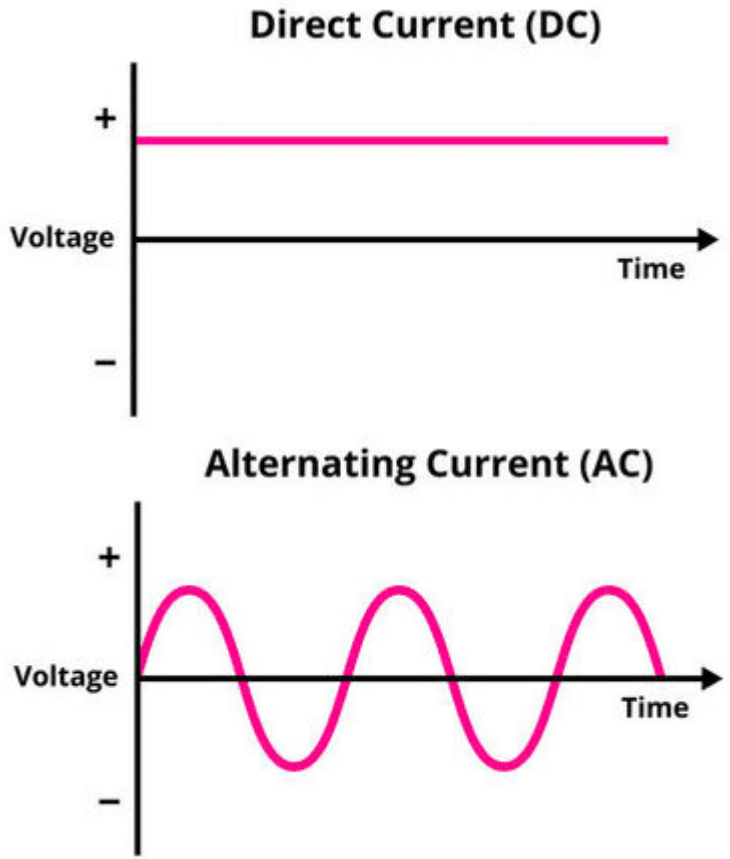
Introduction to AC

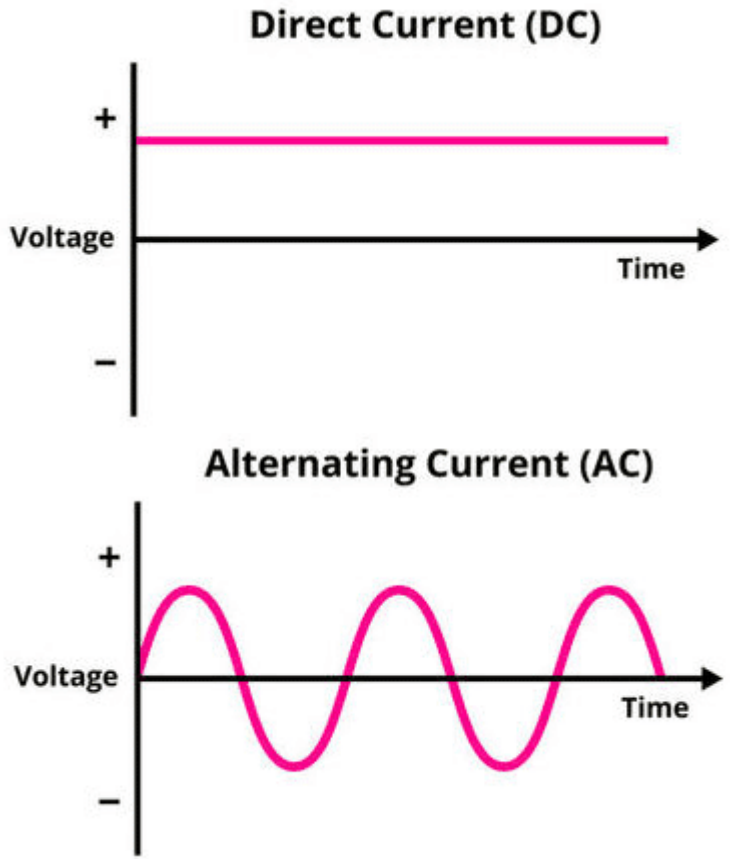
What is alternating current

- Alternating Current (AC) is an electrical current that continuously changes direction and magnitude over time.
- Unlike direct current (DC), which flows in one direction only, AC reverses direction periodically.



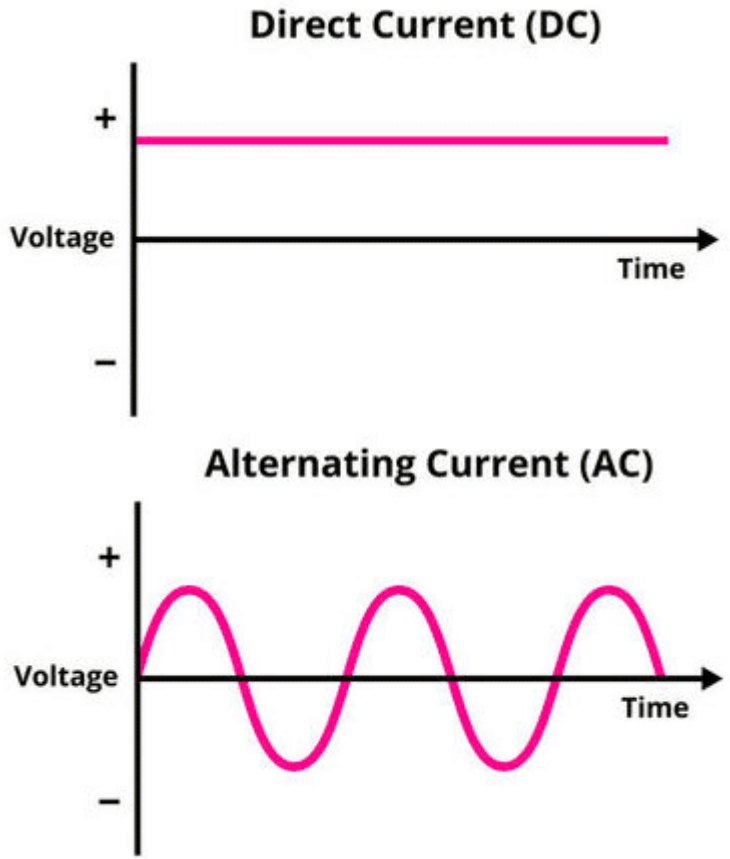
What is alternating current

- The current flows **back and forth** in the circuit
- The voltage and current values vary with **time**
- Most AC supplies follow a **sinusoidal waveform**
- Direction changes occur at **regular intervals**



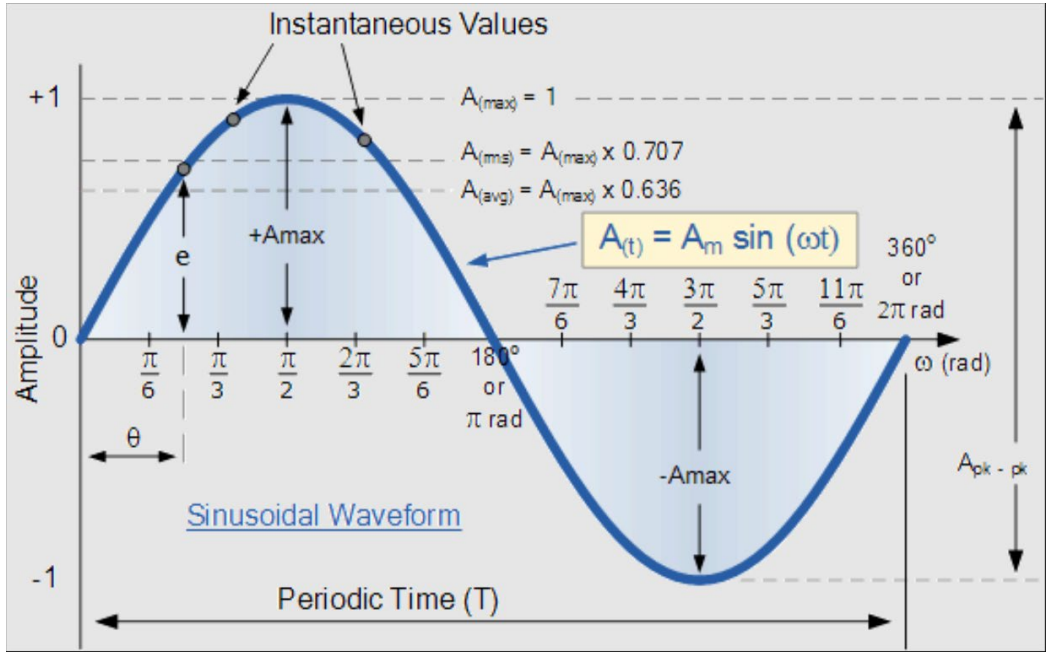
What is alternating current

- Easily **stepped up or down** in voltage using **transformers**
- More efficient for **long-distance power transmission**
- Well suited to **rotating machines** (motors and generators)
- Standard for **mains electricity** supplies



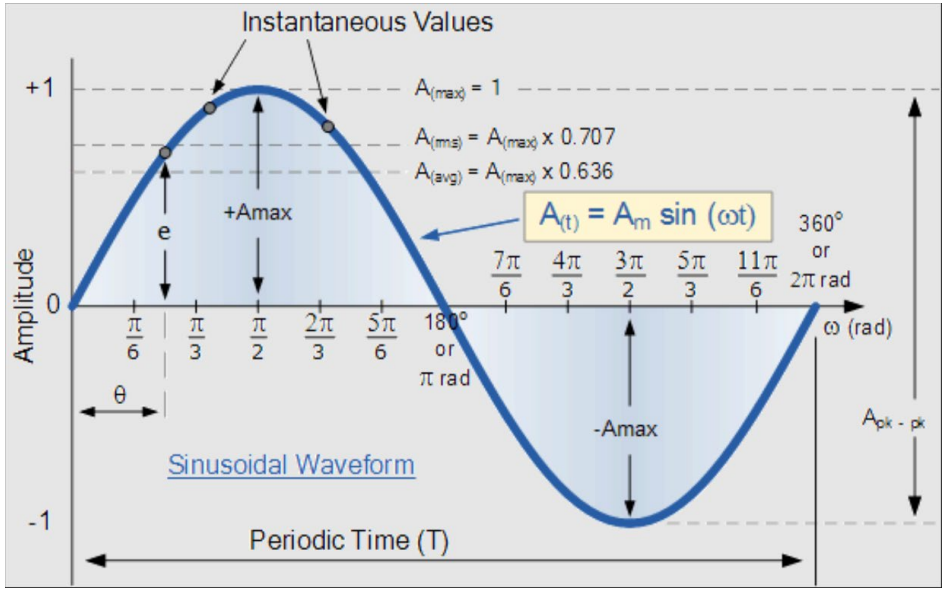
AC Waveform

- An AC waveform shows how **voltage** or **current changes** with time.
- The most common AC waveform is a **sinusoidal (sine) wave**, because it is naturally produced by **rotating generators**.



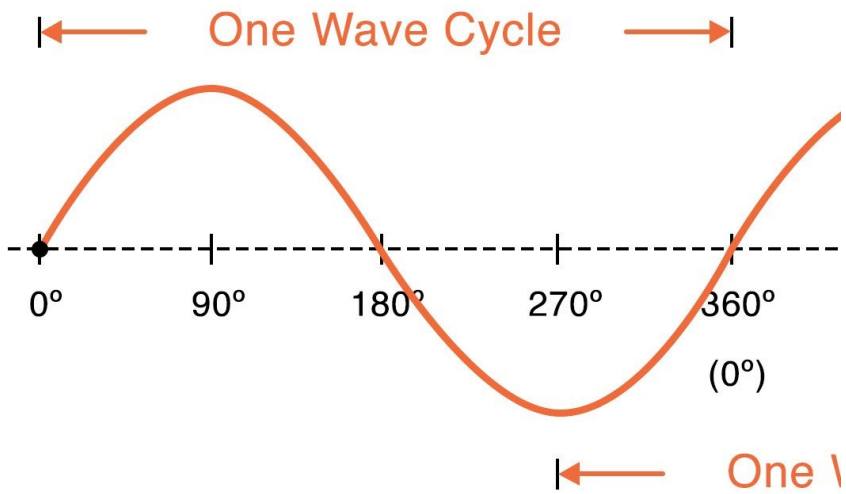
AC Waveform

- **Instantaneous value**
  - The value of voltage or current at any specific moment in time.
- **Peak value (Vp / Ip)**
  - The maximum positive or negative value reached.
- **Peak-to-peak value (Vpp)**
  - The total distance from the positive peak to the negative peak.
- **Zero crossing**
  - The point where the waveform crosses zero and changes direction.



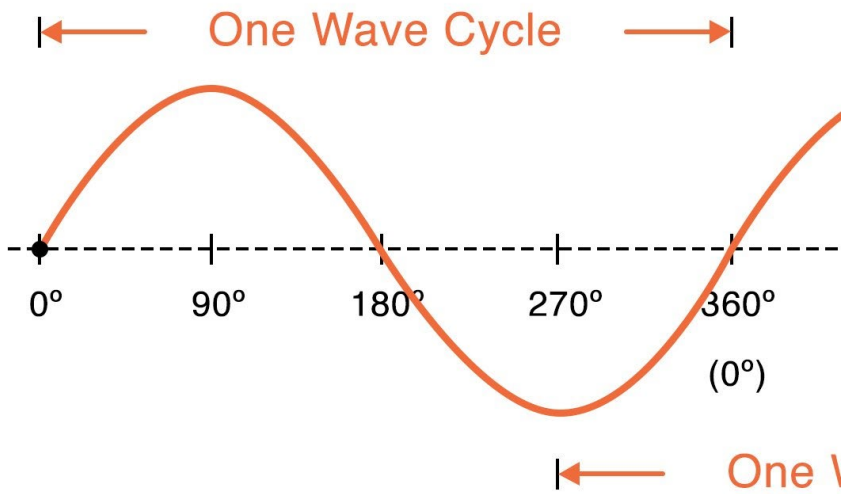
Frequency and Period

- **Frequency** describes how often an AC waveform repeats **each second**.
- **Period** describes how long **one complete cycle** takes.



Frequency

- Measured in **hertz (Hz)**
- **1 Hz = 1 cycle per second**
- Higher frequency → waveform repeats more quickly
- UK mains supply operates at **50 Hz**



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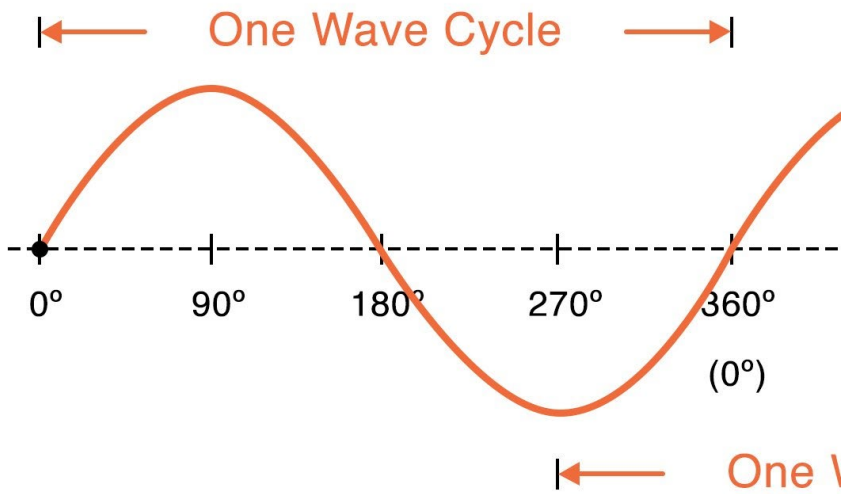
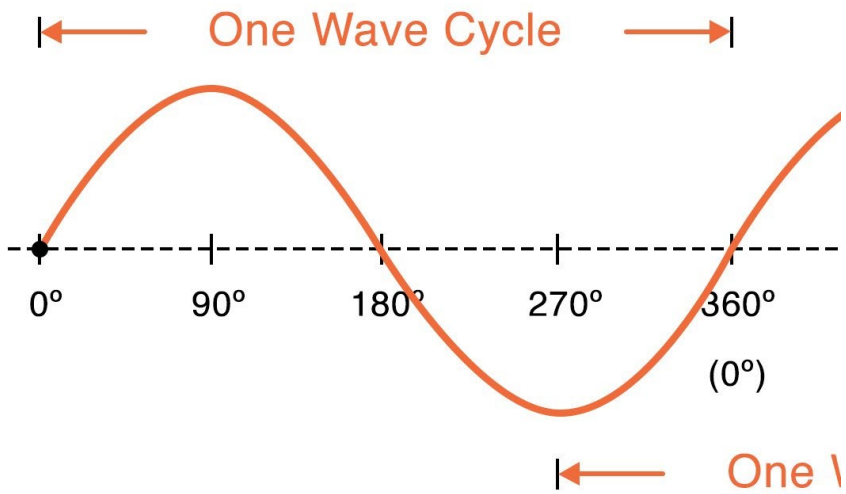


Period

- Measured in **seconds (s)**
- Time taken for **one full cycle** of the waveform
- One cycle = one complete **positive and negative** alternation



Relationship Between Frequency and Period

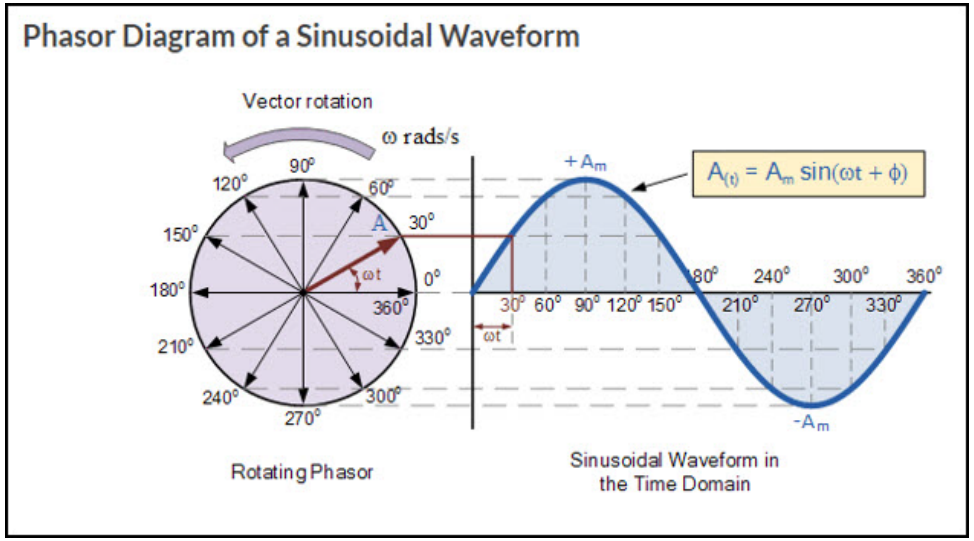
- As frequency increases, period decreases
- As frequency decreases, period increases

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

Angular Frequency (ω)

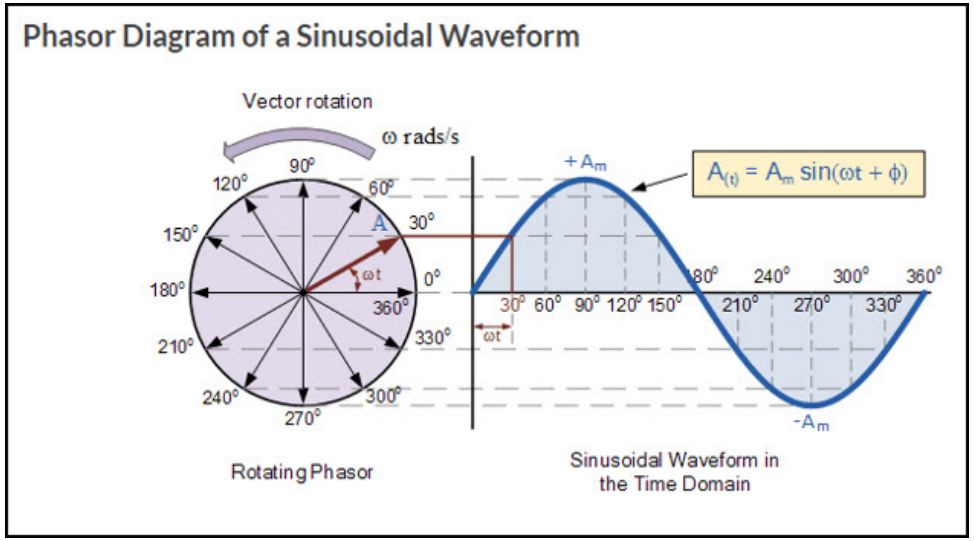
- Angular frequency describes how fast an AC waveform **rotates in angular terms**, rather than cycles per second.

- It is most useful when **analysing sinusoidal AC signals** and **rotating machines.**



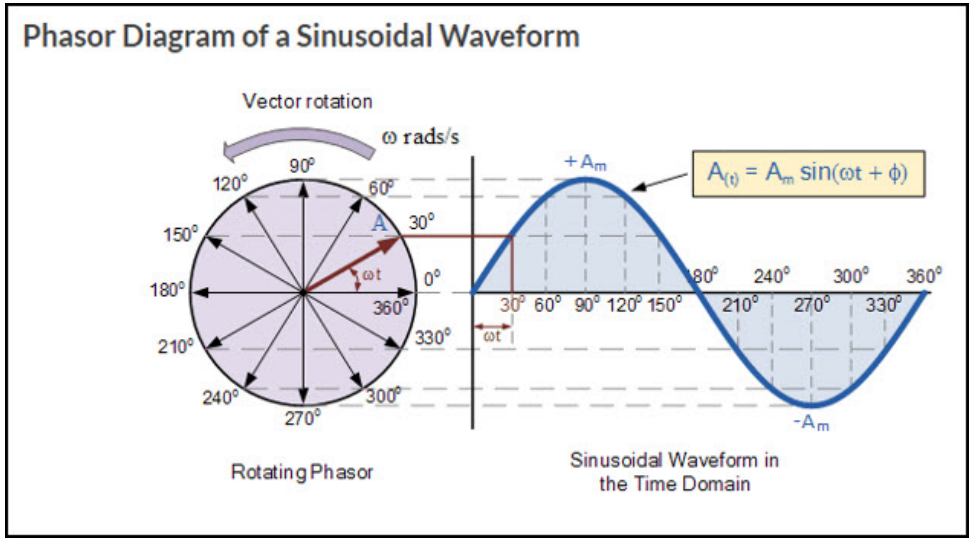
Angular Frequency (ω)

- Symbol: ω (omega)
- Unit: radians per second (rad/s)
- One complete cycle = 2π radians



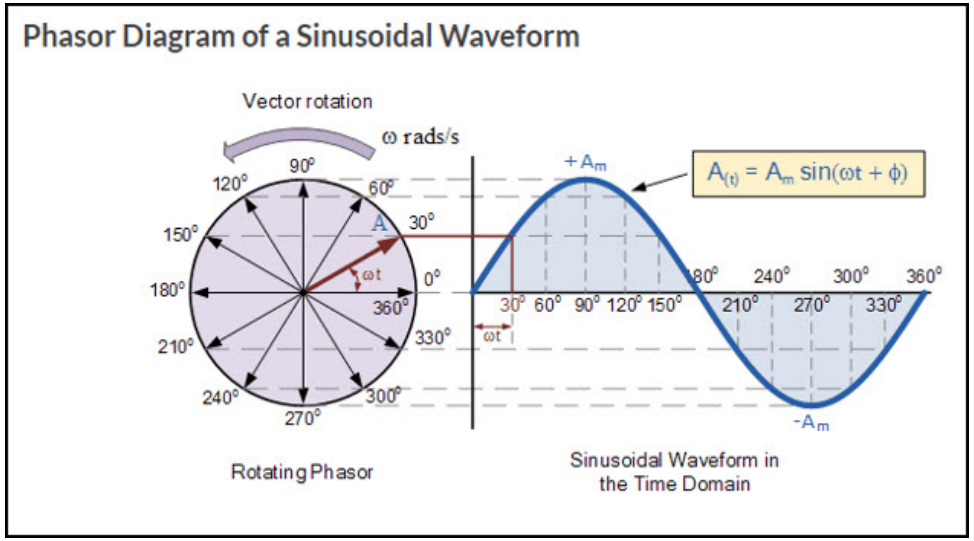
Relationship to Frequency

- $\omega = 2\pi f$
- Where:
- $\omega = Angular\ Frequency$
- $f = Frequency$



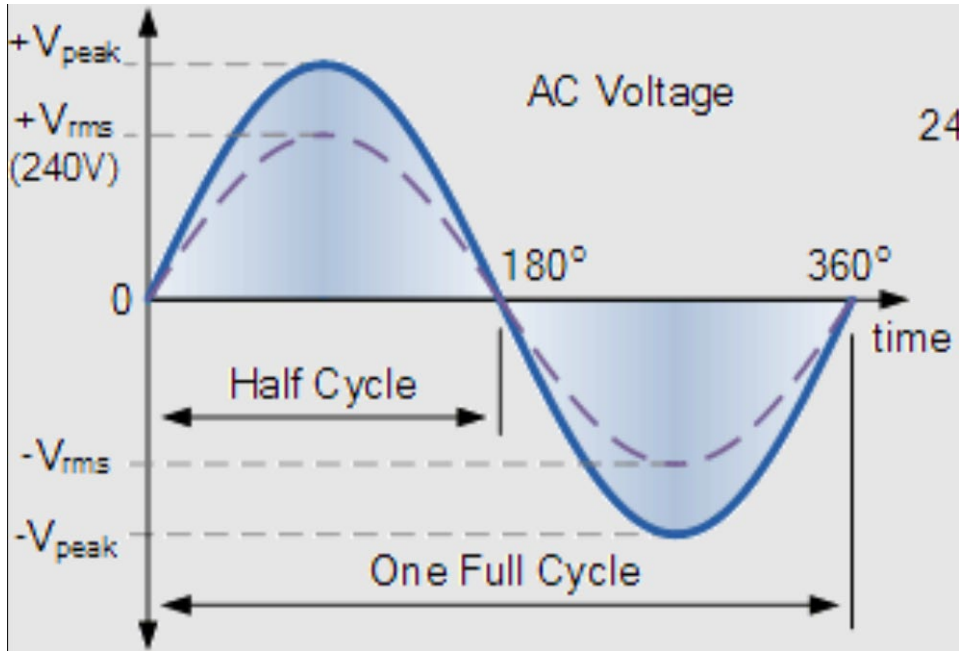
Why Angular Frequency Is Used

- Simplifies AC equations
- Links electrical signals to rotational motion
- Essential for:
  - Reactance ($X_L = \omega L, X_C = \frac{1}{\omega C}$)
  - Phasor diagrams
  - Motor and generator analysis



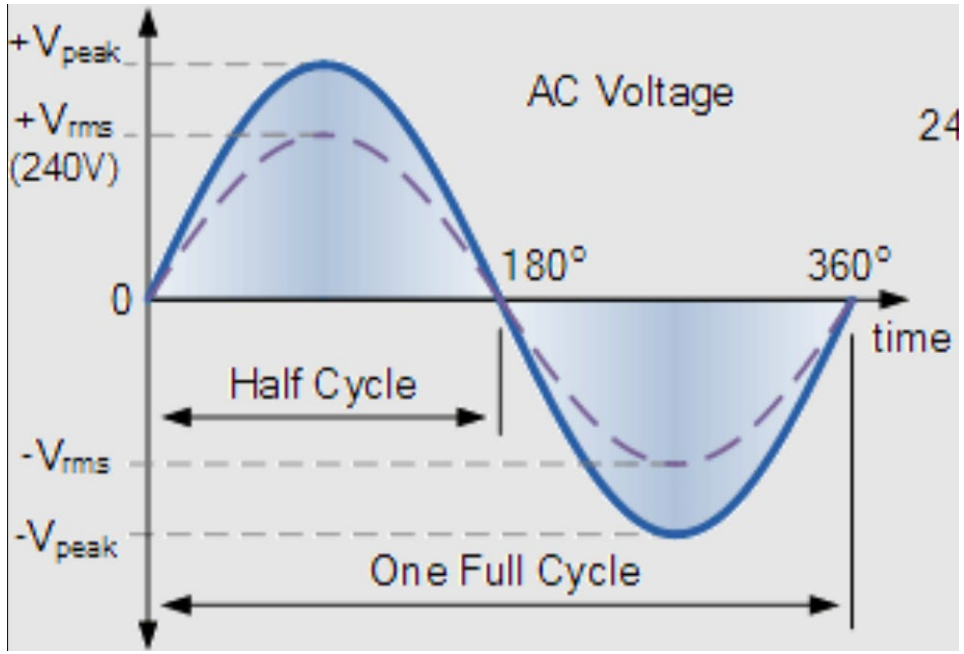
RMS Values (Root Mean Square)

- RMS value is the effective value of an AC voltage or current.
- It is the value of AC that would produce the same heating effect as an equivalent DC value in a resistor.



RMS Values (Root Mean Square)

- AC voltage and current are constantly changing
- Peak values are not useful for power calculations
- RMS allows AC and DC power to be compared directly
- Electrical ratings (mains voltage, equipment specs) are given in RMS



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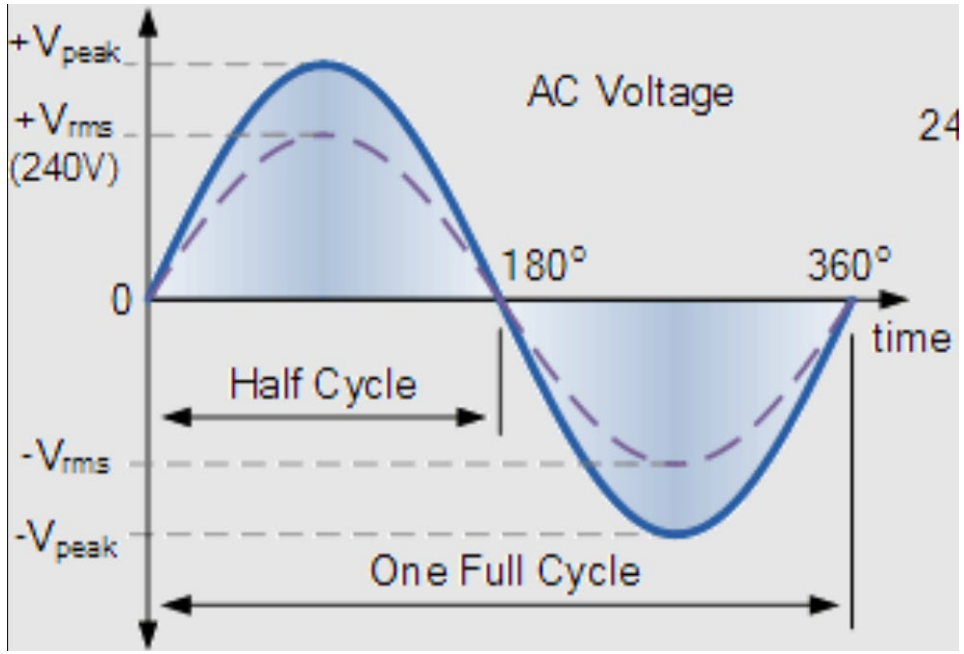


RMS Values (Root Mean Square)

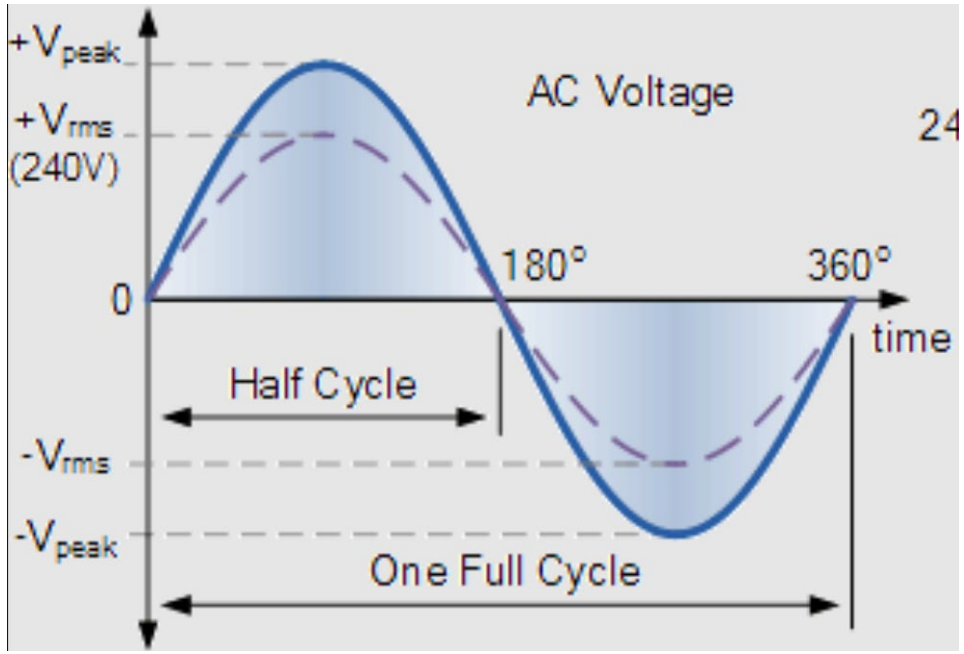
- To work out the RMS value we can divide our regular value by $\sqrt{2}$
- This is the same as multiplying the value by 0.707

$$V_{\mathrm{RMS}} = \frac{V_{\mathrm{peak}}}{\sqrt{2}}$$

$$I_{\mathrm{RMS}} = \frac{I_{\mathrm{peak}}}{\sqrt{2}}$$

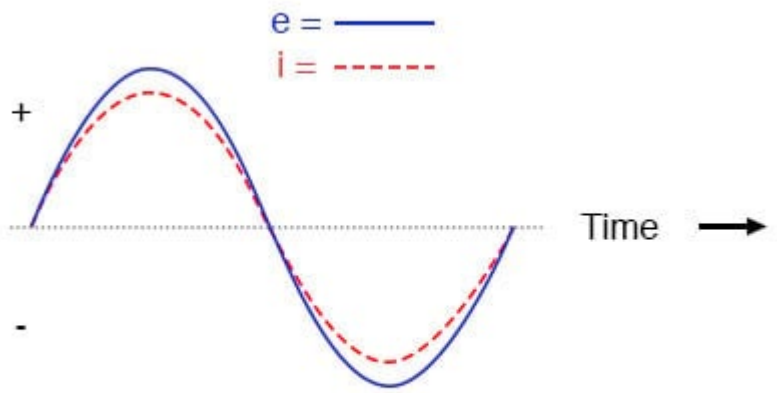
RMS Values (Root Mean Square)

- RMS ≠ peak value
- RMS is based on power and heating effect
- Measuring AC with a standard multimeter gives RMS (for sine waves)



AC and Resistive Circuits

- When an AC supply is applied to a pure resistor, the circuit behaviour is simple and predictable.
- The resistor opposes current by a fixed amount, regardless of direction.



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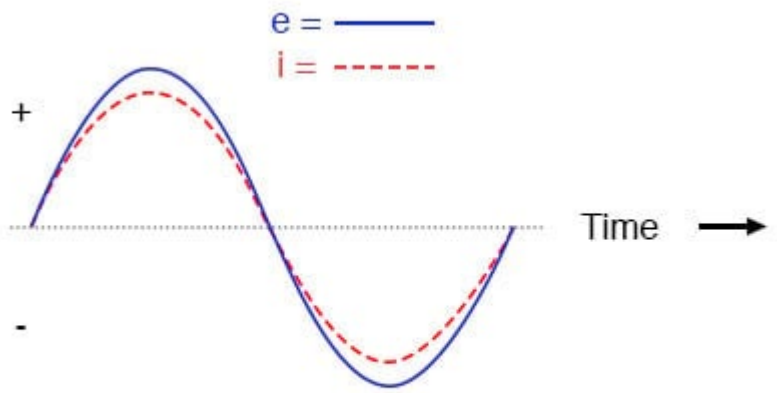
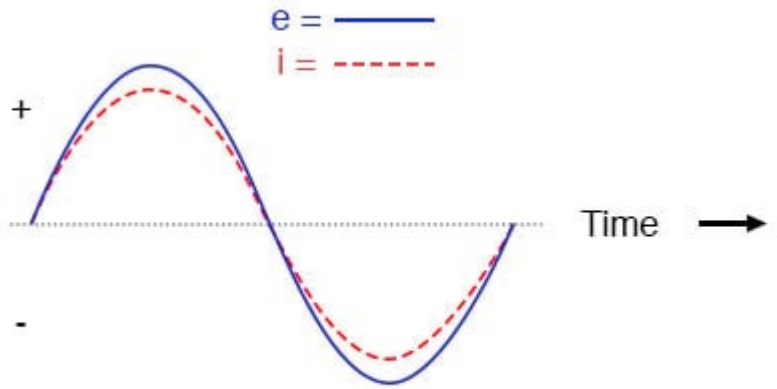


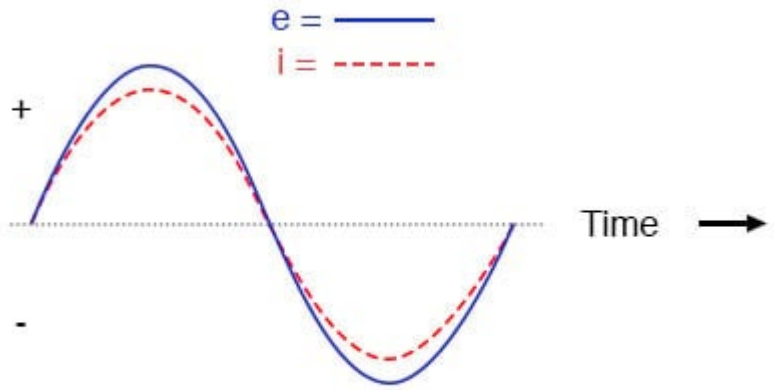
AC and Resistive Circuits

- Voltage and current change together
- They reach zero, positive peak, and negative peak at the same time
- Voltage and current are said to be in phase



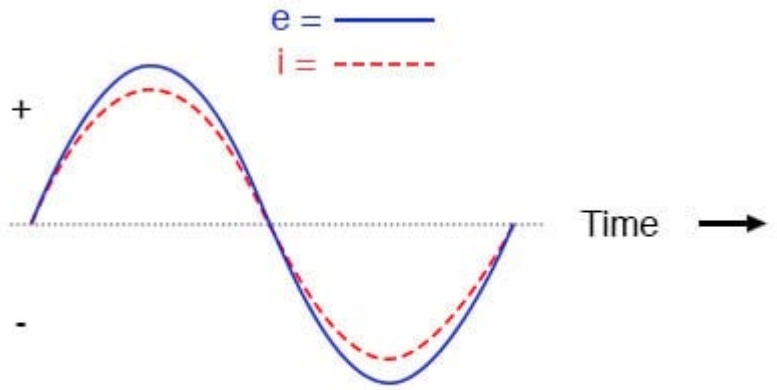
AC and Resistive Circuits

- Ohm's Law still applies using RMS values:
- $V_{RMS} = I_{RMS}R$
- Valid only for purely resistive AC circuits
- No phase shift to consider



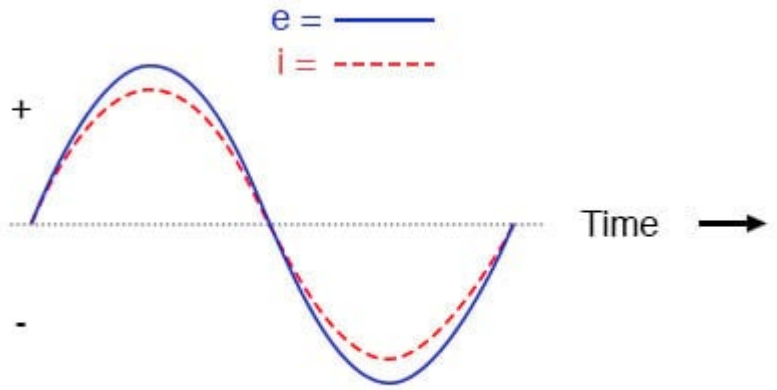
AC and Resistive Circuits

- Power is dissipated as heat
- Instantaneous power is always positive
- Average power is given by:
- $P = I_{RMS} * V_{RMS}$



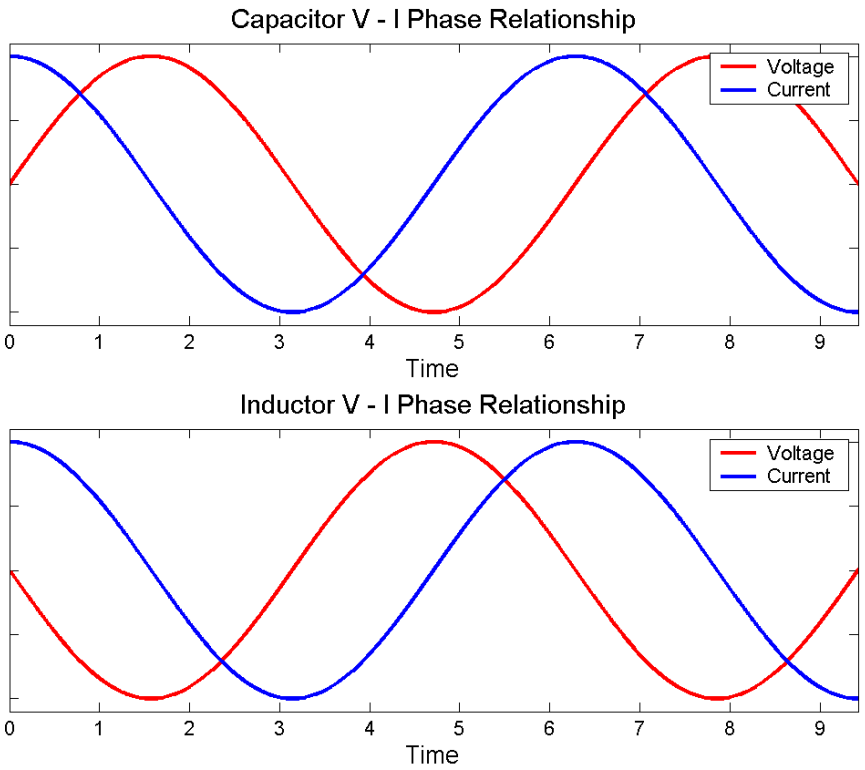
AC and Resistive Circuits

- No energy storage in resistors
- No phase difference between voltage and current
- AC resistive circuits behave similarly to DC, when using RMS values



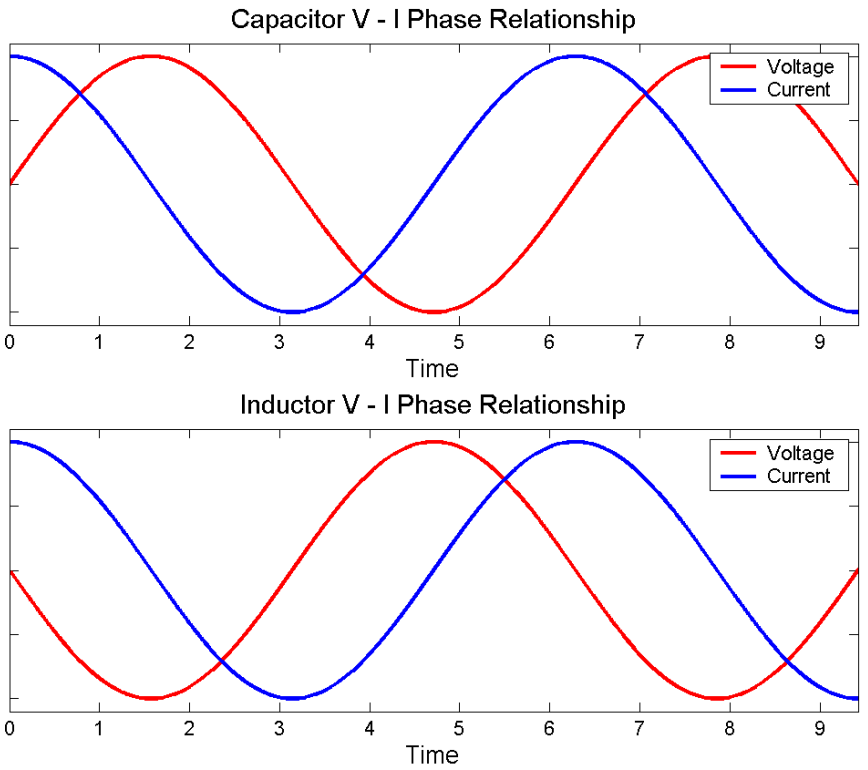
Reactance

- Reactance is the opposition to changing current or voltage in an AC circuit, caused by inductors and capacitors.
- Unlike resistance, reactance does not dissipate energy — it stores and releases energy.



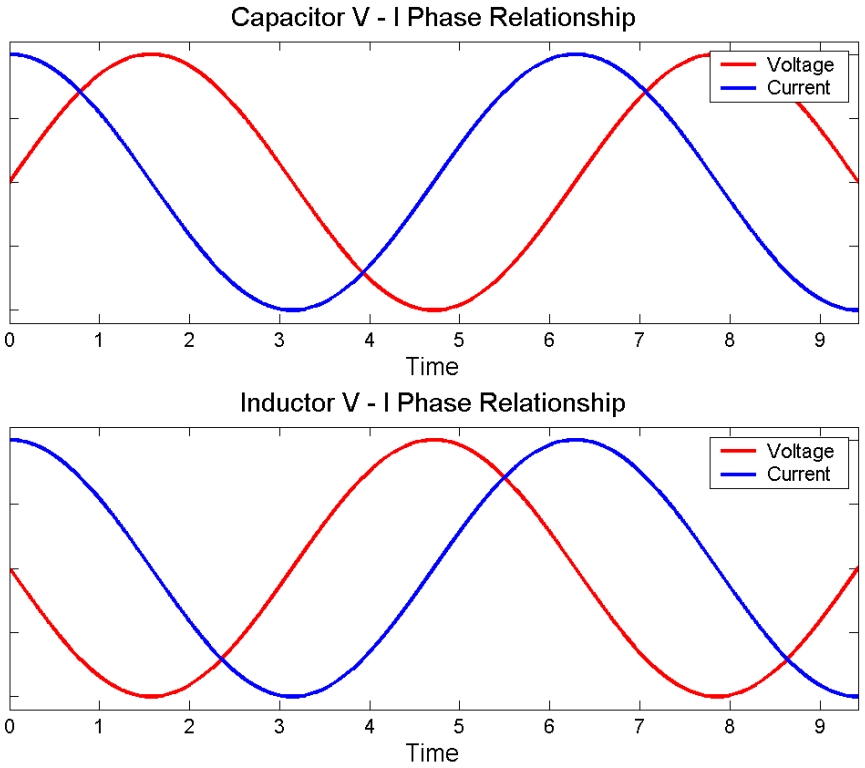
Reactance

- AC is constantly changing
- Some components resist change, not flow
- This creates a delay between voltage and current



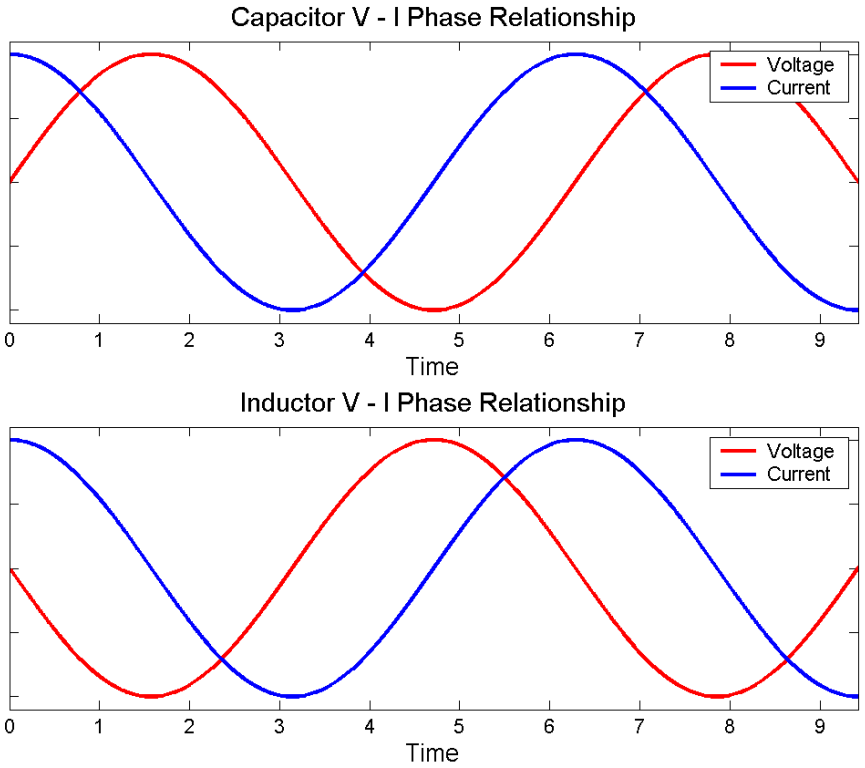
Types of Reactance

- Inductive reactance (X_L)
  - Caused by inductors
  - Opposes changes in current
  - Current lags voltage
- Capacitive reactance (X_C)
  - Caused by capacitors
  - Opposes changes in voltage
  - Current leads voltage



Reactance

- Reactance depends on frequency
- Reactance causes a phase shift
- Average power associated with reactance is zero



Why Reactance Matters

- Determines current in AC circuits
- Affects power factor
- Critical in motors, transformers, and filters