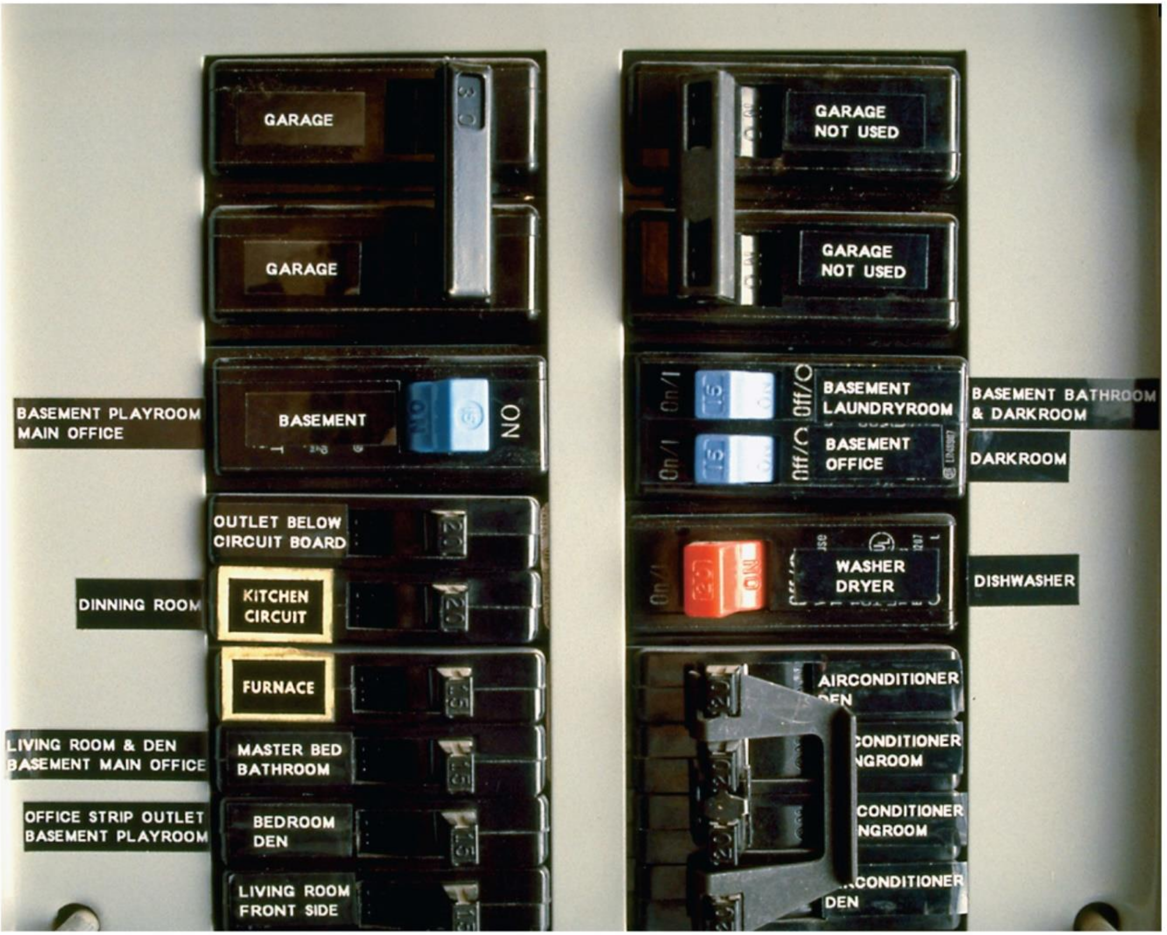
Listrik (3)

Arus bolak balik

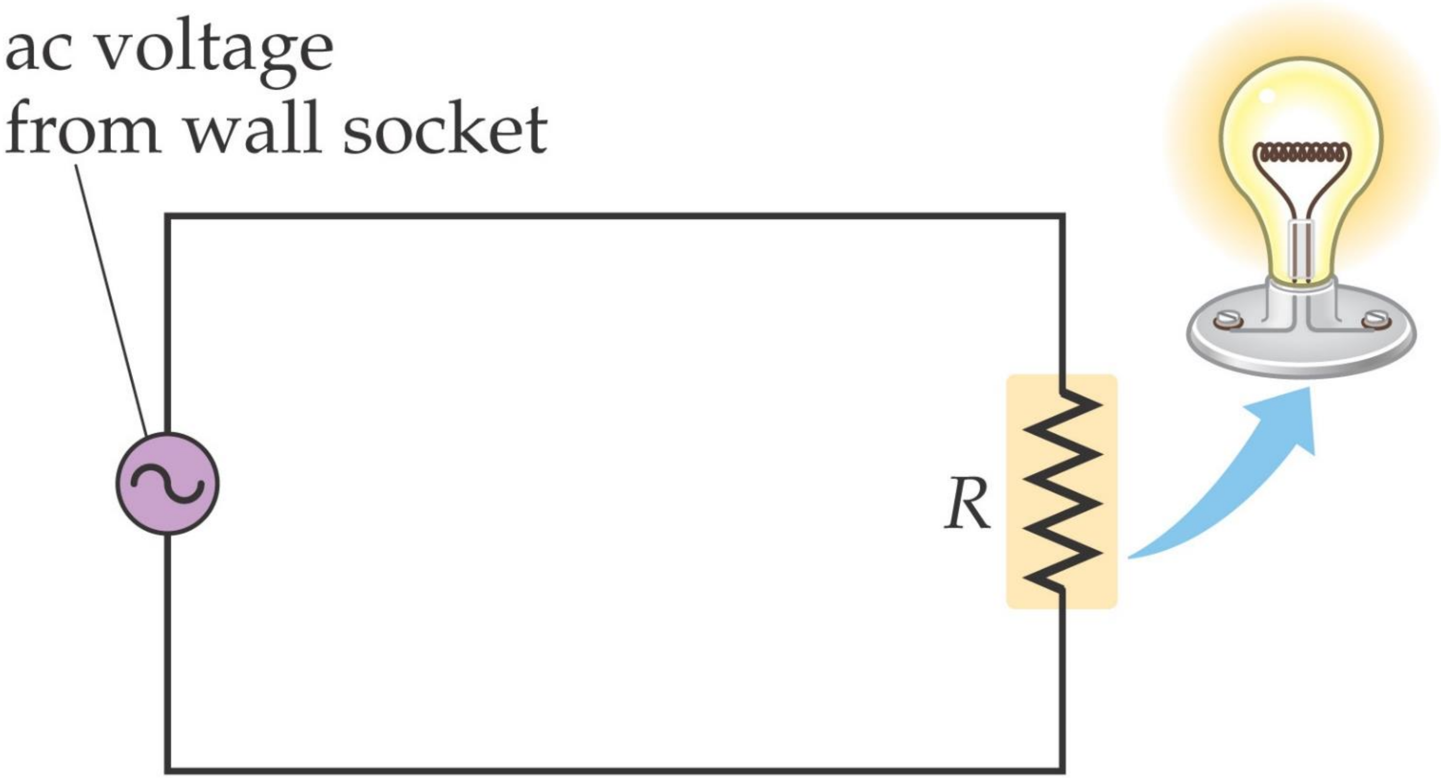
Alternating-Current Circuits



Alternating Voltages and Currents

Wall sockets provide current and voltage that vary sinusoidally with time.

Here is a simple ac circuit:



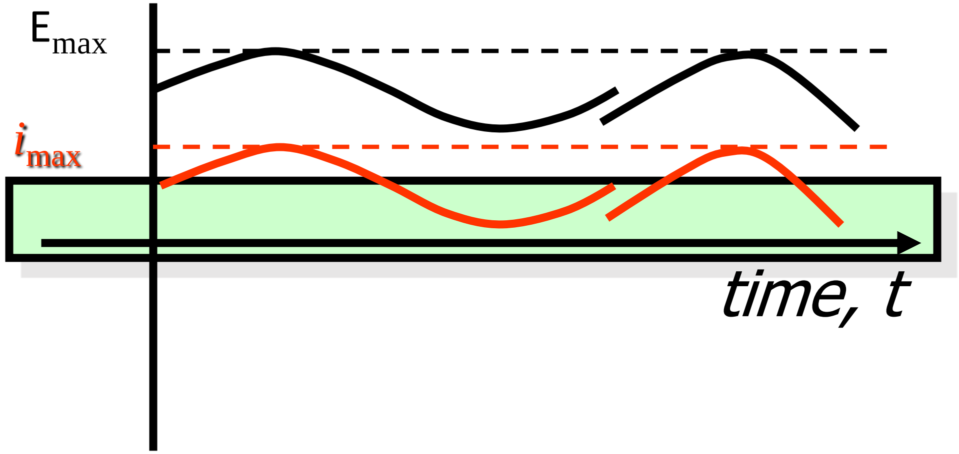
Alternating Currents

An alternating current such as that produced by a generator has no direction in the sense that direct current has. The magnitudes vary sinusoidally with time as given by:

AC-voltage and current

$V = V_{max} \sin \theta$

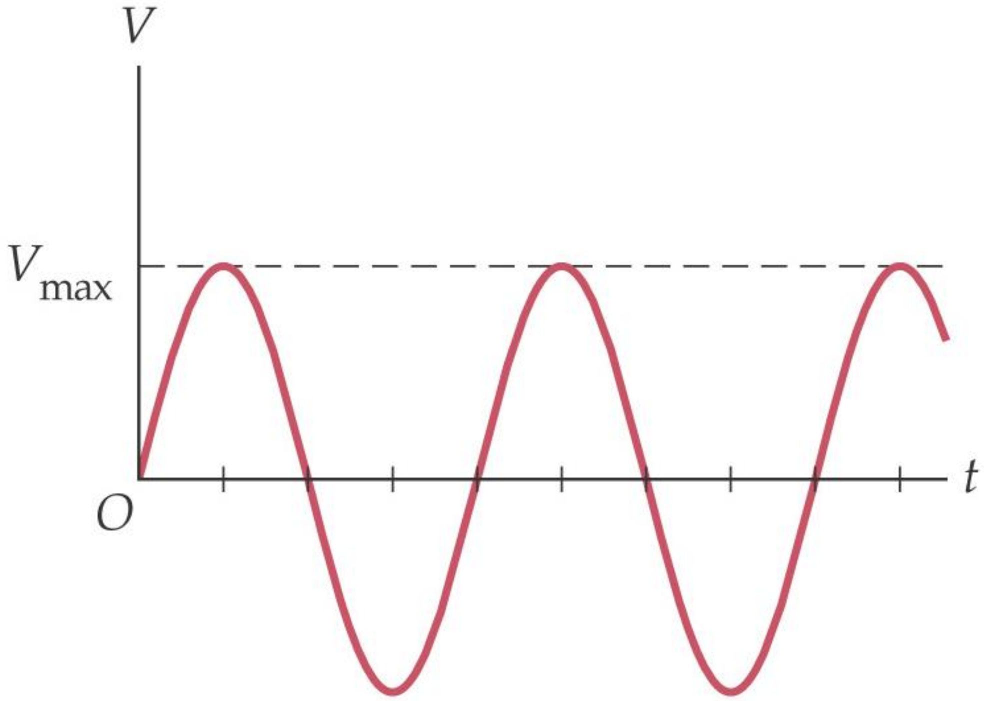
$i = i_{max} \sin \theta$



Alternating Voltages and Currents

The voltage as a function of time is:

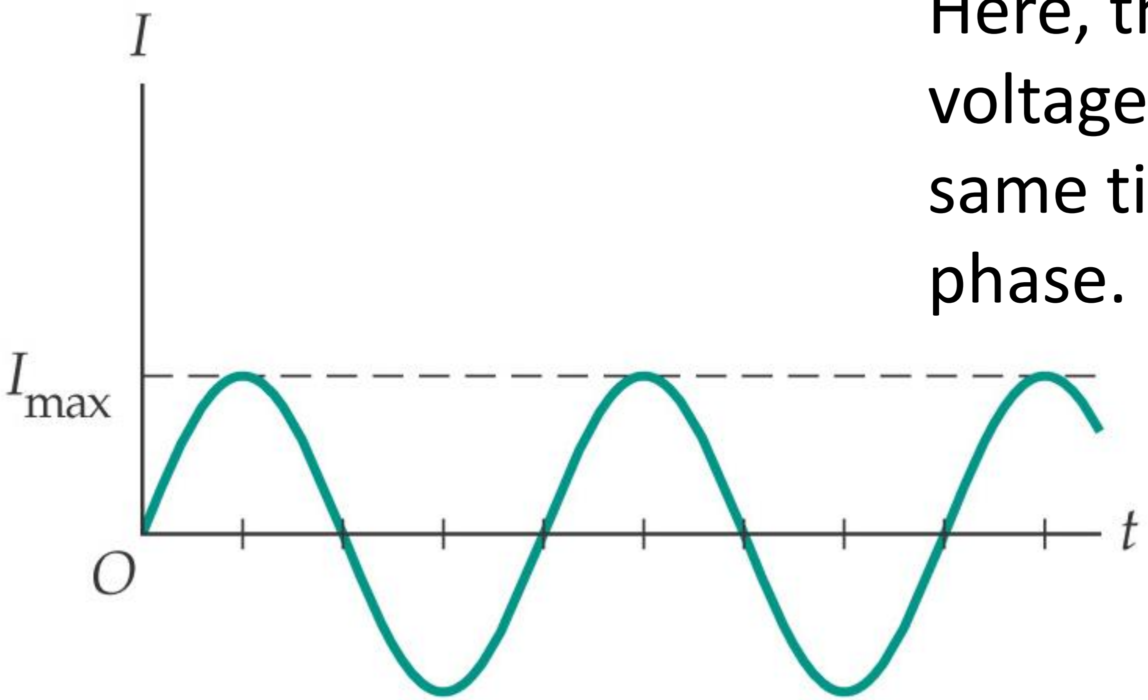
$$V = V_{max} \sin \omega t$$



Alternating Voltages and Currents

Since this circuit has only a resistor, the current is given by:

$$I = \frac{V}{R} = \left(\frac{V_{max}}{R}\right)\sin \omega t = I_{max}\sin \omega t$$

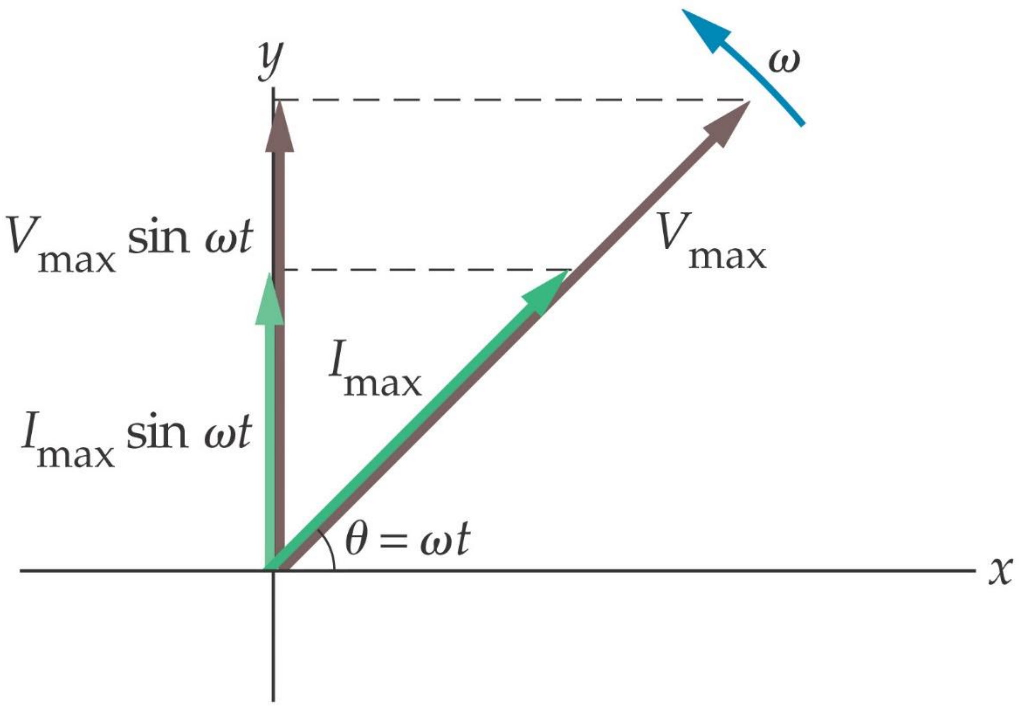


Here, the current and voltage have peaks at the same time – they are in phase.

Alternating Voltages and Currents

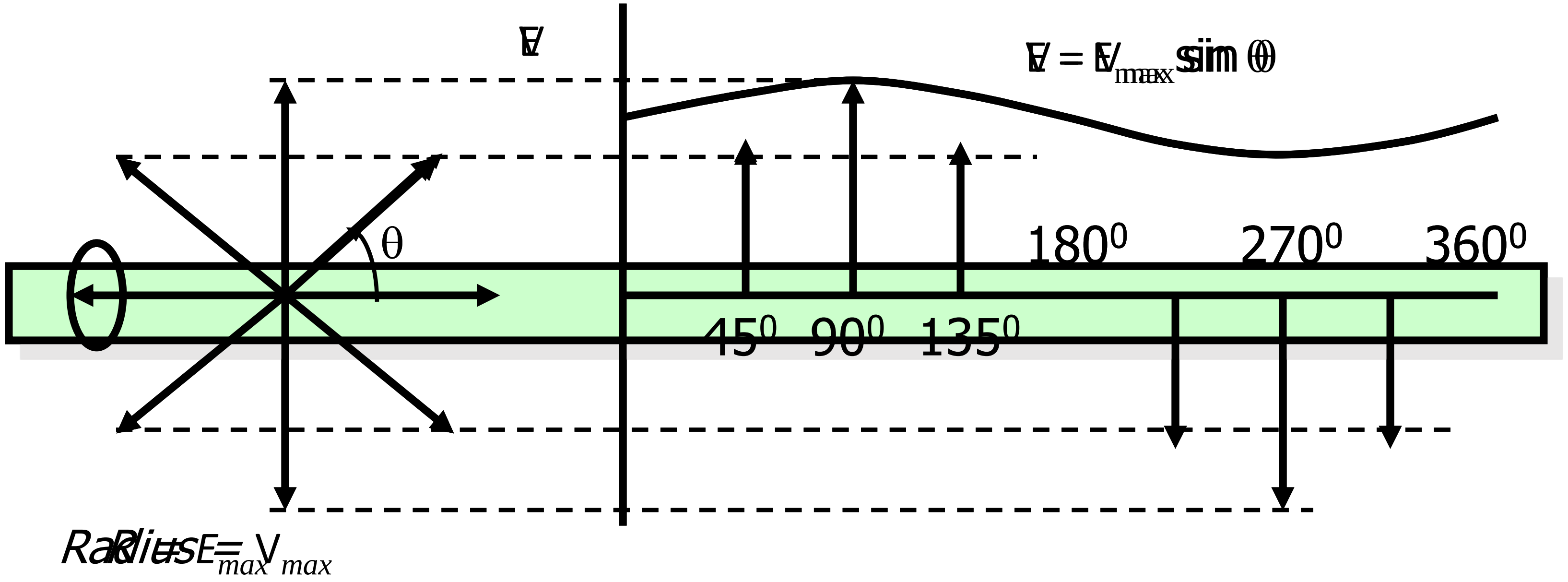
In order to visualize the phase relationships between the current and voltage in ac circuits, we define phasors – vectors whose length is the maximum voltage or current, and which rotate around an origin with the angular speed of the oscillating current.

The instantaneous value of the voltage or current represented by the phasor is its projection on the *y* axis.



Rotating Vector Description

The coordinate of the V at any instant is the value of V_{max} sin θ. Observe for incremental angles in steps of 45^0. Same is true for *i*.



Alternating Voltages and Currents

The voltage and current in an ac circuit both average to zero, making the average useless in describing their behavior.

We use instead the root mean square (rms); we square the value, find the mean value, and then take the square root:

RMS Value of a Quantity with Sinusoidal Time Dependence

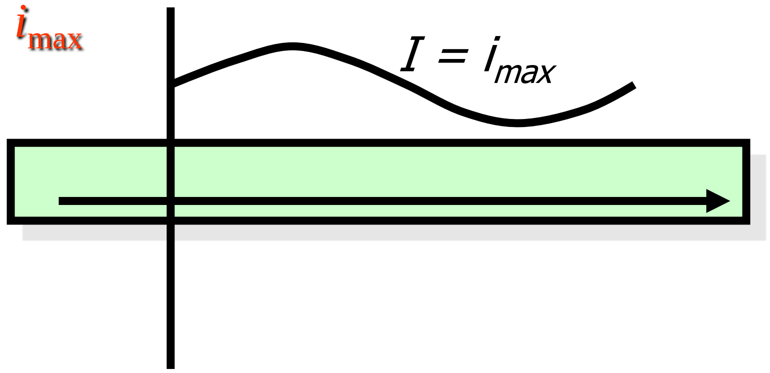
$$(x^2)_{av} = \frac{1}{2} x_{max}{}^2$$

$$x_{rms} = \frac{1}{\sqrt{2}} x_{max}$$

120 volts is the rms value of household ac.

Effective AC Current

The average current in a cycle is zero—half + and half -.



But energy is expended, regardless of direction. So the "root-mean-square" value is useful.

$$I_{rms} = \sqrt{\frac{I^2}{2}} = \frac{I}{0.707}$$

The rms value I_{rms} is sometimes called the effective current I_{eff}:

The effective ac current:

$i_{eff} = 0.707\ i_{max}$

AC Definitions

One effective ampere is that ac current for which the power is the same as for one ampere of dc current.

Effective current: $i_{eff} = 0.707\ i_{max}$

One effective volt is that ac voltage that gives an effective ampere through a resistance of one ohm.

Effective voltage: $V_{eff} = 0.707\ V_{max}$

Example 1: For a particular device, the house ac voltage is 120-V and the ac current is 10 A. What are their maximum values?

$i_{eff} = 0.707\ i_{max}$

$V_{eff} = 0.707\ V_{max}$

$$i_{max} = \frac{i_{eff}}{0.707} = \frac{10\ \text{A}}{0.707}$$

$$V_{max} = \frac{V_{eff}}{0.707} = \frac{120\text{V}}{0.707}$$

$i_{max} = 14.14$ A

$V_{max} = 170$ V

The ac voltage actually varies from +170 V to -170 V and the current from 14.1 A to –14.1 A.

Alternating Voltages and Currents

By calculating the power and finding the average, we see that:

$$P = I^2R = I_{\max}{}^2 R \sin^2 \omega t$$

$$P_{\text{av}} = I_{\max}{}^2 R(\sin^2 \omega t)_{\text{av}} = \frac{1}{2} I_{\max}{}^2 R$$

$$= I_{\text{rms}}{}^2 R$$

Alternating Voltages and Currents

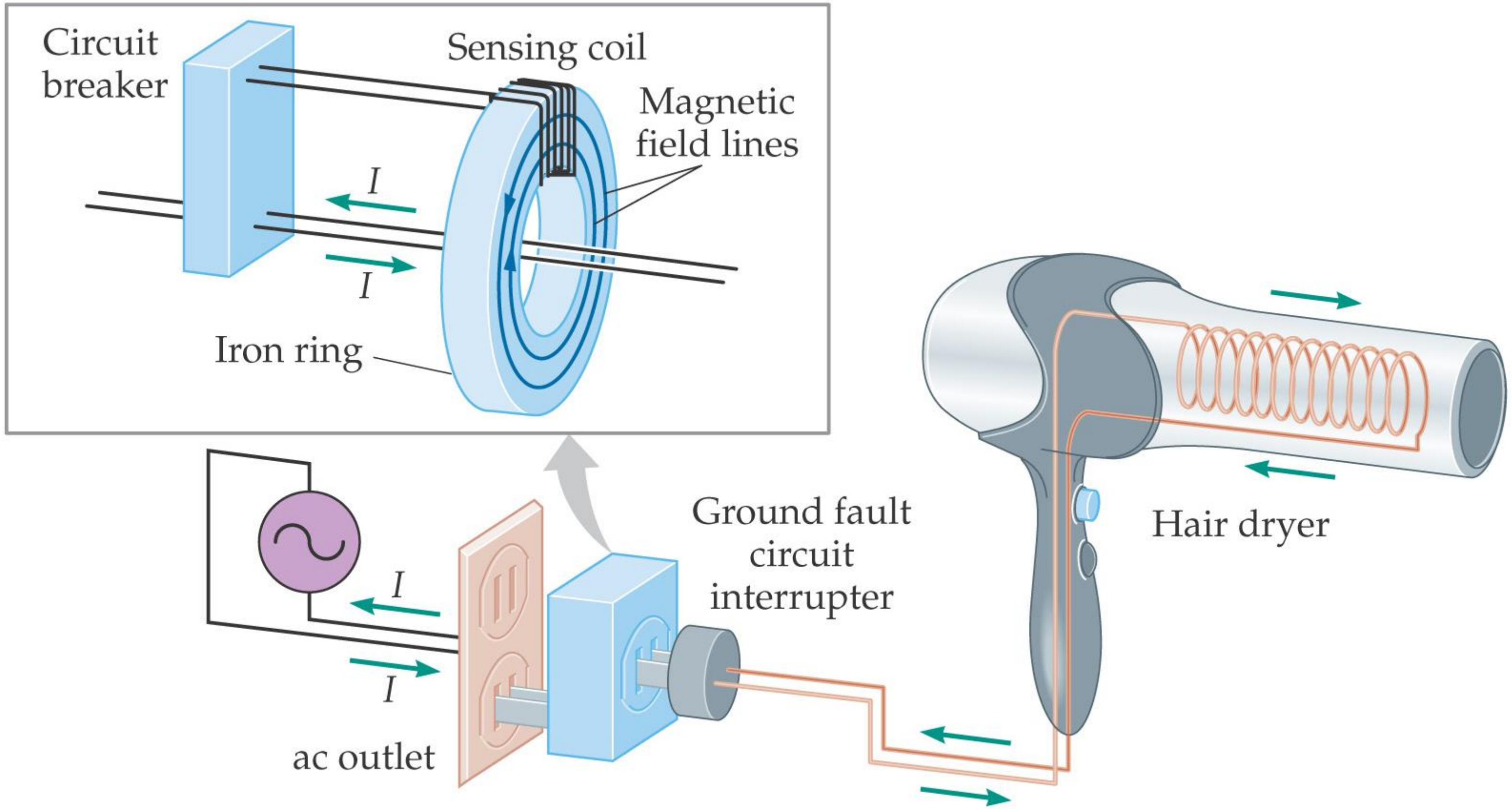
Electrical fires can be started by improper or damaged wiring because of the heat caused by a too-large current or resistance.

A fuse is designed to be the hottest point in the circuit – if the current is too high, the fuse melts.

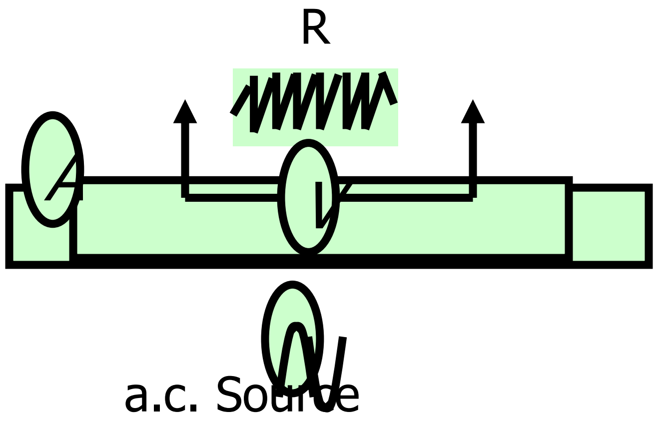
A circuit breaker is similar, except that it is a bimetallic strip that bends enough to break the connection when it becomes too hot. When it cools, it can be reset.

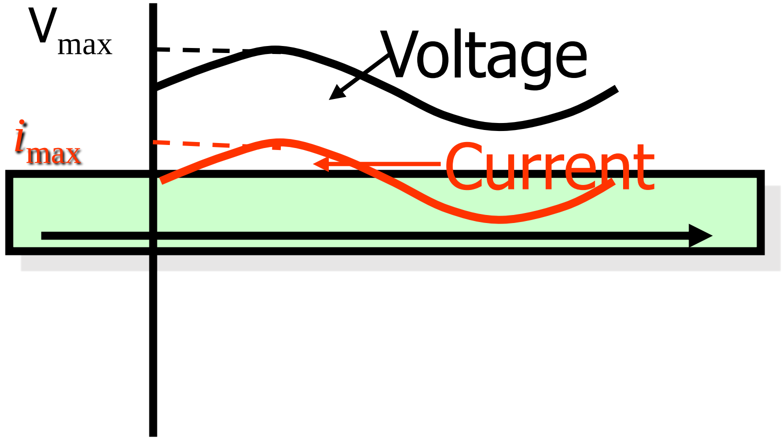
Alternating Voltages and Currents

A ground fault circuit interrupter can cut off the current in a short circuit within a millisecond.



Pure Resistance in AC Circuits

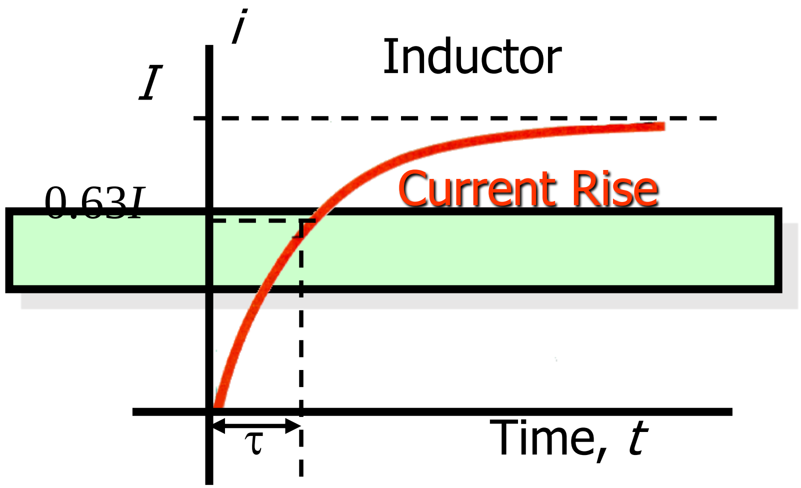


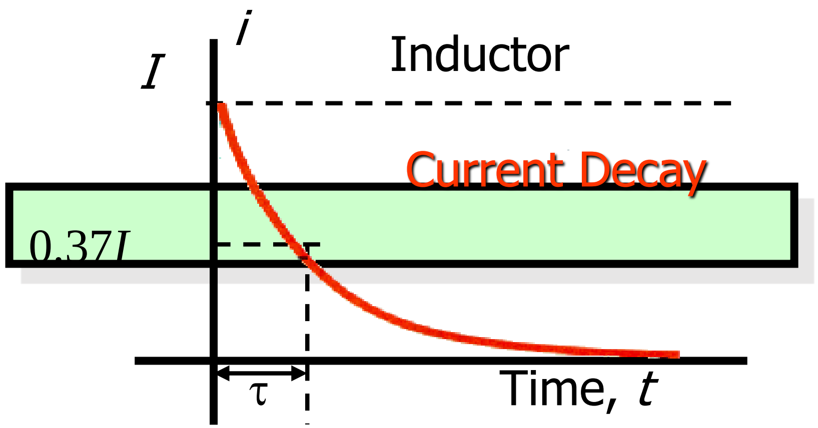


Voltage and current are in phase, and Ohm's law applies for effective currents and voltages.

Ohm's law: $V_{eff} = i_{eff}R$

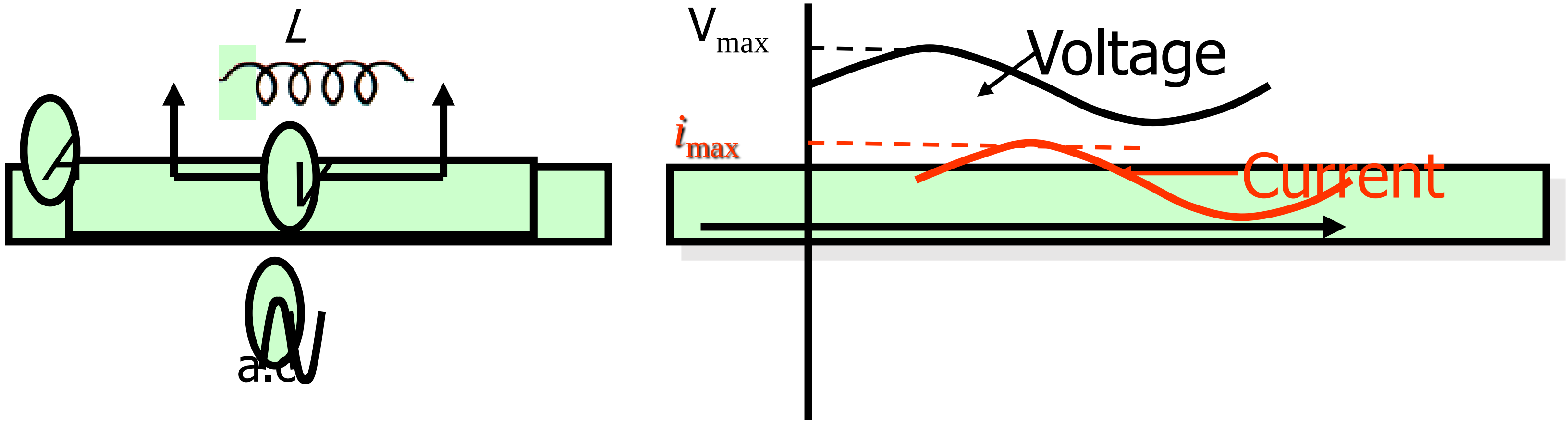
AC and Inductors





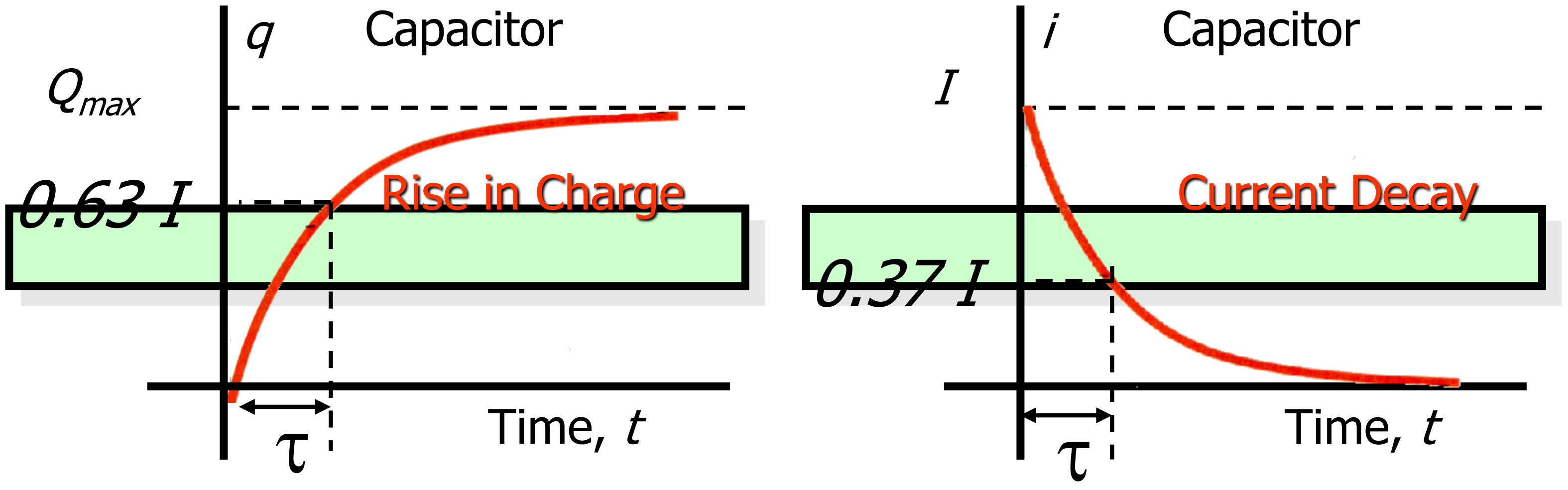
The voltage *V* peaks first, causing rapid rise in *i* current which then peaks as the emf goes to zero. Voltage leads (peaks before) the current by 90^0. Voltage and current are out of phase.

A Pure Inductor in AC Circuit



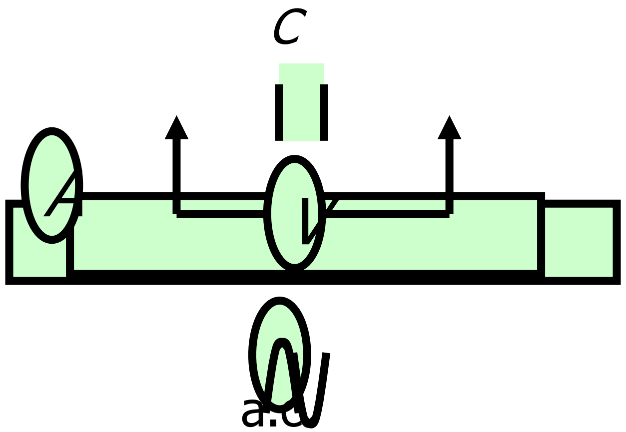
The voltage peaks 90^0 before the current peaks.

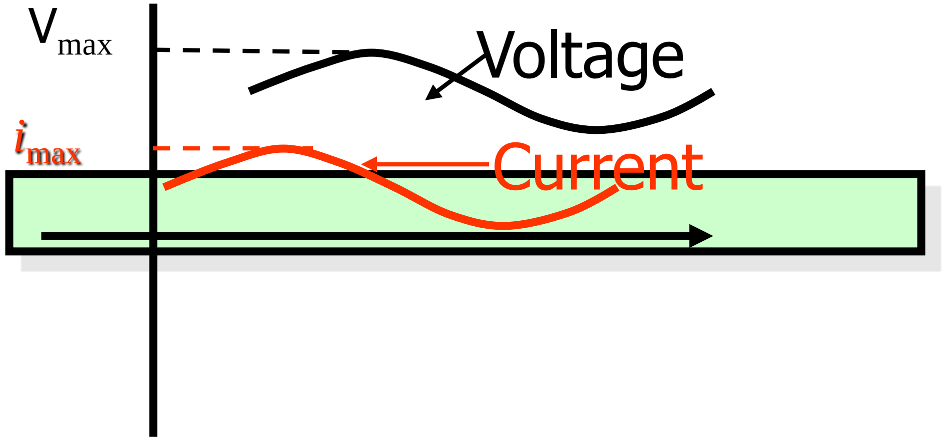
AC and Capacitance



The voltage V peaks ¼ of a cycle after the current *i* reaches its maximum. The voltage lags the current. Current *i* and V out of phase.

A Pure Capacitor in AC Circuit

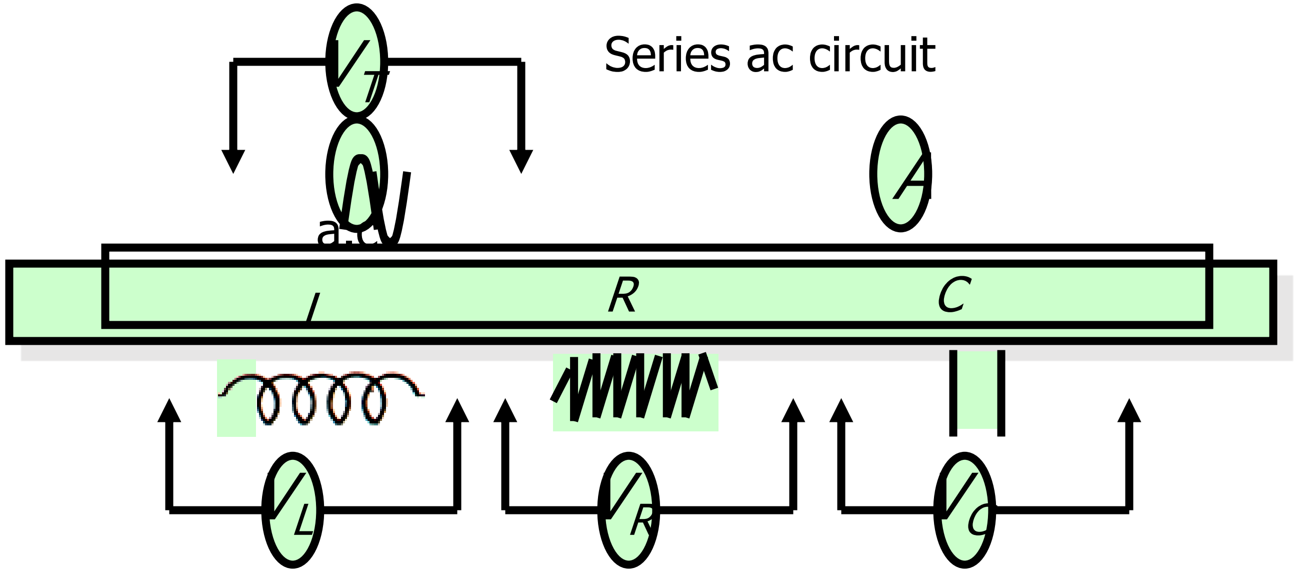




The voltage peaks 90^0 after the current peaks. One builds as the other falls and vice versa.

The diminishing current *i* builds charge on C which increases the back emf of $V_{C.}$

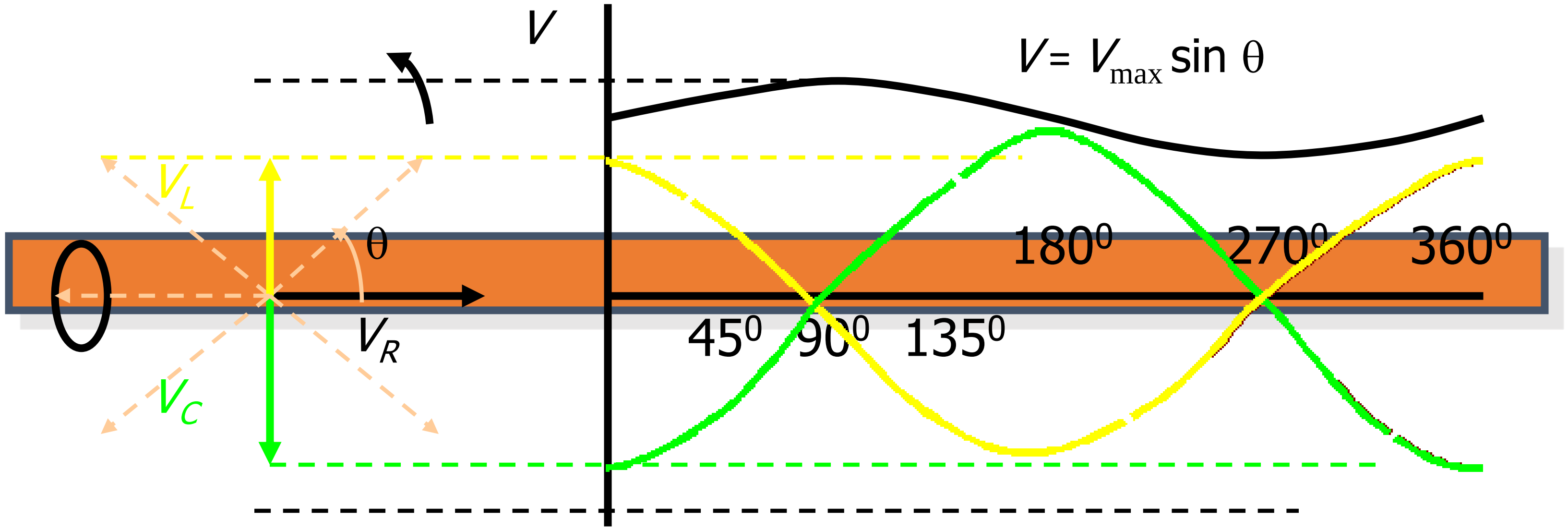
Series LRC Circuits



Consider an inductor *L*, a capacitor *C*, and a resistor *R* all connected in series with an ac source. The instantaneous current and voltages can be measured with meters.

Phase in a Series AC Circuit

The voltage leads current in an inductor and lags current in a capacitor. In phase for resistance *R*.

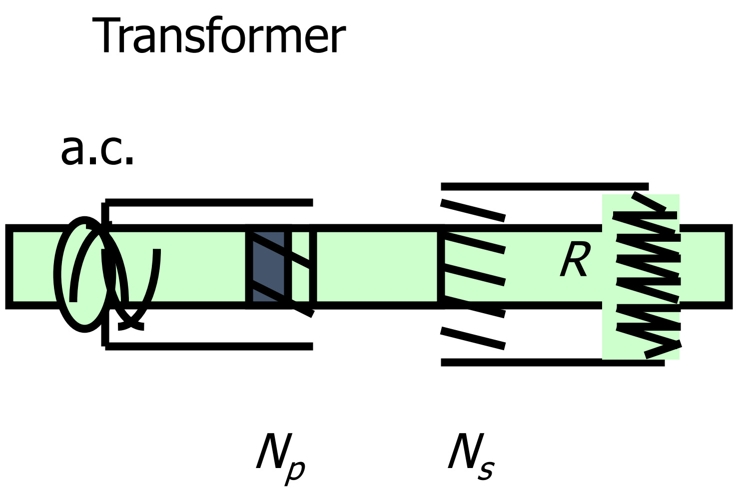


Rotating phasor diagram generates voltage waves for each element *R*, *L*, and *C* showing phase relations. Current *i* is always in phase with V_R.

The Transformer

A transformer is a device that uses induction and ac current to step voltages up or down.

An ac source of emf E_p is connected to primary coil with N_p turns. Secondary has N_s turns and emf of E_s.



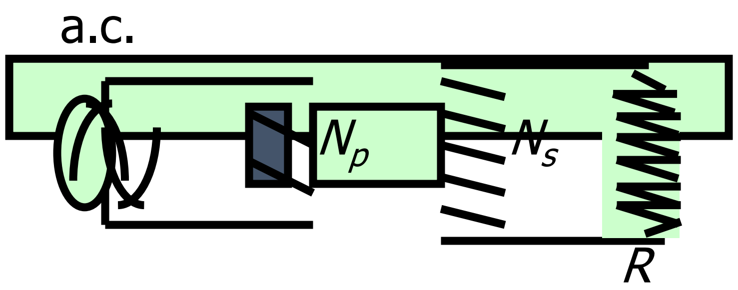
Induced emf's are:

$$\mathcal{E}_P = -N_P \frac{\Delta\Phi}{\Delta t}$$

$$\mathcal{E}_S = -N_S \frac{\Delta\Phi}{\Delta t}$$

Transformers (Continued):

Transformer



$$\mathcal{E}_P = -N_P \frac{\Delta\Phi}{\Delta t}$$

$$\mathcal{E}_S = -N_S \frac{\Delta\Phi}{\Delta t}$$

Recognizing that $\Delta\phi/\Delta t$ is the same in each coil, we divide first relation by second and obtain:

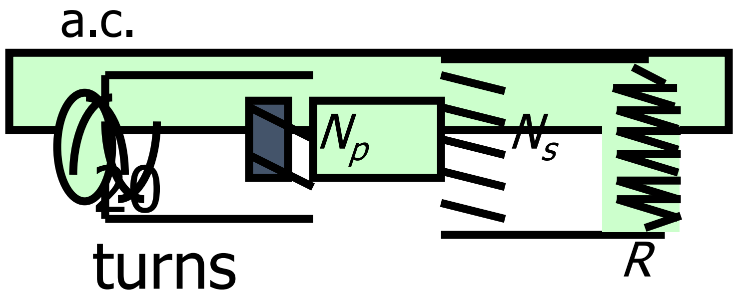
The transformer equation:

$$\frac{\mathcal{E}_P}{\mathcal{E}_S} = \frac{N_P}{N_S}$$

Example: A generator produces 10 A at 600 V. The primary coil in a transformer has 20 turns. How many secondary turns are needed to step up the voltage to 2400 V?

Applying the transformer equation:

I = 10 A; V_p = 600 V



$$\frac{V_P}{V_S} = \frac{N_P}{N_S}$$

$$N_S = \frac{N_P V_S}{V_P} = \frac{(20)(2400\text{ V})}{600\text{ V}}$$

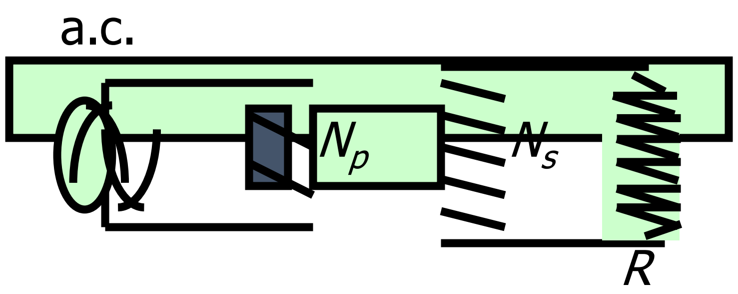
N_S = 80 turns

This is a step-up transformer; reversing coils will make it a step-down transformer.

Transformer Efficiency

There is no power gain in stepping up the voltage since voltage is increased by reducing current. In an ideal transformer with no internal losses:

Ideal Transformer



An ideal transformer:

$$\mathcal{E}_P i_P = \mathcal{E}_S i_S \quad \text{or} \quad \frac{i_P}{i_s} = \frac{\mathcal{E}_S}{\mathcal{E}_P}$$

The above equation assumes no internal energy losses due to heat or flux changes. Actual efficiencies are usually between 90 and 100%.

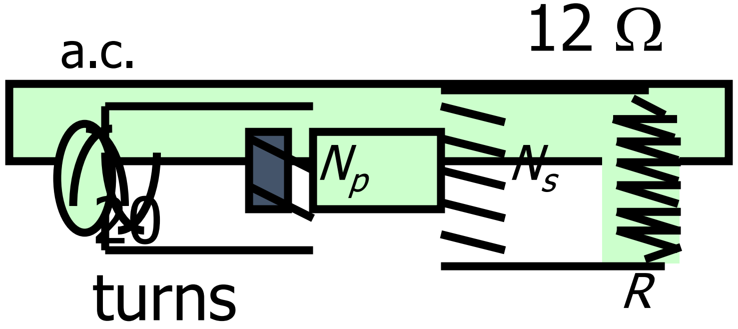
Example: The transformer in (Ex.) is connected to a power line whose resistance is 12 Ω. How much of the power is lost in the transmission line?

I = 10 A; V_p = 600 V

V_S = 2400 V

$$\mathcal{E}_P i_P = \mathcal{E}_S i_S \qquad i_S = \frac{\mathcal{E}_P i_P}{\mathcal{E}_S}$$

$$i_S = \frac{(600\,\text{V})(10\,\text{A})}{2400\,\text{V}} = 2.50\ \text{A}$$



$P_{lost} = i^2R$ = (2.50 A)^2(12 Ω)

P_{lost} = 75.0 W

P_{in} = (600 V)(10 A) = 6000 W

%Power Lost = (75 W/6000 W)(100%) = 1.25%