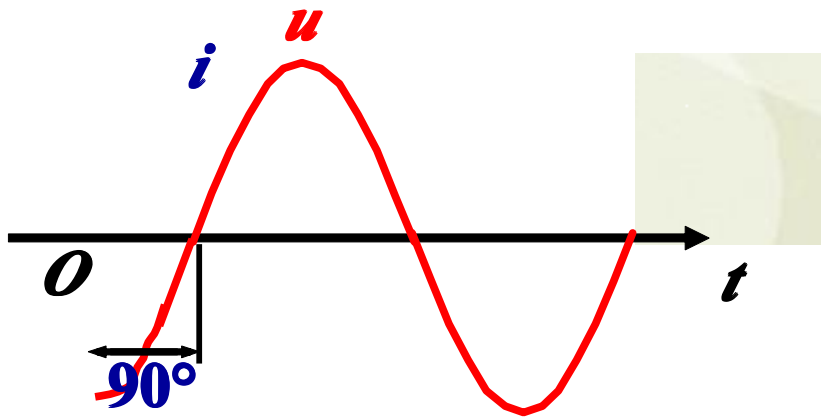
4.1.3 ( )

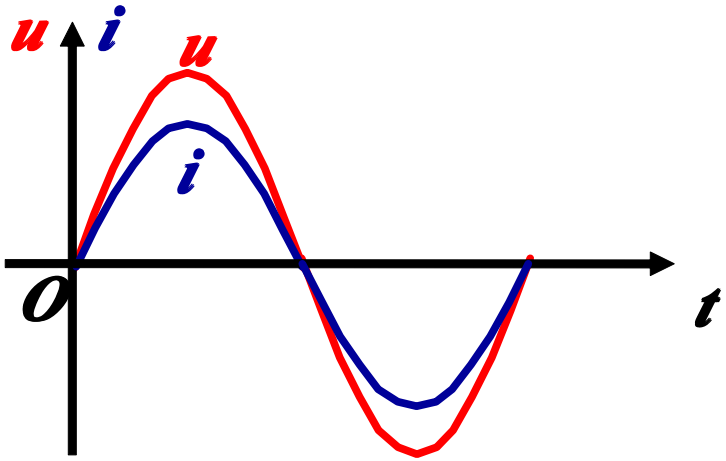
$\omega t + \varphi$






u
i
i
u
o
t


i
u
o
t
90°


u
i
u
i
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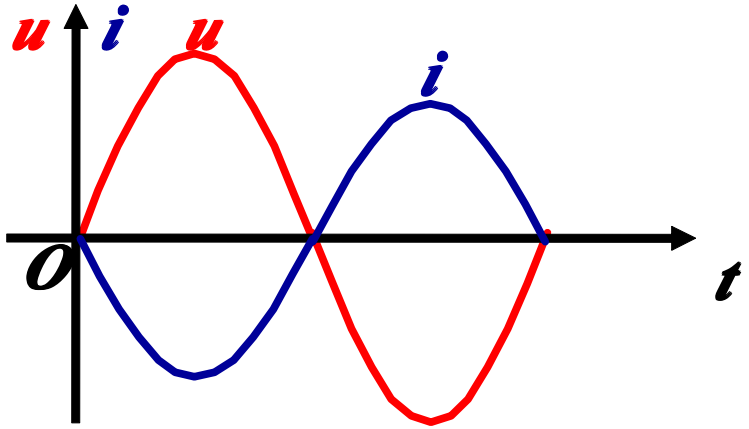
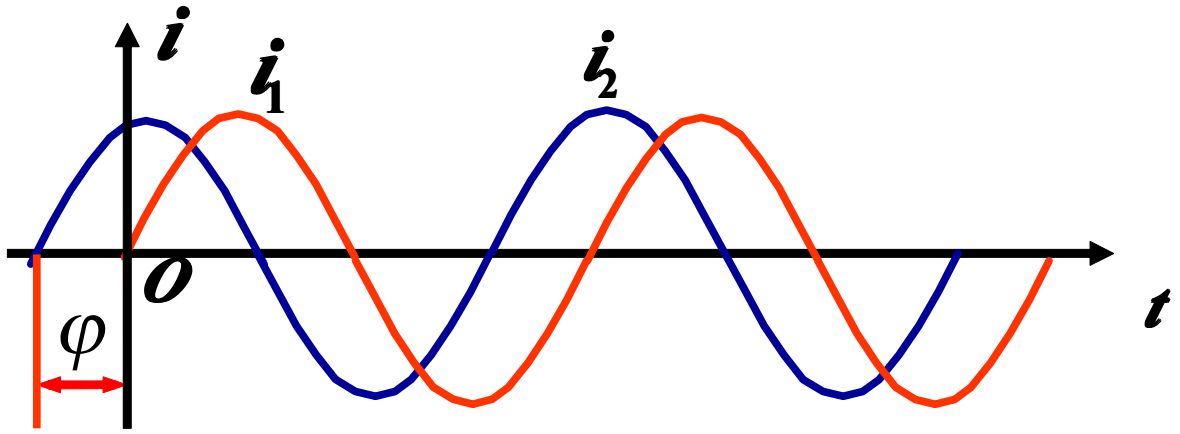
t


u
i
u
i
o
t

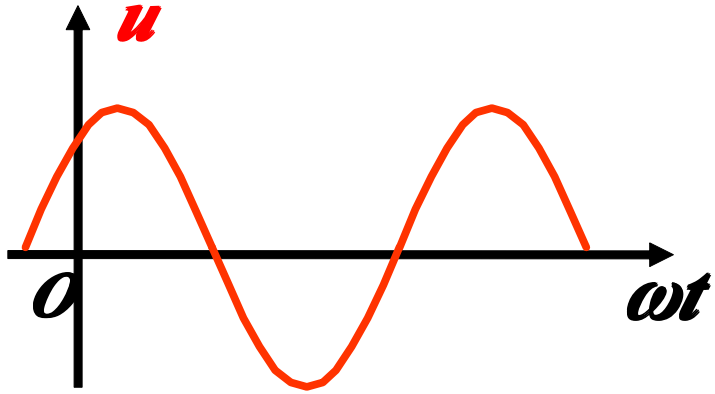
(1)



(2)

4.2

4.2.1

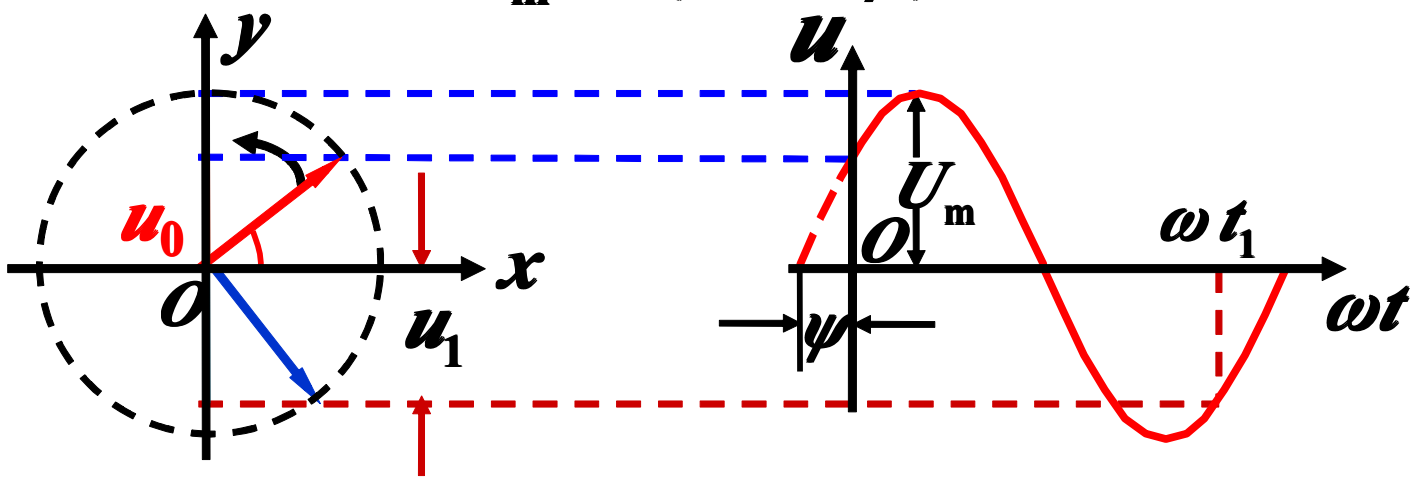


$$u = U_m \sin(\quad t + \quad)$$

$$U = U \quad \psi$$

4.2.2

：$u = U_m \sin(\quad t + \psi)$



：$= U_m$

$=$

：

2011

：$e^{j\psi} = \cos\psi + j\sin\psi$

(3) $A = re^{j\psi}$

(4) $A = r\angle\psi$

$$A = a + jb = r\cos + jr\sin = re^{j\psi} = r\angle\psi$$

：

：$u = U_m \sin(\omega t + \psi)$

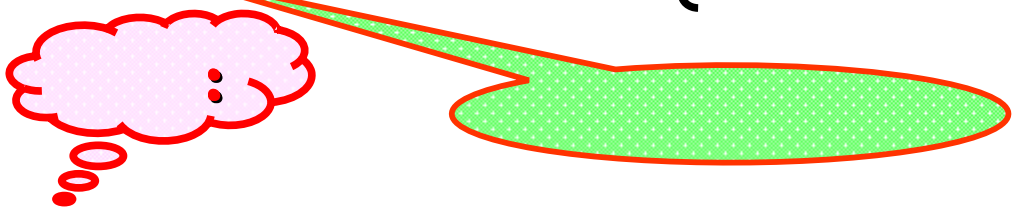
：

$$U = Ue^{j\psi} = U\angle\psi \begin{cases} = \\ = \end{cases}$$

$$\dot{U}_m = U_m e^{j\psi} = U_m \angle \psi$$

=

=



(1)

$$i = I_m \sin(\omega t + \psi) \neq \dot{I}_m e^{j\psi} = \dot{I}_m \quad \psi$$

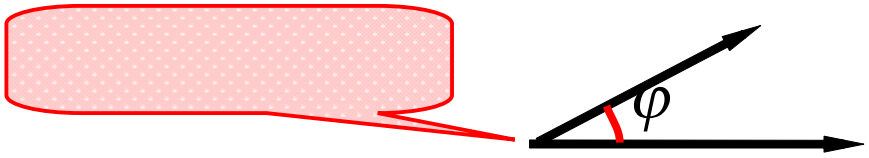
(2)

(3)

(4)

：$\dot{U} = U e^{j\psi} = U\angle\psi = U(\cos\psi + j\sin\psi)$

：



(5)

U_m I_m

$\dot{U}$ $\dot{I}$

$$u = 220\sin(\omega t + 45^\circ)\text{V}$$

$$\dot{U}_m = 220\,e^{j45^\circ}\ \text{V} \qquad \dot{U} = \frac{220}{\sqrt{2}}e^{j45^\circ}\ \text{V}$$

(6) $e^{j\theta}$

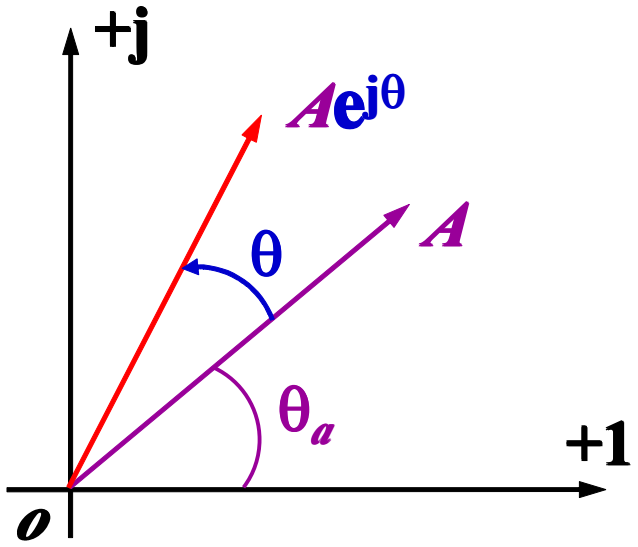
☝ $e^{j\theta}=1$ θ

1 q

✌ $A=|A|e^{j\theta_a}$

$e^{j\theta}$ A θ

$|A|$



$$\left.\begin{aligned} e^{j\frac{\pi}{2}} &= j \\ e^{-j\frac{\pi}{2}} &= -j \\ e^{j\pi} &= -1 \end{aligned}\right\}$$

A $j=jA$ A

90^o。

$\frac{A}{j}=-jA$ A

90^o。

1.

$u = 220\sin(\omega t + 45^\circ)\text{V}$

$\dot{U} \neq \frac{220}{\sqrt{2}} \angle 45^\circ \text{ V}$

j45

$U_m \neq 220\ e^{45^\circ}\text{ V}$

2.

$I = 10 \angle 60^\circ \text{ A}$

$i \neq 10\sin(\omega t + 60^\circ)\text{A}$

3.

$I = 4\ e^{j30^\circ}\text{ A}$

$\neq 4\sqrt{2}\sin(\omega t + 30^\circ)\text{A}$

4.

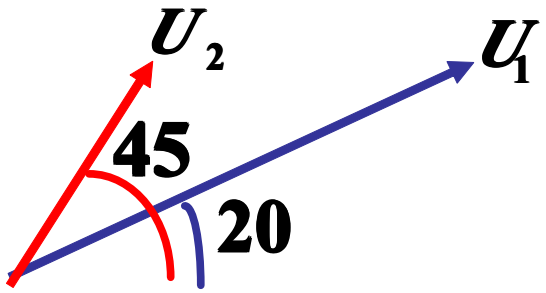
$U = 100 \angle -15^\circ \text{ V}$

$U = 100\text{ V}$

$U \neq 100\ e^{j15^\circ}\text{ V}$

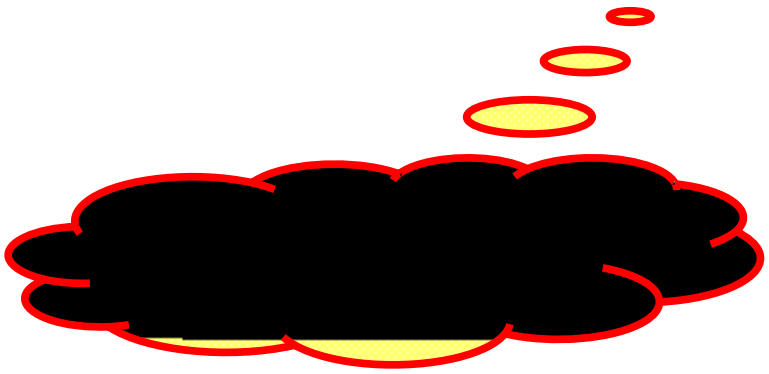
例1:

: (1)



(2)

U_1 U_2



2: $i_1 = 12.7\sqrt{2}\sin(314t + 30°)\text{A}$

$i_2 = 11\sqrt{2}\sin(314t - 60°)\text{A}$

$i = i_1 + i_2$

$\dot{I}_1 = 12.7\angle 30° \text{ A}$

$\dot{I}_2 = 11\angle -60° \text{ A}$

$\dot{I} = \dot{I}_1 + \dot{I}_2 = 12.7\angle 30° \text{ A} + 11\angle -60° \text{ A}$

$= 12.7(\cos 30° + j\sin 30°)\text{A} + 11(\cos 60° - j\sin 60°)\text{A}$

$= (16.5 - j3.18)\text{A} = 16.8\angle -10.9° \text{ A}$

$i = 16.8\sqrt{2}\sin(314t - 10.9°)\text{ A}$

$I = 16.8$ A

4.3

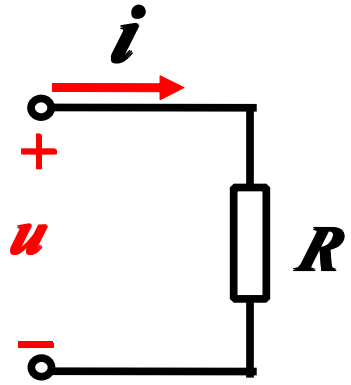
4 3 1

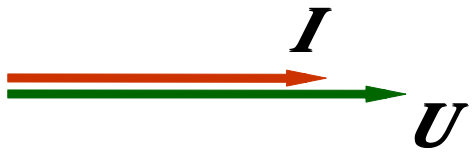
: $u = iR$

$$u = U_m \sin \omega t$$

$$i = \frac{u}{R} = \frac{U_m \sin \omega t}{R} = \frac{\sqrt{2}U}{R} \sin \omega t$$

$$= I_m \sin \omega t = \sqrt{2} I \sin \omega t$$





(1)

(2) $I = \frac{U}{R}$

(3) u i

$= \quad _u - \quad _i = 0$

$I = I \angle 0$

$U = U \angle 0 = \quad I$

4 3 2

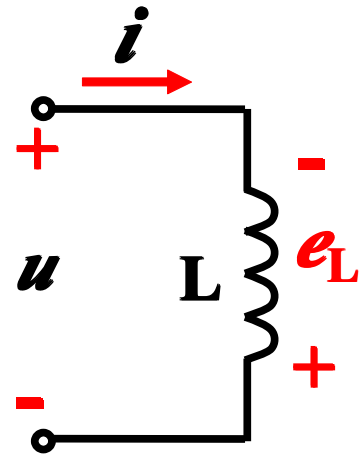
$$u = -e_L = L\frac{\mathrm{d}i}{\mathrm{d}t}$$

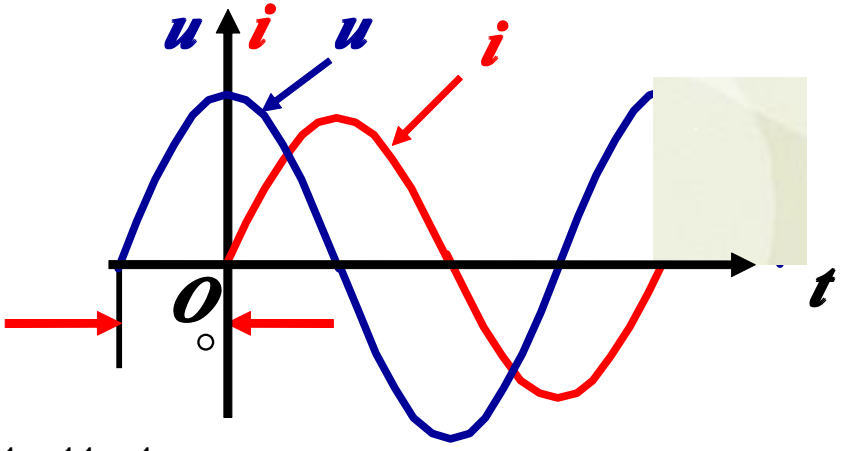
$$i = \sqrt{2}I\sin\omega t$$

$$u = L\frac{\mathrm{d}(I_m\sin\omega t)}{\mathrm{d}t}$$

$$= \sqrt{2}I\omega L\sin(\omega t + 90^\circ)$$

$$= \sqrt{2}U\sin(\omega t + 90^\circ)$$





(1)

(2) $U = I$ L

(3) 90

$$\varphi = \psi_u - \psi_i = 90$$

$$\begin{cases} i = \sqrt{2}I\sin\omega t \\ u = \sqrt{2}I\omega L\cdot\sin(\omega t+90°) \end{cases}$$

$$\because U = I\cdot\omega L \qquad I = \frac{U}{L}$$

$$X_L = \omega L = 2\pi fL$$

$$U = I X_L$$

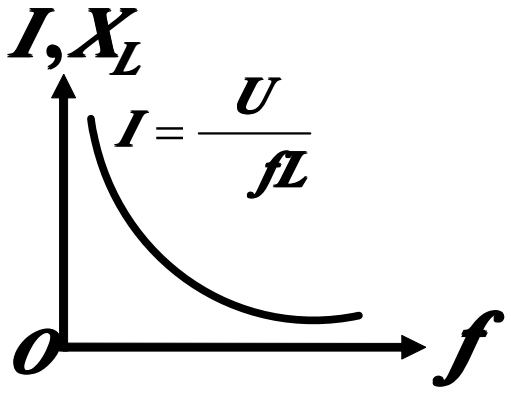
$X_L = 2\pi fL$

$f = 0,\ X_L = 0$ L

$f \uparrow \longrightarrow X_L \uparrow$

$\therefore$ L

$X_L = \omega L = 2\pi f L$



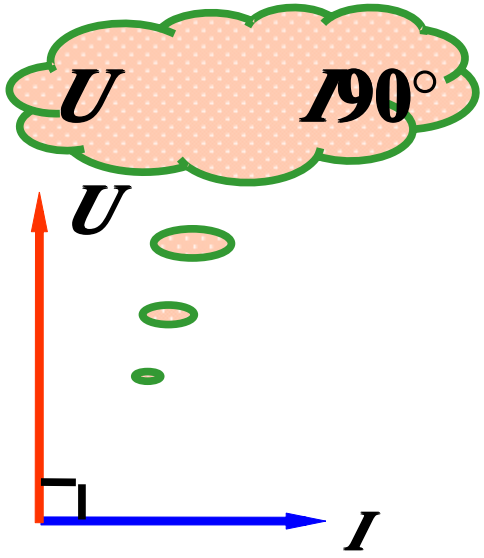
$$\begin{cases} i = \sqrt{2} I \sin \omega t \\ u = \sqrt{2} I \omega L \cdot \sin(\omega t + 90^\circ) \end{cases}$$

$$\dot{I} = I \angle 0$$

$$\dot{U} = U \angle 90 = I\omega L \angle 90$$

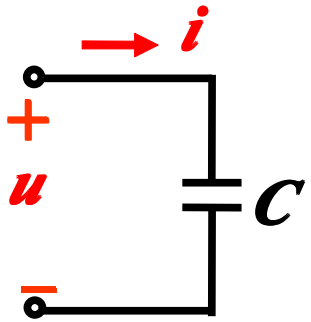
$$\frac{\dot{U}}{\dot{I}} = \frac{U}{I} \angle 90 = \mathrm{j}\, \omega L$$

$$\dot{U} = \mathrm{j} I \omega L = (\mathrm{j} X_L)$$



4 3 3

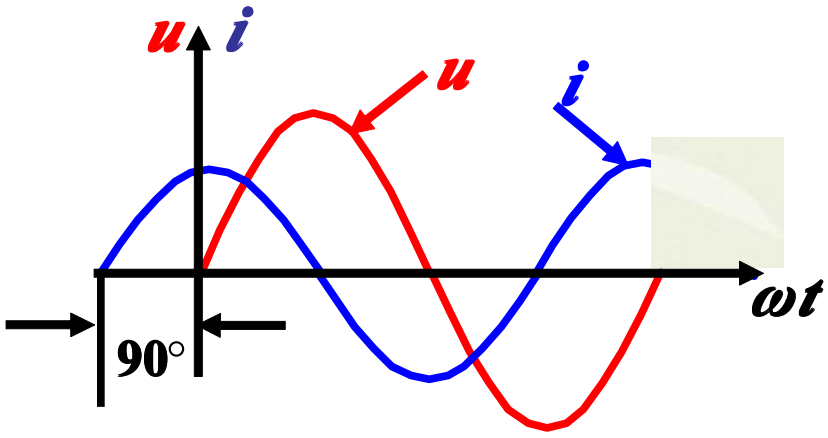
$$i = C\frac{\mathrm{d}u}{\mathrm{d}t}$$



$$u = \sqrt{2}U\sin\omega t$$

$$i = C\frac{\mathrm{d}u}{\mathrm{d}t} = \sqrt{2}\,UC\,\omega\cos\,\omega t$$

$$= \sqrt{2}\,U\,\omega C\sin(\omega t + 90°)$$



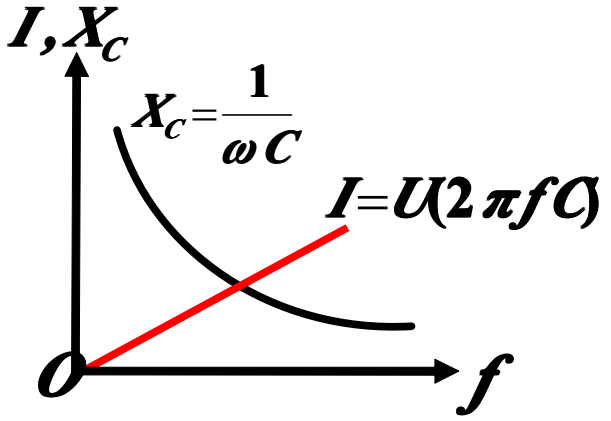
(1)

(2) $I = U\ \ C$

(3) 90

$$\varphi = \psi_u - \psi_i = -\quad °$$

$$X_C = \frac{1}{2\pi f C}$$

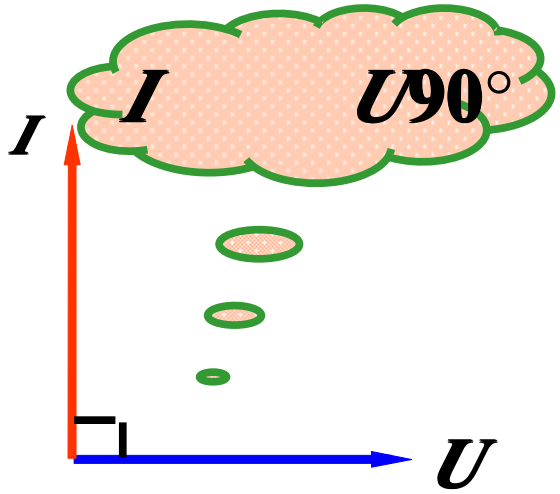


X_C

$$\begin{cases} u = \sqrt{2}U\sin\ \omega t \\ i = \sqrt{2}U\omega C\sin(\omega t + 90°) \end{cases}$$

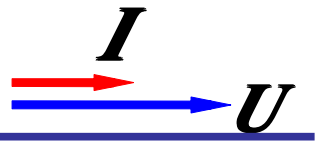
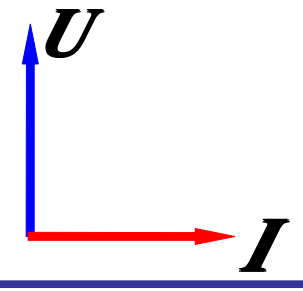
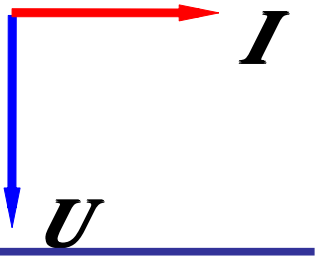
$$= \angle\ °$$

$$= \angle\ °= \omega$$



$$U = -\mathrm{j}I\frac{1}{\omega C} = -\mathrm{j}X_C$$

小 结

R	R	$u = iR$	$U = IR$	
L	$\mathrm{j}X_L = \mathrm{j}\omega L$	$u = L\dfrac{\mathrm{d}i}{\mathrm{d}t}$	$U = \mathrm{j}X_L I$	
C	$-\mathrm{j}X_C = -\mathrm{j}\dfrac{1}{\omega C}$	$i = C\dfrac{\mathrm{d}u}{\mathrm{d}t}$	$U = -\mathrm{j}X_C I$	

4.4

$$R \to R \quad L \to \mathrm{j}\omega L \quad C \to -\mathrm{j}\frac{1}{\omega C}$$

$U \quad I$

$$U = IR \qquad U = I(\mathrm{j}X_L) \qquad U = I(-\mathrm{j}X_C) \qquad U = IZ$$

KCL $I = 0$ **KVL** $U = 0$

4.4.1

(1)

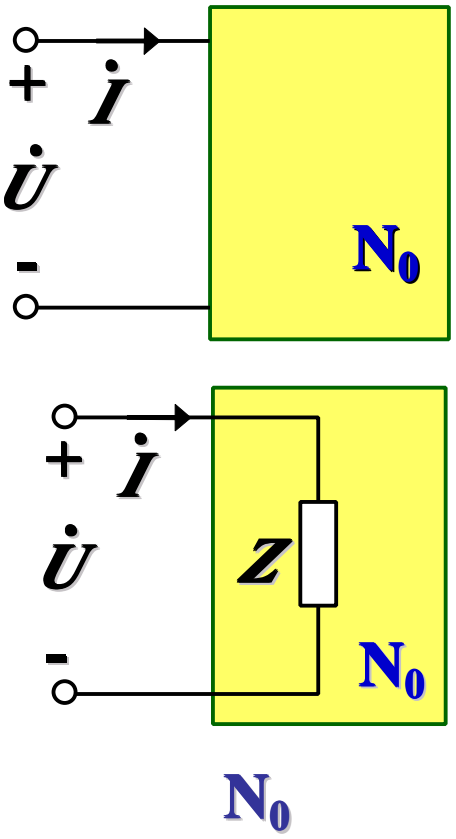
$$\dot{U} = U\angle_{u} \qquad \dot{I} = I\angle_{i}$$

$$Z \overset{\text{def}}{=\!=} \frac{\dot{U}}{\dot{I}} = \frac{U}{I}\angle_{u-i} = |Z|\angle_{z}$$

$$|Z| = \frac{U}{I}$$

$|Z|$

$z = u - i$



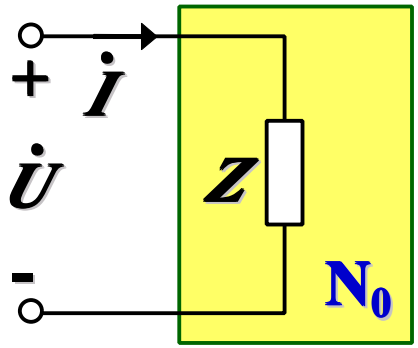
(2)

$$Z=|Z|e^{j\varphi_z}$$

$$Z=|Z|\angle\varphi_z$$

$$Z=|Z|\cos\varphi_z+j|Z|\sin\varphi_z$$

$$Z=R+jX$$

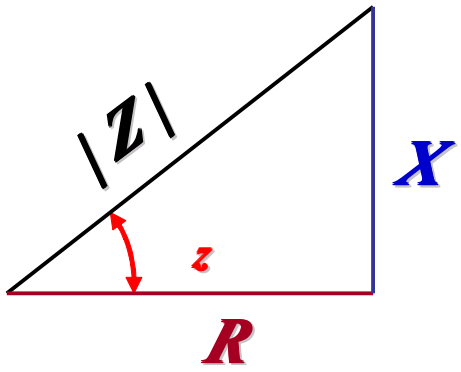


Z R Z X

$$\begin{cases} R=|Z|\cos\varphi_z \\ X=|Z|\sin\varphi_z \end{cases}$$

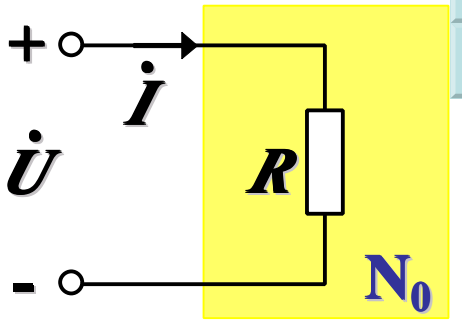
$$\begin{cases} |Z|=\sqrt{R^2+X^2} \\ \varphi_z=\operatorname{arctg}\dfrac{X}{R} \end{cases}$$

$|Z|$ R X

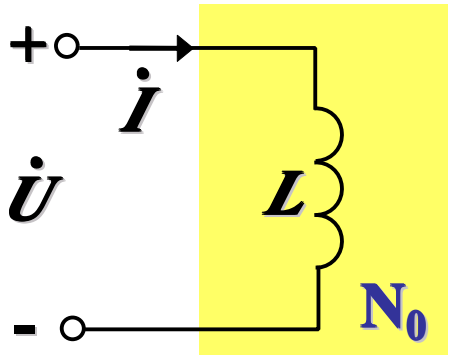


(3)

$$Z=\frac{\dot{U}}{\dot{I}}=R$$

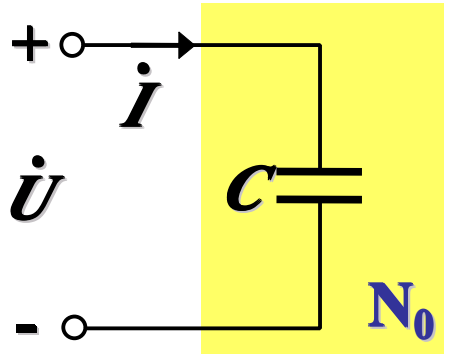


$$Z=\frac{\dot{U}}{\dot{I}}=\mathrm{j}\ L=\mathrm{j}\ X_L$$



$X_L = L$ ——

$$Z=\frac{\dot{U}}{\dot{I}}=\frac{1}{\mathrm{j}\ C}=-\mathrm{j}\ \frac{1}{C}=-\mathrm{j}\ X_C$$

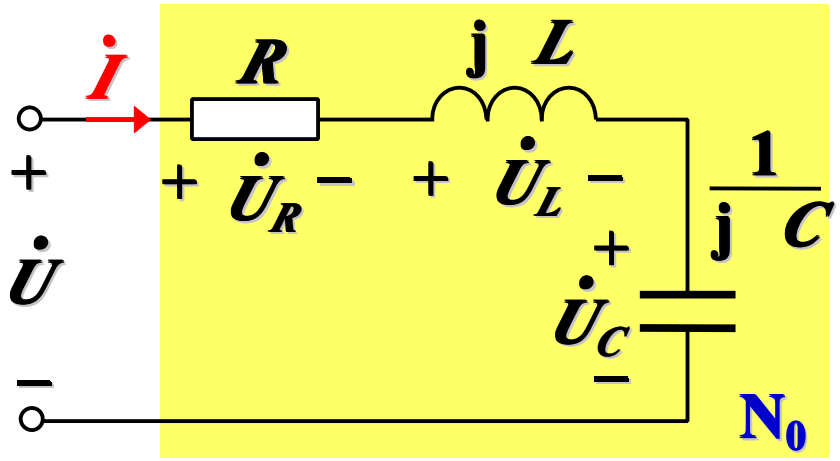


$X_C = \frac{1}{C}$ ——

Z

(4) *RLC*

KVL　VCR



$$\dot{U}=R\dot{I}+\mathrm{j}\ L\dot{I}-\mathrm{j}\frac{1}{C}\dot{I}$$

$$=\left(R+\mathrm{j}\ L-\mathrm{j}\frac{1}{C}\right)\dot{I}=[R+\mathrm{j}(X_L-X_C)]\ \dot{I}$$

$$=(R+\mathrm{j}X)\dot{I}=Z\dot{I}$$

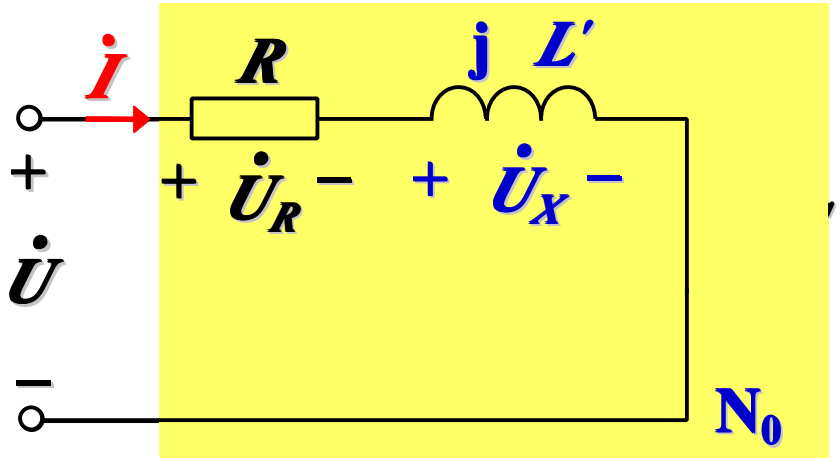
$$Z=\frac{\dot{U}}{\dot{I}}=R+\mathrm{j}\,X=|Z|\angle_{z}$$

$$X=X_L-X_C=\ L-\frac{1}{C}\qquad {}_{z}=\mathrm{arctg}\frac{X}{R}$$

$$Z=\frac{\dot{U}}{\dot{I}}=R+\mathrm{j}X=|Z|\angle_{z}$$

$$X=X_L-X_C=L-\frac{1}{C}$$

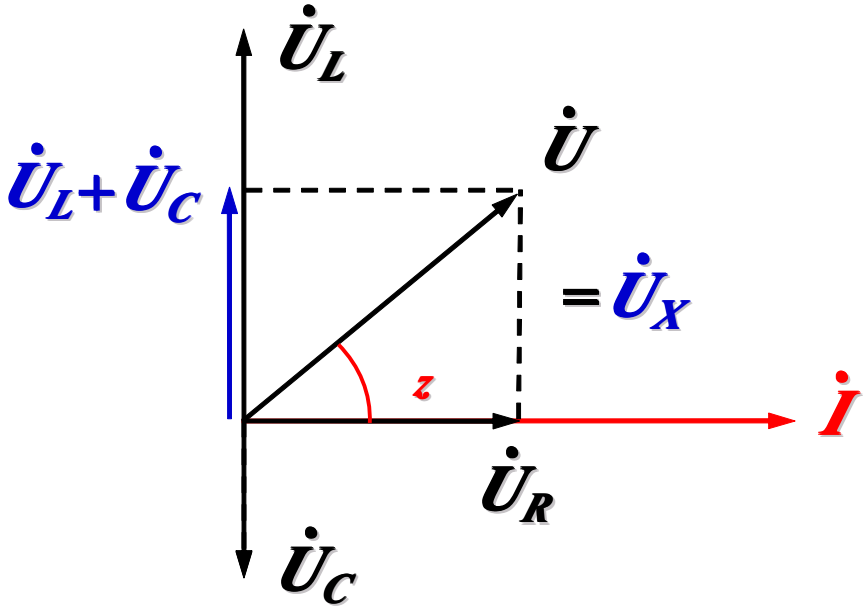
$$_{z}=\mathrm{arctg}\frac{X}{R}$$



L $\frac{1}{C}$

X 0 $_{z}$ 0

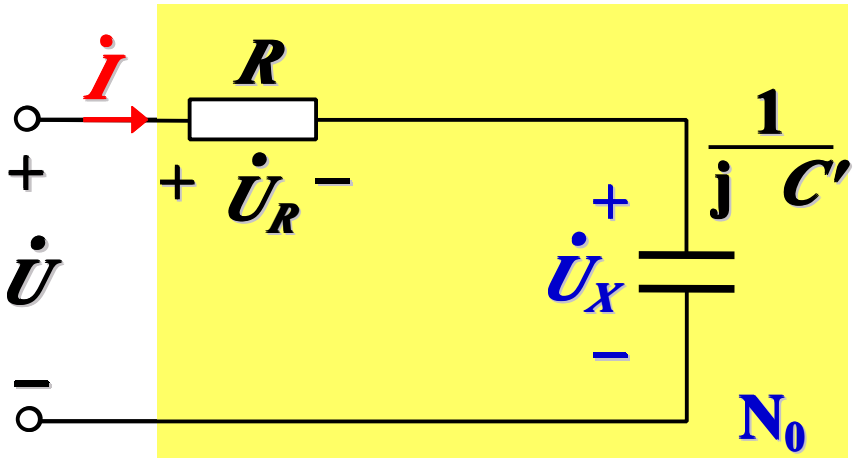
Z



$$Z=\frac{\dot{U}}{\dot{I}}=R+\mathrm{j}X=|Z|\angle\varphi_z$$

$$X=X_L+X_C=\omega L-\frac{1}{\omega C}$$

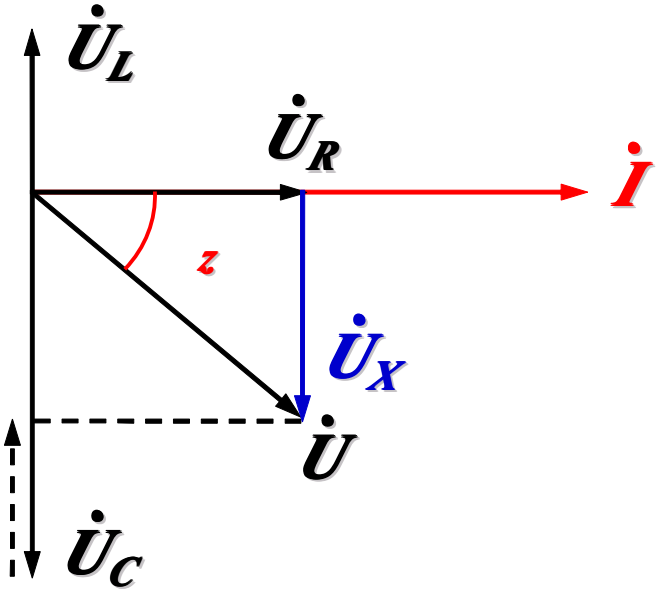
$$\varphi_z=\mathrm{arctg}\frac{X}{R}$$



L $\frac{1}{\omega C}$

X 0 φ_z 0

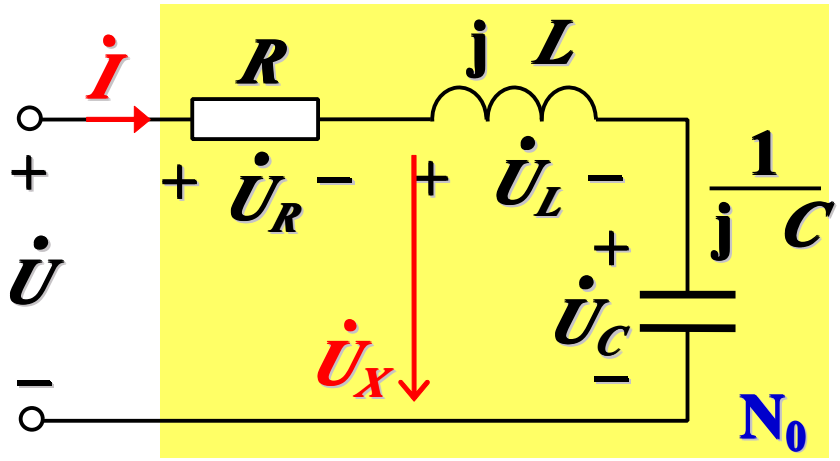
Z



$$Z=\frac{\dot{U}}{\dot{I}}=R+\mathrm{j}X=|Z|\angle_{z}$$

$$X=X_L+X_C=\omega L-\frac{1}{\omega C}$$

$$_{z}=\arctg\frac{X}{R}$$



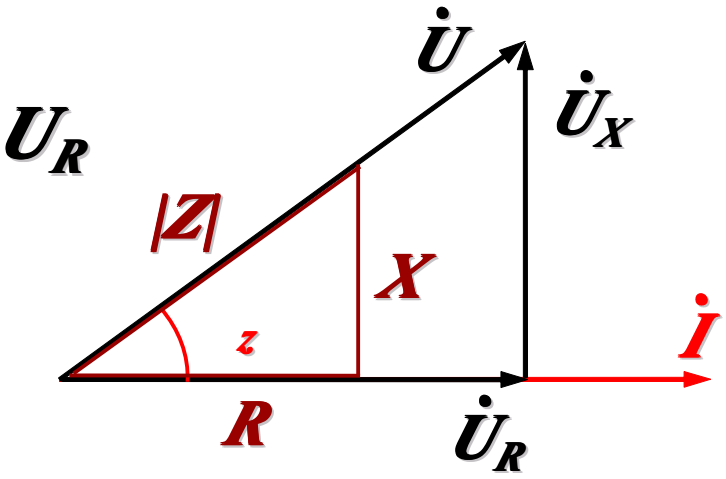
$R=0 \quad X>0 \quad Z$

$R=0 \quad X<0 \quad Z$

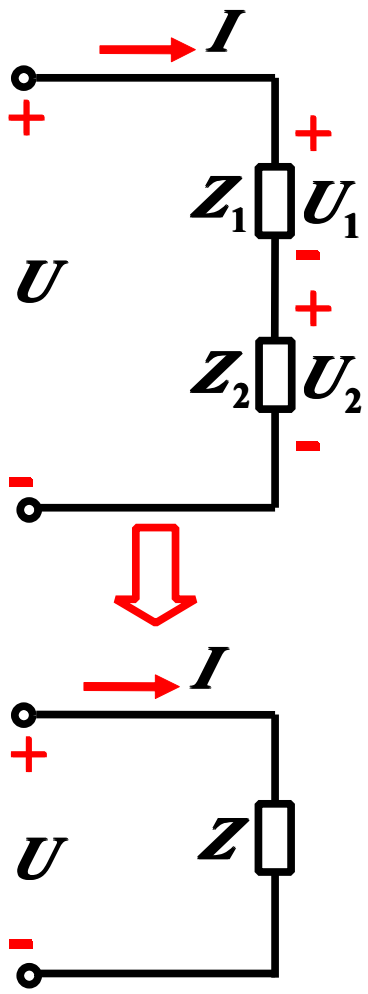
☞ RLC

$U_X \quad U$

$$U=\sqrt{U_R^2+U_X^2}$$



4.4.2



$$U = U_1 + U_2 = Z_1 I + Z_2 I$$

$$= (Z_1 + Z_2) I$$

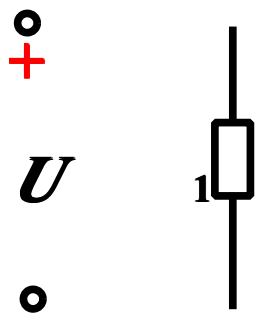
$$Z = Z_1 + Z_2 \qquad I = \frac{U}{Z}$$

: $Z =$ $Z_k =$ $R_k + \mathrm{j}$ X_k

$|Z|$ $|Z_1| + |Z_2|$

$$U_1 = \frac{Z_1}{Z_1 + Z_2} U \qquad U_2 = \frac{Z_2}{Z_1 + Z_2} U$$

4.4.3



$$I = I_1 + I_2 = \frac{U}{Z_1} + \frac{U}{Z_2}$$

$$I = \frac{U}{Z} \qquad \frac{1}{Z} = \frac{1}{Z_1} + \frac{1}{Z_2}$$

$$Z = \frac{Z_1 \ Z_2}{Z_1 + Z_2}$$

$$\frac{1}{|Z|} \neq \frac{1}{|Z_1|} + \frac{1}{|Z_2|}$$

$$I_2 = \frac{Z_1}{Z_1 + Z_2} I$$

RLC

$$\dot{I} = I\angle 0°$$

$$I = \frac{U}{|Z|} \qquad \varphi = \arctan\frac{U_L - U_C}{U_R} \qquad I \neq \frac{U}{R + X_L + X_C}$$

$$I = \frac{U}{Z} \qquad U \neq U_R + U_L + U_C$$

$$I \neq \frac{U}{Z} \qquad \varphi = \arctan\frac{X_L - X_C}{R} \qquad u = u_R + u_L + u_C$$

$$i \neq \frac{u}{|Z|} \qquad \varphi \neq \arctan\frac{\omega L - \omega C}{R} \qquad Z \neq R + X_L + X_C$$

$$I \neq \frac{U}{|Z|} \qquad \varphi \neq \arctan\frac{U_L - U_C}{U} \qquad Z \neq R + j(X_L + X_C)$$

1. （ ）

$$R \rightarrow R,\quad L \rightarrow \mathrm{j}X_L,\quad C \rightarrow -\mathrm{j}X_C$$

$$u \rightarrow U,\quad i \rightarrow I,\quad e \rightarrow E$$

2.

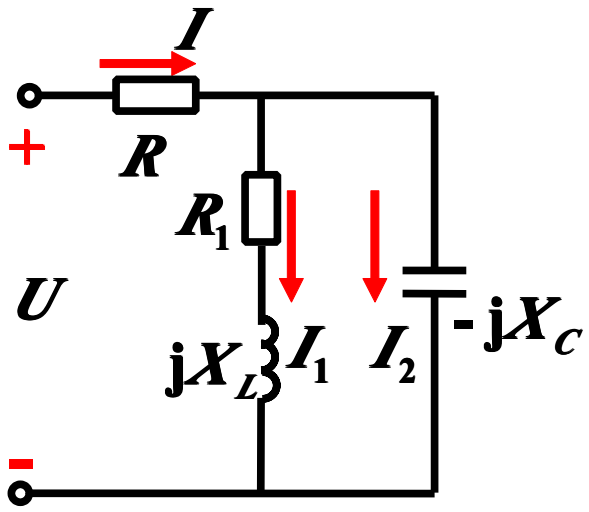
3.

4.

1 ：$u = 220\sqrt{2}\sin\omega t\ \mathrm{V}$

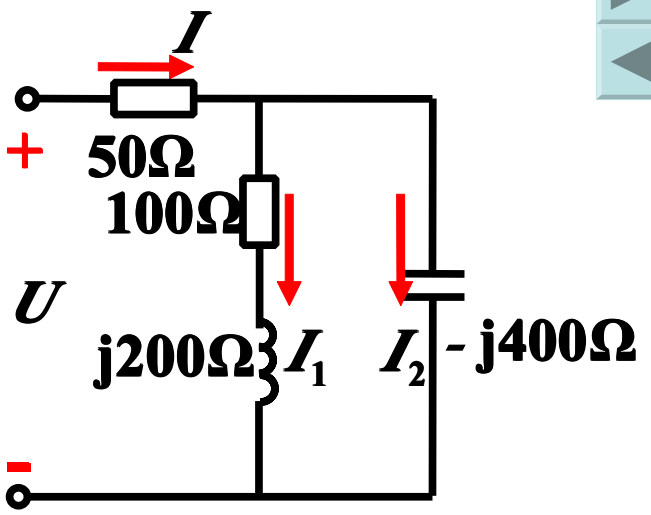
$R = 50\ \Omega, R_1 = 100\ \Omega, X_L = 200\ \Omega, X_C = 400\ \Omega$

：i i_1 i_2



$\dot{U} = 220\angle 0^\circ\ \mathrm{V}$

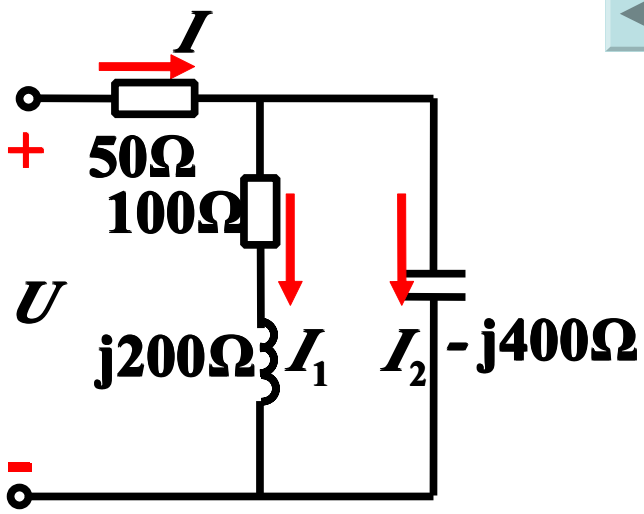
$Z_1 = R_1 + \mathrm{j}X_L = (100 + \mathrm{j}200)\ \Omega$


I
+
50Ω
100Ω
U
j200Ω
I1
I2
- j400Ω
-

$$\dot{I}_2 = \frac{Z_1}{Z_1 + Z_2}$$

$$= \frac{100 + j200}{100 + j200 - j400} \quad 0.5\angle -33^\circ \text{ A}$$

$$= 0.5\angle 93.8^\circ \text{ A}$$

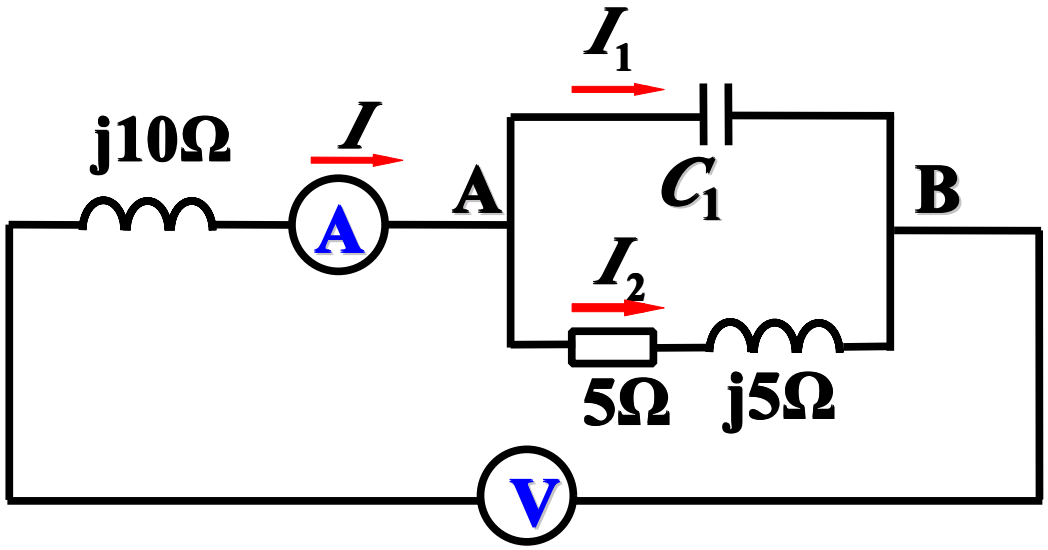


$$i = 0.5\sqrt{2}\sin(\omega t - 33^\circ)\text{A}$$

$$i_1 = 0.89\sqrt{2}\sin(\omega t - 59.6^\circ)\text{A}$$

$$i_2 = 0.5\sqrt{2}\sin(\omega t + 93.8^\circ)\text{A}$$

2 I_1=10A U_{AB} =100V



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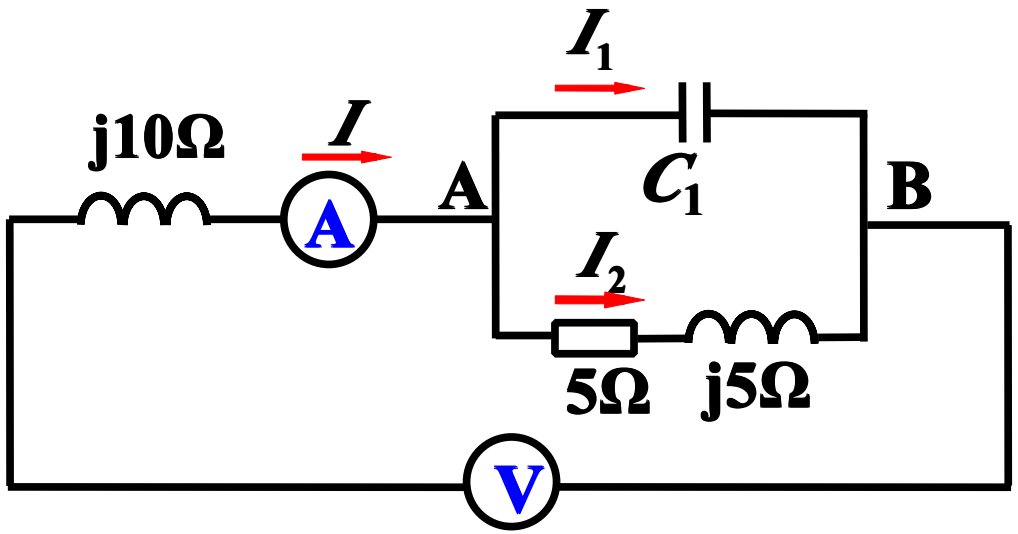


I_1= 10A

U_{AB} =100V

A V

：

U_{AB}

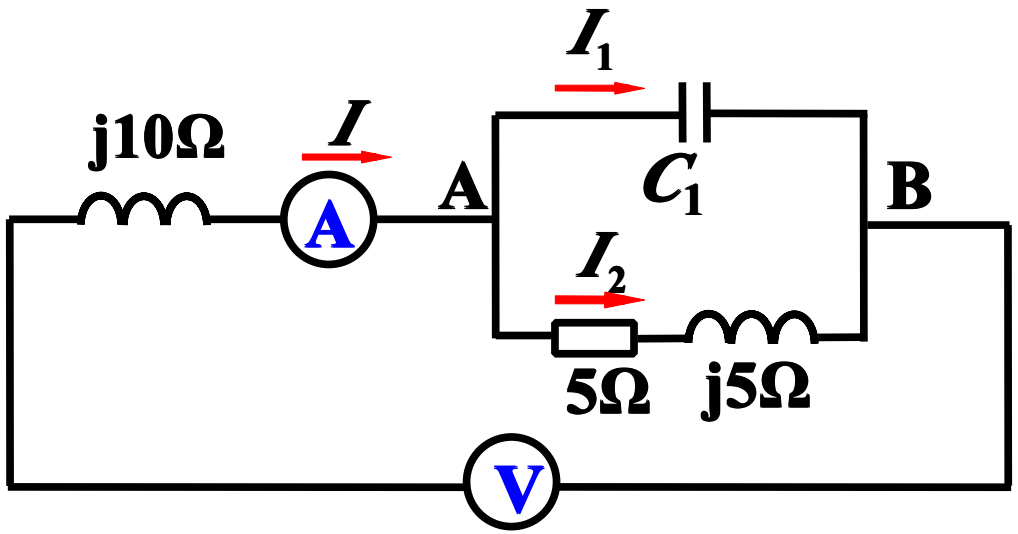
$U_{AB} = 100 \angle 0 \ \text{V}$

$I_2 = [100/(5+\text{j}5)]\text{A} = 10\sqrt{2}\angle -45 \ \text{A}$

$I_1 = 10\angle 90 \ \text{A} = \text{j}10 \ \text{A}$

$I = I_1 + I_2 = 10\angle 0 \ \text{A}$

A 10



I_1=10A

U_{AB} =100V

A V

$$\dot{I} = \dot{I}_1 + \dot{I}_2 = 10\angle 0^\circ \text{ A}$$

$$\dot{U}_L = \dot{I}(\text{j}10)\text{V} = \text{j}100 \text{ V}$$

$$\dot{U} = \dot{U}_L + \dot{U}_{AB} = 100 + \text{j}100\text{V}$$

$$= 100\sqrt{2}\angle 45^\circ \text{ V}$$

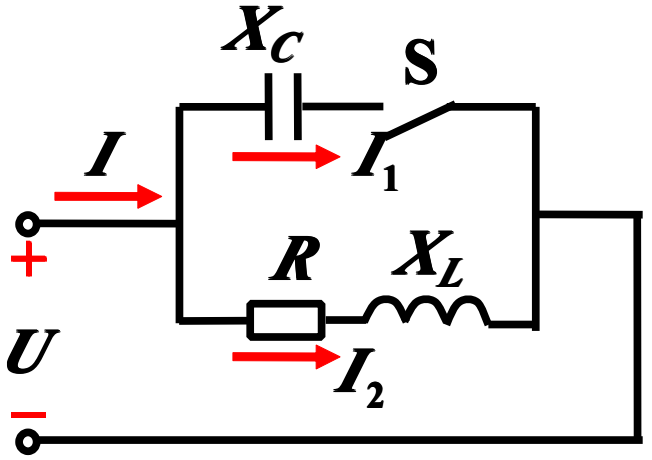
∴ V 141V

3 $U = 200\,\mathrm{V},\ R = X_L,$

$I = I_2 = 10\,\mathrm{A}$

$u \quad i$

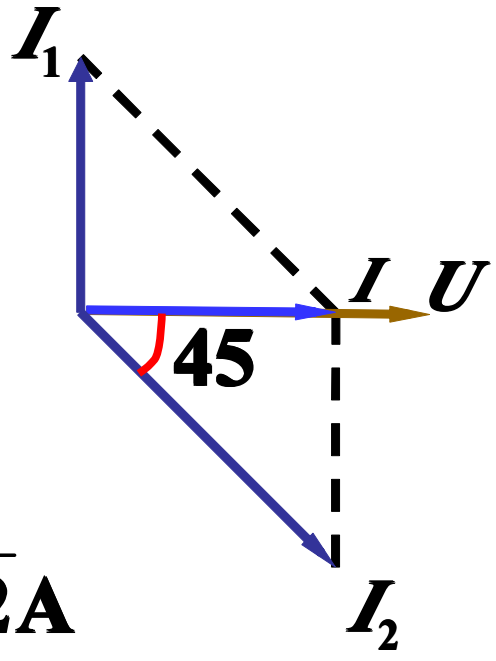
: I, R, X_L, X_C



I_2

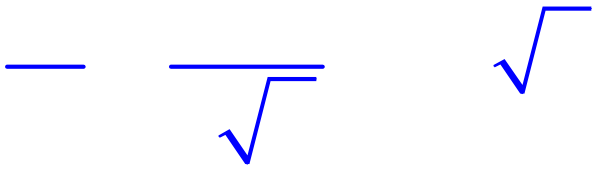
$$I_2 = \frac{U}{|Z|} = \frac{200}{\sqrt{R^2 + X_L^2}} = \frac{200}{\sqrt{2}R} = 10\,\mathrm{A}$$

$$R = X_L = \frac{200}{10\sqrt{2}} = 10\sqrt{2}\,\Omega$$



$$I = I_2\cos 45^\circ = 5\sqrt{2}\,\mathrm{A}$$

$$I_1 = I_2 \sin 45^\circ = 10 \times \sin 45^\circ = 5\sqrt{2}\,\mathrm{A}$$



u i

$$I = I_1 + I_2$$

$$I = I_2 \cos 45° \text{A}$$

$$I_1 = I_2 \sin 45° \text{A}$$

4: $\dot{I} = 18 \quad 45 \quad \text{A}$ $: \dot{U}_{AB}$

$: \dot{I}_1 = \dfrac{j8}{30+j8} \quad 18 \quad 45$

$= 4.64 \quad 120 \quad \text{A}$

$\dot{I}_2 = \dfrac{30}{30+j8} \quad 18 \quad 45$

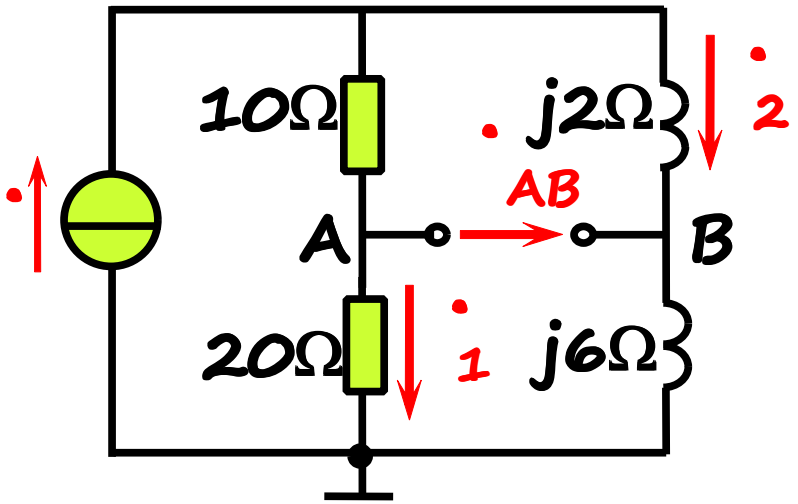
$= 17.4 \quad 30 \quad \text{A}$

$\dot{U}_A = 20\,\dot{I}_1 = 92.8 \quad 120 \quad \text{V}$

$\dot{U}_B = j6\,\dot{I}_2 = 104.4 \quad 120 \quad \text{V}$

$\dot{U}_{AB} = \dot{U}_A - \dot{U}_B = 92.8 \quad 120 \quad - 104.4 \quad 120$

$= -11.6 \quad 120 \quad \text{V} = 11.6 \quad -60 \quad \text{V}$



4.5

4.5.1.

1. p

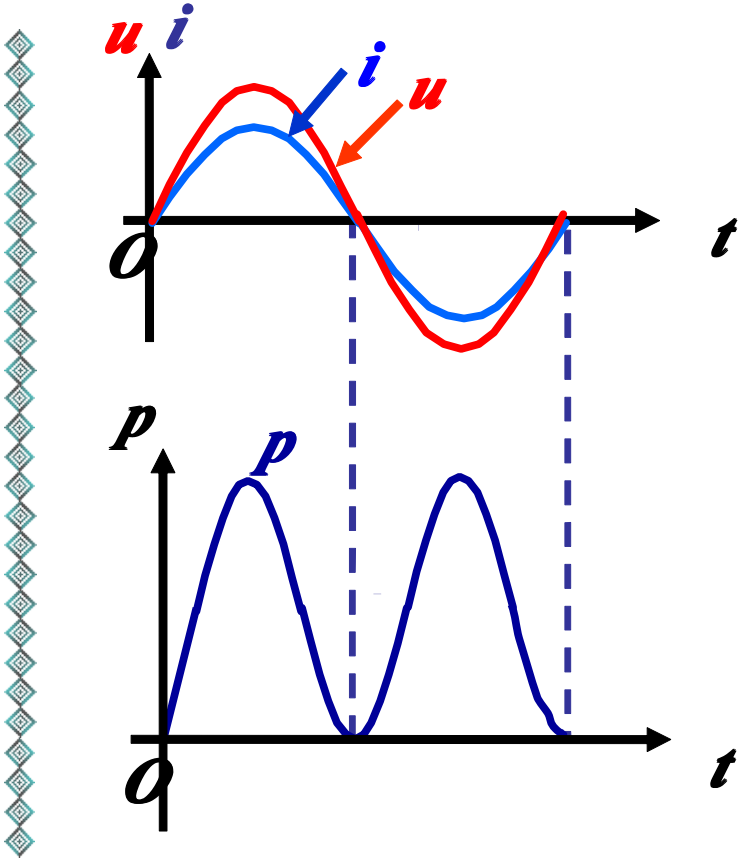
$$i=\sqrt{2}I\sin\omega t$$

$$u=\sqrt{2}U\sin\omega t$$

$$p = u\cdot i$$

$$= U_{\mathrm{m}}I_{\mathrm{m}}\sin^2\omega t$$

$$=\frac{1}{2}U_{\mathrm{m}}I_{\mathrm{m}}(1-\cos 2\omega t)$$



: $p\geq 0$

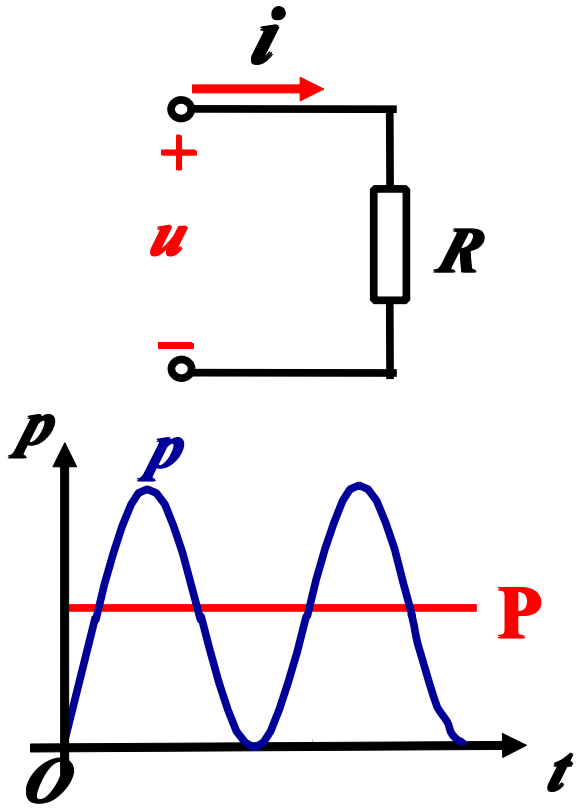
2. ( )P

$$P=\frac{1}{T}\int_0^T p\,\mathrm{d}t=\frac{1}{T}\int_0^T u\cdot i\,\mathrm{d}t$$

$$=\frac{1}{T}\int_0^T\frac{1}{2}U_{\mathrm{m}}I_{\mathrm{m}}(1-\cos 2\omega t)\,\mathrm{d}t$$

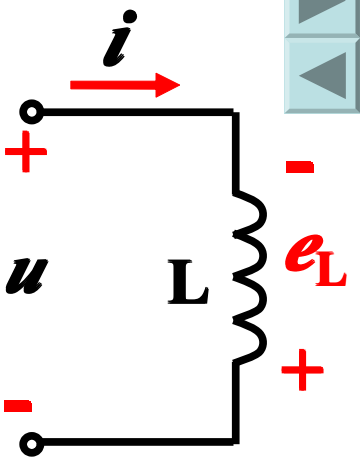
$$=\frac{1}{T}\int_0^T UI(1-\cos 2\omega t)\,\mathrm{d}t=UI$$

$$P=U\quad I=I^2R=\frac{U^2}{R}$$: W



4.5.2

$$\begin{cases} i = \sqrt{2}I\sin\omega t \\ u = \sqrt{2}I\omega L\cdot\sin(\omega t+90°) \end{cases}$$



1.

$$p = i\cdot u = U_m I_m \sin\omega t\sin(\omega t+90°)$$

$$= U_m I_m \sin\omega t\cos\omega t = \frac{U_m I_m}{2}\sin 2\omega t$$

$$= UI\sin 2\omega t$$

2.

$$P = \frac{1}{T}\int_0^T p\,\mathrm{d}t = \frac{I}{T}\int_0^T UI\sin(2\omega t)\,\mathrm{d}t = 0$$

L

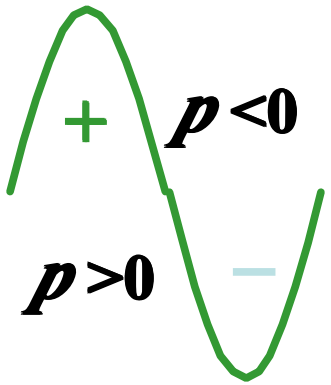
3. Q

$$p = i \cdot u = UI \sin 2\omega t$$

= = =——

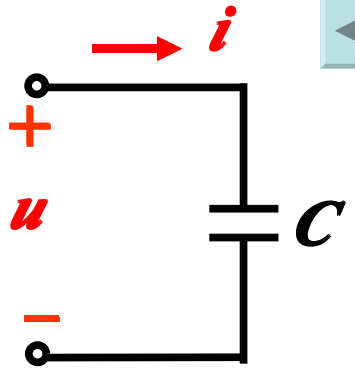
var

$$p = i \cdot u = UI \sin 2\omega t$$



4.5.3

$$\begin{cases} u = \sqrt{2}U\sin\ \omega t \\ i = \sqrt{2}U\omega C\sin\left(\omega t + 90°\right) \end{cases}$$



1.

$$p = i \cdot u = U_{\mathrm{m}} I_{\mathrm{m}} \sin\ \omega t \sin\left(\omega t + 90°\right)$$

$$= \frac{U_{\mathrm{m}} I_{\mathrm{m}}}{2} \sin\ 2\omega t = UI \sin\ 2\omega t$$

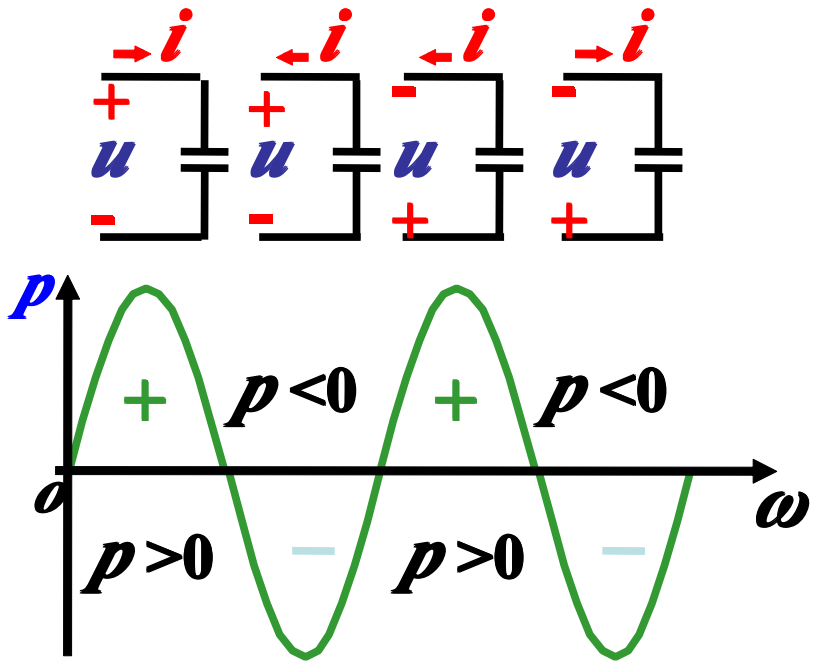
2.

$$P = \frac{1}{T}\int_0^T p\,\mathrm{d}t$$

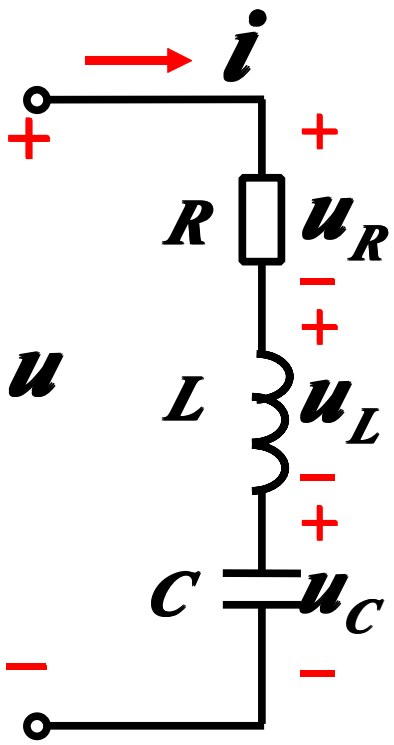
$$= \frac{1}{T}\int_0^T UI \sin\left(2\omega t\right)\mathrm{d}t = 0$$

C

$$p = i \cdot u = UI \sin 2\omega t$$



4.5.4 RLC



1.

$$i = I_m \sin \omega t$$

$$u = U_m \sin(\omega t + \varphi)$$

$$p = u \cdot i = U_m \sin(\omega t + \varphi) \cdot I_m \sin \omega t$$

$$= U_m I_m \cos\varphi \sin^2 \omega t + UI \sin\varphi \sin 2\omega t$$

，

，

2. P

$$P = \frac{1}{T}\int_0^T p\,\mathrm{d}t$$

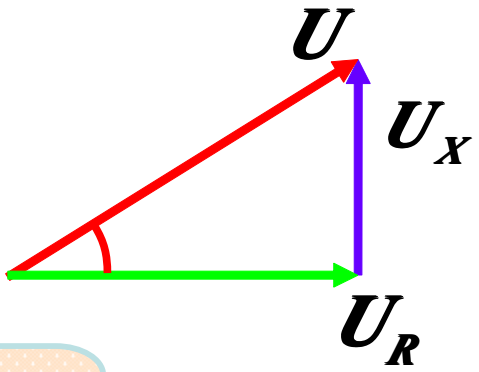
$$= \frac{1}{T}\int_0^T [UI\cos\ \ - UI\cos(2\omega t + \ \ )]\,\mathrm{d}t$$

$$= UI\cos \qquad : \mathrm{W}$$

$P = UI\cos$

u i

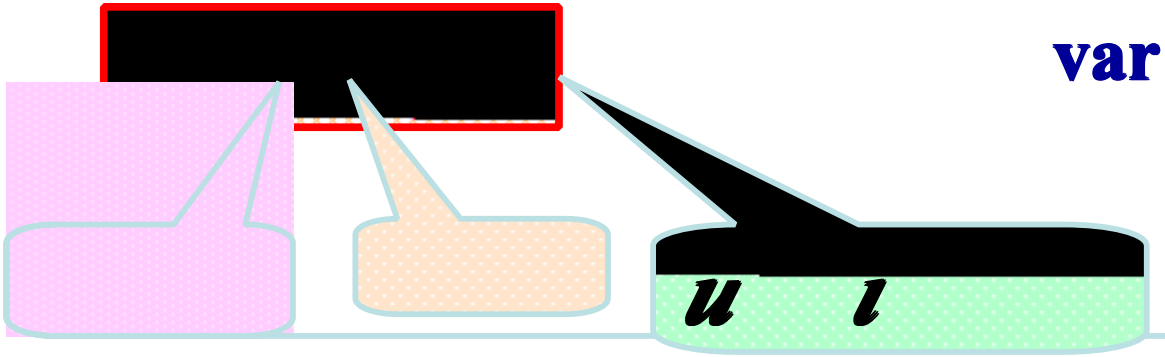
$$P = UI\cos\varphi = U_R I = I^2 R$$



3. Q

$$Q = U_L I - U_C I = (U_L - U_C) I = I^2 (X_L - X_C)$$

var



4. S

$$S = UI = |Z|I^2$$

V·A

S_N U_N I_N

$$S = \sqrt{P^2 + Q^2}$$

$\neq$ +

♣ P Q S

$$I$$

$$I$$

$$U=\sqrt{U_R^2+(U_L-U_C)^2}$$

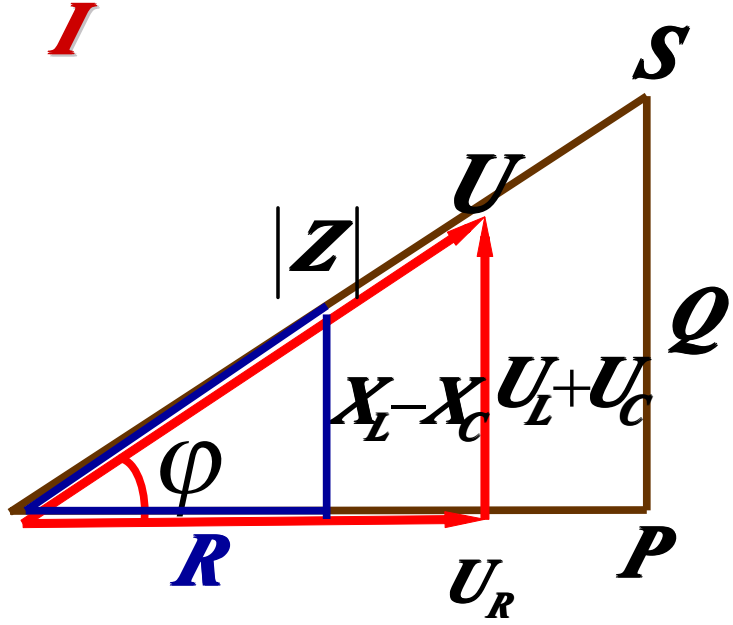
$$U_R = U\cos\varphi$$

$$U_X = U\sin\varphi$$

$$|Z|=\sqrt{R^2+(X_L-X_C)^2}$$

$$R=|Z|\cos\varphi$$

$$X=|Z|\sin\varphi$$



$$S=\sqrt{P^2+Q^2}$$

$$P = S\cos\varphi$$

$$Q = S\sin\varphi$$

4.5.5

1. P

$$= \sum \qquad P = \sum_{1}^{i} U I \cos\varphi$$

i U_i I_i

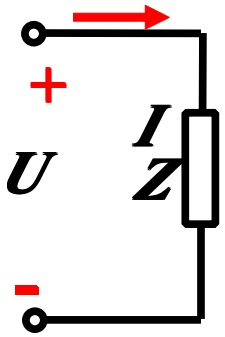
2. Q

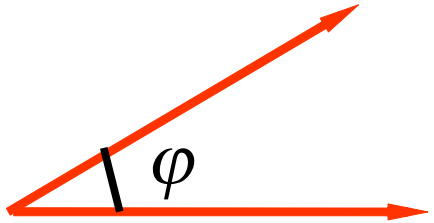
$$= \sum \qquad - \qquad Q = \sum \qquad \sin\varphi$$

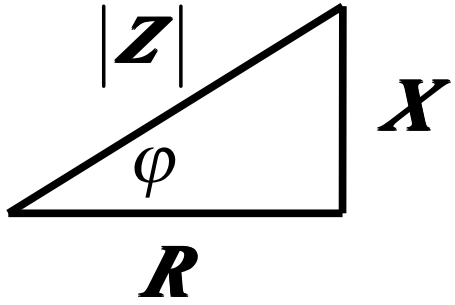
4.6

1. φ **:**

φ







$$Z = R + jX$$

$\cos\varphi < 1$ **,** **,**

$$Q = UI\sin\varphi$$ **:**

(1)

$$S_{\mathrm{N}} = U_{\mathrm{N}} \cdot I_{\mathrm{N}} = 1000\ \mathrm{kV} \cdot \mathrm{A}$$

$$\cos\varphi = 1$$

$$\cos\varphi = 0.6$$

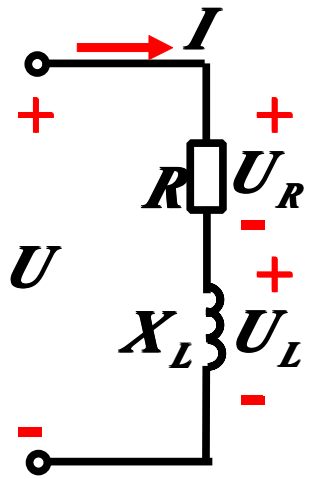
sin 800kvar

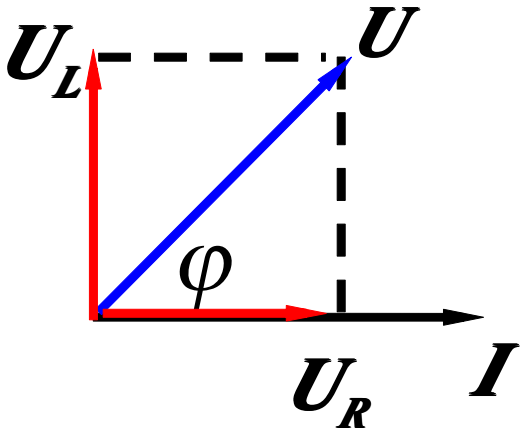
2

r :

: $P = UI\cos\varphi$ ( )

$$I = \frac{P}{U\cos\varphi}$$ I r ( )


I
+
+
R
U_R
-
U
+
X_L
U_L
-
-

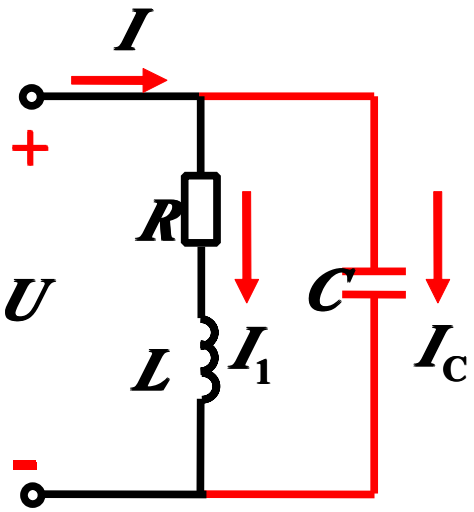

U_L
U
φ
U_R
I

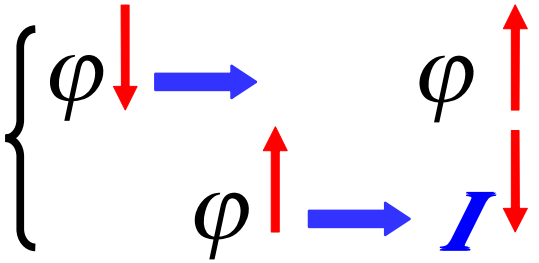
	$\cos\varphi = 1 \quad (\varphi = 0)$
	$\cos\varphi = 0 \quad (\varphi = \pm 90^\circ)$
R-L-C	$1 > \cos\varphi > 0$ $(-90^\circ < \varphi < +90^\circ)$
	$\cos\varphi = 0.2 \sim 0.3$ $\cos\varphi = 0.7 \sim 0.9$
R-L	$\cos\varphi = 0.5 \sim 0.6$

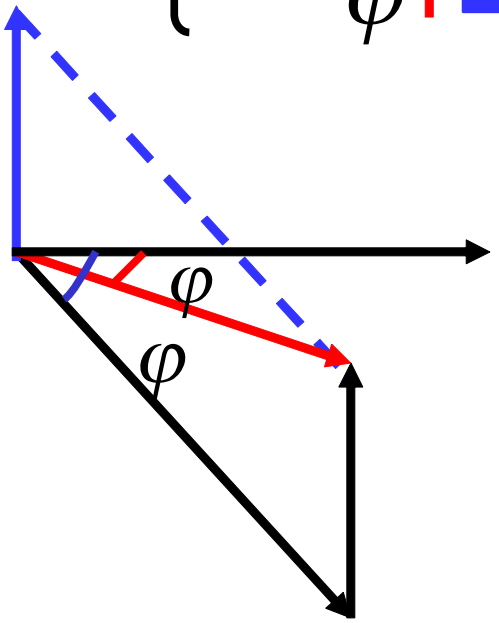
3.

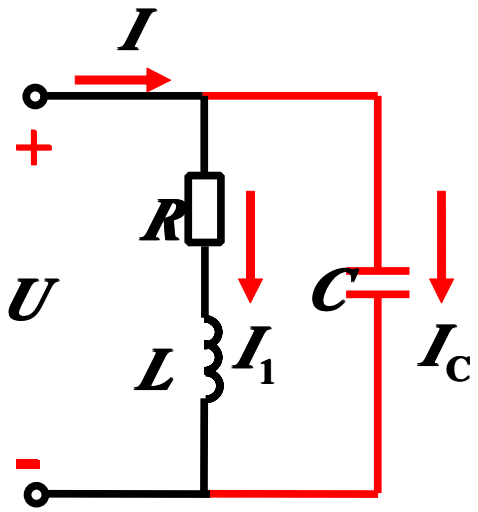
(1)

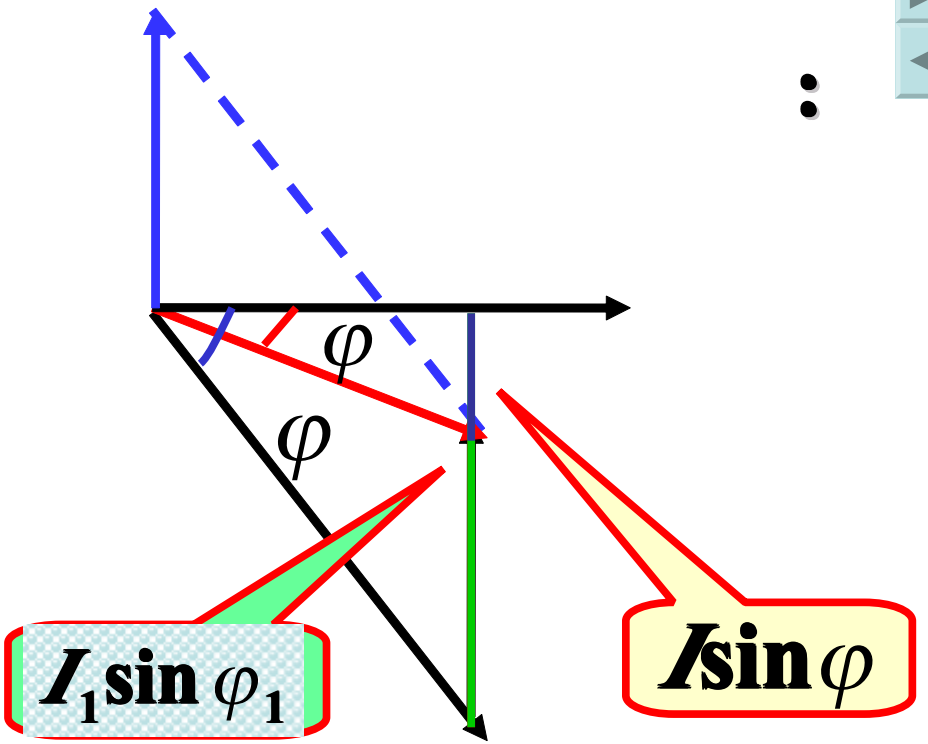
(2)











：

$$I_C = I_1 \sin\varphi_1 - I\sin\varphi$$

：$U\omega C = I_1\sin\varphi_1 - I\sin\varphi$

$$U\omega C = \frac{P}{U\cos\ _1}\sin\ _1 - \frac{P}{U\cos}\sin$$

：， P=10kW, $\cos\varphi = 0.6$

U=220V , f=50Hz

1 $\cos\varphi = 0.95$,

C, C

2 $\cos\varphi$ 0.95 1

C

(1) $C = \dfrac{P}{\omega U^2}(\tan\varphi_1 - \tan\varphi)$

$\cos\varphi = 0.6$ $\varphi = 53°$

$\cos\varphi = 0.95$ $\varphi = 18°$

$$C = \frac{10 \quad 10^3}{314 \quad 220^2}(\tan 53 \quad -\tan 18 \quad) \text{ F} = 656 \ \mu$$

C

C ：$I_1 = \dfrac{P}{U\cos_{\ 1}} = \dfrac{10\ \ 10^3}{220\ \ 0.6}\,\mathrm{A} = 75.6\,\mathrm{A}$

C ：$I = \dfrac{P}{U\cos} = \dfrac{10\ \ 10^3}{220\ \ 0.95}\,\mathrm{A} = 47.8\,\mathrm{A}$

(2) $\cos\varphi$ 0.95 1

$$C = \frac{10\ \ 10^3}{314\ \ 220^2}(\tan 18\ -\tan 0\ )\mathrm{F} = 213.6\ \mu\mathrm{F}$$

：cos 1

( ) 1

4.7

,

,

,

:

:

L C

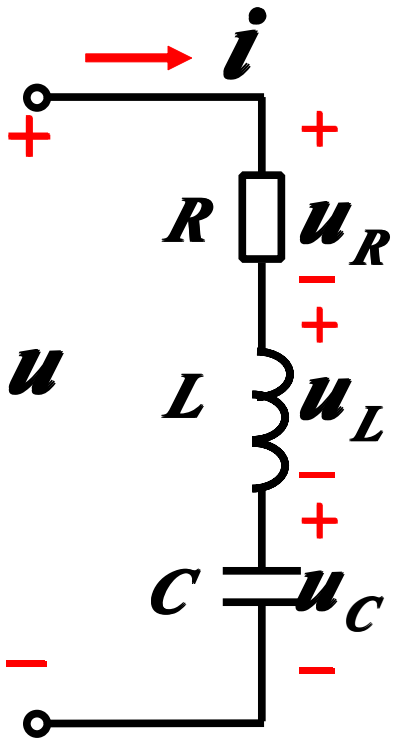
L C u i

L C u i

(

)

4.7.1.



1.

$$\begin{matrix} U & I \end{matrix}$$

$$\varphi = \arctan\frac{X_L - X_C}{R} = 0$$

$$X_L = X_C$$

$$\omega_0 L = \frac{1}{\omega_0 C}$$

2.

$$\omega_0 L = \frac{1}{\omega_0 C}$$

2.

$$2\pi f_0 L = \frac{1}{2\pi f_0 C}$$

$$_0 = \frac{1}{\sqrt{LC}}$$

$$f_0 = \frac{1}{2\sqrt{LC}}$$

f L C $f_0=f$

LC f $f=f_0$

3.

(1) $$|Z| = \sqrt{R^2 + (X_L - X_C)^2} = R$$

(2)

$$I = I_0 = \frac{U}{R}$$

(3) U I $\varphi = \arctan\dfrac{X_L - X_C}{R} = 0$

Q_L Q_C

(4)

$U_R = I_0 R = U$

$U_L = -U_C$ **180**

$$U_L = I_0 X_L = U_C = I_0 X_C$$

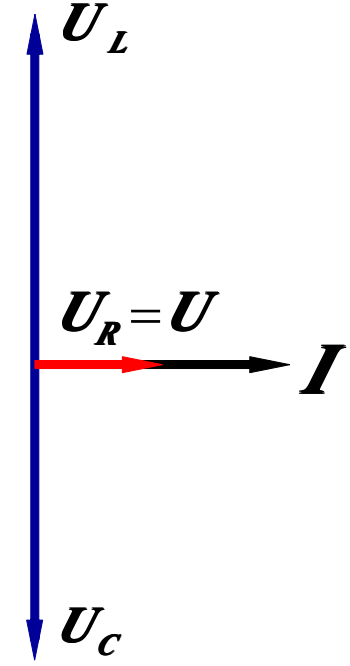
$$U_L = U_C = QU$$

：U_L U_C

Q

$$U_L = I_0 X_L = \frac{{}_0 L}{R} U = QU$$

$$U_C = I_0 X_C = \frac{1}{{}_0 CR} U = QU$$



Q=100, U=220V,

$$U_L = U_C = QU = 22000\text{V}$$

4.

(1)

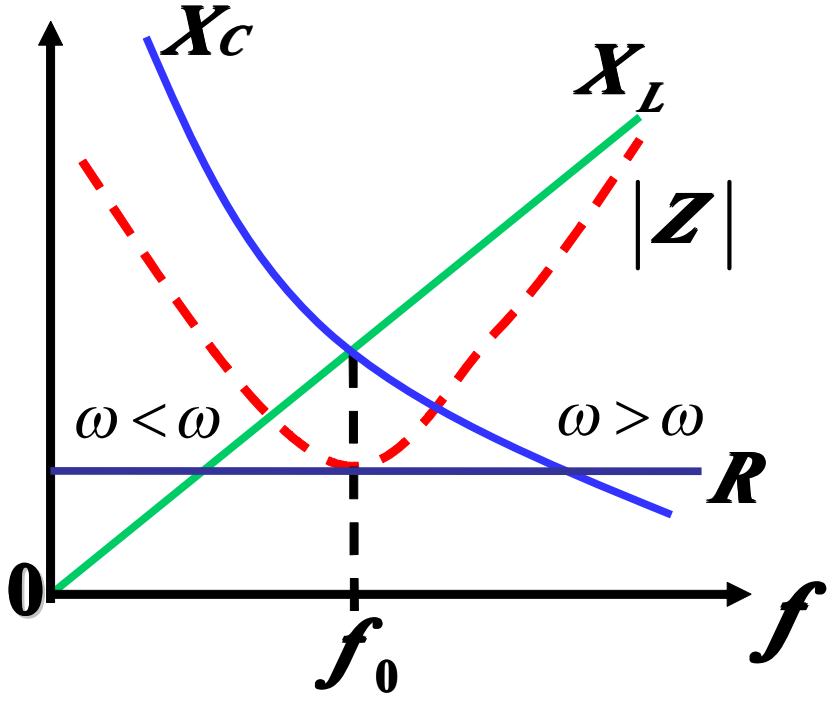
$$X_L = \omega L$$

$$X_C = \frac{1}{\omega C}$$

$$Z = R + j(X_L - X_C)$$

$$|Z| = \sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}$$

$$\begin{cases} < 0 & |Z| \\ = 0 & |Z| = R \\ > 0 & |Z| \end{cases}$$



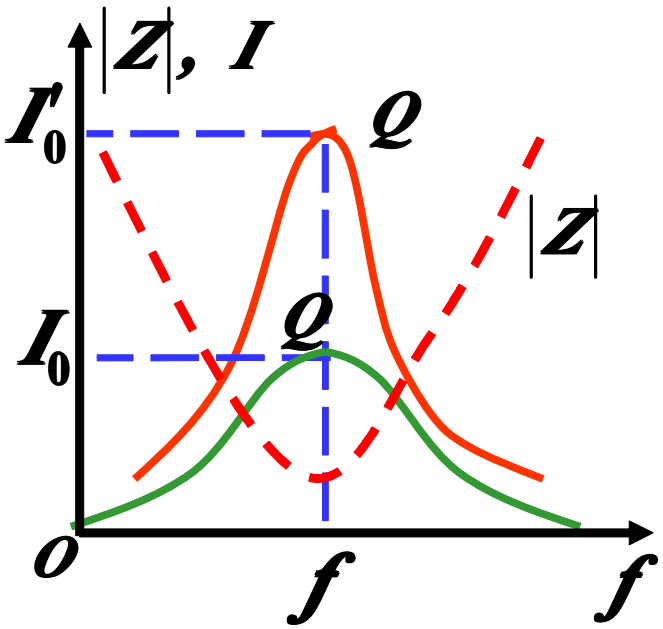
(2)

$$I(\quad)=\frac{U}{|Z|}=\frac{\quad}{\sqrt{R^2+(\quad L-1/\quad C)^2}}$$

$$I_0=\frac{U}{R}$$

$R\downarrow$

$$\begin{cases} I_0 \\ Q=\dfrac{{}_0L}{R} \end{cases}$$



Q

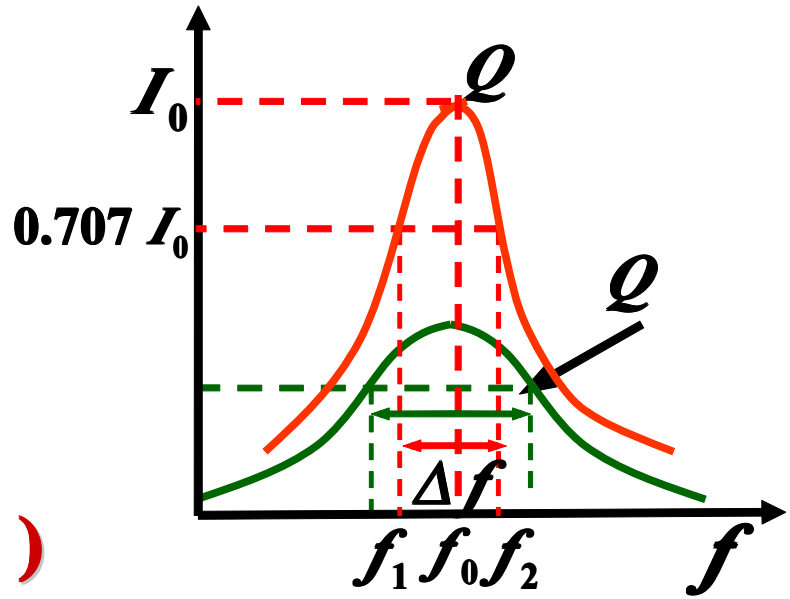
$0.707I_0$

$f = f_2 \quad f_1$

f_0

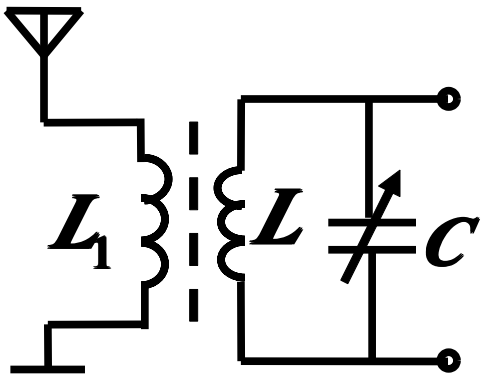
f_1

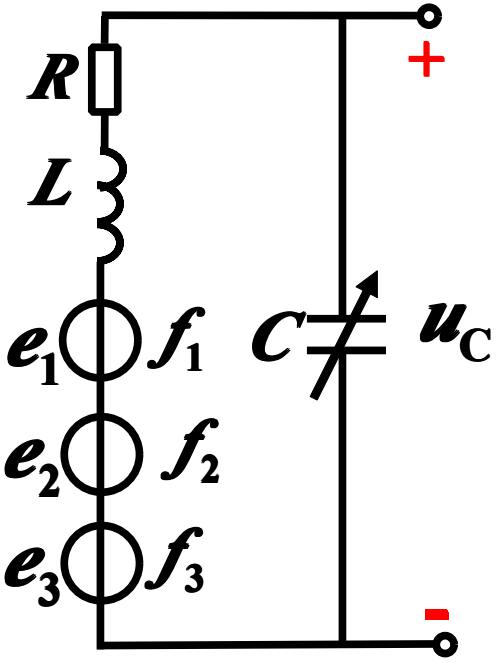
f_2

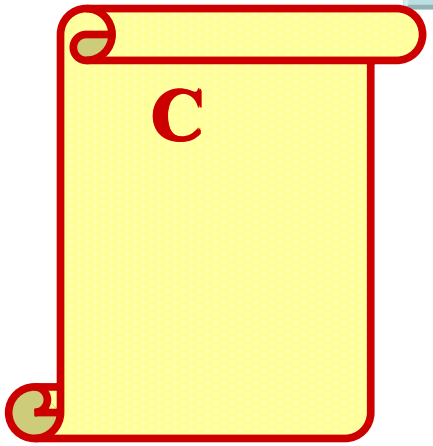


(Q)

5.







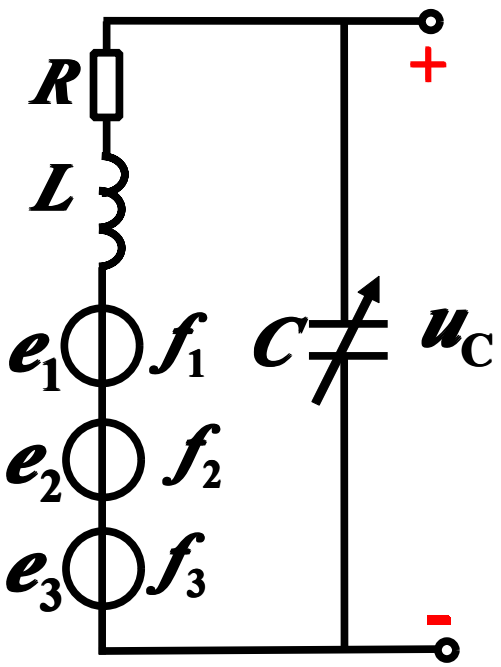
$$I_0 = I_{max} \Rightarrow$$

$$U_C = QU$$

$$\begin{cases} L_1 \\ LC \end{cases}$$

e_1 e_2 e_3 3 ( )

1 (1) e_1 C



$L = 0.3\text{mH}$ $R = 16\Omega$

$f_1 = 640\text{kHz}$

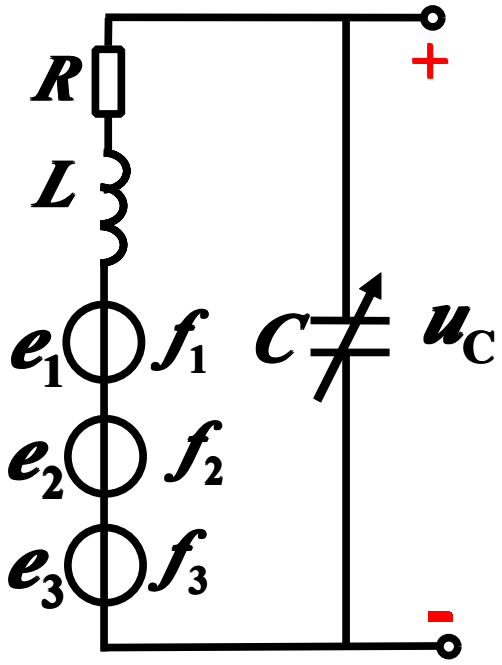
$$f_0 = f_1 = \frac{1}{2\pi\sqrt{LC}}$$

$$C = \frac{1}{(2\ \pi f_0)^2 L}$$

$$C = \frac{1}{(2\pi\ \ 640\ \ 10^3)^2\ \ 0.3\ \ 10^{-3}} = 204\text{pF}$$

C 204 pF e_1

1 (2) e_1



C

$E_1 = 2\ \mu V$

$f_1 = 640 kHz$

$I = E_1 / 16 = 0.13 \mu A$

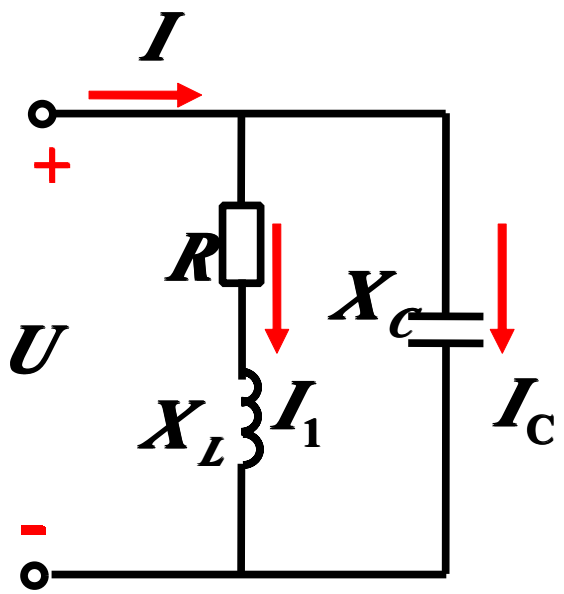
78

$X_L = X_C = \omega L = 2\pi f_1 L = 1200\Omega$

$U_{C1} = IX_C = 156 \mu V$ $\quad Q = \dfrac{U_{C1}}{E_1} = \dfrac{156}{2} = 78$

4.7.2

1.



$$Z=\frac{\dfrac{1}{\mathrm{j}\omega C}(R+\mathrm{j}\omega L)}{\dfrac{1}{\mathrm{j}\omega C}+(R+\mathrm{j}\omega L)}$$

$$=\frac{R+\mathrm{j}\omega L}{1+\mathrm{j}\omega RC-\omega^2 LC}$$

$$\omega_0 L \gg R$$

$$Z \quad \frac{\mathrm{j}\omega L}{1-\omega^2 LC+\mathrm{j}\omega RC}=\frac{1}{RC/L+\mathrm{j}\,\omega C-1/\omega L}$$

1.

$$Z \quad \frac{j\omega L}{1-\omega^2 LC+j\,\omega RC}=\frac{1}{RC/L+j\,(\omega C-1/\omega L}$$

$$\omega_0 C-\frac{1}{\omega_0 L}\approx 0$$

2.

$$\omega_0 \approx \frac{1}{\sqrt{LC}}$$

$$f=f_0 \quad \frac{1}{2\sqrt{LC}}$$

3.

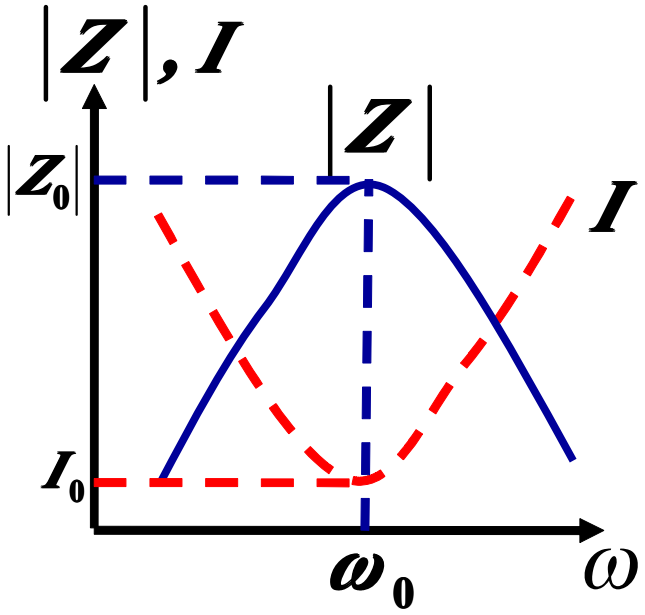
(1)

$$|Z_0|=\frac{L}{RC}$$

($_0L>>R$)

(2)

$$I = I_{L/RC} = \frac{U}{|Z|}$$



$$U = I_S |Z_0|$$

(3)

$$\omega_0 L >> R$$

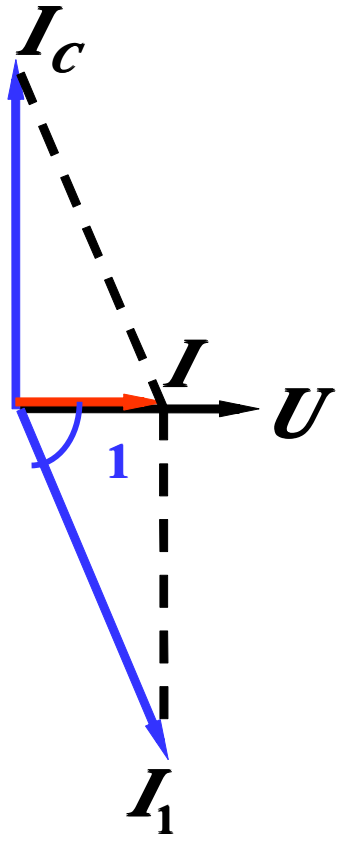
$$I_1 = \frac{U}{\sqrt{R^2 + (2\pi f_0 L)^2}} \approx \frac{U}{2\pi f_0 L}$$

$$I_C = \frac{U}{\frac{1}{2\pi f_0 C}} = U \cdot 2\pi f_0 C$$

$$\frac{I_C}{I_0} = \frac{U(2 f_0 C)}{U/|Z_0|} = \frac{U(2 f_0 C)}{U/\frac{L}{RC}}$$

$$= \frac{2 f_0 L}{R} = \frac{{}_0 L}{R} = Q$$

$$\therefore I_1 \quad I_C = QI_0$$

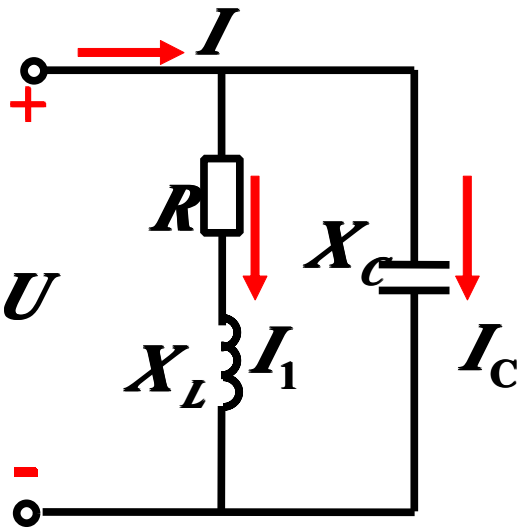


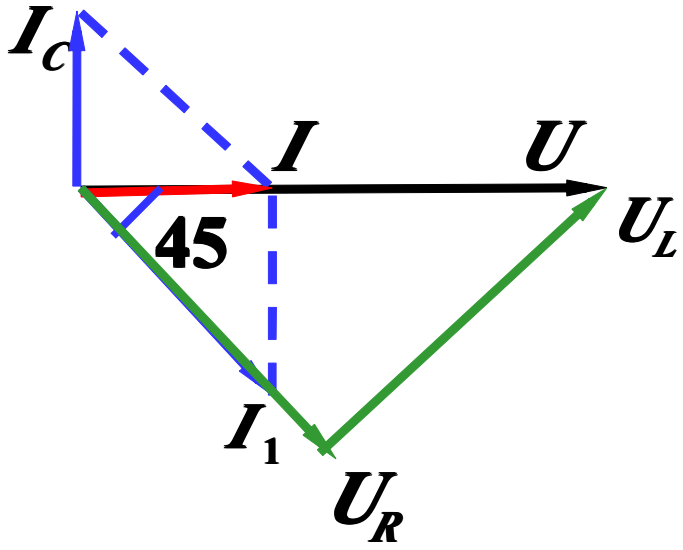
Q

2 R=10 Ω I_C=1A $_1$ =45

U, I_1 f=50Hz

I I_1 U L C





:

$I_1 \sin$ $_1 = I_C$ $I_C = 1\text{A}$