

# EEE2035F EXAM SIGNALS AND SYSTEMS I

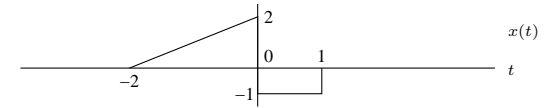
University of Cape Town  
Department of Electrical Engineering

June 2010  
2 hours

## Information

- The exam is closed-book.
- There are *eight* questions totalling 80 marks. You must answer all of them.
- The last page of this exam paper contains an information sheet with standard Fourier transforms, transform properties, and some trigonometric identities.
- You have 2 hours.

1. Let  $x(t)$  be the signal below:

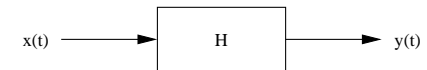


Sketch the following:

- (a)  $x_1(t) = x(1 - t)$
- (b)  $x_2(t) = -x(t - 1)$
- (c)  $x_3(t) = \int_{-\infty}^t x(\tau) d\tau$
- (d)  $x_4(t) = \delta(t + 1)x(t)$
- (e)  $x_5(t) = \frac{d}{dt}x(t)$ .

(10 marks)

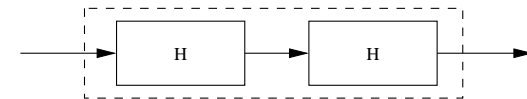
2. Consider the system



with input-output relationship

$$y(t) = \int_{t-1}^t x(\tau) d\tau$$

- (a) Assuming that the system is linear and time invariant, show that the impulse response is  $h(t) = u(t) - u(t - 1)$ .
- (b) Is the system causal? Why?
- (c) Find and sketch the impulse response of the cascaded system below:



(10 marks)

3. A linear time-invariant system has an impulse response of  $h(t) = e^{-2(t-1)}u(t-1)$ .
- (a) Use time-domain convolution to find and sketch the output  $y(t)$  when the input is  $x(t) = u(t)$ .
- (b) Is the system causal? Why?

(10 marks)

4. Consider a continuous-time LTI system described by

$$\frac{dy(t)}{dt} + 2y(t) = x(t),$$

where  $x(t)$  is the input and  $y(t)$  is the output. Using the Fourier transform and assuming initial rest conditions, find the output  $y(t)$  for each of the following input signals:

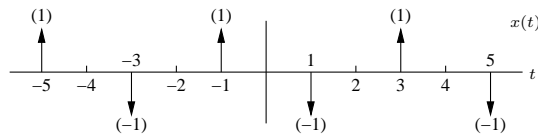
- (a)  $x(t) = e^{-t}u(t)$ ,
- (b)  $x(t) = u(t)$ .

(10 marks)

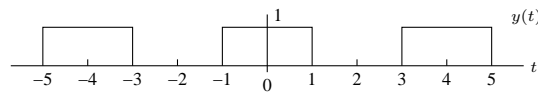
5. (a) Find the Fourier transform of the signal  $g(t) = e^{-\pi|t-2|}$ .
- (b) Find the inverse Fourier transform of  $F(\omega) = \frac{6j(\omega+1)}{2+j(\omega+1)}$ .
- (c) Find the Fourier transform of  $m(t) = p_2(t) * \text{sinc}(t)$ .

(15 marks)

6. Find the Fourier series representation for the periodic signal below:

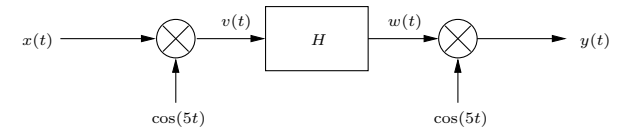


Use this result to find the Fourier series representation of



(10 marks)

7. Consider the system shown below

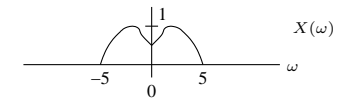


where  $H$  is an ideal lowpass filter with frequency response  $H(\omega) = p_2(\omega)$ .

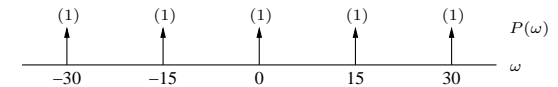
- (a) What is the output  $y(t)$  of the system if the input is the constant DC signal  $x(t) = 1$ ?
- (b) What is the output  $y(t)$  of the system if the input is the complex exponential  $x(t) = e^{j5t}$ ?

(10 marks)

8. Let  $X(\omega)$  be the signal



- (a) If  $P(\omega)$  is the impulse train  $P(\omega) = \sum_{k=-\infty}^{\infty} \delta(\omega - 15k)$ , shown below,



then sketch  $Y(\omega) = X(\omega) * P(\omega)$ .

- (b) Can  $X(\omega)$  be recovered from  $Y(\omega)$ ? If so, how?

(5 marks)

## INFORMATION SHEET

### Fourier transform properties

Property	Transform Pair/Property
Linearity	$ax(t) + bv(t) \leftrightarrow aX(\omega) + bV(\omega)$
Time shift	$x(t - c) \leftrightarrow X(\omega)e^{-j\omega c}$
Time scaling	$x(at) \leftrightarrow \frac{1}{a}X(\frac{\omega}{a}) \quad a > 0$
Time reversal	$x(-t) \leftrightarrow X(-\omega) = \overline{X(\omega)}$
Multiplication by power of $t$	$t^n x(t) \leftrightarrow j^n \frac{d^n}{d\omega^n} X(\omega) \quad n = 1, 2, \dots$
Frequency shift	$x(t)e^{j\omega_0 t} \leftrightarrow X(\omega - \omega_0) \quad \omega_0 \text{ real}$
Multiplication by $\cos(\omega_0 t)$	$x(t) \cos(\omega_0 t) \leftrightarrow \frac{1}{2}[X(\omega + \omega_0) + X(\omega - \omega_0)]$
Differentiation in time domain	$\frac{d^n}{dt^n} x(t) \leftrightarrow (j\omega)^n X(\omega) \quad n = 1, 2, \dots$
Integration	$\int_{-\infty}^t x(\lambda) d\lambda \leftrightarrow \frac{1}{j\omega} X(\omega) + \pi X(0) \delta(\omega)$
Convolution in time domain	$x(t) * v(t) \leftrightarrow X(\omega)V(\omega)$
Multiplication in time domain	$x(t)v(t) \leftrightarrow \frac{1}{2\pi} X(\omega) * V(\omega)$
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	$X(t) \leftrightarrow 2\pi x(-\omega)$

### 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
$\delta(t - c)$	$e^{-j\omega c} \quad (c \text{ any real number})$
$e^{-bt} u(t)$	$\frac{1}{j\omega + b} \quad (b > 0)$
$e^{j\omega_0 t}$	$2\pi \delta(\omega - \omega_0) \quad (\omega_0 \text{ any real number})$
$p_{\tau}(t)$	$\tau \text{sinc} \frac{\tau\omega}{2\pi}$
$\tau \text{sinc} \frac{\tau t}{2\pi}$	$2\pi p_{\tau}(\omega)$
$\left(1 - \frac{2 t }{\tau}\right) p_{\tau}(t)$	$\frac{\tau}{2} \text{sinc}^2 \left(\frac{\tau\omega}{4\pi}\right)$
$\frac{\tau}{2} \text{sinc}^2 \frac{\tau t}{4\pi}$	$2\pi \left(1 - \frac{2 \omega }{\tau}\right) p_{\tau}(\omega)$
$\cos(\omega_0 t + \theta)$	$\pi[e^{-j\theta} \delta(\omega + \omega_0) + e^{j\theta} \delta(\omega - \omega_0)]$
$\sin(\omega_0 t + \theta)$	$j\pi[e^{-j\theta} \delta(\omega + \omega_0) - e^{j\theta} \delta(\omega - \omega_0)]$

### Trigonometric identities

$$\begin{aligned} \sin(-\theta) &= -\sin(\theta) & \cos(-\theta) &= \cos(\theta) & \tan(-\theta) &= -\tan(\theta) \\ \sin^2(\theta) + \cos^2(\theta) &= 1 & \sin(2\theta) &= 2\sin(\theta)\cos(\theta) \\ \cos(2\theta) &= \cos^2(\theta) - \sin^2(\theta) = 2\cos^2(\theta) - 1 = 1 - 2\sin^2(\theta) \\ \sin(\theta_1 + \theta_2) &= \sin(\theta_1)\cos(\theta_2) + \cos(\theta_1)\sin(\theta_2) & \cos(\theta_1 + \theta_2) &= \cos(\theta_1)\cos(\theta_2) - \sin(\theta_1)\sin(\theta_2) \\ e^{j\theta} &= \cos(\theta) + j\sin(\theta) \end{aligned}$$