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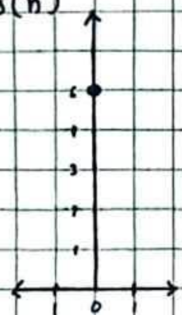
Class & Section: BSCOE 4-4 Date: November 22, 2024

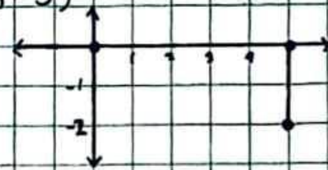
DSP: MP5 Lecture 3

3.1. Sketch each of the following special digital sequences

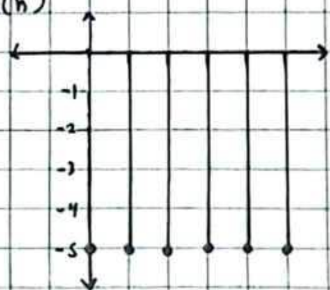
a.) $5\delta(n)$



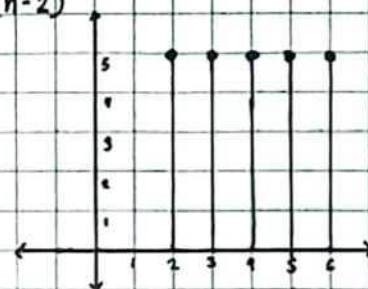
b.) $-2\delta(n-5)$



c.) $-5u(n)$



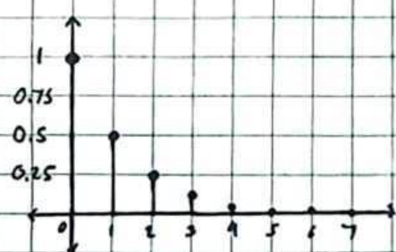
d.) $5u(n-2)$



3.2. Calculate the first eight sample values and sketch each of the following sequences:

a.) $x(n) = 0.5^n u(n)$

$0.5^0 u(0)$, amplitude = 1, u(n) = 0
$0.5^1 u(1)$, amplitude = 0.5, u(n) = 1
$0.5^2 u(2)$, amplitude = 0.25, u(n) = 2
$0.5^3 u(3)$, amplitude = 0.125, u(n) = 3
$0.5^4 u(4)$, amplitude = 0.0625, u(n) = 4
$0.5^5 u(5)$, amplitude = 0.03125, u(n) = 5
$0.5^6 u(6)$, amplitude = 0.015625, u(n) = 6
$0.5^7 u(7)$, amplitude = 0.0078125, u(n) = 7



b.) $x(n) = 5\sin(0.2\pi n)u(n)$

$x(0) = 5\sin(0.2\pi(0))u(0)$, amp = 0, u(n) = 0
$x(1) = 5\sin(0.2\pi(1))u(1)$, amp = 2.94, u(n) = 1
$x(2) = 5\sin(0.2\pi(2))u(2)$, amp = 4.75, u(n) = 2
$x(3) = 5\sin(0.2\pi(3))u(3)$, amp = 4.76, u(n) = 3
$x(4) = 5\sin(0.2\pi(4))u(4)$, amp = 2.94, u(n) = 4
$x(5) = 5\sin(0.2\pi(5))u(5)$, amp = 0, u(n) = 5
$x(6) = 5\sin(0.2\pi(6))u(6)$, amp = -2.94, u(n) = 6
$x(7) = 5\sin(0.2\pi(7))u(7)$, amp = -4.75, u(n) = 7

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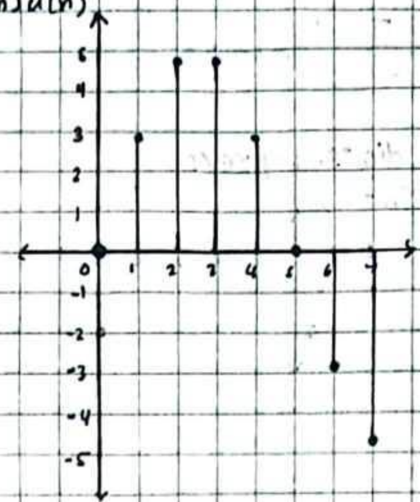
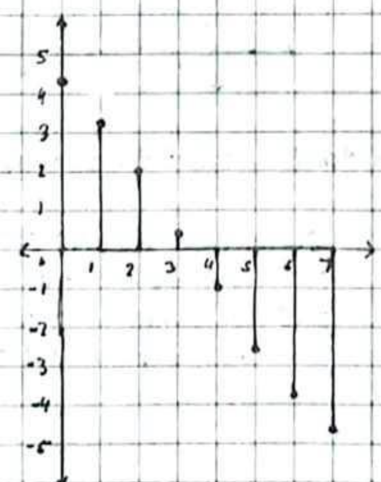
$x(n) = 5\sin(0.2\pi n)u(n)$



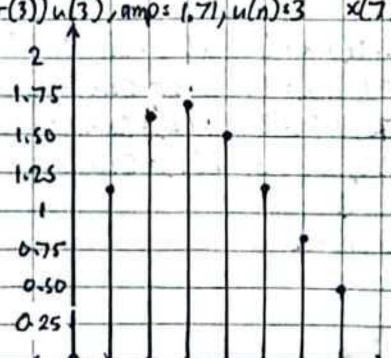
c.) $x(n) = 5\cos(0.1\pi n + 30°)u(n)$

$x(0) = 5\cos(0.1\pi(0) + 30°)u(0)$, amp = 4.33, u(n) = 0
$x(1) = 5\cos(0.1\pi(1) + 30°)u(1)$, amp = 3.35, u(n) = 1
$x(2) = 5\cos(0.1\pi(2) + 30°)u(2)$, amp = 2.03, u(n) = 2
$x(3) = 5\cos(0.1\pi(3) + 30°)u(3)$, amp = 0.52, u(n) = 3
$x(4) = 5\cos(0.1\pi(4) + 30°)u(4)$, amp = -1.04, u(n) = 4
$x(5) = 5\cos(0.1\pi(5) + 30°)u(5)$, amp = -2.5, u(n) = 5
$x(6) = 5\cos(0.1\pi(6) + 30°)u(6)$, amp = -3.72, u(n) = 6
$x(7) = 5\cos(0.1\pi(7) + 30°)u(7)$, amp = -4.57, u(n) = 7



d) $x(n) = 5(0.75)^n \sin(0.1\pi n)u(n)$

$x(0) = 5(0.75)^0 \sin(0.1\pi(0))u(0)$, amp = 0, u(n) = 0
$x(1) = 5(0.75)^1 \sin(0.1\pi(1))u(1)$, amp = 1.16, u(n) = 1
$x(2) = 5(0.75)^2 \sin(0.1\pi(2))u(2)$, amp = 1.65, u(n) = 2
$x(3) = 5(0.75)^3 \sin(0.1\pi(3))u(3)$, amp = 1.71, u(n) = 3
$x(4) = 5(0.75)^4 \sin(0.1\pi(4))u(4)$, amp = 1.5, u(n) = 4
$x(5) = 5(0.75)^5 \sin(0.1\pi(5))u(5)$, amp = 1.19, u(n) = 5
$x(6) = 5(0.75)^6 \sin(0.1\pi(6))u(6)$, amp = 0.85, u(n) = 6
$x(7) = 5(0.75)^7 \sin(0.1\pi(7))u(7)$, amp = 0.54, u(n) = 7



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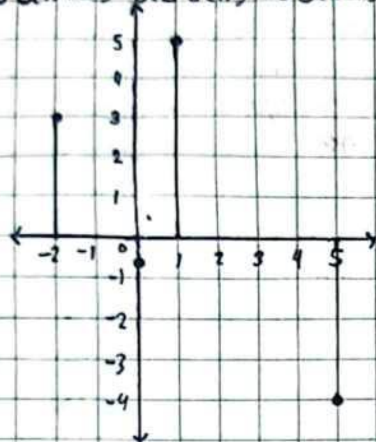
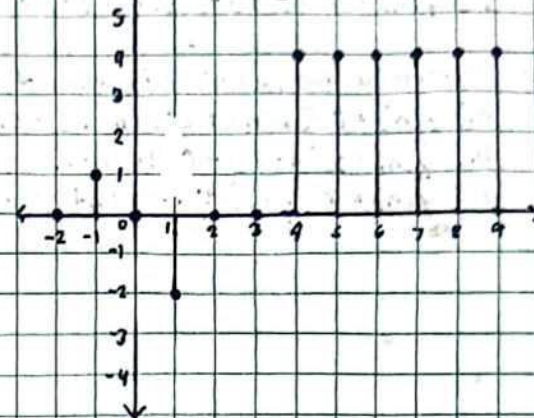
3.3. Sketch the following sequences:

a.) $x(n) = 3\delta(n+2) - 0.5\delta(n) + 5\delta(n-1) - 4\delta(n-5)$

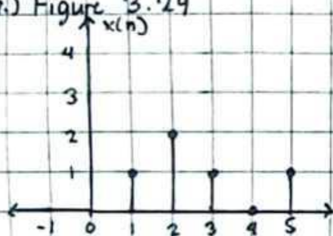


b.) $x(n) = \delta(n+1) - 2\delta(n-1) + 5u(n-4)$



3.4. Given the digital signals $x(n)$ in Figures 3.24 and 3.25, write an expression for each digital signal using the unit-impulse and its shifted sequences.

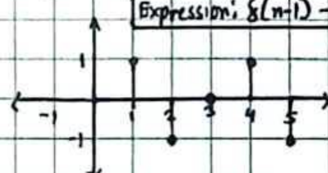
a.) Figure 3.24



Expression: $\boxed{\delta(n-1) + 2\delta(n-2) + \delta(n-3) + 0\delta(n-4) + \delta(n-5)}$

b.) Figure 3.25

Expression: $\boxed{\delta(n-1) - \delta(n-2) + 0\delta(n-3) + \delta(n-4) - \delta(n-5)}$



3.5. Assuming that a DS processor with a sampling time interval of 0.01 second converts each of the following analog signals to $x(t)$ to the digital signal $x(n)$, determine the digital sequences for each of the following analog signals.

a.) $x(t) = e^{-50t}u(t)$

$x(n) = x(nT)$

$= e^{-50(0.01n)}u(nT)$

$\boxed{x(n) = e^{-0.5n}u(n)}$

b.) $x(t) = 5\sin(20\pi t)u(t)$

$x(n) = x(nT)$

$= 5\sin(20\pi(0.01n))u(nT)$

$\boxed{x(n) = 5\sin(0.2\pi n)u(n)}$

c.) $x(t) = 10\cos(40\pi t + 30^\circ)u(t)$

$x(n) = x(nT)$

$= 10\cos(40\pi(0.01n) + 30^\circ)u(nT)$

$\boxed{x(n) = 10\cos(0.4\pi n + 30^\circ)u(n)}$

d.) $x(t) = 10e^{-100t}\sin(15\pi t)u(t)$

$x(n) = x(nT)$

$= 10e^{-100(0.01n)}\sin(15\pi(0.01n))u(nT)$

$\boxed{x(n) = 10e^{-n}\sin(0.15\pi n)u(n)}$

3.6. Determine which of the following is a linear system.

a.) $y(n) = 5x(n) + 2x^2(n)$ - non linear

b.) $y(n) = x(n-1) + 4x(n)$ - linear

c.) $y(n) = 4x^3(n-1) - 2x(n)$ - non linear

3.7. Given the following linear systems, find which one is time invariant

a.) $y(n) = -5x(n-10)$ - time invariant

b.) $y(n) = 4x(n^2)$ - not time invariant

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3.8. Determine which of the following linear systems is causal.

a.) $y(n) = 0.5x(n) + 100\,x(n-2) - 20x(n-10)$ - causal

b.) $y(n) = x(n+4) + 0.5x(n) - 2x(n-2)$ - not causal

3.9. Determine the causality for each of the following linear systems.

a.) $y(n) = 0.5x(n) + 20x(n-2) - 0.1y(n-1)$ - causal

b.) $y(n) = x(n+2) - 0.4y(n-1)$ - not causal

c.) $y(n) = x(n-1) + 0.5y(n+2)$ - not causal

3.10. Find the unit-impulse response for each of the following linear systems.

a.) $y(n) = 0.5x(n) - 0.5x(n-2)$; for $n \geq 0$, $x(-2) = 0$, $x(-1) = 0$

$\boxed{h(n) = 0.5\delta(n) - 0.5\delta(n-2) \; [n \geq 0]}$

b.) $y(n) = 0.75y(n-1) + x(n)$; for $n \geq 0$, $y(-1) = 0$

$h(n) = 0.75h(n-1) + \delta(n) \; [n \geq 0, h(-1) = 0]$

Mathematical induction:

$h(-1) = 0$, at $n = 0$: $h(0) = 0.75h(0-1) + \delta(0) \rightarrow h(0) = 0.75h(-1) + \delta(0)$

$h(0) = 0.75(0) + 1 \rightarrow h(0) = 1$

at $n = 1$: $h(1) = 0.75h(1-1) + \delta(1) \rightarrow 0.75h(0) + \delta(1) \rightarrow 0.75(1) + 0 \rightarrow h(1) = 0.75$

at $n = 2$: $h(2) = 0.75h(2-1) + \delta(2) \rightarrow 0.75h(1) + \delta(2) \rightarrow 0.75(0.75) + 0 \rightarrow h(2) = 0.5625$

Therefore: $\boxed{h(n) = 0.75^n \; [n \geq 0]}$

c.) $y(n) = -0.8y(n-1) + x(n-1)$; for $n \geq 0$, $x(-1) = 0$, $y(-1) = 0$

$h(n) = -0.8h(n-1) + \delta(n-1) \; [n \geq 0, \delta(-1) = 0, h(-1) = 0]$

at $n = 0$: $h(0) = -0.8h(0-1) + \delta(0-1) \rightarrow -0.8h(-1) + \delta(-1) \rightarrow -0.8(0) + 0 \rightarrow h(0) = 0$

at $n = 1$: $h(1) = -0.8h(1-1) + \delta(1-1) \rightarrow -0.8h(0) + \delta(0) \rightarrow -0.8(0) + 1 \rightarrow h(1) = 1$

at $n = 2$: $h(2) = -0.8h(2-1) + \delta(2-1) \rightarrow -0.8h(1) + \delta(1) \rightarrow -0.8 + 0 \rightarrow h(2) = -0.8$

at $n = 3$: $h(3) = -0.8h(3-1) + \delta(3-1) \rightarrow -0.8h(2) + \delta(2) \rightarrow -0.8(-0.8) + 0 \rightarrow 0.64$

Therefore:

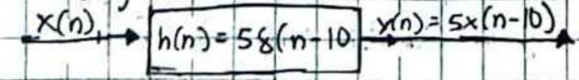
$$\boxed{h(n) = \begin{cases} 0, & n = 0 \\ (-0.8)^{n-1}, & n \geq 1 \end{cases}}$$

3.11. For each of the following linear systems, find the unit-impulse response, and draw the block diagram.

a.) $y(n) = 5x(n-10)$

$\boxed{h(n) = 5\delta(n-10)}$

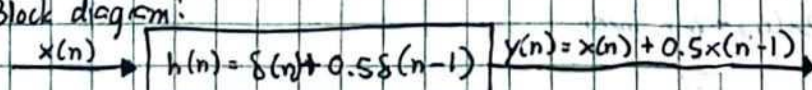
Block diagram:



b.) $y(n) = x(n) + 0.5x(n-1)$

$\boxed{h(n) = \delta(n) + 0.5\delta(n-1)}$

Block diagram:



3.12. Determine the stability for the following linear system.

$$y(n) = 0.5x(n) + 100x(n-2) - 20x(n-10)$$

Since the coefficients 0.5, 100, and -20 are bound and finite, the system is $\boxed{\text{stable}}$

3.13. Determine the stability for each of the following linear systems.

a.) $y(n) = \sum_{k=0}^{\infty} 0.75^k x(n-k)$

$$y(n) = \frac{1}{1-0.75} = 4$$ since the system converges, the system is $\boxed{\text{BIBO stable.}}$

b.) $y(n) = \sum_{k=0}^{\infty} 2^k x(n-k)$

$$y(n) = \frac{1}{1-2} = -1$$ since the system diverges, the system is $\boxed{\text{BIBO unstable}}$

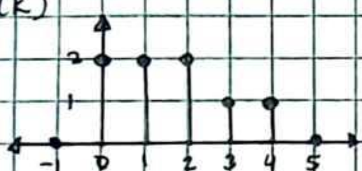
3.14. Given the sequence:

$$h(k) = \begin{cases} 2, & k = 0, 1, 2 \\ 1, & k = 3, 4 \\ 0 & \text{elsewhere} \end{cases}$$

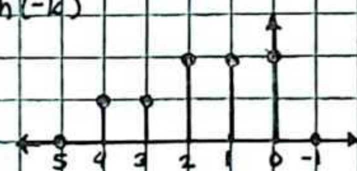
where k is the time index or sample number,

a.) sketch the sequence $h(k)$ and the reverse sequence $h(k)$;

h(k)



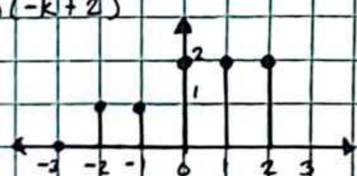
h(-k)



$$h(-k) = \begin{cases} 2, & k = 0, -1, -2 \\ 1, & k = -3, -4 \\ 0 & \text{elsewhere} \end{cases}$$

b.) sketch the shifted sequence $h(-k+2)$ and $h(-k-3)$

h(-k+2)



h(-k-3)

$$h(-k+2) = \begin{cases} 2, & k = 0+2, -1+2, -2+2 \\ 1, & k = -3+2, -4+2 \\ 0 & \text{elsewhere} \end{cases}$$

$\downarrow$

$$h(-k+2) = \begin{cases} 2, & k = 2, 1, 0 \\ 1, & k = -1, -2 \\ 0 & \text{elsewhere} \end{cases}$$

$$h(-k-3) = \begin{cases} 2, & k = 0-3, -1-3, -2-3 \\ 1, & k = -3-3, -4-3 \\ 0 & \text{elsewhere} \end{cases}$$

$\downarrow$

$$h(-k-3) = \begin{cases} 2, & k = -3, -4, -5 \\ 1, & k = -6, -7 \\ 0 & \text{elsewhere} \end{cases}$$