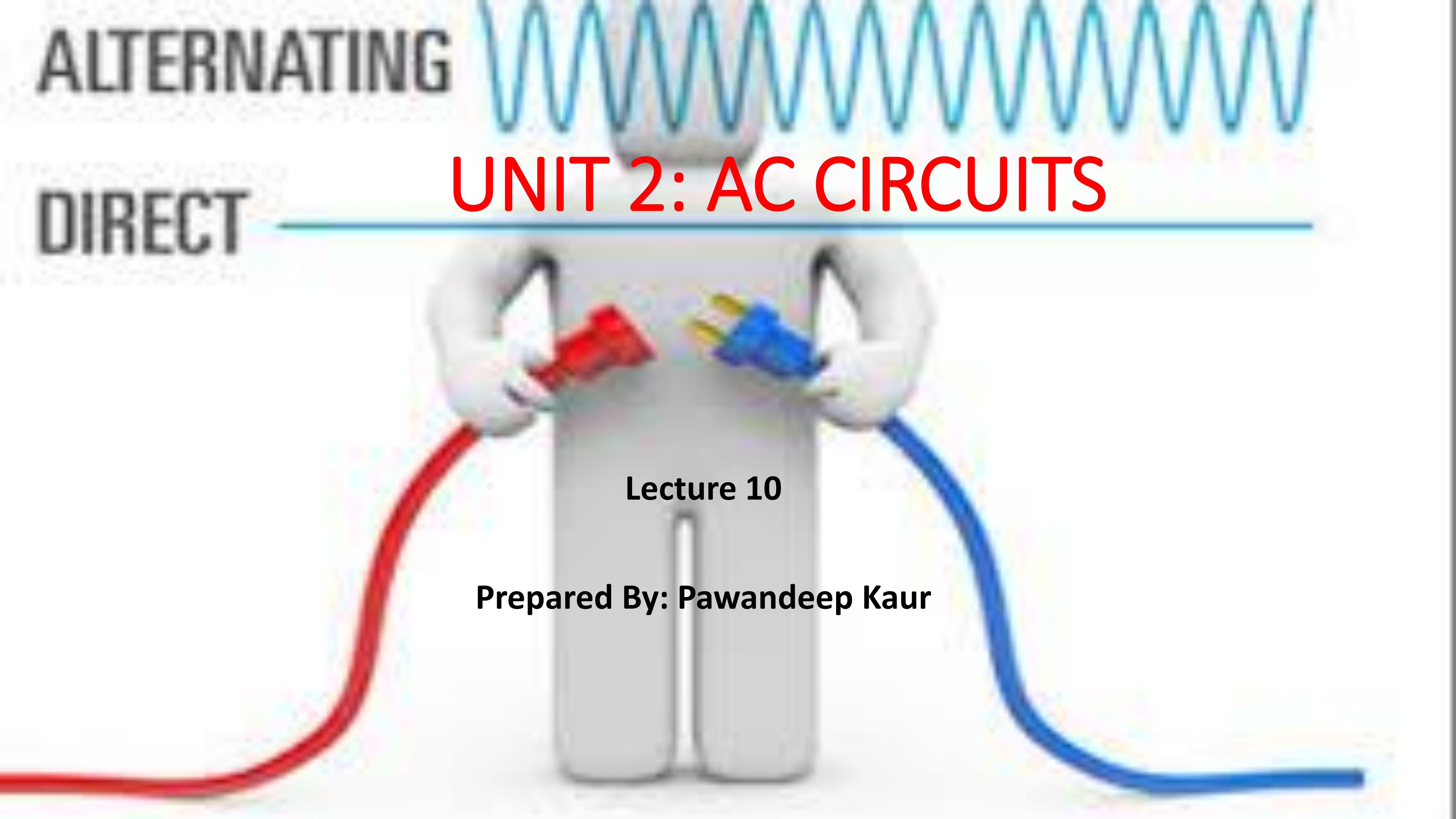


UNIT 2: AC CIRCUITS

Lecture 10

Prepared By: Pawandeep Kaur

Syllabus

Have an Overview!

Unit I

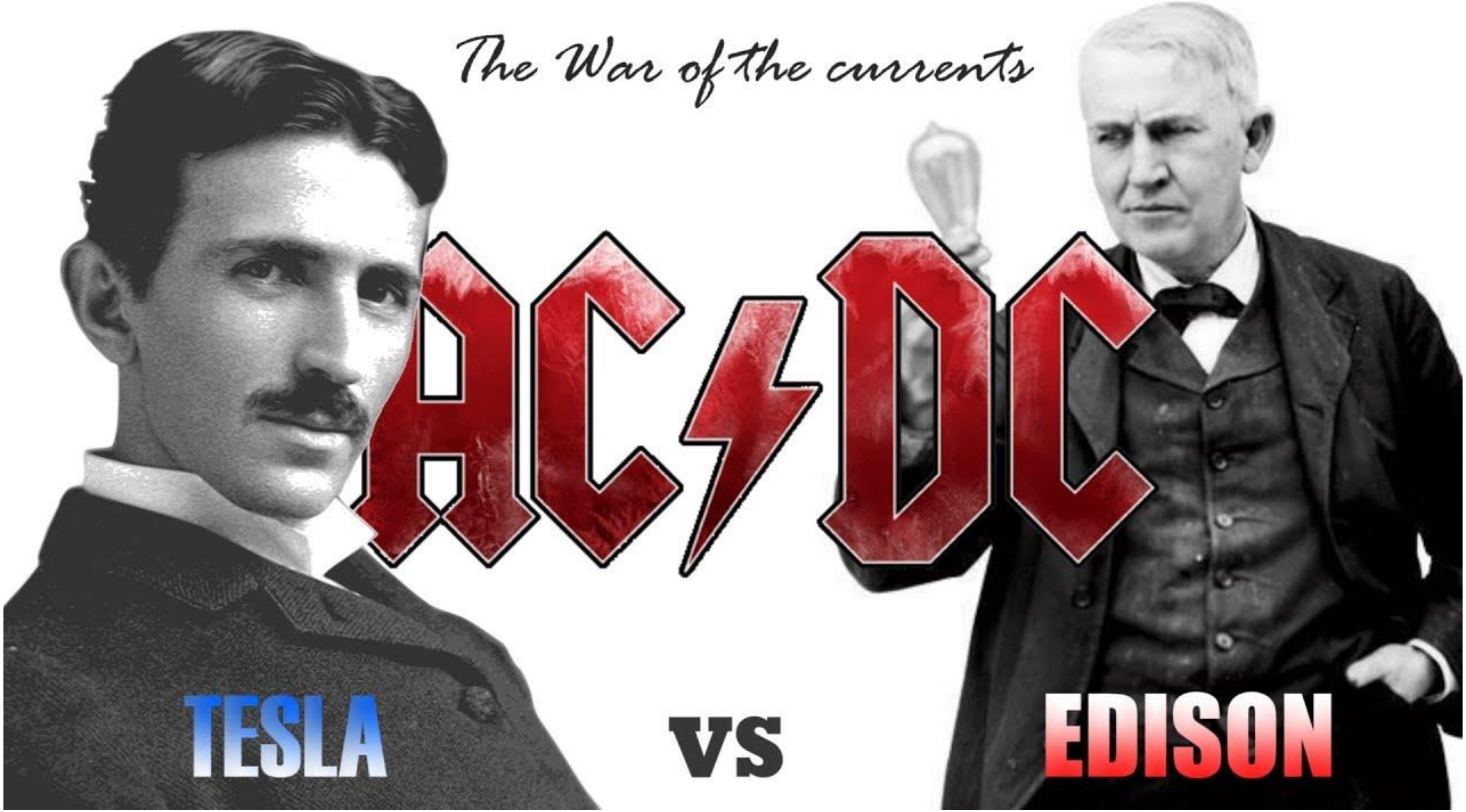
Fundamentals of D.C. circuits : resistance, inductance, capacitance, voltage, current, power and energy concepts, ohm's law, Kirchhoff's laws, basic method of circuit analysis, intuitive method of circuit analysis- series and parallel simplification, voltage division rule, current division rule, star–delta transformation, mesh and nodal analysis, introduction to dependent and independent sources, network theorems- superposition theorem, Thevenin's theorem, Norton's theorem, maximum power transfer theorem

Unit II

Fundamentals of A.C. circuits : alternating current and voltage, concept of notations (i, v, I, V), definitions of amplitude, phase, phase difference, RMS value and average value of an AC signal, complex representation of impedance, steady state analysis of ac circuits consisting of RL, RC and RLC (series), resonance in series RLC circuit, power factor and power calculation in RL, RC and RLC circuits, three-phase circuits- numbering and interconnection (delta or mesh connection) of three phases, relations in line and phase voltages and currents in star and delta

Todays Topic

- ✓ **Difference between DC and AC**
- ✓ **Alternating voltage and current**
- ✓ **Concept of Notations (i, v, I, V)**
- ✓ **Definitions of amplitude, phase, phase difference**
- ✓ **Average and RMS value of an AC signal**

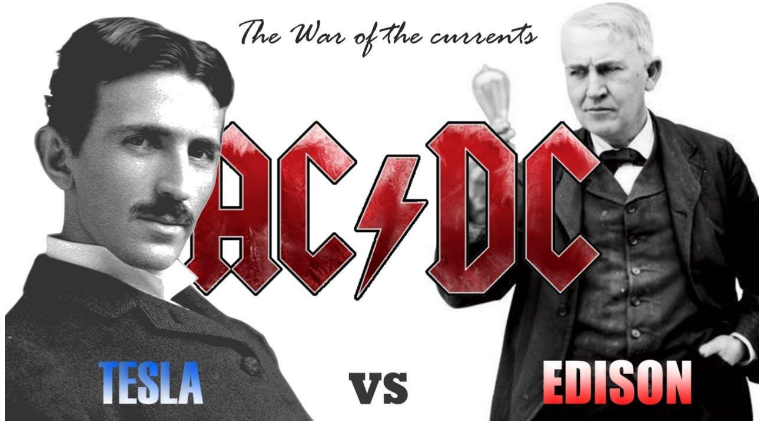

The War of the currents
AC/DC
TESLA
vs
EDISON

The war of the current

Introduction

- Historically, dc sources were the main means of providing electric power up until the late 1800s.
- At the end of that century, the battle of direct current versus alternating current began. Both had their advocates among the electrical engineers of the time.
- Because ac is more efficient and economical to transmit over long distances, ac systems ended up the winner.

DC	AC
Cannot be transmitted to longer distances because of the losses.	Safe to transfer over longer city distances
It flows in one direction in the circuit.	It reverses its direction while flowing in a circuit.
Magnitude of current or voltage does not vary with time	Magnitude of current or voltage does not vary with time
Electrons move steadily in one direction only.	Electrons keep switching directions - forward and backward.
Power Factor is always 1	Power Factor lies between 0 & 1.
The frequency of direct current is zero.	The frequency of alternating current is 50Hz or 60Hz depending upon the country.
Example: Cell, Battery.	Example: Generator.



Terminologies used in AC Circuits

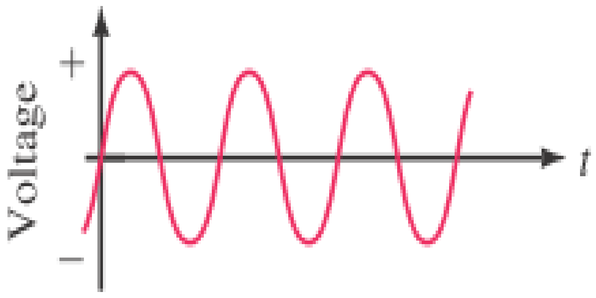
1. Peak value
2. Peak to Peak value
3. Instantaneous value
4. Average (Mean) value
5. Cycle
6. Frequency
7. Timeperiod
8. Phase
9. RMS value

Notation

- Sinusoidal ac Voltage

One complete variation is referred to as a cycle.

Starting at zero,
the voltage increases to a positive peak amplitude,
decreases to zero,
changes polarity,
increases to a negative peak amplitude,
then returns again to zero.



(b) A continuous stream of cycles

- Since the waveform repeats itself at regular intervals, it is called a **periodic signal**.

- Symbol for an ac Voltage Source

Lowercase letter e is used
to indicate that the voltage varies with time.

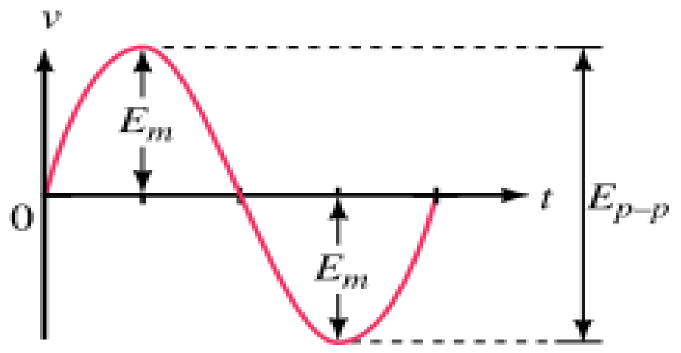
Notations

Attributes of Periodic Waveforms

Amplitude , Peak-Value, and Peak-to-Peak Value

Amplitude (E_m):

The amplitude of a sine wave is the distance from its average to its peak.



(a)

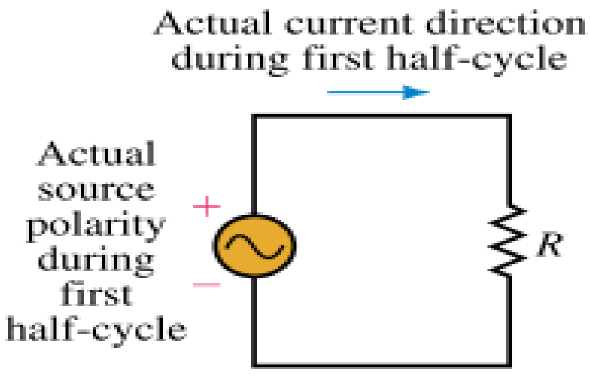
Peak-to-Peak Value (E_{p-p}):

It is measured between minimum and maximum peaks.

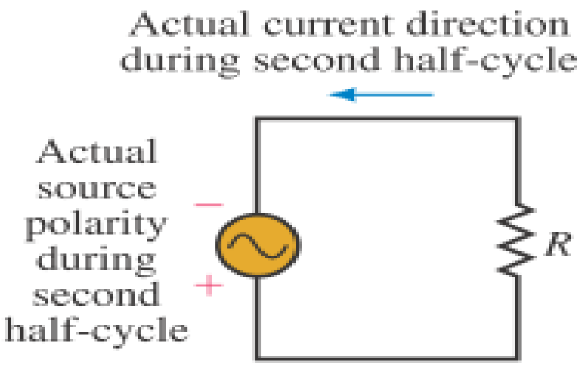
Peak Value

The peak value of a voltage or current is its maximum value with respect to zero.

Sinusoidal ac Current



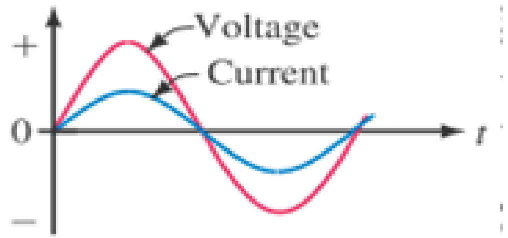
(a)



- During the first half-cycle, the source voltage is positive
- Therefore, the current is in the clockwise direction.

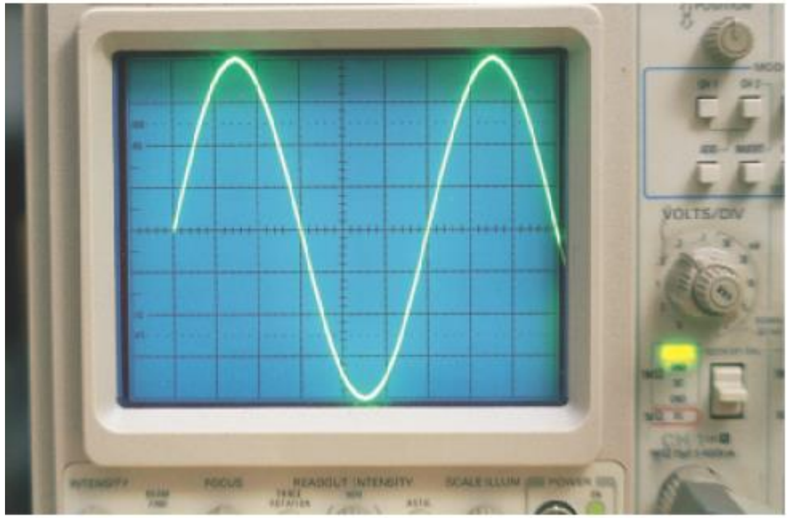
- During the second half-cycle, the voltage polarity reverses
- Therefore, the current is in the counterclockwise direction.

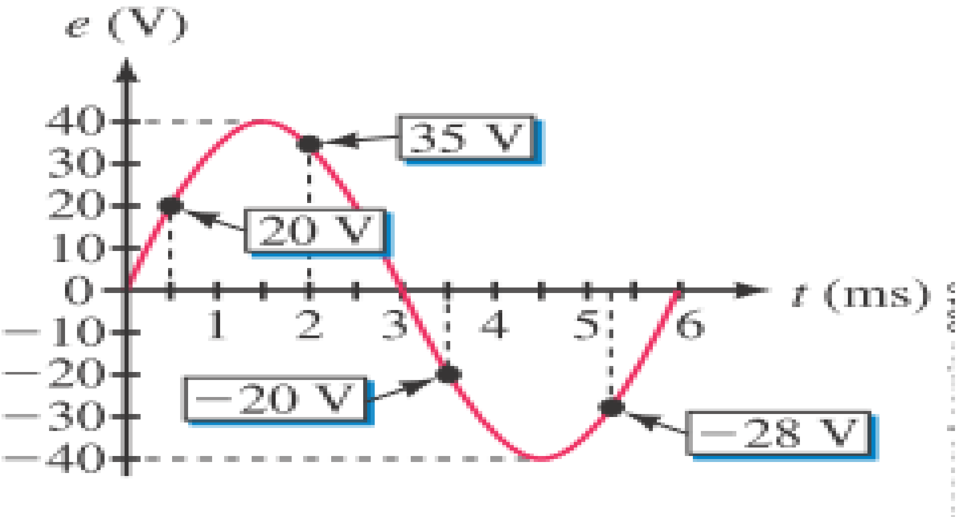
- Since current is proportional to voltage, its shape is also sinusoidal



Instantaneous Value

- As the coil voltage changes from instant to instant. The value of voltage at any point on the waveform is referred to as its **instantaneous value.**





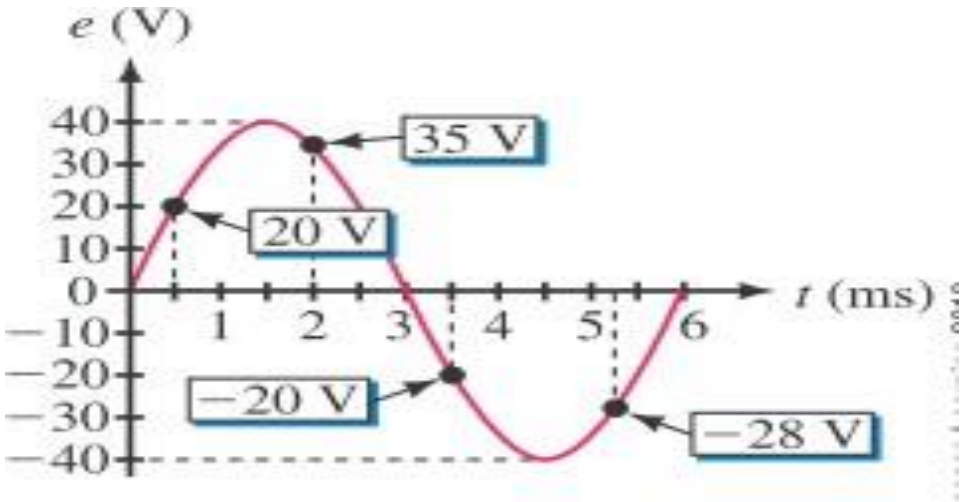
(b) Values scaled from the photograph

- ✓ at t = 0 ms, the voltage is zero.
- ✓ at t=0.5 ms, the voltage is 20V.

Quick Quiz (POLL)

Peak to Peak Value for the given signal is:

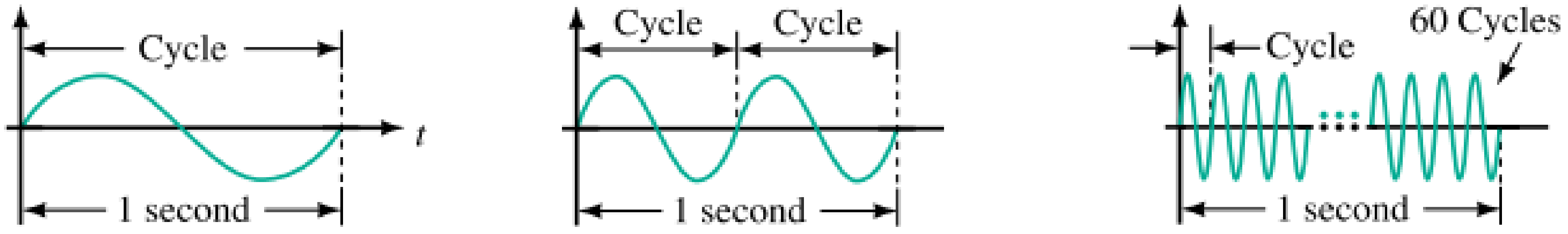
A. 40
B. -40
C. 0
D. 80



Attributes of Periodic Waveforms

- Periodic waveforms (i.e., waveforms that repeat at regular intervals), regardless of their wave shape, may be described by a group of attributes such as:
  - ✓ **Frequency, Period, Amplitude, Peak value.**

Frequency: The number of cycles per second of a waveform is defined



(a) 1 cycle per second = 1 Hz (b) 2 cycles per second = 2 Hz (c) 60 cycles per second = 60 Hz

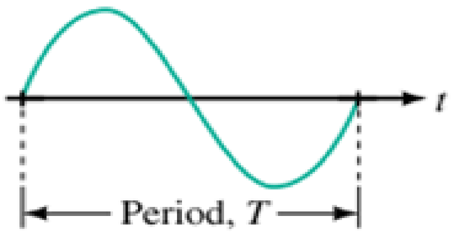
- Frequency is denoted by the lower-case letter f.
- In the SI system, its unit is the hertz (Hz, named in honor of pioneer researcher Heinrich Hertz, 1857–1894).

$$1 \text{ Hz} = 1 \text{ cycle per second}$$

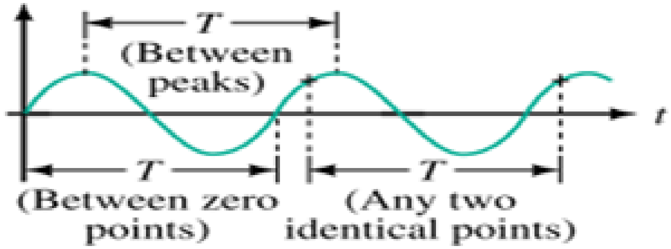
Attributes of Periodic Waveforms

- **Period:**
  - The period, T, of a waveform, is the duration of one cycle.
- It is the inverse of frequency.

$$T = \frac{1}{f} \quad \text{(s)}$$



- The period of a waveform can be measured between any two corresponding points (Often it is measured between zero points because they are easy to establish on an oscilloscope trace).



Quick Quiz (POLL)

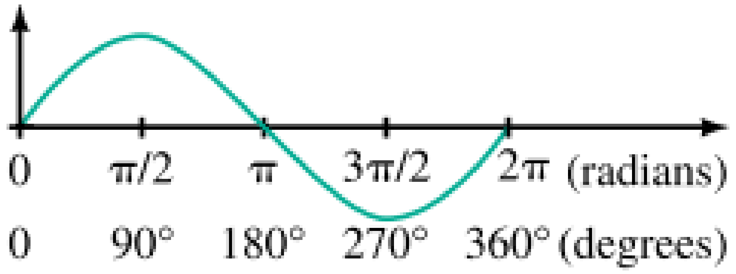
What is the Time period of the sinusoidal signal for AC in India?

A. 50 ms
B. 50 Hz
C. 20 ms
D. 10 ms

Radian Measure

- In practice, q is usually expressed in radians per second,
- Radians and degrees are related by :

$$2\pi \text{ radians} = 360^\circ$$



(b) Cycle length scaled in degrees and radians

For Conversion:

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

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

Relationship between ω, T, and f

- Earlier you learned that one cycle of sine wave may be represented as either:

$$\alpha = 2\pi \text{ rads} \qquad t = T \text{ s}$$

- Substituting these into:

$$\alpha = \omega t$$

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

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

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

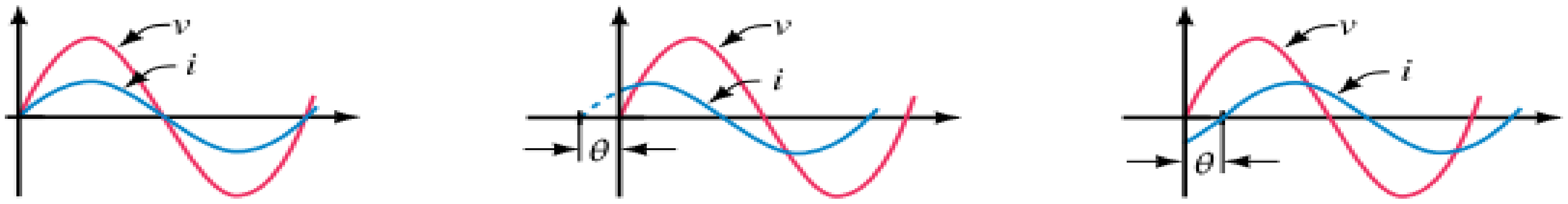
Sinusoidal Voltages and Currents as Functions of Time:

- We could replace the angle α as:

$$e = E_m \sin \omega t$$

Phasor Difference

- Phase difference refers to the angular displacement between different waveforms of the same frequency.



(a) In phase (b) Current leads (c) Current lags

FIGURE 15–40 Illustrating phase difference. In these examples, voltage is taken as reference.

- The terms lead and lag can be understood in terms of phasors. If you observe phasors rotating as in Figure, the one that you see passing first is leading and the other is lagging.

Practice Problem 1

Given the sinusoid $30\sin(4\pi t - 75°)$calculate its amplitude, phase, angular frequency, period, and frequency.

Practice Problem 1

Practice Problem 2

The equation for an ac voltage is given as $v = 0.04 \sin(2000t + 60°)$ V. Determine the frequency, the angular frequency, and the instantaneous voltage when $t = 160$ µs. What is the time represented by a 60° phase angle?

Practice Problem 2

The equation for an ac voltage is given as $v = 0.04 \sin(2000t + 60°)$ V. Determine the frequency, the angular frequency, and the instantaneous voltage when $t = 160\ \mu s$. What is the time represented by a 60° phase angle?

UNIT 2: AC CIRCUITS

Lecture 11

Prepared By: Pawandeep Kaur

Recap Quick Quiz (POLL)

$\frac{2\pi}{3}$ radians correspond to________ angle?

A)120

B)270

C)360

D)120

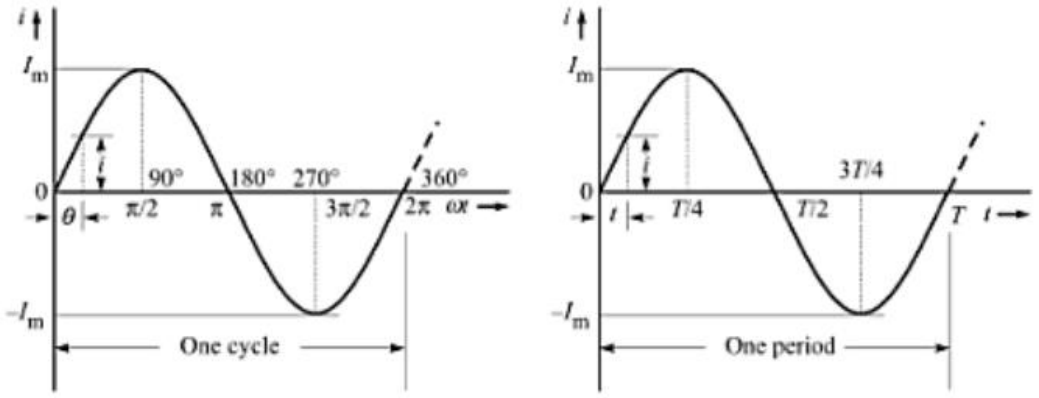
Average Value

Algebraic sum of all the values divided by the total number of values.

Same concept is applicable for a waveform that varies with time.

$$V_{av} = \frac{\text{Area under full cycle}}{\text{Length of one cycle}} = \frac{\int_0^{2\pi} v\,d\theta}{2\pi} = \frac{1}{2\pi}\int_0^{2\pi} v\,d\theta = \frac{1}{2\pi}\int_0^{2\pi} v\,d(\omega t)$$

$$V_{av} = \frac{1}{T}\int_0^{T} v\,dt$$



(a) Current i versus angle ωt. (b) Current i versus time t.

Thus, the average value over full cycle is ZERO

Quick Quiz (Poll)

The average value of current in a sinusoidal signal over full cycle is:

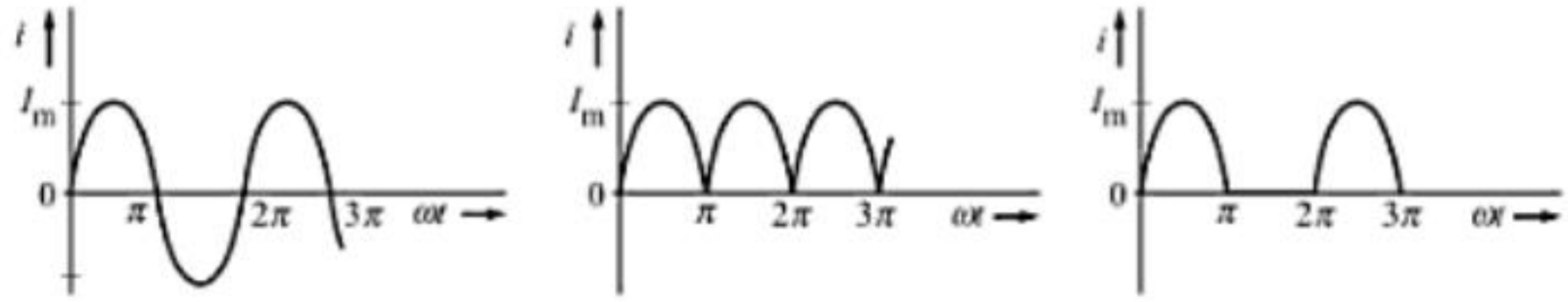
A. $I_m/2$

B. $I_m/\sqrt{2}$

C. 1

D. 0

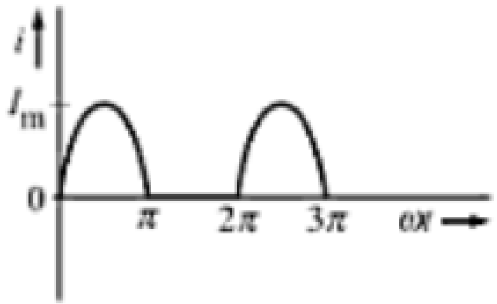
However, an average value can be defined for the half-cycle (positive or negative) for a sinusoidal signal.



(a) Sinusoidal ac current. (b) Full-wave rectifier output. (c) Half-wave rectifier output.

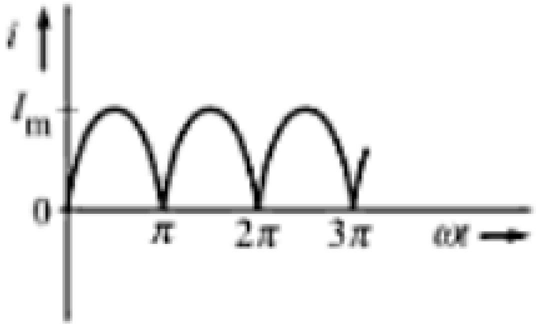
Average Value

Half Wave Rectifier



Half-wave rectifier output.

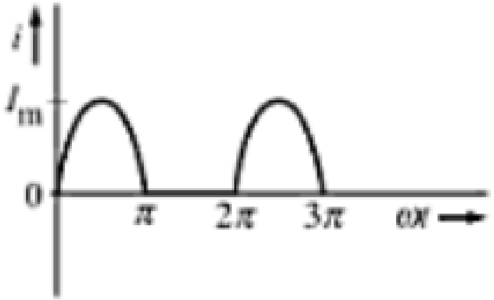
Full Wave Rectifier



Full-wave rectifier output.

Average Value

Half Wave Rectifier

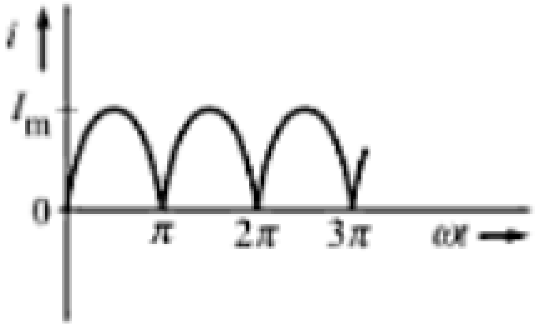


Half-wave rectifier output.

$$I_{av} = \frac{1}{2\pi}\int_0^{2\pi} i\,d(\omega t) = \frac{1}{2\pi}\left[\int_0^{\pi} I_m \sin\omega t\, d(\omega t) + \int_{\pi}^{2\pi} 0\, d(\omega t)\right]$$

$$= \frac{I_m}{2\pi}[-\cos\omega t]_0^{\pi} = \frac{I_m}{\pi} = \mathbf{0.318}I_m$$

Full Wave Rectifier



Full-wave rectifier output.

$$I_{av} = \frac{\text{Area under half cycle}}{\text{Length of half cylcle}} = \frac{1}{\pi}\int_0^{\pi} i\,d(\omega t) = \frac{1}{\pi}\int_0^{\pi} I_m \sin\,\omega t\, d(\omega t)$$

$$= \frac{I_m}{\pi}[-\cos\omega t]_0^{\pi} = \frac{I_m}{\pi}[-\cos\pi + \cos 0°] = \frac{2I_m}{\pi} = \mathbf{0.637}I_m$$

Quick Quiz (Poll)

Based on the previous results, we can say that the average value of half wave rectifier is__________ than full wave rectifier.

A. Double
B. Half
C. Same
D. None of these

RMS (Effective) Value

- The r.m.s value is defined in terms of heating effect.
- The r.m.s. value of an alternating current is given by that steady (d.c.) current which when flowing through a given circuit for a given time produces the same heat as produced by the alternating current when flowing through the same circuit for the same time.

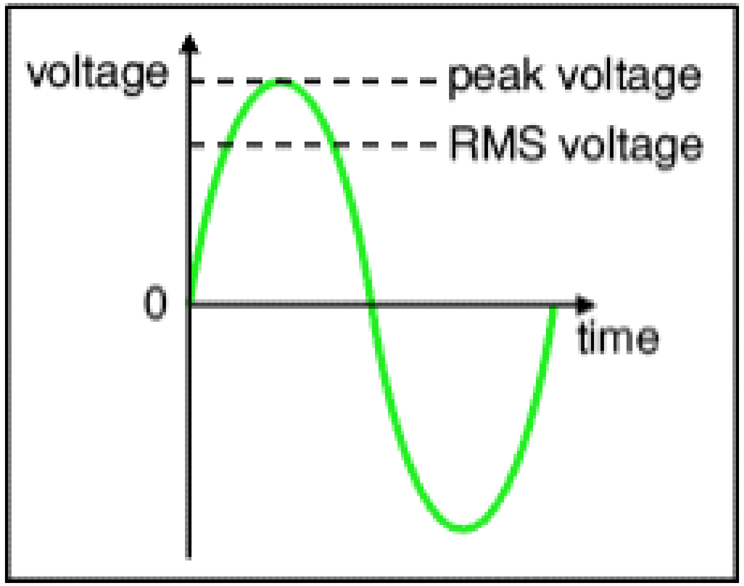
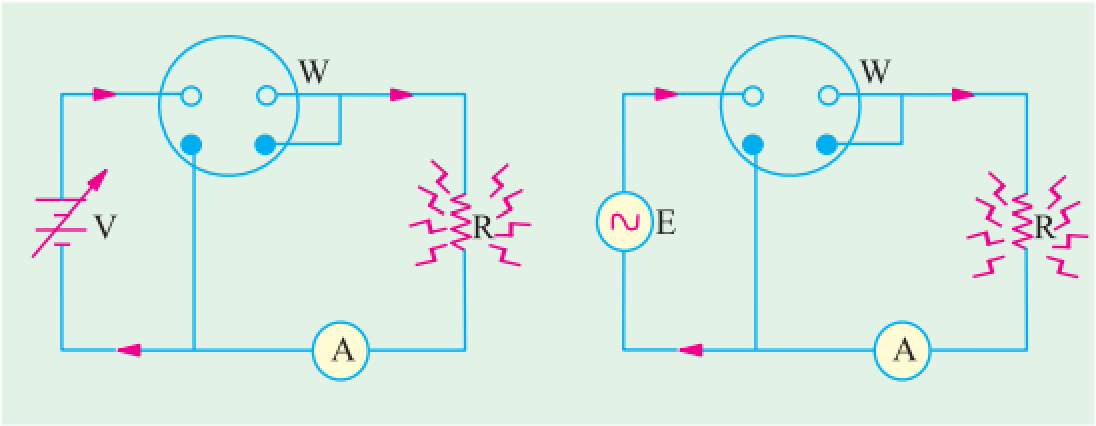
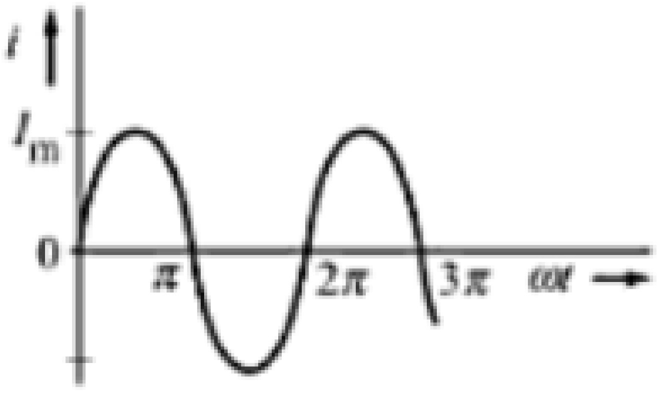


Figure- Difference between peak and RMS voltage

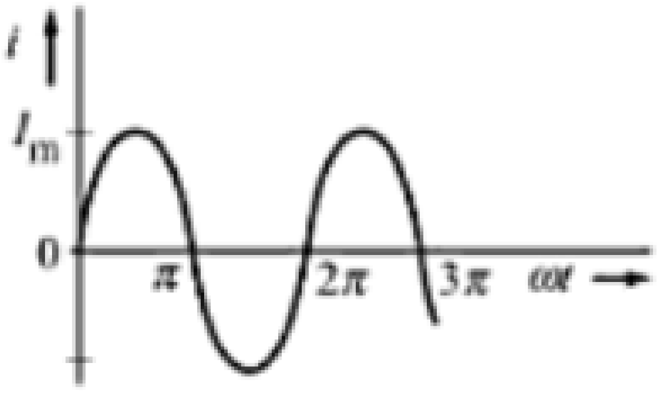


RMS (Effective) Value



Sinusoidal ac current.

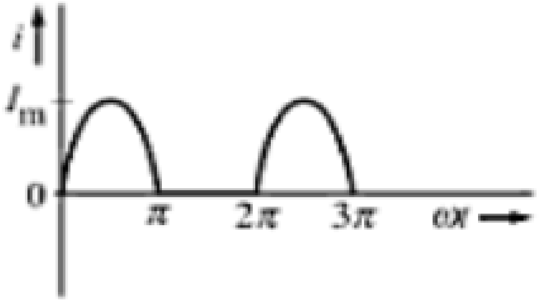
RMS (Effective) Value



Sinusoidal ac current.

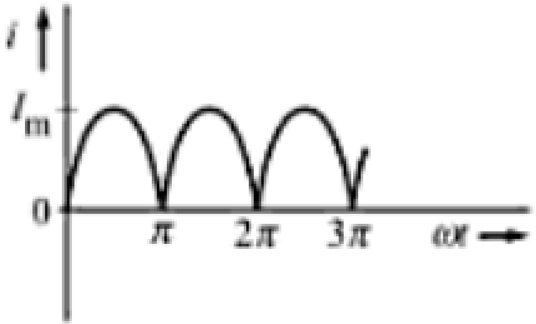
RMS Value

Half Wave Rectifier



Half-wave rectifier output.

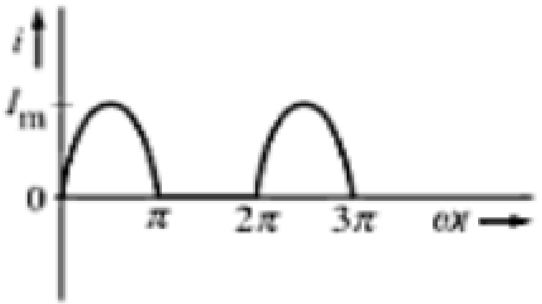
Full Wave Rectifier



Full-wave rectifier output.

RMS Value

Half Wave Rectifier

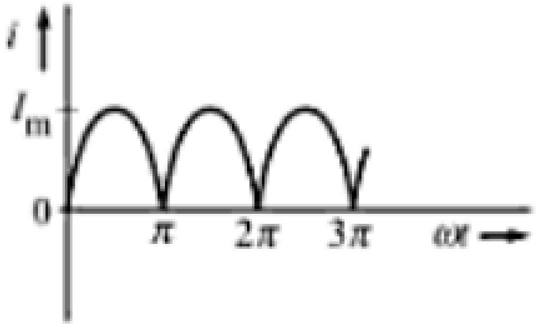


Half-wave rectifier output.

$$I_{eff} = \sqrt{\frac{1}{2\pi}\int_0^{2\pi} i^2\, d(\omega t)} = \sqrt{\frac{1}{2\pi}\int_0^{\pi} I_m^2 \sin^2 \omega t\, d(\omega t) + \frac{1}{2\pi}\int_{\pi}^{2\pi} 0\, d(\omega t)}$$

$$= \sqrt{\frac{I_m^2}{4\pi}\int_0^{\pi}(1-\cos 2\omega t)\, d(\omega t) + 0} = \sqrt{\frac{I_m^2}{4\pi}\left[\omega t - \frac{\sin 2\omega t}{2}\right]_0^{\pi}} = \frac{I_m}{\sqrt{4}} = \frac{I_m}{2}$$

Full Wave Rectifier



Full-wave rectifier output.

$$I_{eff} = \sqrt{\frac{1}{\pi}\int_0^{\pi} i^2\, d(\omega t)} = \sqrt{\frac{1}{\pi}\int_0^{\pi} I_m^2 \sin^2 \omega t\, d(\omega t)} = \sqrt{\frac{I_m^2}{2\pi}\int_0^{\pi}(1-\cos 2\omega t)\, d(\omega t)}$$

$$= \sqrt{\frac{I_m^2}{2\pi}\left[\omega t - \frac{\sin 2\omega t}{2}\right]_0^{\pi}} = \frac{I_m}{\sqrt{2}}$$

Quick Quiz (Poll)

- What is the effective value of current ?
- A)RMS current
- B)Average current
- C)Instantaneous current
- D)total current

Quick Quiz (Poll)

- The voltage of domestic supply is 230V.This figure represents
- A)Mean value
- B)RMS value
- C)Peak Value
- D) Average value

Form Factor and Peak Factor

- Form Factor, $K_f = \frac{V_{rms}}{V_{avg}}$

- Peak Factor or Crest Factor, $K_p = \frac{V_m}{V_{rms}}$

Let us calculate these two factors for ***a sinusoidal voltage waveform***,

$$K_f = \frac{V_{rms}}{V_{av}} = \frac{V_m/\sqrt{2}}{2V_m/\pi} = \frac{0.707\,V_m}{0.637\,V_m} = \mathbf{1.11}$$

And

$$K_p = \frac{V_m}{V_{rms}} = \frac{V_m}{V_m/\sqrt{2}} = \sqrt{2} = \mathbf{1.414}$$

Quick Quiz (Poll)

For a pure sinusoidal waveform the Form Factor will always be equal to:

A. $\frac{1}{\sqrt{2}}$

B. 0.637

C. 1.11

D. 1.414

Importance of Form Factor and Peak Factor

- Actually some of our meters are designed to measure the RMS values but that is of pure sinusoidal waveforms, if there comes any distortion in the waveform, the meter **won't give the correct** RMS value. For meter the waveform is still a sinusoidal but it doesn't detect the distortion that's why we use form factor to get accurate value of RMS by just multiplying form factor with the average value of that distorted waveform. It is helpful in finding the RMS values of waveforms other than pure sinusoidal.
- Similarly, Some loads, such as switching power supplies or lamp ballasts, have current waveforms that are not sinusoidal. They draw a high current for a short period of time, and their crest factors, therefore, can be quite a bit higher than 1.414.