

Intro to ECSE

Quiz 3

Spring 2024

1.	/13
2.	/27
3.	/8
Total	/48

Name _____

RIN _____

Section _____

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.

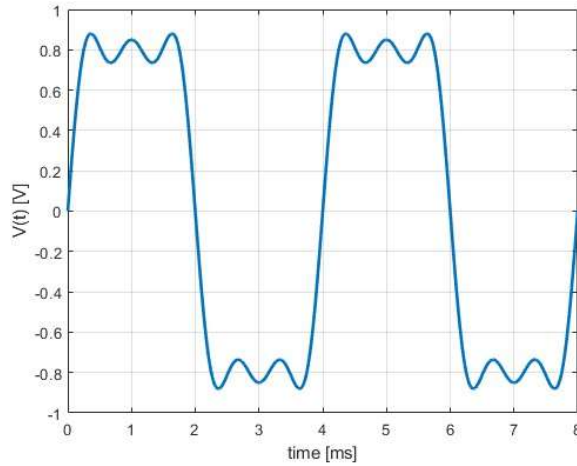
Many problems can be solved using more than one method. check your answers by using a second method.

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.

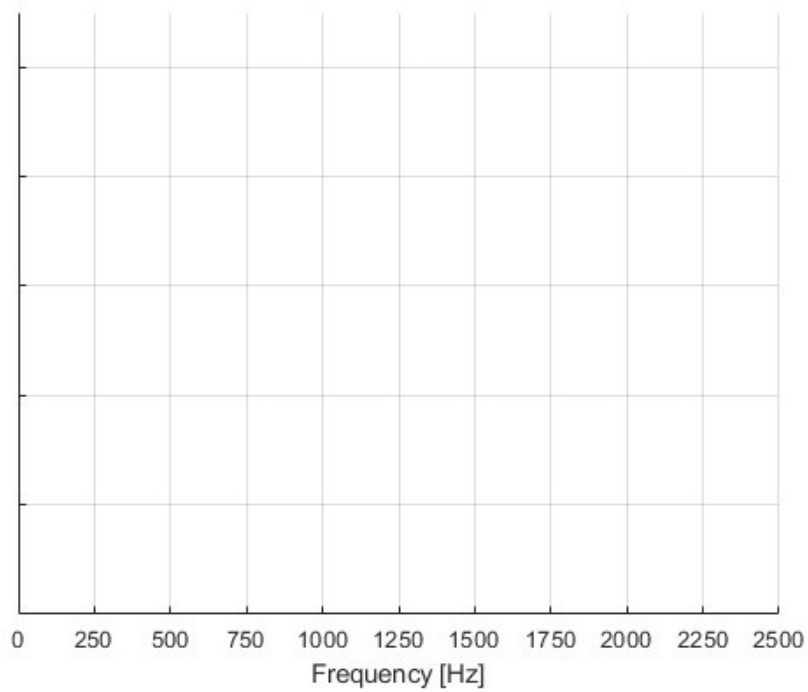
Problem 1 [13 Points]: Time Domain vs. Frequency Domain

1.1 [10 pts] Answer the following questions about the signal whose time-domain expression $V(t)$ and time-domain plot are shown below.

$$V(t) = \sin(500\pi t) + 0.3 \sin(1500\pi t) + 0.15 \sin(2500\pi t)$$



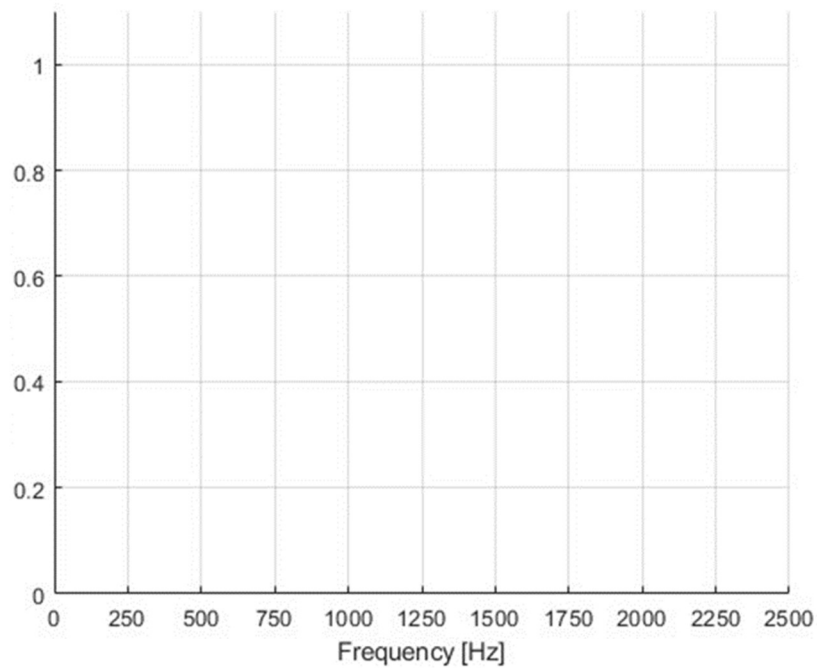
- a. [3 pts] Sketch the frequency response of $V(t)$ on the axes below (**in Hz**). *Note:* the relative amplitudes of different signal components in the frequency domain will not be graded, only their locations on the frequency axis.



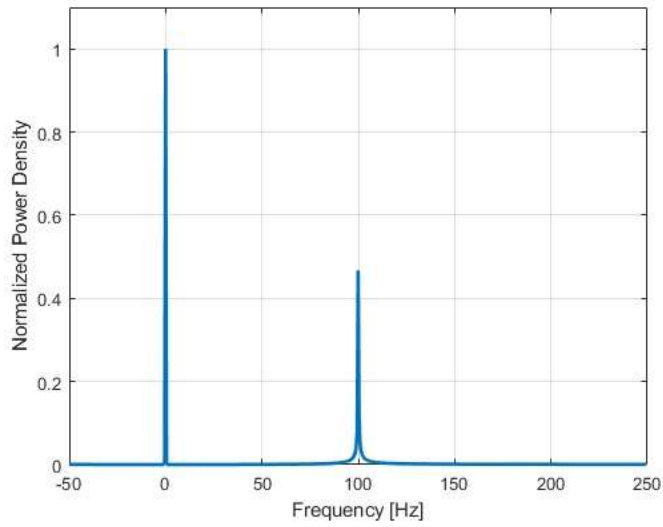
b. [2 pts] What is the fundamental frequency of $V(t)$ in Hz? Explain how you arrived at your answer.

c. [2 pts] What kind of filter would you use to keep only the $0.3 \sin(1500\pi t)$ portion of the signal (and eliminate the others)?

d. [3 pts] Draw the transfer function for the *ideal filter* you specified in part c. Label all relevant values for your transfer function on the y-axis and x-axis.



1.2 [3 pts] The frequency-domain representation of a signal is shown below. Write down the time domain expression $V(t)$ for this signal. *Note:* you do not need to specify numerical values for the amplitude of individual signal components in your expression (you may use V_1 , V_2 , etc.), but you must specify numerical values for frequency where relevant.



Problem 2 [27 Points]: Filter Circuits and Transfer Functions

2.1 [12 pts] Design Problem: 1st Order High-Pass Filter

- a. [3 pts] Draw a circuit that implements a 1st order high-pass filter using a resistor and a capacitor. You must specify the input voltage source and output voltage. You do not need to specify numerical resistance and capacitance values (you will do that in part *b*).

- b. [3 pts] Choose values for your resistor and capacitor to give a corner frequency of approximately $f_c = 3200$ Hz, and label your circuit in part *a* with them. You have only the following resistor and capacitor values available:

Resistance (Ω)	Capacitance (F)
47	1×10^{-7}
100	5×10^{-7}
200	1×10^{-6}

- c. [3 pts] Sketch the Bode plot of the magnitude of the transfer function for your high-pass filter **on a log-log scale** (decibels vs. frequency in Hz) to the right. Label the location of the corner frequency, as well as the filter's slope in terms of db per decade.



- d. [3 pts] Derive the transfer function $H(s)$ for your filter circuit in part *a* and put it in the form $H(s) = \frac{N(s)}{s+\alpha}$, where $N(s)$ is a function of s , and α is a constant. Express your transfer function in terms of R , C , and s .

2.2 [6 pts] *Transfer Functions and Complex Voltages*: Answer the following questions for the transfer function below. When referenced in this problem, the input voltage is $V_{in} = 2 \sin(1200t)$ V.

$$H(j\omega) = \frac{j\omega}{j\omega + 2 \times 10^3}$$

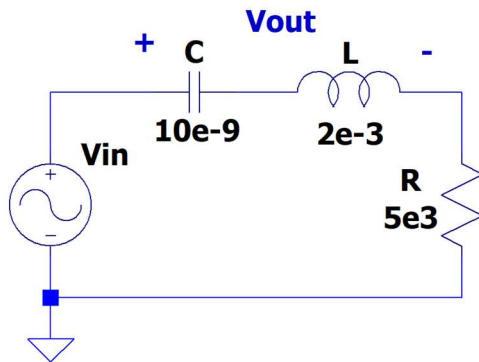
- a. [2 pts] Find the expression for the magnitude of the transfer function $|H(j\omega)|$. Express your answer in terms of ω .

b. [2 pts] Calculate the magnitude of the transfer function **in decibels** at the frequency of the input voltage V_{in} .

c. [2 pts] Calculate the amplitude of the output voltage $|V_{out}|$ **in volts** for the given input voltage V_{in} .

2.3 [9 pts]: *2nd Order Filter Circuit Analysis*

- a. [3 pts] Derive the transfer function for the circuit below in terms of L, R, C, and s. Express your transfer function in the form $H(s) = \frac{N(s)}{s^2 + \beta s + \alpha}$, where N(s) is a function of s, and β and α are constants.



- b. [4 pts] Sketch a plot of $|H(j\omega)|$ **on a log-linear** scale. You must show your work in evaluating $H(j\omega)$ in the limit of very low frequencies and very high frequencies. Label all relevant filter frequency parameters (corner frequency/frequencies, center frequency, etc.) on the plot. *Note:* You do not need to give numerical frequencies for any corner frequencies, but you must give a numerical frequency for a center frequency (if applicable to your filter).

If you're not confident in your answer for part *a*, you may choose to sketch the alternate transfer function below instead for full credit. If you choose this option, you must clearly circle "I am sketching the alternate transfer function". The given circuit element values may be useful.

I am sketching the alternate transfer function

$$H(s) = \frac{10^3 s}{s^2 + 10^3 s + 10^8}$$

$$R = 10\Omega; L = 10 \times 10^{-3} \text{ H}; C = 1 \times 10^{-6} \text{ F}$$



- c. [2 pts] What kind of filter does your transfer function sketch in part *b* represent?

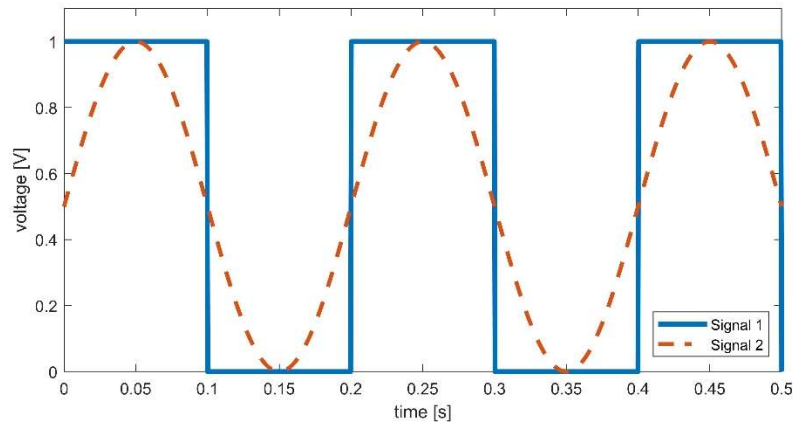
Problem 3 [8 Points]: Concepts and Short Answer

3.1 [2 pts] True or False: All signals can be represented as an infinite sum of sinusoidal waves with different frequencies and amplitudes. Circle one:

True

False

3.2 [2 pts] Two signals are shown below in the time domain. Which of these signals has more peaks at high frequencies in its frequency spectrum? Explain your reasoning.



3.3 [2 pts] Short answer: Explain how an RL circuit can serve as both a high-pass filter and a low-pass filter. *Hint:* You should mention Kirchhoff's voltage law in justifying your response.

3.4 [2 pts] For the circuit below, draw the equivalent circuit at both very low frequencies and very high frequencies.

Low Frequency

High Frequency

