EXAM QUESTION PAPER

College/ Institute	Engineering, Design and Physical Sciences		
Department	Electronic and Electrical Engineering		
Exam Author(s)	Dr Mingliang Deng		
Module Code	EE2637		
Module Title	Digital Signal Processing		
Month	January	**Year**	2024/25
Exam Type	Full/~~Resit~~	**Format**	
Duration	Two Hours		
Number of questions	Five		
Question Instructions	Answer all FIVE questions		
Are calculators permitted	Yes		
Make/Model number of permitted calculators.	None		
Can students include drawings/ diagrams?	No		
Any permitted reference materials	None		
Required Stationery / Equipment			

By continuing beyond this point, you confirm that you have read the information and instructions above, and understand the conditions of this examination.

1. Consider a causal LTI system where the input x[n] and the output y[n] are related by the linear constant coefficient difference equation below

$$y[n] = 0.9y[n-1] + x[n] + 0.9x[n-1]$$

[100%]

a) Determine the transfer function H(z) of this system.

[20%]

b) Determine the unit sample response h(n) of this system.

[20%]

c) Determine the frequency response and plot the magnitude response.

[20%]

d) Use the frequency response c) to determine the response to an input of $e^{j\omega n}$.

[40%]

2. Assume that there are two four-point sequences x[n] and h[n] as follows

$$x[n] = \cos\left(\frac{\pi n}{2}\right), n = 0,1,2,3$$
$$h[n] = 2^n, n = 0,1,2,3$$

[100%]

a) Calculate the four-point DFT X[k] for x[n].

[33%]

b) Calculate the four-point DFT H[k] for h[n].

[33%]

c) Calculate y[n] by multiplying the DFTs of x[n] and h[n] and performing an IDFT.

[33%]

3. Consider a discrete-time linear causal system defined by the difference equation

$$y[n]-\frac{3}{4}y[n-1]+\frac{1}{8}y[n-2]=x[n]+\frac{1}{3}x[n-1]$$

Draw a signal flow graph to implement this system in each of the following forms

[100%]

a) Direct from I.

[20%]

b) Direct from II (Canonic form).

[20%]

c) Cascade form.

[30%]

d) Parallel form.

[30%]

For the cascade and parallel forms, only use the first-order sections.

4. Write down the features of unit sample response for four types of linear phase FIR filters. Determine whether the following unit sample response corresponds to a linear phase FIR filter. If it is, state its type, explain why and calculate its phase response and group delay.

$$\begin{cases} 1, & 0 \leqslant n \leqslant 3 \\ 0, & \text{others} \end{cases}$$

[100%]

5. Design a causal linear phase FIR system to approximate an ideal low-pass digital filter with a cut-off frequency of 0.3π and satisfying

$$0.95 < H(e^{j\omega}) < 1.05, \qquad 0 \le |\omega| \le 0.25\,\pi$$
$$-0.1 < H(e^{j\omega}) < 0.1, \qquad 0.35\pi \le |\omega| \le \pi$$

[100%]

a) What kinds of windows can be used to meet this specification and why? Here, Kaiser window is NOT considered.

[20%]

b) For each window obtained in Table 1, give the minimum filter length required.

[25%]

c) Determine the impulse response of the low-pass FIR filter with the minimum design complexity and passband/stopband ripples.

[30%]

d) Calculate the impulse response of a linear phase high-pass FIR filter with a cut-off frequency and a filter length of the low-pass filter obtained in (c). Here, rectangular window is only considered.

[25%]

Appendix

Table 1 Characteristics of Various Window Functions (The filter length is M+1.)

Type of Window	Peak Side-Lobe Amplitude (Relative) (r_p)	Approximate Width of Main Lobe ($\Delta\omega_m$)	Peak Approximation Error ($e_p = 20\log_{10}\delta$)	Transition Widths ($\Delta\omega$)	Equivalent Kaiser Window (β)
Rectangular	-13	$4\pi\mathrm{T}(M+1)$	-21	$1.81\,\pi\mathrm{T}M$	0
Bartlett	-25	$8\,\pi\mathrm{T}M$	-25	$2.37\,\pi\mathrm{T}M$	1.33
Hanning	-31	$8\,\pi\mathrm{T}M$	-44	$5.01\,\pi\mathrm{T}M$	3.86
Hamming	-41	$8\,\pi\mathrm{T}M$	-53	$6.27\,\pi\mathrm{T}M$	4.86
Blackman	-57	$12\,\pi\mathrm{T}M$	-74	$9.19\,\pi\mathrm{T}M$	7.04