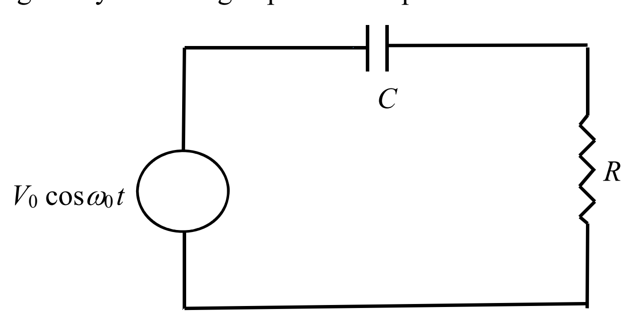
Physics 3150
Problem Set 2

Due on Monday, February 15, 2016. This problem set is likely the most difficult of the semester, so be sure to allow a little extra time.

1. In a atandard US 208-Volt power distribution system, thre are three active wires or "phases," each with a sinusoidal waveform having a phase shift of $2\pi/3$ or 120° relative to the next. These three phases have equal amplitudes. There is also a fourth "neutral" wire which is electrically at the average valueof the three phases, and is sometimes connected to ground. The rms value of the voltage measured between any two phases is 208 Volts, and the frequency is 60 Hz.
   a. Write explicit expressions $V_0 \cos(\omega t + \phi_i)$ for the time-dependent voltages of each of the three phases, determining values of V_0, ω, and ϕ_i that satisfy the description above. Don't just write a result —you should show that V_0 actually corresponds to an rms voltage difference of 208 Volts between adjacent phases.
   b. Show that at any fixed time t, the average of all three of these phase voltages is zero.
   c. Show that the rms voltage between any one of the phases and the neutral is 120 V. This is how the 120 V "single-phase" power in a standard home electrical distribution system is obtained. The neutral is the white wire in a standard outlet box, the "hot" wire is typically black, and there is also an explicitly grounded wire that's either bare or green.
2. In the simple series RC circuit below, V_0 = 10 Volts, R = 50 Ω, and $\omega_0 = (RC)^{-1}$.
   a. Calculate the power dissipated in this circuit using the general expression for cycle-averaged power in a complex impedance,

$$P = \frac{V_{\text{rms}}^2}{|Z|}\cos\phi.$$

   b. Repeat the calculation by calculating the current through the resistor, then explicitly evaluating the cycle-averaged power dissipated in the resistor.



3. Eggleston 2-11.
4. Using the same circuit as in Problem 2-11, calculate the short-circuit current $\hat{I}_{\text{sc}}$ at the output and use it to determine the *output impedance* of the circuit using the generalized Thévenin theorem,

$$Z = \frac{\hat{V}_{\text{oc}}}{\hat{I}_{\text{sc}}}$$

(Continued)

Compare your result with a calculation done the easy way, by replacing the signal source V_s with a short and calculating the impedance directly.

5. Still working with the same circuit as Problem 2-11, find the *input impedance* as seen by the signal source. That is, find the impedance of the circuit as viewed by a pair of terminals located where the signal source V_s is normally connected. Evaluate this impedance and its magnitude numerically for $R_1 = R_2 = 100\ \Omega$ and $C = 0.1\ \mu\text{F}$, at frequency $\omega = 10^5$ rad/s. Will a signal generator with an output impedance of 50 Ω have trouble driving the circuit at this frequency?

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