• write all steps in detail

• Do not left question Incomplete

MADE EASY

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ESE 2023 : Mains Test Series

UPSC ENGINEERING SERVICES EXAMINATION

Electrical Engineering

Test-2 : Systems and Signal Processing + Microprocessors + Electrical Circuits-1 + Control Systems-1

Name :

Roll No :

Test Centres | **Student's Signature**

Delhi ☑ Bhopal ☐ Jaipur ☐

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Instructions for Candidates

1. Do furnish the appropriate details in the answer sheet (viz. Name & Roll No).
2. There are Eight questions divided in TWO sections.
3. Candidate has to attempt FIVE questions in all in English only.
4. Question no. 1 and 5 are compulsory and out of the remaining THREE are to be attempted choosing at least ONE question from each section.
5. Use only black/blue pen.
6. The space limit for every part of the question is specified in this Question Cum Answer Booklet. Candidate should write the answer in the space provided.
7. Any page or portion of the page left blank in the Question Cum Answer Booklet must be clearly struck off.
8. Last two pages of this booklet are provided for rough work. Strike off these two pages after completion of the examination.

FOR OFFICE USE	
Question No.	Marks Obtained
Section-A	
Q.1	44
Q.2	20
Q.3	
Q.4	
Section-B	
Q.5	54
Q.6	48
Q.7	30
Q.8	
Total Marks Obtained	196

Signature of Evaluator .... Cross Checked by ....

• Draw diagram properly.

IMPORTANT INSTRUCTIONS

CANDIDATES SHOULD READ THE UNDERMENTIONED INSTRUCTIONS CAREFULLY. VIOLATION OF ANY OF THE INSTRUCTIONS MAY LEAD TO PENALTY.

DONT'S

1. Do not write your name or registration number anywhere inside this Question-cum-Answer Booklet (QCAB).
2. Do not write anything other than the actual answers to the questions anywhere inside your QCAB.
3. Do not tear off any leaves from your QCAB, if you find any page missing do not fail to notify the supervisor/invigilator.
4. Do not leave behind your QCAB on your table unattended, it should be handed over to the invigilator after conclusion of the exam.

DO'S

1. Read the Instructions on the cover page and strictly follow them.
2. Write your registration number and other particulars, in the space provided on the cover of QCAB.
3. Write legibly and neatly.
4. For rough notes or calculation, the last two blank pages of this booklet should be used. The rough notes should be crossed through afterwards.
5. If you wish to cancel any work, draw your pen through it or write "Cancelled" across it, otherwise it may be evaluated.
6. Handover your QCAB personally to the invigilator before leaving the examination hall.

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Section A : Systems and Signal Processing + Microprocessors

Q.1 (a) The input $x(n)$ and the impulse response $h(n)$ of a discrete-time LTI system are given by

$$x(n) = \alpha^n u(n), h(n) = \alpha^{-n}u(-n); 0 < \alpha < 1$$

Using z-transform, find the response $y(n)$.

[12 marks]

$x(n) = \alpha^n u(n)$ $0 < \alpha < 1$

$\Updownarrow$ Z-T

$X(z) = \dfrac{1}{1-\alpha z^{-1}}$, $|z| > |\alpha|$

write all steps

also $h(n) = \alpha^{-n} u(-n)$,

$= \left(\dfrac{1}{\alpha}\right)^n u(-n)$

$= \left(\dfrac{1}{\alpha}\right)^{n \cancel{-1+1}} u(-n-1+1)$ $= \left(\dfrac{1}{\alpha}\right)^{(n-1)} \cdot \left(\dfrac{1}{\alpha}\right) u(-(n-1)-1)$

$= \cancel{\left(\dfrac{1}{\alpha}\right)^{n-1+1}}$ $= \left(\dfrac{1}{\alpha}\right) \left(\dfrac{1}{\alpha}\right)^{n-1} u(-(n-1)-1)$

applying ZT

$h(n) \rightleftharpoons H(z) = \dfrac{1}{\alpha}\left[\dfrac{-1}{1-\left(\frac{1}{\alpha}\right)z^{-1}}\right] \cdot z^{-1}$ $|z| < \left|\dfrac{1}{\alpha}\right|$

using time shifting property

$h(n) \rightleftharpoons H(z)$

$h(n-n_0) \rightleftharpoons H(z) \cdot z^{-n_0}$

now $y(n) = x(n) * h(n)$

$\Big\Updownarrow ZT$

$Y(z) = X(z) \cdot H(z)$ $(ROC_1 \cap ROC_2)$

$\therefore Y(z) = \left(\frac{1}{1-\alpha z^{-1}}\right) \cdot \left(\frac{-1}{\alpha}\right) \frac{z^{-1}}{1-\frac{1}{\alpha}z^{-1}}$; $|\alpha| < |z| < \frac{1}{|\alpha|}$

$\frac{Y(z)}{z^{-1}} = \left(-\frac{1}{\alpha}\right) \frac{1}{(1-\alpha z^{-1})(1-\frac{1}{\alpha}z^{-1})}$

$= \left(\frac{-1}{\alpha}\right) \left[\frac{\left(\frac{1}{1-\frac{1}{\alpha}2}\right)}{1-\alpha z^{-1}} + \frac{\left(\frac{1}{1-\alpha 2}\right)}{1-\frac{1}{\alpha}z^{-1}} \right]$

$= \left(\frac{-1}{\alpha}\right) \left[\frac{\left(\frac{\alpha^2}{\alpha^2-1}\right)}{1-\alpha z^{-1}} + \left(\frac{\left(\frac{1}{1-\alpha 2}\right)}{1-\frac{1}{\alpha}z^{-1}}\right) \right]$

8

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$= \frac{-1}{\alpha(1-\alpha^2)} \left[\frac{-\alpha^2}{1-\alpha z^{-1}} + \frac{1}{1-\frac{1}{\alpha}z^{-1}} \right]$

$Y(z) = \frac{1}{\alpha(1-\alpha^2)} \left[\alpha^2 \frac{z^{-1}}{1-\alpha z^{-1}} + \frac{z^{-1}}{1-\frac{1}{\alpha}z^{-1}} \right]$; $|\alpha| < z < \frac{1}{|\alpha|}$

$\Big\Updownarrow$ Inverse $Z-T$

$y(n) = \frac{1}{\alpha(1-\alpha^2)} \left[\alpha^2 \alpha^{n-1} u(n-1) - \left(\frac{1}{\alpha}\right)^{n-1} u(-(n-1)-1) \right]$

$= \frac{1}{\alpha(1-\alpha^2)} \left[\alpha^{n+1} u(n-1) - \alpha^{1-n} u(-n) \right]$

$y(n) = \frac{1}{1-\alpha^2}\left[\alpha^n u(n) + \alpha^{-n} u(-n-1)\right]$

$\therefore y(n) = \frac{1}{\alpha(1-\alpha^2)} \left[\alpha^{n+1} u(n-1) - \alpha^{1-n} u(-n) \right]$

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Q.1 (b) For an 8085 microprocessor, explain the followings :

(i) Logical operations

(ii) Branching operations

[8 + 4 = 12 marks]

(i) Logical operations — These are operations which are based on some digital logic like AND, OR, XOR

8085 supports only 3 logical operations AND, OR, XOR.

These can be used wrt various operands like
AND R , AND m , ANI 8 bit data . . .
similarly for OR & XOR

AND — AND operation performs bit wise AND of the specified operand & accumulator [A]

AND B => [A] AND [B]

let's take A = 11 H , B = 23 H

then AND B will result in

[A] ⟵ [A] AND [B]

0001 0001 AND 0010 0011

0 0 0 0 0 0 0 1

∴ [A] ⟶ 01 H

6

These are based on Boolean logic.

(ii) Branching operations – these are operations which when executed takes the execution to a different memory location

Some branching operations of 8085 are

CALL 16 bit address

JMP 16 bit address

These can be conditional, which got executed when certain flag is set or reset

or it can be unconditional which executed irrespective of flag value.

CALL 8000H

when this is executed, the sequence of execution is shifted to m/m address location 8000 H

while the previous value of ~~stack poi~~ program counter [PC] is stored in stack such that after RET (return) it can go to the previous location.

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Q.1 (c) Find the inverse laplace transform of the following :

(i) $X(s) = \dfrac{s^2 + 6s + 7}{s^2 + 3s + 2}$; $\mathrm{Re}\{s\} > -1$

(ii) $X(s) = \dfrac{5s + 13}{s(s^2 + 4s + 13)}$; $\mathrm{Re}\{s\} > 0$

[6 + 6 marks]

i) $\dfrac{s^2 + 6s + 7}{s^2 + 3s + 2}$ $\sigma > -1$

Here N^r degree $= D^r$ degree

$\therefore$ we first divide the polynomial

$$\begin{array}{r|l} s^2 + 3s + 2 \,\big) & s^2 + 6s + 7 \,\big(1 \\ & s^2 + 3s + 2 \\ & - \quad - \quad - \\ \hline & 3s + 5 \end{array}$$

$\Rightarrow \dfrac{s^2 + 6s + 7}{s^2 + 3s + 2} = 1 + \dfrac{3s + 5}{(s+1)(s+2)}$

as $\sigma > -1 \Rightarrow \sigma > -2$

$\Rightarrow$ right sided signal

$\therefore X(s) = 1 + \dfrac{2}{s+1} + \dfrac{1}{s+2}$

applying inverse LT

$x(t) = \delta(t) + 2e^{-t}u(t) + e^{-2t}u(t)$

(ii) $\dfrac{5s+13}{s(s^2+4s+13)}$ $\sigma > 0$

using partial fraction we can write as

$$\frac{5s+13}{s(s^2+4s+13)} = \frac{A}{s} + \frac{Bs+C}{s^2+4s+13}$$

residue at $s=0$ gives $A = 1$

$\therefore\ s^2+4s+13 + Bs^2 + Cs = 5s+13$

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

$4+C = 5 \Rightarrow C = 1$

$$\therefore\ X(s) = \frac{1}{s} + \frac{-s+1}{s^2+4s+13}$$

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

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

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

Good Approach

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Taking inverse laplace Transfor

$$x(t) = u(t) - e^{-2t}\cos 3t\ u(t) + e^{-2t}\sin 3t\ u(t)$$

$$= \left(1 - e^{-2t}\cos 3t + e^{-2t}\sin 3t\right) u(t)$$

Q.1.(d) Explain the flag register of 8086 microprocessor.

[12 marks]

In 8086 μP, there are 9 flags

they are

S — sign flag = $\begin{cases} 0 & \text{+ve data} \\ 1 & \text{-ve data} \end{cases}$

Z — zero flag = $\begin{cases} 0 & \text{non-zero data} \\ 1 & \text{zero data} \end{cases}$

P — parity flag = $\begin{cases} 0 & \text{odd no of 1's} \\ 1 & \text{even no of 1's} \end{cases}$

CY — carry flag = $\begin{cases} 0 & \text{if no carry} \\ 1 & \text{if carry generated} \end{cases}$

6

AC — auxiliary carry = $\begin{cases} 0 & \text{if no auxiliary carry} \\ 1 & \text{if auxiliary carry present} \end{cases}$

V — overflow = $\begin{cases} 0 & \text{if no overflow} \\ 1 & \text{if overflow occurs} \end{cases}$

and there are 3 more flags which are

Interrupt,

Incomplete solution

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Q.1 (e) Consider the following discrete time system :

(i) $y(n) = |x(n)|$

(ii) $y(n) = \mathrm{sgn}[x(n)]$

Check whether these systems are static or dynamic, linear or non-linear, time varying or time-invariant, causal or non-causal and stable or unstable.

[6 + 6 marks]

(i) $y(n) = |x(n)| = \begin{cases} x(n) & x(n) \geq 0 \\ -x(n) & x(n) < 0 \end{cases}$

as present value of o/p depends only on present value of i/p $\Rightarrow$ Static system

o/p doesnot depend on future i/p

$\Rightarrow$ Causal system

for every bounded i/p $x(n)$; $|x(n)|$ & hence $y(n)$ is bounded $\Rightarrow$ stable system

$x(n) \longrightarrow y(n) \xrightarrow{\text{delay}} y(n-n_0) = |x(n-n_0)|$

$x(n) \xrightarrow{\text{delay}} x(n-n_0) \longrightarrow y(n) = |x(n-n_0)|$

as the delay in i/p is reflected in o/p

$\Rightarrow$ time invariant system

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$x_1(n) \longrightarrow y_1(n) = |x_1(n)|$

$x_2(n) \longrightarrow y_2(n) = |x_2(n)|$

$x_1(n) + x_2(n) \longrightarrow y(n) = |x_1(n) + x_2(n)|$

$\neq |x_1(n)| + |x_2(n)|$

$\Rightarrow$ non-linear system

Do not write in this margin

(ii) $y(n) = sgn\left(x(n)\right) = \begin{cases} 1 & x(n) > 0 \\ 0 & x(n) = 0 \\ -1 & x(n) < 0 \end{cases}$

as present value of o/p depends only on present value of i/p

$\Rightarrow$ static system

o/p is independent of future i/p

$\Rightarrow$ causal system

~~for $x(n) = 10$ (bounded~~

for $x(n) > 0$ (any bounded $x(n)$)

$y(n) = 1$ is unbounded

$\Rightarrow$ unstable system

system is stable

4

$x_1(n) \longrightarrow y_1(n) = sgn\left(x_1(n)\right)$

$x_2(n) \longrightarrow y_2(n) = sgn\left(x_2(n)\right)$

$x_1 + x_2 \longrightarrow y(n) = sgn\left[x_1(n) + x_2(n)\right]$

$\neq sgn\left(x_1(n)\right) + sgn\left(x_2(n)\right)$

$\Rightarrow$ non - linear system

as $y(n)$ can take only 3 discrete value

$\Rightarrow$ delay in input will not reflect in o/p

$\Rightarrow$ time variant system

Q.2 (a) Derive the DFT of the sample data sequence $x(n) = \{1, 1, 2, 2, 3, 3, 0, 0\}$.

[20 marks]

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Q.2 (b) Write an assembly language program in 8085 to find 1's and 2's complement of 16-bit number. Assume that the number is stored at 2040 H and store the result at 2050 H and 2052 H respectively. Also give the algorithm of the program.

[20 marks]

To find 1's complement of a 16bitnumber, we can subtract the number from FFFF H

To find 2's complement of a 16 bit number, we can add 0001 H to it's 1's complement

Q 3

LXI H, 2040 H

MOV C, M

INX H

MOV B, M

MVI A, FF H

Incomplete Solution

Q.2 (c) (i) A causal and stable LTI system S has the frequency response :

$$H(\omega) = \frac{4 + j\omega}{6 - \omega^2 + 5j\omega}$$

(a) Determine a differential equation relating the input $x(t)$ and output $y(t)$ of S.

(b) Determine the impulse response $h(t)$ of S.

(c) What is the output of S when the input is $x(t) = e^{-4t}u(t) - te^{-4t}u(t)$.

(ii) Compute the linear convolution of the following sequence to obtain $y(n)$

$$x(n) = \{1, \underset{\uparrow}{3}, 0, 4, -2\}$$

$$h(n) = \{2, 4, \underset{\uparrow}{-1}, -3\}$$

[15 + 5 marks]

(i)

(a) $H(\omega) = \dfrac{4+j\omega}{6-\omega^2+5j\omega} = \dfrac{4+j\omega}{(j\omega)^2 + 5j\omega + 6}$

$$\frac{Y(\omega)}{X(\omega)} = \frac{4+j\omega}{(j\omega)^2 + 5j\omega + 6}$$

$\Rightarrow (j\omega)^2 Y(\omega) + 5j\omega Y(\omega) + 6Y(\omega) = j\omega X(\omega) + 4X(\omega)$

applying inverse Fourier Transform

$$\frac{d^2y}{dt^2} + 5\frac{dy}{dt} + 6y = \frac{dx}{dt} + 4x$$

$$\frac{d^2y(t)}{dt^2} + 5\frac{dy(t)}{dt} + 6y(t) = \frac{dx(t)}{dt} + 4x(t)$$

(b) applying LT

$$\frac{Y(s)}{X(s)} = \frac{s+4}{s^2+5s+6} = \frac{s+4}{(s+2)(s+3)}$$

$$= \frac{2}{S+2} - \frac{1}{S+3}$$

$$\therefore \quad h(t) = \left(2e^{-2t} - e^{-3t}\right) u(t)$$ (By inverse Laplace)

~~(c) $e^{-4t} u(t)$ &~~

(c) $$x(t) = e^{-4t} u(t) - te^{-4t} u(t)$$

$$\Rightarrow X(s) = \frac{1}{s+4} - \frac{1}{(s+4)^2}$$ (using laplace)

$$= \frac{s+3}{(s+4)^2}$$

$$\therefore Y(s) = \frac{(s+3)}{(s+4)^2} \cdot \frac{(s+4)}{(s+2)(s+3)}$$

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

$$= \frac{1/2}{S+2} - \frac{1/2}{S+4}$$

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using inverse laplace

$$y(t) = \left(\frac{1}{2}e^{-2t} - \frac{1}{2}e^{-4t}\right) u(t)$$

Write all steps

(ii) $x(n) = (1 \quad \underset{\uparrow}{3} \quad 0 \quad 4 \quad -2)$

$h(n) = (2 \quad 4 \quad \underset{\uparrow}{-1} \quad -3)$

to obtain $y(n)$, using table method

	1	3	0	4	-2
2	2	6	0	8	-4
4	4	12	0	16	-8
-1	-1	-3	0	-4	2
-3	-3	-9	0	-12	6

$\therefore y(n) = \{2 \quad 10 \quad 11 \quad 2 \quad 3 \quad -12 \quad -10 \quad 6\}$

4

$x(n)$ starts at $l_1 = 1$

$h(n)$ starts at $l_2 = 2$

$\therefore y(n)$ starts at $l = l_1 + l_2 = 1 + 2 = 3$

$\therefore y(n) = \{2 \quad 10 \quad 11 \quad \underset{\uparrow}{2} \quad 3 \quad -12 \quad -10 \quad 6\}$

Q.3 (a) **(i)** Explain the status pins ($\bar{S}_2, \bar{S}_1$ and $\bar{S}_0$) and queue status pins (Q_{S1} and Q_{S0}) of 8086 with their function.

(ii) Discuss the pointers and index group of registers of 8086.

[10 + 10 marks]

Q.3 (b) Design an ideal band reject filter with a desired frequency response

$$H_d(e^{j\omega}) = \begin{cases} 1, & |\omega| < \dfrac{\pi}{3} \text{ and } |\omega| \geq \dfrac{2\pi}{3} \\ 0, & \text{otherwise} \end{cases}$$

Find the impulse response $h(n)$ and transfer function H(z) of the filter for length $M = 11$.

[20 marks]

Q.3 (c) Ten 8-bit numbers are stored starting from memory location 3000H. Write an 8085 assembly language program, by giving suitable flow chart to find the greatest of the ten numbers and store it at memory location 4000H.

[20 marks]

Q.4 (a) **(i)** The input to a linear shift-invariant system is $x(n) = 2\cos\left(\frac{n\pi}{4}\right) + 3\sin\left(\frac{3n\pi}{4} + \frac{\pi}{8}\right)$.

Find the output if the unit sample response of the system is $h(n) = \dfrac{2\sin(n-1)\frac{\pi}{2}}{(n-1)\pi}$.

(ii) Consider a system described by the difference equation

$$y(n) = y(n-1) - y(n-2) + 0.5x(n) + 0.5x(n-1).$$

Find the response of this system to the input $x(n) = (0.5)^n u(n)$, with initial conditions $y(-1) = 0.75$ and $y(-2) = 0.25$

[10 + 10 marks]

Q.4 (b) For $x(n) = \{1, 2, 3, 4, 4, 3, 2, 1\}$. Compute the DFT, $X(k)$ using DIF FFT algorithm.

[20 marks]

Q.4 (c) **(i)** Draw the lattice filter implementation of FIR filter $H(z) = 8 + 4z^{-1} + 2z^{-2} + z^{-3}$.

(ii) It is required to move a 16-byte long data string from offset 4000H to offset 5000H. Write an assembly language program to accomplish the above task for 8085 microprocessor.

[12 + 8 marks]

Section B : Electrical Circuits - 1 + Control Systems - 1

Q.5 (a) The open-loop transfer function of a unity feedback system is

$$G(s) = \frac{K(s+1)}{s(s-1)(s^2+4s+20)}$$

Find the range of K for which the system is stable. Also show that the system response can oscillate at two different frequencies.

[12 marks]

$$GH(s) = \frac{K(s+1)}{s(s-1)(s^2+4s+20)}$$

$$\Rightarrow q(s) = s(s-1)(s^2+4s+20) + K(s+1)$$

$$= s(s^3+4s^2+20s-s^2-4s-20) + K(s+1)$$

$$= s(s^3+3s^2+16s-20) + K(s+1)$$

$$= s^4 + 3s^3 + 16s^2 + (-20+K)s + K$$

Constructing RH table

s^4	1	16	K
s^3	3	K-20	
s^2	$\frac{48-K+20}{3} = \left(\frac{68-K}{3}\right)$	K	
s^1	$\frac{\left(\frac{68-K}{3}\right)(K-20) - 3K}{\left(\frac{68-K}{3}\right)}$		
s^0	K		

from necessary conditions

$-20+K > 0$ & $K > 0$

$\Rightarrow K > 20$

also for system to be stable, coefficient of 1st column of RH table should be +ve (no sign change)

$\therefore \frac{68-K}{3} > 0 \Rightarrow K < 68$

$\left(\frac{68-K}{3}\right)(K-20) - 3K > 0$

or $(68-K)(K-20) - 9K > 0$

$68K - 1360 - K^2 + 20K - 9K > 0$

$-K^2 + 79K - 1360 > 0$

$K^2 - 79K + 1360 < 0$

$K^2 - 79K + 1360 < 0$

$(K-53.65)(K-25.35) < 0$

$\Rightarrow 25.35 < K < 53.65$

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Good Approach

Hence range of K is $\boxed{25.35 < K < 53.65}$

for oscillatory response

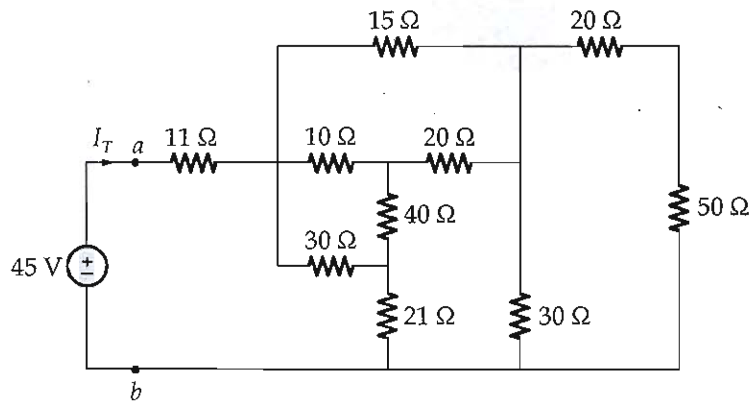
s^1 - row coefficient $= 0 \Rightarrow K = 25.35$ or $K = 56.65$

putting these values in s^2 - row

for $K = 25.35$ $\quad 14.2s^2 + 25.35 = 0 \Rightarrow \boxed{\omega = 1.3 \text{ rad/s}}$

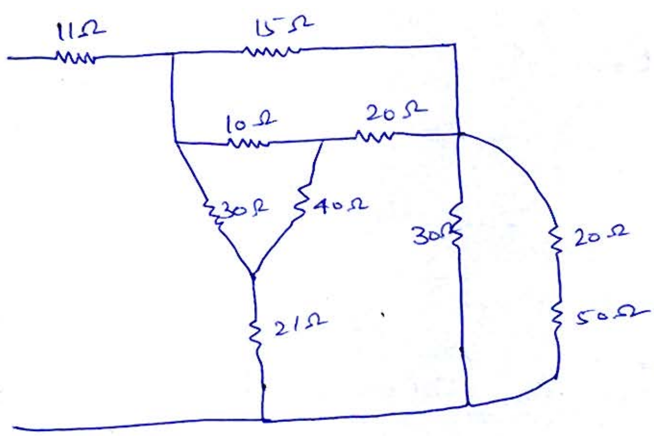
for $K = 53.65$ $\quad 4.78s^2 + 53.65 = 0 \Rightarrow \boxed{\omega = 3.3 \text{ rad/s}}$

Q.5 (b) For the circuit shown in figure below, obtain the equivalent resistance at terminals $a - b$. Also find total current I_T as indicated below.



[12 marks]

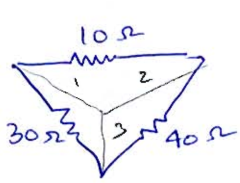
for calculating R_{ab}, circuit can be redrawn as



$$30\Omega \,||\, (20+50)\,\Omega$$

$$= 21\,\Omega$$

2D



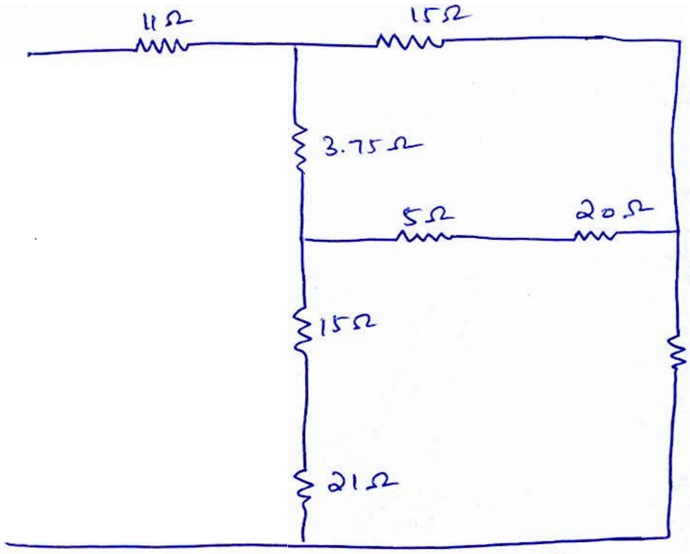
converting Δ connection to Y

$Y_1 = 3.75\,\Omega$

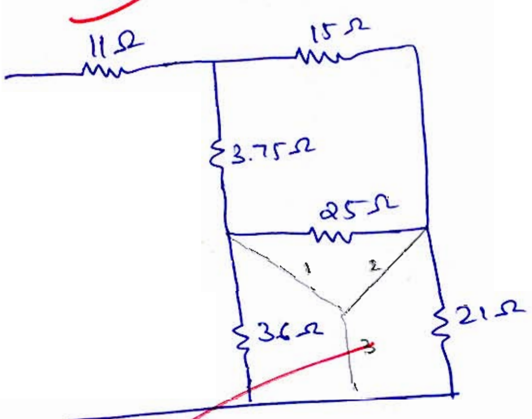
$Y_2 = 5\,\Omega$

$Y_3 = 15\,\Omega$

∴



⇓
on simplification



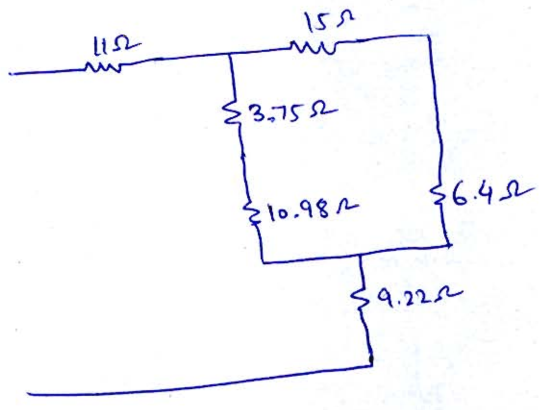
converting Δ to Y, $Y_3 = \dfrac{\Delta_1 \Delta_2}{\Delta_1 + \Delta_2 + \Delta_3}$

∴ $Y_1 = 10.98\,\Omega$

$Y_2 = 6.4\,\Omega$

$Y_3 = 9.22\,\Omega$

$\therefore$



$(3.75 + 10.98) \,//\, (15 + 6.4)$

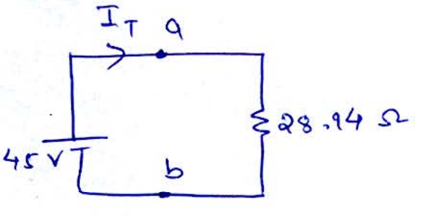
$= 14.73 \,//\, 21.4$

$= 8.72\ \Omega$

$\therefore \quad Z_{eq} = (11 + 8.72 + 9.22)\ \Omega = 28.94\ \Omega$

$\therefore \quad \boxed{R_{ab} = 28.94\ \Omega}$

$\therefore$ circuit can be redrawn as



Hence using Ohm's law

$V = iR$

$I_T = \frac{45}{28.94}$

$\boxed{I_T = 1.55\ A}$

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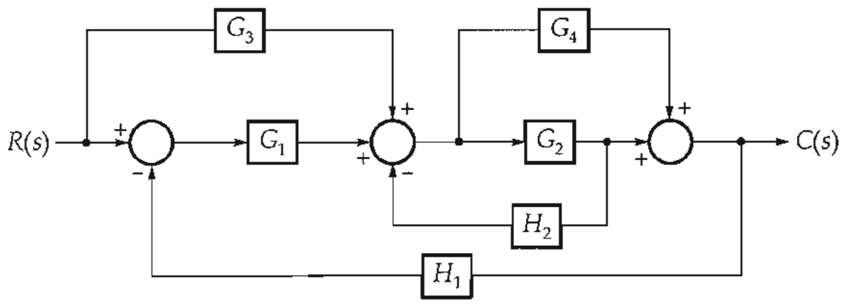
Q.5 (c) Determine the transfer function $\frac{C(s)}{R(s)}$ for a system represented by the block diagram shown below :



[12 marks]

Forward paths

$P_1 = G_1 G_2$ $\Delta_1 = 1$

$P_2 = G_1 G_4$ $\Delta_2 = 1$

$P_3 = G_3 G_2$ $\Delta_3 = 1$

$P_4 = G_3 G_4$ $\Delta_4 = 1$

loops

$L_1 = -G_2 H_2$

$L_2 = -G_1 G_2 H_1$

$\cancel{L_3 = -G_3 G_2 H_1}$ $L_3 = -G_1 G_4 H_1$

$\cancel{L_4 = G_3 G}$

no possibility of ~~two or~~ two or more non-touching loops

$\therefore$ $TF = \dfrac{P_1\Delta_1 + P_2\Delta_2 + P_3\Delta_3 + P_4\Delta_4}{\Delta}$

using mason's formula

$$\therefore \quad TF = \frac{C(s)}{R(s)}$$

$$= \frac{G_1G_2 + G_1G_4 + G_3G_2 + G_3G_4}{1 + G_2H_2 + G_1G_2H_1 + G_1G_4H_1}$$

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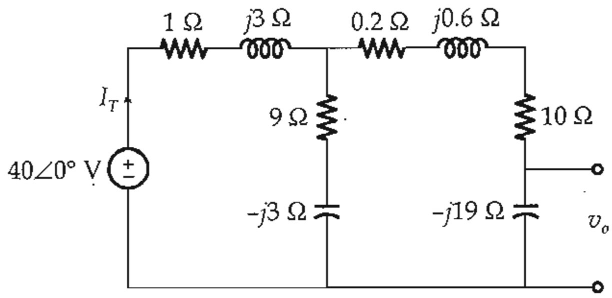
Good Approach

Q.5 (d) Use the concept of source transformation to find the phasor voltage v_o in the circuit shown below. Also, calculate the total current I_T of the circuit.

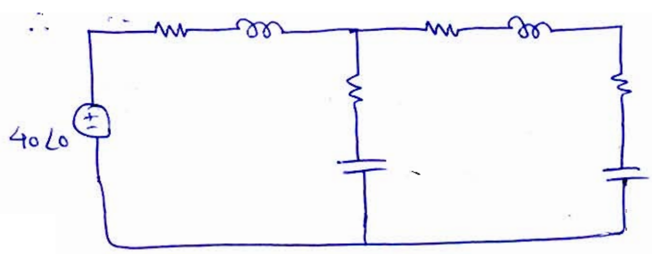


[12 marks]

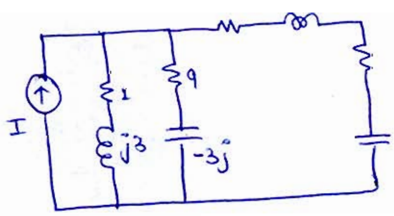
using source transformation

$$\tilde{V}, Z \longleftrightarrow \tilde{I}, Z \qquad \text{where } \tilde{I} = \frac{\tilde{V}}{Z}$$

∴

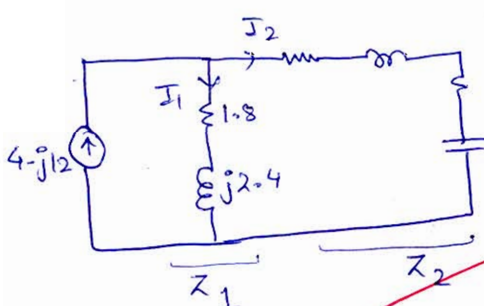


$\Rightarrow$



$$I = \frac{40\angle 0}{1+j3} = 4-j12$$

Now $(1+j3) \,//\, (9-j3) = 1.8+j2.4$



$$Z_1 = (1.8 + j2.4)\ \Omega$$

$$Z_2 = (10.2 - j18.4)\ \Omega$$

Now using current division rule

$$I_2 = I \cdot \frac{Z_1}{Z_1+Z_2} = \frac{(4-j12)(1.8+j2.4)}{1.8+j2.4+10.2-j18.4}$$

$$= (1.56 + j1.08)\ A$$

Do not write in this margin

$\therefore \quad V_0 = I_2(-j19)$

$= (1.56 + j1.08)(-j19)$

$= 20.52 - j29.64$

$= (36.05 \angle -55.3^\circ)$ V

Now to obtain I_T

$Z_{eq} = (10.2 - j18.4) // (9 - 3j) + (1 + j3)$

$= 6.96 \angle -5.03^\circ \ \Omega$

$\therefore \quad I_T = \frac{V}{Z_{eq}} = \frac{40 \angle 0}{6.96 \angle -5.03}$

$= 5.75 \angle 5.03^\circ$ A

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$\therefore \quad V_0 = 36.05 \angle -55.3$ V

$I_T = 5.75 \angle 5.03$ A

Good Approach

Do not write in this margin

Q.5 (e) A second-order servo-mechanism with unity feedback, has the open-loop transfer function $G(s) = \dfrac{K}{s(s+4)}$. Find the gain k so that the steady-state error shall not exceed 0.4 degree when the input shaft is rotated at 3 rpm. (Assume input $r(t) = \omega t$)

[12 marks]

$G = \dfrac{K}{s(s+4)}$

The system is Type 1 system $\Rightarrow$ only velocity error is finite

we know $e_{ss} = \dfrac{1}{K_v} \cdot (i/p)$, $K_v = \lim_{s\to 0} s\,GH(s)$

$\therefore K_v = \lim_{s\to 0} s \cdot \dfrac{K}{s(s+4)} = \dfrac{K}{4}$

Now i/p is 3rpm $\Rightarrow \left(3 \times \dfrac{2\pi}{60}\right)$ rad/sec

$= \dfrac{\pi}{10}$ rad/sec

error $= 0.4^\circ = \dfrac{\pi}{450}$ rad

$\therefore e_{ss} < 0.4^\circ$

$\dfrac{\pi}{10} \times \dfrac{1}{K/4} < \dfrac{\pi}{450}$

$\dfrac{4\pi}{10K} < \dfrac{\pi}{450}$

$K > 180$

$\therefore \boxed{K > 180}$ $\boxed{K_{min} = 180}$

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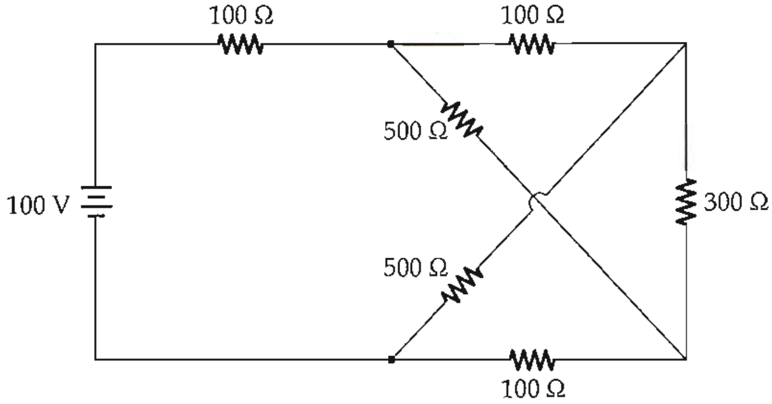
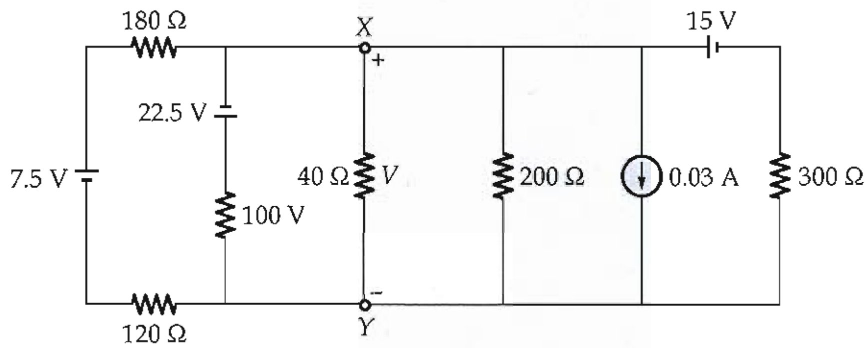
Good Approach

Q.6 (a) (i) Determine the current supplied by the battery in the circuit shown below by using Mesh Analysis only.

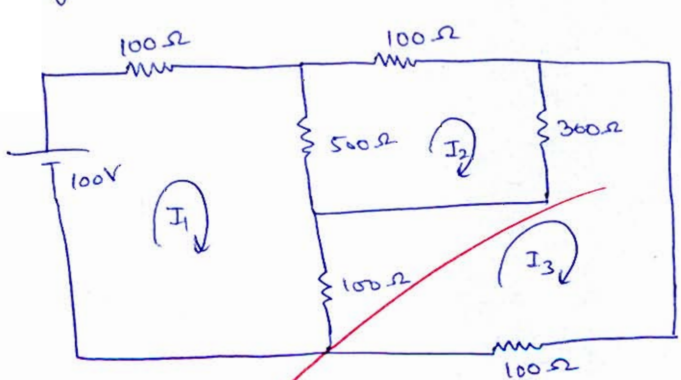


(ii) By constructing Millman equivalent voltage source with respect to terminals x-y, find the voltage across 40 Ω resistor.



[10 + 10 marks]

(i) Redrawing the circuit we get



using mesh analysis

(1) $-100 + 100 I_1 + 500(I_1 - I_2) + 100(I_1 - I_3) = 0$

$700 I_1 - 500 I_2 - 100 I_3 = 100$

$7 I_1 - 5 I_2 - I_3 = 1$ ——— (1)

(2) $500(I_2 - I_1) + 100 I_2 + 300(I_2 - I_3) = 0$

$-500 I_1 + 900 I_2 - 300 I_3 = 0$

$-5 I_1 + 9 I_2 - 3 I_3 = 0$ — (ii)

(3) $100 I_3 + 100 (I_3 - I_1) + 300 (I_3 - I_2) = 0$

$-100 I_1 - 300 I_2 + 500 I_3 = 0$

$-I_1 - 2 I_2 + 5 I_3 = 0$ — (iii)

writing in matrix form

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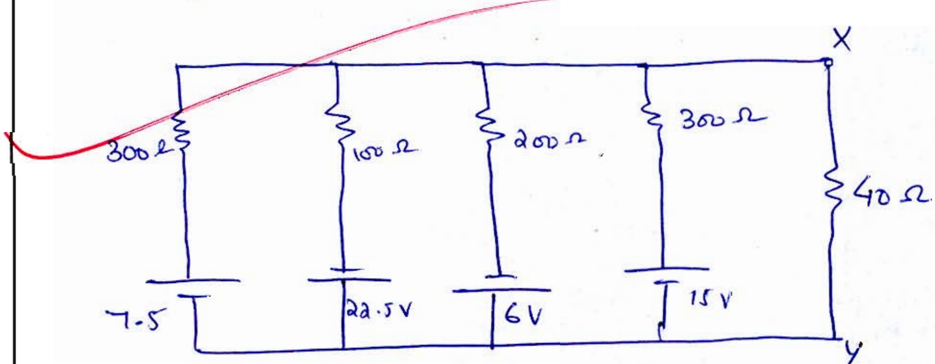
$$\begin{bmatrix} 7 & -5 & -1 \\ -5 & 9 & -3 \\ -1 & -2 & 5 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix} = \begin{bmatrix} 1 \\ 0 \\ 0 \end{bmatrix}$$

$\Rightarrow \boxed{I_1 = 0.34 A}$ 0.3A

(ii) converting current source to voltage source

$0.03A, 200\Omega \Rightarrow V = iR = 6V, 200\Omega$

redrawing the circuit



As per Millman's theorem

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4} = \frac{13}{600}$$

$$R_{eq} = 46.15\,\Omega$$

and
$$E = \frac{\frac{E_1}{R_1} + \frac{E_2}{R_2} + \frac{E_3}{R_3} + \frac{E_4}{R_4}}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4}}$$

$$= \frac{\frac{7.5}{300} - \frac{22.5}{100} - \frac{6}{200} + \frac{15}{300}}{\frac{13}{600}}$$

$$= -8.31\text{ V}$$

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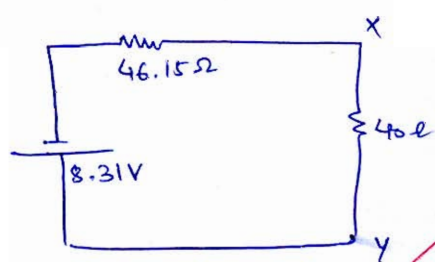
∴ equivalent circuit

Good Approach



$$\therefore V_{40\Omega} = 8.31 \times \frac{40}{40 + 46.15}$$ using voltage division

$$\therefore V_{40\Omega} = 3.85\text{ V}$$

$$\therefore V_{40\,YX} = 3.85\text{ V}$$

$$\boxed{V_{40\,XY} = -3.85\text{ V}}$$

Q.6 (b) The open-loop transfer function of a system is $G(s) = \dfrac{K(s+4)}{(s+10)^2}$. What must be the value of K that the gain cross-over frequency is $\omega_{gc} = 30$ rad/s. Also find gain margin and phase margin for that value of K. Also comment on stability of system.

[20 marks]

given $\omega_{gc} = 30$ rad/s

$\Rightarrow |G|_{\omega_{gc}} = 1$

$\Rightarrow \left| \dfrac{K(30j+4)}{(30j+10)^2} \right| = 1$

$\left| \dfrac{K\sqrt{30^2+4^2}}{30^2+10^2} \right| = 1$

$\Rightarrow \boxed{K = 33}$

$\phi_G = \angle G(\omega) = \tan^{-1}\dfrac{\omega}{4} - 2\tan^{-1}\dfrac{\omega}{10}$

for GM, $\angle G_{\omega pc} = -180$

$\therefore \tan^{-1}\dfrac{\omega}{4} - 2\tan^{-1}\dfrac{\omega}{10} = -180$

$\tan^{-1}\dfrac{\omega}{4} - \tan^{-1}\dfrac{\frac{2\omega}{10}}{1-\frac{\omega^2}{100}} = -180$

$\dfrac{\omega}{4} - \dfrac{\omega/5}{1-\omega^2/100} = 0$

$\omega\left(1-\dfrac{\omega^2}{100}\right) - \dfrac{4\omega}{5} = 0$

$1 - \dfrac{\omega^2}{100} - \dfrac{4}{5} = 0$

$\omega = 2\sqrt{5}$

$\boxed{\omega_{pc} = 2\sqrt{5} \text{ rad/s}}$

$$|G|_{\omega_{pc}} = \left| \frac{K(2\sqrt{5}j+4)}{(2\sqrt{5}j+10)^2} \right| = 1.65$$

$$\therefore \quad GM = -20\log 1.65 = -4.35 \text{ dB}$$

for PM

$$\angle G \Big|_{\omega_{gc}} = \angle \frac{K(30j+4)}{(30j+10)^2}$$

$$= -60.72^\circ$$

$$\therefore \quad PM = 180 + \phi$$

$$= 180 - 60.72^\circ$$

$$= 119.27^\circ$$

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$\therefore \quad K = 33$

$\omega_{gc} = 30$ rad/sec

$\omega_{pc} = 2\sqrt{5}$ ~~rad/s~~

$GM = -4.35$ ~~dB~~

$PM = 119.27^\circ$

as $GM < 0$ & $PM > 0$

$\Rightarrow$ system is unstable

ω_{pc} is Undefined, hence GM is also undefined. The system is said to be stable based on positive phase margin

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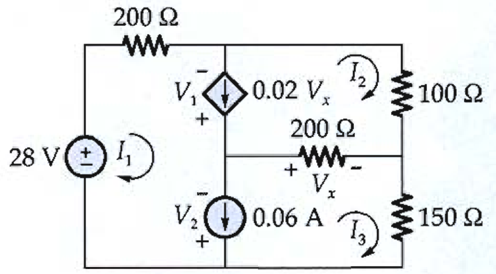
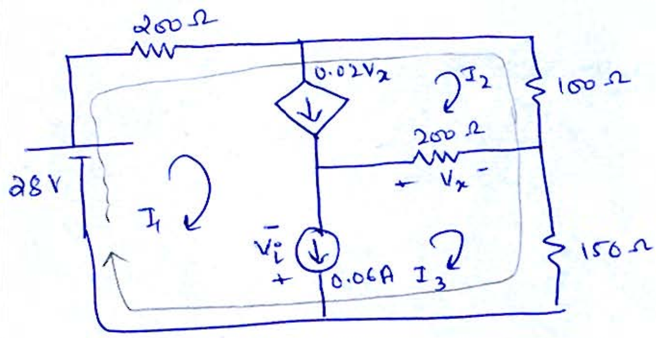
Q.6 (c) Find the values for the loop currents I_1, I_2, I_3 and the power delivered by each independent source.



[20 marks]



$V_x = (I_3 - I_2)\,200$, we'll use this in other eqn where ever required

loop ①

$-28 + 200I_1 + 100 I_2 + 150 I_3 = 0$ — (I)

as the loops form super mesh, we considered only the bigger outer loop

Now $I_1 - I_2 = 0.02V_x = 0.02 \times 200\,(I_3 - I_2)$

$I_1 - I_2 = 4I_3 - 4I_2$

$I_1 + 3I_2 - 4I_3 = 0$ —— (II)

& $I_1 - I_3 = 0.06$ — (III)

solving eq^n (ii), (iii) & (iv), we get

$$\boxed{\begin{aligned} I_1 &= 0.1\ A \\ I_2 &= 0.02\ A \\ I_3 &= 0.04\ A \end{aligned}}$$

Now for power delivered by sources

in loop (3) $(I_3 - I_2)200 + I_3 \cdot 150 + V_i = 0$

$\therefore \quad V_i = -10$

$\therefore$ for current source

$P_{delivered} = (-10)(0.06) = -0.6\ W$

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for voltage source

$P_{delivered} = 28 \times 0.1 = 2.8\ W$

Good Approach

$\therefore$ $P_{delivered}$ by $28V = 2.8W$

$P_{delivered}$ by $0.06A = -0.6W$ (0.6W absorbed)

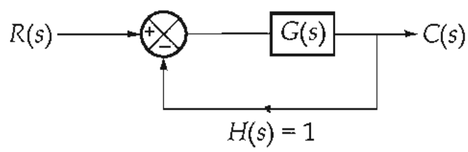
Q.7 (a) (i) The response of a feedback system to a unit step input is

$$C(t) = 1 + 0.2e^{-60t} - 1.2e^{-10t}.$$

(a) Obtain the expression for the closed loop transfer function.

(b) Determine the undamped natural frequency and damping ratio of the system.

(ii) Consider the unity feedback system whose open loop transfer function $G(s)H(s) = \dfrac{4}{s(s+5)}$. When this system is excited by a unit step input then calculate the output response and comment on the peak overshoot of the system.



[10 + 10 marks]

(i)

$$c(t) = 1 + 0.2\,e^{-60t} - 1.2\,e^{-10t}$$

$$r(t) = u(t)$$

$$\Rightarrow C(s) = \frac{1}{s} + \frac{0.2}{s+60} - \frac{1.2}{s+10}$$

$$R(s) = \frac{1}{s}$$

(a)

$$\frac{C(s)}{R(s)} = \frac{\left(\frac{1}{s} + \frac{0.2}{s+60} - \frac{1.2}{s+10}\right)}{\frac{1}{s}}$$

$$= \frac{(s+60)(s+10) + 0.2\,s(s+10) - 1.2\,s(s+60)}{(s+10)(s+60)}$$

$$= \frac{s^2 + 70s + 600 + 0.2s^2 + 2s - 1.2s^2 - 72s}{s^2 + 70s + 600}$$

$$= \frac{600}{s^2 + 70s + 600}$$

(b) compairing the denomination with standard 2^{nd} order TF

$$s^2 + 2\zeta\omega_n s + \omega_n^2 = s^2 + 70s + 600$$

$\therefore$ $\omega_n^2 = 600$

$2\zeta\omega_n = 70$

$\omega_n = 10\sqrt{6} = 24.5$ rad/s

$\zeta = \frac{70}{2\omega_n} = 1.43$

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Good Approach

$\therefore$ it is overdamped system with $\zeta = 1.43$, $\omega_n = 24.5$ rad/s

(ii) closed loop TF $= \frac{G(s)}{1 + GH(s)}$

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

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

$$\frac{C(s)}{R(s)} = \frac{4}{s^2 + 5s + 4}$$

given $R(s) = \frac{1}{s}$ [unit step i/p]

$\therefore$ $C(s) = \frac{4}{(s^2+5s+4)} \cdot \frac{1}{s}$

$$C(s) = \frac{4}{s(s+4)(s+1)}$$

$$= \frac{1}{s} \quad \frac{-4/3}{s+1} \quad + \frac{1/3}{s+4}$$

taking inverse LT

$$c(t) = \left(1 - \frac{4}{3}e^{-t} + \frac{1}{3}e^{-4t}\right) u(t)$$

$q(s)$ of system $= s^2 + 5s + 4$

$\Rightarrow \quad \omega_n = 2$

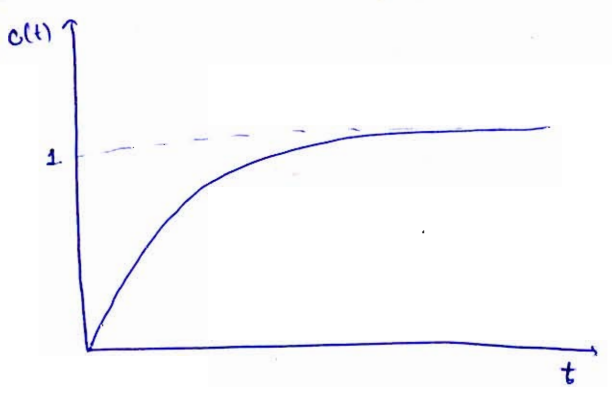
$\zeta = 1.25$

$\Rightarrow$ it is an overdamped system

9

response will be

Good Approach



$\therefore$ there is no peak overshoot as the system is overdamped

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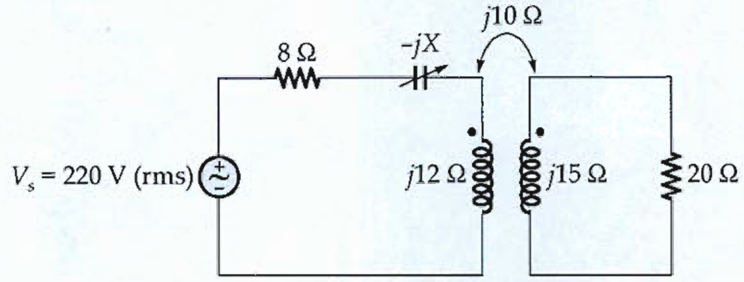
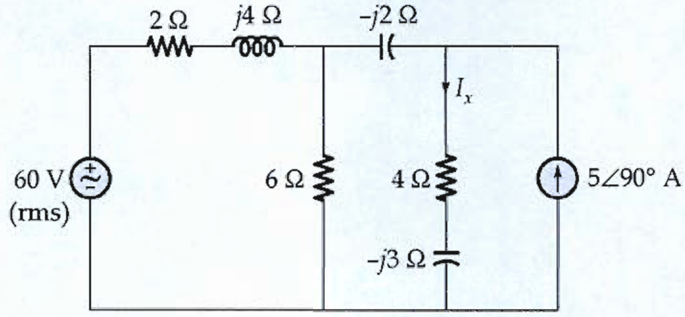
Q.7 (b) **(i)** For the circuit shown in figure, calculate the value of X that will give maximum power transfer to the 20 Ω load. Also calculate the maximum power delivered to load.

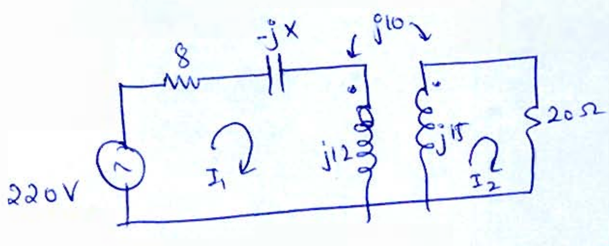


(ii) Calculate current I_X for the circuit shown below :



[12 + 8 marks]

(i)



as I_1 enters dot, I_2 leaves dot

⇒ -ve coupling

4

$$-220 + (8 - jX) I_1 + j12 I_1 - j10 I_2 = 0$$

$$I_1 \left[8 + (12 - X) j \right] - I_2 (10j) = 220$$

$$I_1 = \frac{220 + 10j I_2}{8 + (12 - X) j} \quad - (1)$$

$j15\, I_2 - j10\, I_1 + 20\, I_2 = 0$

$j15\, I_2 + 20\, I_2 = j10\, I_1$ — (ii)

substituting (i) in (ii)

$j15\, I_2 + 20 I_2 = j10 \left[\dfrac{220 + 10j\, I_2}{8 + (12 - X)j} \right]$

$\dfrac{(j15 + 20)}{j10} I_2 \left[8 + (12 - x)j\right] = 220 + 10j\, I_2$

$\left[(1.5 - j2)(8 + (12 - xj)) - 10j \right] I_2 = 220$

$\cancel{I_2 = \dfrac{220}{(1.5 - j2)(8 + (12 - x)j) - 10j}}$

~~Power will be max, when I_2 will be max~~

~~$\Rightarrow I_2$ will be max, when denominator will be min~~

~~$\therefore \dfrac{d}{dx}\left[[(1.5 - j2)(8 + (12 - x)j] - 10j \right] = 0$~~

~~$(1.5 - j2)(-$~~

Try to avoid

$P = I_2^2 R = \dfrac{220^2}{\left[(1.5 - j2)(8 + (12 - x)j)^2 - 10j \right]^2} \times 20$

$\dfrac{dP}{dx} = 0 \Rightarrow 2\left[(1.5 - j2)(8 + (12 - x)j) - 10j \right] \left[(1.5 - j2)(-j) \right] = 0$

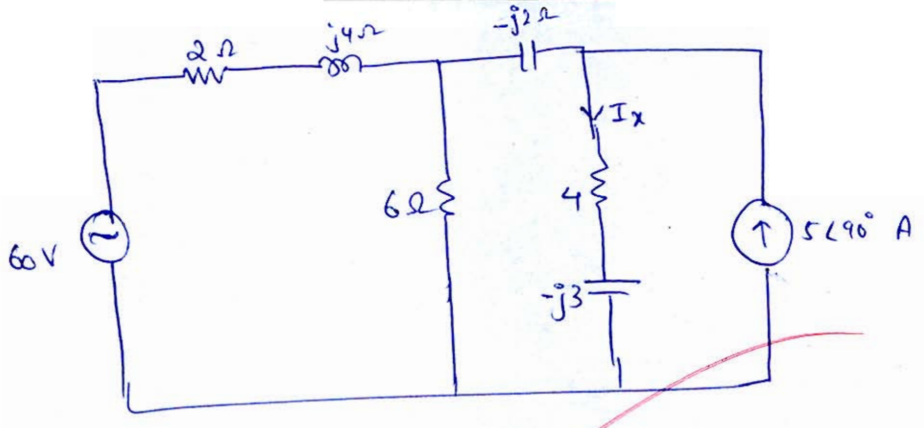
~~$\Rightarrow (1.5 - j2)(8 + 12j - jx) = 10j$~~

~~$8 + 12j - jx = -3.2 + j2.4$~~

~~$8 + 12j + 3.2 - j2.4 = jx$~~

$\boxed{|x| = 14.75\ \Omega}$

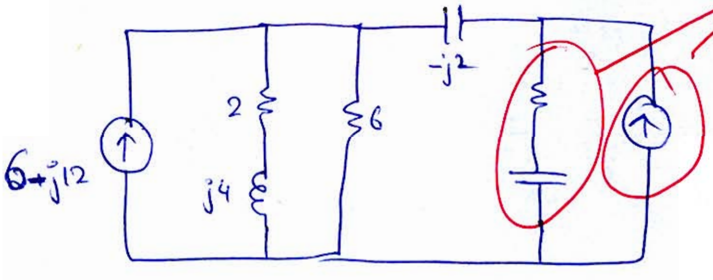
(ii)



using source transformation 60 V, (2 + j4) converted to

$i = \frac{60}{2+j4} = \cancel{6-j2}\ (6-j12)$ A , (2+j4) Ω

write value also



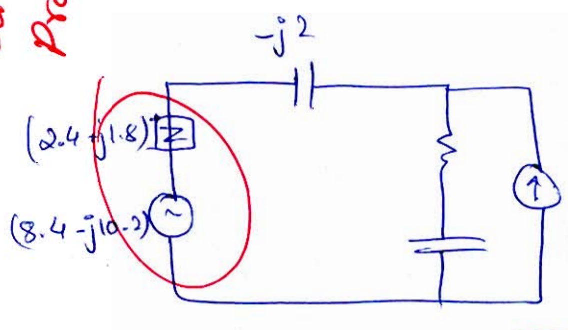
3

$(2+j4) \parallel 6 = (2.4 + j1.8)\ \Omega$

again converting (6 - j12) A & (2.4 + j1.8) Ω to voltage source

Draw diagram Properly

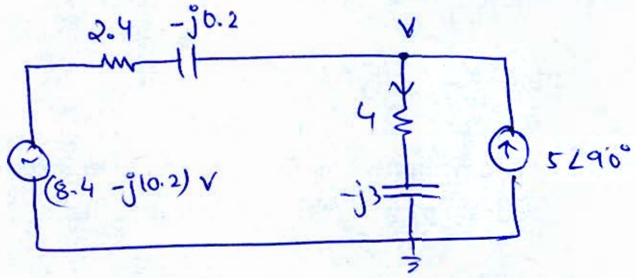
$V = (6 - j12)(2.4 + j1.8) = (8.4 - j10.2)$ V



Try to avoid

~~$(2.4 + j1.8) \parallel j2 = (1.655 - j1.86)\ \Omega$~~

$(2.4 + j1.8) + (-j2) = (2.4 - j0.2)\ \Omega$



~~Again~~ using nodal analysis

$$\frac{V-(8.4-j10.2)}{2.4-j0.2} + \frac{V}{4-j3} = 5\angle 90^\circ$$

$$\therefore V\left[\frac{1}{2.4-j0.2} + \frac{1}{4-j3}\right] = 5\angle 90 + \frac{(8.4-j10.2)}{(2.4-j0.2)}$$

$$V = 6.69\angle 0.53^\circ$$

$$\therefore I_x = \frac{V}{4-j3}$$

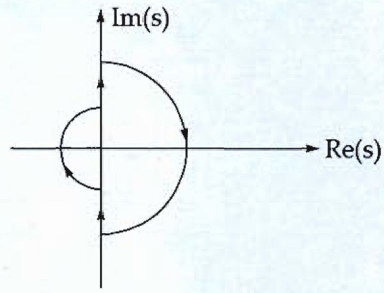
$$\cancel{= 1.34} = (1.06+j0.81) \text{ A}$$

$$= 1.034\angle 37.4^\circ \text{ A}$$

Q.7 (c) The open loop transfer function of a unity negative feedback system is given as

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

The Nyquist contour in s-plane encloses the entire right half plane and a small neighbour around origin in left half plane, as shown in figure. Draw the Nyquist plot of the system and examine its closed loop stability.

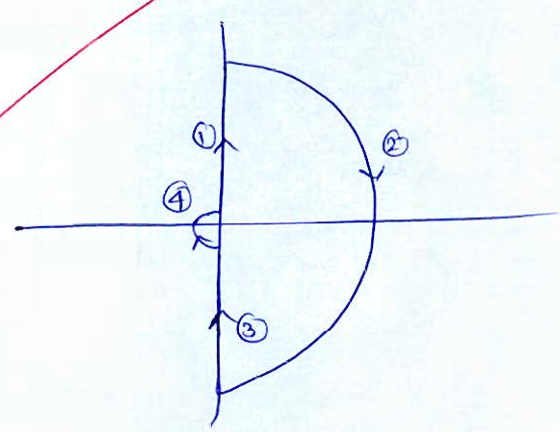


[20 marks]

There are two poles at origin, rest of the open loop poles are situated in LHP

$\therefore$ open loop poles $P = 2$

Nyquist contour



path 1

$s = j\omega \qquad \omega: 0$ to $\omega: \infty$

$$G(j\omega) = \frac{1+4j\omega}{(j\omega)^2(1+j\omega)(1+2j\omega)}$$

$$|G(j\omega)| = \frac{\sqrt{1+16\omega^2}}{\omega^2\sqrt{1+\omega^2}\sqrt{1+4\omega^2}}$$

$$\angle G(j\omega) = \tan^{-1}4\omega - 180 - \tan^{-1}\omega - \tan^{-1}2\omega$$

$\omega = 0$ $\quad |G| = \infty \quad \angle G = -180^\circ$

$\omega = \infty$ $\quad |G| = 0 \quad \angle G = -270^\circ$

path 2

$$S = \lim_{R\to\infty} Re^{j\theta} \qquad \theta: 90 \text{ to } -90^\circ \text{ via } 0^\circ$$

$$G(j\omega) \simeq \frac{4Re^{j\theta}}{R^2e^{2j\theta}\cdot Re^{j\theta}\cdot 2Re^{j\theta}} \approx \frac{1}{R^3}e^{-j3\theta}$$

$\theta = 90^\circ \quad |G| = 0 \quad \angle G = -270^\circ$

$\theta = -90 \quad |G| = 0 \quad \angle G = 270^\circ$

path 3

$$S = -j\omega \qquad \omega: \infty \text{ to } \omega: 0$$

$$|G(j\omega)| = \frac{\sqrt{1+16\omega^2}}{\omega^2\sqrt{1+\omega^2}\sqrt{1+4\omega^2}}$$

$$\angle G(j\omega) = -\tan^{-1}4\omega + 180 + \tan^{-1}\omega + \tan^{-1}2\omega$$

$\omega = \infty \quad |G| = 0 \quad \angle G = 270^\circ$

$\omega = 0 \quad |G| = \infty \quad \angle G = 180^\circ$

path 4

$S = \lim_{r \to 0} r e^{j\theta}$ θ: -90 to -270 via $-180°$

$G(j\omega) \approx \frac{1}{r^2 e^{j2\theta}}$

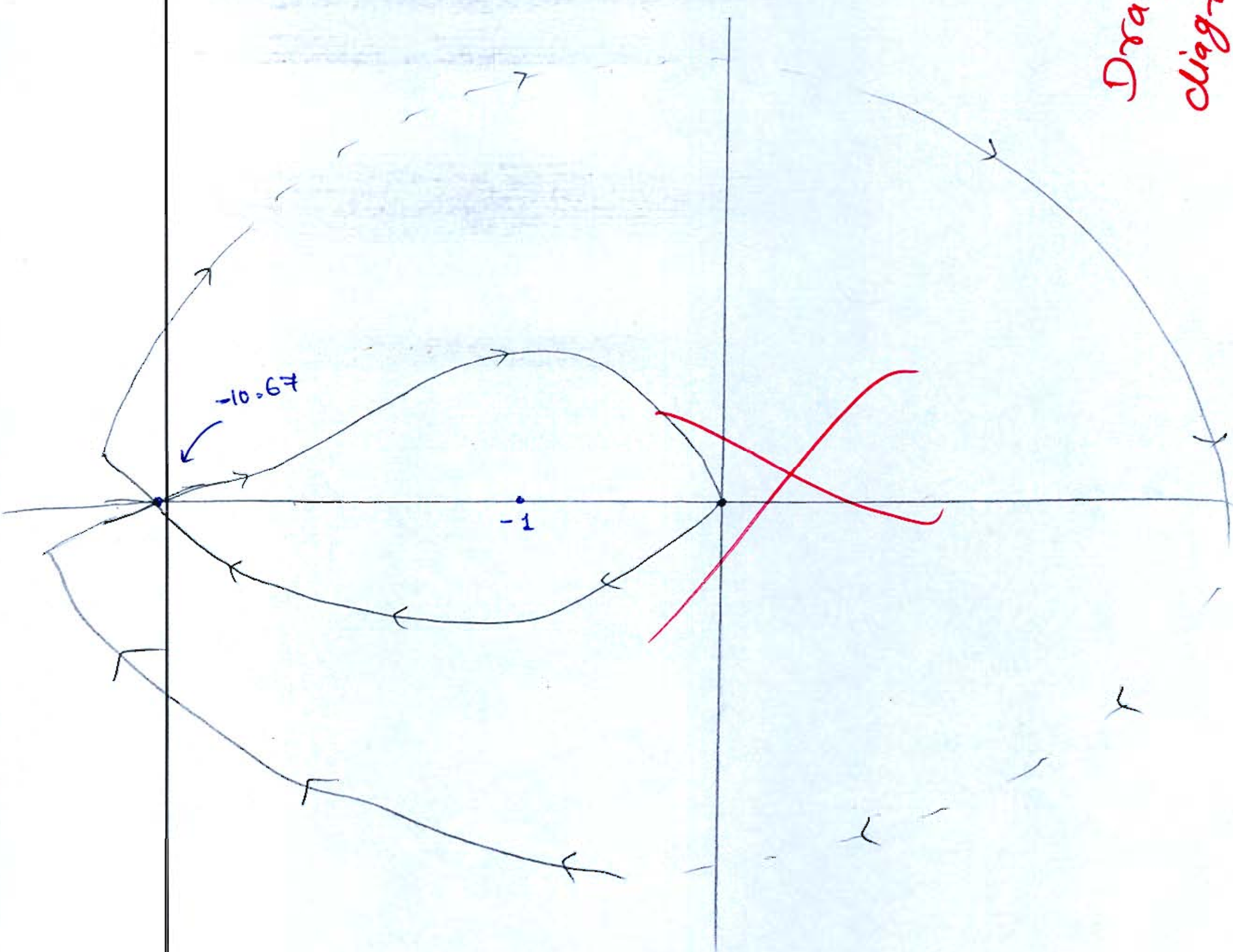
$\theta = -90$ $|G| = \infty$ $\angle G = 180°$

$\theta = -270$ $|G| = \infty$ $\angle G = -180°$

when $\theta = -180°$ $|G| = \infty$ $\angle G = 0°$

Therefore the Nyquist plot will be drawn as

Draw diagram properly



To find intersection with -ve real axis

$\phi = -180°$

$\tan^{-1} 4\omega - 180° - \tan^{-1}\omega - \tan^{-1} 2\omega = -180$

$\tan^{-1} 4\omega = \tan^{-1}\omega + \tan^{-1} 2\omega$

$4\omega = \frac{\omega + 2\omega}{1 - 2\omega^2}$

$4\omega = \frac{3\omega}{1-2\omega^2}$

$1 - 2\omega^2 = \frac{3}{4}$

$\frac{1}{4} = 2\omega^2$

$\cancel{\omega = \frac{1}{2\sqrt{2}}}$

5

at this ω, gain of system is

$|G| = +10.67$

$\Rightarrow$ point of intersection is -10.67

$\therefore$ -1 will lie left to it

$\therefore$ Encirclement ~~of -1~~ = 2 in clockwise direction

$\cancel{\Rightarrow N = -2}$

we know $N = P - Z$

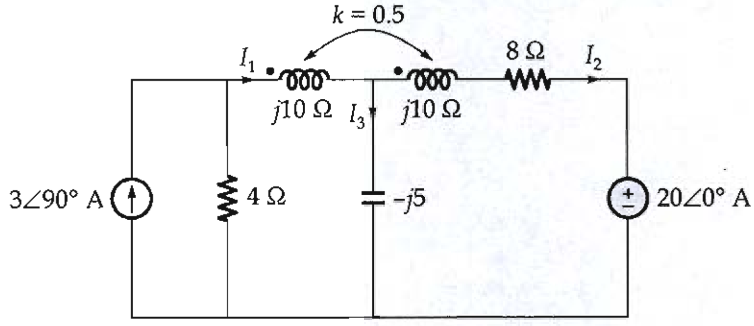
$\cancel{-2 = 2 - Z}$

$\cancel{Z = 4}$

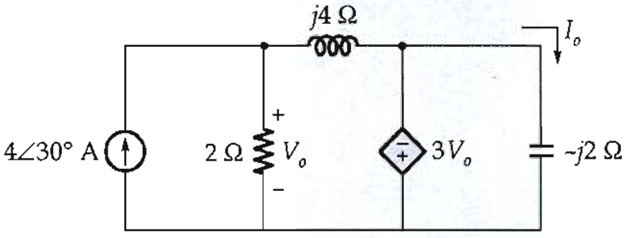
$\therefore$ ~~4 poles in RHS~~

$\Rightarrow$ system is unstable

Q.8 (a) (i) Determine the current I_1, I_2 and I_3 in the circuit shown. Take $\omega = 1000$ rad/sec.



(ii) Calculate voltage V_o for the circuit shown below.



[15 + 5 marks]

Q.8 (b) Let $G(s) = \dfrac{K(s-1)}{(s+2)(s+3)}$ with unity negative feedback.

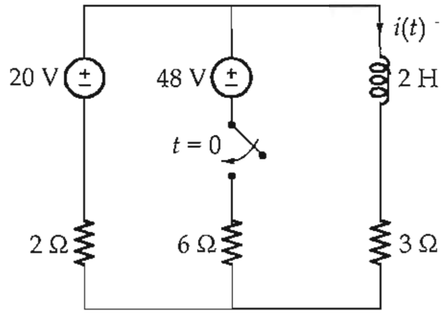
(i) Find the range of K for closed loop stability.

(ii) Plot the root locus for $K < 0$.

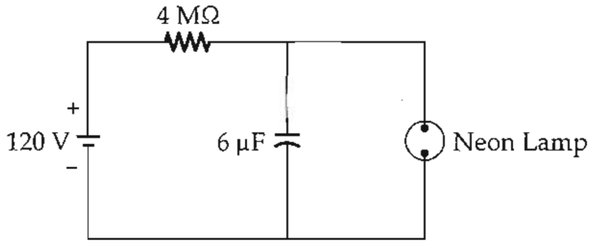
(iii) Assuming a step input, what value of K will result in the smallest attainable settling time?

[20 marks]

Q.8 (c) (i) Obtain the current $i(t)$ for both $t < 0$ and $t > 0$.



(ii) A simple relaxation oscillator circuit is shown in figure. The neon lamp fires when its voltage reaches 75 V and turns off when its voltage drop to 30 V. Its resistance is 120 Ω, when 'ON' and infinitely high when 'OFF'.



For how long is the lamp on each time the capacitor discharges? What is the time interval between two flashes?

[10 + 10 marks]

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Space for Rough Work

Space for Rough Work

Space for Rough Work

Space for Rough Work

Space for Rough Work

$$\frac{1}{1-\frac{1}{\alpha}\frac{1}{\alpha}}$$

$$\frac{1}{1-\frac{1}{\alpha^2}}$$

$z^{-1} = \alpha$

$$\frac{1}{1-\alpha\alpha}$$