PHYS 104
1ST semester 1439-1440

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Lecture 27

Chapter 33
Alternating Current Circuits

- 33.1 AC Sources
- 33.2 Resistors in an AC Circuit
- 33.3 Inductors in an AC Circuit
- 33.4 Capacitors in an AC Circuit
- 33.5 The RLC Series Circuit
- 33.6 Power in an AC Circuit
- 33.7 Resonance in a Series RLC Circuit

33.1 AC Sources

- An AC circuit consists of circuit elements and a power source that provides an alternating voltage Δv.
- This time-varying voltage is described by $\Delta v = \Delta V_{\max} \sin \omega t$
  - where ΔV_{max} is the maximum output voltage of the AC source, or the **voltage amplitude.**
- The angular frequency of the AC voltage is

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

  - where f is the frequency of the source and T is the period.
- Because the output voltage of an AC source varies sinusoidally with time, the voltage is positive during one half of the cycle and negative during the other half.

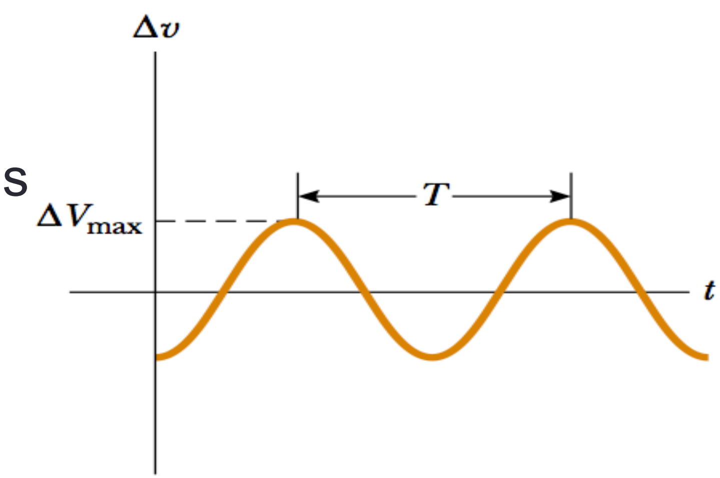
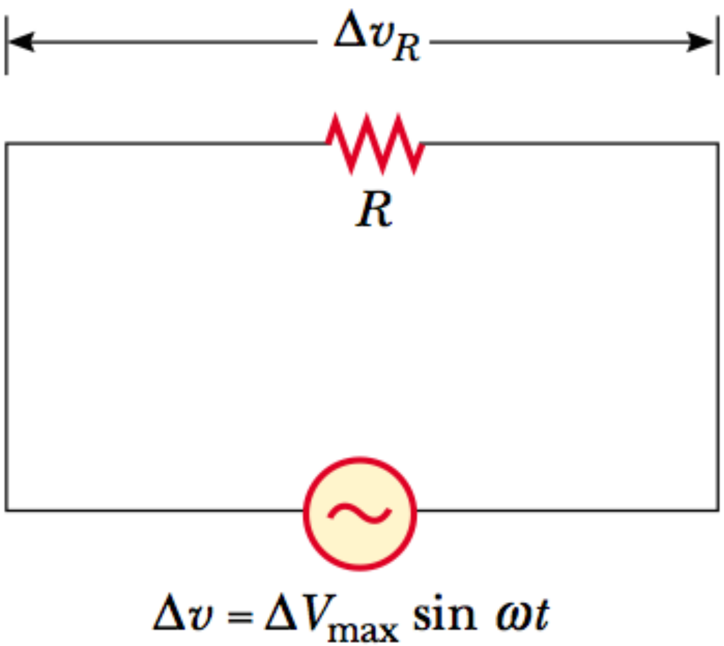


Figure 33.1 The voltage supplied by an AC source is sinusoidal with a period T.

33.2 Resistors in an AC Circuit

- Consider a simple AC circuit consisting of a resistor and an AC source.
- At any instant, the algebraic sum of the voltages around a closed loop in a circuit must be zero (Kirchhoff's loop rule). Therefore, $\Delta v + \Delta v_R = 0$, so that the magnitude of the source voltage equals the magnitude of the voltage across the resistor:

$$\Delta v = \Delta v_R = \Delta V_{\max} \sin \omega t$$



- Δv_R is the instantaneous voltage across the resistor.

33.2 Resistors in an AC Circuit

- The instantaneous current in the resistor is

$$i_R = \frac{\Delta v_R}{R} = \frac{\Delta V_{\max}}{R} \sin \omega t = I_{\max} \sin \omega t$$

- where I_{max} is the maximum current:

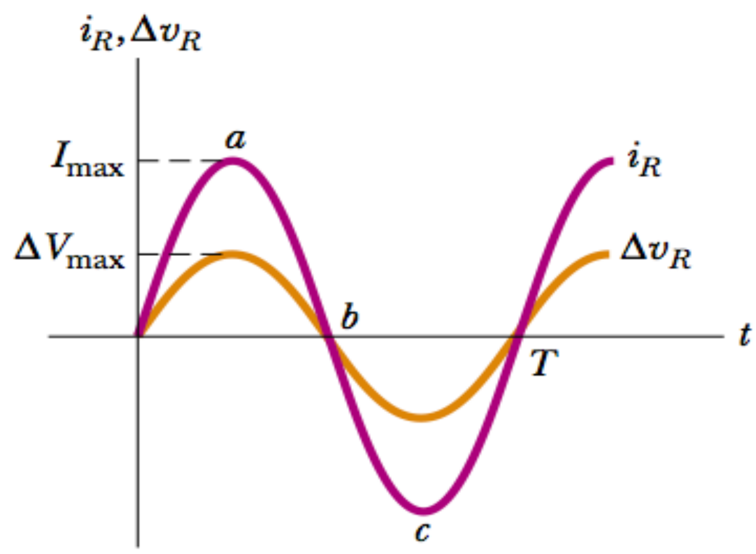
$$I_{\max} = \frac{\Delta V_{\max}}{R}$$

- The instantaneous voltage across the resistor is

$$\Delta v_R = I_{\max} R \sin \omega t$$

33.2 Resistors in an AC Circuit

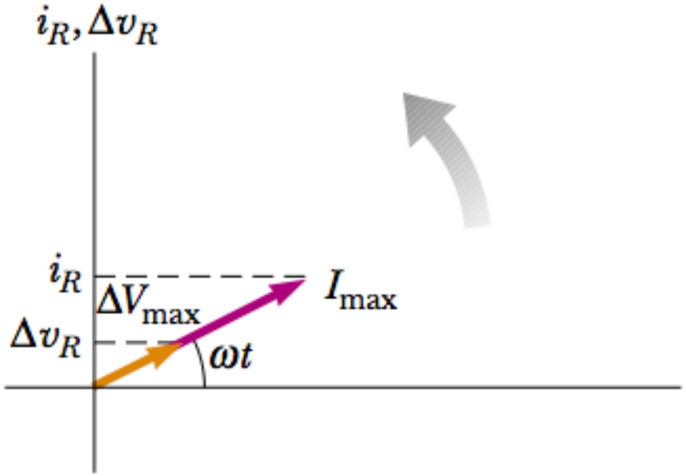
- Plots of the instantaneous current i_R and instantaneous voltage Δv_R across a resistor as functions of time.
- The current is **in phase** with the voltage, which means that the current is zero when the voltage is zero, maximum when the voltage is maximum, and minimum when the voltage is minimum.
- At time $t = T$, one cycle of the time-varying voltage and current has been completed.



(a)

33.2 Resistors in an AC Circuit

- To simplify our analysis of circuits containing two or more elements, we use graphical constructions called *phasor diagrams.*
- A **phasor** is a vector whose length is proportional to the maximum value (ΔV_{max} for voltage and I_{max} for current) and which rotates counterclockwise at an angular speed equal to the angular frequency.
- The projection of the phasor onto the vertical axis represents the instantaneous value.
- Thus, we can use the projections of phasors to represent current values that vary sinusoidally in time. We can do the same with time-varying voltages.



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33.2 Resistors in an AC Circuit

- **The average value of the current over one cycle is zero.** That is, the current is maintained in the positive direction for the same amount of time and at the same magnitude as it is maintained in the negative direction.
- The **rms current** (the notation *rms* stands for *root-mean-square*)

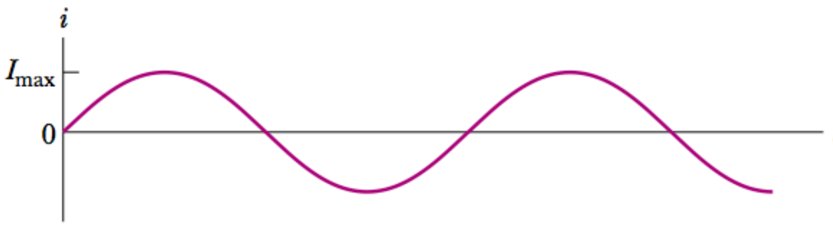
$$I_{rms} = \frac{I_{max}}{\sqrt{2}} = 0.707 I_{max}$$

- The average power delivered to a resistor

$$\mathcal{P}_{av} = I_{rms}^2 R$$

- The rms voltage

$$\Delta V_{rms} = \frac{\Delta V_{max}}{\sqrt{2}} = 0.707\,\Delta V_{max}$$



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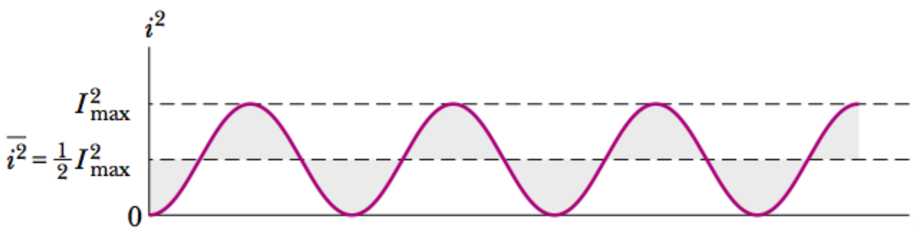

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Example 33.1 What Is the rms Current?

The voltage output of an AC source is given by the expression $\Delta v = (200\text{ V}) \sin \omega t$. Find the rms current in the circuit when this source is connected to a $100\text{-}\Omega$ resistor.

Solution Comparing this expression for voltage output with the general form $\Delta v = \Delta V_{\max} \sin \omega t$, we see that $\Delta V_{\max} = 200\text{ V}$. Thus, the rms voltage is

$$\Delta V_{\text{rms}} = \frac{\Delta V_{\max}}{\sqrt{2}} = \frac{200\text{ V}}{\sqrt{2}} = 141\text{ V}$$

Therefore,

$$I_{\text{rms}} = \frac{\Delta V_{\text{rms}}}{R} = \frac{141\text{ V}}{100\ \Omega} = \boxed{1.41\text{ A}}$$