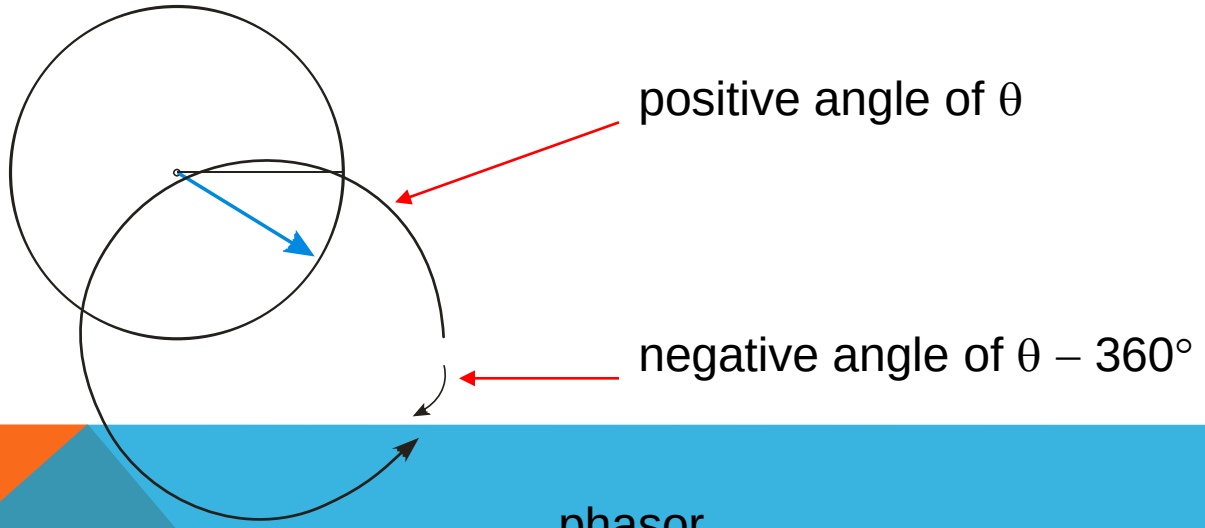
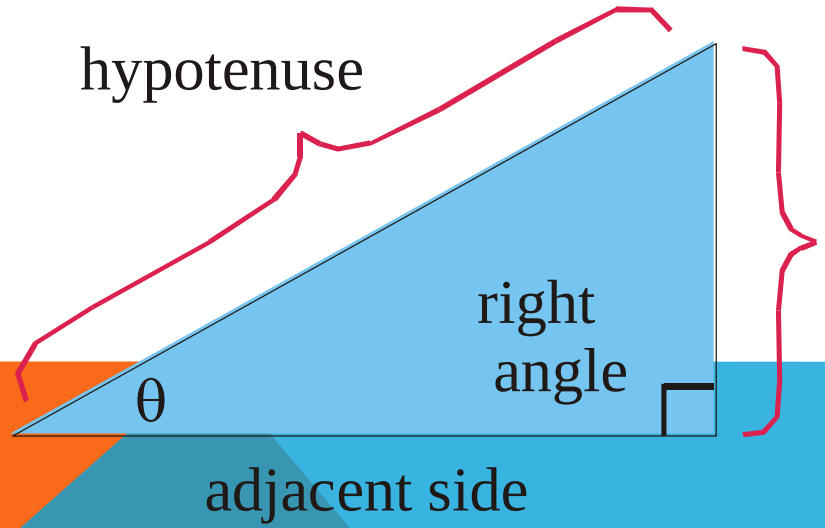
Phasors

The position of a phasor at any instant can be expressed as a positive angle, measured counterclockwise from 0° or as a negative angle equal to $\theta - 360°$.



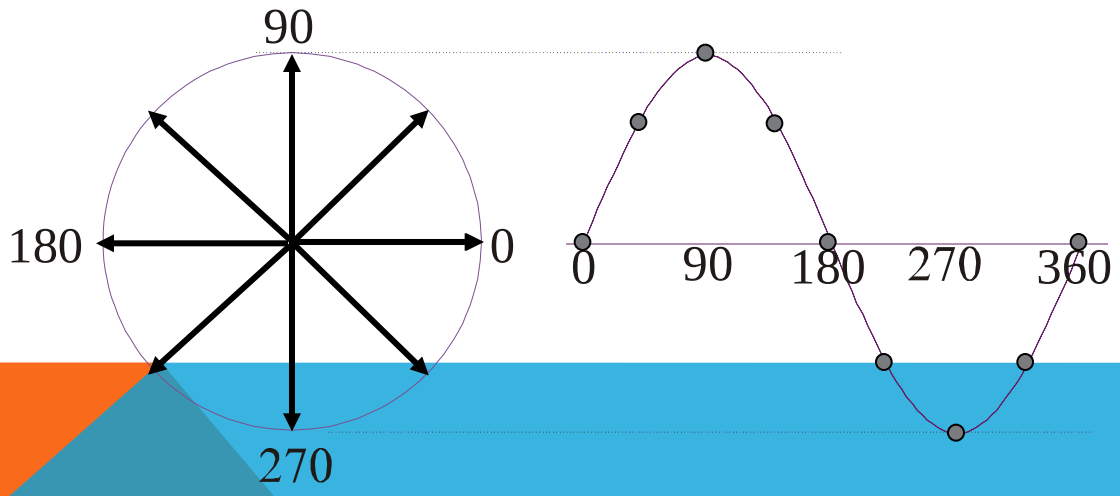
Phasors

Phasors allow ac calculations to use basic trigonometry. The sine function in trigonometry is the ratio of the opposite side of a right triangle to the adjacent side.



Phasors

The sine wave can be represented as the projection of a vector rotating at a constant rate. This rotating vector is called a **phasor**.



Phase shift

The phase of a sine wave is an angular measurement that specifies the position of a sine wave relative to a reference. To show that a sine wave is shifted to the left or right of this reference, a term is added to the equation given previously.

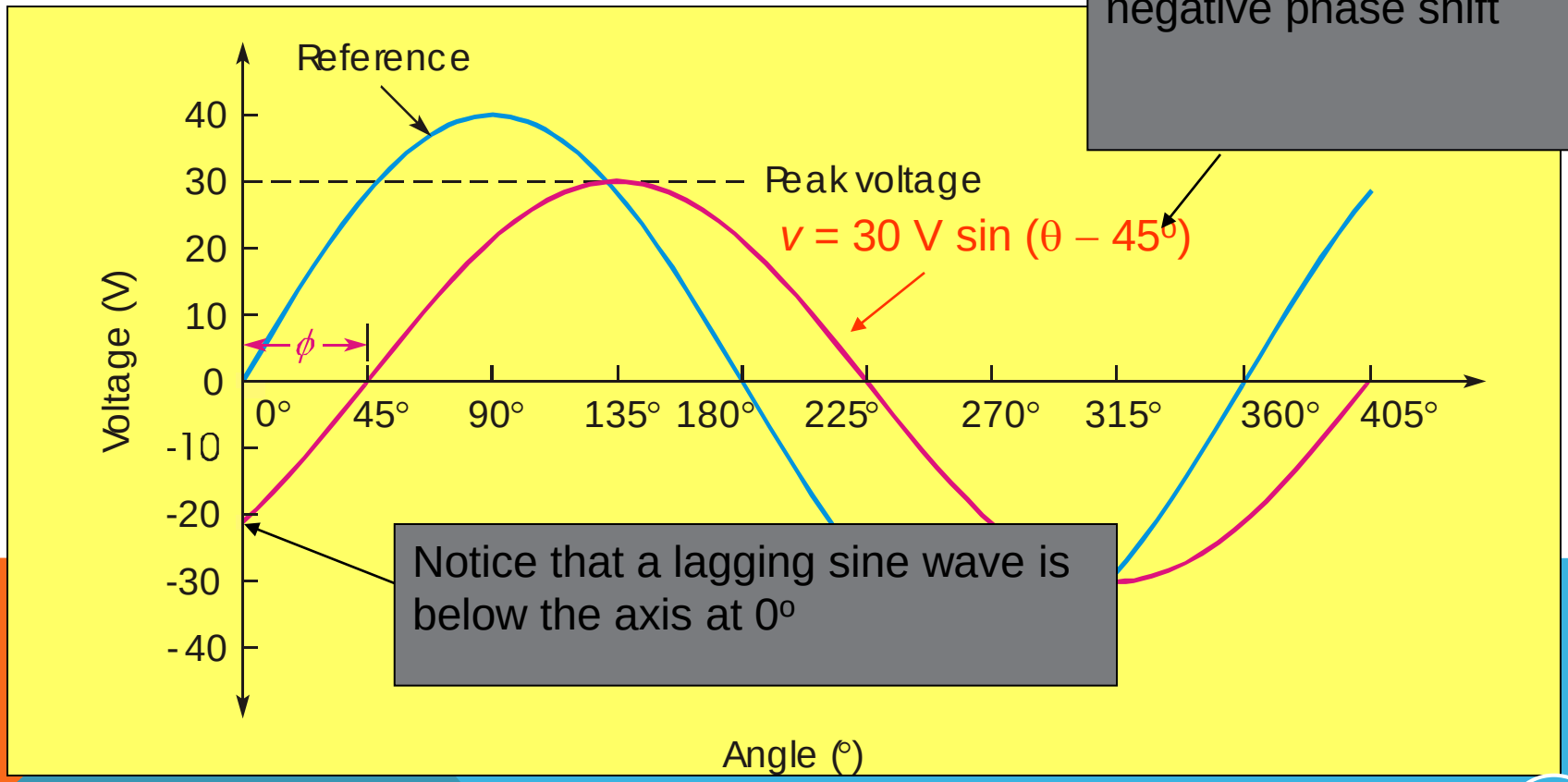
$$v = V_P \sin(\theta \pm \phi)$$

where

ϕ = Phase shift

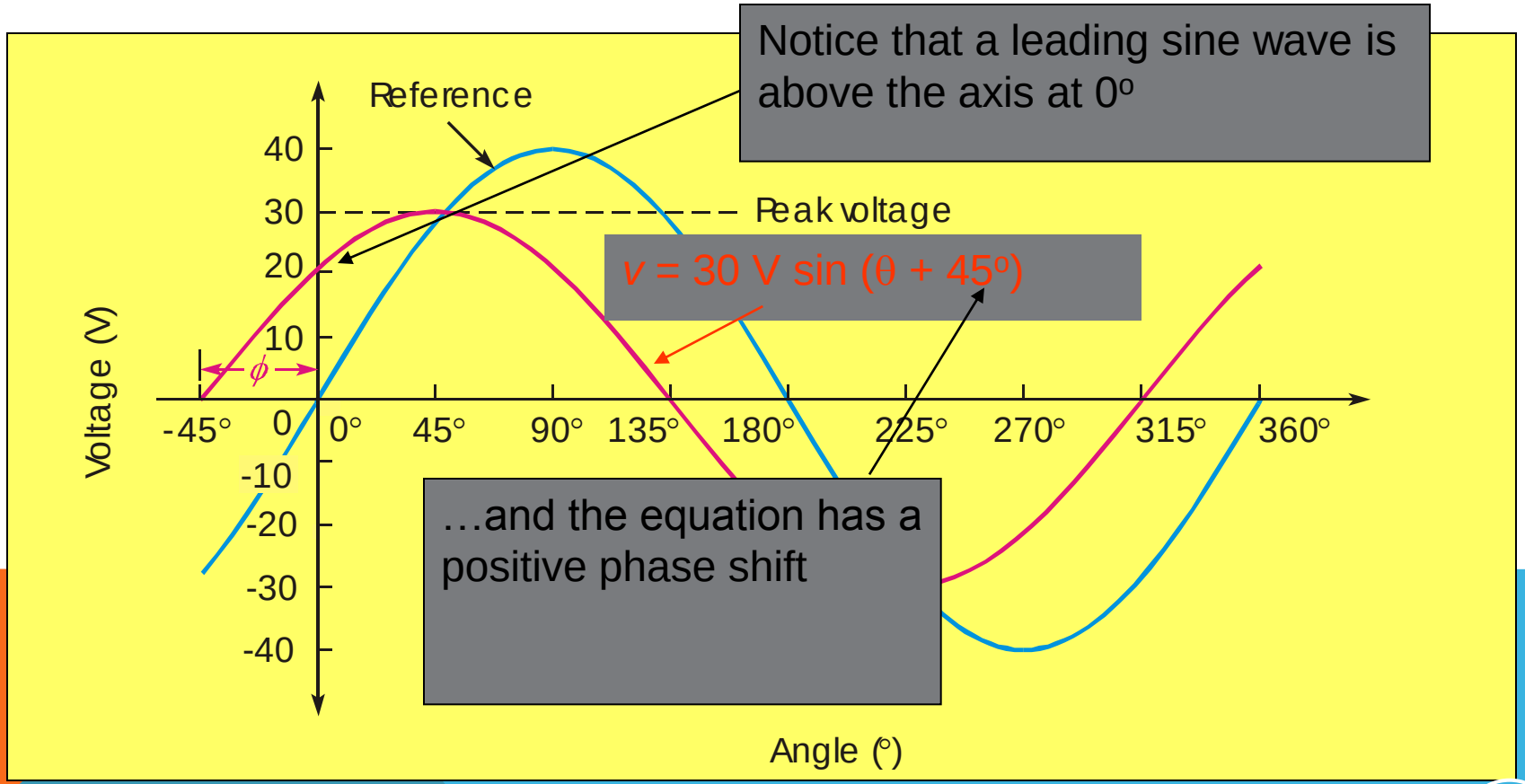
Phase shift

Example of a wave that lags the reference



Phase shift

Example of a wave that leads the reference



Angular velocity of a phasor

When a phasor rotates through 360° or 2π radians, one complete cycle is traced out.
The velocity of rotation is called the **angular velocity** (ω).

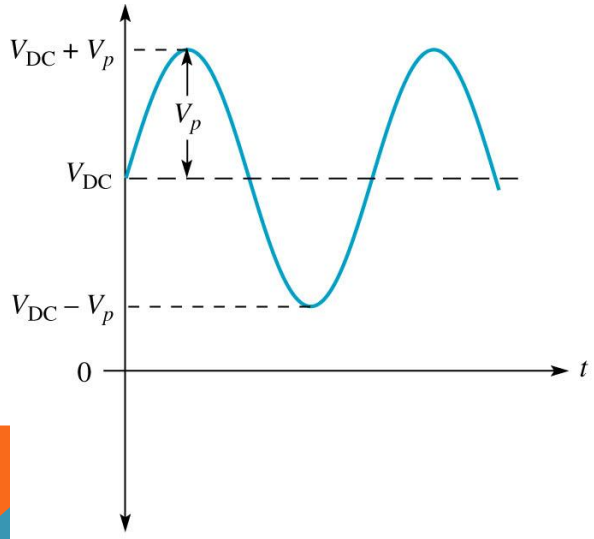
$$\omega = 2\pi f$$

(Note that this angular velocity is expressed in radians per second.)
The instantaneous voltage at any point in time is given by

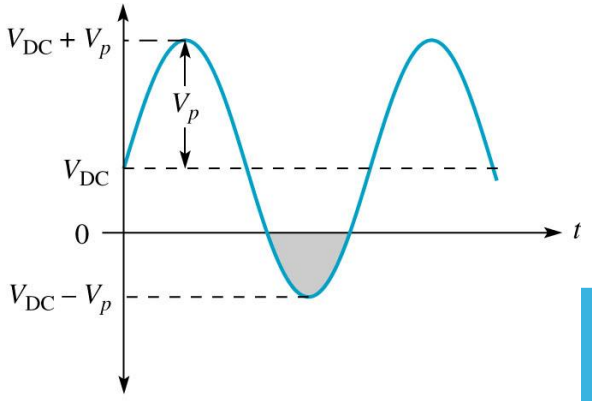
$$v = V_p \sin 2\pi f$$

Superimposed dc and ac V

Frequently dc and ac voltages are together in a waveform. They can be added algebraically, to produce a composite waveform of an ac voltage “riding” on a dc level.

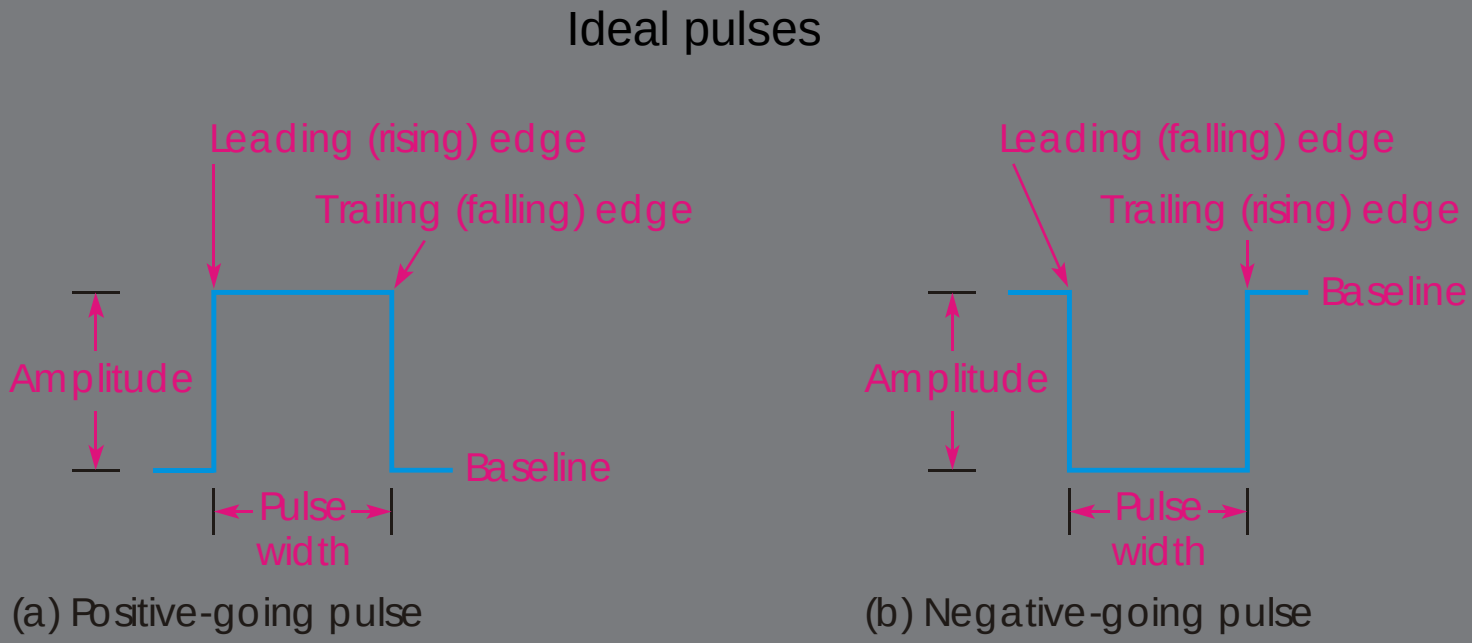


(a) $V_{DC} > V_p$. The sine wave never goes negative.



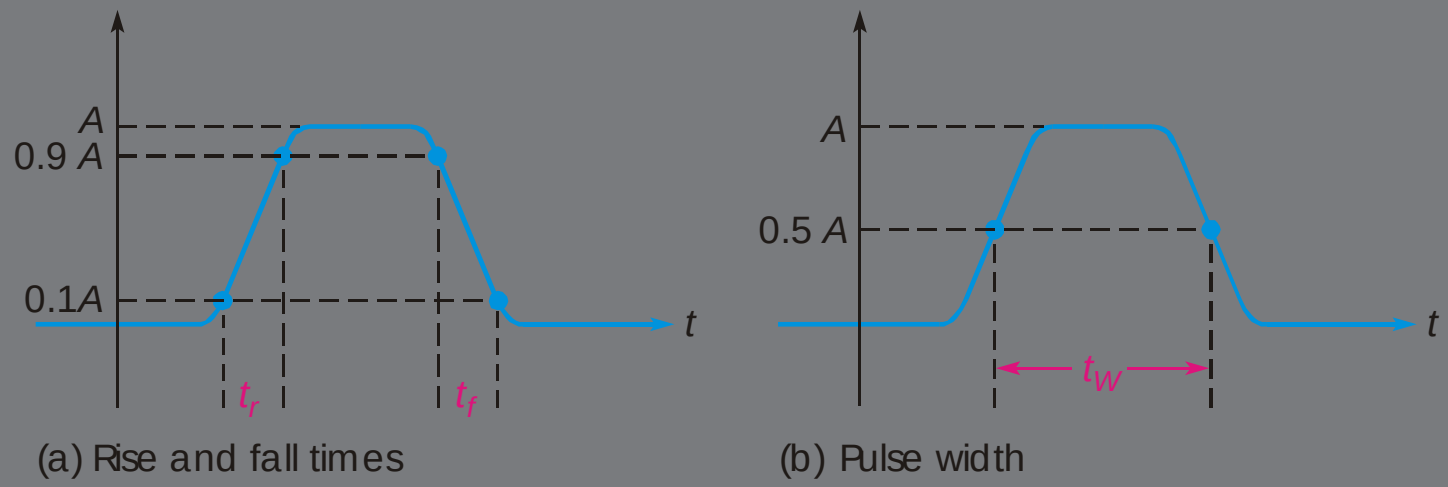
(b) $V_{DC} < V_p$. The sine wave reverses polarity during a portion of its cycle, as indicated by the gray area.

Pulse definitions



Pulse definitions

Non-ideal pulses

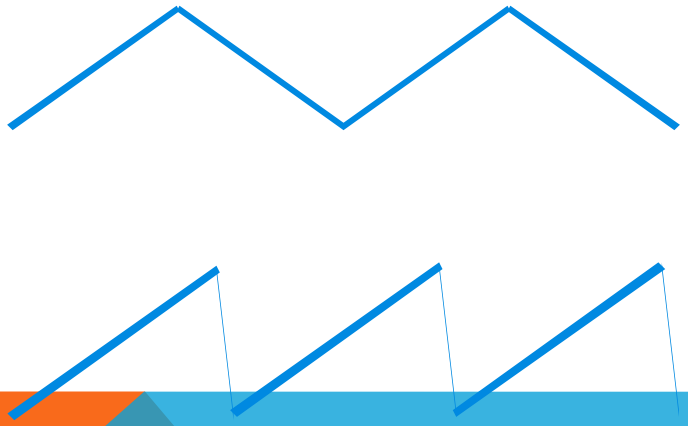


(a) Rise and fall times (b) Pulse width

Notice that rise and fall times are measured between the 10% and 90% levels whereas pulse width is measured at the 50% level.

Triangular and sawtooth waves

Triangular and sawtooth waveforms are formed by voltage or current ramps (linear increase/decrease)



Triangular waveforms have positive-going and negative-going ramps of equal slope.

The sawtooth waveform consists of two ramps, one of much longer duration than the other.

Harmonics

All repetitive non-sinusoidal waveforms are composed of a **fundamental frequency** (repetition rate of the waveform) and **harmonic frequencies**.

Odd harmonics are frequencies that are odd multiples of the fundamental frequency.

Even harmonics are frequencies that are even multiples of the fundamental frequency.

Selected Key Terms

Sine wave	A type of waveform that follows a cyclic sinusoidal pattern defined by the formula $y = A \sin \theta$.
Alternating current	Current that reverses direction in response to a change in source voltage polarity.
Period (T)	The time interval for one complete cycle of a periodic waveform.
Frequency (f)	A measure of the rate of change of a periodic function; the number of cycles completed in 1 s.
Hertz	The unit of frequency. One hertz equals one cycle per second.

Selected Key Terms

Instantaneous value	The voltage or current value of a waveform at a given instant in time.
Peak value	The voltage or current value of a waveform at its maximum positive or negative points.
Peak-to-peak value	The voltage or current value of a waveform measured from its minimum to its maximum points.
rms value	The value of a sinusoidal voltage that indicates its heating effect, also known as effective value. It is equal to 0.707 times the peak value. *rms* stands for root mean square.

Selected Key Terms

Radian	A unit of angular measurement. There are 2π radians in one complete 360^{o} revolution.
Phasor	A representation of a sine wave in terms of its magnitude (amplitude) and direction (phase angle).
Amplitude	The maximum value of a voltage or current.
Pulse	A type of waveform that consists of two equal and opposite steps in voltage or current separated by a time interval.
Harmonics	The frequencies contained in a composite waveform, which are integer multiples of the pulse repetition frequency.