FUNDAMENTALS OF DIGITAL SIGNAL PROCESSING
(AEIE 3104)

Time Allotted : 3 hrs **Full Marks : 70**

Figures out of the right margin indicate full marks.

Candidates are required to answer Group A and any 5 (five) from Group B to E, taking at least one from each group.

Candidates are required to give answer in their own words as far as practicable.

Group – A
(Multiple Choice Type Questions)

1. Choose the correct alternative for the following: **10 × 1 = 10**

(i) If $X(k)$ consists of N-number of frequency samples, then its discrete frequency locations are given by,
(a) $f_k = \frac{kF_s}{N}$ (b) $f_k = \frac{F_s}{N}$ (c) $f_k = \frac{kN}{F_s}$ (d) $f_k = N$

(ii) For analog signal with maximum frequency F_{max} , the sampling frequency should be
(a) greater than $2F_{max}$ (b) less than $2F_{max}$
(c) greater than $\frac{F_{max}}{2}$ (d) less than $\frac{F_{max}}{2}$

(iii) The Characteristics of ideal linear phase FIR filter are,
(a) $\left|H\left(e^{j\omega}\right)\right|$=Constant and $\angle H\left(e^{j\omega}\right) = \frac{1}{\omega}$
(b) $\left|H\left(e^{j\omega}\right)\right|$=Constant and $\angle H\left(e^{j\omega}\right) = -\alpha\omega$
(c) $\left|H\left(e^{j\omega}\right)\right| = -\alpha\omega$ and $\angle H\left(e^{j\omega}\right)$=Constant
(d) $\left|H\left(e^{j\omega}\right)\right| = \frac{1}{\omega}$ and $\angle H\left(e^{j\omega}\right)$=Constant

(iv) The structure that uses separate delays for input and output samples is,
(a) direct form – I (b) direct form – II
(c) cascade form (d) parallel form

(v) An analog filter has poles at $s = 0$, $s = -2$, $s = -1$. If impulse invariant transformation is employed then the corresponding poles of digital filters are respectively,
(a) $0, e^{\frac{-T}{2}}, e^{T}$ (b) $1, e^{-2T}, e^{T}$
(c) $1, e^{2T}, e^{-T}$ (d) $0, e^{-2T}, e^{-T}$

(vi) The signal $x(n) = x(-n)$ is
(a) an even signal (b) an odd signal
(c) both (a) and (b) (d) none of (a) and (b)

(vii) The frequency response of a digital filter is periodic in the range
(a) $0 < \omega < 2\pi$ (b) $-\pi < \omega < \pi$
(c) $0 < \omega < \pi$ (d) $0 < \omega < 2\pi$ or $-\pi < \omega < \pi$

(viii) A square summable sequence is also known as
(a) finite power sequence (b) finite energy sequence
(c) both (a) and (b) (d) none of (a) and (b)

(ix) The signal $x(n) = \cos(3n)$ isknown as
(a) periodic signal (b) aperiodic signal
(c) both (a) and (b) (d) none of (a) and (b)

(x) A digital system used to increase the sampling rate is known as
(a) Down-ampler (b) Up-sampler
(c) Interpolator (d) both (b) and (c)

Group- B

2. (a) Determine the average power of a periodic sequence x(n) with period "N". [(CO1) (Apply/IOCQ)]

(b) Draw the symbolic diagram of a digital system having output $y(n) = ax(n) + bx(n-1) - cy(n-2)$. [(CO1) (Understand/LOCQ)]

(c) Determine the response of the LTI system whose input$x(n)$ and impulse response $h(n)$ are given by,$x(n) = \{\underline{1},\ 2,\ 3\ ,1\}$ and$h(n) = \{\underline{1},\ 2,\ 1\ ,-1\}$, where the underlined numbersrepresent $x(0)$and $h(0)$, respectively. [(CO2) (Evaluate/HOCQ)]

4 + 3 + 5 = 12

3. (a) What are the linear time invariant and time variant systems? How the stability of a discrete system is determined? [(CO2) (Remember/LOCQ)]

(b) Evaluate the result of sampling a signal which contains three signals $\cos 6\pi t$, $\cos 14\pi t$ and $\cos 26\pi t$ at a sampling interval of 0.1sec. [(CO1)(Evaluate/HOCQ)]

(c) Find the z-transform of $a^{n+1}U(n+1)$. [(CO2) (Analyse/IOCQ)]

3 + 5 + 4 = 12

Group - C

4. (a) Given the sequences $x_1(n) = \{1, 2, 3, 4\}$; $x_2(n) = \{1, 1, 2, 2\}$. Find $x_3(n)$ such that $X_3(k) = X_1(k)\, X_2(k)$ where $X(k) = DFT\{x(n)\}$. [(CO3) (Analyze/IOCQ)]

(b) Evaluate the IDFT of the sequence$X(k) = \{3, -j, 1, j\}$. [(CO3) (Evaluate/HOCQ)]

(c) Show that with $x(n)$ as an N-point sequence and $X(k)$as its N-point DFT,

$$DFT[x((n-m))_N] = e^{\frac{-j2\pi km}{N}} X(k).$$

[(CO3)(Analyze/IOCQ)]

4 + 4 + 4 = 12

5. (a) Compute 8-point DFT of the following sequence using radix-2 DIT FFT algorithm:

$$x(n) = \begin{cases} 2, \text{for } n = 0, 2, 5, 7 \\ 1, \text{for } n = 1, 3, 4, 6 \\ 0, \text{elsewhere} \end{cases}$$ [(CO3) (Apply/IOCQ)]

(b) Why is FFT needed? [(CO3) (Understand/LOCQ)]

10 + 2 = 12

Group - D

6. (a) Design a Butterworth digital IIR low pass filter using bilinear transformation by taking T=0.1 second to satisfy the following specifications:
$0.6 \leq |H(j\Omega)| \leq 1$ for $0 \leq \Omega \leq 0.35\pi$
$|H(j\Omega)| \leq 0.1$ for $0.7\pi \leq \Omega \leq \pi$. [(CO4) (Evaluate/HOCQ)]

(b) Realize the direct form – I structure of the designed filterin question 6(a). [(CO5) (Analyze/IOCQ)]

7 + 5 = 12

7. (a) Realize the following system with minimum number of multipliers:
$H(z) = (1 + z^{-1})\left(1 + \frac{1}{2}z^{-1} + \frac{1}{2}z^{-2} + z^{-3}\right)$. [(CO5) (Analyze/IOCQ)]

(b) Distinguish between FIR and IIR filters. [(CO4) (Understand/LOCQ)]

(c) What is wrapping effect? [(CO4)(Remember/LOCQ)]

(d) What is the necessary and sufficient condition for the linear phase characteristic of an FIR filter? [(CO5) (Remember/LOCQ)]

5 + 3 + 2 + 2 = 12

Group - E

8. (a) Give advantages of multi-rate DSP. [(CO6) (Remember/LOCQ)]

(b) Construct a schematic block diagram for implementing the sampling rate conversion by a fractional number and elaborate its working principle. [(CO6) (Create/HOCQ)]

(c) What are the advantages of DCT over DFT? Write the applications of DCT. [(CO6) (Understand/LOCQ)]

2 + 5 + (3 + 2) = 12

9. (a) What are the limitations of FFT and how it is overcome by STFT? What is spectrogram? [(CO6) (Understand/LOCQ)]

(b) What is wavelet transform? What are the applications of wavelets? Write down the expression of forward and inverse continuous wavelet transform and explain each term. [(CO6) (Understand/LOCQ)]

4 + (2 + 2 + 4) = 12

Cognition Level	LOCQ	IOCQ	HOCQ
Percentage distribution	35.42%	38.54%	26.04%

Course Outcome (CO):

After the completion of the course students will be able to

1. Characterize and analyze the properties of discrete time signals and systems.
2. Analyze a discrete linear time invariant system using Z-transform.
3. Perform Fourier Transform of Discrete-Time signals and learn implementation of Fast Fourier Transform algorithms.
4. Distinguish between analog and digital filter, methods to transform from one type to another types of filter.
5. Design digital FIR and IIR filters according to the given specification and realize structure of a digital filter for given transfer function.
6. Familiarize with short time Fourier transform, discrete cosine transform, wavelet transform and multirate digital signal processing.

*LOCQ: Lower Order Cognitive Question; IOCQ: Intermediate Order Cognitive Question; HOCQ: Higher Order Cognitive Question

Department & Section	Submission Link
AEIE	https://classroom.google.com/c/NDA1MTg0Nzk0OTM0/a/NDYzODM0MzUzNTc2/details