Circuits I Review

Note Title 8/31/2014

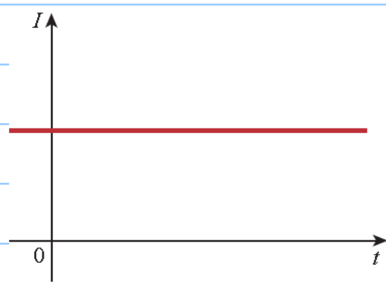
Ch 1: Basic Concepts

Charge is an electrical property of the atomic particles of which matter consists, measured in coulombs (C).

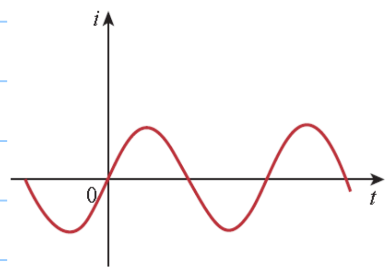
Electric current is the time rate of change of charge, measured in amperes (A).

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

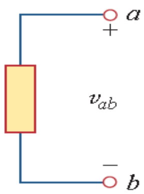
A **direct current** (dc) is a current that remains constant with time.



An **alternating current** (ac) is a current that varies sinusoidally with time.



Voltage (or **potential difference**) is the energy required to move a unit charge through an element, measured in volts (V).

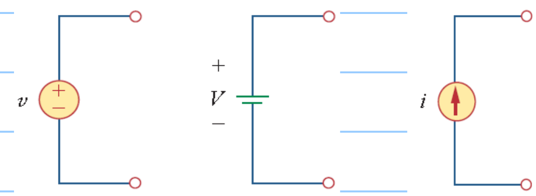


Power is the time rate of expending or absorbing energy, measured in watts (W).

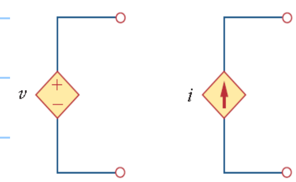
Energy is the capacity to do work, measured in joules (J).

$$p \triangleq \frac{dw}{dt} \quad \text{or} \quad p = vi$$

An **ideal independent source** is an active element that provides a specified voltage or current that is completely independent of other circuit elements.



An **ideal dependent** (or **controlled**) **source** is an active element in which the source quantity is controlled by another voltage or current.



* Problems Solving:

1. Carefully **define** the problem.
2. **Present** everything you know about the problem.
3. Establish a set of **alternative** solutions and determine the one that promises the greatest likelihood of success.
4. **Attempt** a problem solution.
5. **Evaluate** the solution and check for accuracy.
6. Has the problem been solved **satisfactorily**? If so, present the solution; if not, then return to step 3 and continue through the process again.

Ch 2: Basic Laws

Ohm's law states that the voltage *v* across a resistor is directly proportional to the current *i* flowing through the resistor.

The **resistance** *R* of an element denotes its ability to resist the flow of electric current; it is measured in ohms (Ω).

$$v = iR$$

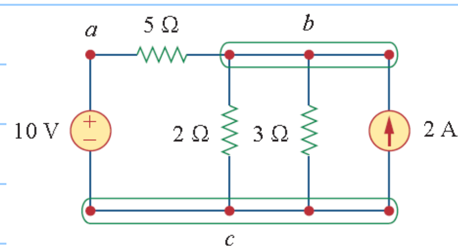
A **short circuit** is a circuit element with resistance approaching zero.

An **open circuit** is a circuit element with resistance approaching infinity.

Conductance is the ability of an element to conduct electric current; it is measured in mhos (℧) or siemens (S).

A **branch** represents a single element such as a voltage source or a resistor.

A **node** is the point of connection between two or more branches.

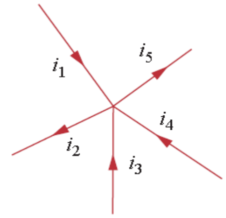


A **loop** is any closed path in a circuit.

Two or more elements are in **series** if they exclusively share a single node and consequently carry the same current.
Two or more elements are in **parallel** if they are connected to the same two nodes and consequently have the same voltage across them.

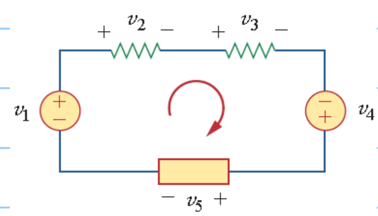
Kirchhoff's current law (KCL) states that the algebraic sum of currents entering a node (or a closed boundary) is zero.

$$\sum_{n=1}^{N} i_n = 0$$



Kirchhoff's voltage law (KVL) states that the algebraic sum of all voltages around a closed path (or loop) is zero.

$$\sum_{m=1}^{M} v_m = 0$$



Series

$$R_{eq} = R_1 + R_2 + \cdots + R_N = \sum_{n=1}^{N} R_n$$

$$v_n = \frac{R_n}{R_1 + R_2 + \cdots + R_N} v$$

Parallel

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

$$G_{eq} = G_1 + G_2 + G_3 + \cdots + G_N$$

$$i_n = \frac{G_n}{G_1 + G_2 + \cdots + G_N} i$$

Ch 3: Methods of Analysis

Steps to Determine Node Voltages:

1. Select a node as the reference node. Assign voltages $v_1, v_2, \ldots, v_{n-1}$ to the remaining $n - 1$ nodes. The voltages are referenced with respect to the reference node.
2. Apply KCL to each of the $n - 1$ nonreference nodes. Use Ohm's law to express the branch currents in terms of node voltages.
3. Solve the resulting simultaneous equations to obtain the unknown node voltages.

Current flows from **a higher** potential to **a lower** potential in a resistor.

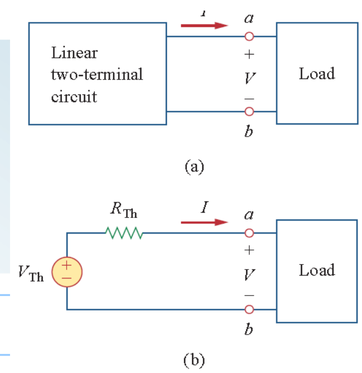
A **mesh** is a loop which does not contain any other loops within it.

Steps to Determine Mesh Currents:

1. Assign mesh currents $i_1, i_2, \ldots, i_n$ to the n meshes.
2. Apply KVL to each of the n meshes. Use Ohm's law to express the voltages in terms of the mesh currents.
3. Solve the resulting n simultaneous equations to get the mesh currents.

Ch 4: Circuit Theorems

Thevenin's theorem states that a linear two-terminal circuit can be replaced by an equivalent circuit consisting of a voltage source V_{Th} in series with a resistor R_{Th}, where V_{Th} is the open-circuit voltage at the terminals and R_{Th} is the input or equivalent resistance at the terminals when the independent sources are turned off.



Ch 9: Sinusoids and Phasors

$$v(t) = V_m \sin \omega t \qquad v(t) = V_m \sin(\omega t + \phi)$$

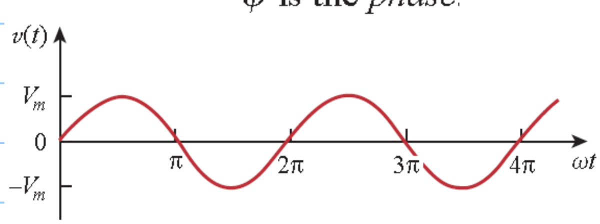
where

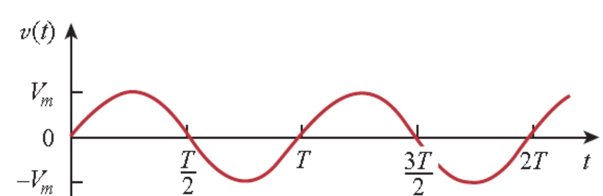
V_m = the *amplitude* of the sinusoid

ω = the *angular frequency* in radians/s

ωt = the *argument* of the sinusoid

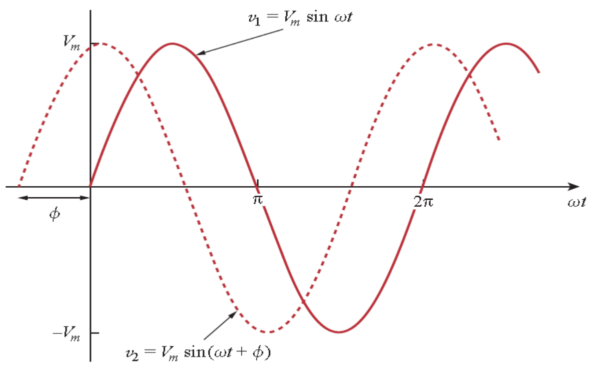
ϕ is the *phase*.





A **periodic function** is one that satisfies $f(t) = f(t + nT)$, for all t and for all integers n.

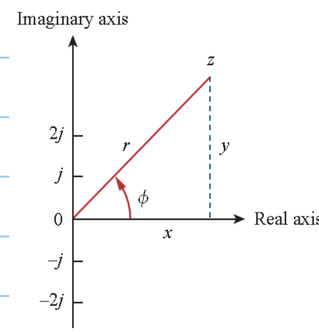
$$f = \frac{1}{T}$$

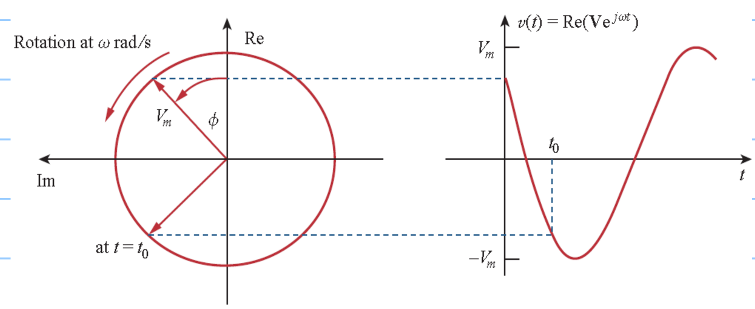


A **phasor** is a complex number that represents the amplitude and phase of a sinusoid.

$$z = x + jy = r\angle\phi = r(\cos\phi + j\sin\phi)$$

$$e^{\pm j\phi} = \cos\phi \pm j\sin\phi$$





$$v(t) = V_m \cos(\omega t + \phi) \quad \Leftrightarrow \quad \mathbf{V} = V_m\angle\phi$$

(Time-domain representation) (Phasor-domain representation)

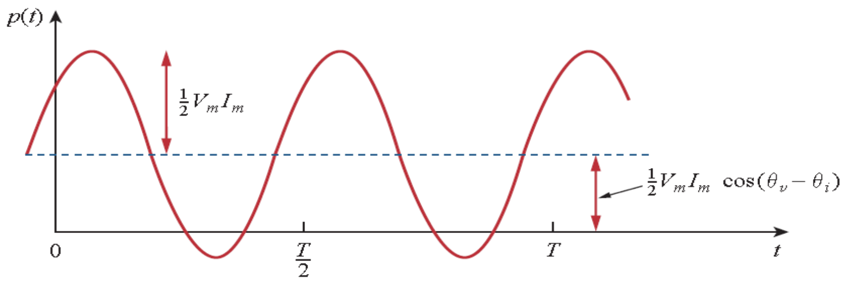
Impedances and admittances of passive elements.

Element	Impedance	Admittance
R	$\mathbf{Z} = R$	$\mathbf{Y} = \dfrac{1}{R}$
L	$\mathbf{Z} = j\omega L$	$\mathbf{Y} = \dfrac{1}{j\omega L}$
C	$\mathbf{Z} = \dfrac{1}{j\omega C}$	$\mathbf{Y} = j\omega C$

Ch 11: AC Power Analysis

The **instantaneous power** (in watts) is the power at any instant of time.

$$p(t) = v(t)i(t)$$



The **average power,** in watts, is the average of the instantaneous power over one period.

$$P = \frac{1}{2}\text{Re}[\mathbf{VI}^*] = \frac{1}{2}V_m I_m \cos(\theta_v - \theta_i)$$

A resistive load (R) absorbs power at all times, while a reactive load (L or C) absorbs zero average power.

The **effective value** of a periodic current is the dc current that delivers the same average power to a resistor as the periodic current.

The **effective value** of a periodic signal is its root mean square (rms) value.

$$V_{\text{rms}} = \frac{V_m}{\sqrt{2}}$$

The **apparent power** (in VA) is the product of the rms values of voltage and current.

$$S = V_{\text{rms}} I_{\text{rms}}$$

The **power factor** is the cosine of the phase difference between voltage and current. It is also the cosine of the angle of the load impedance.

$$\text{pf} = \frac{P}{S} = \cos(\theta_v - \theta_i)$$

Complex power (in VA) is the product of the rms voltage phasor and the complex conjugate of the rms current phasor. As a complex quantity, its real part is real power P and its imaginary part is reactive power Q.

$$\mathbf{S} = I_{\text{rms}}^2 \mathbf{Z} = \frac{V_{\text{rms}}^2}{\mathbf{Z}^*} = \mathbf{V}_{\text{rms}} \mathbf{I}_{\text{rms}}^*$$