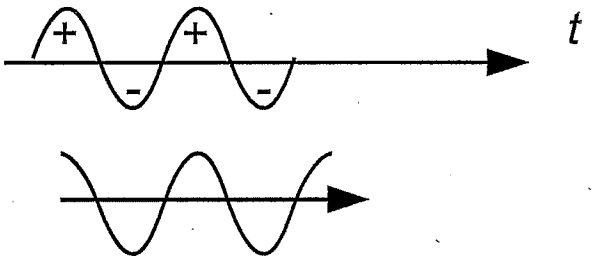
AC Voltage

- What is AC?
  - The power company jiggles electrons back and forth instead of one direction (DC)
  - It's called 'alternating current', but the actual electrons are not moving very far, just the electrons already in the home appliances are moving back and forth under the influence of the power company's applied voltage.
  - The voltage and current from the power company are sinusoidal:

$$V = A * \sin 2\pi f t$$

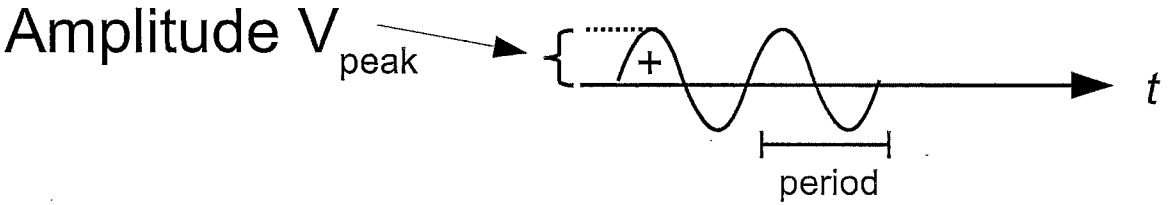
or

$$V = A * \cos 2\pi f t$$



- Why AC?
  - Because Faraday's Law plus Iron make possible the transformer
  - Because transformers can be used to transmit power with low energy losses

'RMS' Current and Voltage are smaller than 'Peak' values



- Define V_{rms} : if V_{peak} is the amplitude of the voltage, then
- Similarly, if I_{peak} is the amplitude of the current,

$$V_{rms} = \frac{V_{peak}}{\sqrt{2}}$$

$$I_{rms} = \frac{I_{peak}}{\sqrt{2}}$$

'rms' ⇔ root-mean-square

- Example: if the rms voltage is 24 volts, what are the maximum, minimum, and average voltages?

Example: House current

House current is 120 VAC, 60 Hz. The actual function representing instantaneous house voltage is:

Nominal AC voltage

# of complete cycles per second

V_{peak}

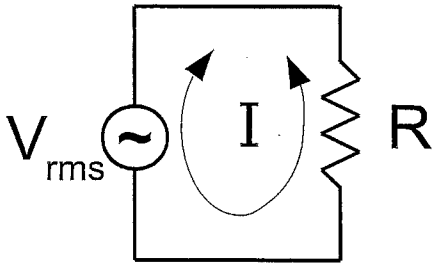
frequency in radians per second

Instantaneous: $V = 120\sqrt{2} * \sin(2\pi\ 60\ t) = 170\ \sin(377\,t)$ Volts

RMS: $120\ \ VAC$

V_{rms} also called 'VAC'

Why 'RMS'? Answer: I_{rms} and V_{rms} give a simple Power formula

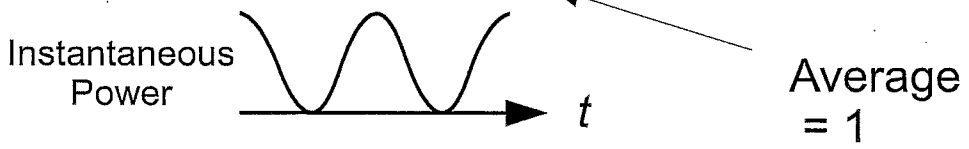


- For a resistive load, the instantaneous power P in terms of V_{rms} and I_{rms}:

$$V = V_{peak}\sin(2\pi f t) = \sqrt{2}\,V_{rms}\sin(2\pi f t)$$

$$I = \sqrt{2}\,I_{rms}\sin(2\pi f t)$$

$$P = \left[V_{rms} * I_{rms}\right] * 2\sin^2(2\pi f t)$$

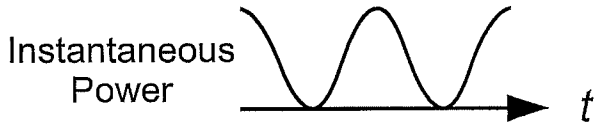


$$\boxed{P_{avg} = V_{rms} * I_{rms}}$$

simple!

The average power is same old V*I if the latter are rms values

Summary for rms current, voltage, and power



- What is the 'peak' power $P_{peak} = V_{ampl} * I_{ampl} = 2 * V_{rms} I_{rms}$
- What is the minimum P? $P_{min} = 0 * 0 = 0$
- What is the average P? $avg\,P = \frac{P_{peak}}{2} = V_{rms} * I_{rms}$
- What is Ohm's Law in terms of V_{rms} and I_{rms}? $\boxed{V_{rms} = I_{rms} * R}$

I_{rms} and V_{rms} were defined specifically so that average power = I_{rms} * V_{rms}

AC Power Problems

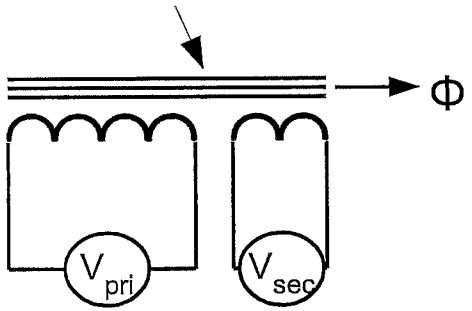
1. Consider a 100 W light bulb operating on house current, 120 VAC 60 Hz.
   - What is the average current of the lightbulb?
   - What is the average power of the lightbulb?
   - What is the peak power of the lightbulb?
   - What is the peak current of the lightbulb?
   - Is the resistance of the lightbulb constant when run on AC power?

Transformers

- AC voltages and currents are readily amplified or reduced using transformers.
- A Transformer is 2 solenoids sharing the same iron core

  So **ΔΦ/Δ**t is same for both
- The primary coil has Np turns and the secondary coil has Ns turns

Iron core makes an easy magnetic path



$$V_s = -N_s \frac{\Delta \Phi}{\Delta t}$$

$$V_p = -N_p \frac{\Delta \Phi}{\Delta t}$$

- Therefore equating **ΔΦ/Δ**t

$$\frac{V_s}{N_s} = \frac{V_p}{N_p}$$

- Vs can be made larger or smaller than Vp, depending on turns ratio

$$\boxed{\frac{V_s}{V_p} = \frac{N_s}{N_p}}$$

T 24

Transformer voltages are pr ortional to the number of tur s

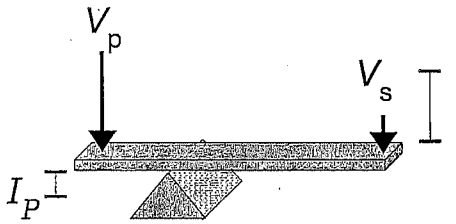
Transformers-Matching

- The turns ratio determines the voltage ratio due to Faraday's Law.

$$\frac{V_s}{V_p} = \frac{N_s}{N_p}$$

- But power must be conserved

$$I_p * V_p = I_s * V_s$$



- This fixes ratio between current in primary and the secondary: I_P & I_s

$$\frac{I_s}{I_p} = \frac{N_p}{N_s}$$

- But now the effective resistance of the load in the secondary looks very different in the primary due to the square of the turns ratio

$$R_p = \frac{V_p}{I_p} = \frac{N_p^2}{N_s^2}\frac{V_s}{I_s}$$

The transformer is like a lever: It matches a large voltage to a small voltage

Transformer Problems

1. You travel to the Far East where the AC voltage is 220 VAC 50 Hz. You operate your U.S. hair dryer using a transformer to step down the voltage to 110 VAC. What is the turns ratio (primary-to-secondary)?

- The hair dryer is designed to deliver 1675 Watts. What is the current in the secondary?

- What is the current in the primary?

- What is the power delivered to the primary?

- With all that power going into the primary, why doesn't the transformer get very hot?

- What is the minimum required rating of the transformer in Volt-Amperes (VA)?

2. A step-down transformer is used to operate a loudspeaker. The loudspeaker voice coil has a resistance of 3.2 ohm. What turns ratio is needed to 'match' this to an audio mixer which operates best when delivering 10 Volts and 10 milliamps to the primary?