Basic Electrical and Electronics Engineering

LECTURE 2.2

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BEEE102L

Basic Electrical and Electronics Engineering

1. DC Circuits
2. AC Circuits
3. Magnetic Circuits
4. Electrical Machines
5. Semiconductor Devices and Applications
6. Digital Systems
7. Sensors and Transducers

$$e = E_m \sin \alpha \quad (V)$$

α is the instantaneous angular position of the coil.

Angular Velocity ω

The rate at which the generator coil rotates is called its **angular velocity**

$$\alpha = \omega t$$

$$t = \frac{\alpha}{\omega} \quad (s)$$

$$\omega = \frac{\alpha}{t}$$

Radian Measure

In practice, ω is usually expressed in radians per second, where radians and degrees are related by the identity

$$2\pi \text{ radians} = 360°$$

Relationship between ω, T, and f

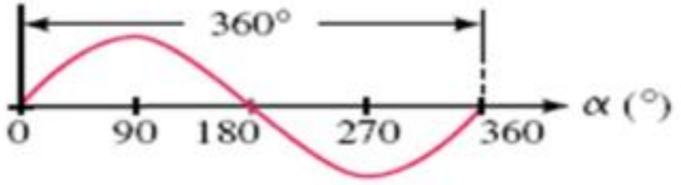
$$\omega T = 2\pi \quad \text{(rad)}$$

$$\omega = \frac{2\pi}{T} \quad \text{(rad/s)}$$

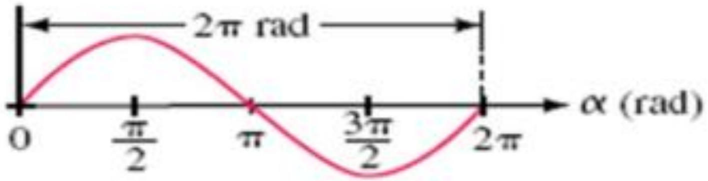
$$\omega = 2\pi f \quad \text{(rad/s)}$$

$$\alpha_{\text{radians}} = \frac{\pi}{180^\circ} \times \alpha_{\text{degrees}}$$

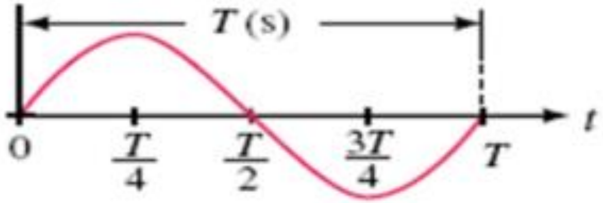
$$\alpha_{\text{degrees}} = \frac{180^\circ}{\pi} \times \alpha_{\text{radians}}$$



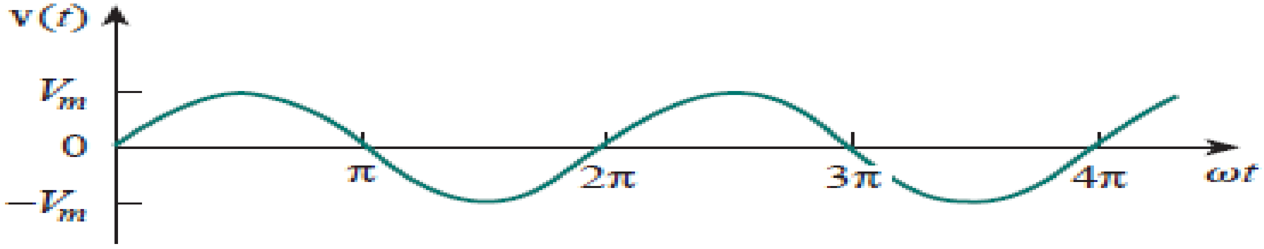
(a) Degrees



(b) Radians



(c) Period



(a)

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

we observe that $\omega T = 2\pi$,

$$\boxed{T = \frac{2\pi}{\omega}}$$

The fact that *v(t) repeats itself every T seconds is shown by replacing t* by *t + T*

$$v(t+T) = V_m \sin \omega(t+T) = V_m \sin \omega\left(t + \frac{2\pi}{\omega}\right)$$

$$= V_m \sin(\omega t + 2\pi) = V_m \sin \omega t = v(t)$$

Hence,

$$\boxed{v(t+T) = v(t)}$$

Let us now consider a more general expression for the sinusoid,

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

<u>**where (ωt + φ)** ***is the argument and φ is the phase.***</u> *Both argument and* phase can be in radians or degrees.

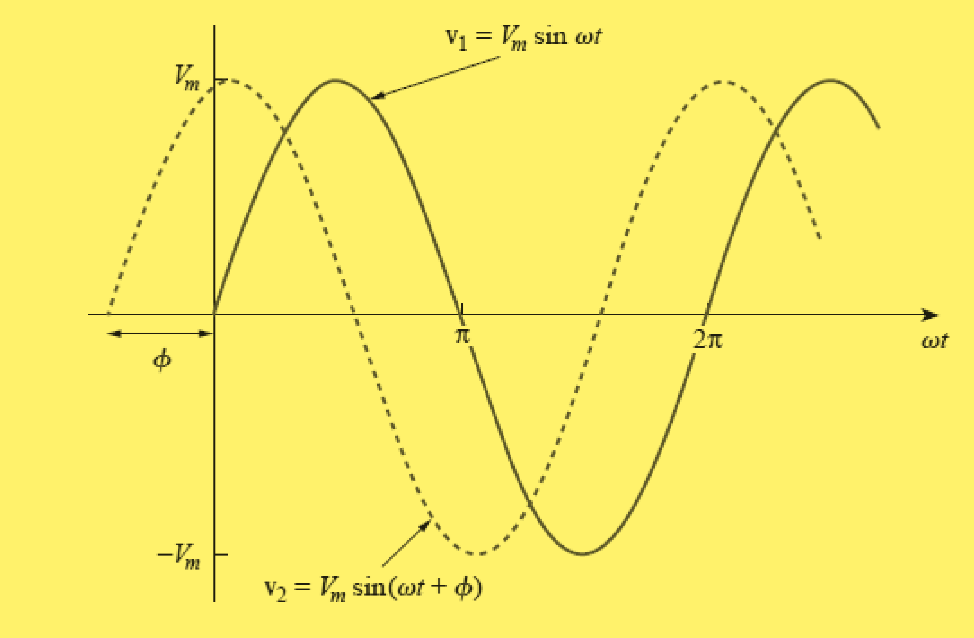
Let us examine the two sinusoids

$$v_1(t) = V_m \sin \omega t \qquad \text{and} \qquad v_2(t) = V_m \sin(\omega t + \phi)$$

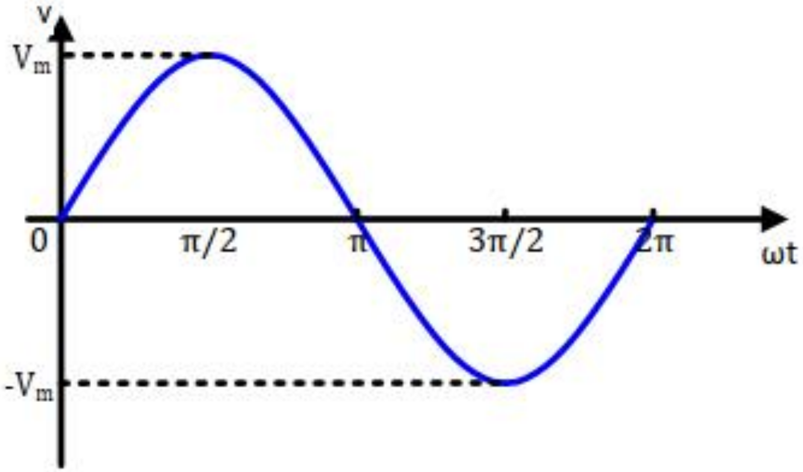
The starting point of *v2 in Figure occurs first in time.*

Therefore, we say that *v2 leads v1 by φ or that v1 lags v2 by φ.*

If φ = 0, then v1 and v2 are said to be *in phase; they reach their minima and maxima at exactly the* same time.



Representation

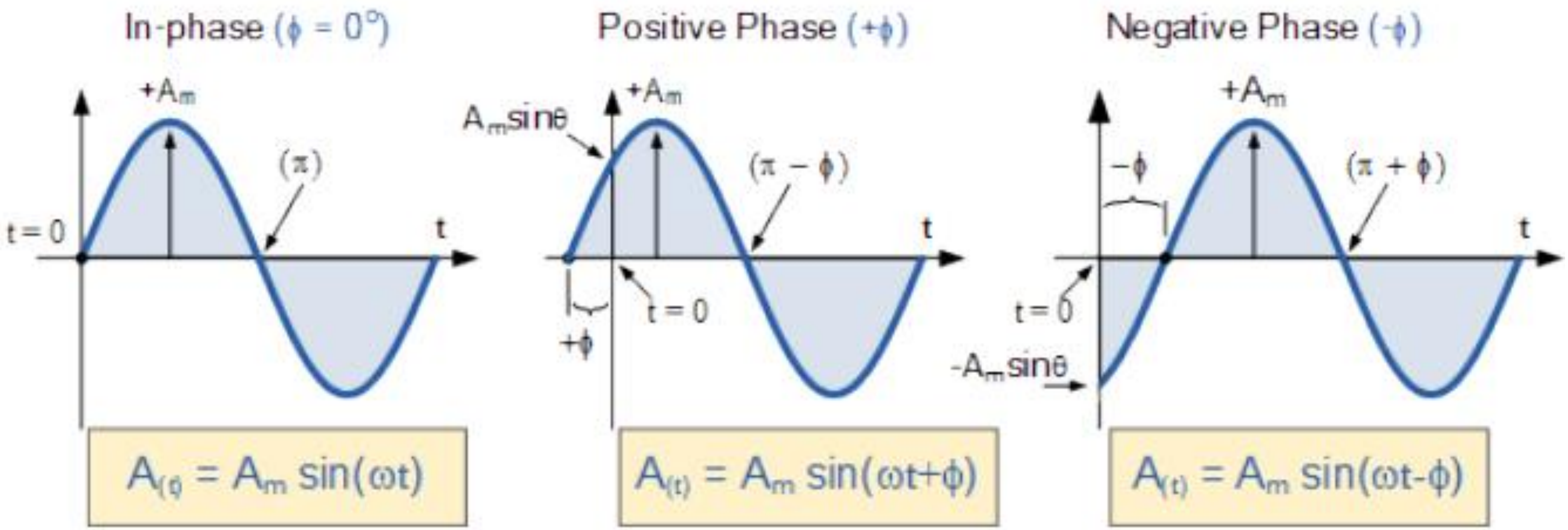


$$v(t) = V_m \sin \omega t$$

V_m = the amplitude of the sinusoid
ω = the angular velocity in radians/s
ωt = the argument of the sinusoid

In general $\quad v(t) = V_m \sin(\omega t + \emptyset)$

$(\omega t + \varphi)$ is the argument and $\emptyset$ is the phase. Both argument and phase can be in radians or degrees

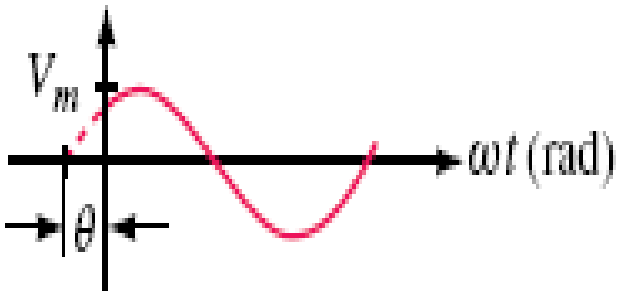


Voltages and Currents with Phase Shifts

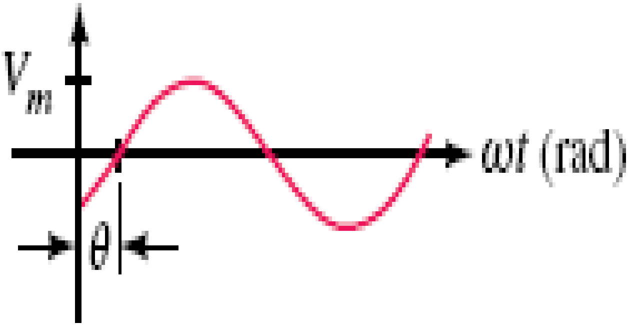
If a sine wave does not pass through zero at t = 0 s it has a **phase shift.** Waveforms may be shifted to the left or to the right

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

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



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



(b) $v = V_m \sin(\omega t - \theta)$

Example Problem 1

- Find the amplitude **(Vm)**, phase (**Φ**) , period **(T)**, and frequency (**F**) of the sinusoid

$$\boldsymbol{v(t) = 12\sin\left(50t + 10^{\circ}\right)}$$

$$\boldsymbol{v(t) = V_m \sin(\omega t + \varphi)}$$

Example Problem 1

- Find the amplitude, phase, period, and frequency of the sinusoid

$$\boldsymbol{v(t) = 12\sin\left(50t + 10^{\circ}\right)}$$

Solution:

The amplitude is $V_m = 12$ V.

The phase is $\phi = 10^{\circ}$.

The angular frequency is $\omega = 50$ rad/s.

The period $T = \dfrac{2\pi}{\omega} = \dfrac{2\pi}{50} = 0.1257$ s.

The frequency is $f = \dfrac{1}{T} = 7.958$ Hz.

Example Problem 2

- Find the amplitude **(Vm)**, phase (**Φ**) , period **(T)**, and frequency (**F**) of the sinusoid

$$5\sin(4\pi t - 60^\circ)$$

$$v_2(t) = V_m \sin(\omega t + \phi)$$

Answer: 5, −60°, 0.5 s, 2 Hz.

EXAMPLE 13.9

a. Determine the angle at which the magnitude of the sinusoidal function $v = 10 \sin 377t$ is 4 V.

b. Determine the time at which the magnitude is attained.

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Solutions:

a. Eq. (13.15):

$$\alpha_1 = \sin^{-1}\frac{\upsilon}{E_m} = \sin^{-1}\frac{4\text{ V}}{10\text{ V}} = \sin^{-1}0.4 = \mathbf{23.58^\circ}$$

However, Fig.13.19 reveals that the magnitude of 4 V (positive) will be attained at two points between 0° and 180°. The second intersection is determined by

$$\alpha_2 = 180^\circ - 23.578^\circ = \mathbf{156.42^\circ}$$

In general, therefore, keep in mind that Eqs. (13.15) and (13.16) will provide an angle with a magnitude between 0° and 90°.

b. Eq. (13.10): $\alpha = \omega t$, and so $t = \alpha/\omega$. However, α must be in radians. Thus,

$$\alpha\,(\text{rad}) = \frac{\pi}{180^\circ}(23.578^\circ) = 0.412\text{ rad}$$

and

$$t_1 = \frac{\alpha}{\omega} = \frac{0.412\text{ rad}}{377\text{ rad/s}} = \mathbf{1.09\ ms}$$

For the second intersection,

$$\alpha\,(\text{rad}) = \frac{\pi}{180^\circ}(156.422^\circ) = 2.73\text{ rad}$$

$$t_2 = \frac{\alpha}{\omega} = \frac{2.73\text{ rad}}{377\text{ rad/s}} = \mathbf{7.24\ ms}$$