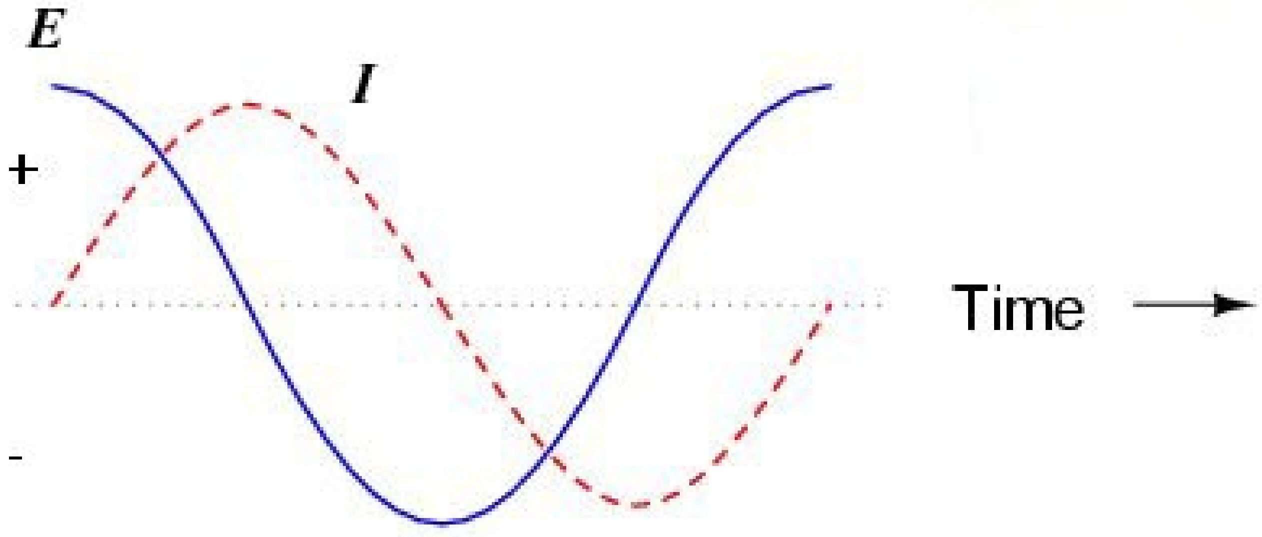
The New England Radio Discussion Society's "Electronics for Amateur Radio operators" course

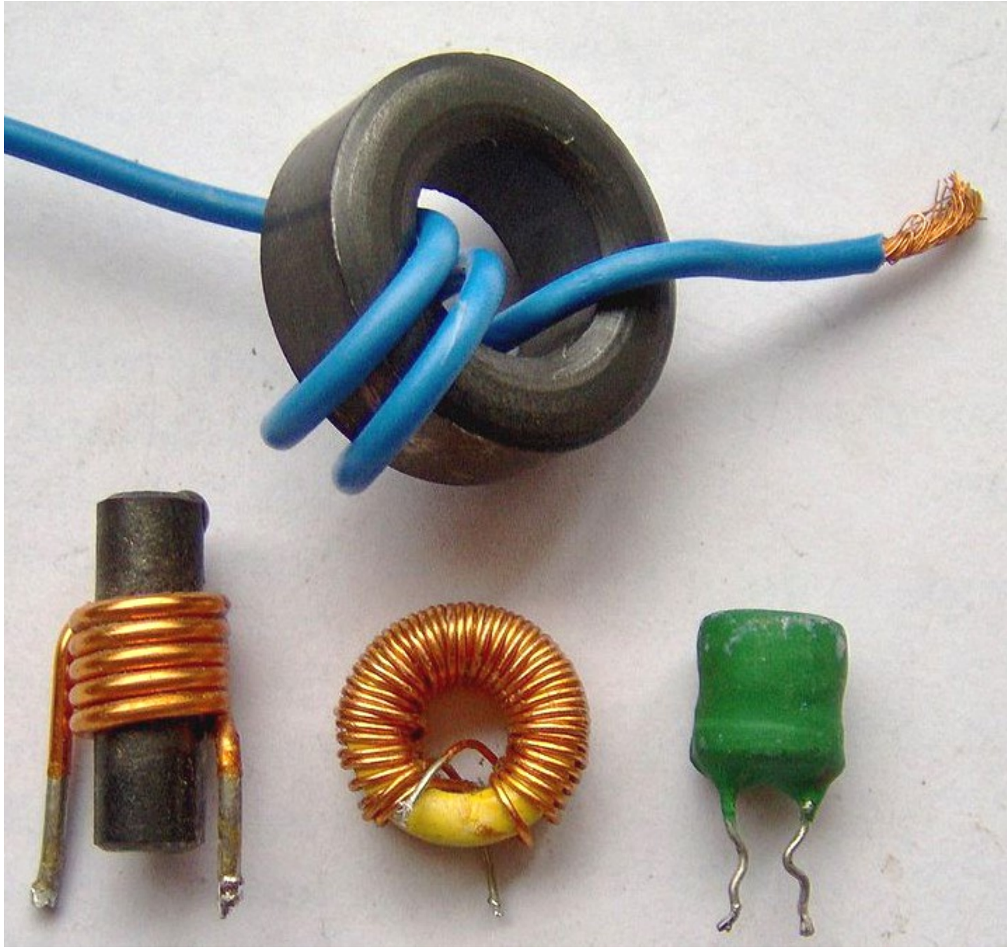
"Getting down to nuts and volts"

Phase Two, PPT4
October 2016

REVIEW: "E<u>L</u>I the ICE man" for inductors (L)



REVIEW: Inductors store energy in their magnetic fields

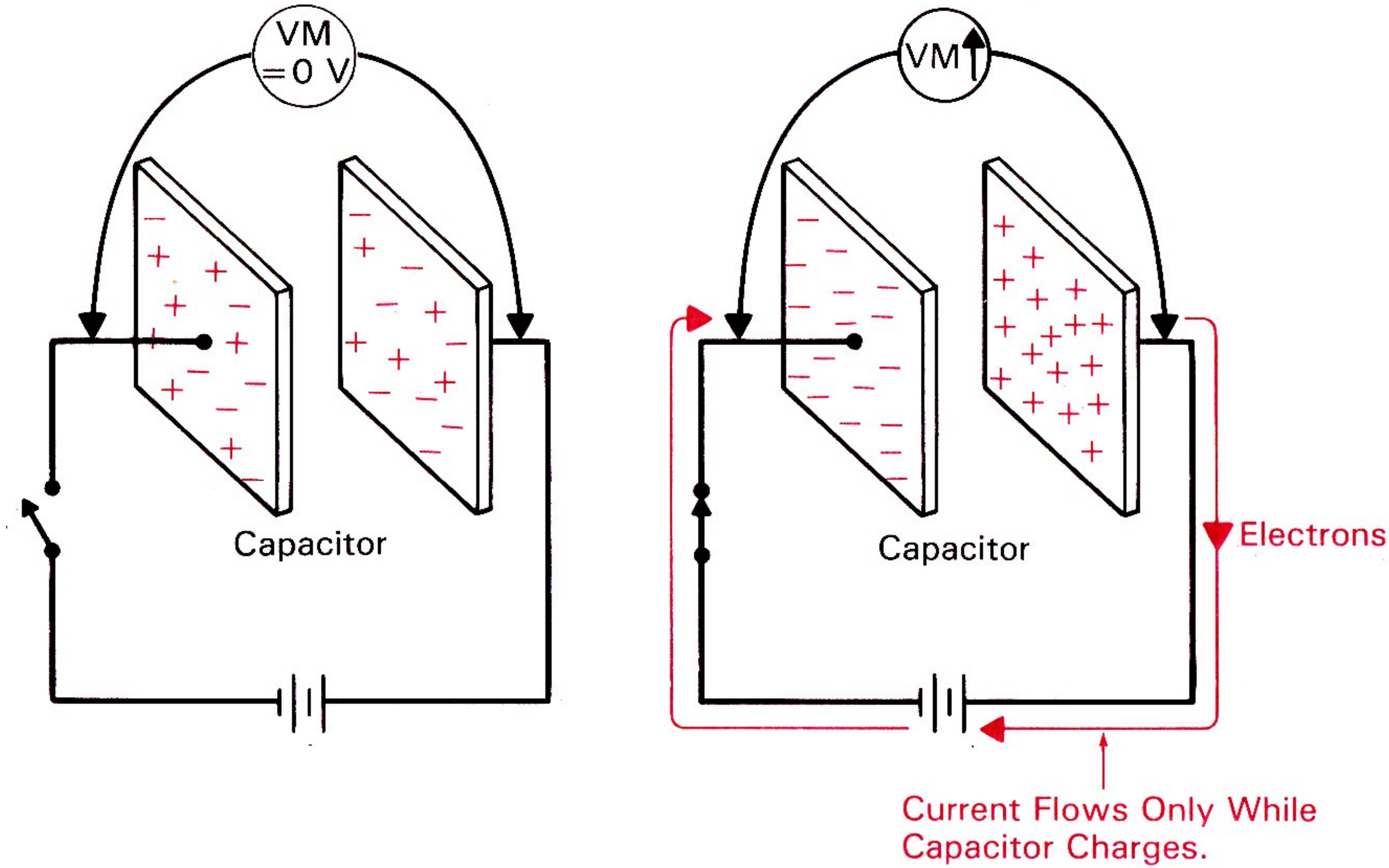


REVIEW:

Capacitors store electrical *charge*.

Like inductors, capacitors store *energy* --- and return that energy back to the circuits they're connected to.

Neither "pure" inductors nor "pure" capacitors dissipate power as heat.

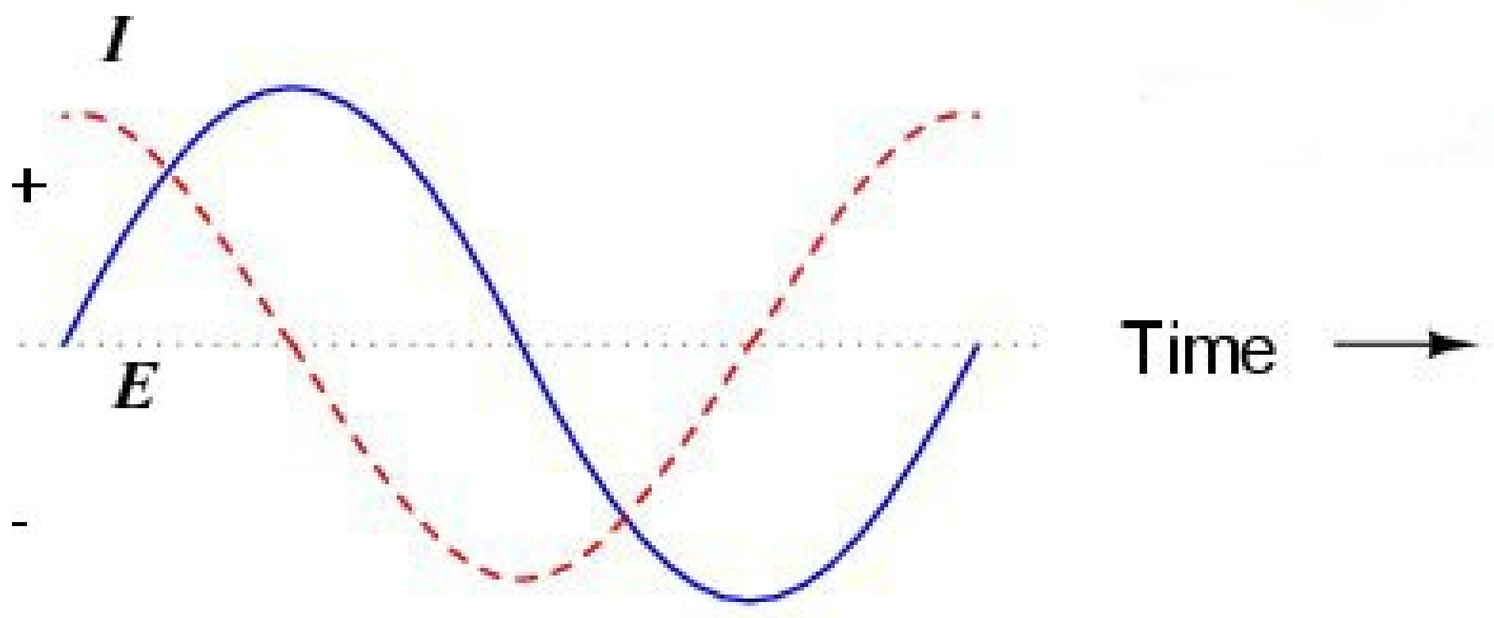


We now know there's virtually <u>no</u> internal DC resistance to a good capacitor!

REVIEW: In <u>AC circuits</u>, caps exhibit *capacitive reactance, stated as* X_c

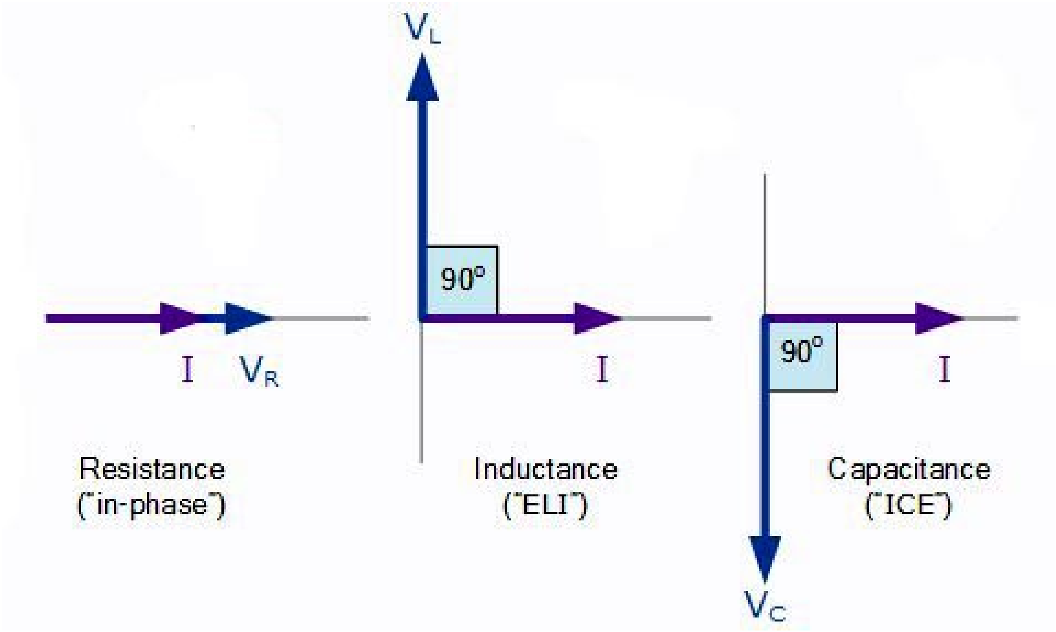
$$X_C = \frac{1}{2\pi f C}$$

REVIEW: “ELI the I<u>C</u>E man” for capacitors

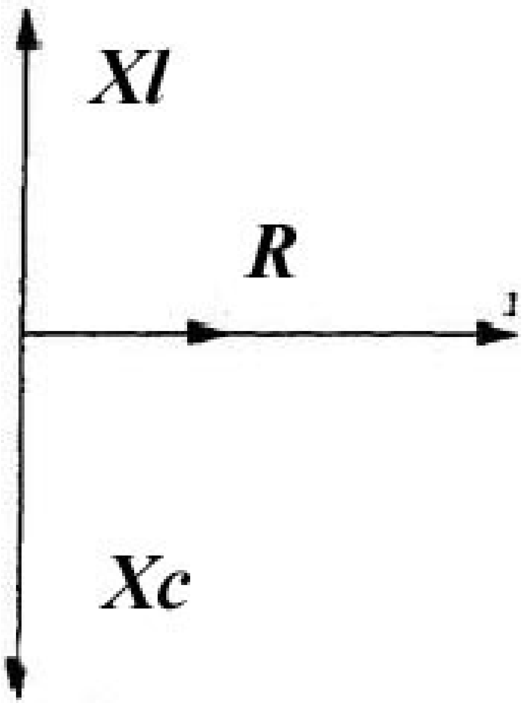


REVIEW: A *vector* is a graphical tool describing magnitude and direction.

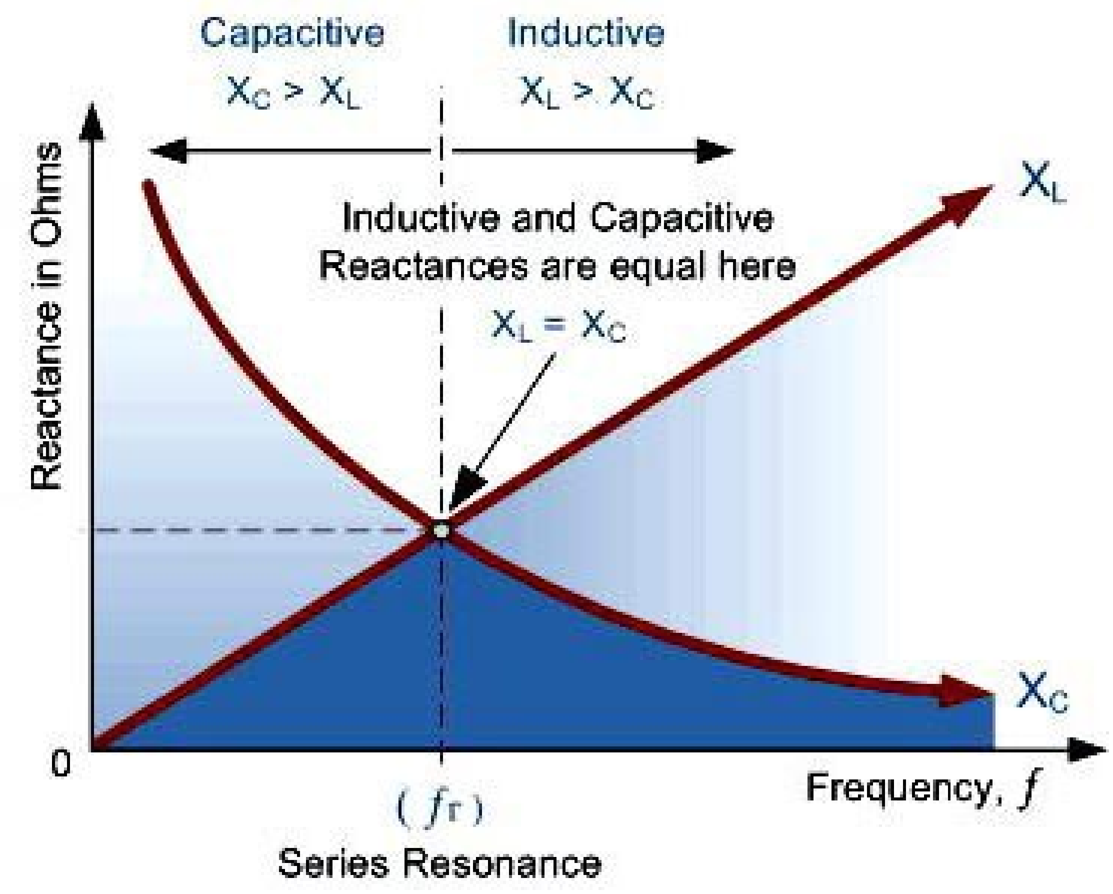
ELI the ICE man's *vectors*



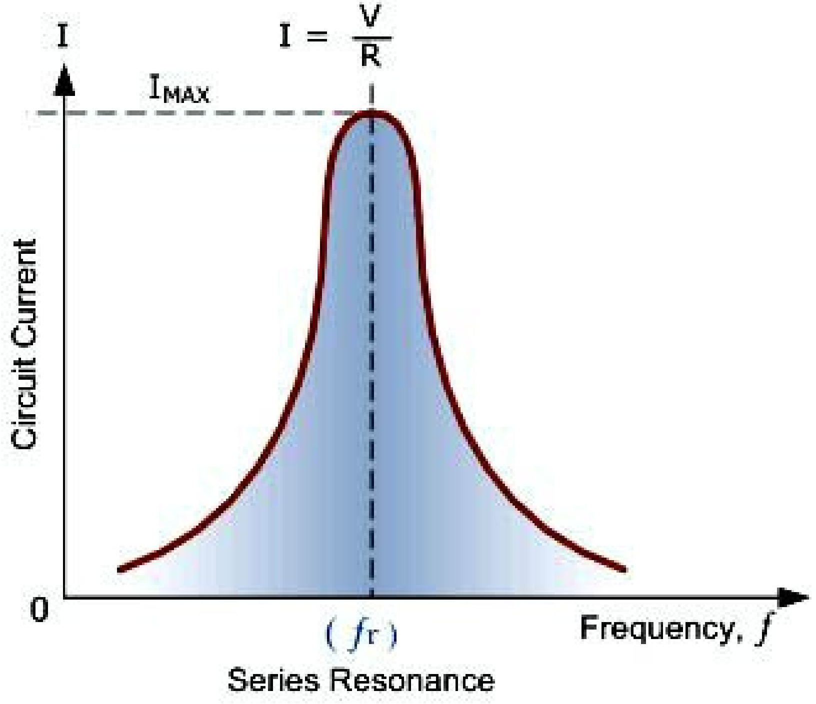
Here's a vector diagram where X_l and X_c vectors are equal and opposite, shown in the Y axes, and resistance is shown in the X axis.



REVIEW: $X_L = X_C$


Capacitive
X_C > X_L
Inductive
X_L > X_C
Reactance in Ohms
X_L
Inductive and Capacitive
Reactances are equal here
X_L = X_C
X_C
0
Frequency, f
(fr)
Series Resonance

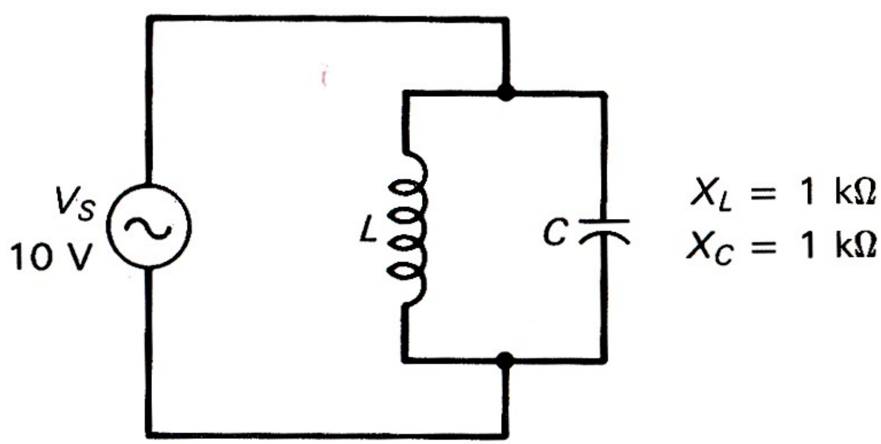
REVIEW: Series reactances cancel, resulting in a low *impedance* (it's only resistive), so current peaks

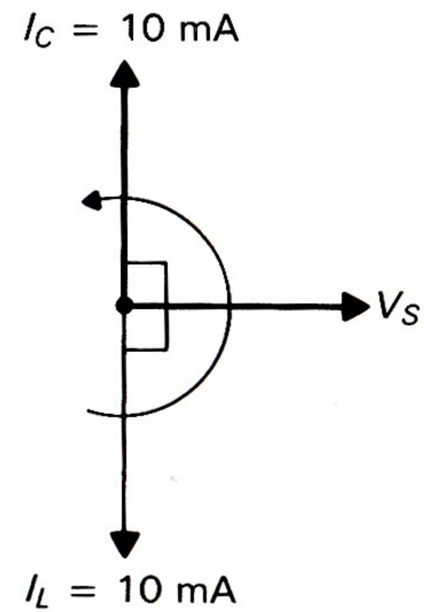


This is called *series resonance*.

More on *impedance* in a moment ....

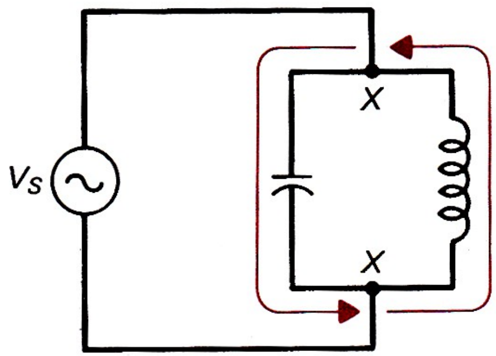
Now, what happens if we place L and C in parallel rather than series?



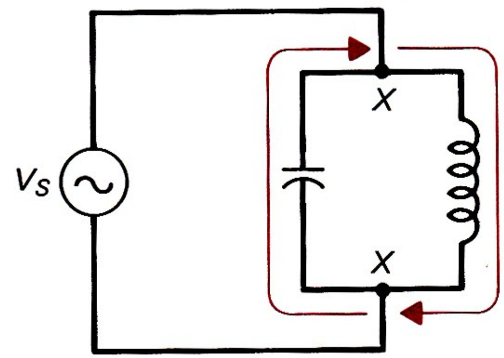


Assume a 10V ac source that causes X_L and X_C to be equal and opposite, and L and C exhibit 1-kohm reactance each, resulting in 10-mA currents that are *<u>out of phase</u>* by 180 degrees.

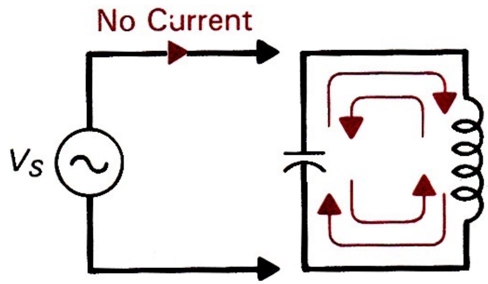
Say 10-mA initially flows up through the inductor. Then, 10-mA flows in the opposite direction down through the cap, charging it, as in "a."



a.

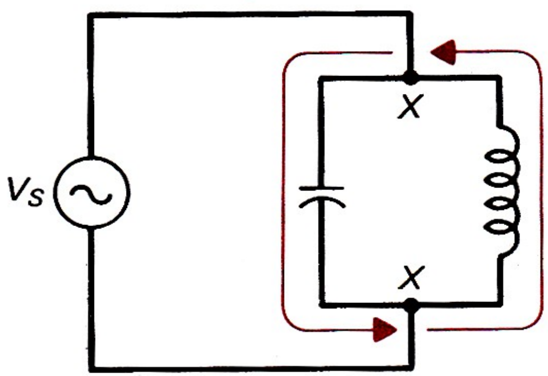


b.

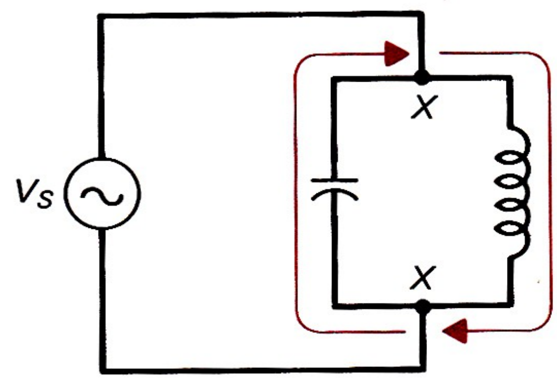


In the next alternation 10-mA flows down through L and up through C, as in "b."

If 10-mA arrives at Point X and 10-mA leaves Point X, then zero current is flowing into the LC combo from the source, V_S. This is shown in diagram "c."

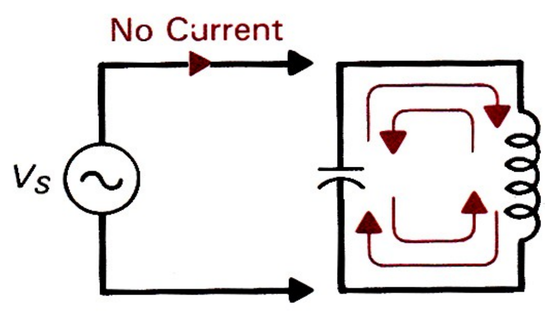


a.



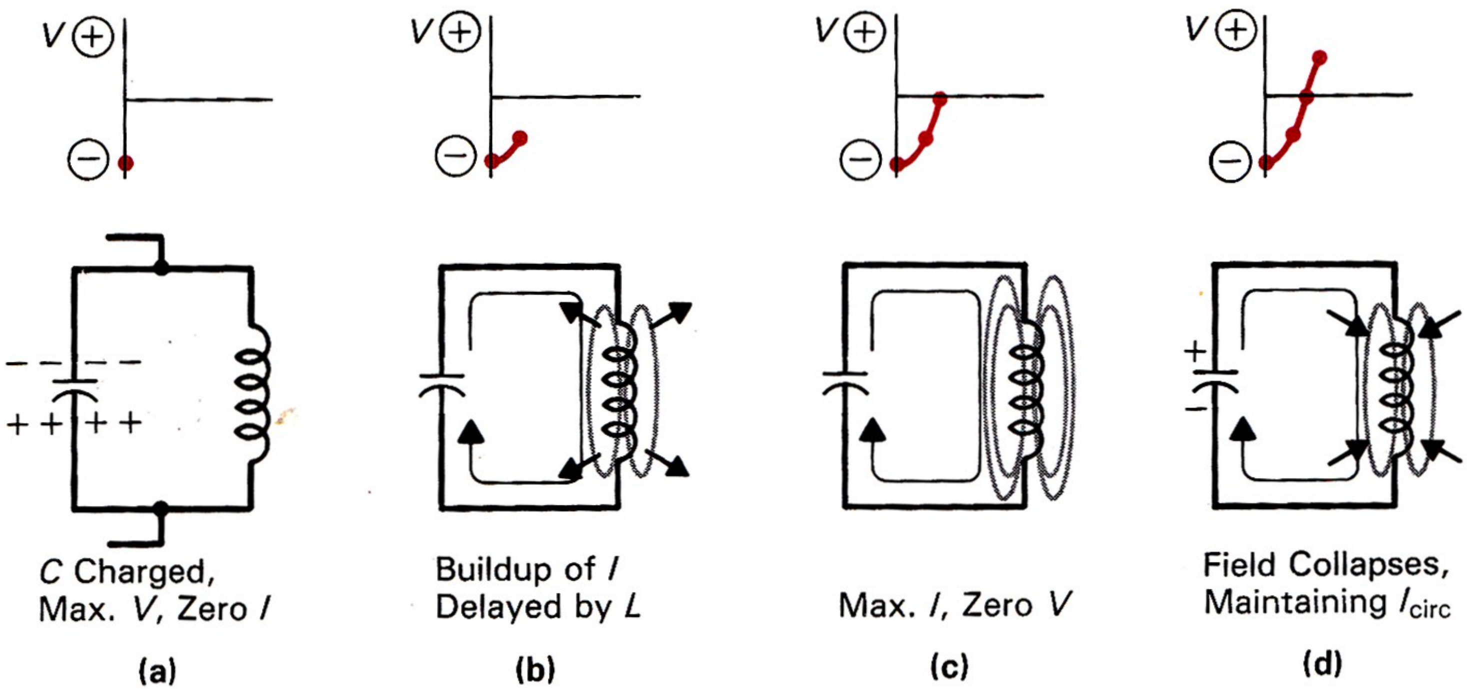
b.

c.



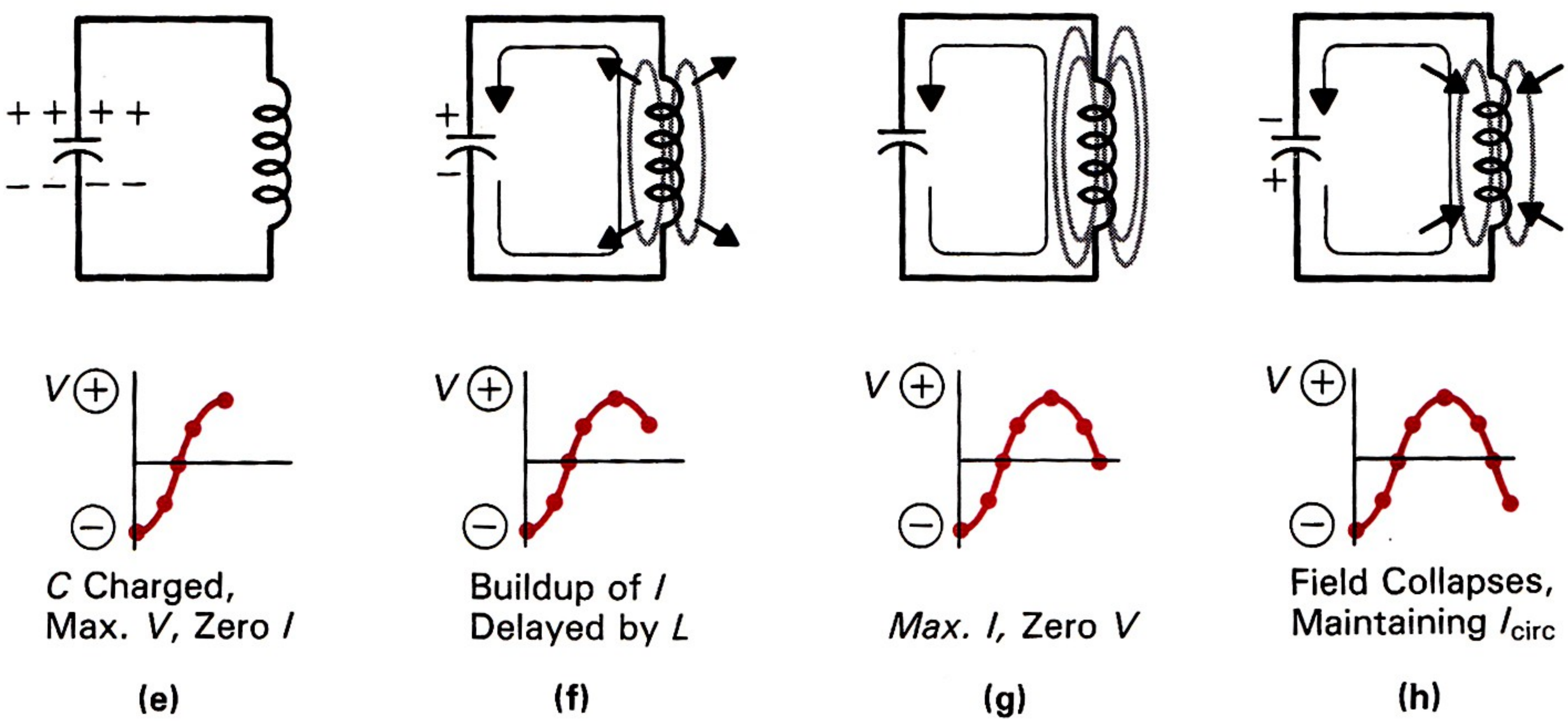
NOTE: you can now disconnect the source, V_S and if <u>zero current</u> is supplied, then the impedance of the LC combo must be *infinite*!

The parallel LC circuit exhibits *flywheel action*. The current in the circuit transfers energy between L and C, and the current reverses at each half-cycle at the frequency of resonance.



==>

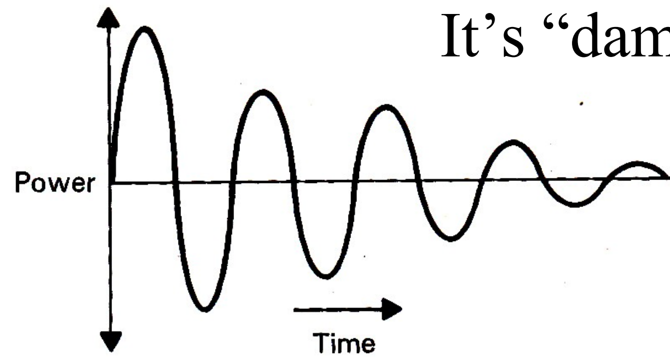
The cap stores energy in its electric field. It discharges through the inductor, which stores the energy in its magnetic field. When the mag field collapses it charges the capacitor, etc. This sets up an infinite *oscillation* --- back and forth.



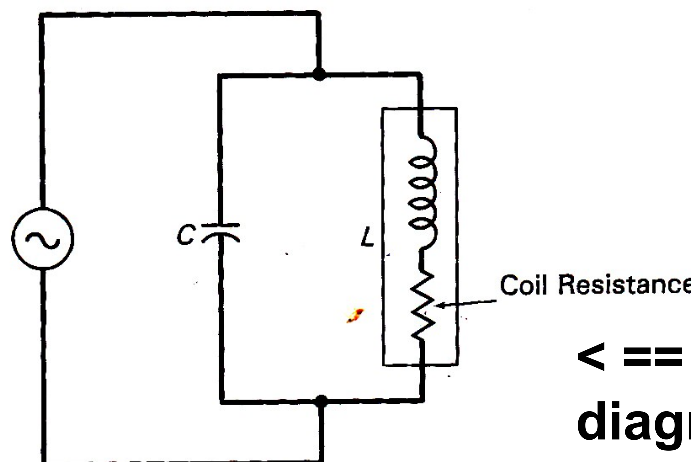
The spinning flywheel eventually slows and stops, due to air resistance and friction in its bearings.

The sine wave oscillation would go on forever if it were not for one derned factor – resistance!

It’s “damped”

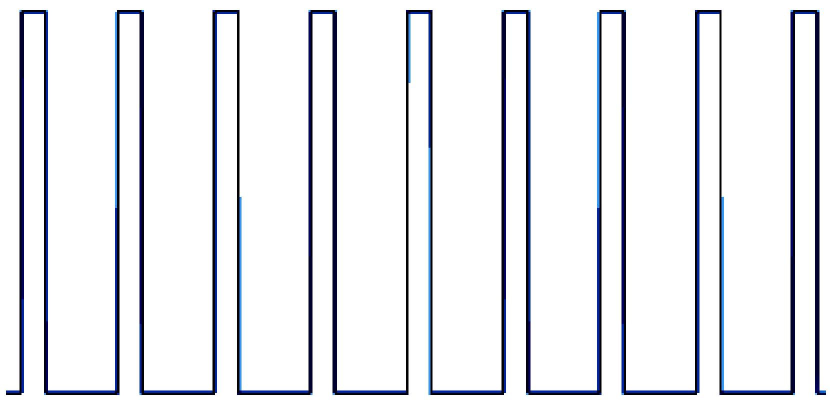


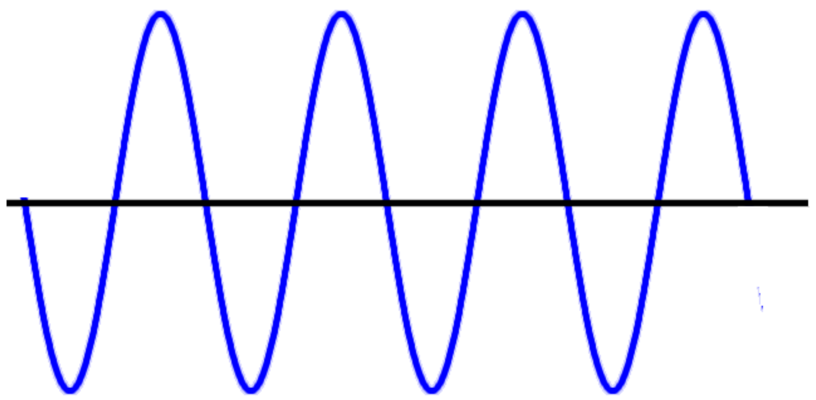
Our old DC friend called resistance is in the coil windings. That R causes power to be dissipated. For its part, the capacitor has *almost* no loss.



< == Equivalent diagram for the inductor

If you “pinged” the LC circuit with a train of input pulses from the source, you might generate a continuous sine wave.





REVIEW: Pythagoras's right-triangle

$$a^2 + b^2 = c^2$$

C is equal to the square root of $A^2 + B^2$

REVIEW: ***Impedance*** **(Z) is the** ***vector sum*** **of R and** ***reactance*** **(X), derived from the Pythagorean theorem.**

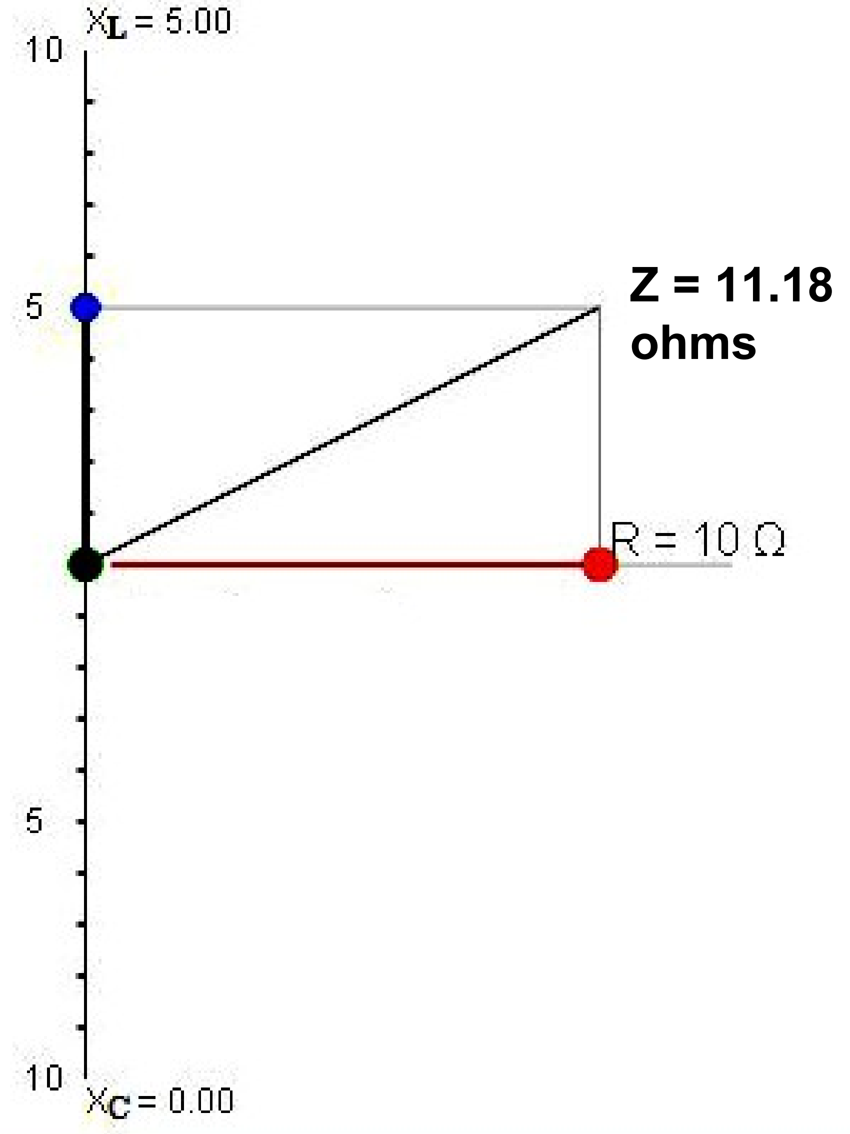
$$C = \sqrt{A^2 + B^2}$$

$$\text{Impedance, } Z = \sqrt{R^2 + X^2}$$

The right-triangle calculation is useful for *vector analysis* of circuits that contain reactance as well as resistance.

The reactances can be inductive (X_L) or capacitive (X_C), or a combination of both.

In this example *vector diagram* a coil's X_L is 5 ohms of inductive reactance and its winding resistance is 10 ohms. The resultant, or impedance Z, is 11.18 ohms.

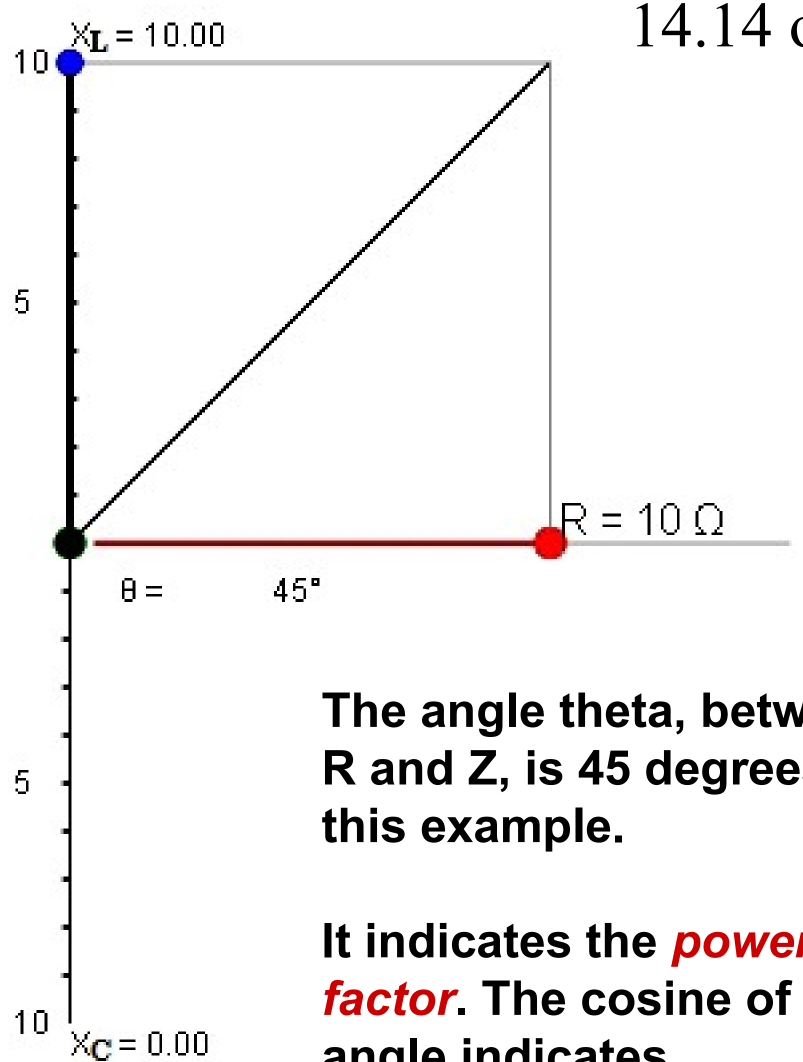


In this example X_L is increased from the previous example, to 10 ohms.

The resistive portion of the inductor is still 10 ohms, but the combined *impedance* (Z) is now 14.14 ohms.

Z is called the ***resultant***.

Z = 14.14 ohms



The angle theta, between R and Z, is 45 degrees in this example.

It indicates the ***power factor***. The cosine of that angle indicates dissipated power.

The cosine of theta is *power factor*, which indicates dissipated power.

The COS of zero is 1.

The COS of 90 is zero!

In our AC circuits, the power factor is the ratio of the real power that's used to do work, and the *apparent power* that's supplied to a circuit.

When all the power is reactive power with no real power the power factor is 0.

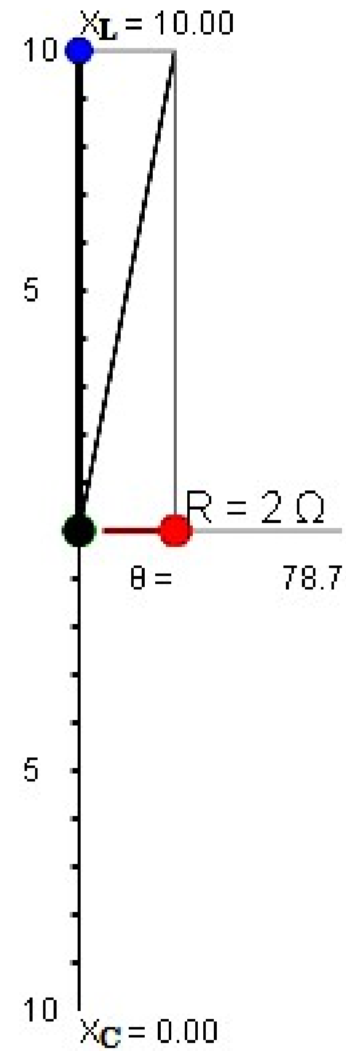
When all the power is real power with no reactive power the power factor is 1.

In this example, X_L remains at 10 ohms, but the coil's internal resistance is now reduced to only 2 ohms.

The resultant, Z, is 10.2 ohms of impedance.

The angle is almost 79 degrees. The cosine of theta approaches zero, indicating that there's little power, or heat or light energy, dissipated in this highly inductive circuit.

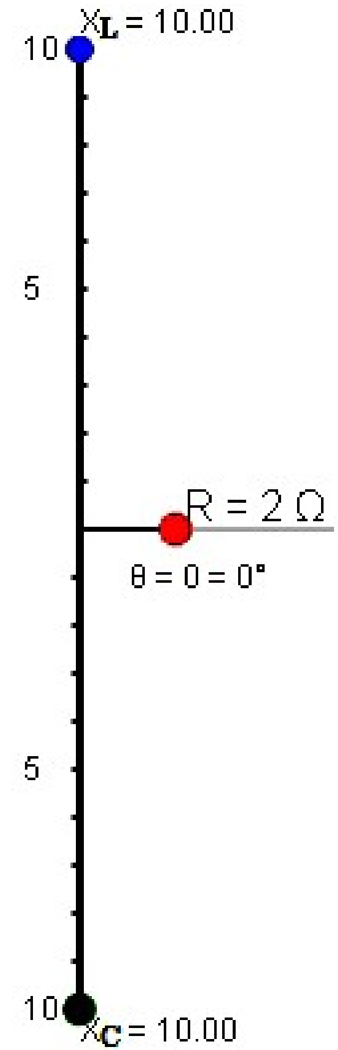
Z = 10.2 ohms



Now consider an LC circuit. We've added a capacitor, and assume its capacitive reactance X_C is equal and opposite to its inductive reactance X_L. Both are 10 ohms.

The 10-ohm reactances cancel, as they're equal and opposite, the current and voltage is in phase, and the resultant, Z, is comprised of resistance only.

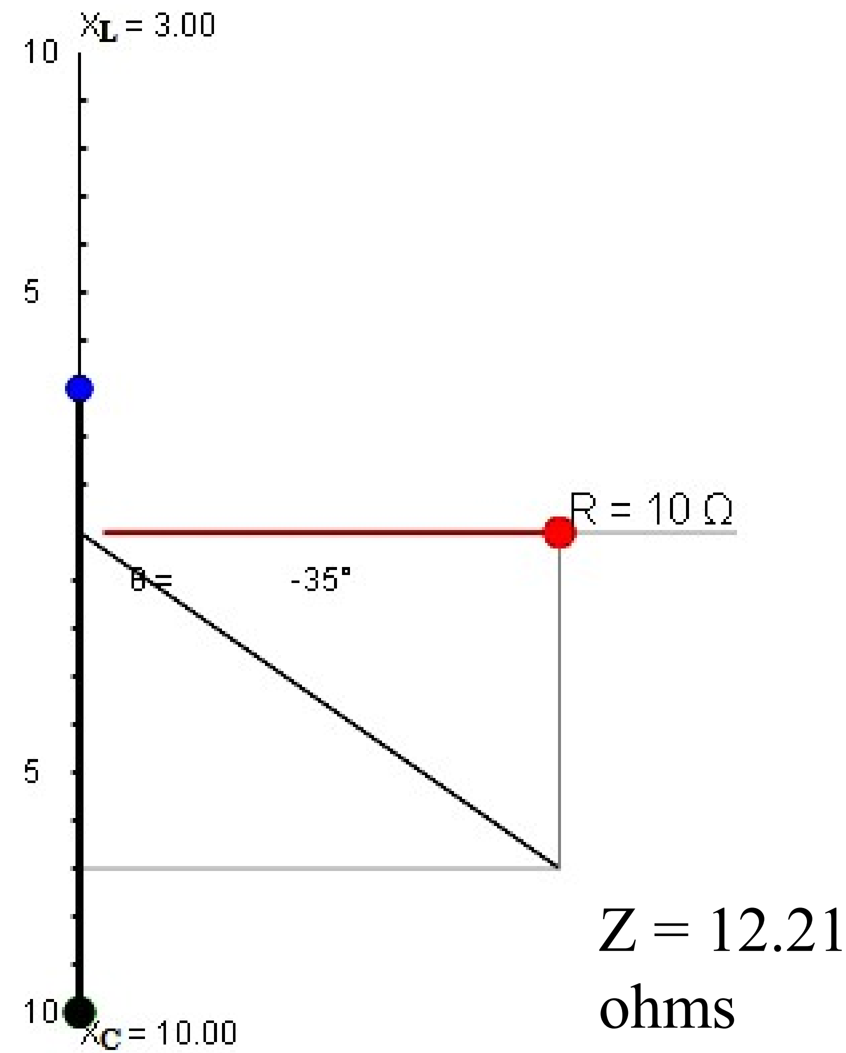
The power factor is the cosine of theta, or 1. The circuit dissipates power in the resistive portion only.



Next, let's examine an LC circuit where X_C is greater than X_L. Here X_C is 10 ohms and X_L is only 3 ohms.

The capacitive circuit exhibits 12.21 ohms of impedance, but the impedance is now capacitive.

The power factor, PF, is 0.81. That indicates R is still substantial.



In conclusion ...

More to come ...

73,
AI2Q, Alex