King Saud University  
College of Engineering  
Electrical Engineering Department  

EE301: Signals and System Analysis  

Final Exam  

Instructors: **R. Djemal & S. Aldosari**  

Date: **14/1/1429**  
Time: **8:00-11:00 pm**  

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Problem I  (20 points)

(a) Suppose that the input and the impulse response $h(t)$ of LTI system are given by

$$x(t) = \begin{cases} e^{-3t} & 1 \leq t \leq 2 \\ 0 & \text{otherwise} \end{cases} \quad h(t) = \begin{cases} e^{-t} & t < 0 \\ 0 & \text{otherwise} \end{cases}$$

Find and Sketch $y(t) = x(t) * h(t)$.
(b) Consider a system with impulse response

$$h[n] = \left(\frac{3}{4}\right)^n u[n]$$

Find the **unit step response** of the system using the convolution at times \( n = -5, 5, \) and \( n = 10 \)
Problem II  (20 points)

Consider the interconnection of four LTI systems as depicted in the following figure:

The impulse responses of the systems are:

\[
\begin{align*}
    h_1[n] &= u[n] \\
    h_2[n] &= u[n+2] - u[n] \\
    h_3[n] &= \delta[n-2] \\
    h_4[n] &= \alpha^n u[n]
\end{align*}
\]

i. Find the impulse response of the overall system

ii. Consider \( h[n] \) where \( \alpha = 3/2 \), Find the unit step response of this LTI system using the convolution
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Problem III  (20 points)

(a) A CT signal is given by: 
\[ x(t) = \begin{cases} 
  e^{-2t} & 0 < t < 1 \\
  0 & \text{otherwise} 
\end{cases} \]

(i) Find the **autocorrelation** of \( x(t) \)
(ii) Find the **energy** of \( x(t) \)
(b) For the following DT signals:
(i) Find the cross-correlation $R_{yx}[n]$
(ii) Find the cross-correlation $R_{xy}[n]$
Problem IV  (20 points)

(a) Use the differentiation property to find the Fourier transform of \( x(t) = \begin{cases} t^3 & 0 < t < 1 \\ 0 & \text{otherwise} \end{cases} \)
(b) A LTI DT system is described by the following difference equation
\[ y[n] - \frac{1}{3} y[n-1] = 4x[n] \]

(i) Draw a block diagram of this system.
(ii) Find the Frequency response \( H(e^{j\omega}) \) of this system.
(iii) Find the impulse response \( h(t) \) of this system.
(iv) Find the output \( y[n] \) if the input is \( x[n] = \delta[n] - \frac{1}{3} \delta[n-1] \)
**Problem V**  (20 points)

The spectrum of a male ($X(f)$) and female ($Y(f)$) speech signal is shown above. Note that $f = \omega / 2\pi$ is the frequency in Hz.

**(a)** For the male speech signal $x(t)$:

(i) What is the **minimum sampling frequency** $f_s$ (in Hz) (show how you get it)

(ii) Explain what happens if you use a sampling frequency lower than $f_s$ in (i) ?

**(b)** Assuming that we used a proper sampling frequency to convert $x(t)$ into a discrete-time signal. Now we want to reconstruct the original signal $x(t)$.

(i) What **type of filter** is needed?

(ii) What is the **minimum and maximum cutoff frequency** $f_c$ (in Hz) of the filter.
(c) Suppose that we generated a new signal $z(t)$ by mixing (adding) the two speech signals $x(t)$ and $y(t)$, what would be the minimum sampling frequency of $z(t)$? Why?

(d) Suppose that we generated a new signal $m(t)$ by multiplying $x(t)$ with $c(t) = \cos(2\pi(5000)t)$. (This process is called Amplitude Modulation (AM)).

(i) Express $M(f)$ (the Fourier transform of $m(t)$) as a function of $X(f)$

(ii) Find the minimum sampling frequency of $m(t)$?
Problem VI (20 points)

An LTI system is described by the following differential equation:
\[
\frac{d^2 y(t)}{dt^2} + 3 \frac{dy(t)}{dt} - 4y(t) = \frac{dx(t)}{dt} - 3
\]

(a) Draw a block diagram of this system

(b) Find the transfer function \( H(s) \) of this system

(c) Find the poles and zeros of this system and Sketch the zero-pole plot.

(d) Find all possibilities of the ROC. For each ROC, explain if the system is stable or not?