UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER I
SESSION 2022/2023

COURSE NAME	:	SIGNALS AND SYSTEMS
COURSE CODE	:	BEJ 20203
PROGRAMME CODE	:	BEJ
EXAMINATION DATE	:	FEBRUARY 2023
DURATION	:	3 HOURS
INSTRUCTION		1. ANSWER **ALL** QUESTIONS IN **SECTION A** AND **TWO (2)** QUESTIONS ONLY IN **SECTION B**. 2. THIS FINAL EXAMINATION IS CONDUCTED VIA **CLOSED BOOK**. 3. STUDENTS ARE **PROHIBITED** TO CONSULT THEIR OWN MATERIAL OR ANY EXTERNAL RESOURCES DURING THE EXAMINATION CONDUCTED VIA CLOSED BOOK

THIS QUESTION PAPER CONSISTS OF **THIRTEEN (13)** PAGES

SECTION A: ANSWER ALL QUESTIONS.

Q1 (a) Calculate the period of $x(t)$.

$$x(t) = 2\sin(9\pi t) - 6\sin(6\pi t) + 10\sin(3\pi t)$$

(6 marks)

(b) Determine whether the signal $z(t)$ as shown in **Figure Q1(b)** is a power or energy signal. Show your calculation.

(6 marks)

Q2 Consider a system as shown in **Figure Q2(a).**

(a) (i) Find the overall impulse response of the system, $h_T(t)$ with impulse responses given below.

$$h_1(t) = h_3(t) = 3u(t)$$
$$h_2(t) = 5tu(t)$$

(7 marks)

(ii) Determine the stability of the system.

(3 marks)

(b) Explain steps to determine the causality of a system.

(2 marks)

Q3 Consider a periodic signal as shown in **Figure Q3(a)**.

(a) Show that the Fourier series coefficients (a_0, a_n and b_n) for the signal $x(t)$ are:

$$a_0 = -\frac{1}{2};$$
$$a_n = -\frac{1}{(\pi n)^2}[(-1)^n - 1]; \text{ and}$$
$$b_n = \frac{1}{\pi n}(-1)^n.$$

Write down the trigonometric Fourier series expansion $x(t)$.

(8 marks)

(b) Use the answer in **Q3(a)** to find the amplitude-phase Fourier series expansion, $x(t)$.

(4 marks)

Q4 (a) Determine the Fourier transform of the following signals.

(i) $x(t) = e^{-3(t+2)}u(t+2)$

(2 marks)

(ii) $z(t) = e^{-3t}u(t+2)$

(2 marks)

(ii) $y(t) = \frac{1}{5}\text{rect}(3t)$

(2 marks)

(b) Given $x(t) = e^{-4t}u(t)$ and $X(\omega) = \mathcal{F}[x(t)] = \frac{1}{4+j\omega}$. Determine the Fourier transform of:

(i) $x(t-4)$

(2 marks)

(ii) $x(-2t-4)$

(4 marks)

Q5 (a) Given that $x(t) = \sin(2t)u(t)$ and $X(s) = \mathcal{L}[x(t)] = \frac{2}{s^2+4}, Re\{s\} > 0$, calculate the Laplace transform of:

(i) $x(2t-2)$

(4 marks)

(ii) $e^{t}x(t)$

(2 marks)

(b) Given $X(s) = \frac{1}{s^2+6s+8}, Re\{s\} > -2$, calculate

(i) $x(t)$

(4 marks)

(ii) $\mathcal{L}\left[\frac{dx(t)}{dt}\right]$ using differentiation property of Laplace transform.

(2 marks)

SECTION B: ANSWER TWO (2) QUESTIONS ONLY.

Q6 (a) Given the Fourier series expansion $x(t)$ as follows:

$$x(t) = 1 + \frac{2}{\pi} \sum_{\substack{n=1 \\ n\ odd}}^{5} \frac{1}{n} \cos(\pi n \times 10^5 t - 90°)$$

Based on the given Fourier series expansion $x(t)$, calculate:

(i) the fundamental period, T_o and harmonics for the range given.

(3 marks)

(ii) the exponential Fourier series coefficient, x_n for the range given in **Q6(a)**.

(7 marks)

(b) The exponential Fourier series coefficient x_n of signal $v_{in}(t)$ is given as the following expression:

$$x_n = \begin{cases} 0, & n = 0, 2, 6, \ldots \\ \dfrac{3j}{\pi n}, & n = 4, 8, 12, \ldots \\ \dfrac{6j}{\pi n}, & n = odd \end{cases}$$

(i) Express the Fourier series expansion using exponential Fourier series of $v_{in}(t)$ for the range $-6 \leq n \leq 6$.

(5 marks)

(ii) The signal $v_{in}(t)$ with period, $T_0 = 2 \times 10^{-5}$ s is passed through a low pass filter, where the magnitude and phase of the frequency response $H(f)$ are shown in **Figure Q6(b)(i)** and **Figure Q6(b)(ii)**, respectively. Express the output of the system, $v_{out}(t)$.

(5 marks)

Q7 (a) An exponential function is given by

$$x(t) = \begin{cases} e^{-t} & \text{for } t > 0 \\ e^{t} & \text{for } t < 0 \end{cases}$$

(i) Sketch the exponential signal.

(2 marks)

(ii) Calculate the Fourier transform of $x(t)$ by using the definition of Fourier transform.

(6 marks)

(iii) Plot the magnitude spectrum and the phase spectrum of **Q7(a)(ii)**.

(2 marks)

(b) Determine $v_0(t)$ of an electrical circuit as shown in **Figure Q7(b)** for

$$v_i(t) = 3e^{-5t}u(t).$$

(10 marks)

Q8 (a) A Linear Time-Invariant (LTI) with feedback system is described by the block diagram in **Figure Q8(a)**.

(i) Prove that the overall system function H(s) is as follows:

$$H(s) = \frac{3(s+2)}{s^2 - 2s + 1}$$

(6 marks)

(ii) Based on overall system function $H(s)$ in **Q8(a)(i)**, calculate the output $y(t)$ when the input $x(t) = e^{-2(t+4)}u(t+4)$.

(4 marks)

(b) Given the following facts about a real signal $x(t)$ with Laplace transform of $X(s)$.

$X(s)$ has exactly two poles.
$X(s)$ has no zeros in the finite s-plane.
$X(s)$ has a pole at $s = -1 + j$.
$X(0) = 8$.
$e^{2t}x(t)$ is not absolutely integrable.

Determine $X(s)$ and specify its region of convergence.

(10 marks)

-END OF QUESTIONS-

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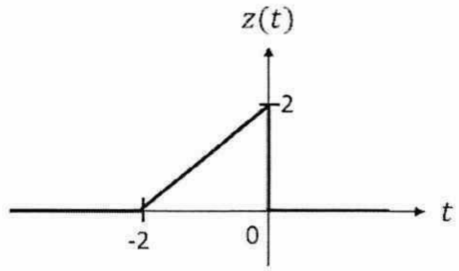

Figure Q1(b)

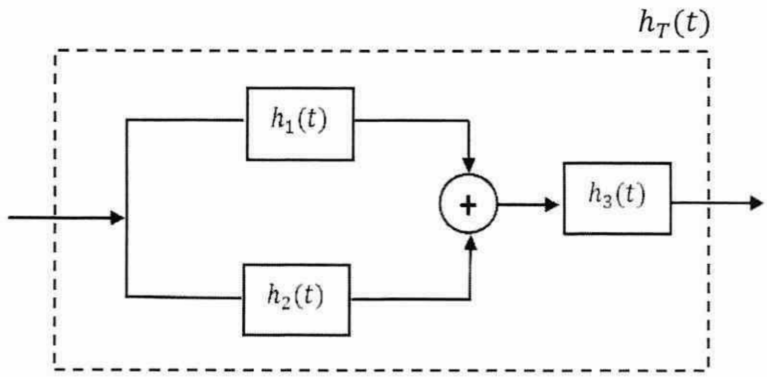

Figure Q2(a)

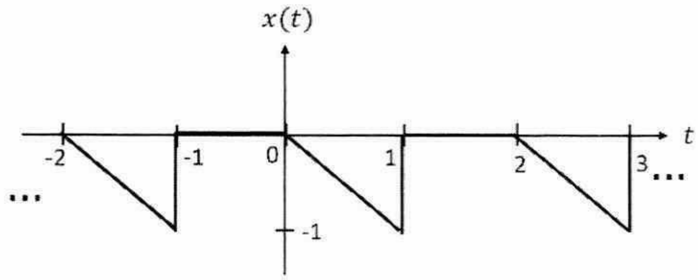

Figure Q3(a)

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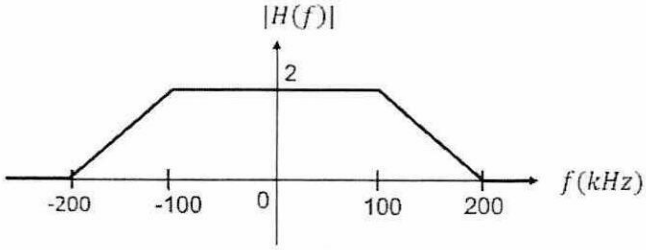

Figure Q6(b)(i)

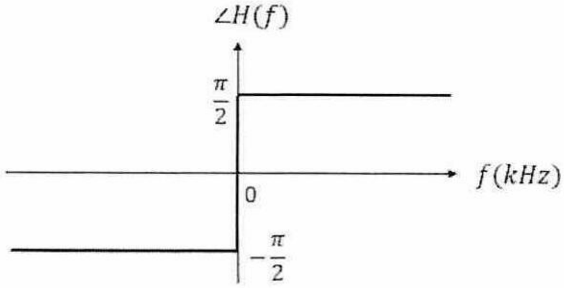

Figure Q6(b)(ii)

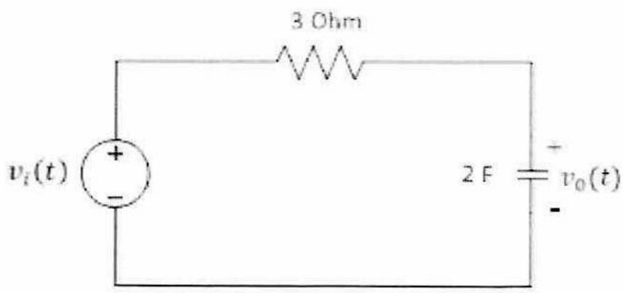

Figure Q7(b)

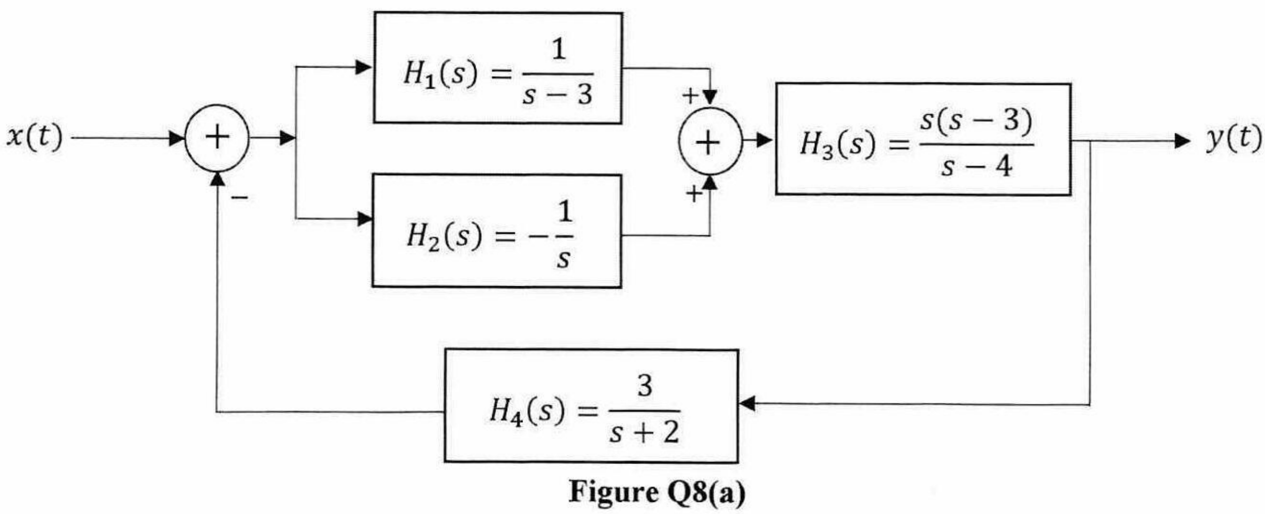

Figure Q8(a)

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TABLE 1: INDEFINITE INTEGRALS

$\int \cos at\, dt = \frac{1}{a}\sin at$	$\int \sin at\, dt = -\frac{1}{a}\cos at$
$\int t\cos at\, dt = \frac{1}{a^2}\cos at + \frac{1}{a} t\sin at$	$\int t\sin at\, dt = \frac{1}{a^2}\sin at - \frac{1}{a} t\cos at$
$\int te^{at} dt = \frac{1}{a^2} e^{at}(at-1)$	$\int \frac{1}{(a^2+t^2)} dt = \frac{1}{a}\tan^{-1}\left(\frac{t}{a}\right)$

TABLE 2: EULER'S IDENTITY

$e^{\pm j\pi/2} = \pm j$	$A\angle \pm \theta = Ae^{\pm j\theta}$
$e^{\pm jk\pi} = \cos k\pi$	$e^{\pm}j\theta = \cos\theta \pm j\sin\theta$
$\cos\theta = \frac{1}{2}\left(e^{j\theta} + e^{-j\theta}\right)$	$\sin\theta = \frac{1}{2j}\left(e^{j\theta} - e^{-j\theta}\right)$

TABLE 3: COMPLEX NUMBER

$s = a + jb = \|s\|\angle \pm \theta = \|s\|e^{\pm j\theta}$	$\|s\| = \sqrt[2]{a^2+b^2}$	$\theta = \tan^{-1}\left(\frac{b}{a}\right)$

TABLE 4: TRIGONOMETRIC IDENTITIES

$\sin\theta = \cos\left(\theta - \frac{\pi}{2}\right)$	$\cos\theta = \sin\left(\theta + \frac{\pi}{2}\right)$
$\sin(\propto \pm \beta) = \sin\alpha\cos\beta \pm \cos\alpha\sin\beta$	$\cos(\alpha \pm \beta) = \cos\alpha\cos\beta \mp \sin\alpha\sin\beta$
$\sin^2\alpha + \cos^2\beta = 1$	
$\sin 2\alpha = 2\sin\alpha\cos\alpha$	$\cos 2\alpha = 2\cos^2\alpha - 1$
$\cos 2\alpha = 1 - 2\sin^2\alpha$	$\cos 2\alpha = \cos^2\alpha - \sin^2\alpha$

TABLE 5: VALUES OF COSINE, SINE AND EXPONENTIAL FUNCTIONS FOR INTEGRAL MULTIPLE OF π.

Function	Value	Function	Value
$\cos 2n\pi$	1	$e^{j2n\pi}$	1
$\sin 2n\pi$	0	$e^{jn\pi}$	$(-1)^n$
$\cos n\pi$	$(-1)^n$	$e^{\frac{jn\pi}{2}}$	$\begin{cases} (-1)^{\frac{n}{2}} & ,n = \text{even} \\ j(-1)^{\frac{n-1}{2}} & ,n = \text{odd} \end{cases}$
$\sin n\pi$	0		
$\cos\left(\frac{n\pi}{2}\right)$	$\begin{cases} (-1)^{\frac{n}{2}} & ,n = \text{even} \\ 0 & ,n = \text{odd} \end{cases}$	$\sin\left(\frac{n\pi}{2}\right)$	$\begin{cases} (-1)^{\frac{n-1}{2}} & ,n = \text{odd} \\ 0 & ,n = \text{even} \end{cases}$

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TABLE 6: PARTIAL FRACTION FORMULA

Type of proper rational function	Partial Fraction
$\dfrac{px+q}{(x-a)(x-b)}, a \neq b$	$\dfrac{A}{x-a}+\dfrac{B}{x-b}$
$\dfrac{px^2+qx+r}{(x-a)(x-b)(x-c)}, a \neq b \neq c$	$\dfrac{A}{x-a}+\dfrac{B}{x-b}+\dfrac{C}{x-c}$
$\dfrac{px+q}{(x-a)^3}$	$\dfrac{A}{x-a}+\dfrac{B}{(x-a)^2}+\dfrac{C}{(x-a)^3}$
$\dfrac{px^2+qx+r}{(x-a)^2(x-b)}$	$\dfrac{A}{x-a}+\dfrac{B}{(x-a)^2}+\dfrac{C}{x-b}$
$\dfrac{px^2+qx+r}{(x-a)(x^2+bx+c)}$, where x^2+bx+c cannot be factorised.	$\dfrac{A}{x-a}+\dfrac{Bx+C}{x^2+bx+c}$
$\dfrac{px^3+qx^2+rx+s}{(x^2+ax+b)(x^2+cx+d)}$, where (x^2+ax+b) and (x^2+cx+d) cannot be factorised.	$\dfrac{Ax+B}{x^2+ax+b}+\dfrac{Cx+D}{x^2+cx+d}$

TABLE 7: FOURIER SERIES

Exponential	$x(t)=\sum_{n=-\infty}^{\infty} x_n e^{jn\frac{2\pi}{T}t}$ $x_n=\frac{1}{T}\int_{\alpha}^{\alpha+T} x(t)\, e^{-jn\frac{2\pi}{T}t} dt$
Trigonometric	$x(t)=\frac{a_0}{2}+\sum_{n=1}^{\infty}\left(a_n \cos n\frac{2\pi}{T}t+b_n \sin n\frac{2\pi}{T}t\right)$ $a_n=\frac{2}{T}\int_{\alpha}^{\alpha+T} x(t)\cos n\frac{2\pi}{T}t\, dt, \quad n=0,1,2,3\ldots$ $b_n=\frac{2}{T}\int_{\alpha}^{\alpha+T} x(t)\sin n\frac{2\pi}{T}t\, dt, \quad n=1,2,3\ldots$
Amplitude-phase	$x(t)=X_0+\sum_{n=1}^{\infty} A_n \cos(n\frac{2\pi}{T}t+\theta_n)$ $A_n=2\lvert X_n\rvert=\sqrt[2]{a_n^2+b_n^2} \quad , \quad \theta_n=\angle X_n=-\tan^{-1}\left(\frac{b_n}{a_n}\right)$
Average Power	$P=V_{dc}I_{dc}+\frac{1}{2}\sum_{n=1}^{\infty} V_n I_n \cos(\theta_{V_n}-\theta_{I_n})$

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TABLE 8: DEFINITION OF FOURIER AND LAPLACE TRANSFORM

FOURIER TRANSFORM	INVERSE FOURIER TRANSFORM
$\mathcal{F}[x(t)] = X(\omega) = \int_{-\infty}^{\infty} x(t)e^{-j\omega t}\, dt$ $\mathcal{F}[x(t)] = X(f) = \int_{-\infty}^{\infty} x(t)e^{-j2\pi ft}\, dt$	$x(t) = \mathcal{F}^{-1}[X(\omega)] = \frac{1}{2\pi}\int_{-\infty}^{\infty} X(\omega)e^{j\omega t}\, d\omega$ $x(t) = \mathcal{F}^{-1}[X(f)] = \int_{-\infty}^{\infty} X(f)e^{j2\pi ft}\, df$
LAPLACE TRANSFORM **Bilateral** $\mathrm{L}[x(t)] = X(s) = \int_{-\infty}^{\infty} x(t)e^{-st}dt$ **Unilateral** $\mathrm{L}[x(t)] = X(s) = \int_{0}^{\infty} x(t)e^{-st}dt$ $s = \sigma + j\omega$	**INVERSE LAPLACE TRANSFORM** $x(t) = \mathrm{L}^{-1}[X(s)] = \frac{1}{2\pi j}\int_{c-j\infty}^{c+j\infty} X(s)e^{st}ds$

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TABLE 9: FOURIER TRANSFORM PAIRS

Time domain, $x(t)$	**Frequency domain,** $X(\omega)$	**Frequency domain,** $X(f)$
$\delta(t)$	1	1
1	$2\pi\delta(\omega)$	$\delta(f)$
$u(t)$	$\pi\delta(\omega)+\frac{1}{j\omega}$	$\frac{\delta(f)}{2}+\frac{1}{j2\pi f}$
$u(t+\tau)-u(t-\tau)$	$\frac{2\sin(\omega\tau)}{\omega}=2\tau\,\mathrm{sinc}(\omega\tau)$	$2\tau\,\mathrm{sinc}\,2f\tau$
$\mathrm{rect}(t)$	$\mathrm{sinc}\left(\frac{\omega}{2}\right)$	$\mathrm{sinc}(f)$
$\|t\|$	$-\frac{2}{\omega^2}$	$-\frac{2}{(2\pi f)^2}$
$\mathrm{sgn}(t)$	$\frac{2}{j\omega}$	$\frac{1}{j\pi f}$
$e^{-at}u(t)$	$\frac{1}{a+j\omega}$	$\frac{1}{\alpha+j2\pi f}$
$e^{at}u(-t)$	$\frac{1}{a-j\omega}$	$\frac{1}{\alpha-j2\pi f}$
$e^{-a\|t\|}$	$\frac{2a}{a^2+\omega^2}$	$\frac{2a}{a^2+4\pi^2 f^2}$
$e^{j\omega_0 t}$	$2\pi\delta(\omega-\omega_0)$	$\delta(f-f_0)$
$t^n e^{-at}u(t)$	$\frac{n!}{(a+j\omega)^{n+1}}$	$\frac{n!}{(a+j2\pi f)^{n+1}}$
$\sin\omega_0 t$	$\frac{\pi}{j}[\delta(\omega-\omega_0)-\delta(\omega+\omega_0)]$	$\frac{\delta(f-f_o)-\delta(f+f_o)}{2j}$
$\cos\omega_0 t$	$\pi[\delta(\omega+\omega_0)+\delta(\omega-\omega_0)]$	$\frac{\delta(f-f_o)+\delta(f+f_o)}{2}$
$e^{-at}\sin\omega_0 t\,u(t)$	$\frac{\omega_0}{(a+j\omega)^2+\omega_0^2}$	$\frac{2\pi f_0}{(a+j2\pi f)^2+(2\pi f_0)^2}$
$e^{-at}\cos\omega_0 t\,u(t)$	$\frac{a+j\omega}{(a+j\omega)^2+\omega_0^2}$	$\frac{a+2\pi f}{(a+j2\pi f)^2+(2\pi f_0)^2}$

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TABLE 10: FOURIER TRANSFORM PROPERTIES

Property	Time domain, $x(t)$	Frequency domain, $X(\omega)$	Frequency domain, $X(f)$
Linearity	$a_1x_1(t)+a_2x_2(t)$	$a_1X_1(\omega)+a_2X_2(\omega)$	$a_1X_1(f)+a_2X_2(f)$
Time scaling	$x(at)$	$\frac{1}{\lvert a\rvert}X\left(\frac{\omega}{a}\right)$	$\frac{1}{\lvert a\rvert}X\left(\frac{f}{a}\right)$
Time shifting	$x(t-t_0)u(t-t_0)$	$e^{-j\omega t_0}X(\omega)$	$e^{-j2\pi f t_0}X(f)$
Frequency shifting	$e^{j\omega_0 t}x(t)$	$X(\omega-\omega_0)$	$X(f-f_o)$
Modulation	$\cos(\omega_0 t)\,x(t)$ $\sin(\omega_0 t)\,x(t)$	$\frac{1}{2}[X(\omega+\omega_0)+X(\omega-\omega_0)]$ $\frac{1}{2j}[X(\omega-\omega_0)-X(\omega+\omega_0)]$	$\frac{1}{2}[X(f-f_o)+X(f+f_o)]$ $\frac{1}{2j}[X(f-f_o)-X(f+f_o)]$
Time differentiation	$\frac{d}{dt}(x(t))$ $\frac{d^n}{dt^n}(x(t))$	$j\omega X(\omega)$ $(j\omega)^n X(\omega)$	$j2\pi f X(f)$ $(j2\pi f)^n X(f)$
Time integration	$\int_{-\infty}^{t} x(t)dt$	$\frac{X(\omega)}{j\omega}+\pi X(\omega)\,\delta(\omega)$	$\frac{X(f)}{j2\pi f}+\frac{1}{2}X(0)\delta(f)$
Frequency differentiation	$t^n x(t)$	$(j)^n\frac{d^n}{d\omega^n}X(\omega)$	$\left(\frac{j}{2\pi}\right)^n\frac{d^n}{df^n}X(f)$
Time Reversal	$x(-t)$	$X(-\omega)$ or $X^*(\omega)$	$X(-f)$
Duality	$X(t)$	$2\pi x(-\omega)$	$X(-f)$
Convolution in t	$x_1(t)*x_2(t)$	$X_1(\omega)\cdot X_2(\omega)$	$X(f)\cdot Y(f)$
Multiplication	$x_1(t)\cdot x_2(t)$	$\frac{1}{2\pi}X_1(\omega)*X_2(\omega)$	$X(f)*Y(f)$
Parseval's Theorem	$\int_{-\infty}^{\infty}\lvert x(t)\rvert^2dt$	$\frac{1}{2\pi}\int_{-\infty}^{\infty}\lvert X(\omega)\rvert^2d\omega$	$\int_{-\infty}^{\infty}\lvert X(f)\rvert^2df$

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TABLE 11: LAPLACE TRANSFORM PAIR

Time domain, $x(t)$, $t > 0$	s-domain, $X(s)$	ROC	Time domain, $x(t)$, $t > 0$	s-domain, $X(s)$	ROC
$\delta(t)$	1	All s	$\cos bt$	$\frac{s}{s^2+b^2}$	$Re(s) > 0$
$u(t)$	$\frac{1}{s}$	$Re(s) > 0$	$\sin bt$	$\frac{b}{s^2+b^2}$	$Re(s) > 0$
t	$\frac{1}{s^2}$	$Re(s) > 0$	$e^{-at}\cos bt$	$\frac{s+a}{(s+a)^2+b^2}$	$Re(s) > -a$
t^n	$\frac{n!}{s^{n+1}}$	$Re(s) > 0$	$e^{-at}\sin bt$	$\frac{b}{(s+a)^2+b^2}$	$Re(s) > -a$
e^{-at}	$\frac{1}{s+a}$	$Re(s) > -a$	$t\cos bt$	$\frac{s^2-b^2}{(s^2+b^2)^2}$	$Re(s) > 0$
te^{-at}	$\frac{1}{(s+a)^2}$	$Re(s) > -a$	$t\sin bt$	$\frac{2bs}{(s^2+b^2)^2}$	$Re(s) > 0$

TABLE 12: LAPLACE TRANSFORM PROPERTIES

Property	Signal	Laplace Transform	ROC
	$x(t)$	$X(s)$	R
	$x_1(t), x_2(t)$	$X_1(s), X_2(s)$	R_1, R_2
Linearity	$ax_1(t) + bx_2(t)$	$aX_1(s) + bX_2(s)$	At least $R_1 \cap R_2$
Time shifting	$x(t-t_0)$	$e^{-st_0}X(s)$	R
Shifting in the s-Domain	$e^{s_0t}x(t)$	$X(s-s_0)$	Shifted version of R (i.e., s is in the ROC if $s - s_0$ is in R)
Time scaling	$x(at)$	$\frac{1}{\lvert a\rvert}X\left(\frac{s}{a}\right)$	Scaled ROC (i.e., s is in the ROC if s/a is in R)
Conjugation	$x^*(t)$	$X^*(s^*)$	R
Convolution	$x_1(t) * x_2(t)$	$X_1(s) \cdot X_2(s)$	At least $R_1 \cap R_2$
Differentiation in the Time Domain	$\frac{d}{dt}x(t)$	$sX(s)$	At least R
		$sX(s) - x(0^+)$ (Unilateral)	R right hand plane
	$\frac{d^n}{dt^n}x(t)$	$s^nX(s) - s^{n-1}x(0^+) - \cdots - sx^{n-2}(0^+) - x^{n-1}(0^+)$	
Differentiation in the s-Domain	$-tx(t)$	$\frac{d}{ds}X(s)$	R
Integration in the Time Domain	$\int_{-\infty}^{t} x(\tau)d\tau$	$\frac{1}{s}X(s)$	At least $R \cap \{Re(s) > 0\}$

Initial- and Final- Value Theorems

If $x(t) = 0$ for $t < 0$ and $x(t)$ contains no impulses or higher order singularities at $t = 0$, then

$$x(0^+) = \lim_{s\to\infty} sX(s)$$

If $x(t) = 0$ for $t < 0$ and has a finite limit as $t \to \infty$, then

$$\lim_{t\to\infty} x(t) = \lim_{s\to\infty} sX(s)$$