First Semester Examination
2022/2023 Academic Session

February 2023

EEE228 – Signal and System
(Isyarat dan Sistem)

Duration : 3 hours
(Masa : 3 jam)

Please check that this examination paper consists of **TWENTY (20)** pages of printed material including appendix before you begin the examination.

*[Sila pastikan bahawa kertas peperiksaan ini mengandungi **DUA PULUH (20)** muka surat yang bercetak termasuk lampiran sebelum anda memulakan peperiksaan ini.]*

Instructions : This paper consists of **THREE (3)** questions. Answer **THREE (3)** questions.

*[**Arahan** : Kertas ini mengandungi **TIGA (3)** soalan. Jawab **TIGA (3)** soalan.]*

In the event of any discrepancies, the English version shall be used.

[Sekiranya terdapat sebarang percanggahan pada soalan peperiksaan, versi Bahasa Inggeris hendaklah digunapakai.]

1. a) A continuous-time signal, $x(t)$ is shown in Figure 1(a). Plot $f(t) = 2x(-3t-2)$.

Suatu isyarat masa berterusan, $x(t)$ ditunjukkan dalam Rajah 1(a). Lakarkan $f(t) = 2x(-3t-2)$.

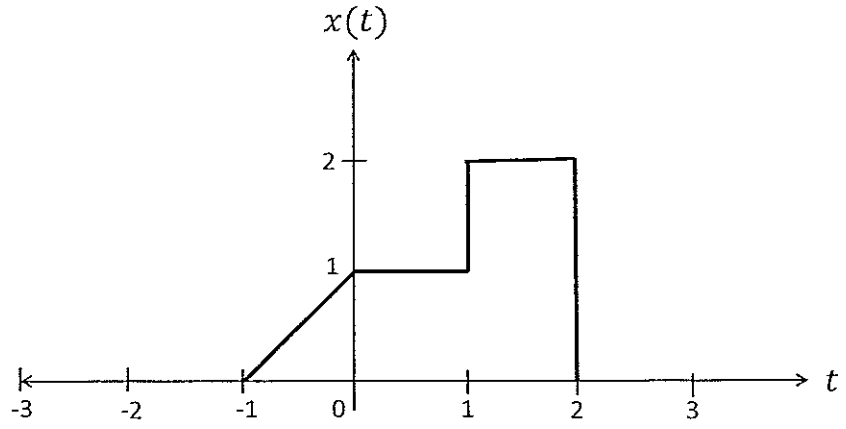

Figure 1(a)
Rajah 1(a)

(15 marks/*markah*)

b) Consider the signal $v(t) = x_1(t) + x_2(t) + x_3(t)$, where:

Pertimbangkan isyarat $v(t) = x_1(t) + x_2(t) + x_3(t)$, di mana:

$$x_1(t) = 4\cos 12t$$

$$x_2(t) = sin\ 16t$$

$$x_3(t) = 2\cos\frac{1}{2}t$$

(i) Determine whether the $v(t)$ signal is periodic. If the signal is periodic, find its fundamental period $T_0 = k_0 T_1$.

Tentukan sama ada isyarat $v(t)$ adalah berkala. Jika isyarat berkala, carikan nilai pekala utama $T_0 = k_0 T_1$.

(30 marks/*markah*)

(ii) If signal $x_4(t) = 2\cos(2\pi t + 12)$ is added to $v(t)$, determine whether the signal is periodic or not.

Jika isyarat $x_4(t) = 2\cos(2\pi t + 12)$ *ditambahkan ke* $v(t)$, *tentukan sama ada isyarat tersebut adalah berkala atau tidak.*

(10 marks/*markah*)

c) The discrete-time shown in Figure 1(b) is known as the unit time delay element. Determine whether the system is:

Sistem diskret ditunjukkan dalam Rajah 1(b) dikenali sebagai elemen pelengah masa unit. Tentukan sama ada sistem tersebut:

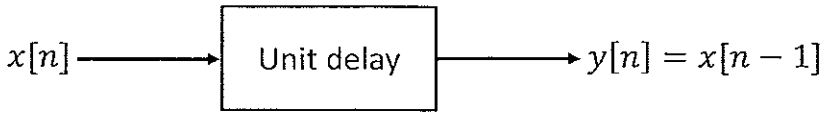

Figure 1(b)
Rajah 1(b)

(i) Memory or memoryless?

Memori atau tanpa memori?

(5 marks/*markah*)

(ii) Causal or noncausal?

Kausal atau tidak kausal?

(5 marks/*markah*)

(iii) Time-invariant or time-varying?

Tidak varian masa atau varian masa?

(5 marks/*markah*)

d) Sketch the even and odd components of the following discrete-time function.

Lakarkan komponen-komponen genap dan ganjil bagi fungsi masa diskret berikut.

$$x[n] = 2u[n+1] - 2u[n-1] - 4u[n-1] + 4u[n-3]$$

(30 marks/*markah*)

2. a)

(i) Figure 2(a) shows a system with input signals $x(t)$ and $y(t)$. Signal $x(t)$ is given in Figure 2(b) and signal $y(t)$ is given in Figure 2(c). *Rajah 2(a) menunjukkan sebuah sistem dengan isyarat-isyarat masukan x(t) and y(t). Isyarat x(t) adalah diberikan dalam Rajah 2(b) dan isyarat y(t) adalah diberikan dalam Rajah 2(c).*

Draw the output signal $z(t)$ given that:
Lukis isyarat keluaran z(t) jika diberikan:

$$f_1(t) = u(t) - u(t-2)$$
$$f_2(t) - u(t-1) - u(t-2)$$

(20 marks/*markah*)

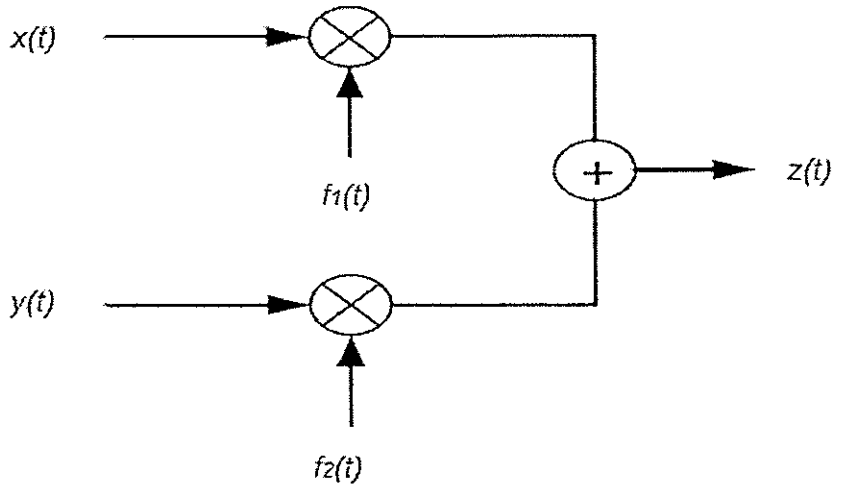

Figure 2(a)
Rajah 2(a)

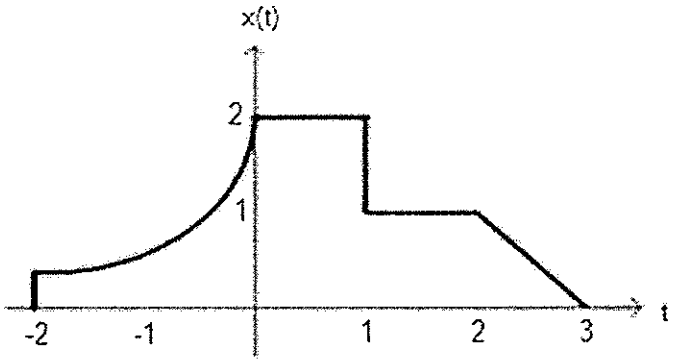

Figure 2(b)

Rajah 2(b)

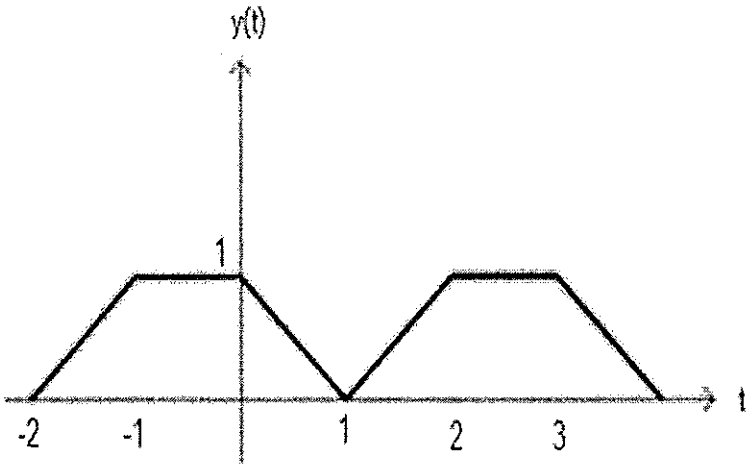

Figure 2(c)

Rajah 2(c)

(ii) Based on the system in Figure 3 and given that:

Berdasarkan sistem yang diberikan dalam Rajah 3 dan diberikan bahawa:

$$x(t) = 2u(t) - u(t-2) - u(t-4)$$

Find the expression for signal *f(t)* to produce an output signal as follows:

...6/-

Tentukan ekspresi untuk isyarat f(t) untuk menghasilkan suatu isyarat keluaran seperti yang berikut:

$$y(t) = 4u(t - 1.5) - 2u(t - 2) - 2u(t - 3)$$

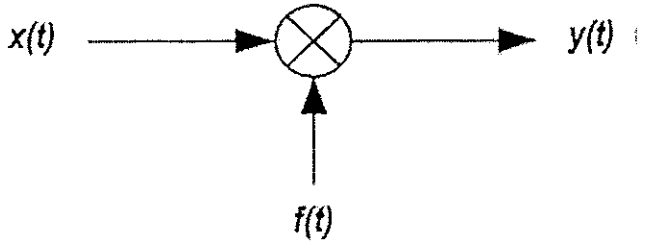

Figure 3

Rajah 3

(20 marks/*markah*)

b) Rectangular wave, *f(t)* in Figure 4(a) is fed into a Linear Time Invariant (LTI) system as shown in Figure 4(b).

Gelombang segiempat tepat f(t) dalam Rajah 4(a) adalah dimasukkan ke dalam sebuah sistem Linear Time Invariant (LTI) seperti yang ditunjukkan dalam Rajah 4(b).

(i) Determine mathematical expression for *g(t)*.

Tentukan ekspresi matematik bagi g(t)

(5 marks/*markah*)

(ii) Visualize g(t) in time domain graphical representation.

Visualisasikan g(t) dalam persembahan grafik domain masa.

(5 marks/*markah*)

(iii) Express mathematical equation of output signal, *h(t)* and determine all transformation processes involve in this system.
Nyatakan persamaan matematik bagi isyarat keluaran, h(t) dan tentukan semua proses-proses transformasi yang terlibat di dalam sistem tersebut.

(10 marks/*markah*)

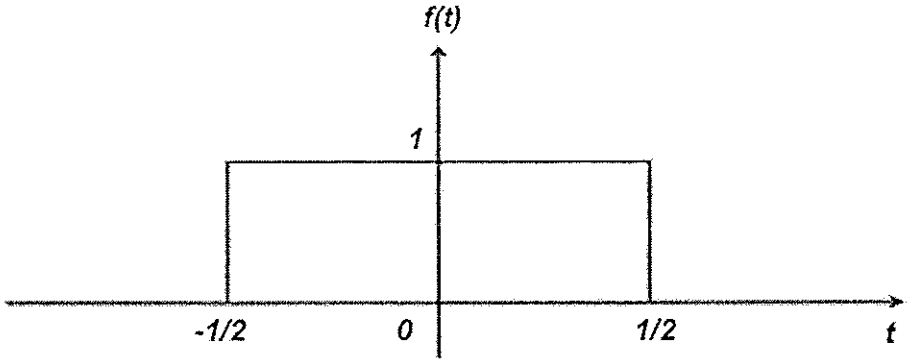

Figure 4(a)
Rajah 4(a)

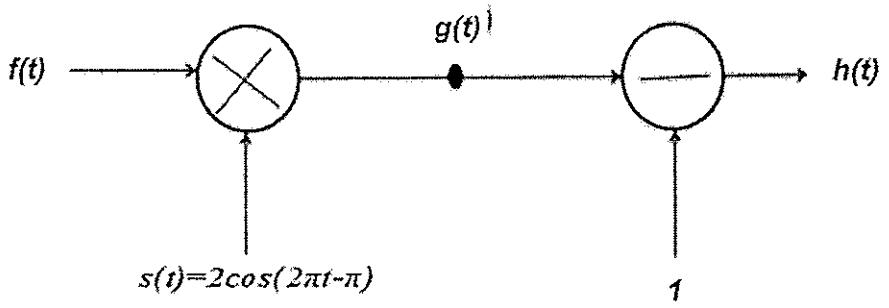

Figure 4(b)
Rajah 4(b)

c) Find the Trigonometric Fourier series coefficients for *f(t)* as shown in Figure 5 below.

Dapatkan pemalar-pemalar siri Fourier Trigonometrik bagi f(t) seperti yang ditunjukkan di dalam Rajah 5 di bawah.

(20 marks/*markah*)

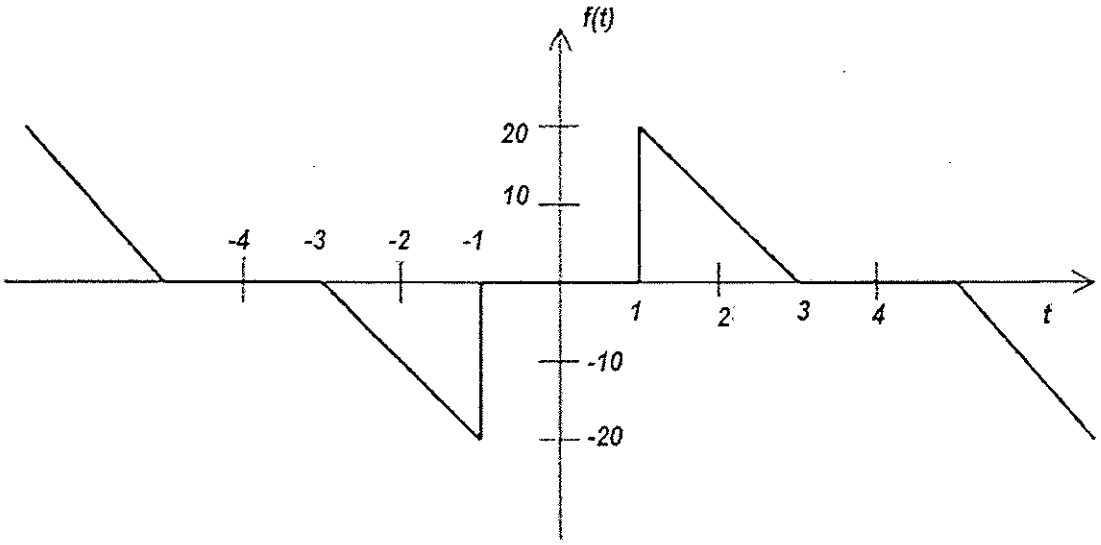

Figure 5

Rajah 5

d) Figure 6 shows a periodic signal of *f(t)*:

Rajah 6 menunjukkan isyarat bertempoh bagi f(t):

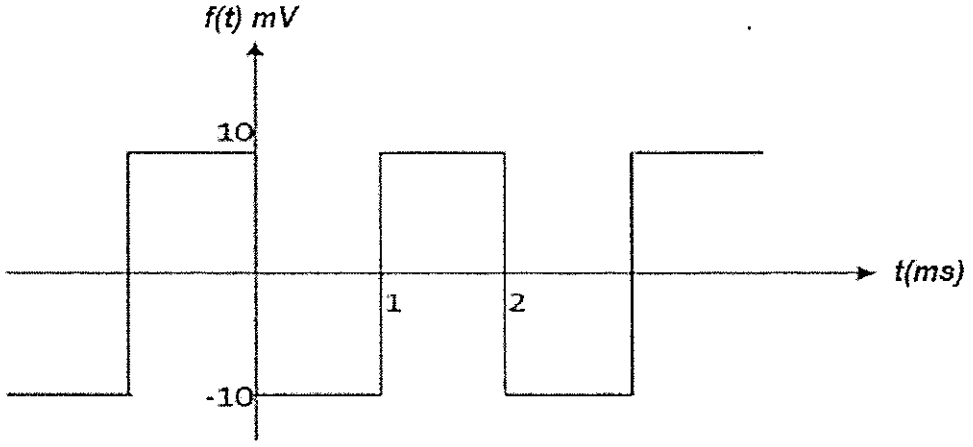

Figure 6

Rajah 6

(i) Sketch $v(t) = f(-t)$.

Lakar v(t)=f(-t).

(10 marks/*markah*)

(ii) Write the complex exponential Fourier Series for *v(t)* up to the 5th harmonics.

Tuliskan Siri Fourier Eksponen Komplek sehingga ke harmonik ke 5.

(10 marks/*markah*)

3. a)

(i) By using the definition of Fourier Transform (FT), find the FT of aperiodic signal given by:

Dengan menggunakan definisi Jelmaan Fourier (FT), cari FT bagi isyarat tidak berkala berikut:

$$x(t) = e^{-2t}u(t-1)$$

(15 marks/*markah*)

(ii) By using the modulating signal of $f(t)$ and the carrier of $\cos(\omega_c)t$, describe briefly the Double Sideband, Suppressed Carrier (DSB-SC) Modulation with the aid of related formulae and block diagrams of modulation and demodulation process.

Dengan menggunakan isyarat dimodulat $f(t)$ dan pembawa $\cos(\omega_c)t$, terangkan secara ringkas apakah Modulasi Jalur Sisi Berganda Pembawa Tertindas dengan bantuan formula yang berkaitan dan blok diagram am bagi proses modulasi dan demodulasi.

(15 marks/markah)

b) If the system is described by the differential equation given by:

Jika sistem diungkapkan oleh persamaan pembezaan seperti berikut:

$$\frac{d^2}{dt^2}y(t) + 5\frac{d}{dt}y(t) + 6y(t) = 2\frac{d}{dt}x(t) + x(t)$$

By using Fourier Transform, find the frequency response of the system.

Dengan menggunakan Jelmaan Fourier, cari sambutan frekuensi sistem.

(25 marks/*markah*)

c) For the following baseband signal,

Bagi isyarat jalur dasar berikut,

$$m(t) = \cos(1000t)cos(3000t)$$

(i) Sketch the spectrum of m(t).

Lakarkan spektrum m(t).

(5 marks/*markah*)

(ii) Sketch the spectrum of the DSB-SC signal, *m(t)cos (10,000t).*

Lakarkan spektrum isyarat DSB-SC, m(t)cos (10,000t).

(10 marks/*markah*)

(iii) Identify the upper sideband (USB) and the lower sideband (LSB) spectra.

Kenalpasti spektrum jalur sisi atas (USB) dan jalur sisi bawah (LSB).

(10 marks/*markah*)

...11/-

d) Find the inverse z-transform of this function and evaluate the first four value of x[n].

Cari Jelmaan z songsang bagi fungsi berikut dan tentukan nilai 4 ungkapan pertama x[n].

$$X(z) = \frac{z^2}{\left(z - \frac{1}{2}\right)\left(z + \frac{1}{3}\right)}$$

(20 marks/*markah*)

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APPENDICES

LAMPIRAN

- Trigonometric Fourier Series:

$$f(t) = a_o + \sum_{n=1}^{\infty}(a_n \cos n\omega t + b_n \sin n\omega t)$$

Where the Fourier Coefficients are:

$$a_0 = \frac{1}{T}\int_0^T f(t)dt$$

$$a_n = \frac{2}{T}\int_0^T f(t)\cos n\omega t dt$$

$$b_n = \frac{2}{T}\int_0^T f(t)\sin n\omega t dt$$

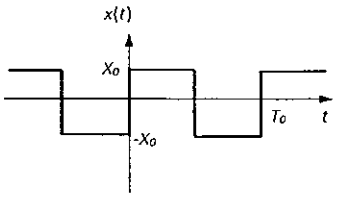
- Spectrum frequency form can be obtained from this equation:

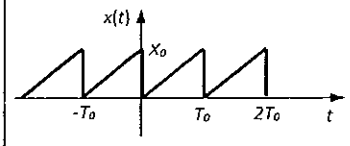
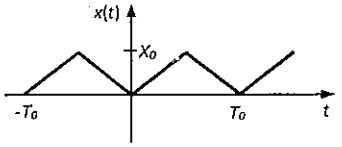
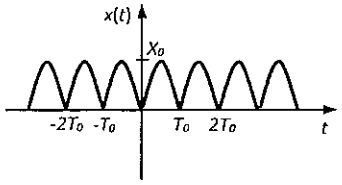
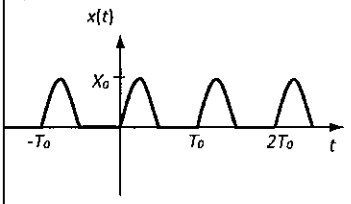
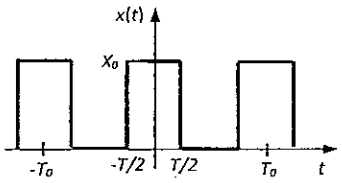
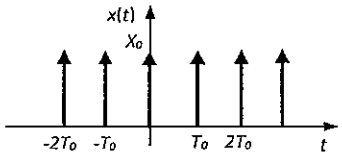
$$f(t) = a_0 + \sum_{1}^{\infty}(a_n{}^2 + b_n{}^2)^{\frac{1}{2}}\cos(n\omega t + \theta_n)$$

Where $\theta_n = \tan^{-1}(-\frac{b_n}{a_n})$

TABLE 1: COMPLEX FOURIER COEFFICIENTS

JADUAL 1: PEKALI COMPLEX FOURIER

Name	Waveform	C_0	$C_n, n \neq 0$	Comments
1. Square Wave		0	$-j\frac{2X_n}{\pi n}$	$C_n = 0$. n even

2. Sawtooth		$\frac{X_0}{2}$	$j\frac{X_0}{2\pi n}$	
3. Trlangular Wave		$\frac{X_0}{2}$	$\frac{-2X_0}{(\pi n)^2}$	$C_n = 0,$ n even
4. Full-wave rectified		$\frac{2X_0}{\pi}$	$\frac{-2X_0}{\pi(4n^2-1)}$	
5. Half-wave rectified		$\frac{X_0}{\pi}$	$\frac{-X_0}{\pi(n^2-1)}$	$C_n = 0,$ n odd, except for ıli $C_1 = -j\frac{X_0}{4},$ and $C_{-1} = j\frac{X_0}{4}$
6. Rectangular Wave		$\frac{TX_0}{T_0}$	$\frac{TX_0}{T_0}\text{sinc}\frac{Tn\omega_0}{2}$	$\frac{Tn\omega_0}{2} = \frac{\pi Tn}{T_0}$
7. Impulse Train		$\frac{X_0}{T_0}$	$\frac{X_0}{T_0}$	

- General Exponential Fourier Series

$$x(t) = C_0 + \sum_{\substack{n=-\infty \\ n\neq 0}}^{\infty} C_n e^{jn\omega_0 t}$$

- Parseval's Theorem

$$P_{ave} = C_0^2 + \frac{1}{2}\sum_{1}^{\infty}\left(a_n^2 + b_n^2\right)$$

$$= C_0^2 + 2\sum_{1}^{\infty}\left|C_n\right|^2$$

$$P_{ave} = \sum_{-\infty}^{\infty}\left|C_n\right|^2$$

THE EXPONENTIAL FUNCTION

FUNGSI EKSPONENTIAL

$$
\begin{aligned}
e^x &\triangleq \lim_{n\to\infty}\left(1+\frac{x}{n}\right)^n \\
e^x &= \sum_{n=0}^{\infty}\frac{x^n}{n!}
\end{aligned}
$$

$$
\begin{aligned}
e^{j\theta} &= \cos(\theta)+j\sin(\theta) \\
e^{jn\theta} &= \cos(n\theta)+j\sin(n\theta)
\end{aligned}
$$

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

$$e = 2.7182818284590\ldots$$

TRIGONOMETRIC IDENTITIES

IDENTITI TRIGONOMETRI

$$
\begin{aligned}
\sin(-\theta) &= -\sin(\theta) \\
\cos(-\theta) &= \cos(\theta)
\end{aligned}
$$

$$
\begin{aligned}
\sin(A+B) &= \sin(A)\cos(B)+\cos(A)\sin(B) \\
\cos(A+B) &= \cos(A)\cos(B)-\sin(A)\sin(B)
\end{aligned}
$$

$$
\begin{aligned}
\sin^2(\theta) &= \frac{1-\cos(2\theta)}{2} \\
\cos^2(\theta) &= \frac{1+\cos(2\theta)}{2}
\end{aligned}
$$

$$
\begin{aligned}
\sin(A)\sin(B) &= \frac{\cos(A-B)-\cos(A+B)}{2} \\
\cos(A)\cos(B) &= \frac{\cos(A+B)+\cos(A-B)}{2} \\
\sin(A)\cos(B) &= \frac{\sin(A+B)+\sin(A-B)}{2} \\
\cos(A)\sin(B) &= \frac{\sin(A+B)-\sin(A-B)}{2}
\end{aligned}
$$

$$
\begin{aligned}
\sin(A)+\sin(B) &= 2\sin\left(\frac{A+B}{2}\right)\cos\left(\frac{A-B}{2}\right) \\
\cos(A)+\cos(B) &= -2\cos\left(\frac{A+B}{2}\right)\cos\left(\frac{A-B}{2}\right)
\end{aligned}
$$

$$
\begin{aligned}
\sin(A)-\sin(B) &= 2\cos\left(\frac{A+B}{2}\right)\sin\left(\frac{A-B}{2}\right) \\
\cos(A)-\cos(B) &= -2\sin\left(\frac{A+B}{2}\right)\sin\left(\frac{A-B}{2}\right)
\end{aligned}
$$

$$
\begin{aligned}
\sin^2(A)-\sin^2(B) &= \sin(A+B)\sin(A-B) \\
\cos^2(A)-\cos^2(B) &= -\sin(A+B)\sin(A-B) \\
\cos^2(A)-\sin^2(B) &= \cos(A+B)\cos(A-B)
\end{aligned}
$$

$$\tan(\theta) \triangleq \frac{\sin(\theta)}{\cos(\theta)}$$

$$
\begin{aligned}
\tan(A)+\tan(B) &= \frac{\sin(A+B)}{\cos(A)\cos(B)} \\
\tan(A+B) &= \frac{\tan(A)+\tan(B)}{1-\tan(A)\tan(B)}
\end{aligned}
$$

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A Short Table of Fourier Transforms

	$f(t)$	$F(\omega)$	
1	$e^{-at}u(t)$	$\frac{1}{a+j\omega}$	$a > 0$
2	$e^{at}u(-t)$	$\frac{1}{a-j\omega}$	$a > 0$
3	$e^{-a\|t\|}$	$\frac{2a}{a^2+\omega^2}$	$a > 0$
4	$te^{-at}u(t)$	$\frac{1}{(a+j\omega)^2}$	$a > 0$
5	$t^n e^{-at}u(t)$	$\frac{n!}{(a+j\omega)^{n+1}}$	$a > 0$
6	$\delta(t)$	1	
7	1	$2\pi\delta(\omega)$	
8	$e^{j\omega_0 t}$	$2\pi\delta(\omega-\omega_0)$	
9	$\cos\omega_0 t$	$\pi[\delta(\omega-\omega_0)+\delta(\omega+\omega_0)]$	
10	$\sin\omega_0 t$	$j\pi[\delta(\omega+\omega_0)-\delta(\omega-\omega_0)]$	
11	$u(t)$	$\pi\delta(\omega)+\frac{1}{j\omega}$	
12	$\operatorname{sgn} t$	$\frac{2}{j\omega}$	
13	$\cos\omega_0 t\,u(t)$	$\frac{\pi}{2}[\delta(\omega-\omega_0)+\delta(\omega+\omega_0)]+\frac{j\omega}{\omega_0^2-\omega^2}$	
14	$\sin\omega_0 t\,u(t)$	$\frac{\pi}{2j}[\delta(\omega-\omega_0)-\delta(\omega+\omega_0)]+\frac{\omega_0}{\omega_0^2-\omega^2}$	
15	$e^{-at}\sin\omega_0 t\,u(t)$	$\frac{\omega_0}{(a+j\omega)^2+\omega_0^2}$	$a > 0$
16	$e^{-at}\cos\omega_0 t\,u(t)$	$\frac{a+j\omega}{(a+j\omega)^2+\omega_0^2}$	$a > 0$
17	$\operatorname{rect}\left(\frac{t}{\tau}\right)$	$\tau\operatorname{sinc}\left(\frac{\omega\tau}{2}\right)$	
18	$\frac{W}{\pi}\operatorname{sinc}(Wt)$	$\operatorname{rect}\left(\frac{\omega}{2W}\right)$	
19	$\Delta\left(\frac{t}{\tau}\right)$	$\frac{\tau}{2}\operatorname{sinc}^2\left(\frac{\omega\tau}{4}\right)$	
20	$\frac{W}{2\pi}\operatorname{sinc}^2\left(\frac{Wt}{2}\right)$	$\Delta\left(\frac{\omega}{2W}\right)$	
21	$\sum_{n=-\infty}^{\infty}\delta(t-nT)$	$\omega_0\sum_{n=-\infty}^{\infty}\delta(\omega-n\omega_0)$	$\omega_0=\frac{2\pi}{T}$
22	$e^{-t^2/2\sigma^2}$	$\sigma\sqrt{2\pi}e^{-\sigma^2\omega^2/2}$	

Fourier Transform Operations

Operation	$f(t)$	$F(\omega)$
Addition	$f_1(t) + f_2(t)$	$F_1(\omega) + F_2(\omega)$
Scalar multiplication	$kf(t)$	$kF(\omega)$
Symmetry	$F(t)$	$2\pi f(-\omega)$
Scaling (a real)	$f(at)$	$\frac{1}{\lvert a\rvert}F\left(\frac{\omega}{a}\right)$
Time shift	$f(t - t_0)$	$F(\omega)e^{-j\omega t_0}$
Frequency shift (ω_0 real)	$f(t)e^{j\omega_0 t}$	$F(\omega - \omega_0)$
Time convolution	$f_1(t) * f_2(t)$	$F_1(\omega)F_2(\omega)$
Frequency convolution	$f_1(t)f_2(t)$	$\frac{1}{2\pi}F_1(\omega) * F_2(\omega)$
Time differentiation	$\frac{d^n f}{dt^n}$	$(j\omega)^n F(\omega)$
Time integration	$\int_{-\infty}^{t} f(x)\,dx$	$\frac{F(\omega)}{j\omega} + \pi F(0)\delta(\omega)$

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(Unilateral) z-Transform Pairs

	$f[k]$	$F[z]$
1	$\delta[k-j]$	z^{-j}
2	$u[k]$	$\frac{z}{z-1}$
3	$ku[k]$	$\frac{z}{(z-1)^2}$
4	$k^2u[k]$	$\frac{z(z+1)}{(z-1)^3}$
5	$k^3u[k]$	$\frac{z(z^2+4z+1)}{(z-1)^4}$
6	$\gamma^{k-1}u[k-1]$	$\frac{1}{z-\gamma}$
7	$\gamma^k u[k]$	$\frac{z}{z-\gamma}$
8	$k\gamma^k u[k]$	$\frac{\gamma z}{(z-\gamma)^2}$
9	$k^2\gamma^k u[k]$	$\frac{\gamma z(z+\gamma)}{(z-\gamma)^3}$
10	$\frac{k(k-1)(k-2)\cdots(k-m+1)}{\gamma^m m!}\gamma^k u[k]$	$\frac{z}{(z-\gamma)^{m+1}}$
11a	$\lvert\gamma\rvert^k \cos \beta k\, u[k]$	$\frac{z(z-\lvert\gamma\rvert\cos\beta)}{z^2-(2\lvert\gamma\rvert\cos\beta)z+\lvert\gamma\rvert^2}$
11b	$\lvert\gamma\rvert^k \sin \beta k\, u[k]$	$\frac{z\lvert\gamma\rvert\sin\beta}{z^2-(2\lvert\gamma\rvert\cos\beta)z+\lvert\gamma\rvert^2}$
12a	$r\lvert\gamma\rvert^k \cos(\beta k+\theta)u[k]$	$\frac{rz[z\cos\theta-\lvert\gamma\rvert\cos(\beta-\theta)]}{z^2-(2\lvert\gamma\rvert\cos\beta)z+\lvert\gamma\rvert^2}$
12b	$r\lvert\gamma\rvert^k \cos(\beta k+\theta)u[k]$ $\quad \gamma=\lvert\gamma\rvert e^{j\beta}$	$\frac{(0.5re^{j\theta})z}{z-\gamma}+\frac{(0.5re^{-j\theta})z}{z-\gamma^*}$
12c	$r\lvert\gamma\rvert^k \cos(\beta k+\theta)u[k]$ $r=\sqrt{\frac{A^2\lvert\gamma\rvert^2+B^2-2AaB}{\lvert\gamma\rvert^2-a^2}}$ $\beta=\cos^{-1}\frac{-a}{\lvert\gamma\rvert},\ \theta=\tan^{-1}\frac{Aa-B}{A\sqrt{\lvert\gamma\rvert^2-a^2}}$	$\frac{z(Az+B)}{z^2+2az+\lvert\gamma\rvert^2}$

...19/-

Z- Transform Operations

Operation	$f[k]$	$F[z]$
Addition	$f_1[k] + f_2[k]$	$F_1[z] + F_2[z]$
Scalar multiplication	$af[k]$	$aF[z]$
Right-shift	$f[k-m]u[k-m]$	$\frac{1}{z^m}F[z]$
	$f[k-m]u[k]$	$\frac{1}{z^m}F[z] + \frac{1}{z^m}\sum_{k=1}^{m} f[-k]z^k$
	$f[k-1]u[k]$	$\frac{1}{z}F[z] + f[-1]$
	$f[k-2]u[k]$	$\frac{1}{z^2}F[z] + \frac{1}{z}f[-1] + f[-2]$
	$f[k-3]u[k]$	$\frac{1}{z^3}F[z] + \frac{1}{z^2}f[-1] + \frac{1}{z}f[-2] + f[-3]$
Left-shift	$f[k+m]u[k]$	$z^m F[z] - z^m \sum_{k=0}^{m-1} f[k]z^{-k}$
	$f[k+1]u[k]$	$zF[z] - zf[0]$
	$f[k+2]u[k]$	$z^2F[z] - z^2f[0] - zf[1]$
	$f[k+3]u[k]$	$z^3F[z] - z^3f[0] - z^2f[1] - zf[2]$
Multiplication by γ^k	$\gamma^k f[k]u[k]$	$F\left[\frac{z}{\gamma}\right]$
Multiplication by k	$kf[k]u[k]$	$-z\frac{d}{dz}F[z]$
Time Convolution	$f_1[k] * f_2[k]$	$F_1[z]F_2[z]$
Frequency Convolution	$f_1[k]f_2[k]$	$\frac{1}{2\pi j}\oint F_1[u]F_2\left[\frac{z}{u}\right]u^{-1}\,du$
Initial value	$f[0]$	$\lim_{z\to\infty} F[z]$
Final value	$\lim_{N\to\infty} f[N]$	$\lim_{z\to 1}(z-1)F[z]$ poles of $(z-1)F[z]$ inside the unit circle.

Course Outcomes (CO) – Programme Outcomes (PO) Mapping

Pemetaan Hasil Pembelajaran Kursus – Hasil Program

Questions *Soalan*	CO	PO
1	CO1	PO1
2	CO3	PO2
3	CO4	PO1