ECE 2026 Exam 2
Fall 2022

Name ______________________________

General Instructions:

- Exam is closed book / closed notes other than the one-page of handwritten notes.
- Choose the best possible answer available in all cases.
- Blank scratch paper is allowed

_______ Part I: Objective Questions

_______ Part II: Open Response Question

_______ Final Score

Part I: Objective Questions

These questions have straight-forward answers. Make sure to put your answer in the line required as that is the part that will be graded for the answer given. Only the final answers, as indicated by the question, will be considered correct for each question. Each question is worth 4 points (total of 80 points)

Matching:

_________ 1. $a^n u[n]$

_________ 2. $\frac{1}{M}(u[n] - u[n-M])$

_________ 3. IIR System

_________ 4. z-transform to frequency response

_________ 5. FIR system

_________ 6. IIR Frequency Response

_________ 7. δ[n-1]

a. $H(z) = \dfrac{1}{1 - z^{-1}}$

b. $H(\hat{\omega}) = \dfrac{\sum_{k=0}^{M} b_k e^{-jk\hat{\omega}}}{1 - \sum_{k=1}^{M} a_k e^{-jk\hat{\omega}}}$

c. $H(\hat{\omega}) = \sum_{k=0}^{M} h_k e^{-j\hat{\omega}k}$

d. $y[n] = \sum_{k=0}^{M} b_k x[n-k] + \sum_{k=1}^{M} a_k y[n-k]$

e. 1

f. $z^{-1} = e^{-j\hat{\omega}}$

g. $y[n] = \sum_{k=0}^{M} h_k x[n-k]$

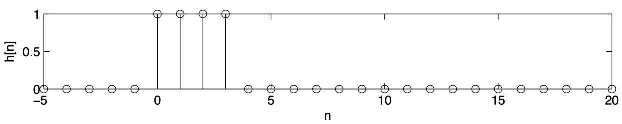
h. $H(z) = \dfrac{1}{1 - az^{-1}}$

i. $H(z) = \dfrac{1 - z^{-M}}{1 - z^{-1}}$

_________ 8. (True / False) A 6 impulse long boxcar filter has 6 zeros around the unit circle.

Match the h[n] and discrete frequency response

__________ 9.



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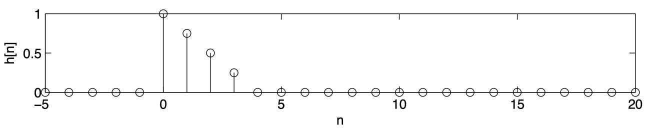

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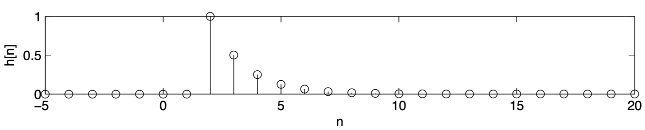

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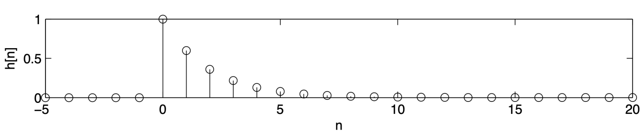

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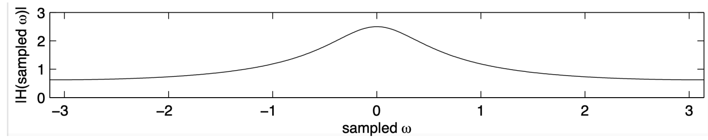
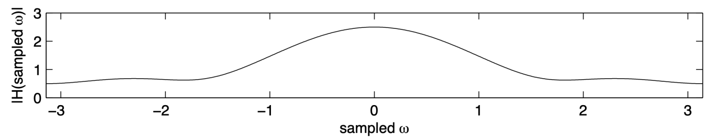
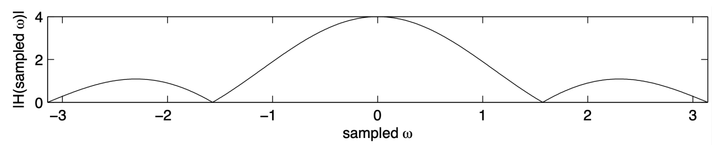


b.



c.



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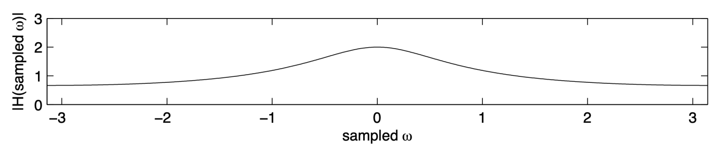
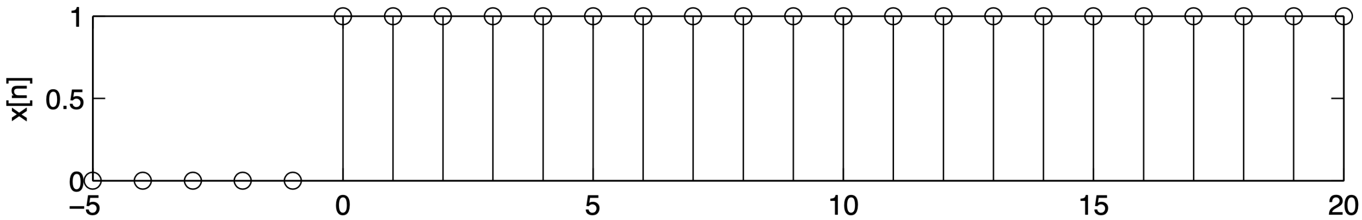


Match the h[n] and output response for the following input



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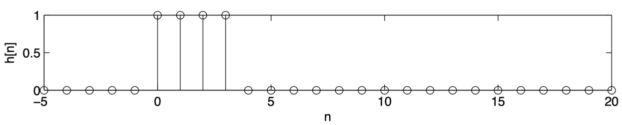

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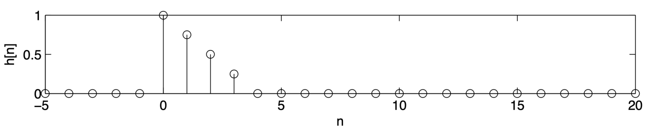

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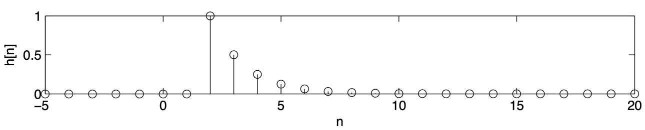

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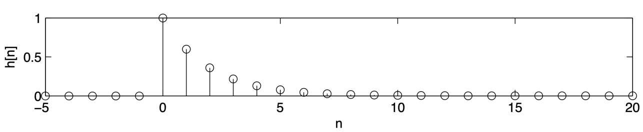
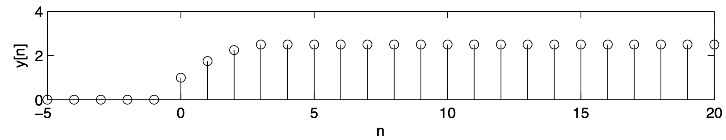


a.



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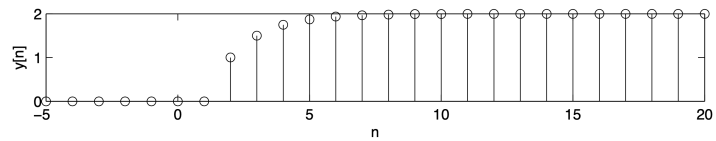

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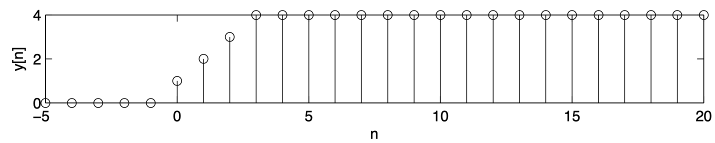

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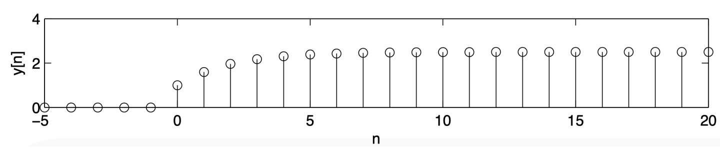
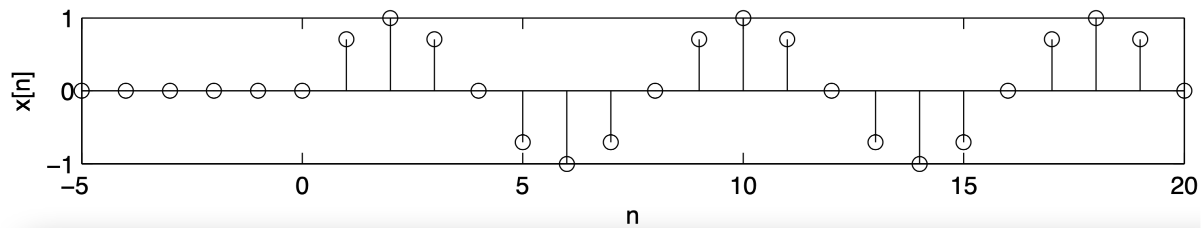


Match the h[n] and output response for the following input



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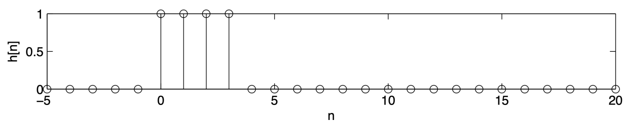

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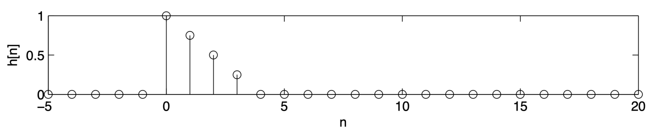

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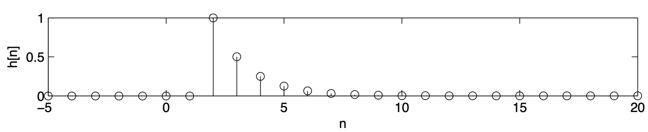

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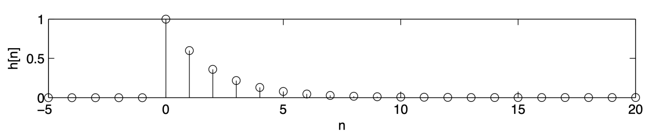
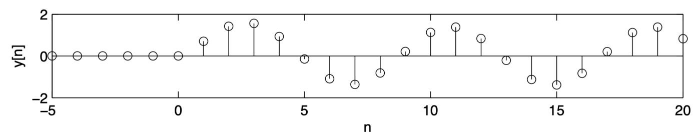


a.



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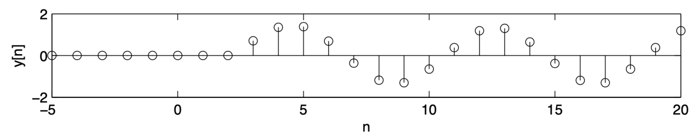

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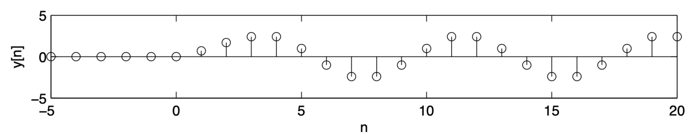

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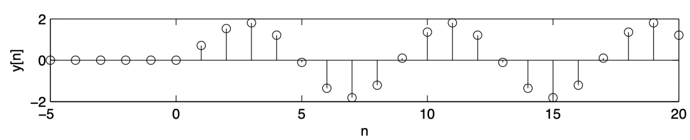
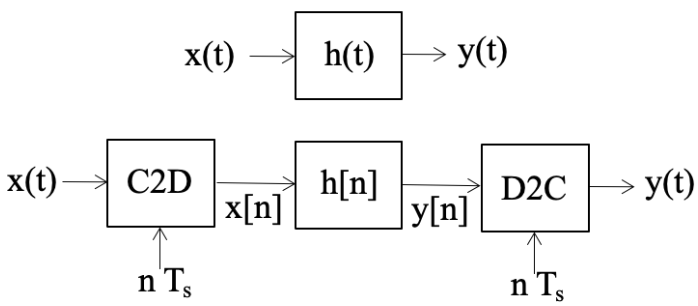


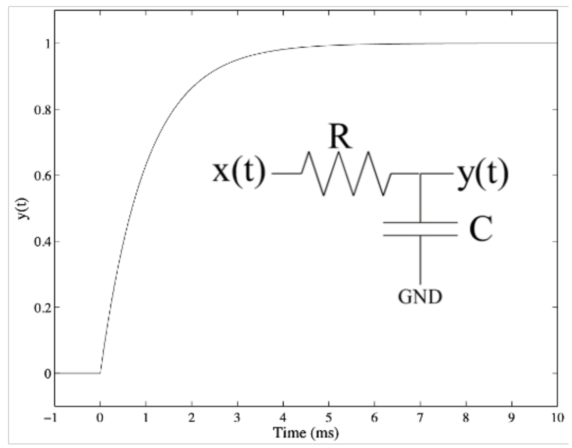
Part II: Open Response Question (20 points)

There is a well-known quote about Digital Signal Processing,

“DSP is a discipline that allows us to replace a simple resistor and capacitor with two antialiasing filters, an A-to-D and D-A converter, and a general-purpose computer or an array processor as long as the signal we are interested in doesn’t vary too quickly” – Tom Barnwell, Professor, ECE, GT

This question will investigate this statement abit further by investigating a discrete-time filter that emulates a simple resistor (R) and capacitor (C) circuit.





For this problem assume that $T_s = 0.7$ms, $f_s = 1.428$kHz, R = 1MΩ, C = 1nF.

The output (in particular output voltage) gives the response graphed above for an input step response (1V u(t) that we can consider u(t)), and follows the expression

$$y(t) = \left(1 - e^{-t/(1ms)}\right) u(t)$$

The circuit would have its continuous-time impulse response, h(t). For the DSP version, assume an ideal Continuous to Discrete (C2D) transformation, and assume an ideal Discrete to Continuous to (D2C) transformation that smoothly eliminates any frequencies above half of the sampling frequency.

This question has four parts (a, b, c, & d).

a) What is the function for y[n] that best satisfies this response for y(t)?

b) Given that y[n], what would be our y[n] be for x[n] = δ[n]?

c) Assume one wanted an FIR approximation of this IIR response. What is the approximate FIR impulse response assuming a 2-3% accurate approximation?

d) Assume that one might use an approximate FIR representation:

h[n] = 0.5*δ[n-1] + 0.25*δ[n-1] + 0.25*δ[n-2]

Sketch the resulting frequency response and compare how closely it approximates the continuous-time solution, $H(\omega) = \frac{Y(\omega)}{X(\omega)} = \frac{1}{1 + j\omega\tau}$?

Extra credit: Derive the continuous-time frequency response above for this given circuit. You can start with the initial equation derived from KCL at y node:

$$C\frac{dy}{dt} = \frac{x - y}{R}$$