UNIVERSITY OF BOLTON

SCHOOL OF ENGINEERING

MSC SYSTEM ENGINEERING AND MANAGEMENT

EXAMINATION FOR SEMESTER 1 - 2022/2023

SIGNAL PROCESSING

MODULE NO: EEM7011

Date: Wednesday 11th January 2023 **Time:14:00 – 16:00**

INSTRUCTIONS TO CANDIDATES:

There are SIX questions.

Answer FOUR questions.

All questions carry equal marks.

Marks for parts of questions are shown in brackets.

This examination paper carries a total of 100 marks.

All working must be shown. A numerical solution to a question obtained by programming an electronic calculator will not be accepted.

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Question 1

A sequence of ECG signal is to be used to automate an artificial intelligence machine for healthcare services. Before being fed into a machine learning algorithm, a feature engineering that involves signal processing technique need to be performed on the signal. A portion of the ECG signal, $s(t)$, as shown in **Figure Q1a** undergoes a standard transformation resulting in $y(t) = s(2t) + 6$.

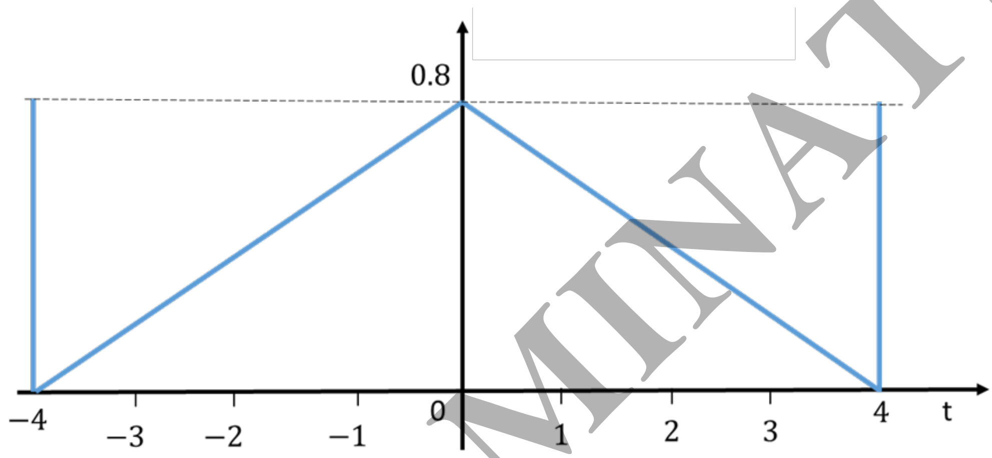

Fig. Q1a

Based on Figure Q1a and the information provided in Q1,

i) draw the transformation table and determine the output signal. **[15 marks]**

ii) sketch the output transformed signal. **[10 marks]**

Total 25 marks

Question 2

a) State any five advantages of digital signal processing over analogue signal processing. **[10 marks]**

b) Consider a causal signal that is the sum of three real exponentials such as

$$y(t) = 2e^{-3t}u(t) - e^{-2t}u(t) + 3e^{-1.2t}u(t)$$

where

$$u(t) = \begin{cases} 1, & t \geq 0 \\ 0, & t < 0 \end{cases}$$

represents a unit step function. Find the Laplace transform of the signal. **[15 marks]**

Total 25 marks

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<u>Question 3</u>

Consider the following stable LTI system for which the input $v[n]$ and output $y[n]$ satisfy the linear constant-coefficient difference equation, namely

$$y[n] - \frac{3}{4}y[n-1] = v[n] - \frac{1}{8}v[n-1]$$

Assuming that $x[n] = \delta[n]$, determine the

i) transfer function **[10 marks]**

ii) impulse response **[15 marks]**

Take $\frac{z}{z-b} = b^n u[n]$ and $\frac{1}{z-b} = b^{n-1}u[n-1]$.

Total 25 marks

<u>Question 4</u>

You have been recruited as a senior digital signal processing engineer in a company. It was reported to you that a young engineer realised the following results by your client and they require an interpretation to what the Figure Q4 could represent.

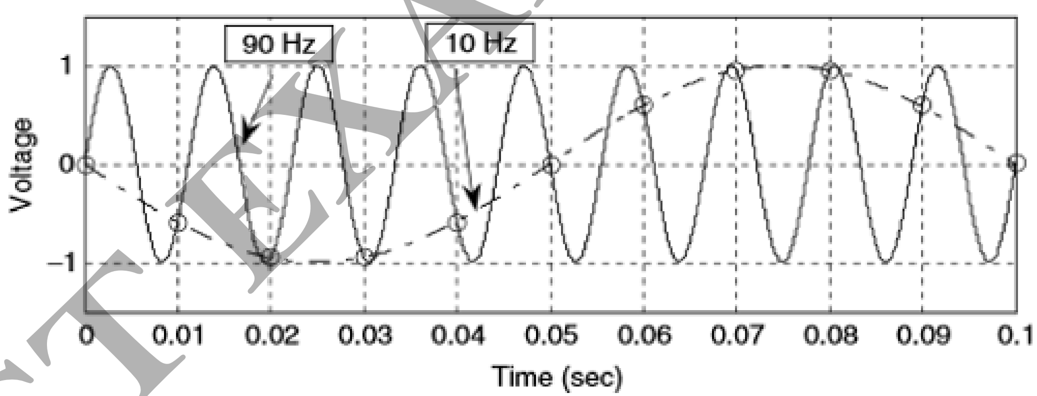

Figure Q4

Having looked at Figure Q4 closely, you identified that the analogue signal is being digitised.

a) Determine the frequency of the analogue signal **[2 marks]**

[Question 4 Continues on the next page …]

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[….Question 4 Continued from the previous page]

b) Determine the frequency of the digital signal **[2 marks]**

c) Based on your knowledge how would you interpret the graph shown in Figure Q4 and what signal processing phenomenon underpins the output digital signal? **[3 marks]**

d) Based on the information depicted in Figure Q4, obtain an expression that governs the analog signal **[3 marks]**

e) Obtain the expression for the digital signal. **[15 marks]**

Total 25 marks

Question 5

a) State the difference between IIR and FIR filters. **[2 Marks]**

b) A causal LTI system is represented by the following transfer function:

$$H(z) = \frac{1 - z^{-1}}{1 + \frac{1}{2}z^{-2}}$$

i) Find the equivalent difference equation that can be used to implement the system.

[6 Marks]

ii) Z-transform method, find the response of the system to a unit-step input $u[n]$

[8 Marks]

iii) Determine the poles and zeros of the system. Using suitable plot, determine if the response in 3-b-ii) above is stable or not. **[6 Marks]**

iv) In terms of filters, explain the filter type of the LTI transfer function. **[3 Marks]**

Total 25 Marks

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Question 6

Consider the following R-C-L filter circuit with a voltage source v(t) and current flowing as shown in Figure Q6.

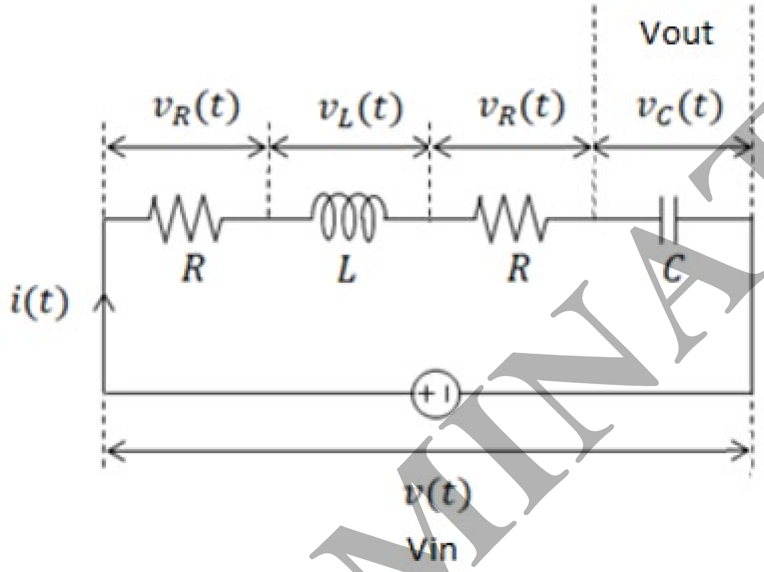

Figure Q6

Determine the

a) transfer function of the system **[9 marks]**
b) poles and zeros **[8 marks]**
c) impulse response **[8 marks]**

Take $R = 1.0\Omega$, $L = 1\ H$ and $C = 2\ F$.

Total 25 marks

END OF QUESTIONS

Formula Sheets follow over the page…

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SUPLEMENTRY RESOURCES

	$f(t) = \mathcal{L}^{-1}\{F(s)\}$	$F(s) = \mathcal{L}\{f(t)\}$
1.	1	$\frac{1}{s}$
2.	e^{at}	$\frac{1}{s-a}$
3.	$t^n, \quad n = \text{positive integer}$	$\frac{n!}{s^{n+1}}$
4.	$t^p, \quad p > -1$	$\frac{\Gamma(p+1)}{s^{p+1}}$
5.	$\sin at$	$\frac{a}{s^2+a^2}$
6.	$\cos at$	$\frac{s}{s^2+a^2}$
7.	$\sinh at$	$\frac{a}{s^2-a^2}$
8.	$\cosh at$	$\frac{s}{s^2-a^2}$
9.	$e^{at}\sin bt$	$\frac{b}{(s-a)^2+b^2}$
10.	$e^{at}\cos bt$	$\frac{s-a}{(s-a)^2+b^2}$
11.	$t^n e^{at}, \quad n = \text{positive integer}$	$\frac{n!}{(s-a)^{n+1}}$
12.	$u_c(t)$	$\frac{e^{-cs}}{s}$
13.	$u_c(t)f(t-c)$	$e^{-cs}F(s)$
14.	$e^{ct}f(t)$	$F(s-c)$
15.	$f(ct)$	$\frac{1}{c}F\left(\frac{s}{c}\right)$
16.	$(f*g)(t) = \int_0^t f(t-\tau)g(\tau)\,d\tau$	$F(s)G(s)$
17.	$\delta(t-c)$	e^{-cs}
18.	$f^{(n)}(t)$	$s^nF(s) - s^{n-1}f(0) - \cdots - f^{(n-1)}(0)$
19.	$(-t)^n f(t)$	$F^{(n)}(s)$

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Signal $x[n]$	**z-Transform** $X(z)$	**ROC**
$\delta[n]$	1	All z
$u[n]$	$\frac{1}{1-z^{-1}}$	$\|z\|>1$
$n\,u[n]$	$\frac{z^{-1}}{(1-z^{-1})^2}$	$\|z\|>1$
$a^n u[n]$	$\frac{1}{1-az^{-1}}$	$\|z\|>\|a\|$
$na^n\,u[n]$	$\frac{az^{-1}}{(1-az^{-1})^2}$	$\|z\|>\|a\|$
$-a^n u[-n-1]$	$\frac{1}{1-az^{-1}}$	$\|z\|<\|a\|$
$-na^n\,u[-n-1]$	$\frac{az^{-1}}{(1-az^{-1})^2}$	$\|z\|<\|a\|$
$(\cos\omega_o n)u[n]$	$\frac{1-z^{-1}\cos\omega_o}{1-2z^{-1}\cos\omega_o+z^{-2}}$	$\|z\|>1$
$(\sin\omega_o n)u[n]$	$\frac{z^{-1}\sin\omega_o}{1-2z^{-1}\cos\omega_o+z^{-2}}$	$\|z\|>1$
$(a^n\cos\omega_o n)u[n]$	$\frac{1-az^{-1}\cos\omega_o}{1-2az^{-1}\cos\omega_o+a^2z^{-2}}$	$\|z\|>\|a\|$
$(a^n\sin\omega_o n)u[n]$	$\frac{az^{-1}\sin\omega_o}{1-2az^{-1}\cos\omega_o+a^2z^{-2}}$	$\|z\|>\|a\|$

END OF EXAMINATION