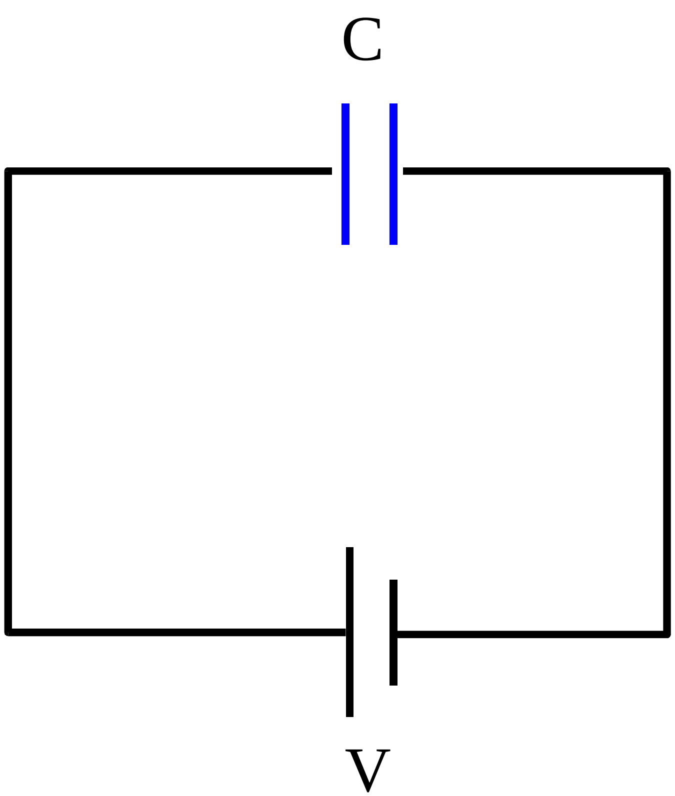
Chapter 23

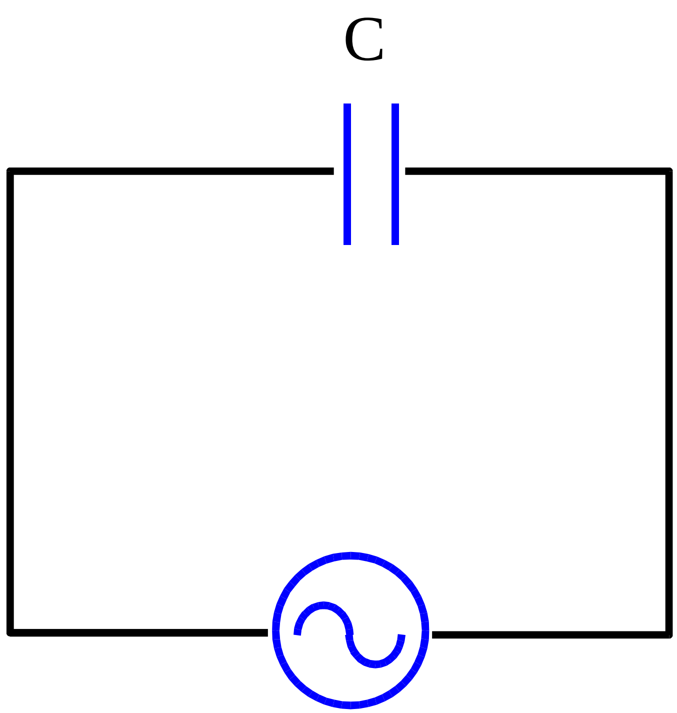
Alternating Current Circuits

Capacitor in a dc Circuit



Recall that a capacitor in a dc circuit does not pass a current through it (in a sense, it breaks the circuit). Instead, charge builds up on each plate until a maximum charge has been transferred from one plate to the other.

Capacitor in an ac Circuit



In an ac circuit, because charge is continuously moving back and forth, the capacitor appears to pass charge through it.

Because of this, we may write an equation analogous to Ohm's Law:

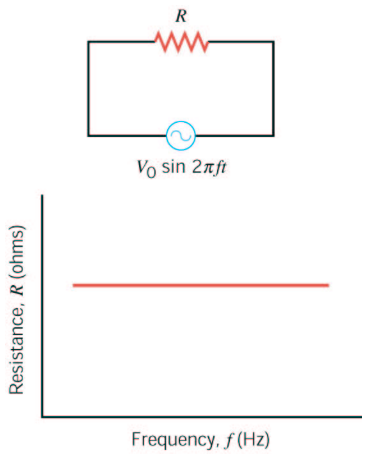
Ohm's Law: $V = I\,R \quad (dc\;circuit)$

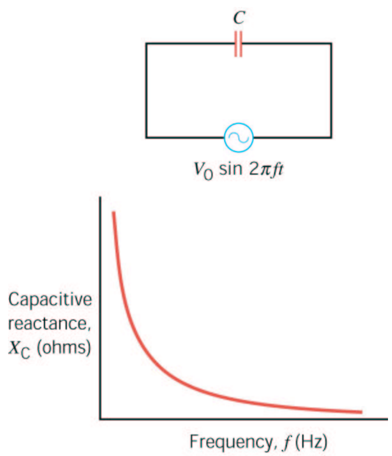
$$V_{rms} = I_{rms}\;R \quad (ac\;circuit)$$

Capacitor in an ac circuit: $V_{rms} = I_{rms}\;X_c$

Unlike a resistor, a capacitor <u>does not</u> dissipate energy when current passes through it!

Capacitance Reactance





Cutnell & Johnson
Wiley Publishing
Physics 5th Ed.
Figure 23.02 (W0939)
C M Y K

Xc is known as the reactance of the capacitor and is given by:

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

Let's look at the limits of the frequency in the above equation.

$$\lim_{f \to 0} X_c = \infty$$

$$\lim_{f \to \infty} X_c = 0$$

Example Problem (1)

Problem 1 from book:

At what frequency does a 7.50 μF capacitor have a reactance of 168 Ω?

Given: $f = ?, C = 7.5 \times 10^{-6} F, X_c = 168\,\Omega$

$$X_c \frac{1}{2\pi f C} \Rightarrow f = \frac{1}{2\pi X_c C}$$

$$f = \frac{1}{2\pi(160\,\Omega)\,7.50 \times 10^{-6} F} = 126.3\,Hz.$$

Example Problem (2)

Problem 4 from the book:

A capacitor is connected across the terminals of an ac generator that has a frequency of 440 Hz. and supplies a voltage of 24 V. When a second capacitor is connected in parallel with the first one, the current from the generator increases by 0.18 A. Find the capacitance of the second capacitor.

$$f_1 = 440\,Hz.\,, V = 24\,V$$

$$V_{rms} = I_{rms} X_{c_1} = I_{rms} \frac{1}{2\pi f C_1} \Rightarrow C_1 = \frac{I_{rms}}{2\pi (440)(24)}$$

Now put both capacitors in parallel

$$C_T = C_1 + C_2$$

$$C_T = \frac{I_{rms_1}}{2\pi (440)(24)} + C_2$$

Example Problem (2-2)

Now: $V_{rms} = I_{rms_2} X_{c_2} = I_{rms_2}\left(\frac{1}{2\pi(C_1+C_2)}\right)$

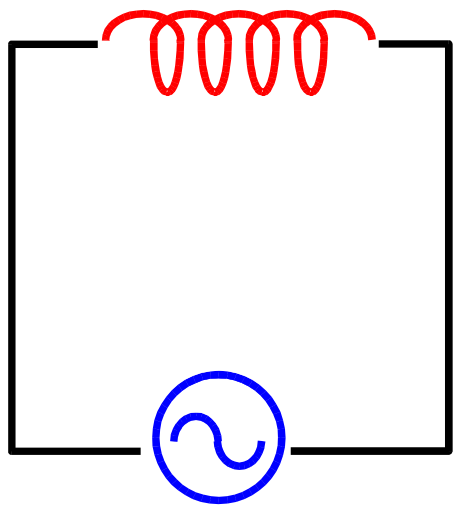
$$24V = \frac{(I_{rms_1} + 0.18A)}{2\pi f(C_1+C_2)} = \frac{I_{rms_1} + 0.18A}{2\pi f\left(\frac{I_{rms_1}}{2\pi(440)(24)} + C_2\right)}$$

$$\frac{\cancel{(24)}\cancel{2\pi}\cancel{(440)} I_{rms_1}}{\cancel{2\pi}\cancel{(440)}\cancel{(24)}} + (24)(2\pi\, 440)C_2 = I_{rms_1} + 0.18A$$

$$\cancel{I_{rms_1}} + 48\pi(440)C_2 = \cancel{I_{rms\,sub1}} + 0.18$$

$$C_2 = \frac{0.18}{48\pi(440)} = 2.71\times 10^{-6} F$$

Inductors



When a coil of wire is placed in an ac circuit, it is called an inductor (since a current in the wire induces a field through and around the coil).

The current is produced by an ac source so it is always changing it's magnitude and direction. A changing current produces a changing field in the coil. Lenz's Law tells us that a coil experiencing a changing field through it (a magnetic flux) induces an Emf such that the field produced tries to negate the change in flux (even if the field is created by the current in the coil itself - this is called self-induction).

Inductance of a Coil

Recall that $Emf = -N\dfrac{\Delta\Phi}{\Delta t}$

and the inductance of a coil is given by:
(see CH. 22, eq. 22.9)

$$N\Phi = LI$$

so: $Emf = -N\dfrac{\Delta\Phi}{\Delta t} = \dfrac{-\Delta(N\Phi)}{\Delta t} = \dfrac{-\Delta(LI)}{\Delta t} = -L\dfrac{\Delta I}{\Delta t}$

Inductors

You typically find inductors wrapped about an iron core because this significantly increases the inductance.

Inductors, like capacitors, do not dissipate energy in the circuit.

Now let's put this inductor into an ac circuit. As you pass an alternating current through the inductor, it resists the current change through itself and therefore acts just like a resistor in the circuit. We can now write another analogy to Ohm's Law:

$$V_{rms} = I_{rms} X_L$$

where

$$X_L = 2\pi f L$$

and the SI unit is once again the Ohm