

# EEE2047S: Signals and Systems I

Class Test 1

14 August 2019

Name:

Student number:

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## Information

- The test is closed-book.
  - This test has *four* questions, totaling 20 marks.
  - There is an information sheet attached at the end of this paper.
  - Answer *all* the questions.
  - You have 60 minutes.
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1. (5 marks) Plot the following signals:

(a)  $y_1(t) = \int_t^\infty \delta(\lambda) d\lambda$

(b)  $y_2(t) = \int_0^\infty \delta(\lambda - t) d\lambda$

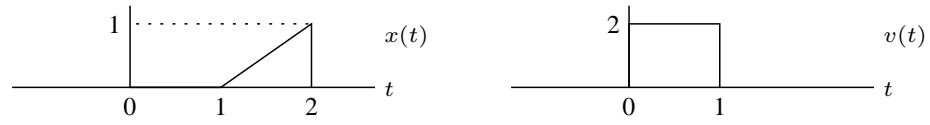
(c)  $y_3(t) = \frac{d}{dt} (t(u(t) - u(t - 1)))$ .

2. (5 marks) Suppose the output  $y(t)$  of a system is related to the input  $x(t)$  via the relation

$$y(t) = 3x(t + 2) + 4x(t - 1).$$

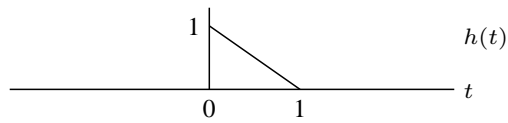
- (a) Is the system causal? Why?
- (b) Find and plot the output  $y(t)$  when the input is  $x(t) = u(t - 1)$ .
- (c) Is the system time invariant? Why?

3. (5 marks) Consider the signal  $y(t) = x(t) * v(t)$  for the signals given below:

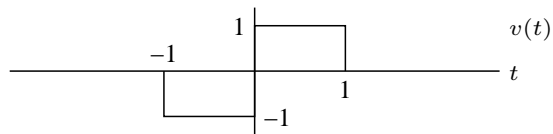


- (a) For what range of values of  $t$  is  $y(t) = 0$ ?
- (b) Specify  $y(t)$  over the interval  $1 \leq t \leq 2$ .

4. (5 marks) Consider an LTI system with impulse response



- (a) Is the system causal? Why?
- (b) Find and sketch the step response of the system, i.e. the output  $g(t)$  when the input is  $x(t) = u(t)$ .
- (c) Find the response of the system to the signal below:



Express the result in terms of the step response  $g(t)$  in (b), and sketch your solution.

# INFORMATION SHEET

## Fourier transform properties

Property	Transform Pair/Property
Linearity	$ax(t) + bv(t) \iff aX(\omega) + bV(\omega)$
Time shift	$x(t - c) \iff X(\omega)e^{-j\omega c}$
Time scaling	$x(at) \iff \frac{1}{ a }X\left(\frac{\omega}{a}\right) \quad a > 0$
Time reversal	$x(-t) \iff X(-\omega) = \overline{X(\omega)}$
Multiplication by power of $t$	$t^n x(t) \iff j^n \frac{d^n}{d\omega^n} X(\omega) \quad n = 1, 2, \dots$
Frequency shift	$x(t)e^{j\omega_0 t} \iff X(\omega - \omega_0) \quad \omega_0 \text{ real}$
Multiplication by $\cos(\omega_0 t)$	$x(t) \cos(\omega_0 t) \iff \frac{1}{2}[X(\omega + \omega_0) + X(\omega - \omega_0)]$
Differentiation in time domain	$\frac{d^n}{dt^n} x(t) \iff (j\omega)^n X(\omega) \quad n = 1, 2, \dots$
Integration	$\int_{-\infty}^t x(\lambda) d\lambda \iff \frac{1}{j\omega} X(\omega) + \pi X(0)\delta(\omega)$
Convolution in time domain	$x(t) * v(t) \iff X(\omega)V(\omega)$
Multiplication in time domain	$x(t)v(t) \iff \frac{1}{2\pi} X(\omega) * V(\omega)$
Parseval's theorem	$\int_{-\infty}^{\infty} x(t)v(t) dt = \frac{1}{2\pi} \int_{-\infty}^{\infty} \overline{X(\omega)}V(\omega) d\omega$
Parseval's theorem (special case)	$\int_{-\infty}^{\infty} x^2(t) dt = \frac{1}{2\pi} \int_{-\infty}^{\infty}  X(\omega) ^2 d\omega$
Duality	$X(t) \iff 2\pi x(-\omega)$

## Common Fourier Transform Pairs

$x(t) = \frac{1}{2\pi} \int_{-\infty}^{\infty} X(\omega)e^{j\omega t} d\omega$	$X(\omega) = \int_{-\infty}^{\infty} x(t)e^{-j\omega t} dt$
1 $(-\infty < t < \infty)$	$2\pi\delta(\omega)$
$-0.5 + u(t)$	$\frac{1}{j\omega}$
$u(t)$	$\pi\delta(\omega) + \frac{1}{j\omega}$
$\delta(t)$	1
$\delta(t - c)$	$e^{-j\omega c} \quad (c \text{ any real number})$
$e^{-bt}u(t)$	$\frac{1}{j\omega + b} \quad (b > 0)$
$e^{j\omega_0 t}$	$2\pi\delta(\omega - \omega_0) \quad (\omega_0 \text{ any real number})$
$p_\tau(t)$	$\tau \text{sinc} \frac{\tau\omega}{2\pi}$
$\tau \text{sinc} \frac{\tau t}{2\pi}$	$2\pi p_\tau(\omega)$
$\left(1 - \frac{2 t }{\tau}\right) p_\tau(t)$	$\frac{\tau}{2} \text{sinc}^2\left(\frac{\tau\omega}{4\pi}\right)$
$\frac{\tau}{2} \text{sinc}^2 \frac{\tau t}{4\pi}$	$2\pi \left(1 - \frac{2 \omega }{\tau}\right) p_\tau(\omega)$
$\cos(\omega_0 t + \theta)$	$\pi[e^{-j\theta}\delta(\omega + \omega_0) + e^{j\theta}\delta(\omega - \omega_0)]$
$\sin(\omega_0 t + \theta)$	$j\pi[e^{-j\theta}\delta(\omega + \omega_0) - e^{j\theta}\delta(\omega - \omega_0)]$
$\sum_{n=-\infty}^{\infty} \delta(t - nT)$	$\frac{2\pi}{T} \sum_{k=-\infty}^{\infty} \delta(\omega - k\frac{2\pi}{T})$

with  $p_\tau(t) = u(t + \tau/2) - u(t - \tau/2)$  and  $\text{sinc}(\lambda) = \sin(\pi\lambda)/(\pi\lambda)$ .

# Laplace transform properties

Property	Transform Pair/Property
Linearity	$ax(t) + bv(t) \iff aX(s) + bV(s)$
Time shift	$x(t-a)u(t-a) \iff e^{-as}X(s) \quad a \geq 0$
Time scaling	$x(at) \iff \frac{1}{a}X\left(\frac{s}{a}\right) \quad a > 0$
Frequency differentiation	$t^n x(t) \iff (-1)^n X^{(n)}(s)$
Frequency shift	$e^{at}x(t) \iff X(s-a)$
Differentiation	$x'(t) \iff sX(s) - x(0^-)$ $x''(t) \iff s^2X(s) - sx(0^-) - x'(0^-)$ $x^{(n)}(t) \iff s^n X(s) - s^{n-1}x(0^-) - \dots - x^{(n-1)}(0^-)$
Integration	$\int_0^t x(\lambda)d\lambda \iff \frac{1}{s}X(s)$ $\int_{-\infty}^t x(\lambda)d\lambda \iff \frac{1}{s}X(s) + \frac{1}{s} \int_{-\infty}^0 x(\lambda)d\lambda$
Time convolution	$x(t) * v(t) \iff X(s)V(s)$
Frequency convolution	$x(t)v(t) \iff \frac{1}{2\pi j} X(s) * V(s)$

Initial value:  $f(0^+) = \lim_{s \rightarrow \infty} sF(s)$

Final value:  $f(\infty) = \lim_{s \rightarrow 0} sF(s)$  with all poles in left-hand plane

## Common Unilateral Laplace Transform Pairs

$x(t) = \frac{1}{2\pi j} \int_{c-j\infty}^{c+j\infty} X(s)e^{st} ds$	$X(s) = \int_0^\infty x(t)e^{-st} dt$
$\delta(t)$	1
$u(t)$	$\frac{1}{s}$
$tu(t)$	$\frac{1}{s^2}$
$t^n u(t)$	$\frac{n!}{s^{n+1}}$
$e^{\lambda t} u(t)$	$\frac{1}{s-\lambda}$
$te^{\lambda t} u(t)$	$\frac{1}{(s-\lambda)^2}$
$t^n e^{\lambda t} u(t)$	$\frac{n!}{(s-\lambda)^{n+1}}$
$\cos(bt)u(t)$	$\frac{s}{s^2+b^2}$
$\sin(bt)u(t)$	$\frac{b}{s^2+b^2}$
$e^{-at} \cos(bt)u(t)$	$\frac{s+a}{(s+a)^2+b^2}$
$e^{-at} \sin(bt)u(t)$	$\frac{b}{(s+a)^2+b^2}$
$re^{-at} \cos(bt + \theta)u(t)$	$\frac{(r \cos \theta)s + (ar \cos \theta - br \sin \theta)}{s^2 + 2as + (a^2 + b^2)}$
$re^{-at} \cos(bt + \theta)u(t)$	$\frac{0.5re^{j\theta}}{s+a-jb} + \frac{0.5re^{-j\theta}}{s+a+jb}$
$re^{-at} \cos(bt + \theta)u(t)$	$\frac{As+B}{s^2+2as+c}$
	$r = \sqrt{\frac{A^2c+B^2-2ABa}{c-a^2}}, b = \sqrt{c-a^2}, \theta = \tan^{-1} \frac{Aa-b}{A\sqrt{c-a^2}}$

## Trigonometric identities

$$\sin(-\theta) = -\sin(\theta) \quad \cos(-\theta) = \cos(\theta) \quad \tan(-\theta) = -\tan(\theta) \quad \sin^2(\theta) + \cos^2(\theta) = 1$$

$$\sin(2\theta) = 2 \sin(\theta) \cos(\theta) \quad \cos(2\theta) = \cos^2(\theta) - \sin^2(\theta) = 2 \cos^2(\theta) - 1 = 1 - 2 \sin^2(\theta)$$

$$\sin(\theta_1 + \theta_2) = \sin(\theta_1) \cos(\theta_2) + \cos(\theta_1) \sin(\theta_2) \quad \cos(\theta_1 + \theta_2) = \cos(\theta_1) \cos(\theta_2) - \sin(\theta_1) \sin(\theta_2)$$

$$e^{j\theta} = \cos(\theta) + j \sin(\theta)$$