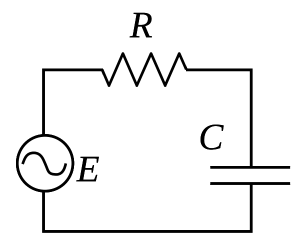
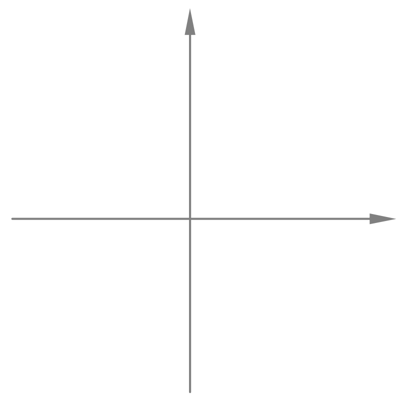
Discussion Question 11E
P212, Week 11
Low-Pass and High-Pass Filters



The circuit shown at right has an AC generator of peak EMF $\mathcal{E}_{max}$ and frequency ω connected in series with a resistor R and a capacitor C. Let's analyze the behavior of this circuit at extreme values of the frequency ω.

*Important note: Since there is no inductor present, you may think that we're back to the material of "RC Circuits" that we studied a month ago. But not so! Those "RC circuits" were connected to **DC batteries** of constant voltage! This one is being driven by an **AC generator**, which makes it behave in a totally different way. This is an RLC circuit like any other … the fact that L = 0 just simplifies things a little bit.*

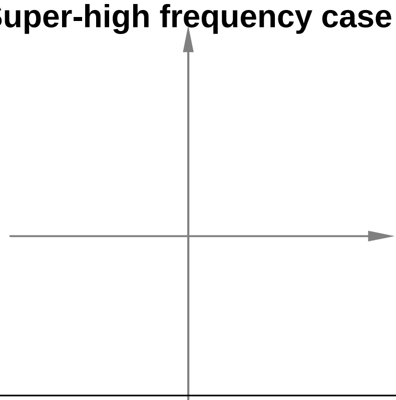
(a) Draw a phasor diagram for this circuit, showing the relative phases of the voltages V_R, V_C, and $\mathcal{E}$.



(b) Now draw phasor diagrams for the cases when the driving frequency ω is extremely small, and when it is extremely large. In both cases, please answer the following questions:

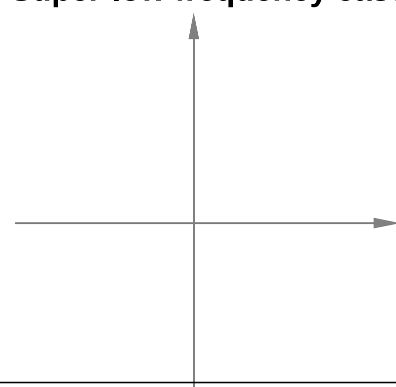
- How does the peak voltage $V_{R,max}$ across the resistor compare with the generator $\mathcal{E}_{max}$? (Are they about the same? Or is one very-much smaller than the other?)
- How does the peak voltage $V_{C,max}$ across the capacitor compare with the generator $\mathcal{E}_{max}$? (Are they about the same? Or is one very-much smaller than the other?)

Super-high frequency case



For the resistor, which is is true?
a) $V_{R,max} \ll \mathcal{E}$ b) $V_{R,max} \approx \mathcal{E}$ c) $V_{R,max} \gg \mathcal{E}$
For the capacitor, which is is true?
a) $V_{C,max} \ll \mathcal{E}$ b) $V_{C,max} \approx \mathcal{E}$ c) $V_{C,max} \gg \mathcal{E}$

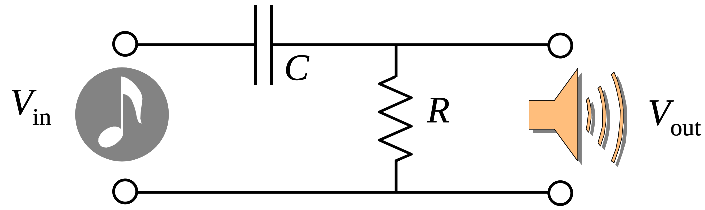
Super-low frequency case

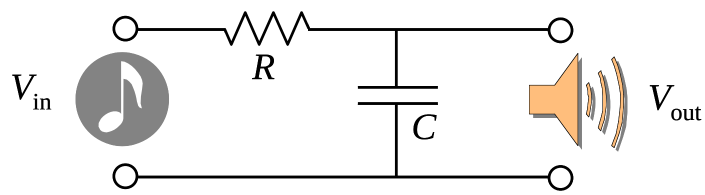


For the resistor, which is is true?
a) $V_{R,max} \ll \mathcal{E}$ b) $V_{R,max} \approx \mathcal{E}$ c) $V_{R,max} \gg \mathcal{E}$
For the capacitor, which is is true?
a) $V_{C,max} \ll \mathcal{E}$ b) $V_{C,max} \approx \mathcal{E}$ c) $V_{C,max} \gg \mathcal{E}$

A common application of the circuit we've been considering is in **audio amplifiers**, which process music signals containing many different frequencies. In this application, the generator EMF is produced by something like a CD player, or an old-fashioned record player. This **input signal** V_{in} is sent through the resistor and capacitor, and an **output signal** V_{out} is produced by connecting an output device (like a speaker) in parallel across either *R* or *C*. Here are the two configurations:

Circuit A





Circuit B

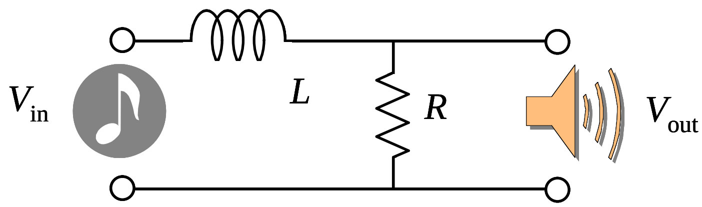
Suppose our music input comes from an old record-player, and is subject to hiss-and-pop scratch noise. These distortions of the music are very short-lived, and so are of very high frequency. Thus, we would like our amplifier to <u>remove</u> signals of very <u>high frequency</u>. This is called a **low-pass filter** (or "scratch filter") → when the input signal is of low frequency, the input signal V_{in} is passed through to V_{out} without much change … but high-frequency input signals are blocked.

(c) Based on your phasor diagrams, which of the circuits shown would provide a **low-pass filter**?

(d) Would the *other* one provide a **high-pass filter** (also called a "rumble filter") which deletes very-low frequency bass noise?

(e) Low-pass and high-pass filters can also be constructed using inductors rather than capacitors. Use your expertise with phasor diagrams to determine which of these two circuits would provide a **low-pass filter** and which would provide a **high-pass filter**.

Circuit A



Circuit B