ECE 405 - REVIEW OF THE BASICS - INVESTIGATION 1
REVIEW OF FREQUENCY RESPONSE

FALL 2005 **A.P. FELZER**

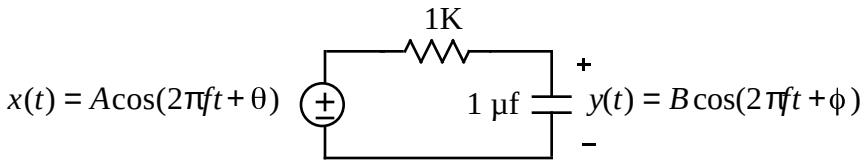
To do "well" on this investigation you must not only get the right answers but must also do neat, complete and concise writeups that make obvious what each problem is, how you're solving the problem and what your answer is. You also need to include drawings of all circuits as well as appropriate graphs and tables.

ECE 405 is an introduction to communication systems designed to efficiently and reliably transmit information from one location to another. We begin with a relatively brief introduction to analog communication systems and then introduce digital communication systems. The objective of the first four investigations is to review frequency response, Fourier series and Fourier transform.

1. How are sinusoids special. How in particular is the steady state response of a linear circuit to a sinusoid different from its steady state response to other periodic signals like pulse trains.

2. What do we mean by the frequency response of a linear circuit or system

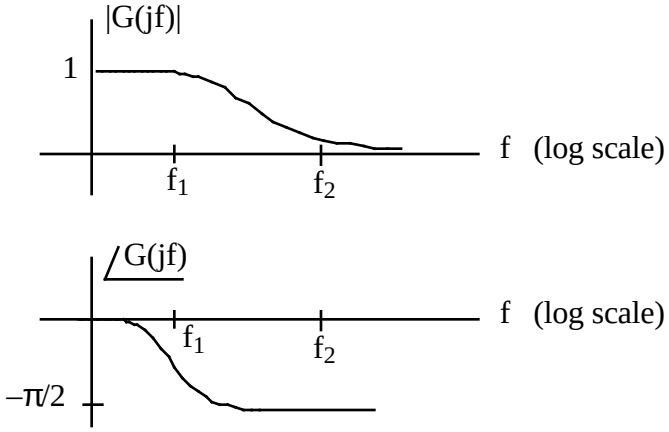
3. The *frequency response* of a circuit like the following



is how the amplitude and phase of the *sinusoidal steady state response* varies as a function of frequency f

   a. Make use of time domain arguments to explain why B will decrease as the frequency increases. Hint - as the frequency increases the charges have less time to accumulate on the plates of the capacitor
   b. Make use of your result in part (a) to sketch the magnitude of the transfer function $|G(jf)| = |B/A|$ as a function of the frequency f with $|G(jf)|$ plotted on a linear scale and f plotted on a log scale
   c. Is $|G(jf)|$ lowpass, highpass or bandpass. How do you know

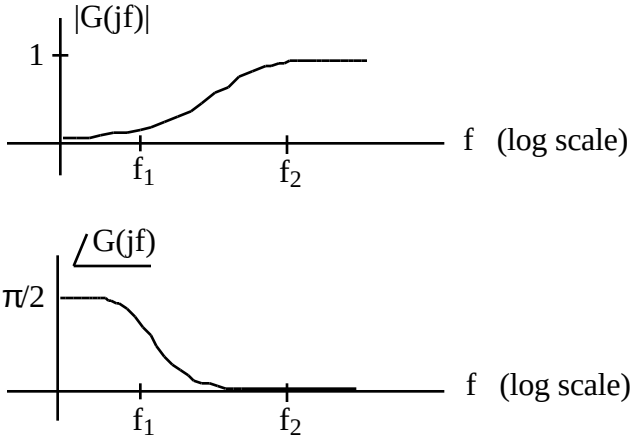
4. Given a linear circuit with transfer function as follows



sketch the input $x(t) = A\cos(2\pi ft)$ and the sinusoidal steady state output $y(t) = B\cos(2\pi ft + \phi)$ at each of the following frequencies. Be sure to draw the higher frequency sinusoids on the same time scale as the lower frequency sinsuoids

a. $f = f_2$ b. $f = f_2$

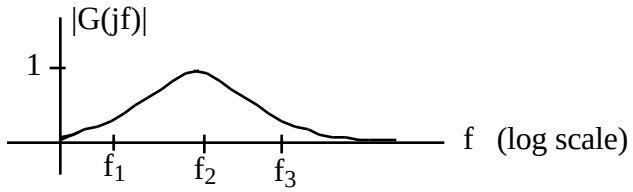
5. Given a linear circuit with transfer function as follows



sketch the input $x(t) = A\cos(2\pi ft)$ and the sinusoidal steady state output $y(t) = B\cos(2\pi ft + \phi)$ at each of the following frequencies. Be sure to draw the higher frequency sinusoids on the same time scale as the lower frequency sinsuoids

a. $f = f_1$ b. $f = f_2$

6. Given a linear circuit with transfer function as follows



sketch the input $x(t) = A\cos(2\pi ft)$ and the sinusoidal steady state output $y(t) = B\cos(2\pi ft + \phi)$ at each of the following frequencies assuming zero phase shift. Be sure to draw the higher frequency sinusoids on the same time scale as the lower frequency sinsuoids

a. $f = f_1$ b. $f = f_2$ c. $f = f_3$

7. Sketch the frequency response of an ideal
   a. Lowpass
   b. Highpass
   c. Bandpass

8. Find and sketch the sinusoidal steady state response y(t) of a first order circuit with the following transfer function

$$G(\mathrm{jf}) = \frac{Y(jf)}{X} = \frac{5000}{5000 + \mathrm{j}2\pi\mathrm{f}}$$

to the input $x(t) = 3\cos(2\pi 1000t)$

9. Find the sinusoidal steady state response y(t) of a circuit with the following transfer function

$$G(\mathrm{j}f) = \frac{5000}{5000 + \mathrm{j}2\pi f}$$

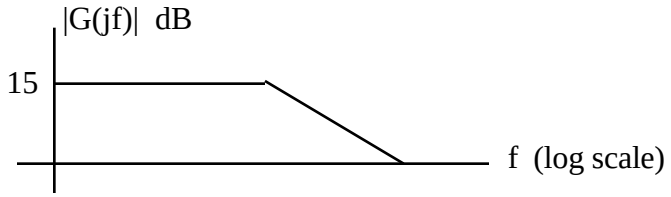
to the input $x(t) = 3\cos(2\pi 300t) + 2\cos(2\pi 1000t) + \cos(2\pi 3000t)$

10. Sketch the magnitude of the following transfer function with f on a log scale

$$G(\mathrm{j}f) = \frac{5000}{5000 + \mathrm{j}2\pi f}$$

11. What do we mean by the 3dB frequency f_{3dB} of a circuit or system

12. What is the gain in dB at the 3dB frequency of the following circuit



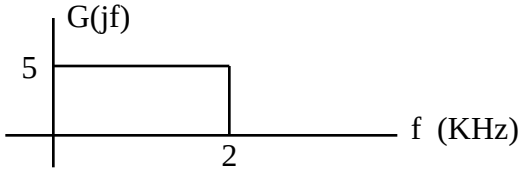
13. Sketch the magnitudes of the frequency responses of the following filters as functions of frequency with the magnitudes on a linear scale and the frequencies on a log scale
    a. Lowpass with $f_{3dB} = 1000$ Hz
    b. Highpass with $f_{3dB} = 1000$ Hz
    c. Bandpass with lower 3dB frequency $f_{l3dB} = 1$ KHz and upper 3dB frequency $f_{u3dB} = 10$ KHz

14. Make use of Euler's Relation as follows

$$re^{j\theta} = r\cos(\theta) + jr\sin(\theta) \qquad r\cos(\theta) = \frac{r}{2}e^{-j\theta} + \frac{r}{2}e^{j\theta}$$

to express the following cosines as sums of complex exponentials
    a. x(t) = cos (2π500t)
    b. x(t) = 3 cos (2π300t + 1.2)

15. Find the steady state response of a filter with the following frequency response



to the input x(t) = 4 cos (2π2000t) cos (2π3000t). Hint - make use of the trig identify cos(x)cos(y) = 0.5 cos (x+y) + 0.5 cos (x–y). **Memorize** this trig identity.