ECE/ENGRD 2100 – Spring 2019 Issued: March 22, 2019, 10 am
Homework 5 Due: April 12, 2019, 11:59 pm

Helpful readings for this homework: Nilsson and Riedel, Chapter 9 and Chapter 14.

Grading Criteria
Show all work, as each problem will be graded using the grading criteria given below:

- 100% of maximum score if approach is correct and answer is also correct
- 80% of maximum score if approach is correct, but answer is incorrect due to algebraic or other math error
- 60% of maximum score if approach is mostly correct, but there is some conceptual error
- 40% of maximum score if problem has been seriously attempted, but approach is incorrect and/or there are major conceptual errors.
- 20% of maximum score if problem has been attempted, but is illegible.
- 0% of maximum score if there is no attempt to solve the problem.

Problem 5.1: [Problem 9.3 from Nilsson and Riedel] ($8\frac{1}{3}$ points)

Consider the sinusoidal voltage $v(t) = 25\cos(400\pi t + 60°)$ V.

(a) What is the maximum amplitude of the voltage?
(b) What is the frequency in hertz?
(c) What is the frequency in radians per second?
(d) What is the phase angle in radians?
(e) What is the phase angle in degrees?
(f) What is the period in milliseconds?
(g) What is the first time after $t = 0$ that $v = 0$ V?
(h) The sinusoidal function is shifted $5/6$ ms to the right along the time axis. What is the expression for $v(t)$?
(i) What is the minimum number of milliseconds that the function must be shifted to the left if the expression for $v(t)$ is $25\sin(400\pi t)$ V?

Problem 5.2: [Problem 9.11 from Nilsson and Riedel] ($8\frac{1}{3}$ points)

Use the concept of the phasor to combine the following sinusoidal function into a single trigonometric expression:

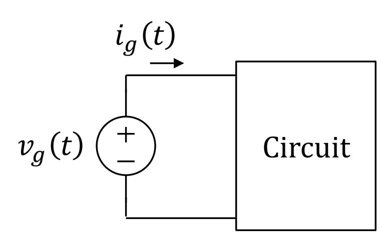
$$y = 30\cos(200t - 160°) + 15\cos(200t + 70°)$$

Problem 5.3: [Problem 9.14 from Nilsson and Riedel] ($8\frac{1}{3}$ points)

The expressions for the steady-state voltage and current at the terminals of the circuit shown to the right are:

$$v_g = 300\cos(5000\pi t - 78°)\text{ V}$$

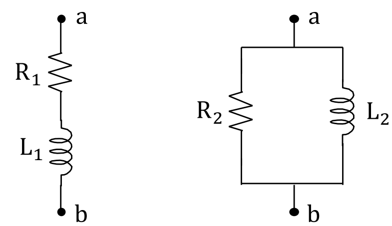
$$i_g = 6\sin(5000\pi t + 123°)\text{ A}$$



(a) What is the impedance seen by the voltage source?
(b) By how many microseconds is the current out of phase with the voltage?

Problem 5.4: [Problem 9.18 from Nilsson and Riedel] ($8\frac{1}{3}$ points)

Consider the two circuits shown to the right.



(a) Show that, at a given frequency ω, the circuits above will have the same impedance between the terminals a, b if:

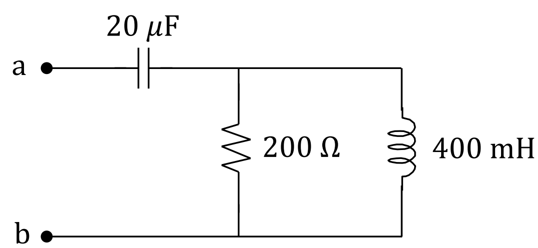
$$R_1 = \frac{\omega^2 L_2^2 R_2}{R_2^2 + \omega^2 L_2^2}$$

$$L_1 = \frac{R_2^2 L_2}{R_2^2 + \omega^2 L_2^2}$$

(b) Find the values of resistance and inductance that when connected in series will have the same impedance at 4 krad/s as that of a 5 kΩ resistor connected in parallel with a 1.25 H inductor.

Problem 5.5: [Problem 9.24 from Nilsson and Riedel] ($8\frac{1}{3}$ points)

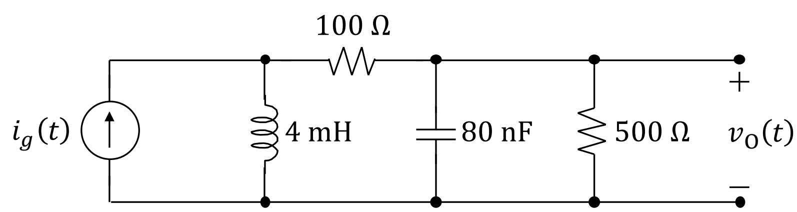
Consider the RLC circuit shown to the right.



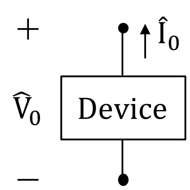
(a) Find the frequency (in radians per second) at which the impedance Z_{ab} of this circuit is purely resistive.
(b) Find the value of Z_{ab} at the frequency determined in part (a).

Problem 5.6: [Problem 9.31 from Nilsson and Riedel] ($8\frac{1}{3}$ points)

For the circuit shown to the right, use node analysis, to find the steady-state expression for v_O if $i_g = 25\cos(50{,}000t)$ mA.



Problem 5.7: [Problem 9.47 from Nilsson and Riedel] ($8\frac{1}{3}$ points)

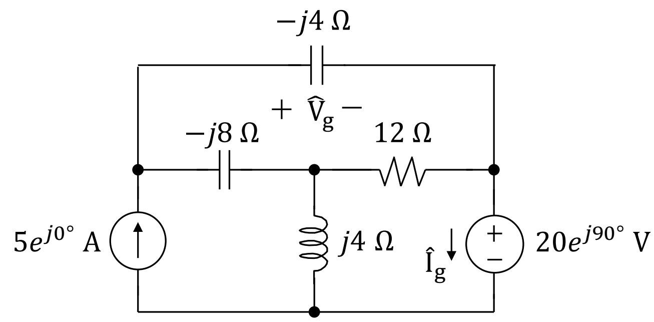


The device shown to the right is represented in the frequency domain by a Thevenin equivalent. When a resistor having an impedance of 200 Ω is connected across the device, the value of $\hat{I}_0$ is $(-150 + j150)$ mA. When an inductor having an impedance of $j200$ Ω is connected across the device, the value of $\hat{V}_0$ is $(-40 - j40)$ V.

Find the Thevenin voltage $\hat{V}_{TH}$ and the Thevenin impedance Z_{TH} of this device.

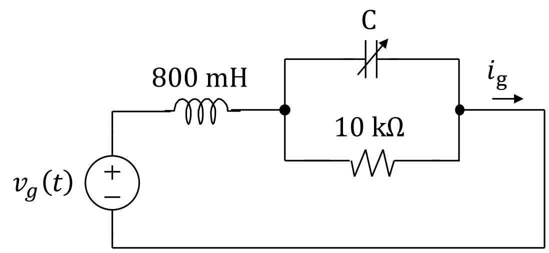
Problem 5.8: [Problem 9.55 from Nilsson and Riedel] ($8\frac{1}{3}$ points)

Use superposition to find the phasor voltage $\hat{V}_g$ in the circuit shown to the right.



Problem 5.9: [Problem 9.41 from Nilsson and Riedel] ($8\frac{1}{3}$ points)

The circuit shown to the right is operating in the sinusoidal steady state. The capacitor is adjusted until the current i_g is in phase with the sinusoidal voltage v_g.

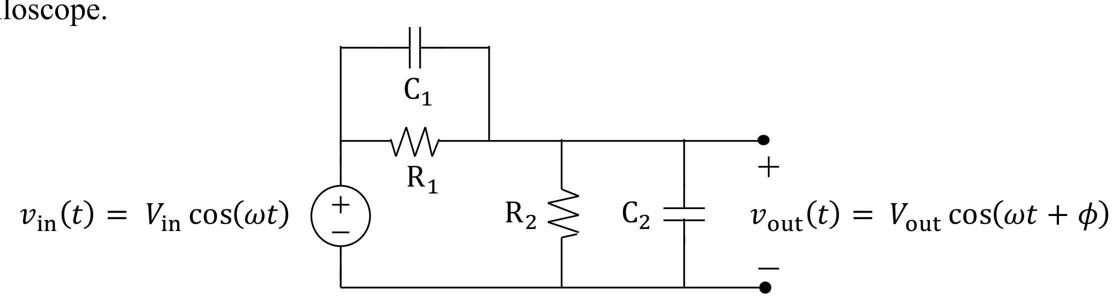


(a) Specify the value of capacitance C in microfarads if $v_g = 80\cos(5000t)$ V.

(b) Give the steady-state expression for i_g when C has the value found in part (a).

Problem 5.10: ($8\frac{1}{3}$ points)

The circuit shown below models an oscilloscope probe that provides a 10:1 voltage attenuation. Resistor R_1 is a fixed resistor in the probe, resistor R_2 models the input resistance of the oscilloscope, capacitor C_1 is a variable capacitor in the probe, and capacitor C_2 models the combined input capacitance of the oscilloscope and the cable between the probe and the oscilloscope.

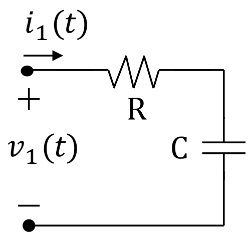


Determine the two relationships that are required between R_1, R_2, C_1 and C_2 so that $v_{out}(t) = 0.1v_{in}(t)$ for all values of radial frequency ω. That is, what relations are required so that $\hat{V}_{out} = 0.1\hat{V}_{in}$ (i.e., $V_{out} = 0.1V_{in}$ and $\phi = 0$) for all values of ω?

(Note that the value of C_2 is difficult to guarantee in practice due to variations in cable length and oscilloscope input capacitance, which is why C_1 is a variable capacitor and made manually adjustable in the probe.)

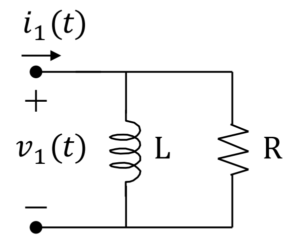
Problem 5.11: ($8\frac{1}{3}$ points)

Determine the impedance (Z) of the circuits shown below. Also using straight lines (asymptotes), sketch the magnitude of the impedance versus angular frequency (ω) on a log-log scale, and sketch the phase of the impedance versus angular frequency (ω) on a semi-log scale. In each case clearly indicate any corner frequencies (i.e., where the asymptotes in the magnitude plot meet).



$$Z(j\omega) = \frac{\hat{V}_1(j\omega)}{\hat{I}_1(j\omega)}$$

(A)

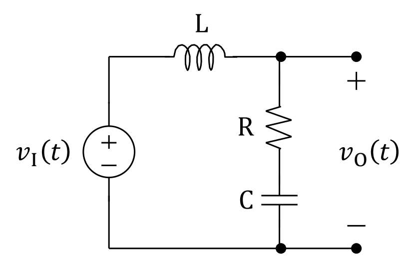


$$Z(j\omega) = \frac{\hat{V}_1(j\omega)}{\hat{I}_1(j\omega)}$$

(B)

Problem 5.12: ($8\frac{1}{3}$ points)

Consider the RLC filter shown to the right.



(a) Derive an expression for the transfer function of this circuit $\hat{V}_O/\hat{V}_I$, in terms of R, L, C, and ω.

(b) Given that $R = 10\ \Omega$, $L = 100\ \mu H$, and $C = 100\ pF$, using a chart similar to the one provided here, sketch the magnitude of the transfer function $|\hat{V}_O/\hat{V}_I|$ across the full range of frequencies shown. Make sure to provide asymptotes for low-frequency and high-frequency behavior and the value of the magnitude of the transfer function at any resonance or corner frequency that might exist.