ECE 5210 Midterm 1

Week of: February 17, 2021

Student's name and section: ______________________________

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You have 2 hours for 5 problems.

- Show enough (neat) work in the clear spaces on this exam to convince us that you derived, not guessed, your answers.
- Put your final answers in the boxes at the bottom of the page.

You are allowed ONE page of notes (front and back) for this exam. You may use a graphing calculator of your choice. Consulting with any third party is considered cheating.

Problem	Score	Possible Points
1		20
2		20
3		20
4		20
5		20
Total score		100

1 DT systems

Listed below are systems that relate the input $x[n]$ to the output $y[n]$. For each, determine whether the system is (1) linear or nonlinear, (2) time-invariant or time-varying, (3) stable or unstable, (4) causal or noncausal, and (5) memoryless or has memory.

(a) $y[n] = \log\{x[n]\}$

(1)	(2)	(3)	(4)	(5)

(b) $y[n] = \text{median}\{x[n-1],\, x[n],\, x[n+1]\}$

(1)	(2)	(3)	(4)	(5)

2 Convolution

Derive a closed-form solution expression for the convolution of $x[n]$ and $h[n]$ where

$$
\begin{aligned}
x[n] &= n(u[n-1] - u[n-3]) \\
h[n] &= u[n-1].
\end{aligned}
$$

Your work, continued...

$x[n] * h[n] =$

3 Z-transform

Consider a discrete LTI system which is described by the difference equation

$$y[n+2] - 5y[n+1] + 6y[n] = x[n+1].$$

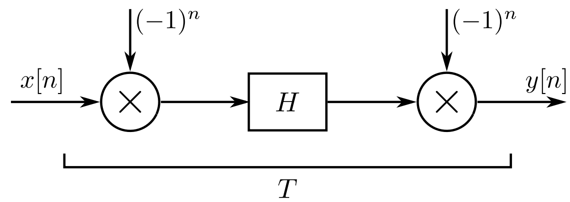
Find the step response of the system (i.e., the response to the input $x[n] = u[n]$).

Your work, continued...

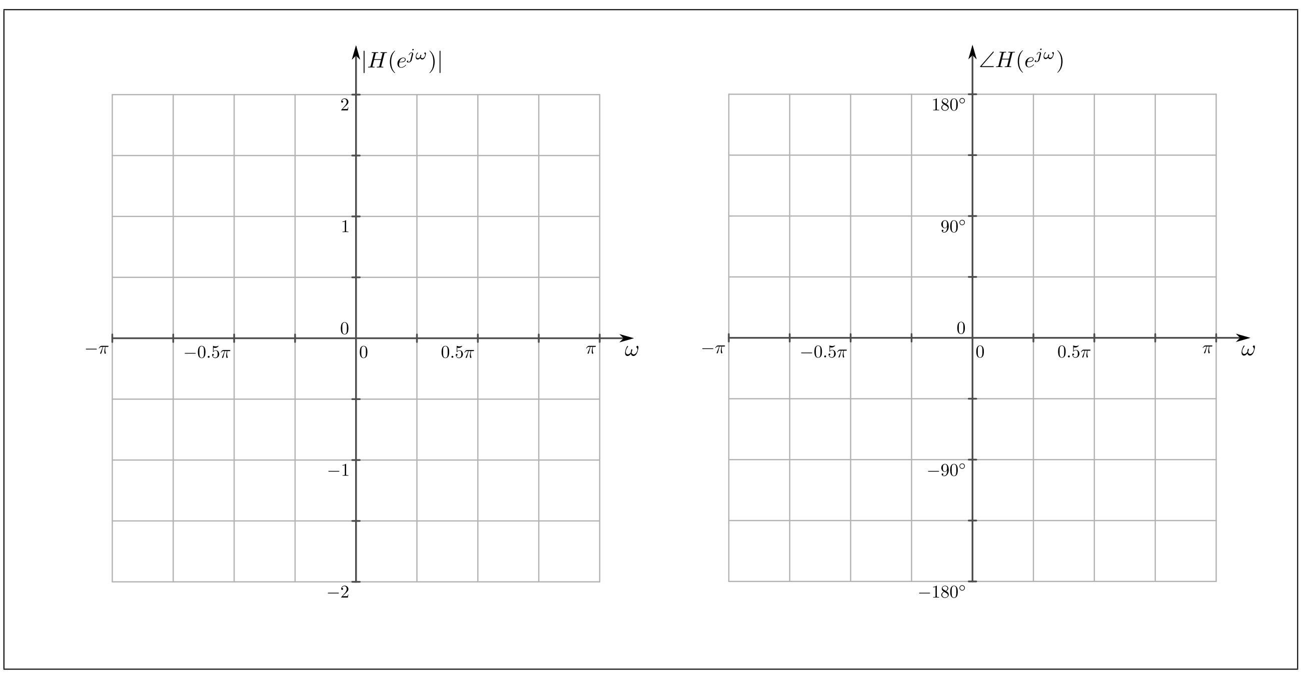
$y[n] =$

4 DTFT

Consider the system below. The entire system $y[n] = T\{x[n]\}$ will have the effect of being an ideal high-pass filter with a cutoff frequency of $\omega_c = \frac{\pi}{2}$. H is a subsystem within the larger system T.



(a) Sketch $|H(e^{j\omega})|$ and $\angle H(e^{j\omega})$ such that entire system will behave as an ideal high-pass filter as described above (i.e., $H(e^{j\omega})$ itself may or may not be a high-pass filter, but we need to design it such that entire system's behavior is).



(b) Find $h[n]$ that would satisfy such a system.

$h[n] =$

5 Sampling

A major problem in the recording of electrocardiograms (ECGs) is the appearance of unwanted 60 Hz interference in the output. The casuses of this power line interference include magnetic induction, displacement currents in the leads on the body of the patient, and equipment interconnections. Ultimately we will want to get rid of this 60 Hz interference. Because this signal is analog, we could use an analog notch filter to remove it, but analog notch filters are a hassle to design. Instead, we are doing to use the C/D, DSP, and D/C signal processing approach discussed in class.

(a) Assume that the bandwidth of the signal of interest is 1 kHz, that is (in radians per second),

$$X_a(j\Omega) = 0 \quad |\Omega| > 2\pi \text{ krad/s}.$$

What should the minimum sampling period T_s be to satisfy Nyquist?

$T_s =$

(b) The analog signal is converted into a discrete-time signal with an ideal C/D converter operating at the sampling frequency Ω_s which is based on the sampling period T_s in the previous part. The resulting signal $x[n] = x_a(nT_s)$ is then processed with a discrete-time system H that is described by the difference equation

$$y[n] = H\{x[n]\} = x[n] + ax[n-1] + bx[n-2]$$

where a and b are some constants. Please find the frequency response $H(e^{j\omega})$ in terms of a and b (i.e., you do not need to solve for a and b at this point).

$H(e^{j\omega}) =$

(c) Solve for $h[n]$. Please solve for a and b such that the 60 Hz frequency is notched. We can assume that this unwanted interference can take the form

$$w_a(t) = A\sin(120\pi t)$$

in continuous time. If $h[n]$ is designed correctly, $w_a(t)$ should not appear in the output of the D/C converter.

$h[n] =$