ECE 307 – FINAL

FALL 1997 **A.P. FELZER**

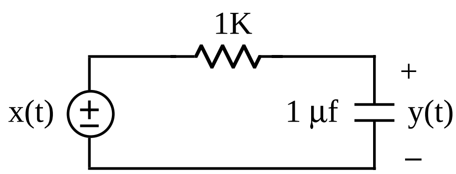
You may consult **your** notes and any books you may have or borrow from the library as well as any computer software or plotting calculators to do the following problems. But you **may not** under any circumstances for any reason talk to any person about the exam except for Felzer. If you **do discuss** this exam or **in any way** make use of the work of others, you will **fail** the course and have a letter put in your file explaining why.

To get a good grade in this exam you must not only get the right answers but also make sure that your solutions are neat, complete, concise, make obvious what each problem is, make obvious how you're solving the problem and make obvious what your answer is. You also need to include drawings of all circuits (including equivalent circuits) as well as appropriate graphs and tables. In addition all equations, graphs and tables must be labeled

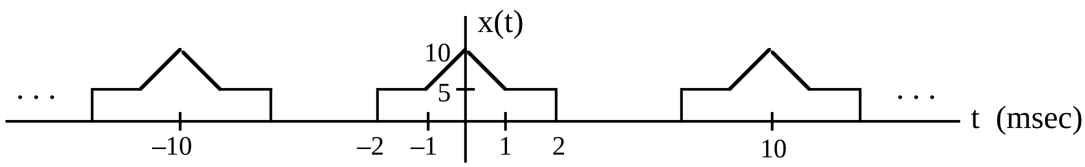
Note that it is better to do a problem with brute force than not at all. But it's better to do a problem "simply". Include any pertinent computer printouts. Be sure you start early enough so that you have time to think about and double check your work

1. Write out a page of notes you would use for this final if it was closed book

2. Find the average value of the steady state response of the following circuit

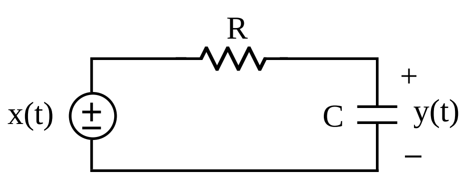


to the following periodic input



Explain in words how you got your result

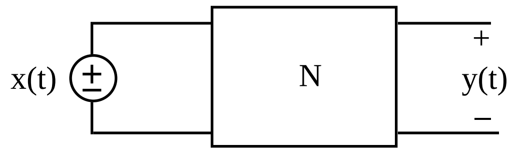
3. Suppose that "adjustments" to the values of R and C in the following circuit



cause the circuit's response to a given pulse train to become distorted. How did the "adjustments" affect the

a. Frequency response – explain how you know
b. Pole location – explain how you know
c. Time constant τ – explain how you know

4. Suppose the input to the following circuit N

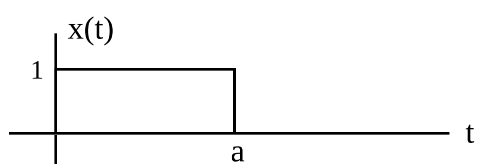


is $x(t) = 5 \cos(1000t) + n(t)$. Where $n(t)$ is a noise signal with frequency content pretty much evenly spread over the spectrum from DC to $\omega = 10^5$

a. Find the average normalized power of the sinusoid
b. Sketch what you expect x(t) to look like if the average normalized power of the noise n(t) is $P_{av} = 2$ watts
c. Sketch the frequency response of an ideal filter that will pass the sinusoid but filter out most of the noise. Explain how you got your result
d. Draw the pole zero diagram of a 2nd order circuit that approximates your ideal filter
e. Find the transfer function G(s) for your poles and zeros
f. Find the frequency response $G(j\omega)$ of your filter and plot its magnitude as a function of ω plotted on a log scale
g. Make a sketch of what you expect for y(t) at the output of your filter. Compare it to your sketch in part (b). Explain what happened

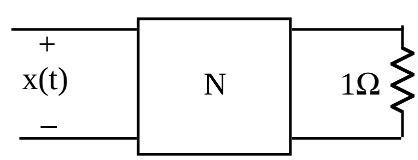
5. Sketch the Fourier Transforms of a
a. Constant
b. Single pulse
c. Impulse
d. Sinusoid
e. Pulse Train
f. Impulse Train

6. Given the following pulse



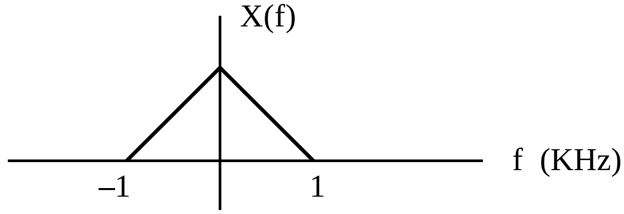
a. Find the Fourier Transform X(f) as a function of a
b. Describe what happens to X(f) as a gets larger
c. Make use of your result in part (b) to "guess" the Fourier Transform $U(\omega)$ of the unit step

7. Given a pulse train x(t) of magnitude 10, period T = 4 msec and pulse width a = T/2
a. Find and sketch the power spectral density of x(t)
b. How much energy will be delivered to the 1Ω resistor at the output of the following circuit in 10 seconds



if N is an ideal lowpass filter of gain $G = 2$ with cutoff frequency $f_c = 1.1$KHz

8. Given $y(t) = x(t) \cos(6\pi 10^3 t)$
   a. Find an expression for the Fourier Transform Y(f) in terms of X(f). Hint – express the sinusoid as a sum of complex conjugates
   b. Sketch Y(f) if X(f) has the following Fourier Transform

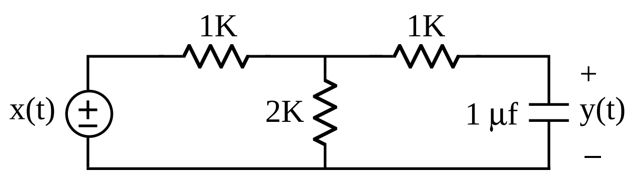


9. Given a 2nd order circuit with differential equation

$$v'' + 10^3 v' + 10^6 v = 10^6 x(t)$$

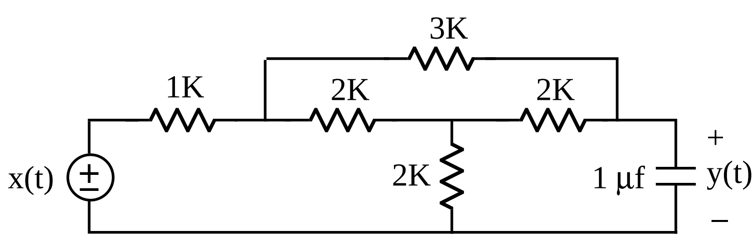
   a. Find the sinusoidal steady state response to $x(t) = 5\cos(1000t + 1.3)$
   b. Is the circuit overdamped, underdamped or critically damped. How can you tell

10. Given the following circuit

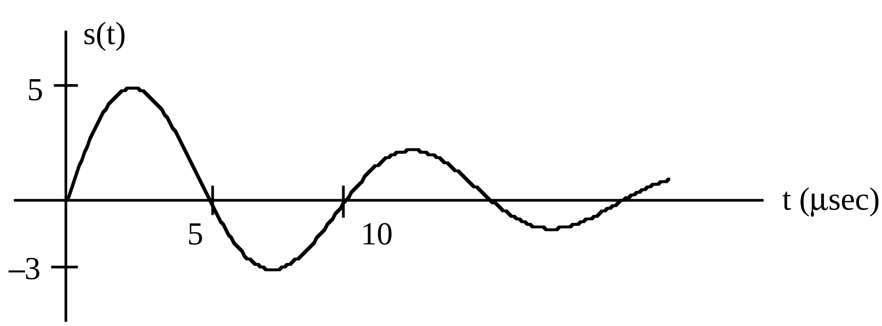


   a. Find and sketch the step response
   b. Find and sketch the impulse response

11. Find the pole of the following circuit



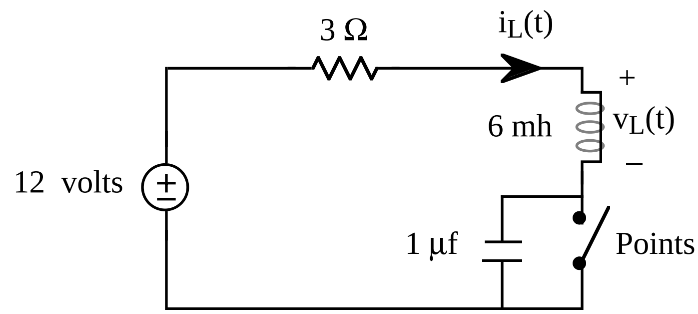
12. Given the following step response of a 2nd order series RLC circuit



a. Is this the step response of the voltage across the inductor, capacitor or resistor. How can you tell

b. Find the circuit's steady state response to $x(t) = 5\cos(4\text{x}10^5 t)$ if $G(j\omega_o) = 1$

13. Given the following simple model of an "old-fashioned" automotive ignition system



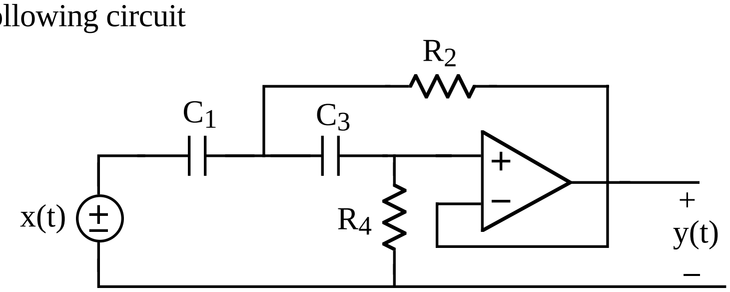
a. Find the steady state $i_L(t)$ when the points are closed (the switch is closed)
b. Find and plot $i_L(t)$ after the switch opens
c. Use SPICE to verify your result in part (b)

14. We know from ECE 209 that filter designers often write the transfer functions of 2nd order bandpass filters as follows

$$G(s) = \frac{Ks}{s^2 + \frac{\omega_p}{Q_p}s + \omega_p^2}$$

a. For what values of Q_p are the poles complex conjugages
b. Assuming the poles are complex conjugates with $p_1 = a + jb$ and $p_2 = p_1^*$
   (i) Find ω_p and Q_p in terms of a and b
   (ii) Describe the geometrical meaning of ω_p and Q_p in the complex plane. Illustrate

15. Given the following circuit



a. Write and put in matrix form the node equations of the transformed network
b. Given that your node equations can be solved for the circuit's transfer function

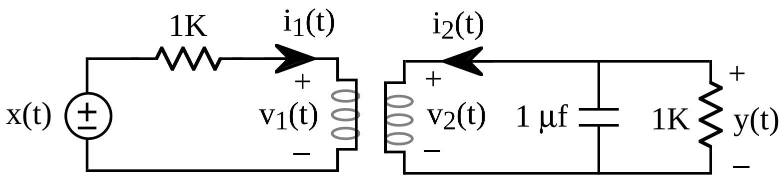
$$G(s) = \frac{s^2}{s^2 + \frac{C_1 + C_3}{C_1 C_3 R_4} s + \frac{1}{C_1 R_2 C_3 R_4}} = \frac{K s^2}{s^2 + \frac{\omega_p}{Q_p} s + \omega_p^2}$$

Come up with a set of equations for R_2 and R_4 in terms of ω_p and Q_p assuming $C_1 = C_3 = 1\ \mu f$

c. Use your results from part (b) to realize a filter with $\omega_p = 10^4$ and $Q_p = 2$
d. Plot the pole-zero diagram of the filter
e. Plot the frequency response of your filter as a function of ω on a log scale
f. Verify that SPICE gives the same results as in part (e)

16. Find a circuit with input admittance $Y(j1000) = 10^{-4} + j10^{-3}$

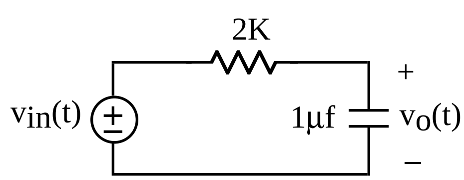
17. Find the transfer function $G(s) = Y(s)/X(s)$ of the following circuit



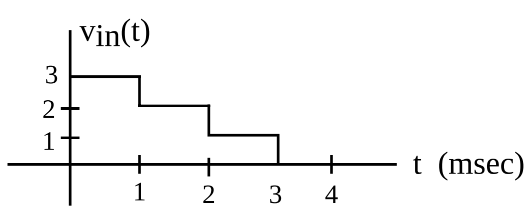
if the coupled inductors are characterized by

$$v_1(t) = 4x10^{-3}\frac{di_1(t)}{dt} + 3x10^{-3}\frac{di_2(t)}{dt}$$
$$v_2(t) = 3x10^{-3}\frac{di_1(t)}{dt} + 6x10^{-3}\frac{di_2(t)}{dt}$$

18. Find the zero state response of the following circuit

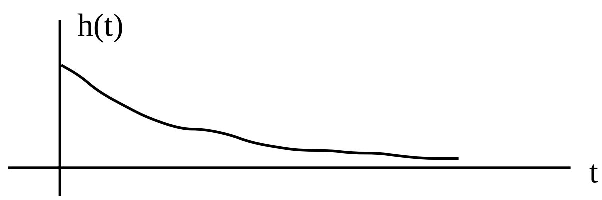


to the input



at time t = 4 msec

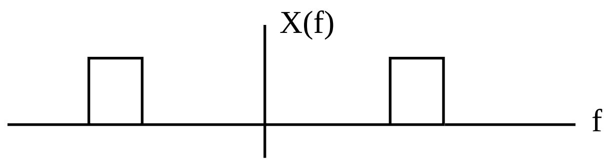
19. Sketch the zero state response of a circuit with the following impulse response



to the input

Explain what you're doing

20. Sketch the Fourier Transform of $x^2(t)$ if x(t) has the Fourier Transform



Explain how you got your result

21. Draw the straight line Bode Plots of

a. $G(s) = \dfrac{100}{s + 100}$

b. $G(s) = \dfrac{1000s}{s + 100}$

c. $G(s) = \dfrac{10^4 s}{(s + 100)(s + 1000)}$

d. $G(s) = \dfrac{10s(s + 100)}{(s + 10)(s + 1000)}$

22. Find the rate, in dB/decade, that the gain of the following transfer function is changing when ω is large

$$G(s) = \frac{1000}{(s + 100)(s^2 + 1000s + 10^6)}$$