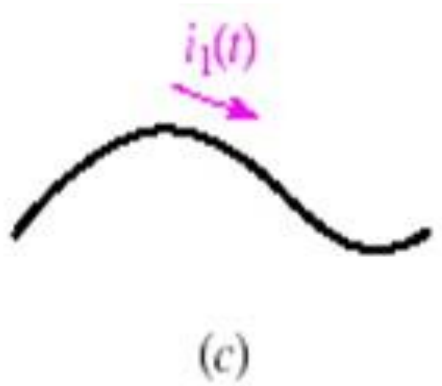
《电路与电子技术》课程
学习反馈调查

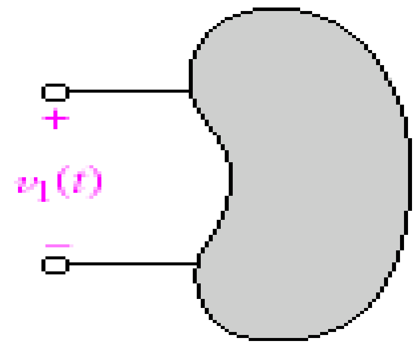
请扫二维码，感谢同学们配合！

Chapter 1-9 REVIEW

符号和数值缺一不可！

$$i = \frac{dq}{dt}$$



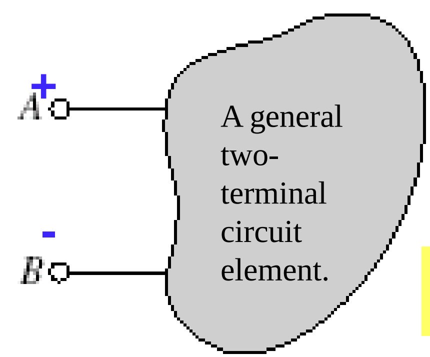


(c)

电压是衡量单位电荷在静电场中由于电势不同所产生的能量差的物理量。其大小等于单位正电荷因受电场力作用从A点移动到B点所做的功。

关联参考方向

passive sign convention

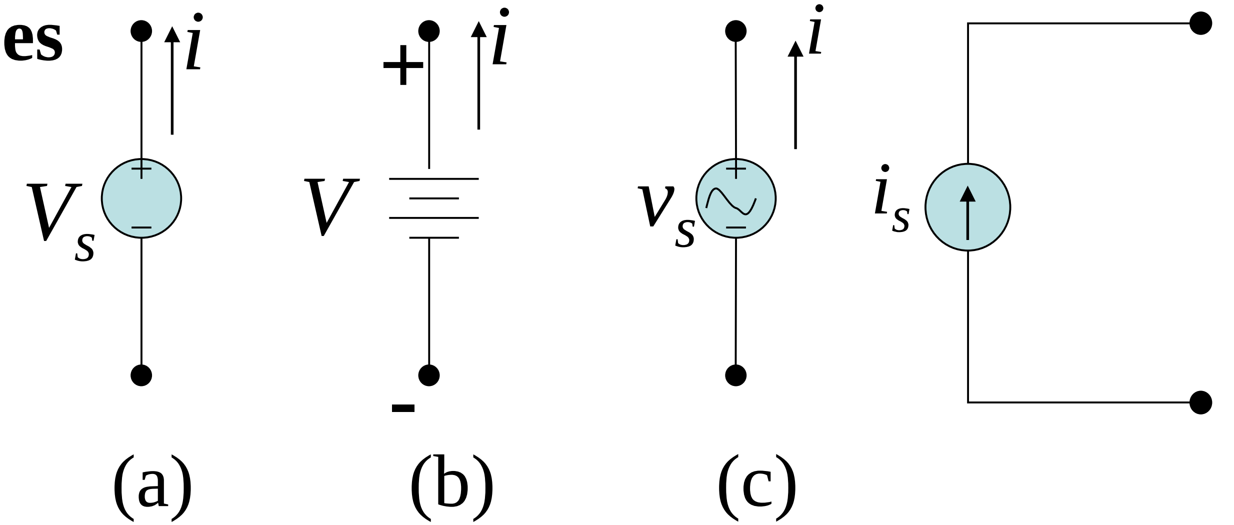


$$p = vi$$

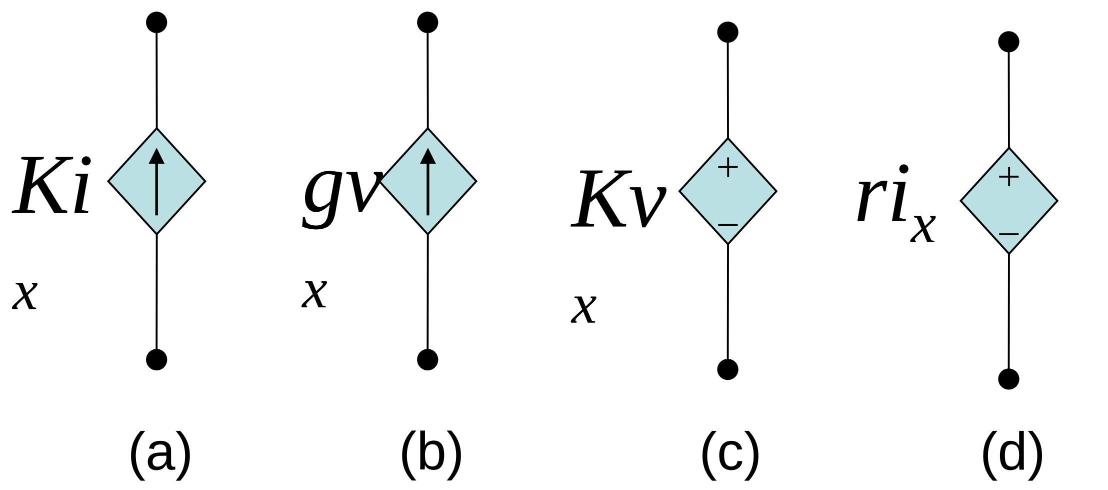
The reference current is defined consistent with passive sign convention（与关联参考方向一致）, which assumes that the element is **absorbing power**.

Voltage and Current Sources

Independent Sources



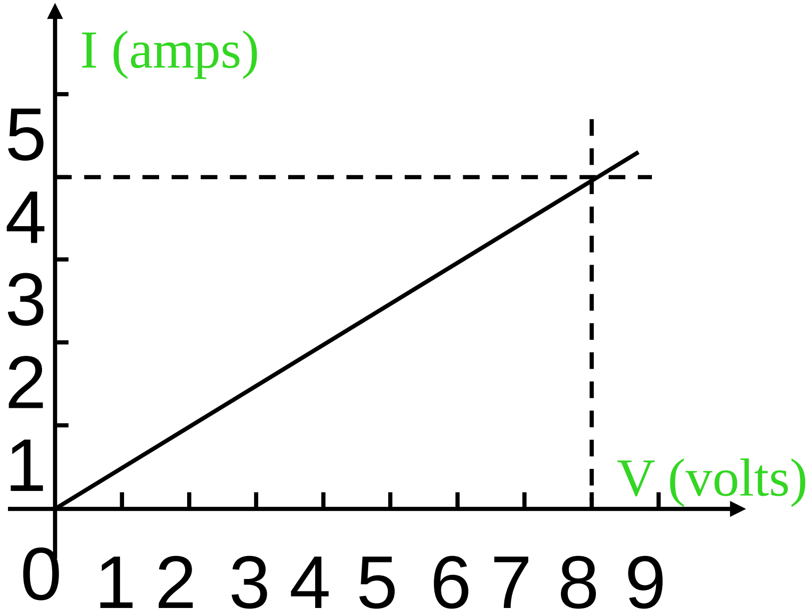
Dependent Sources

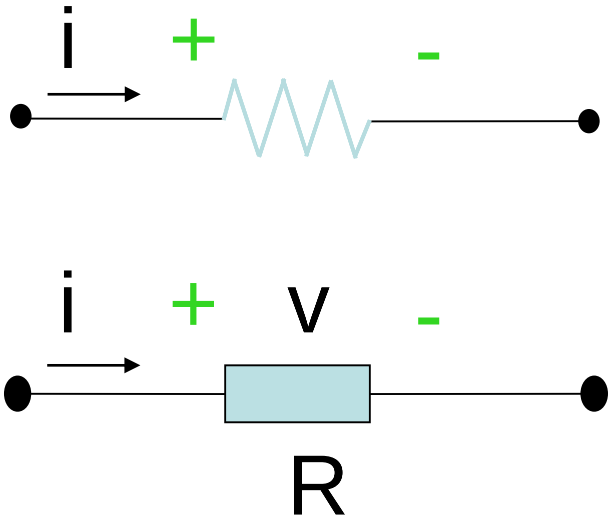


Ohm's Law

$$v = i R$$

$$p = vi = i^2 R = v^2 / R$$





Circit symbol for the resistor

Chapter 2 Voltage and Current Laws

- **Ability to employ Kirchhoff's current law (KCL)**

$$\sum_{n=1}^{N} i_n = 0 \qquad i_1 + i_2 + i_3 + \cdots + i_N = 0$$

the N current arrows are either <u>all directed toward</u> the node in question, or are <u>all directed away from</u> it.

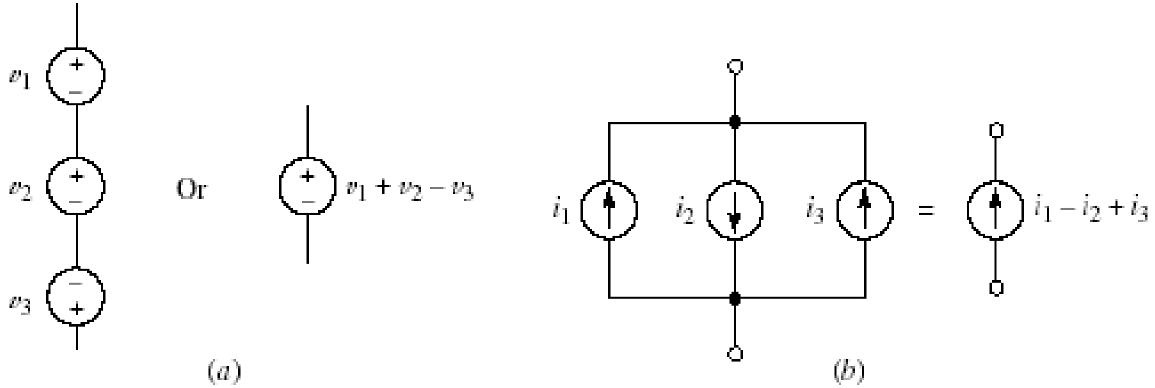
- **Ability to employ Kirchhoff's voltage law (KVL)**

$$\sum_{n=1}^{N} v_n = 0 \qquad v_1 + v_2 + v_3 + \cdots + v_N = 0$$

the algebraic sum of the voltages across the individual elements around any closed path must be zero.

Chapter 2 Voltage and Current Laws

- Simplify series and parallel connected sources. (电源的串并联等效)



理解端口等效的概念

- Reduce series and parallel resistor combinations（电阻的串并联等效）

$$R_{eq} = R_1 + R_2 + R_3 + \cdots + R_N$$

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \cdots + \frac{1}{R_N}$$

- Intuitive understanding of voltage and current division

（理解对分压/分流的概念）

Chapter 3 Basic Nodal and Mesh Analysis

◆ Implementation of nodal analysis(结点法)

- Make a neat, simple circuit diagram. (梳理电路图，标注元件参数)
- Assuming that contains only current sources, **choose one of these nodes as a reference node. Then label the node voltages v_1, v_2, …, v_{N-1}.**（选择参考结点，标注其它结点电压【此处电压实际上是相对参考点电压差】）
- **If the circuit contains only current sources, apply KCL at each nonreference node**. （如果电路中只有电流源，对每个非参考结点列写KCL方程）Equate the total current, leaving each node through all resistors to the total source current entering that node, and order the terms from v_1 to v_N. For each dependent current source, relate the source current and the controlling quantity to the variable v_1, v_2, …, v_{N-1}. （**对于受控电流源，用电压量表示电流量和控制量**）
- **If the circuit contains voltage sources, form a supernode about each one by enclosing the source and its two terminals within a broken-line enclosure**. （如果电路中有电压源，建立超节点，使电压源包含在超节点内）. **Apply KCL at each nonreference node and each supernode that does not contain the reference node. Relate each source voltage to the variable v_1, v_2, …, v_{N-1}.**（对每一个超节点和普通非参考节点列写KCL方程，并列写增补方程【用非参考节点表示电压源】）

EXAMPLE 3.4

Determine the node-to-reference voltages in the circuit of Fig. 3.7.

- We select the central node as the reference as shown, and assign v_1 to v_4 in a clockwise direction starting from the left node.(四个未知量)

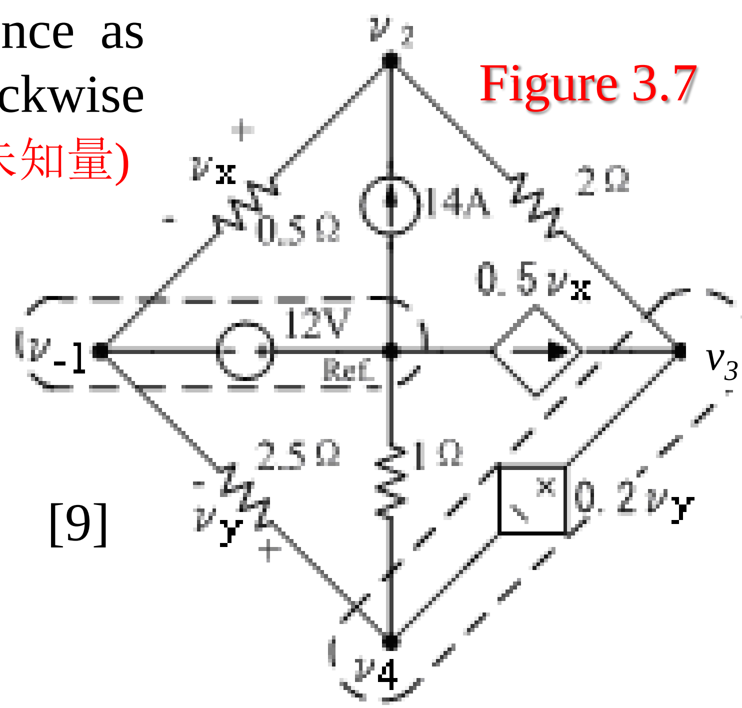


Figure 3.7

After establishing a super node each voltage source, we need to write 2 KCL equations.

At node 2:

$$\frac{v_2 - v_1}{0.5} + \frac{v_2 - v_3}{2} = 14 \qquad [9]$$

At the 3-4 super nodes:

受控电流源电流直接带入方程

$$\boxed{0.5v_x} = \frac{v_3 - v_2}{2} + \frac{v_4}{1} + \frac{v_4 - v_1}{2.5} \qquad [10]$$

No extra equation need be written for the super node containing node 1 and the independent voltage source, since it is clear that v_1 = -12 V.

We next relate the source voltages to the node voltages:

受控电压源电压

$$v_3 - v_4 = \boxed{0.2v_y} \qquad [11]$$

and

受控电压源控制量

$$\boxed{v_y} = v_4 - v_1 \qquad [12]$$

消除 $\mathbf{v_y}$

Finally, we express the dependent current source in terms of the assigned variables:

$$\boxed{0.5v_x} = 0.5(v_2 - v_1) \qquad [13]$$

消除 $\mathbf{v_x}$

受控电流源电流

We can now eliminate v_x and v_y to obtain a set of four equations in the four node voltage:

$$
\begin{array}{rcrcrcrcr}
-2v_1 & + & 2.5v_2 & - & 0.5v_3 & & & = & 14 \\
0.1v_1 & - & v_2 & + & 0.5v_3 & + & 1.4v_4 & = & 0 \\
v_1 & & & & & & & = & -12 \\
0.2v_1 & & & + & v_3 & - & 1.2v_4 & = & 0
\end{array}
$$

Solving,

$$v_1 = -12\text{V}, v_2 = -4\text{V}, v_3 = 0\text{V}, \text{and } v_4 = -2\text{V}.$$

Implementation of mesh analysis(网孔法)

- Make certain that the network is a planar network. Make a neat, simple circuit diagram. Indicate all element and source values. Assuming that the circuit has M meshes, assign a clockwise mesh current in each mesh: i_1, i_2, …, i_M.

- If the circuit contains **only voltage sources**, apply KVL around each mesh. If a circuit has only independent voltage sources, equate the clockwise sum of all resistor voltages to the counterclockwise sum of all the source voltages, and order the terms from i_1 to i_M. <u>For each dependent voltage source present, relate the source voltage and the controlling quantity to the variables i_1, i_2, …, i_M</u>.

- If the circuit **contains current sources**, create a supermesh for each one that is common to two meshes by applying KVL around the larger loop formed by branches not common to the meshes. KVL need not be applied to a mesh containing a current source that lies on the perimeter of the entire circuit. The assigned mesh currents should not be changed. Relate each source current to the variables i_1, i_2, …, i_M.

Practice 3.7

Determine i_1 in the circuit in Fig. 3.17.

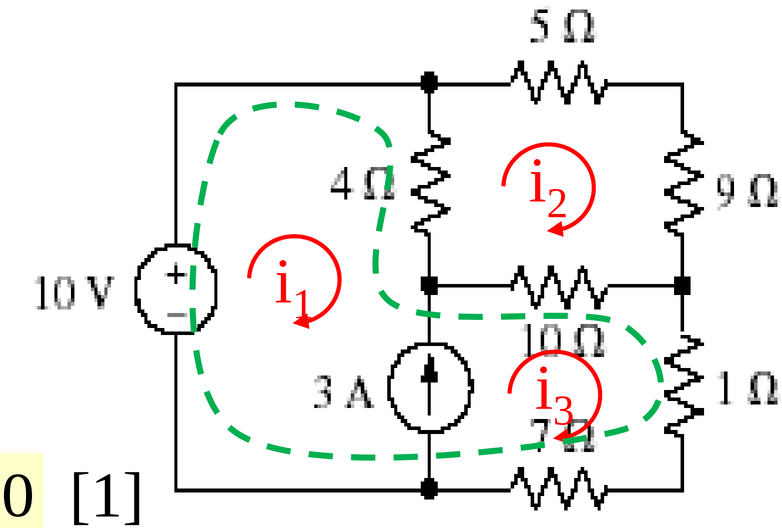


Fig. 3.17

Create a super mesh whose interior is that of meshes 1 and 3.

Apply KVL to this super mesh,

$$-10+4(i_1-i_2)+10(i_3-i_2)+(1+7)i_3=0 \quad [1]$$

Apply KVL to mesh 2,

$$4(i_2-i_1)+(5+9)i_2+10(i_2-i_3)=0 \quad [2]$$

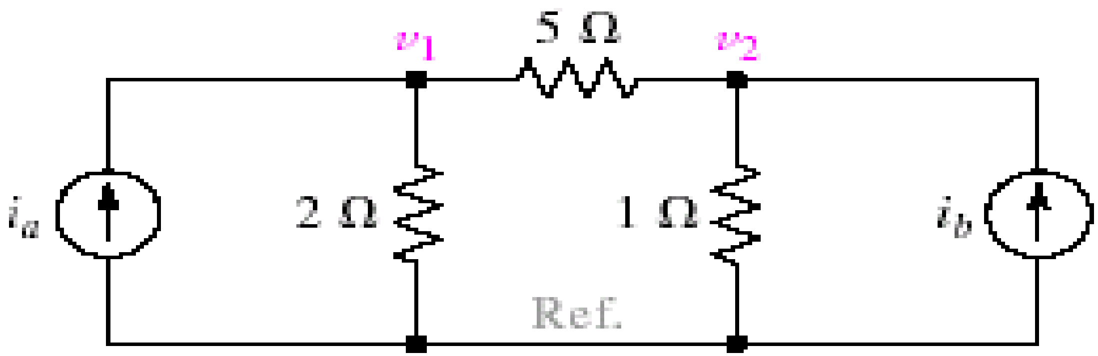
The source current is related to the assumed mesh currents, $i_1-i_3=-3$ [3]

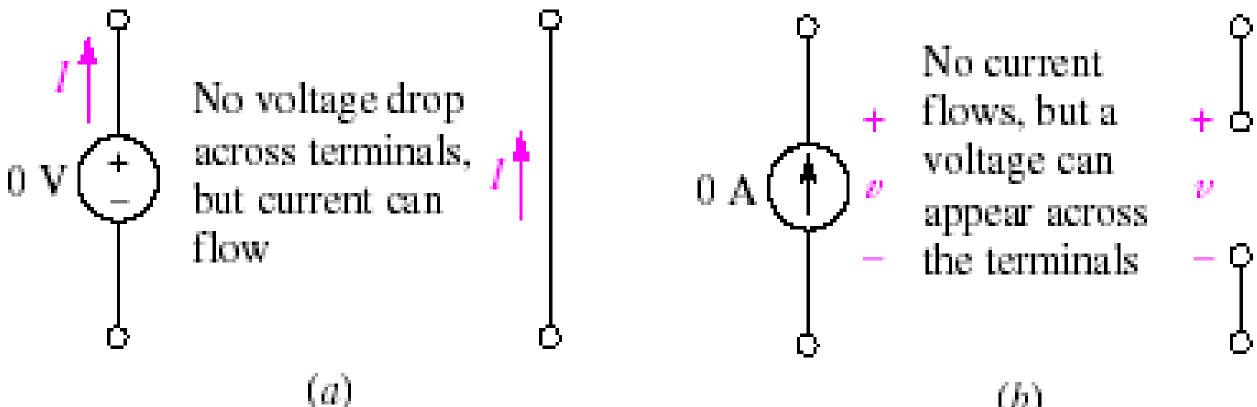
Solving Eqs. [1] - [3],

$$\mathrm{i}_1=-1.93\mathrm{A},$$
$$\mathrm{i}_2=0.11\mathrm{A},$$
$$\mathrm{i}_3=1.07\mathrm{A}.$$

Chapter 4 Useful Circuit Analysis Techniques

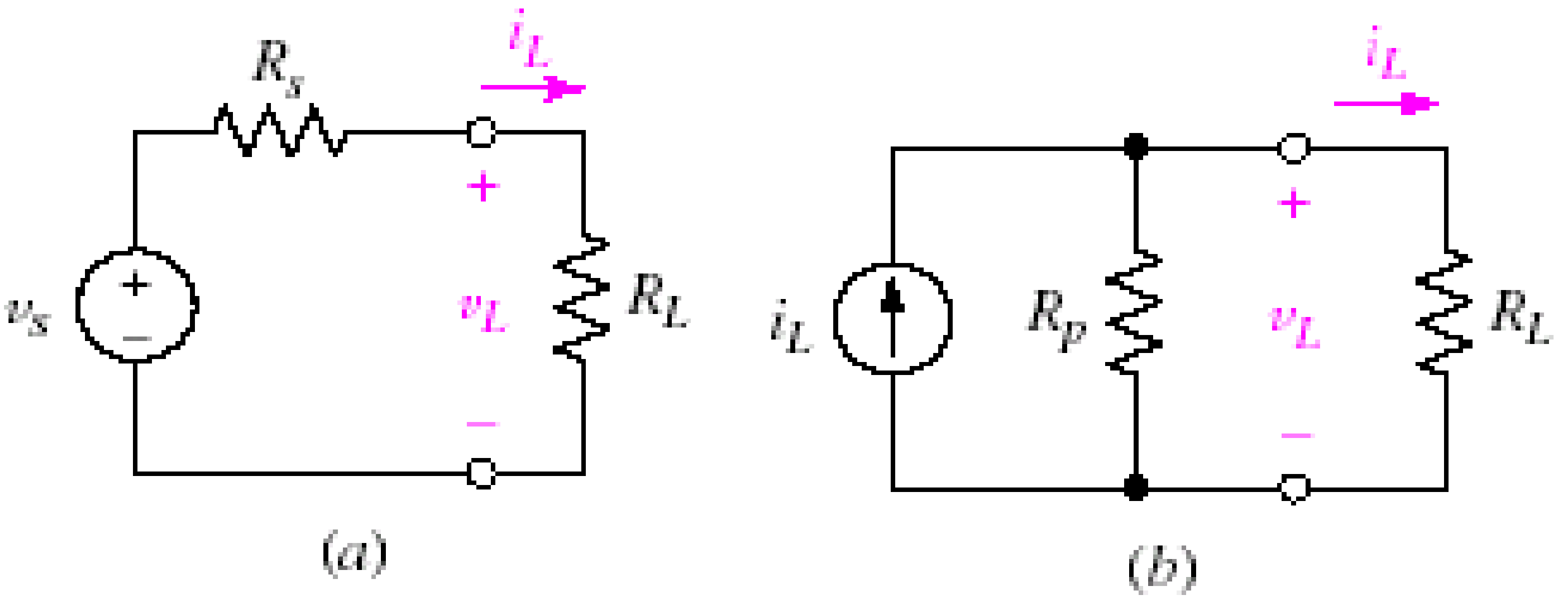
- Use superposition principle 叠加原理 to analyzed circuit





Remove power principle除源原则

- Use source transformations 电源变换 to reduce the complexity of a circuit.

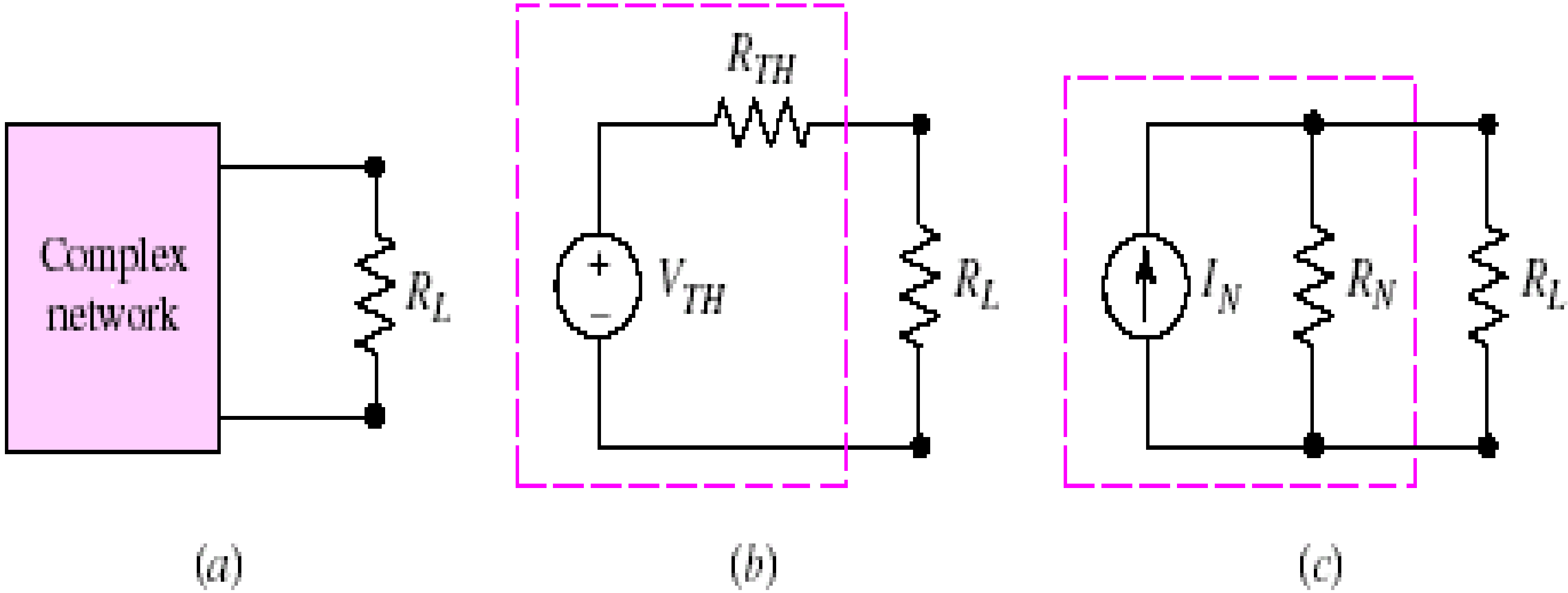


$$R_s = R_p \qquad v_s = R_p i_s = R_s i_s$$

A few parting comments:

- When performing a source transformation, remember that the **head of the current source arrow** corresponds to the “+” **terminal of the voltage source**.[注意变换前后电源方向]
- If the voltage or current associated with a particular resistor is used in a controlling variable for a dependent source, or is the desired response of a circuit, the resistor should not be included in source transformations. [受控源控制量和待求量不要被变没了！]
- In using source transformations, one common goal is to end up with either all current sources or all voltage sources in the final circuit whenever possible. [为方便计算，可全部变为同一种电源]
- Repeated source transformations can be used to simplify a circuit by allowing resistors and sources to be combined.[用电源等效变换化简电路过程中，可结合电阻、电源串并联组合的方法]

- Determine the Thévenin and Norton equivalent Circuits 戴维宁和诺顿等效网络 of any network



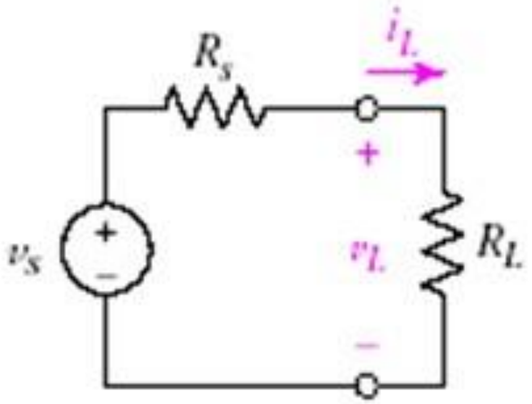
(*a*) A complex network including a load resistor R_L. (*b*) A Thévenin equivalent network connected to the load resistor R_L. (*c*) A Norton equivalent network connected to the load resistor R_L.

$$v_{oc} = R_{TH} i_{sc}$$

P80-82

- Compute the load resistance that will result in maximum power transfer.计算产生最大功率传输的负载电阻

$$p_L = i_L^2 R_L = \frac{v_s^2 R_L}{\left(R_s + R_L\right)^2}$$



maximum

$$\boxed{R_s = R_L}$$

P82-83

Chapter 5 Capacitors and Inductors

$$i = C\frac{dv}{dt}$$

$$v = L\frac{di}{dt}$$

where *v* and *i* satisfy the conventions for a passive element

Inductors in Series

$$L_{eq} = \left(L_1 + L_2 + \cdots + L_N\right)$$

Capacitors in Series

$$C_{eq} = \frac{C_1 C_2}{C_1 + C_2}$$

Inductors in Parallel

$$L_{eq} = \frac{L_1 L_2}{L_1 + L_2}$$

Capacitors in Parallel

$$C_{eq} = C_1 + C_2 + \cdots + C_N$$

Energy Storage

$$p = vi = Cv\frac{dv}{dt}$$

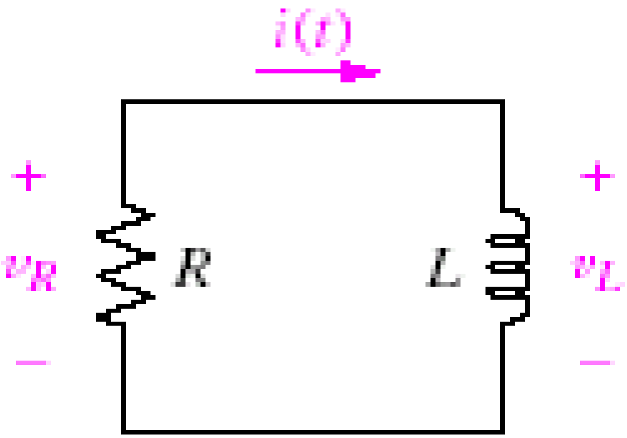
$$w_C = \frac{1}{2}Cv^2$$

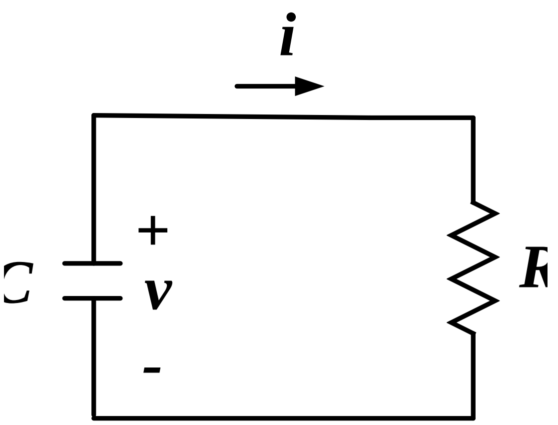
$$p = vi = Li\frac{di}{dt}$$

$$w_L(t) = \frac{1}{2}Li^2$$

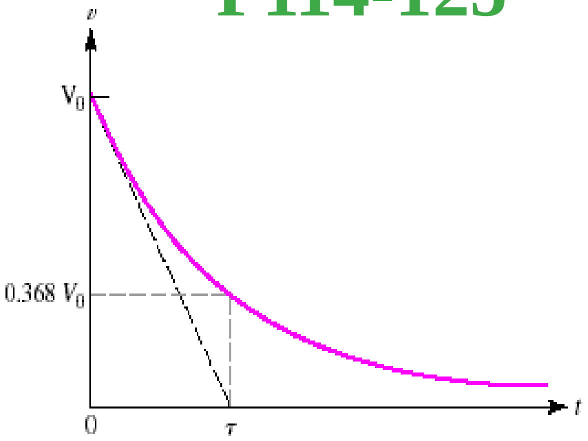
Chapter 6 Basic RL and RC Circuits

- A circuit reduced to a single equivalent inductance L and a single equivalent resistance R will have a natural response given by $i(t) = I_0 e^{-t/\tau}$, where $\tau = L/R$ is the circuit time constant.
- A circuit reduced to a single equivalent capacitance C and a single equivalent resistance R will have a natural response given by $v(t) = V_0 e^{-t/\tau}$, where $\tau = RC$ is the circuit time constant.





P114-125



- Calculation of the total response of *RL* and *RC* circuits

complete response =forced response +natural response

The forced response is thus obtained by inspection of the final circuit.
用分析电路的方法得到强迫相应（稳态解）

The form of the natural response (also referred to as the transient response) depends only on the component values and the way they are wired together.
自由响应与原件性质参数和连接关系有关

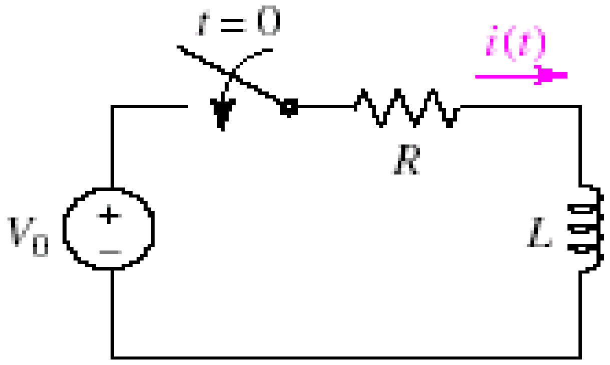
$$i = i_n + i_f$$

$$i_n = Ae^{-Rt/L}$$

$$i_f = V_0 / R$$

$$i = Ae^{-Rt/L} + V_0 / R$$

$$0 = A + V_0 / R$$



$$i = (1 - e^{-Rt/L}) V_0 / R$$

P132-135

$$f(t) = f(\infty) + Ae^{-t/\tau} \qquad f(0^+) = f(\infty) + A$$

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

total response = final value + (initial value – final value) $e^{-t/\tau}$

Chapter 7 Sinusoidal Steady-State Analysis

- If two sine waves (or two cosine waves) both have positive magnitudes and the same frequency, it is possible to determine which waveform is **leading** and which is **lagging** by comparing their phase angles.
  判断两个正弦信号的相位关系。

  $$v(t) = V_m \sin(\omega t + \theta)$$

- The forced response of a linear circuit to a sinusoidal voltage or current source can always be written as a single sinusoid having the same frequency as the sinusoidal source.
  线性电路中正弦激励的稳态响应（强迫响应）是同频率的正弦信号。

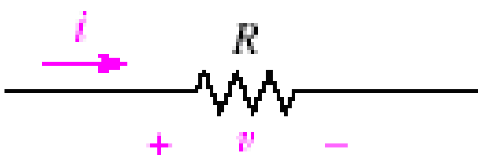
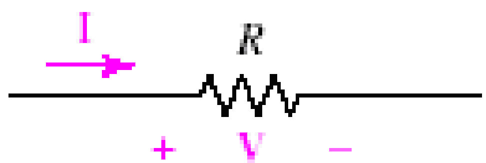
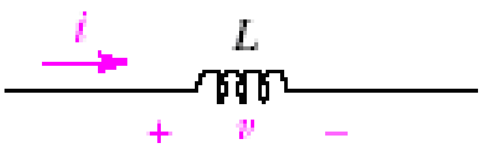
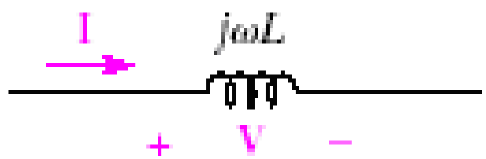
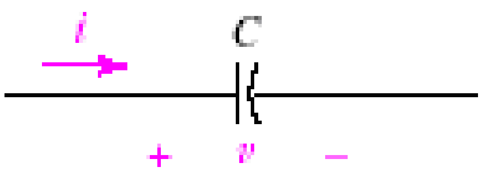
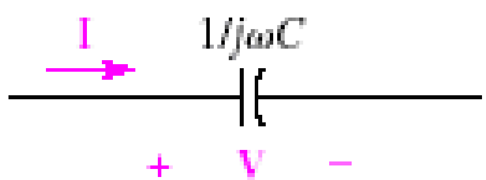
- A phasor transform may be performed on any sinusoidal function. A phasor has both a magnitude and a phase angle; the frequency is understood to be that of the sinusoidal source driving the circuit.
  向量法在正弦信号中的应用。

$$i(t) = I_m \cos(\omega t + \phi) \longrightarrow \dot{I} = I_m \angle \phi$$

Phasor Diagrams 相量图法

- When transforming a time-domain circuit into the corresponding frequency-domain circuit, resistors, capacitors, and inductors are replaced by impedances (or, occasionally by admittances).
  用向量法将时域电路转为频域电路时，电子、电容、电感都要转换为阻抗（或导纳）。

- The impedance of a resistor is simply its resistance.
- The impedance of a capacitor is $1/j\omega C$.
- The impedance of a inductor is $j\ \omega\ L$.

Time domain		Frequency domain	
	$v = Ri$	$\mathbf{V} = R\mathbf{I}$	
	$v = L\dfrac{di}{dt}$	$\mathbf{V} = j\omega L\mathbf{I}$	
	$v = \dfrac{1}{C}\int i\,dt$	$\mathbf{V} = \dfrac{1}{j\omega C}\mathbf{I}$	

- Impedance combine both in series and in parallel combinations in the same manner as resistors.

  阻抗(导纳)的串并联计算

  P162-166 7.7 Impedance

  P166-167 7.8 Admittance

- All analysis techniques previously used on resistive circuits apply to circuits with capacitors and/or inductors once all elements are replaced by their frequency-domain equivalents.

  频域电路（用向量法描述的电路）计算方法

  P167-169 7.9 Nodal and Mesh Analysis

Chapter 8 AC Circuit Power Analysis

- Defining the **average power 平均功率** supplied by a sinusoidal source.（P183-188）

$$v(t) = V_m \cos(\omega t + \theta)$$

$$i(t) = I_m \cos(\omega t + \phi)$$

$$p(t) = \frac{1}{2}V_m I_m \cos(\theta - \phi)(1 + \cos(2\omega t + 2\theta)) + \frac{1}{2}V_m I_m \sin(2\omega t + 2\theta)\sin(\theta - \phi)$$

$$P = \frac{1}{2}V_m I_m \cos(\theta - \phi)$$

- Average Power Absorbed by an **Ideal Resistor**

$$P_R = \frac{1}{2}V_m I_m \cos 0 = \frac{1}{2}V_m I_m$$

$$P_R = \frac{1}{2}I_m^2 R$$

$$P_R = \frac{V_m^2}{2R}$$

- Average Power Absorbed by **Purely Reactive Elements**

$$P_R = \frac{1}{2}V_m I_\mathrm{m} \cos 90° = 0$$

- Calculating the **rms** 均方根/有效值 value of a time-varying waveform.

$$I_{eff} = \sqrt{\frac{1}{T}\int_0^T i^2 dt}$$

root-mean-square

Use of RMS values to compute average power. P192-193

$$I_{eff} = I_m / \sqrt{2}$$

$$P = \frac{1}{2} I_m^2 R \Rightarrow P = I_{eff}^2 R$$

$$V_{eff} = V_m / \sqrt{2}$$

$$P = \frac{V_m^2}{2} R \Rightarrow P = \frac{V_{eff}^2}{R}$$

$$P = V_{eff} I_{eff} \cos(\theta - \phi)$$

- Apparent Power and Power Factor 视在功率和功率因数(P194)

$$v = V_m \cos(\omega t + \theta) \qquad i = I_m \cos(\omega t + \phi)$$

$$P = \frac{1}{2} V_m I_m \cos(\theta - \phi) \qquad P = V_{eff} I_{eff} \cos(\theta - \phi)$$

$$\mathrm{PF} = \frac{\text{average power}}{\text{apparent power}} = \frac{P}{V_{off} I_{off}} = 0 \sim 1$$

- Identifying the **power factor** 功率因数 of a given load, and learning means of improving it. (P195-196)

PF=0.5 → A load having an input impedance with a phase angle of either 60° or - 60° .

→ an inductive load → A lagging PF

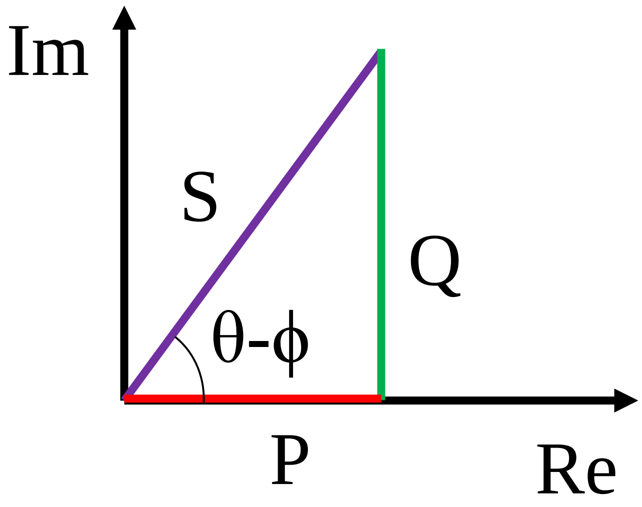
→ a capacitive load → A leading PF

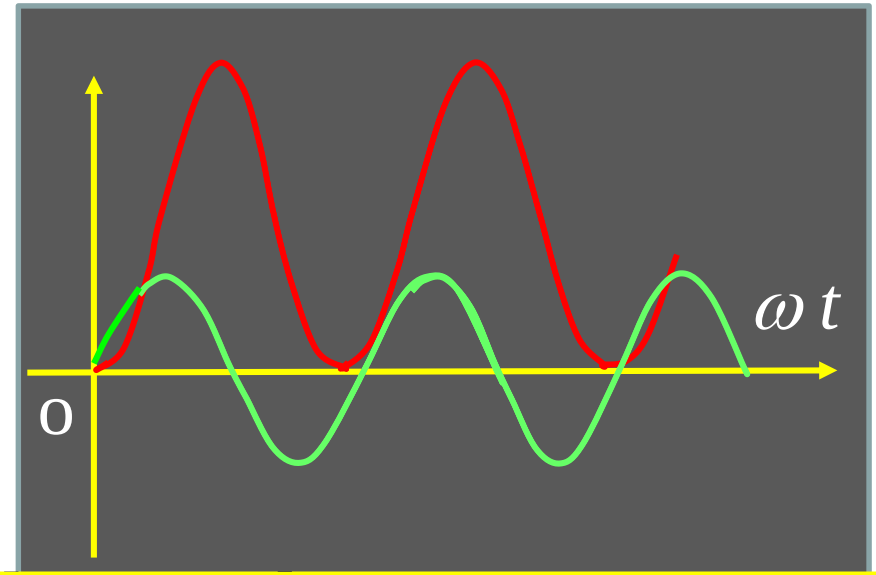
- Using complex power to identify **average** 有功功率 **and reactive power** 无功功率.

The complex power is defined as S=P+jQ, or $S=V_{eff}I^{*}_{eff}$. It is measured in units of volt-amperes (VA).

$$S = V_{eff} I_{eff}^{*} = P + jQ$$

$$Q = V_{eff} I_{eff} \sin(\theta - \phi)$$





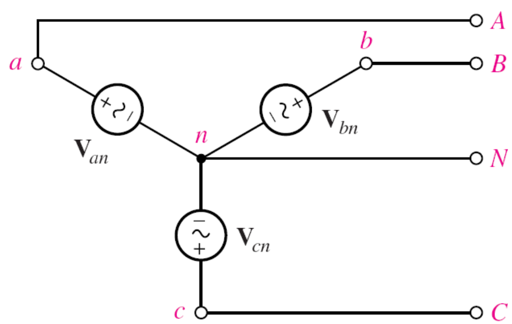
$$p(t) = \frac{1}{2} V_m I_m \cos(\theta - \phi)(1 + \cos(2\omega t + 2\theta)) + \frac{1}{2} V_m I_m \sin(2\omega t + 2\theta)\sin(\theta - \phi)$$

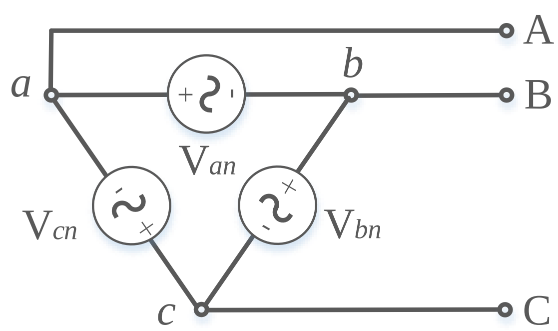
Comparison of Power Terminology P199

Term	Symbol	Unit	Description
Instantaneous power	p(t)	w	p(t)=v(t)i(t). It is the value of the Power at a specific instant in time. It is not the product of the voltage and current phasors.
Average power	P	w	In the sinusoidal steady state, P= ½ $V_m I_m \cos(\theta-\phi)$, where θ is the voltage phase angle, and ϕ is the phase angle of the current. Reactances do not contribute to P.
Effective or RMS value	V_{rms} or I_{rms}	V or A	Defined as $I_{eff} = \sqrt{\frac{1}{T}\int_0^T i^2 dt}$; if i(t) is sinusoidal, then $I_{eff} = I_m / \sqrt{2}$
Apparent power	$\lvert S \rvert$	VA	$\lvert S \rvert = V_{eff} I_{eff}$, and is the maximum value the average power can be; P=$\lvert S \rvert$ only for purely resistive loads.
Power factor	PF(or λ or cosφ)	None	Ratio of the average dissipated power to the apparent power. The PF is unity for a purely resistive load, and zero for a purely reactive load.
Reactive power	Q	VAR	A means of measuring the energy flow rate to and from reactive loads.
Complex power	S	VA	A convenient complex quantity that contains both the average power P and the reactive power Q:S=P+jQ

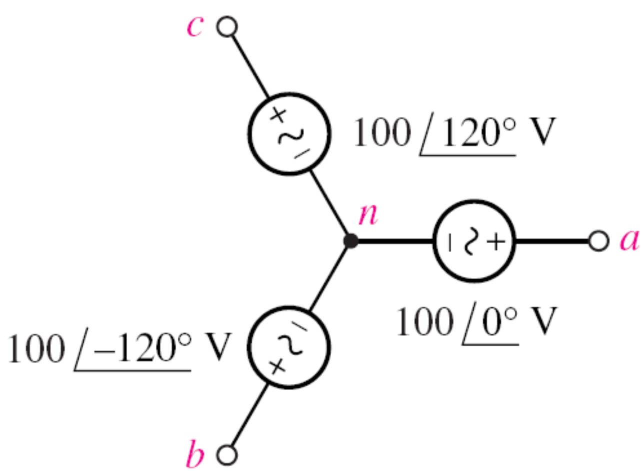
Chapter 9 Polyphase Circuits

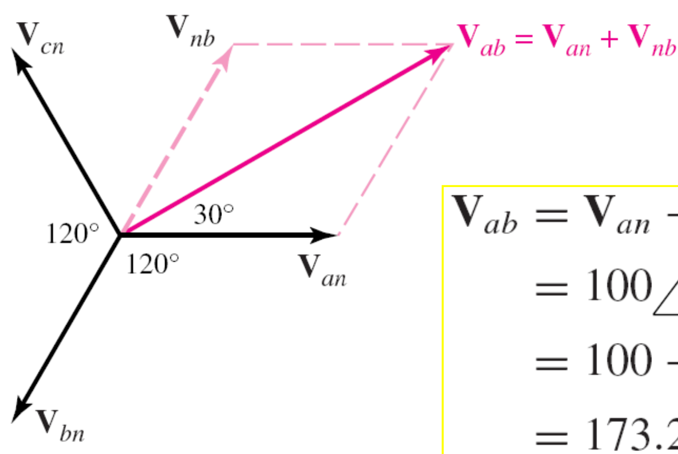
- Three phase sources can be either Y or Δ connected.
- In a balanced three-phase system, each phase voltage has the same magnitude, but is 120° out of phase with the other two.





$$\mathbf{V}_{an} = 100\angle 0^\circ \text{ V}$$
$$\mathbf{V}_{bn} = 100\angle -120^\circ \text{ V}$$
$$\mathbf{V}_{cn} = 100\angle -240^\circ \text{ V}$$





(P209-211)

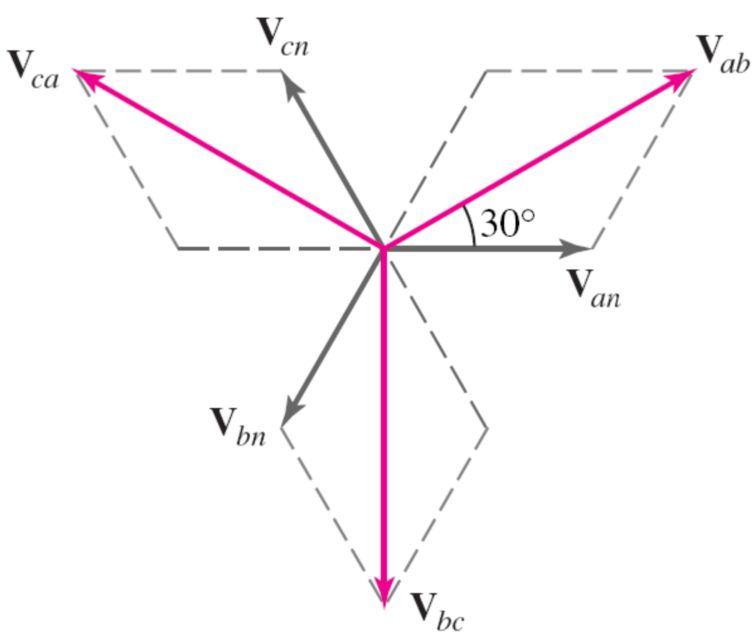
$$\begin{aligned}\mathbf{V}_{ab} &= \mathbf{V}_{an} + \mathbf{V}_{nb} = \mathbf{V}_{an} - \mathbf{V}_{bn} \\ &= 100\angle 0^\circ - 100\angle -120^\circ \text{ V} \\ &= 100 - (-50 - j86.6) \text{ V} \\ &= 173.2\angle 30^\circ \text{ V}\end{aligned}$$

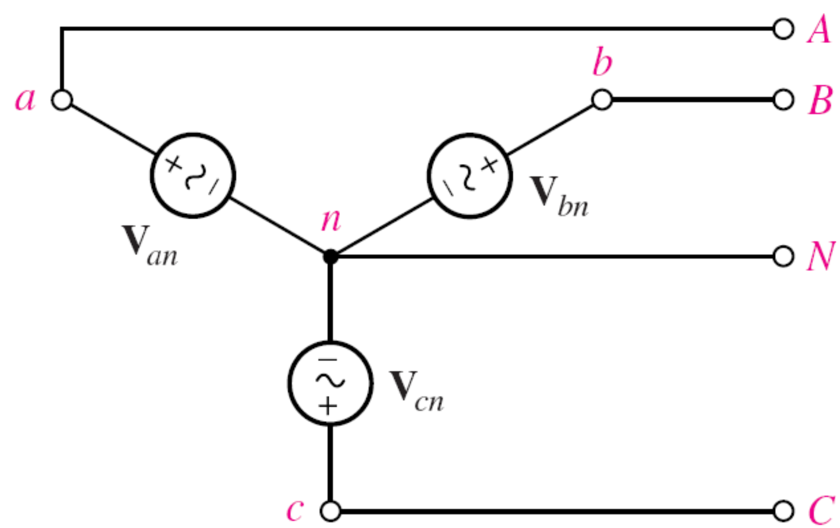
- These three voltages, each existing between one line and the neutral, are called **phase voltages相电压**. (P215)

$$\mathbf{V}_{an} = V_p\angle 0^\circ \qquad \mathbf{V}_{bn} = V_p\angle -120^\circ \qquad \mathbf{V}_{cn} = V_p\angle -240^\circ$$

- These line-to-line voltages are often simply called the **line voltages 线电压**. (P216)

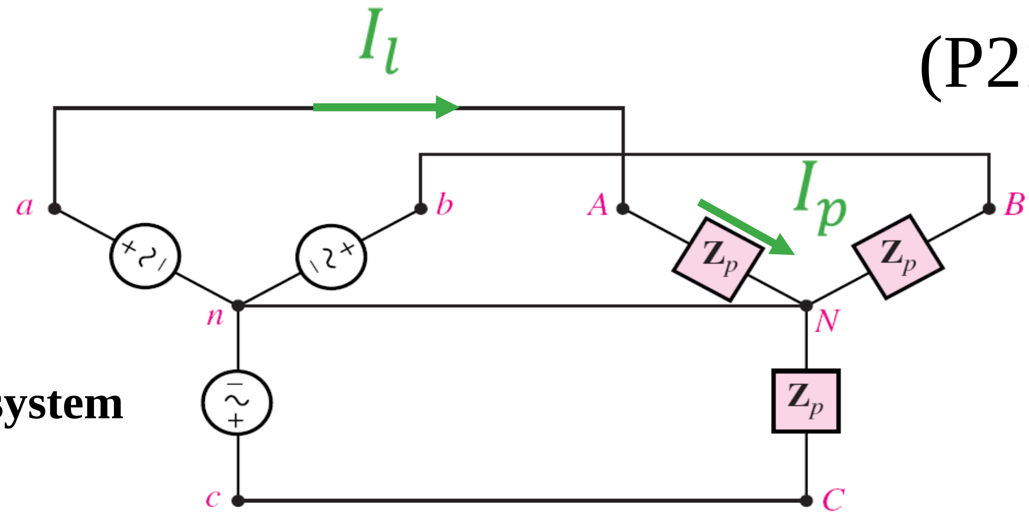
$$\mathbf{V}_{ab} = \sqrt{3}V_p\angle 30^\circ \qquad \mathbf{V}_{bc} = \sqrt{3}V_p\angle -90^\circ \qquad \mathbf{V}_{ca} = \sqrt{3}V_p\angle -210^\circ$$





- Loads in three-phase system may be either Y or Δ connected. In a Y-connected load, the line currents are equal to the phase currents.

(P217-220)



Y-Y connected system

$$\dot{V}_{AB} = \sqrt{3}\dot{V}_{AN}\angle 30°$$

$$\dot{I}_{aA} = \dot{I}_{AN} = \dot{V}_{AN} / Z_p$$

$$|\dot{V}_{AB}| = |\dot{V}_{ab}| = \dot{V}_l \qquad |V_{AN}| = V_p$$

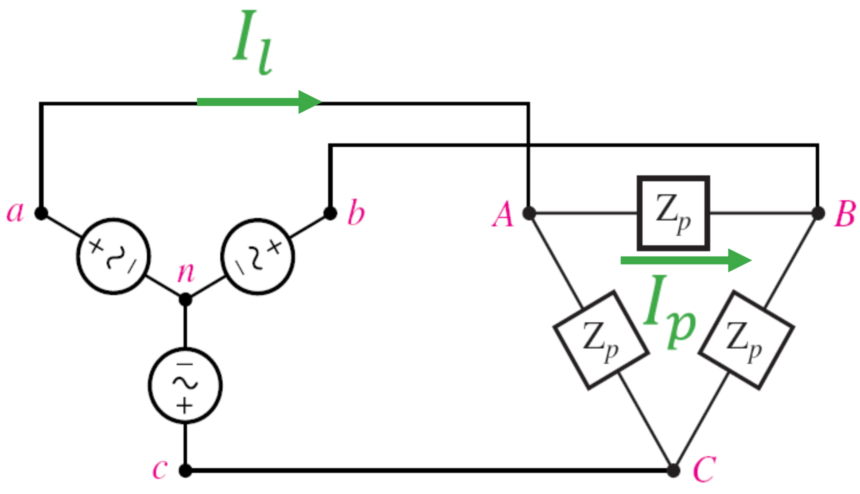
$$|\dot{I}_{aA}| = I_l \qquad |\dot{I}_{AN}| = I_p$$

$$V_l = \sqrt{3}V_p$$

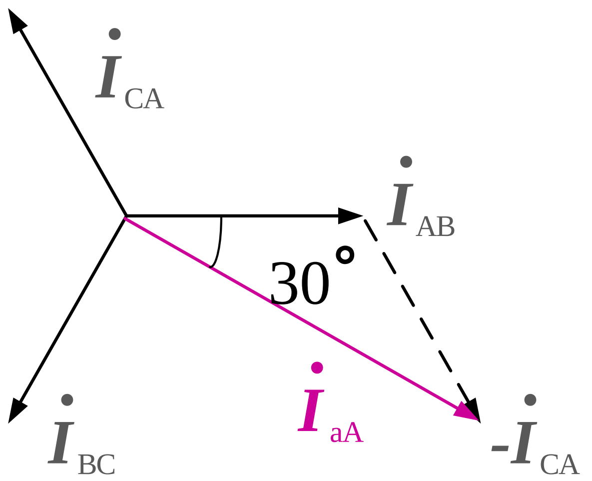
$$I_l = I_p$$

$$P_\Sigma = 3P_p = 3V_p I_p \cos\theta_{Zp} = \sqrt{3}V_l I_l \cos\theta_{Zp}$$

• In a Δ-connected load, the line voltages are equal to the phase voltages.



Y-Δ connected system



$$\dot{V}_{AB} = \dot{V}_{ab}$$

$$\dot{I}_{aA} = \dot{I}_{AB} - \dot{I}_{CA} = \sqrt{3}\dot{I}_{AB}\angle -30°$$

$$|\dot{V}_{ab}| = V_l \qquad |\dot{V}_{AB}| = V_p$$

$$\dot{I}_{AB} = \dot{V}_{AB} / Z_p$$

$$\boxed{V_l = V_p}$$

$$|\dot{I}_{aA}| = I_l \qquad |\dot{I}_{AB}| = I_p \qquad \boxed{I_l = \sqrt{3} I_p}$$

$$\boxed{P_\Sigma = 3P_p = 3V_p I_p \cos\theta_{Zp} = \sqrt{3} V_l I_l \cos\theta_{Zp}}$$