Intro to ECSE

Quiz 3

Fall 2022

1.	/20
2.	/45
Total	/65

Name ____________________

Notes:

SHOW ALL WORK. BEGIN WITH FORMULAS, THEN SUBSTITUTE VALUES AND UNITS. No credit will be given for numbers that appear without justification.
Use the backs of pages if there is not enough room on the front.

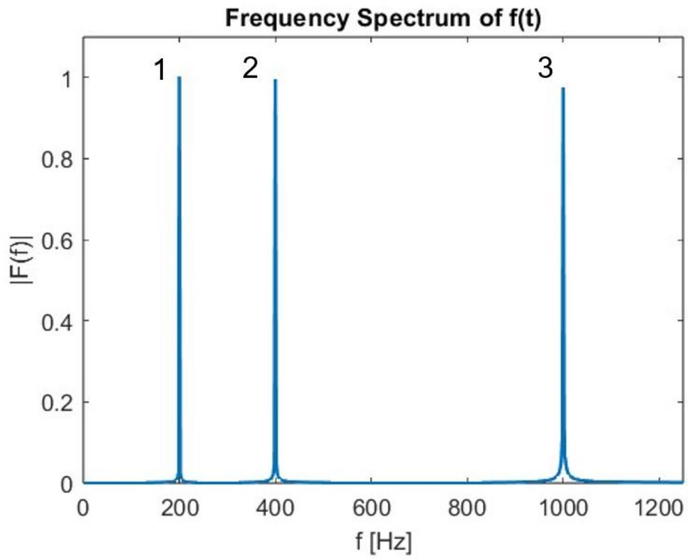
For partial credit on some questions, you may want to re-draw circuit diagrams as you simplify the circuits.

Many problems can be solved using more than one method. Check your answers by using a second method.

At least skim through the entire quiz before you begin and then start with the problems you know best. The proctor will only answer clarification questions where wording is unclear or where there may be errors/typos. No other questions will be responded to.

Problem 1 (20 pts) – Time Domain, Frequency Domain, Fourier Analysis & Synthesis

The frequency spectrum of a signal f(t) is shown below:



1.1: (2 pts) All three peaks of the frequency spectrum correspond to the same basic waveform, but at different frequencies. What type of wave do each of the peaks represent? Circle one.

Sine Triangle Square Sawtooth

Each of the peaks correspond to a sine wave. (+2 correct waveform selected)

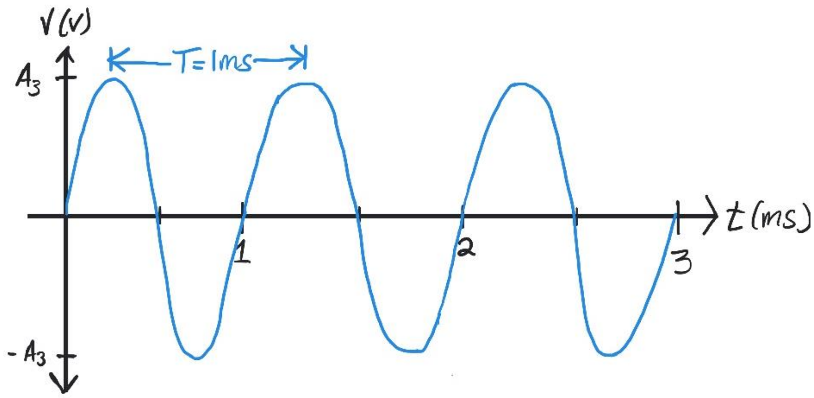
1.2: (3 pts) Give the frequency (in Hz) of the functions corresponding to each of the peaks:

Peak	Frequency (Hz)
1	**200**
2	**400**
3	**1000**

(+1 correct peak 1 frequency)
(+1 correct peak 2 frequency)
(+1 correct peak 3 frequency)

1.3: (4 pts) Sketch two periods of the wave corresponding to peak 3 in the time domain. Calculate and label the period *T* and label both the x-axis and y-axis with appropriate values for time and voltage. Assume that the amplitude of the wave is "A_3".

$$T = \frac{1}{f} = \frac{1}{1000Hz} = 1\, ms$$



(+1 correct waveform drawn)
(+1 period calculated and labeled correctly)
(+1 x-axis labeled appropriately)
(+1 y-axis labeled appropriately)

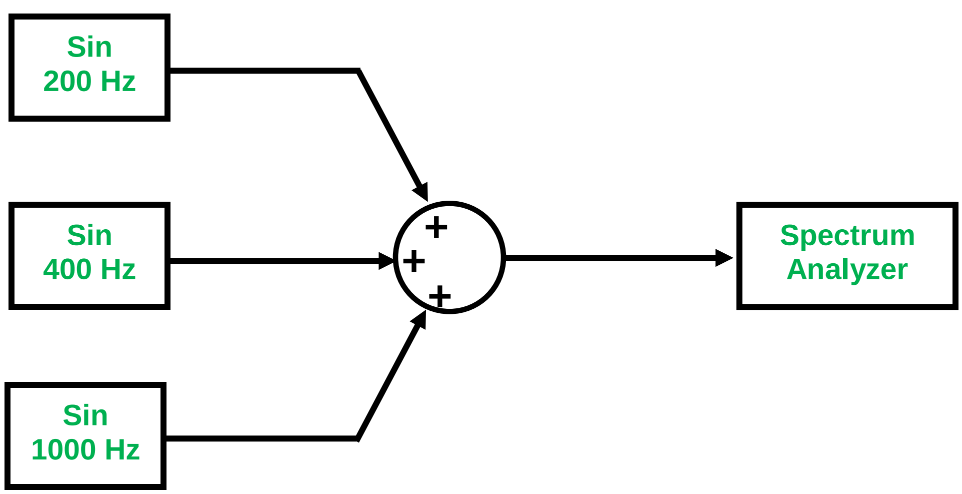
1.4: (4 pts) Assuming that the amplitudes of the waves corresponding to peaks 1, 2 and 3 are A_1, A_2 and A_3 respectively, write the expression for the time-domain function f(t) that corresponds to the frequency spectrum |F(f)|.

The frequency spectrum corresponds to a sum of three sinusoids in the time domain, one with a frequency of 200 Hz, one with a frequency of 400 Hz, and one with a frequency of 1000 Hz. Each one may also have a phase shift from zero (what the phase shift is is unclear from the plot because it's the magnitude of F(f)).

$$f(t) = A_1 sin(2\pi\, 200\, t + \phi_1) + A_2 sin(2\pi\, 400\, t + \phi_2) + A_3 sin(2\pi\, 1000\, t + \phi_3)$$

(+1 correct peak 1 function expression)
(+1 correct peak 2 function expression)
(+1 correct peak 3 function expression)
(+1 f(t) is a sum of functions)

1.5: (3 pts) Sketch a diagram of how you would create this signal in Simulink and view its frequency response.



(+1 used same functions as in 1.4)
(+1 used summing block)
(+1 spectrum analyzer block)

1.6: (2 pts) True or false (circle one): any signal can be represented by an infinite sum of sinusoidal waves. Support your answer with an example from the course material (lecture, lab, etc.) as to why this statement is true or false.

True False

This statement is true and the basis of signal processing: any signal can be represented as an infinite sum of sinusoidal waves of different amplitudes and frequencies. This is called Fourier Series.

Example from lab: in the background information for part B, it is stated that a square wave can be constructed with an infinite sum of sinusoids. The example in the lab shows that a sum of many terms gives a good approximation of a square wave. Part b then requires you to see how well a sum of 10 sinusoids reconstructs a sawtooth wave.

Example from class: demonstration of how well Fourier Series represents different basic functions with different numbers of summed sinusoids.

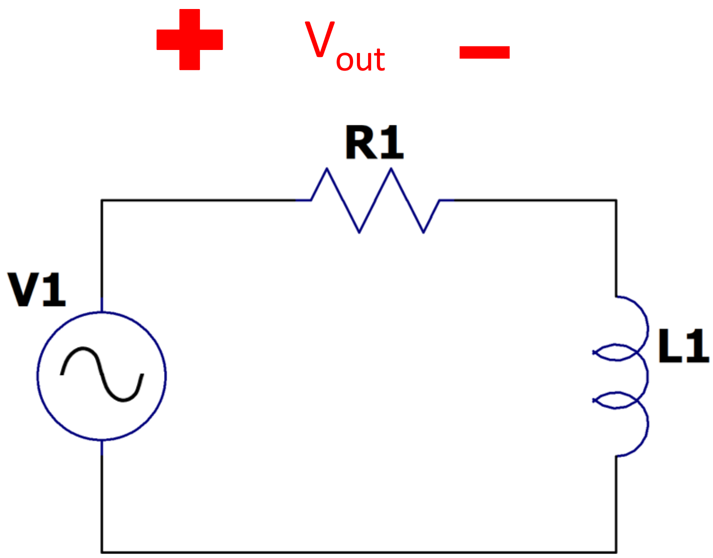
(+1 “true” selected)
(+1 appropriate explanation/example cited)

1.7: (2 pts) In terms of audio signals, changes in a signal’s amplitude correspond to changes in how loud the audio signal is. What do changes in frequency correspond to?

Changes in frequency in an audio signal correspond to changes in that signal’s pitch. Low frequencies correspond to low-pitched sounds (bass) and high frequencies correspond to high-pitched sounds (treble).

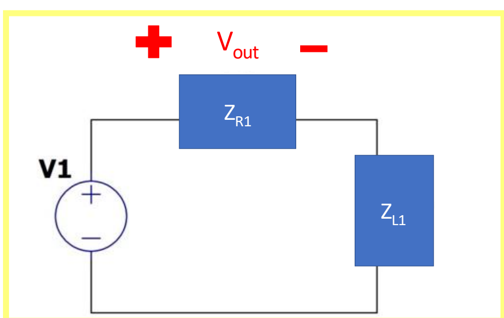
(+2 correct explanation)

Problem 2 (45 pts) - Filters, Transfer Function, Bode Plot Sketches



2.1 : (6 pts) Draw the circuit above in terms of impedances Z_{R1} and Z_{L1}. (Yes, it's a simple conversion, don't overthink the redrawn circuit diagram!) In the box below, write the impedances in terms of s and then in terms of jω.

<u>Circuit schematic:</u>



Impedance	Z_{R1}	Z_{L1}
In terms of s		
In terms of jω		

ZR1 in terms of s is R1
in terms of jω is R1
ZL1 in terms of s is sL1
interms of jω is jωL1

2.2 (7 pts) Find the transfer function of the circuit above, H(s) which means in terms of s, for the voltage across R1 as Vout. (It will help to use your redrawn circuit schematic in terms of impedances from 2.1.) Do the appropriate algebra to ensure s in the denominator is multiplied by 1. (Note: Denominator format should look like s+α) Finally, write this function in terms of H(jω) in the box below.

students should use a voltage divider but technically they can use any method that is equivalent

$$Vout = V_1 \cdot \frac{Z_{R1}}{Z_{L1} + Z_{R1}}$$

$$H(s) = \frac{V_{out}}{V_1} = \frac{Z_{R1}}{sL_1 + R_1}$$

$$H(s) = \frac{R_1}{sL_1 + R_1} \qquad H(s) \div \frac{L_1}{L_1}$$

$$H(s) = \frac{\frac{R_1}{L_1}}{s + \frac{R_1}{L_1}}$$

$$H(j\omega) = \frac{\frac{R_1}{L_1}}{j\omega + \frac{R_1}{L_1}}$$

H(s)	
H(jω)	

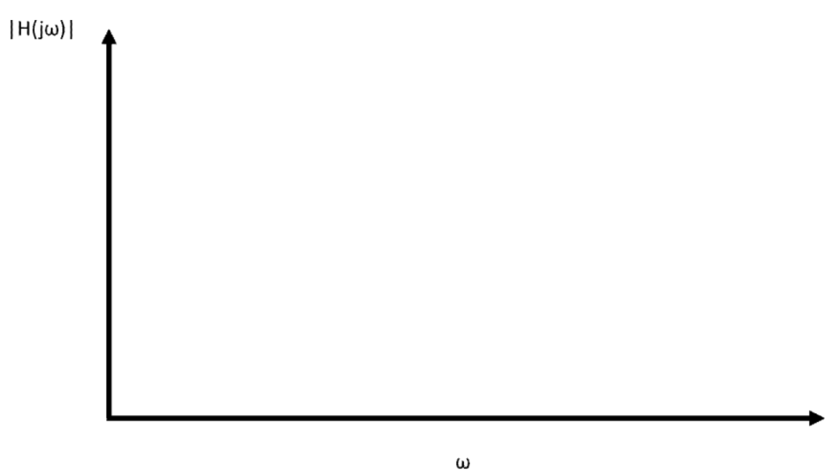
2.3 (6 pts) Sketch the Bode plot of the H(jω) from 2.2. IF YOU ARE UNSURE of your answer from 2.2, you may choose to sketch the Bode Plot of the ALTERNATE H(jω) function below for full credit! Circle the ALT_H(jω) if you intend to use this one instead. For your choice of either function ***SHOW your work by writing H(jω) when ω goes to 0 and ω goes to ∞ for full credit.***

Rewrite your H(jω) from 2.2 below if
you plan to use this to sketch the Bode Plot:

2.2_H(jω)= ____________________

Alternate FULL credit H(jω). Please circle below if you are using this function to draw a Bode Plot for full credit instead of the one you found in 2.2!

$$\text{ALT\_H}(j\omega) = \frac{j\omega}{j\omega + \frac{1}{RC}}$$



Please show work to show what happens at the limits of frequency going to 0 and ∞

From 2.2 carried over

ω goes to 0

$$H(j0) = \frac{\frac{R_1}{L_1}}{\frac{R_1}{L_1}} = 1$$

ω goes to ∞

$$H(\text{jinfinity}) = \frac{\frac{R_1}{L_1}}{\infty} = 0$$

This is a low pass filter

From ALT_H(jω)

ω goes to 0

$$H(j0) = \frac{j\omega}{\frac{R_1}{L_1}} = 0$$

ω goes to ∞

$$H(jinfinity) = \frac{j\omega}{j\omega} = 1$$

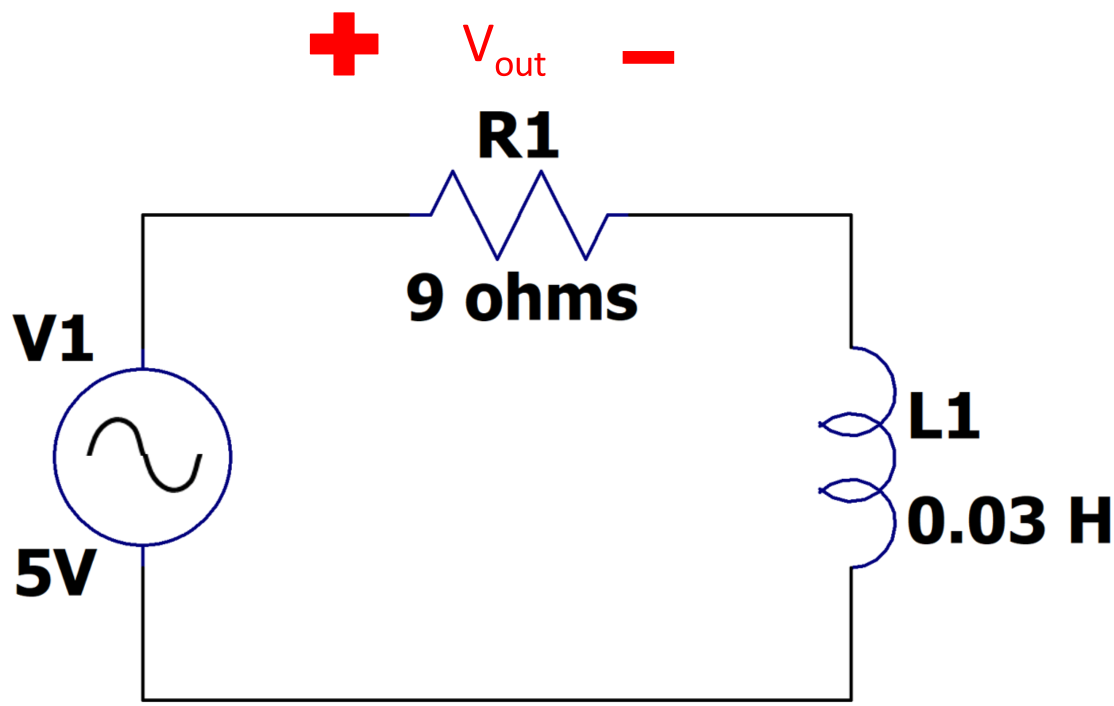
This is a high pass filter

2.4 : (1 pt) Circle the kind of filter that is represented in your choice of H(jω) in 2.3.

Low Pass Filter   High Pass Filter   Band Pass Filter   Band Stop Filter (notch filter)   Boy Band Filter

None of the Above

2.5 : (2 pts) What is the corner frequency in rad/s for the circuit below?



$R_1 := 9\Omega$ $L_1 := 0.03H$

$$\omega_c := \frac{R_1}{L_1}$$

$$\omega_c = 300 \frac{rad}{s}$$

ω_c	(rad/s)

2.6 : (1 pt) What is the value of $|H(j\omega)| = \frac{1}{2}$ Show the formula. You may round to 1 significant digit.

$$20 \cdot \log\left(\frac{1}{2}\right) = -6.021$$

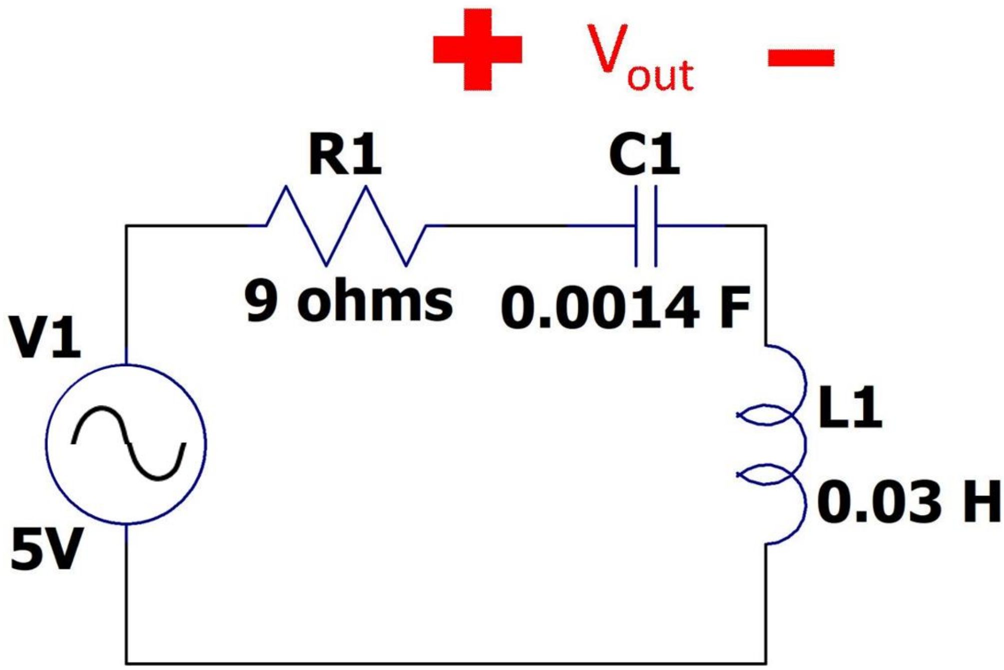
(db)

2.7 : (2 pts) What famous person in history was credited with creating the decibel or bel? You need first name or middle name AND last name....for full credit. Last name is kind of easy...right?

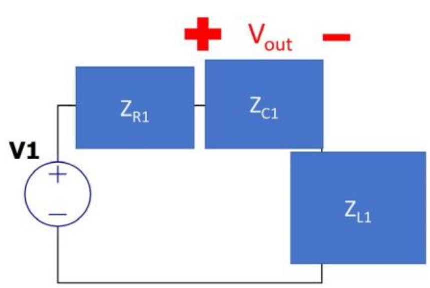
Alexander Graham Bell

2.8 : (fun pts) What discovery would you want to name after yourself, what are the units, and what is it called?

2.9 : (19 pts) Using a similar process as 2.1-2.3 draw the Bode plot for the following circuit where Vout is the voltage across the capacitor. Be sure to write H(s) in terms of s where the highest order of s is multiplied times 1!



Circuit schematic:



Impedance	Z_{R1}	Z_{L1}	Z_{C1}
In terms of s			
In terms of jω			

ZR1 in terms of s is R1
in terms of jω is R1
ZL1 in terms of s is sL1
interms of jω is jωL1
ZC1 in terms of s is 1/sC
in terns of jω is 1/jωC

H(s)	
H(jω)	

see next page for Bode plot axes...

$$H(s) = \frac{Z_{C1}}{Z_{C1} + Z_{R1} + Z_{L1}}$$

$$H(s) = \frac{1}{\frac{sC}{\frac{1}{sC} + R_1 + s \cdot L_1}}$$

$$H(s) \cdot \frac{sC_1}{sC_1} = \frac{1}{1 + s \cdot C_1 \cdot R_1 + s^2 \cdot C_1 \cdot L_1}$$

divide by L1C1

$$H(s) = \frac{\frac{1}{L_1 \cdot C_1}}{s^2 + \frac{R_1}{L_1} \cdot s + \frac{1}{L_1 \cdot C_1}}$$

$$H(j\omega) = \frac{\frac{1}{L_1 \cdot C_1}}{j\omega^2 + \frac{R_1}{L_1} \cdot j\omega + \frac{1}{L_1 \cdot C_1}}$$

ω goes to 0 $\quad \frac{1}{\frac{L_1 \cdot C_1}{\frac{1}{L_1 \cdot C_1}}} = 1$

ω goes to ∞ $\quad \frac{\left(\frac{1}{L_1 \cdot C_1}\right)}{\infty} = 0$

This is a low pass filter

Please show work to show what happens at the limits of frequency going to 0 and ∞

2.10 : (1 pt) Circle the kind of filter that is represented in your calculated H(jω) in 2.9.

Low Pass Filter

High Pass Filter

Band Pass Filter

Band Stop Filter (notch filter)

Boy Band Filter

None of the Above

2.11 (0 pts) Circle for our records please!

Do you expect to be exempt from the final?

I am confident that I will be exempt from the final

I am hoping that I will be exempt from the final

I do not expect to be exempt from the final

Will you take the final regardless of exemption?

I plan to take the final

I do not plan to the final if I am exempt

I have not made my decision to take the final yet if I am exempt