NAME: ______________________

AE & ME 599 - Data Measurement & Analysis

Fall 2020

Mid-Term Exam

Submission Deadline:

Tuesday, October 13 at 10:00 AM Central Time

Late submissions will NOT be accepted

As a student of the University, I pledge that I will neither knowingly give nor receive any inappropriate assistance in academic work, thus affirming my own personal commitment to honor and integrity.

I completed this exam solely on my own, without help from anyone except Dr. Kreth.

Signature: ____

Note: *Show all necessary steps and list assumptions made (if any) in solving each problem.*

Question	Points	Score
1	30	
2	30	
3	25	
4	15	
Total:	100	

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[30 pts] 1. A dynamic system is provided sinusoidal excitation by a sine wave input $u(t) = \sin(t)$. If the system is first-order with an Impulse Response Function of $h(t) = (1/\tau)e^{-t/\tau}$ where $\tau = 2$ [s], determine the system output $y(t)$ by evaluating the convolution integral *numerically* (e.g., in MATLAB).

(a) Produce a graph that shows the system output compared to the input (i.e., $u(t)$ and $y(t)$ on the same graph vs t). Ensure that you have used an appropriate discretization time step and show the solution to $t = 30$ [s].

(b) Does the output ($y(t)$) have the same frequency of the input sine wave ($u(t)$)? If not, what is its frequency? Explain your conclusions.

(c) Does the output lead or lag the input? If so, which is the case? What is the time delay between y and u? What is the phase offset? Justify your answers to this part *analytically*.

(d) What is the system's steady-state response? Provide your answer in an *analytical* form, ensuring that you have correctly determined the amplitude, phase, etc.

(e) How long does the system take to reach the steady-state solution? Justify your answer.

(f) Repeat parts (a) - (e) using a second-order system with an impulse response function of

$$h(t) = e^{-\zeta\omega_n t}\frac{\sin(\omega_d t)}{\omega_d}$$

where $\omega_n = 0.5$ rad/s, $\zeta = \dfrac{1}{\sqrt{2}}$, and $\omega_d = \omega_n\sqrt{1-\zeta^2}$

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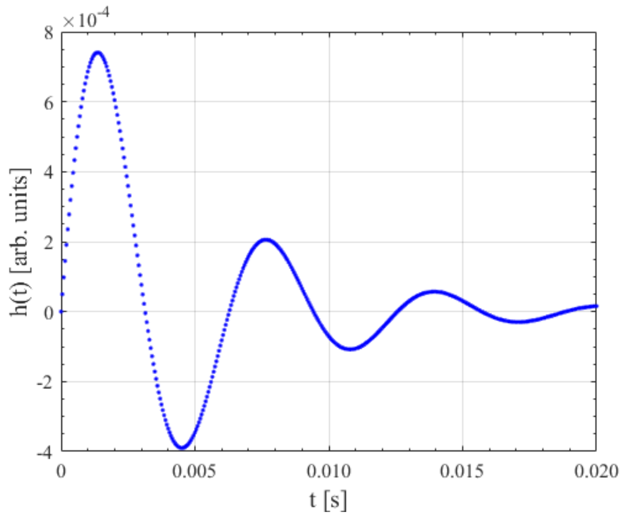
[30 pts] 2. In a recent experiment, you wanted to characterize a new sensor by measuring its response to a short duration pulse input. (Two example scenarios could be (1) gently striking a plate with a new accelerometer mounted on it or (2) clapping a single time in front of a new microphone.)

You know that your new sensor is capable of responding to high-frequency forcing, but you would like to determine the sensor's maximum bandwidth. Your faculty adviser tells you this is the range of frequencies over which the sensor can be used with high accuracy.

You measured the sensor's output with a digital oscilloscope and subsequently imported the data from this experiment into MATLAB and plotted it as shown below. You need to use these data to estimate the Frequency Response Function of the sensor to determine its bandwidth.



Load the data by double-clicking the supplied file ("problem2.mat") in the MATLAB file browser, thus giving you two variables: h [arbitrary units] and t [seconds]. Inspect the data and answer the following questions:

(a) What order dynamic system do you think approximates this sensor best?

(b) Based on your response to (a), what are the relevant characteristic parameters for this "system" (e.g., time constant, damping ratio, natural frequency, etc.)?

(c) What does the sensor's Frequency Response Function look like? Plot both the magnitude and phase as functions of frequency.

(d) What does this tell us about the sensor's response characteristics?

(e) What is the sensor's bandwidth? Provide both upper and lower frequency bounds where the sensor's response is within ± 3 [dB] of being flat.

HINT: To solve for part (b), you need to use a few key features from these data. You can analyze a general form for the function you choose for $h(t)$ to find an expression for the zero-crossing points ($h(t) = 0$). From here, you could use a "guess and check" method to find the other relevant parameters, or you could use other features, like the local extrema values. You have enough information to solve this problem without using curve fitting tools. You should *completely avoid* curve fitting these data because these tools are *extremely* sensitive to the inputs you have to guess. Don't waste your time with toolboxes that we have not covered.

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[25 pts] 3. The Frequency Response Function of a linear system is shown below. Load the supplied data for this problem (in the MATLAB file browser, double-click on "problem3.mat" to load the following variables into your workspace: 'mag' [dB], 'phase' [deg], and 'freq' [Hz]). Inspect the data and answer the following questions:

(a) What is the order of this system?

(b) Based on your response to (a), what are the relevant characteristic parameters for this system (e.g., time constant, damping ratio, natural frequency, etc.)?

(c) What is the system's Transfer Function? Express your answer analytically, and simplify the fraction (the highest order term in the expression should have a constant of 1).

(d) What are the system's pole(s) and/or zero(s)?

(e) Would this system ever have an *amplified* output? If so ...

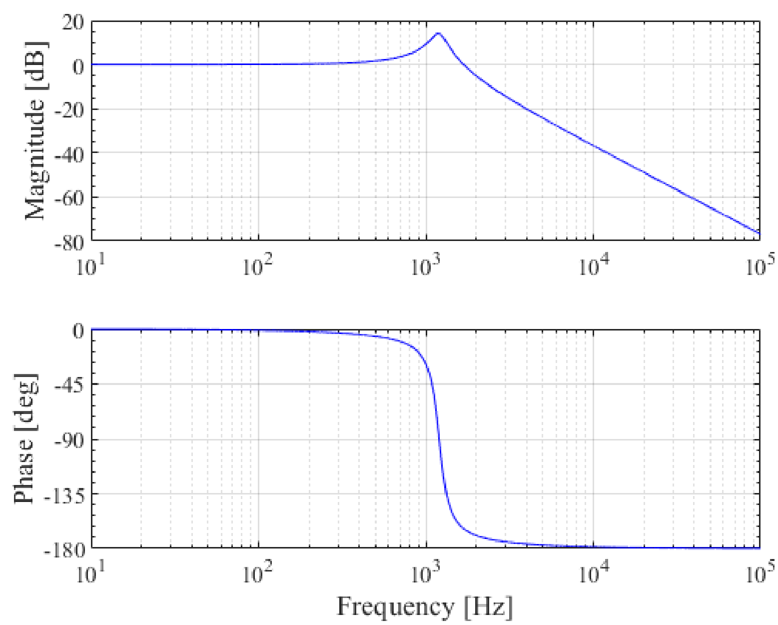
i. Where is it amplified? (Provide upper and lower frequency bounds)

ii. What is the maximum amplification (gain factor)? (Convert your answer from [dB] to gain factor where Mag [dB] $= 20\log_{10}(\text{Gain})$)

(f) Would this system ever have an *attenuated* output? If so ...

i. Where is it attenuated? (Provide upper and lower frequency bounds)

ii. What is the attenuation rate? Express your answer in <u>both</u> dB/decade and dB/octave.



[15 pts] 4. Provide short answers, explanations, graphs, and/or copies of your analytical work for the following questions:

(a) A thermometer, initially at a temperature of 20°C, is suddenly immersed in a tank of water with a temperature of 80°C. If the time constant of the thermometer is 2 seconds, what temperature will the thermometer read after 5 seconds?

(b) A signal amplifier is set to a gain of 60 dB. If the voltage input to the amplifier is 3 mV, what is the output voltage that would be measured?

(c) Consider the first-order system specified in Problem 1. What is the steady-state response of this system to a unit ramp input, $u(t) = t$?

(d) Your faculty adviser asked you to characterize a microphone using an acoustic plane wave tube. You recorded the microphone output when the plane wave tube was forced with a single frequency sinusoidal input tone set to 5 kHz. You computed and plotted the power spectrum shown below. Do you think the microphone is behaving linearly for this case? Why or why not? Explain.