Chapter 15

AC Fundamentals

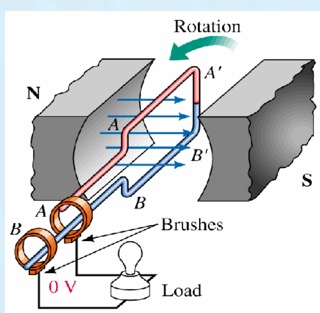
Alternating Current

- Voltages of ac sources alternate in polarity and vary in magnitude
- Voltages produce currents that vary in magnitude and alternate in direction

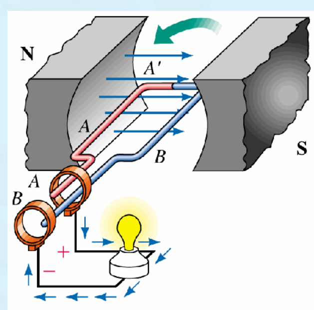
Alternating Current

- A sinusoidal ac waveform starts at zero
  - Increases to a positive maximum
  - Decreases to zero
  - Changes polarity
  - Increases to a negative maximum
  - Returns to zero
- Variation is called a cycle

Generating AC Voltages

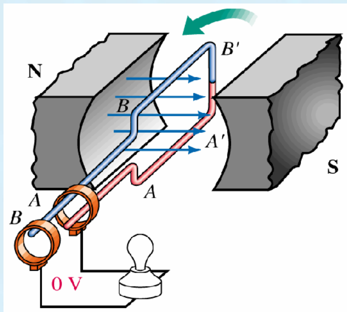


(a) 0° Position: Coil sides move parallel to flux lines. Since no flux is being cut, induced voltage is zero.

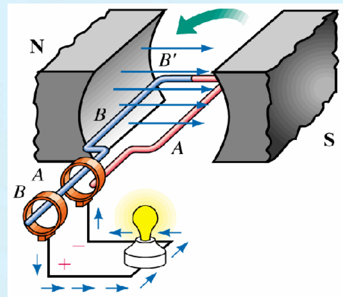


(b) 90° Position: Coil end *A* is positive with respect to *B*. Current direction is out of slip ring *A*.

Generating AC Voltages



(c) 180° Position: Coil again cutting no flux. Induced voltage is zero.



(d) 270° Position: Voltage polarity has reversed, therefore, current direction reverses.

AC Voltage-Current Conventions

- Assign a reference polarity for source
- When voltage has a positive value
  - Its polarity is same as reference polarity
- When voltage is negative
  - Its polarity is opposite that of the reference polarity

AC Voltage-Current Conventions

- Assign a reference direction for current that leaves source at positive reference polarity
- When current has a positive value
  - Its actual direction is same as current reference arrow

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AC Voltage-Current Conventions

- When current is negative
  - Its actual direction is opposite that of current reference arrow

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Frequency

- Number of cycles per second of a waveform
  - Frequency
  - Denoted by *f*
- Unit of frequency is hertz (Hz)
- 1 Hz = 1 cycle per second

9

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Period

- Period of a waveform
  - Time it takes to complete one cycle
- Time is measured in seconds
- The period is the reciprocal of frequency
  - $T = 1/f$

10

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Amplitude and Peak-to-Peak Value

- Amplitude of a sine wave
  - Distance from its average to its peak
- We use E_m for amplitude
- Peak-to-peak voltage
  - Measured between minimum and maximum peaks
- We use E_{pp} or V_{pp}

Peak Value

- Peak value of an ac voltage or current
  - Maximum value with respect to zero
- If a sine wave is superimposed on a dc value
  - Peak value of combined wave is sum of dc voltage and peak value of ac waveform amplitude

The Basic Sine Wave Equation

- Voltage produced by a generator is
  - $e = E_m \sin \alpha$
- E_m is maximum (peak) voltage
- α is instantaneous angular position of rotating coil of the generator

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The Basic Sine Wave Equation

- Voltage at angular position of sine wave generator
  - May be found by multiplying E_m times the sine of angle at that position

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Angular Velocity

- Rate at which the generator coil rotates with respect to time, ω (Greek letter omega)

Angular Velocity

- Units for ω are revolutions/second, degrees/sec, or radians/sec.

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

$$\alpha = \omega t$$

Radian Measure

- ω is usually expressed in radians/second
- 2π radians = 360°
- To convert from degrees to radians, multiply by $\pi/180$

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Radian Measure

- To convert from radians to degrees, multiply by $180/\pi$
- When using a calculator
  - Be sure it is set to radian mode when working with angles measured in radians

Relationship between ω, T, and f

- One cycle of a sine wave may be represented by $\alpha = 2\pi$ rads or $t = T$ sec

$$\alpha = \omega t$$
$$\omega T = 2\pi$$
$$\omega = \frac{2\pi}{T}$$
$$\omega = 2\pi f$$

Voltages and Currents as Functions of Time

- Since $\alpha = \omega t$, the equation $e = E_m \sin \alpha$ becomes $e(t) = E_m \sin \omega t$
- Also, $v(t) = V_m \sin \omega t$ and $i(t) = I_m \sin \omega t$

Voltages and Currents as Functions of Time

- Equations used to compute voltages and currents at any instant of time
- Referred to as instantaneous voltage or current

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Voltages and Currents with Phase Shifts

- If a sine wave does not pass through zero at t = 0, it has a phase shift
- For a waveform shifted left
  – $v = V_m \sin(\omega t + \theta)$
- For a waveform shifted right
  – $v = V_m \sin(\omega t - \theta)$

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Phasors

- Rotating vectors whose projection onto a vertical or horizontal axis can be used to represent sinusoidally varying quantities

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Phasors

- A sinusoidal waveform
  - Produced by plotting vertical projection of a phasor that rotates in the counterclockwise direction at a constant angular velocity ω

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Phasors

- Phasors apply only to sinusoidally varying waveforms

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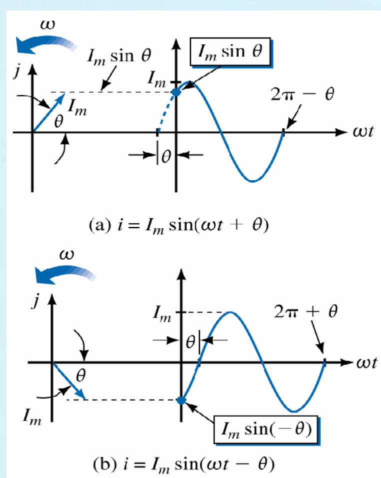
Shifted Sine Waves

- Phasors used to represent shifted waveforms
- Angle θ is position of phasor at t = 0 seconds



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Phase Difference

- Phase difference is angular displacement between waveforms of same frequency
- If angular displacement is 0°
  - Waveforms are in phase

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Phase Difference

- If angular displacement is not 0°, they are out of phase by amount of displacement

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Phase Difference

- If v_1 = 5 sin(100*t*) and v_2 = 3 sin(100*t* - 30°), v_1 leads v_2 by 30°
- May be determined by drawing two waves as phasors
  - Look to see which one is ahead of the other as they rotate in a counterclockwise direction

Average Value

- To find an average value of a waveform
  - Divide area under waveform by length of its base
- Areas above axis are positive, areas below axis are negative

Average Value

- Average values also called dc values
  - dc meters indicate average values rather than instantaneous values

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Sine Wave Averages

- Average value of a sine wave over a complete cycle is zero
- Average over a half cycle is not zero

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Sine Wave Averages

- Rectified full-wave average is 0.637 times the maximum value
- Rectified half-wave average is 0.318 times the maximum value

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Effective Values

- Effective value or RMS value of an ac waveform is an equivalent dc value
  - It tells how many volts or amps of dc that an ac waveform supplies in terms of its ability to produce the same average power

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Effective Values

- In North America, house voltage is 120 Vac.
  - Voltage is capable of producing the same average power as a 120 V battery

35

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Effective Values

- To determine effective power
  - Set Power(dc) = Power(ac)

  $P_{dc} = p_{ac}$

  $I^2R = i^2R$ where $i = I_m \sin \omega t$
- By applying a trigonometric identity
  - Able to solve for I in terms of I_m

36

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Effective Values

- $I_{eff} = .707I_m$
- $V_{eff} = .707V_m$
- Effective value is also known as the RMS value