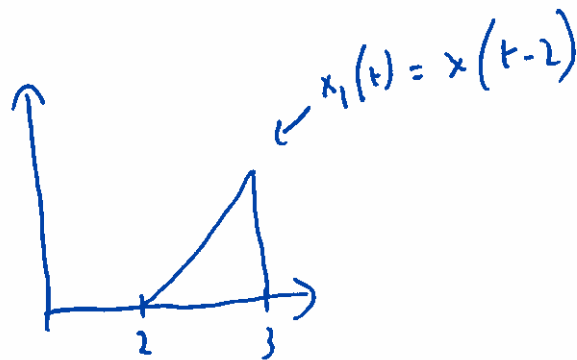


# QUESTION 1

(a)

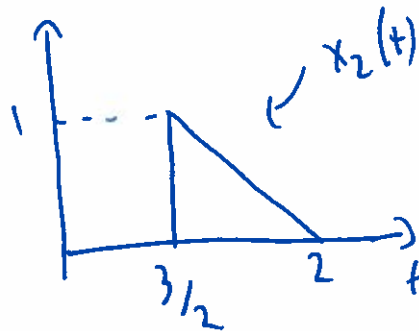


i.



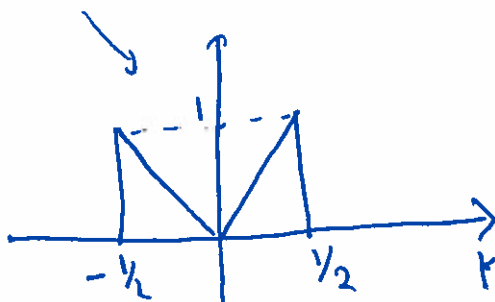
ii.

$$x_2(t) = x(-2(t-2))$$



iii.

$$x_3(t) = x(2t) + x(-2t)$$



(b)

2

$$i. \quad y(t) = x(t-2) + x(2-t)$$

LET US CHECK LINEARITY

$$x_1(t) \rightarrow y_1(t) = x_1(t-2) + x_1(2-t)$$

$$x_2(t) \rightarrow y_2(t) = x_2(t-2) + x_2(2-t)$$

$$\begin{aligned} x_3(t) = ax_1(t) + bx_2(t) \rightarrow y_3(t) &= ax_1(t-2) + bx_2(t-2) \\ &+ ax_1(2-t) + bx_2(2-t) \\ &= ay_1(t) + by_2(t) \end{aligned}$$

HENCE LINEAR

LET US CHECK TIME-INVARIANCE

$$x_1(t) \rightarrow y_1(t) = x_1(t-2) + x_1(2-t)$$

$$\begin{aligned} x_1(t-t_0) = x_2(t) \rightarrow y_2(t) &= x_2(t-2) + x_2(2-t) \\ &= x_1(t-t_0-2) + x_1(2-t-t_0) \\ &\neq y_1(t-t_0) \end{aligned}$$

$$\text{NOTE THAT } y_1(t-t_0) = x_1(t-t_0-2) + x_1(2-t+t_0)$$

HENCE TIME-VARIANT

~~NOT~~ ~~NECESSARILY~~ ~~AS~~ ~~THE~~ ~~PROCESS~~ ~~IS~~ ~~OVER~~ ~~THE~~ ~~TIME~~ ~~AND~~

ii.

3

$$y(t) = x(t) \cos 3t$$

THE SYSTEM IS LINEAR

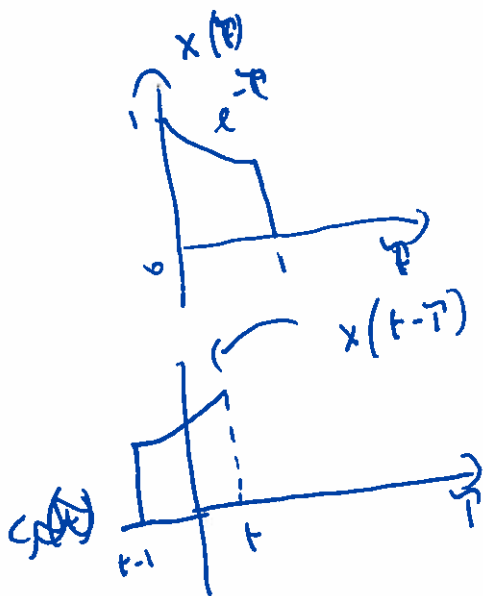
LET US CHECK FOR TIME-INVARIANCE

$$x_1(t) \rightarrow y_1(t) = x_1(t) \cos 3t$$

$$x_2(t) = x_1(t-t_0) \rightarrow y_2(t) = x_1(t-t_0) \cos 3t \neq y_1(t-t_0)$$

HENCE TIME-VARIANT

(c)



THENCE WE HAVE

$$x(t) * x(t) = \begin{cases} 0 & t \leq 0 \\ \int_0^t x(\tau) x(t-\tau) d\tau & 0 < t \leq 1 \\ \int_{t-1}^1 x(\tau) x(t-\tau) d\tau & 1 < t \leq 2 \\ 0 & t > 2 \end{cases}$$

$$\int_0^t x(\tau) x(t-\tau) d\tau = \int_0^t e^{-\tau} e^{-(t-\tau)} d\tau = t e^{-t} \quad 0 \leq t \leq 1$$

$$\int_{t-1}^1 x(\tau) x(t-\tau) d\tau = \int_{t-1}^1 e^{-\tau} e^{-(t-\tau)} d\tau = (2-t) e^{-t} \quad 1 < t \leq 2$$

HENCE

$$x(t) * x(t) = \begin{cases} 0 & t \leq 0 \\ t e^{-t} & 0 < t \leq 1 \\ (2-t) e^{-t} & 1 < t \leq 2 \\ 0 & t > 2 \end{cases}$$

(ol)

5

$$Y(t) = X(t-1) + X(-(t+1))$$

USING SHIFTING AND SCALING PROPERTY  
OF THE FT YIELDS:

$$Y(\omega) = X(\omega) e^{-j\omega} + X(-\omega) e^{j\omega}$$

$$= \frac{1}{\omega^2} \left( 1 - j\omega - e^{-j\omega} + 1 + j\omega - e^{j\omega} \right)$$

$$= \frac{1}{\omega^2} \left( 2 - e^{j\omega} - e^{-j\omega} \right) = 4 \frac{\left( e^{j\frac{\omega}{2}} - e^{-j\frac{\omega}{2}} \right)^2}{\left( j\frac{\omega}{2} \right)^2}$$

$$= \left( \text{sinc} \frac{\omega}{2} \right)^2$$

(2)

i. CHARACTERISTIC POLYNOMIAL

$$s^2 + 4s + 3$$

CHARACTERISTIC ROOTS

$$s_{1,2} = -2 \pm \sqrt{4-3} = \begin{matrix} -1 \\ -3 \end{matrix}$$

CHARACTERISTIC FUNCTION

$$c_1 e^{-t} + c_2 e^{-3t}$$

ii.

$$y(t) = c_1 e^{-t} + c_2 e^{-3t} \quad t \geq 0$$

$$y(0) = c_1 + c_2 = 0$$

$$\Rightarrow c_1 = 1$$

$$\dot{y}(0) = -c_1 - 3c_2 = 2$$

$$c_2 = -1$$

HENCE

$$y(t) = (e^{-t} - e^{-3t}) u(t)$$

iii.

$$(s^2 + 4s + 5)Y(s) = X(s)$$

$$\text{SINCE } X(s) = \frac{1}{s}$$

WE HAVE THAT

$$Y(s) = \frac{1}{s(s+1)(s+3)} = \frac{A}{s} + \frac{B}{s+1} + \frac{C}{s+3}$$

USING COVERING METHOD WE FIND THAT

$$Y(s) = \frac{1}{3s} - \frac{1}{2(s+1)} + \frac{1}{6(s+3)}$$



$$y(t) = \left( \frac{1}{3} - \frac{1}{2} e^{-t} + \frac{1}{6} e^{-3t} \right) u(t)$$

(vi)

4

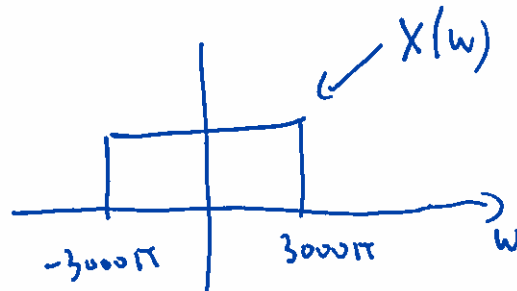
BECAUSE OF LINEARITY  
THE TOTAL ANSWER IS THE  
SUM OF THE RESPONSES IN  
PART ii. AND iii. THAT IS

$$y_{\text{TOT}}(t) = (e^{-t} - e^{-3t})u(t) + \left(\frac{1}{3} - \frac{1}{2}e^{-t} + \frac{1}{6}e^{-3t}\right)u(t)$$
$$= \left(\frac{1}{3} + \frac{1}{2}e^{-t} - \frac{5}{6}e^{-3t}\right)u(t)$$

(8) USING FOURIER TABLES

i.

$$3000 \sin c(3000\pi t) \Leftrightarrow \text{RECT}\left(\frac{\omega}{6000\pi}\right)$$



ii)

$$\text{NYQUIST RATE FOR } x(t): f_s = 2 \cdot \frac{3000\pi}{2\pi} = 3\text{kHz}$$

(9)

$$\frac{X(z)}{z} = \frac{z+1}{z^2-5z+4} = \frac{z+1}{(z-4)(z-1)} = \frac{A}{z-4} + \frac{B}{z-1}$$

$$= \frac{5}{3} \frac{1}{z-4} - \frac{2}{3} \frac{1}{z-1}$$

HENCE

$$X(z) = \frac{5}{3} \frac{z}{z-4} - \frac{2}{3} \frac{z}{z-1}$$

USING z-TRANSFORM TABLE WE GET

$$x[n] = \left( \frac{5}{3} 4^n - \frac{2}{3} \right) u[n]$$



## QUESTION 2

9

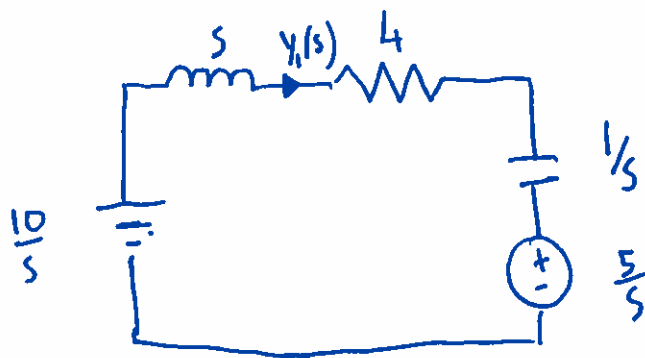
(a)

IN STEADY STATE THE INDUCTOR IS A SHORT CIRCUIT AND THE CAPACITOR IS AN OPEN CIRCUIT THEREFORE

$$y_1(0^-) = 0$$

$$V_C(0^-) = 5V$$

(b) THE EQUIVALENT CIRCUIT IN THE LAPLACE DOMAIN IS:



THUS THE LOOP EQUATION IN THE LAPLACE DOMAIN IS:

$$\frac{10}{s} = s Y_1(s) + 4 Y_1(s) + \frac{Y_1(s)}{s} + \frac{5}{s} ;$$

$$Y_1(s) (s^2 + 4s + 1) = 5 ;$$

$$Y_1(s) = \frac{5}{s^2 + 4s + 1}$$

$$(c) \quad Y_1(s) = \frac{5}{s^2 + 4s + 1} = \frac{5}{(s+2-\sqrt{3})(s+2+\sqrt{3})} = \frac{5}{2\sqrt{3}} \left( \frac{1}{s+2-\sqrt{3}} - \frac{1}{s+2+\sqrt{3}} \right)$$

USING THE FACT THAT

$$e^{-\lambda t} u(t) \Leftrightarrow \frac{1}{s+\lambda}$$

WE OBTAIN

$$y_1(t) = \frac{5}{2\sqrt{3}} \left( e^{-(2-\sqrt{3})t} - e^{-(2+\sqrt{3})t} \right) u(t)$$

### QUESTION 3

(a)

IF WE DENOTE WITH  $F(s)$  THE OUTPUT OF THE FEEDBACK SYSTEM WE HAVE THAT

$$Y(s) = (s+2) F(s)$$

$$F(s) = K (X(s) - (s+a)^2 F(s))$$

THEREFORE

$$F(s) = \frac{K}{1 + K(s+a)^2} X(s)$$

AND

$$Y(s) = \frac{K(s+2)}{1 + K(s+a)^2} X(s)$$

THE TRANSFER FUNCTION IS:

$$H(s) = \frac{Y(s)}{X(s)} = \frac{K(s+2)}{1 + K(s+a)^2}$$

(b)

USING FINAL VALUE THEOREM WE HAVE THAT

$$y(\infty) = \lim_{t \rightarrow \infty} y(t) = \lim_{s \rightarrow 0} s Y(s)$$

SINCE  $X(s) = \frac{1}{s}$  AND  $K=1$

WE HAVE THAT

$$y(\infty) = \lim_{s \rightarrow 0} \frac{s+2}{1+(s+a)^2} = \frac{2}{1+a^2}$$

WE WANT  $y(\infty) = \frac{2}{5}$  WITH  $a > 0 \Rightarrow a = 2$ .

(c) i.

$$Y(s) = \frac{s+2}{1+(s+1)^2} \cdot \frac{1}{s}$$

$$= \frac{C}{s} + \frac{As+B}{s^2+2s+2}$$

(d)

MULTIPLY BOTH SIDES BY  $s$  AND SET  $s=0$

$$1 = C$$

THEN MULTIPLY BOTH SIDES BY  $s$  AND LET  $s \rightarrow \infty$

$$0 = 1 + A \Rightarrow A = -1$$

FINALLY SET  $s = -1$  TO FIND

$$B = -1$$

WE HAVE

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

USING LAPLACE TABLES WE OBTAIN

$$y(t) = u(t) - e^{-t} \cos t \quad u(t)$$

(1.

FOR  $t \geq 0$

$$y(t) = 1 - e^{-t} \cos t$$

$$\frac{dy}{dt} = e^{-t} \cos t + e^{-t} \sin t = 0$$

$$\Rightarrow e^{-t} (\cos t + \sin t) = 0$$

$$\Rightarrow \cos t = -\sin t \quad \Rightarrow \tan t = -1$$

THIS HAPPENS AT  $t = \pi/4 + \pi/2$ .

THE OTHER POINT ARE EITHER LOCAL MINIMA OR LOCAL MAXIMA BECAUSE OF THE TERM  $e^{-t}$  IN THE EXPRESSION OF  $y(t)$ .