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ESE 2024 : Mains Test Series

UPSC ENGINEERING SERVICES EXAMINATION

Electrical Engineering

Test-1 : Electrical Circuits [All Topics]

Control Systems [All Topics]

Name: Satyam Khairnar

Roll No :

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Student's Signature

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. There are few rough work sheets at the end of this booklet. Strike off these pages after completion of the examination.

FOR OFFICE USE

Question No.	Marks Obtained
Section-A	
Q.1	
Q.2	
Q.3	
Q.4	
Section-B	
Q.5	
Q.6	
Q.7	
Q.8	
Total Marks Obtained	

Signature of Evaluator ....

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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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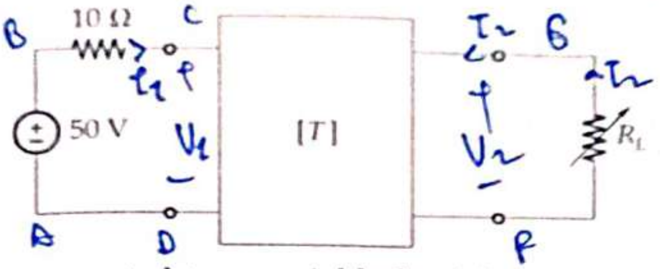
Section A : Electrical Circuits

(a) The $ABCD$ parameter of the two-port network in figure are $\begin{bmatrix} 4 & 20\,\Omega \\ 0.15 & 2 \end{bmatrix}$.



The output port is connected to a variable load for maximum power transfer. Find R_L and the maximum power transferred.

[12 marks]

Ans)

$$\begin{pmatrix} A & B \\ C & D \end{pmatrix} = \begin{bmatrix} 4 & 20\,\Omega \\ 0.15 & 2 \end{bmatrix}$$

$V_1 = AV_2 - BI_2$

$\Rightarrow V_1 = 4V_2 - 20I_2$ — (i).

& $I_1 = 0.1V_2 - 2I_2$. — (ii).

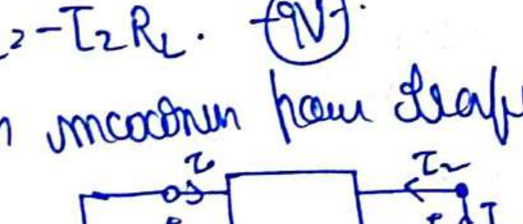
we have,

$V_1 = 50 - 10I_1$ (By KVL between ABCD) — (iii).

Similarly, by ohm's law betn E & F, we have

$V_2 = -I_2R_L$. — (iv).

Now, for maximum power transfer, $R_L = R_{th}$.



$V_1 = -10I_1$.

& $V_1 = 4V_2 - 20I_2$

$\Rightarrow -10I_1 = 4V_2 - 20I_2$

|| $I_1 = 0.1V_2 - 2I_2$.

Putting (ii) on (i), we have

$-10I_1 = 4V_2 - 20I_2$

$-10(0.1V_2 - 2I_2) = 4V_2 - 20I_2$

$-V_2 + 20I_2 = 4V_2 - 20I_2$

$5V_2 = 40I_2$

$\frac{V_2}{I_2} = 8\Omega$

$\Rightarrow R_{th} = 8\Omega \Rightarrow \underline{R_L = 8\Omega}$ $\Rightarrow$ for maximum power transfer.

Now, $R_L = 8\Omega$.

Putting on (iv), we have

~~$V_2 + 8I_2 = 0$~~

$V_2 = -8I_2$

$V_2 + 8I_2 = 0$ — (iv)

$V_1 - 4V_2 + 20I_2 = 0$ — (v)

$V_1 + 10I_1 = 50$ — (vi)

$I_1 - 0.1V_2 + 2I_2 = 0$ — (vii)

$\Rightarrow V_1 = 32.5\,V$

$I_1 = 1.875\,V$

$V_2 = 5\,V$

$I_2 = -\frac{5}{8}\,V$

$\therefore$ we have $P = \frac{V_2^2}{R_L}$

$P = \frac{(5)^2}{8}$

$P = 3.125\,W.$

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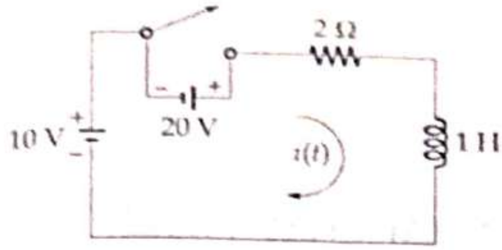
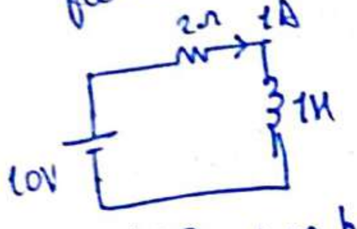
(b) Determine the current $i(t)$ in the circuit shown in figure at an instant t, after opening the switch at $t = 0$, if a current of 1 A had been passed through the circuit at the instant of opening.

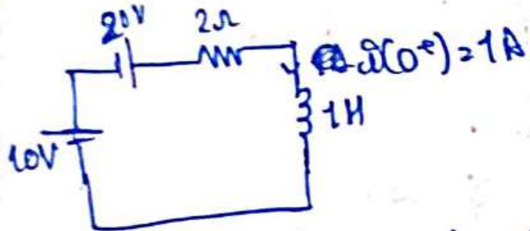


[12 marks]

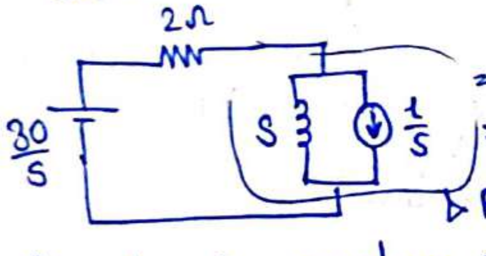
Sol.) For $t = 0^-$, we have



For $t > 0$, we have



Now, converting into laplace, we have

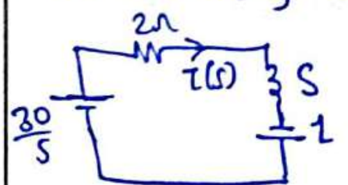


$\Rightarrow V_{th} = S \times \frac{1}{S}$

$\Rightarrow V_{th} = 1V$

& $R_{th} = S$.

Converting the norton source to thevenin, we have



By KVL, we have

$$\frac{30}{s} + 1 = I(s)(2+s)$$

$$I(s) = \frac{s+30}{s(s+2)}$$

$$I(s) = \frac{15}{s} - \frac{14}{s+2}$$

$$i(t) = 15\,u(t) - 14e^{-2t}u(t)$$

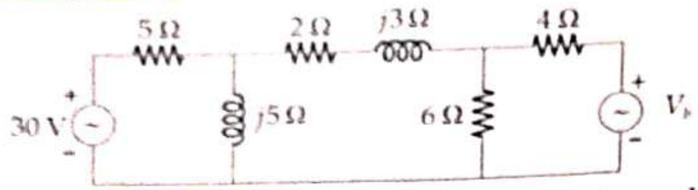
$$\Rightarrow i(t) = (15 - 14e^{-2t})\,u(t)$$

We have,

$i(0^+) = 1A$

$i(\infty) = 15A$

Q.1 (c) For the circuit shown below:

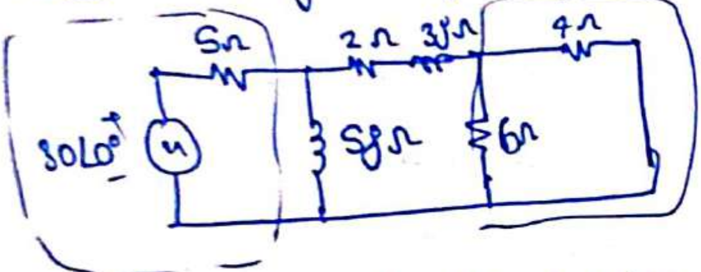


Determine the voltage V_b which results in a zero current through the $(2 + j3)\Omega$ impedance branch. Using superposition theorem.

[12 marks]

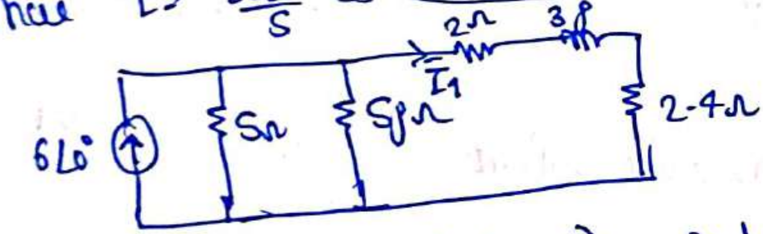
(Ans.): By superposition theorem, we have

(I): Taking only 30V source.



$\Rightarrow R_{eq} = R_1 \| R_2 = 4 \| 6 = \frac{4 \times 6}{4+6} \Rightarrow \boxed{R_{eq} = 2.4\Omega}$

Transforming the given source into current source, we have $\bar{I} = \frac{30\angle 0°}{5} \Rightarrow \boxed{\bar{I} = 6\angle 0° A}$ & $R = 5\Omega$.



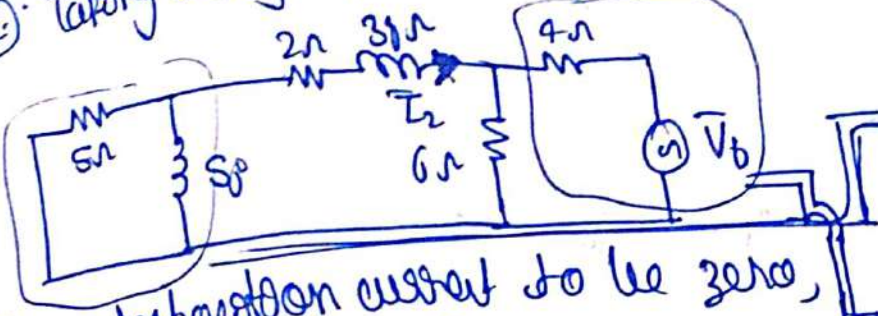
∴ Current through $(2+3j)\Omega$ impedance is given by

$$\bar{I}_1 = 6 \times \frac{\left(\frac{1}{2+3j+2.4}\right)}{\left(\frac{1}{5}\right) + \left(\frac{1}{5j}\right) + \frac{1}{(2+3j+2.4)}}$$ (By current division rule)

$$\Rightarrow \bar{I}_1 = 6 \times \frac{\frac{1}{(4.4+3j)}}{\frac{1}{5} + \frac{1}{5j} + \frac{1}{(4.4+3j)}} = \frac{6 \times (0.1877\angle -34.286°)}{(0.4686\angle -40.728°)}$$

$$\boxed{\bar{I}_1 = 2.404\angle 6.442° A}$$

(II). Taking only V_b source, we have



$Z_{eq} = \frac{5\times 5j}{5+5j}$

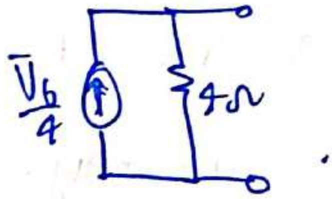
$\Rightarrow \boxed{Z_{eq} = 2.5+j2.5\,\Omega}$

For superposition current to be zero,

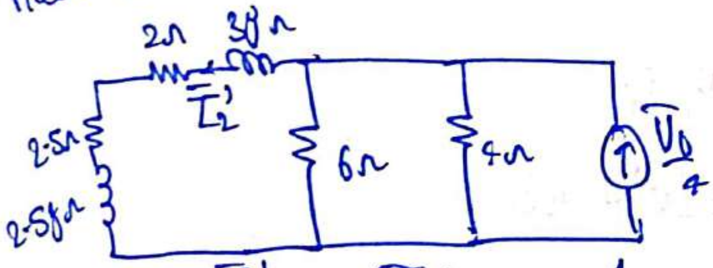
$\bar I_1 + \bar I_2 = 0 \Rightarrow \bar I_2 = -\bar I_1$

$\therefore \bar I_2 = -2.404\angle 6.442^\circ$ A.

Using source transformation, we have



We have the modified circuit as.



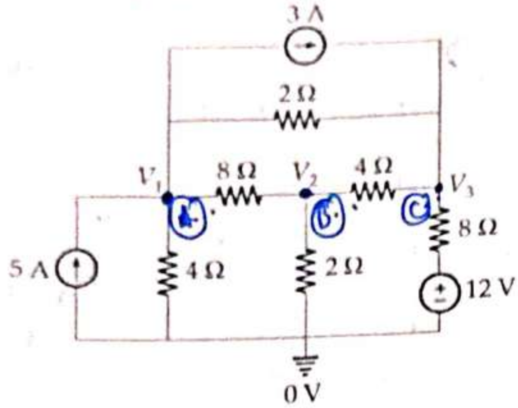
We have, $\bar I_2' = \left(\frac{\bar V_b}{4}\right) \dfrac{\frac{1}{(4.5+5.5j)}}{\left(\frac{1}{4.5+5.5j}\right)+\left(\frac{1}{6}\right)+\left(\frac{1}{4}\right)}$

$I_1' = \frac{\bar V_b}{4}\,(0.272\angle -38.558^\circ)$

$\Rightarrow 2.404\angle 6.442^\circ = \frac{\bar V_b}{4}\,(0.272\angle -38.558^\circ)$

$\Rightarrow \boxed{\bar V_b = 35.354\angle 45^\circ}$

Q.1 (d) Use nodal analysis to find V_1, V_2 and V_3 in the circuit of figure.



[12 marks]

Ans.:

At node (A), we have

$I_{incoming} = I_{outgoing}$

$$5 = \frac{V_1}{4} + \frac{V_1 - V_2}{8} + \frac{V_1 - V_3}{2} + 3$$

$$\Rightarrow 16 = 2V_1 + V_1 - V_2 + 4V_1 - 4V_3$$

$$7V_1 - V_2 - 4V_3 = 16 \quad \text{—(i)}$$

Similarly at node (B); we have

$$\frac{V_2 - V_1}{8} + \frac{V_1}{2} + \frac{V_2 - V_3}{4} = 0$$

$$\Rightarrow V_2 - V_1 + 4V_1 + 2V_2 - 2V_3 = 0$$

$$3V_1 + 3V_2 - 2V_3 = 0 \quad \text{—(ii)}$$

At node (C); we have

$$\frac{V_3 - V_2}{4} + \frac{V_3 - 12}{8} + \frac{V_3 - V_1}{2} = 3$$

$2V_3 - 2V_2 + V_3 - 12 + 4V_3 - 4V_1 = 24$

$-4V_1 - 2V_2 + 7V_3 = 36$ — (iii)

Now, by nodal analysis, we have equation (i), (ii) & (iii).

On solving equations (i), (ii) & (iii),

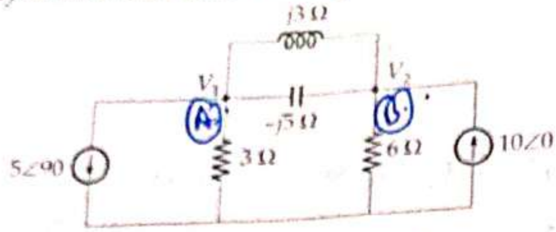
we have

~~$V_1 = 7.185$~~ $V_1 = 7.185V$.

$V_2 = -1.259V$.

$V_3 = 8.888V$.

Q.1 (e) Use nodal analysis on the circuit to find V_2.



[12 marks]

(Ans.): By nodal analysis, we have,

at node (A):

$I_{incoming} = I_{outgoing}$

$$\Rightarrow 0 = 5\angle 90^\circ + \frac{V_1}{3} + \frac{V_1 - V_2}{(3j)} + \frac{V_1 - V_2}{(-5j)}$$

$$\Rightarrow 0 = (15j)(5j) + 5jV_1 + 5V_1 - 5V_2 + \frac{(15j)(V_2 - V_1)}{(5j)}$$

$$75 = 5jV_1 + 5V_1 - 5V_2 + 3V_2 - 3V_1$$

(i) — $(2+5j)V_1 - 2V_2 = 75$

Similarly at node (B), we have

$$10\angle 0^\circ = \frac{V_2}{6} + \frac{V_2 - V_1}{-5j} + \frac{V_2 - V_1}{3j}$$

$$300j = 5jV_2 + 6(V_1 - V_2) + 10(V_2 - V_1)$$

$$300j = 5jV_2 + 6V_1 - 6V_2 + 10V_2 - 10V_1$$

$$300j = -4V_1 + (4+5j)V_2$$

$-4V_1 + (4+5j)V_2 = 300j$ — (ii)

From equations (i) & (ii) we have

$$\begin{bmatrix} 2+5j & -2 \\ -4 & 4+5j \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \end{bmatrix} = \begin{bmatrix} 75 \\ 300j \end{bmatrix}$$

$$\begin{bmatrix} V_1 \\ V_2 \end{bmatrix} = \begin{bmatrix} 2+5j & -2 \\ -4 & 4+5j \end{bmatrix}^{-1} \begin{bmatrix} 75 \\ 300j \end{bmatrix}$$

$$= \frac{\begin{bmatrix} 4+5j & 2 \\ 4 & 2+5j \end{bmatrix} \begin{bmatrix} 75 \\ 300j \end{bmatrix}}{(-17+30j)}$$

$$= \frac{\begin{bmatrix} 300+375j+600j \\ 300+600j-1500 \end{bmatrix}}{(-17+30j)}$$

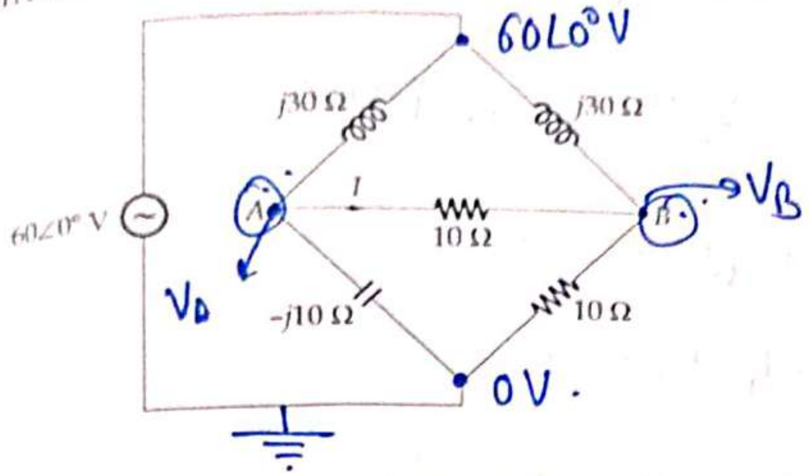
$$= \frac{\begin{bmatrix} 1020.11\angle 72.89^\circ \\ 1341.64\angle 153.43^\circ \end{bmatrix}}{34.48\angle 119.5382^\circ}$$

$$\Rightarrow \begin{bmatrix} V_1 \\ V_2 \end{bmatrix} = \begin{bmatrix} 29.583\angle -46.641^\circ \\ 38.908\angle 33.89^\circ \end{bmatrix} \Rightarrow$$

$V_1 = 29.583\angle -46.641^\circ$ V.

$V_2 = 38.908\angle 33.89^\circ$ V.

Determine the current I through the terminal AB of the network shown below:



[20 marks]

Now, we have nodes A & B & assuming ground,
By nodal analyses, at A.

$$\frac{V_A - 60\angle 0^\circ}{(30j)} + \frac{(V_A - 0)}{(-10j)} + \left(\frac{V_A - V_B}{10}\right) = 0$$

$$(V_A - 60) + (3)(-V_A) + 3j(V_A - V_B) = 0$$

$$\Rightarrow V_A - 60 - 3V_A + 3jV_A - 3jV_B = 0$$

$$\Rightarrow V_A(-2+3j) + V_B(-3j) = 60 \quad \text{— (i)}$$

Now, by nodal analyses at B, we have

$$\frac{V_B - 60}{30j} + \frac{V_B - V_A}{10} + \frac{V_B}{10} = 0$$

$$V_B - 60 + 3j(V_B - V_A) + 3jV_B = 0$$

$$V_B - 60 + 3jV_B - 3jV_A + 3jV_B = 0$$

$(-3j)V_A + (1+6j)V_B = 60$ — (ii)

From eq^n (i) & (ii), we have

$\bar{V}_A(-2+3j) + \bar{V}_B(-3j) = 60$

$\bar{V}_A(-3j) + \bar{V}_B(1+6j) = 60$

$\Rightarrow \begin{bmatrix} -2+3j & -3j \\ -3j & 1+6j \end{bmatrix} \begin{bmatrix} \bar{V}_A \\ \bar{V}_B \end{bmatrix} = \begin{bmatrix} 60 \\ 60 \end{bmatrix}$

$$\begin{bmatrix} \bar{V}_A \\ \bar{V}_B \end{bmatrix} = \begin{bmatrix} -2+3j & -3j \\ -3j & 1+6j \end{bmatrix}^{-1} \begin{bmatrix} 60 \\ 60 \end{bmatrix}$$

$$= \frac{\begin{bmatrix} 1+6j & 3j \\ 3j & -2+3j \end{bmatrix} \begin{bmatrix} 60 \\ 60 \end{bmatrix}}{(-2+3j)(1+6j) - (-3j)(-3j)}$$

$$= \frac{\begin{bmatrix} 60+360j+180j \\ 180j - 120+180j \end{bmatrix}}{-2-9j-18-9}$$

$$= \frac{\begin{bmatrix} 60+540j \\ -120+360j \end{bmatrix}}{(-29-9j)}$$

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$$\begin{bmatrix} \bar{V}_A \\ \bar{V}_B \end{bmatrix} = \begin{bmatrix} 17.893\angle -113.581^\circ \text{ V} \\ 12.4972\angle -88.806^\circ \text{V} \end{bmatrix}$$

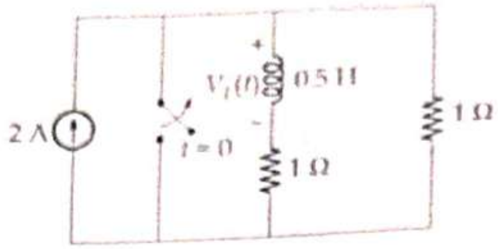
Now, By Ohm's law, we have

$$V_A - V_B = 10 \times \bar{I}$$

$$\Rightarrow (17.893\angle -113.581^\circ) - (12.4972\angle -88.806^\circ) = 10 \times \bar{I}$$

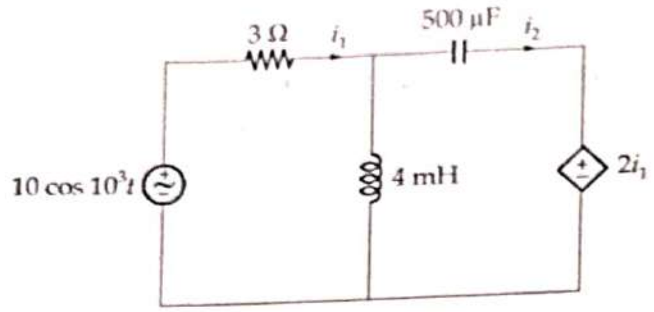
$$\Rightarrow \bar{I} = 0.838\angle -152.241^\circ \text{ A}$$

Q.2 (b) (i) For the network shown in figure below, the switch is closed for a long time and at $t = 0$, the switch is opened.



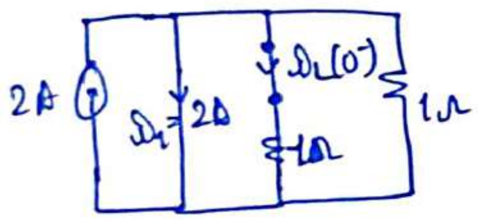
Determine the voltage across inductor for $t > 0$.

(ii) Obtain expressions for the time domain currents i_1 and i_2 in the circuit given as figure.



[10 + 10 marks]

(Ans.): (i) For $t = 0^-$, we have

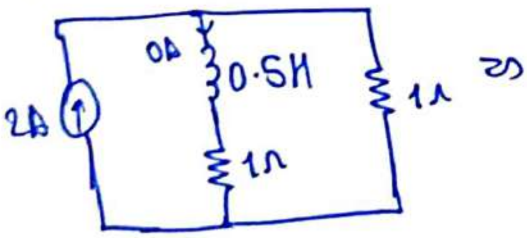


$\because$ of short circuit, we have

$i_1 = 2A$

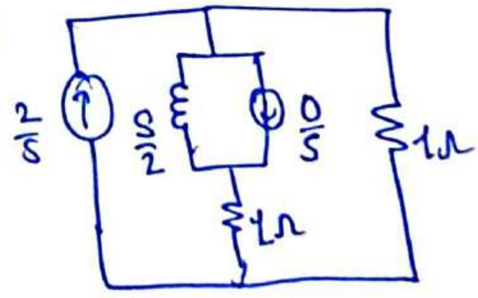
$\therefore i_L(0^-) = 0A$.

Now, at $t = 0^+$, we have

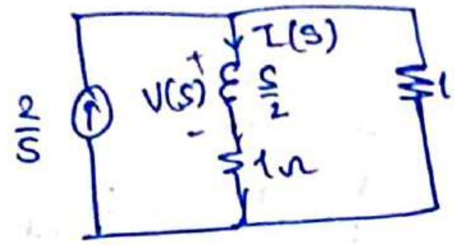


is

Laplacian domain



∴ we have,



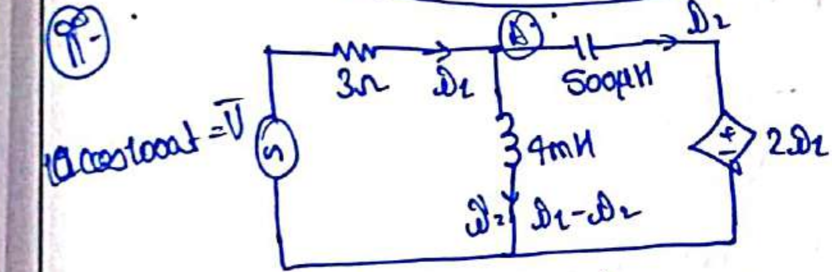
$$I(s) = \frac{2}{s}\,\frac{(1)}{\left(1+\frac{s}{2}+1\right)}$$ (By current division rule).

$$\Rightarrow V(s) = \frac{s}{2}\,I(s) = \frac{s}{2}\left(\frac{2}{s}\right)\left(\frac{1}{2+\frac{s}{2}}\right)$$

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

$$\Rightarrow v(t) = 2e^{-4t}\,u(t)$$

Q.



By KCL at (A), we have

$i_1 = i' + i_2$

$\Rightarrow i' = i_1 - i_2$

taking voltage as reference,

$$V = \frac{10}{\sqrt{2}}\angle 0^\circ = 7.07\angle 0^\circ\ V$$

$\cancel{X_L = j\omega L = 2\pi \times 1000 \times 4m = 8\pi}$

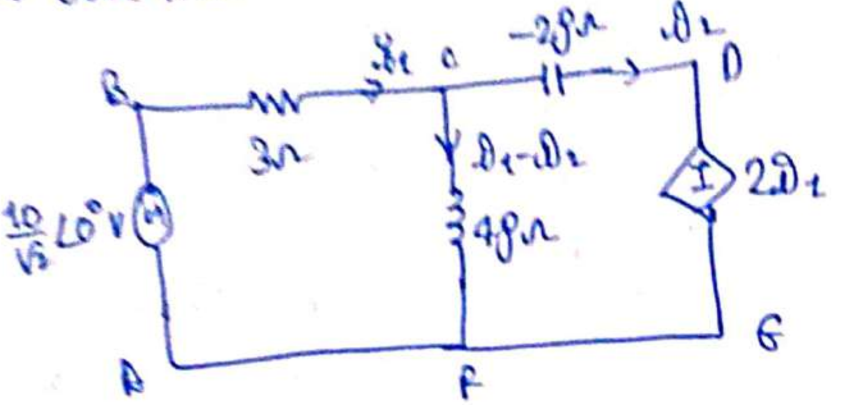
$\cancel{\Rightarrow X_L = j28.133\,\Omega}$

$\cancel{X_C = \frac{j}{2\pi f C} = \frac{j}{2\pi \times 1000}}$

$$X_L = j\omega L = j \times 1000 \times 4m = 4j \Rightarrow X_L = 4j\,\Omega$$

$$X_C = \frac{-j}{\omega C} = \frac{-j}{1000 \times 500\mu} \Rightarrow X_C = -2j\,\Omega$$

$\therefore$ we have



By KVL in loop ABCFA

$$V_A + 7.07\angle 0^\circ - 3I_1 - 4jI_1 + 4jI_2 = V_A$$

$$7.07 = (3+4j)I_1 + (-4j)I_2 \quad \text{— (i)}$$

By KVL in loop ABCDGA, we have

$$7.07\angle 0^\circ - 3I_1 - (-2j)I_2 - 2I_1 = 0$$

$$7.07 = 5I_1 - 2jI_2 \quad \text{— (ii)}$$

$\therefore$ from (i) & (ii), we have

$$\Rightarrow \begin{bmatrix} 3+4j & -4j \\ 5 & -2j \end{bmatrix} \begin{bmatrix} \bar{I}_1 \\ \bar{I}_2 \end{bmatrix} = \begin{bmatrix} 7.07 \\ 7.07 \end{bmatrix}$$

$$\begin{bmatrix} \bar{I}_1 \\ \bar{I}_2 \end{bmatrix} = \begin{bmatrix} 3+4j & -4j \\ 5 & -2j \end{bmatrix}^{-1} \begin{bmatrix} 7.07 \\ 7.07 \end{bmatrix}$$

$$\begin{bmatrix} \bar{I}_1 \\ \bar{I}_2 \end{bmatrix} = \frac{\begin{bmatrix} -2j & 4j \\ -5 & 3+4j \end{bmatrix}}{(-6j+8+20j)} \begin{bmatrix} 7.07 \\ 7.07 \end{bmatrix}$$

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$$\begin{bmatrix}\bar{I}_1\\ \bar{I}_2\end{bmatrix} = \frac{\begin{bmatrix}10\sqrt{2}j\\ -5\left(\frac{10}{\sqrt{2}}\right) + (8+4j)\left(\frac{10}{\sqrt{2}}\right)\end{bmatrix}}{(8+14j)} = \frac{\begin{bmatrix}10\sqrt{2}\angle 90^\circ\\ (-1+2j)(10\sqrt{2})\end{bmatrix}}{(8+14j)}$$

$$\begin{bmatrix}\bar{I}_1\\ \bar{I}_2\end{bmatrix} = \frac{\begin{bmatrix}14.14\angle 90^\circ\\ 31.622\angle 116.565^\circ\end{bmatrix}}{8+14j}$$

$$\begin{bmatrix}\bar{I}_1\\ \bar{I}_2\end{bmatrix} = \begin{bmatrix}\frac{14.14\angle 90^\circ}{8+14j}\\ \frac{31.622\angle 116.565^\circ}{8+14j}\end{bmatrix} = \begin{bmatrix}0.877\angle 29.744^\circ A\\ 1.9611\angle 56.3099^\circ A\end{bmatrix}$$

$$i_1(t) = \sqrt{2}\times 0.877 \cos(1000t + 29.744^\circ)$$

$$i_1(t) = 1.24\cos(1000t + 29.744^\circ)\ A$$

$$\bar{I}_2 = 1.9611\angle 56.3099^\circ A$$

$$i_2(t) = \sqrt{2}\times 1.9611 \cos(1000t + 56.3099^\circ)$$

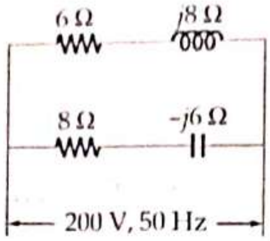
$$i_2(t) = 2.773\cos(1000t + 56.3099^\circ)\ A$$

Q.2 (c) For the circuit shown below, calculate,

(i) Total admittance, total conductance and total susceptance.

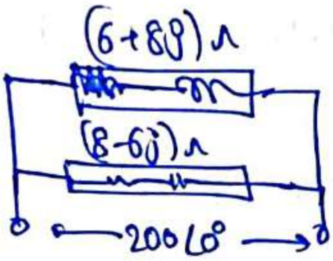
(ii) Total current and total power factor (pf).

(iii) The value of pure capacitance to be connected in parallel with the above combination to make the total power factor (pf) unity.



[20 marks]

(Ans): (i).



Taking voltage as reference, we have

$$Z_{eq} = \frac{(6+8j)(8-6j)}{(6+8j)+(8-6j)}$$

$$\boxed{Z_{eq} = 7+j} \quad \text{— (i)}$$

$$\Rightarrow Y_{eq} = \frac{1}{Z_{eq}} = \frac{1}{7+j}$$

$$\Rightarrow Y_{eq} = 0.14 - 0.02j \ ℧ = G + jB$$

$$G_{eq} = 0.14 ℧ \quad \& \quad B_{eq} = -0.02 ℧$$

~~$B_{eq} = -0.02j$~~

(ii) Now, for total current, we have

$$I = \frac{200\angle 0^\circ}{Z_{eq}} = \frac{200\angle 0^\circ}{7+j}$$

$\bar{I} = \frac{200\angle 0^\circ}{7+j}$

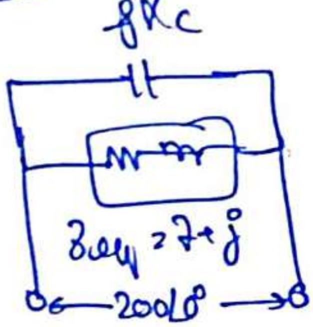
$\Rightarrow \boxed{\bar{I} = 28.284\angle -8.130^\circ A}$.

$\therefore$ Total current $= 28.284A$.

p.f. $= \cos(8.130^\circ)$

$\Rightarrow \boxed{p.f. = 0.9899\ lag.}$

(iii) We have,



$\therefore Y_{eq} = \frac{1}{7+j} + \frac{1}{-jX_C} = \frac{7}{50} - \frac{j}{50} + \frac{j}{X_C}$

$\therefore$ for power factor to be unity,
imaginary part $= 0$

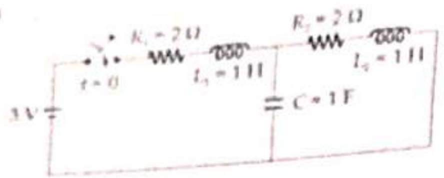
$\Rightarrow -\frac{j}{50} + \frac{j}{X_C} = 0 \Rightarrow \frac{1}{50} = \frac{1}{X_C}$

$\Rightarrow X_C = 50\Omega$

$\Rightarrow \frac{1}{2\pi \times 50 \times C} = 50$

$\Rightarrow \boxed{C = 63.66\mu F.}$

Q.3 (a) In the network shown in figure the switch is closed at time $t = 0$. Assuming all the initial currents and voltages as zero, find the current through the inductor L_2 by the use of Norton's theorem



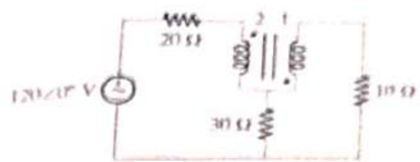
[20 marks]

Show that the resonant frequency ω_0 of a series R-L-C circuit is geometric mean of ω_1 and ω_2 i.e., the upper and lower half power frequencies respectively.

[20 marks]

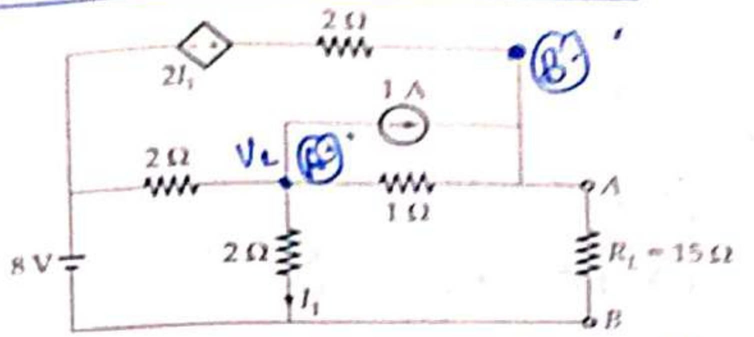
MADE EASY Question Cum Answer Booklet

Calculate the power supplied to the 10 Ω resistor in the ideal transformer circuit given in the figure below



[20 marks]

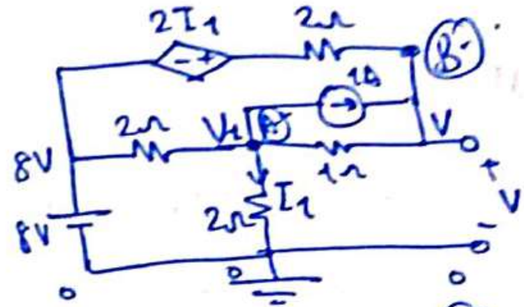
Determine the current through the load resistance $R_L = 15\,\Omega$ across the terminal A-B of the circuit shown in figure below, using Thevenin's theorem. Also find the maximum power that can be transferred to the load resistance R_L.



[20 marks]

For thevenins theorem, we find the V_{th} first

$V_{th} \Rightarrow$



Applying KCL at node (A), we have

$$\frac{V_1-8}{2} + I_1 + \frac{V_1-V}{1} + 1 = 0$$

$$\Rightarrow V_1 - 8 + 2I_1 + 2V_1 - 2V + 2 = 0$$

$$\Rightarrow 3V_1 - 2V + 2I_1 = 6 \quad \text{—(i)}$$

By ohm's law between (A) & ground, we have

$$V_1 = 2I_1 \quad \text{—(ii)}$$

By KCL at node (B), we have

$$\frac{V-(8+2I_1)}{2} + \frac{V-V_1}{1} = 1$$

$$\Rightarrow V - 8 - 2I_1 + 2V - 2V_1 = 2$$

$$3V - 2V_1 - 2I_1 = 6 \quad \text{—(iii)}$$

Now, we have

$3V_1 - 2V + 2I_1 = 6$ — (i)

~~$V_1 - 2I_1 = 0$~~

$V_1 + 0.V + (-2)I_1 = 0$ — (ii)

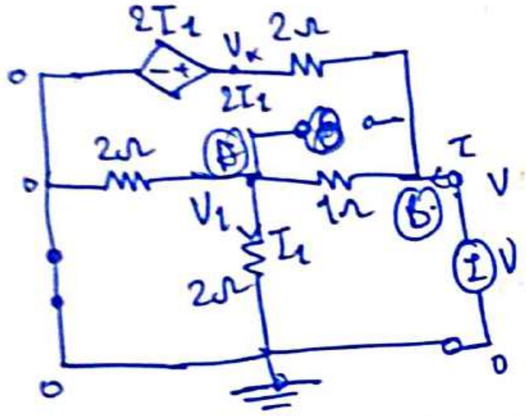
$(-2)V_1 + (3)V + (-2)I_1 = 6$ — (iii)

∴, we have on solving (i), (ii) & (iii)

$V_1 = 5V,\ V = 7V,\ I_1 = 2.5A$

∴, we have $V_{th} = 7V$.

Now, for R_{th}, we have



$V_x = 0 + 2I_1$ (By KVL)

$\Rightarrow \boxed{V_x = 2I_1}$

Let voltage at (A) $= V_1$. By KCL at node A, we have

$\frac{V_1}{2} + \frac{V_1}{2} + \frac{V_1 - V}{1} = 0$

$\Rightarrow 2V_1 = V$.

$\Rightarrow \boxed{V_1 = \frac{V}{2}}$ — (iv)

By Ohm's law between (A) & ground, we have

$\boxed{V_1 = 2I_1}$ — (v)

By KCL at node (B), we have

$I = \frac{V - V_x}{2} + \frac{V - V_1}{1}$

$\Rightarrow I = \frac{V-2I_1}{2} + V - V_1$

$\Rightarrow I = \frac{V}{2} - I_1 + V - V_1$

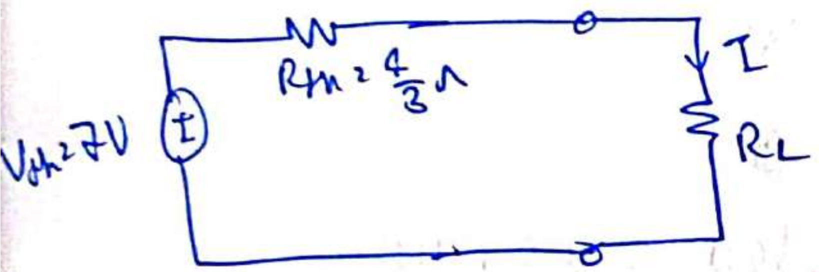
$I = \frac{3V}{2} - V_1 - I_1$

$I = \frac{3V}{2} - \frac{V}{2} - \frac{V_1}{2}$

$I = V - \frac{V_1}{2} = V - \frac{V}{4} = \frac{3V}{4}$

$\Rightarrow \frac{V}{I} = \frac{4}{3} \Rightarrow R_{th} = \frac{4}{3}\,\Omega$

∴ we have thevenin equivalent circuit as



∴ If $R_L = 15\Omega$, then

$I = \frac{7}{\frac{4}{3}+R_L} = \frac{7}{\frac{4}{3}+15} = \frac{7\times3}{49}$

$I = 0.4285A$ ⇒ Current through 15Ω load

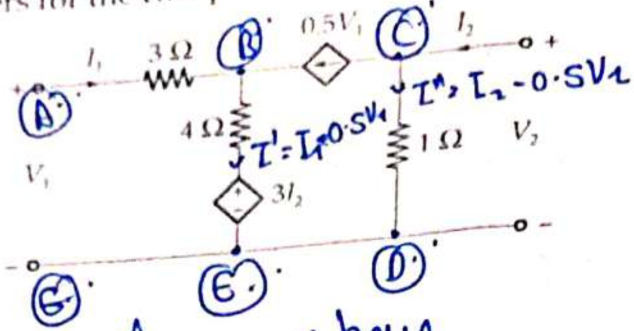
Now, for maximum power transfer, $R_L = R_{th}$

$\Rightarrow R_L = \frac{4}{3}\Omega$ ⇒ for maximum power transfer.

& $P_{max} = \frac{V^2}{4R_{th}} = \frac{(7)^2}{4\times(\frac{4}{3})} = \frac{49}{(\frac{16}{3})}$

$P_{max} = 9.1875W$ ⇒ Maximum power.

Q.4 (b) Find the h-parameters for the two-port network shown



[20 marks]

(Ans.) For h-parameters, we have

$V_1 = h_{11}I_1 + h_{12}V_2$

$I_2 = h_{21}I_1 + h_{22}V_2$

By KVL on loop GABG, we have

$V_G + V_1 - 3I_1 - 4I' - 3I_2 = V_E$

$V_1 = 3I_1 + 3I_2 + 4I'$ — (a)

By KCL at node (B), we have

$I' = I_1 + 0.5V_1$ — (b)

∴ putting (b) in (a), we have

$\underline{V_1} = \underline{3I_1} + 3I_2 + \underline{4I_1} + \underline{2V_1}$

$\underline{\underline{V_1 = -7I_1 - 3I_2}}$ — (i)

By ohm's law between (C) & (D), we have

$I'' = \frac{V_2}{1} \Rightarrow I'' = V_2$ — (c)

Similarly by KCL at (C), we have

Do not write in this margin

$I_2 = I'' + 0.5V_1$

$\Rightarrow I'' = I_2 - 0.5V_1$ --- (d)

$\therefore$ (c) = (d)

$V_2 = I_2 - 0.5V_1$ --- (ii)

$\therefore$ Now, from (i) & (ii), we have

$V_1 = -7I_1 - 3I_2$ --- (i)

$V_2 = I_2 - 0.5V_1$ (ii) $\Rightarrow I_2 = V_2 + 0.5V_1$ --- (iii)

putting (iii) in (i), we have

$V_1 = -7I_1 - 3V_2 - 1.5V_1$

$2.5V_1 = -7I_1 - 3V_2$

$\boxed{V_1 = -2.8I_1 - 1.2V_2}$ --- (iv)

Now, putting (i) in (ii), we have

$V_2 = I_2 - 0.5(-7I_1 - 3I_2)$

$V_2 = I_2 + 3.5I_1 + 1.5I_2$

$V_2 = 2.5I_2 + 3.5I_1$

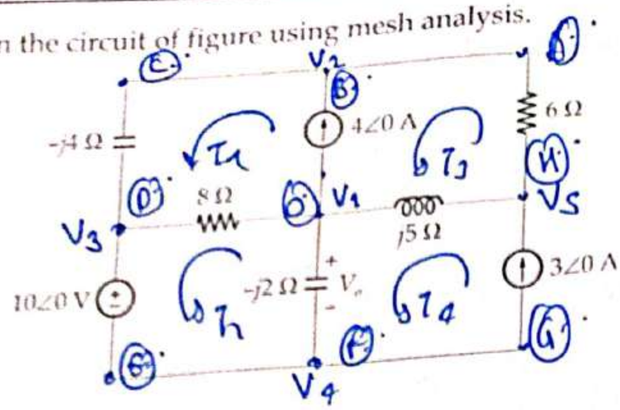
$2.5I_2 = -3.5I_1 + V_2$

$I_2 = -\frac{3.5}{2.5}I_1 + \frac{1}{2.5}V_2$

$\boxed{I_2 = -1.4I_1 + 0.4V_2}$ --- (v)

From (iv) & (v), we have $\boxed{\begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{bmatrix} = \begin{bmatrix} -2.8\Omega & -1.2 \\ -1.4 & 0.4\mho \end{bmatrix}}$

Q.4 (c) Solve for V_o in the circuit of figure using mesh analysis.



[20 marks]

Ans.) We have,

By KVL on ABCDOHA

$$V_A - (-4j)I_1 - 8(I_1 - I_2) - 5j(I_3 - I_4) - 6I_3 = V_A$$

$$4jI_1 - 8I_1 + 8I_2 - 5jI_3 + 5jI_4 - 6I_3 = 0$$

$$(4j-8)I_1 + (8)I_2 + (-6-5j)I_3 + (5j)I_4 = 0 \quad \text{— (i)}$$

We have, $I_4 = 3\angle 0^\circ\, A$ — (ii)

We have, $I_1 - I_3 = 4\angle 0^\circ\, A$ — (iii)

By KVL on loop FODGF, we have

$$V_F - (-2j)(I_2 - I_4) - 8(I_2 - I_1) - 10 = V_F$$

$$10 = 2jI_2 - 2jI_4 - 8I_2 + 8I_1$$

$$8I_1 + (8+2j)I_2 - 2jI_4 = 10$$

$$8I_1 + (8+2j)I_2 = 10 + 6j \quad \text{— (iv)}$$

Putting (ii) on (i)

$(8-4j)I_1 + (-8)I_2 + (6+5j)I_3 = 15j$

$(8-4j)I_1 + (-8I_2) + (6+5j)(I_1-4) = 15$

$(14+j)I_1 + (-8)I_2 = 39+20j$

& $8I_1 + (8+2j)I_2 = 10+6j$

$$\begin{bmatrix} 14+j & -8 \\ 8 & 8+2j \end{bmatrix}\begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} 39+20j \\ 10+6j \end{bmatrix}$$

$$\begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \frac{\begin{bmatrix} 8+2j & 8 \\ -8 & 14+j \end{bmatrix}\begin{bmatrix} 39+20j \\ 10+6j \end{bmatrix}}{(174+36j)} = \begin{bmatrix} 2.5525\angle 22.904^\circ \\ 1.0684\angle -127.348^\circ \end{bmatrix}$$

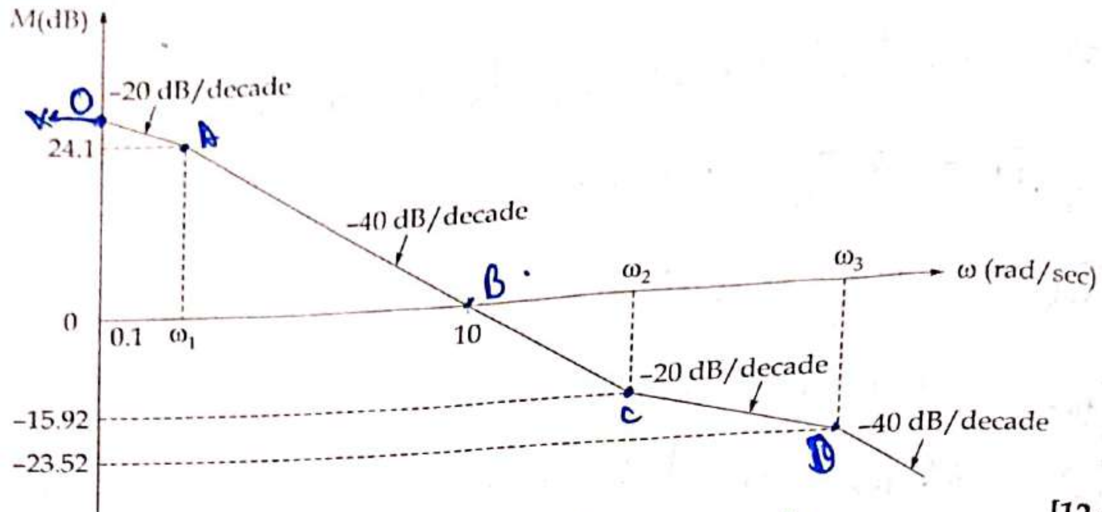
$V_0 = (-2j)(I_4 - I_2)$

$V_0 = (-2j)(3 - 1.0684\angle -127.348^\circ)$

$\boxed{V_0 = 8.1188\angle -82.73^\circ \ V}$

Section B : Control System

Q.5 (a) Obtain the open loop transfer function for a unity negative feedback system whose bode magnitude plot is shown below:



[12 marks]

(Ans.) We have corner frequencies at ω_1, ω_2 & ω_3.

∵ slope decreases by 20 dB/dec ∴ we have 1 pole at ω_1. Similarly ∵ slope increases by 20dB/dec. ∴ we have 1 zero at ω_2 & similarly we have 1 pole at ω_3. Initial slope = -20dB/dec

∴ we have initial 1 pole at origin.

Now, taking the line segment between A & B, we have

$$\frac{24.1 - 0}{\log\left(\frac{10}{\omega_1}\right)} = 40 \Rightarrow 4 = \frac{10}{\omega_1} \Rightarrow \omega_1 = 2.5 \text{ rad/sec}$$

Now, taking the line segment between O & A, we have

Gain at O = x (say).

$\therefore \dfrac{x-29.1}{\log\left(\frac{\omega_1}{0.1}\right)} = 20 \Rightarrow \dfrac{x-29.1}{\log(25)} = 20$

$\Rightarrow x = 52.058\ dB.$

$20\log_{10}k = 52.058 \rightarrow k = 400.811.$

Now, for B, C we have

$\dfrac{0-(-15.92)}{\log\left(\frac{\omega_2}{10}\right)} = 40 \Rightarrow \dfrac{15.92}{40} = \log\left(\dfrac{\omega_2}{10}\right)$

$\Rightarrow \omega_2 = 25\ rad/sec.$

Now, for CD, we have

$\dfrac{-15.92-(-23.52)}{\log\left(\frac{\omega_3}{25}\right)} = 20$

$\omega_3 = 60\ rad/sec.$

Now, from above, we can conclude O.L.T.F.,

$$\boxed{G(s) = \dfrac{(400.811)\left(1+\frac{s}{25}\right)}{s\left(1+\frac{s}{2.5}\right)\left(1+\frac{s}{60}\right)}}$$

Q.5 (b) A servo mechanism is represented by the equation :

$$\frac{d^2y}{dt^2} + 4.8\frac{dy}{dt} = 144E$$

where $E = C - 0.5y$ is the actuating signal. Find the value of damping ratio, damped and undamped frequency of oscillation. Draw the block diagram of the system described by the above equation.

[12 marks]

(Ans.)

$$\frac{d^2y}{dt^2} + 4.8\frac{dy}{dt} = 144E \quad \text{(i)}$$

$$E = C - 0.5y \quad \text{(ii)}$$

Putting (ii) in (i), we have

$$\ddot{y} + 4.8\dot{y} = 144(C - 0.5y) = 144C - 72y$$

$$\ddot{y} + 4.8\dot{y} + 72y = 144C$$

Taking laplace transform, we have

$$s^2Y(s) + 4.8sY(s) + 72Y(s) = 144C(s)$$

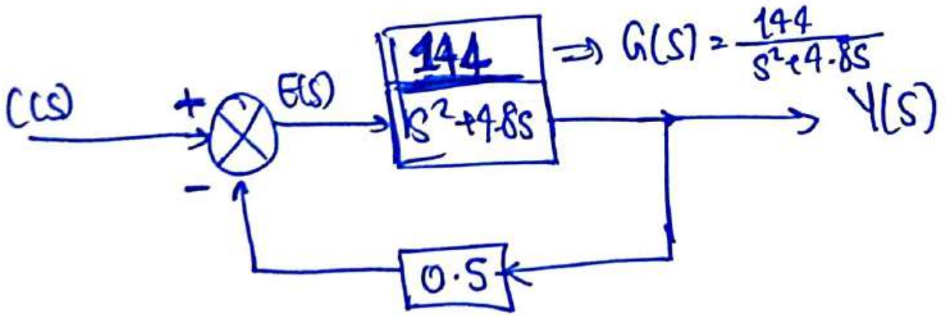
$$\frac{Y(s)}{C(s)} = \frac{144}{s^2 + 4.8s + 72} = \frac{K}{s^2 + 2\zeta\omega_n s + \omega_n^2}$$

now, we have on compary.

$\omega_n^2 = 72 \Rightarrow \omega_n = 6\sqrt{2}$ rad/sec. $\Rightarrow \omega_n = 8.485$ rad/sec.

$\Rightarrow 2\zeta(6\sqrt{2}) = 4.8 \Rightarrow \zeta = 0.2828.$

$\omega_d = \omega_n\sqrt{1-\zeta^2} = 8.485\sqrt{1-(0.2828)^2} \Rightarrow \omega_d = 8.1386$ rad/sec



Closed loop system with unity feedback has the forward loop transfer function as :

$$G(s) = \frac{28.8}{s(1 + 0.2s)}$$

Modify the design using cascaded compensation to satisfy the optimum performance criterion, so that the transient response to unit step input reaches its final steady state value in minimum time without having any overshoot. Take gain of proportional controller equal to 5.

[12 marks]

(d) A unity negative feedback system has open loop transfer fucntion, $G(s) = \frac{K}{s(1+sT)}$, where K and T are positive constants. Determine the factor by which the amplifier gain K be reduced so that peak overshoot of the unit step response is reduced from 80% to 50%?

[12 marks]

S:) we have, $G(s) = \frac{K}{s^2T+s}$

now, $1+G(s)H(s) = 1+\frac{K}{s^2T+s} = s^2T+s+K = 0$

$\Rightarrow s^2+\left(\frac{1}{T}\right)s+\left(\frac{K}{T}\right) = 0$

comparing with $s^2+2\zeta\omega_n s+\omega_n^2 = 0$,

we have $\omega_n = \sqrt{\frac{K}{T}}$

$2\zeta\sqrt{\frac{K}{T}} = \frac{1}{T}$

$\Rightarrow \zeta = \frac{1}{2\sqrt{KT}}$.

Now, we have initial overshoot = 80%

$\Rightarrow 0.8 = e^{-\frac{\zeta\pi}{\sqrt{1-\zeta^2}}}$

$\Rightarrow \ln(0.8) = \frac{-\zeta\pi}{\sqrt{1-\zeta^2}} \Rightarrow 0.071 = \frac{\zeta}{\sqrt{1-\zeta^2}}$

$\Rightarrow 14.078\zeta = \sqrt{1-\zeta^2}$

$199.2125\zeta^2 = 1$

$\zeta_1 = 0.0708$ — (i)

Now, for overshoot to be 50%, we have

$e^{-\frac{\zeta\pi}{\sqrt{1-\zeta^2}}} = 0.5$

$\Rightarrow \frac{-\zeta\pi}{\sqrt{1-\zeta^2}} = \ln(0.5) \Rightarrow \frac{\zeta}{\sqrt{1-\zeta^2}} = 0.2206 \Rightarrow 4.532\zeta = \sqrt{1-\zeta^2}$

$20.5423\zeta^2 = 1-\zeta^2$

$\Rightarrow \zeta_2 = 0.2154$. — (ii)

Now, from (i), we have

$\xi_1 = 0.0708 = \dfrac{1}{2\sqrt{K_1 T}}$. —(i)

from (ii), we have

$\xi_2 = 0.2154 = \dfrac{1}{2\sqrt{K_2 T}}$ —(ii)

(i) ÷ (ii), we have

$\therefore \quad \dfrac{0.0708}{0.2154} = \sqrt{\dfrac{K_2}{K_1}}$

$\Rightarrow \quad 0.108 = \dfrac{K_2}{K_1}$

$\Rightarrow K_2 = 0.108 K_1$

$\therefore$ % reduction $= \dfrac{|K_2 - K_1|}{K_1} \times 100\%$

$= \dfrac{0.108K_1 - K_1}{K_1} \times 100\%$

$\therefore$ there should be 89.196% reduction in K_1.

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e) The open loop transfer function of a unity negative feedback system is given as, $G(s) = \frac{K}{2s(1+0.1s)(1+s)}$. Determine the value of 'K' for which the gain margin of the system is 14 dB.

[12 marks]

we have, $G(j\omega) = \frac{K}{2j\omega(1+0.1j\omega)(1+j\omega)}$

$\angle G(j\omega) = -90^\circ - \tan^{-1}(0.1\omega) - \tan^{-1}(\omega)$

for ω_{pc},

$\angle G(j\omega)\big|_{\omega=\omega_{pc}} = -180^\circ$

$+90^\circ + \tan^{-1}(0.1\omega) + \tan^{-1}\omega = +180^\circ$

$\tan^{-1}(0.1\omega) = 90^\circ - \tan^{-1}\omega$

$\tan^{-1}(0.1\omega) = \tan^{-1}\left(\frac{1}{\omega}\right)$

$\Rightarrow \omega^2 = 10$

$\Rightarrow \omega = \sqrt{10} \Rightarrow \omega_{pc} = 3.1623$ rad/sec

Now, for gain margin, we first find our

$|G(j\omega)|_{\omega=\omega_{pc}}$

$|G(j\omega)| = \frac{K}{2\omega\sqrt{1+0.01\omega^2}\sqrt{1+\omega^2}}$

at $\omega = \sqrt{10}$ rad/sec., we have

$$|G(j\omega)|_{\omega=\omega_{pc}} = \frac{k}{2\sqrt{10}\sqrt{1+0.01\times 10} \times \sqrt{1+10}}$$

$$= \frac{k}{2\sqrt{10}\sqrt{1.1}\sqrt{11}} = \frac{k}{22}.$$

$$|G(j\omega)|_{\omega=\omega_{pc}} = X = \frac{k}{22}$$

Now, $G.M. = 20 \log\left(\frac{1}{X}\right)$ (in dB).

$$\Rightarrow 14\,dB = 20 \log\left(\frac{1}{X}\right)$$

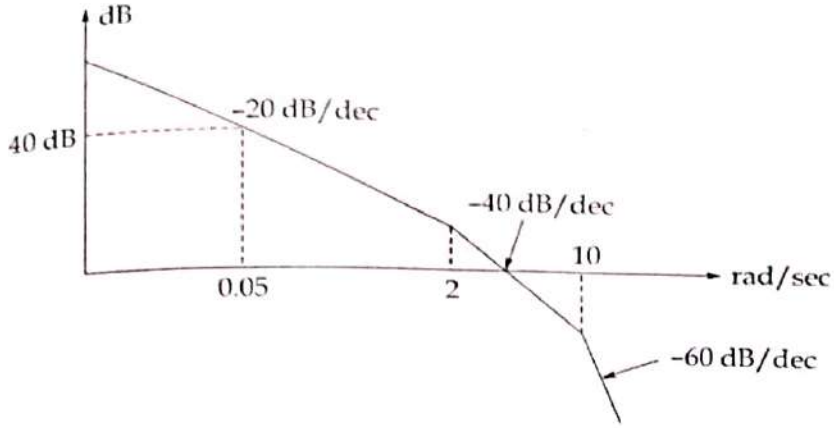
$$\Rightarrow 0.7 = \log\left(\frac{1}{X}\right)$$

$$0.7 = \log\left(\frac{22}{k}\right)$$

$$\frac{22}{k} = 10^{0.7}$$

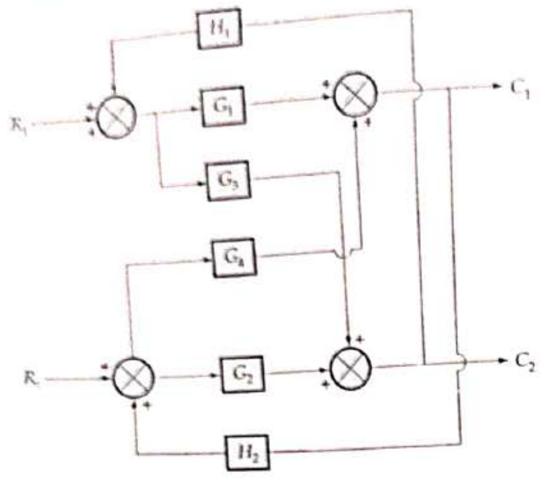
$$\Rightarrow k = 4.3895.$$

a) The open loop transfer function of a unity feedback system is given by $G(s)H(s) = e^{-Ts}G_1(s)$, where $G_1(s)$ is minimum phase system. The approximate bode magnitude plot of the open loop transfer function is shown in the figure below. If the phase margin of the system is $-18.19°$, determine the transportation lag T.

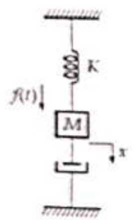


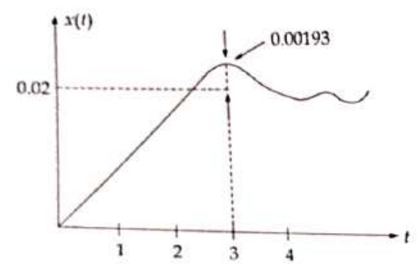
[20 marks]

Q.6 (b) (i) Evaluate $\frac{C_2}{R_1}$ for the system whose block diagram representation is shown in figure below. (Use block diagram reduction technique to solve).



(ii) Figure below shows a mechanical system and the response when 10 N of force is applied to the system. Determine the values of M, F, K. The dimension '*x*' is in meter.





[10 + 10 marks]

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Q.6 (c) Derive the expression for the transfer function of an ac servomotor and obtain the same in respect of a servomotor having following data:

(i) Starting torque = 0.166 N-m

(ii) Moment of inertia, $J = 1 \times 10^{-5}$ kgm^2

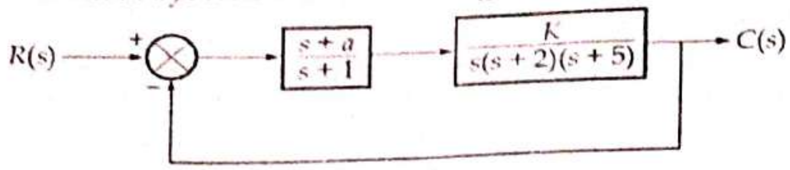
(iii) Supply voltage = 115 Volts

(iv) No load speed = 2904 rpm

(Assume friction to be zero)

[15 + 5 = 20 marks]

Q.7 (a) (i) A position control system is shown in figure below :



K and a are the parameters of the system. Determine the range of K and a for w system is stable.

(ii) Sketch the root-locus of $G(s) = \dfrac{K(s+1)}{s^2(s+2)}$.

[10 + 10 ma

(Ans.) (ii). We have, $G(s) = \dfrac{K(s+1)}{s^2(s+2)}$

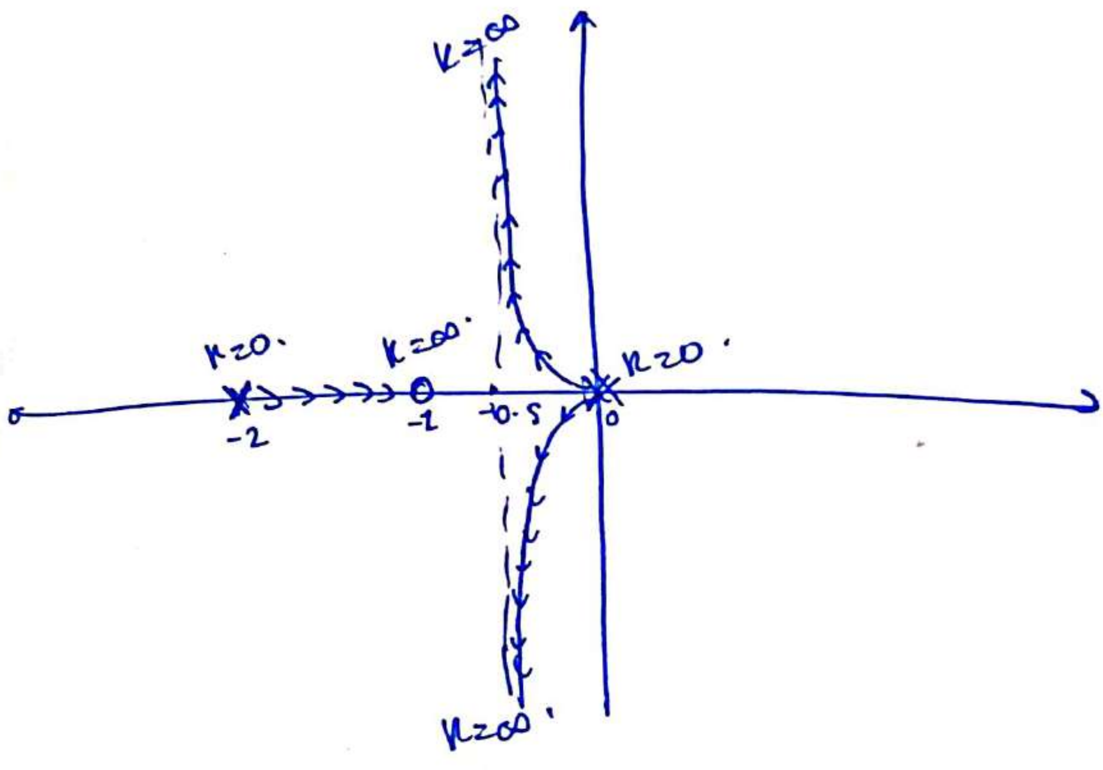
$P \Rightarrow s = 0, 0, -2 \Rightarrow K = 0$

$Z \Rightarrow s = -1 \Rightarrow K = \infty$

$P - Z = 2 \Rightarrow$ 2 asymptotes.

$\therefore \phi_A = \dfrac{(2q+1)(180°)}{2} = 90°, 270°$

Centroid $= \dfrac{\Sigma P - \Sigma Z}{P - Z} = \dfrac{(-2 - (-1))}{2} = -0.5$

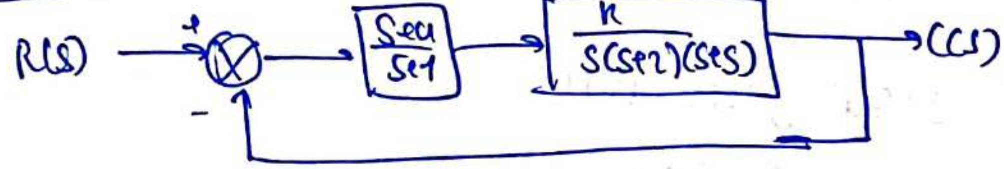


Root locus exists between -1 & -2 on real axis ∵ of even $\Sigma(P+Z)$ on RHS side of it

Now, the root locus would depart to infinity from origin ∵ of two root at origin &

Centroid would be at -0.5 & angles of asymptote would be 90 & 270°.

9.



$$G(s) = \frac{(s+a)k}{s(s+1)(s+2)(s+5)}$$

$$1+G(s)H(s) = 1+\frac{(s+a)k}{s(s+1)(s+2)(s+5)}$$

$$= (s^2+5s)(s^2+3s+2)+ks+ak$$

$$= s^4+3s^3+2s^2+5s^3+15s^2+10s+ks+ak$$

Characteristic eqn $= s^4+8s^3+17s^2+(k+10)s+ak$

$s^4 + 8s^3 + 17s^2 + (k+10)s + ak = 0$

s^4	1	17	ak
s^3	8	$(k+10)$	0
s^2	$\frac{136-k-10}{8} = \frac{126-k}{8}$	ak	0
s^1	$\frac{\left(\frac{126-k}{8}\right)(k+10) - 8ak}{\left(\frac{126-k}{8}\right)}$	0	0
s^0	ak		

from s^2 row, we have

$\frac{126-k}{8} > 0 \Rightarrow k < 126$.

from s^1 row, we have

$$\frac{\left(\frac{126-k}{8}\right)(k+10) - 8ak}{\left(\frac{126-k}{8}\right)} > 0$$

$\Rightarrow (126-k)(k+10) - 64ak > 0$

$126k + 1260 - k^2 - 10k - 64ak > 0$

$k^2 - 116k + 64ak - 1260 < 0$

$k^2 + k(64a - 116) + (-1260) < 0$ — (ii).

$ak > 0 \Rightarrow$ $k > 0$ & $a > 0$ or $k < 0$ & $a < 0$ — (iii).

From (iii)', we have

$k^2 + k(64a - 116) + (-1260) > 0$

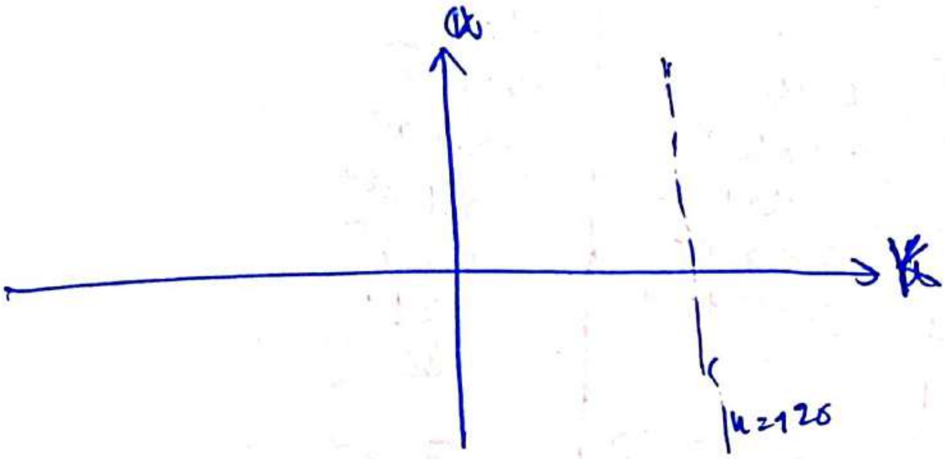
$\Rightarrow$ D < 0 (for system to be always posit)

$(64a - 116)^2 - 4(1)(-1260) < 0$

$(64a - 116)^2 + 5040 < 0$

~~$64a^2 - 1856a + 18496 < 0$ ⇒ True for no value of a.~~

$4096a^2 - 14848a + 18496 < 0 \Rightarrow$ Not true for any value of a.



$\therefore$ the fourth row would always be negative hence the system can never be stable.

Q.7 (b) Sketch the polar plot of the transfer function given below. Determine whether the plot crosses the real axis. If so, determine the frequency at which the plot cross the real axis and the corresponding magnitude $|G(j\omega)|$.

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

[20 marks]

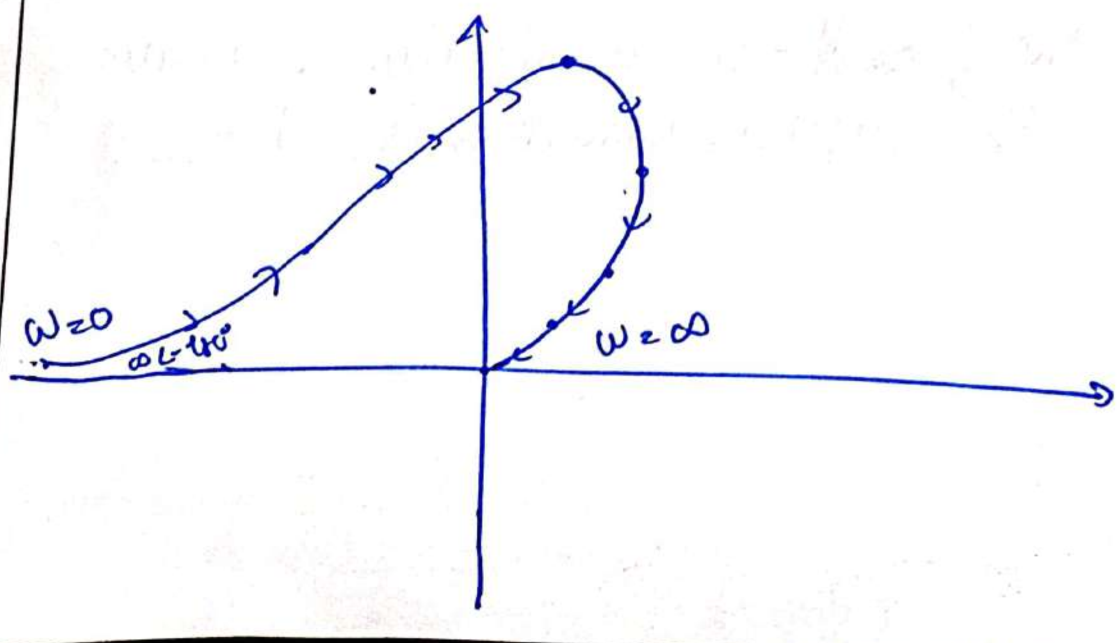
(Ans.) We have, $G(s) = \frac{1}{s^2(1+s)(1+2s)}$

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

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

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

ω	$\lvert G(j\omega)\rvert$	$\angle G(j\omega)$
0	∞	$-180°$
1	0.3162	$-288.4°$
5	2.8×10^{-4}	$-342.9°$
10	4.9×10^{-5}	$-351.4°$
50	2.9×10^{-8}	$-358.2°$
100	4.9×10^{-9}	$-359.1°$
∞	0	$-360°$
1000		
~~∞~~	~~0~~	~~$-360°$~~



$$G(j\omega) = \frac{-1}{\omega^2(1-2\omega^2+3j\omega)} = \frac{-1\ (1-2\omega^2-3j\omega)}{\omega^2(1-2\omega^2+3j\omega)(1-2\omega^2-3j\omega)}$$

$$G(j\omega) = \frac{-1\ (1-2\omega^2-3j\omega)}{\omega^2((1-2\omega^2)^2+9\omega^2)}$$

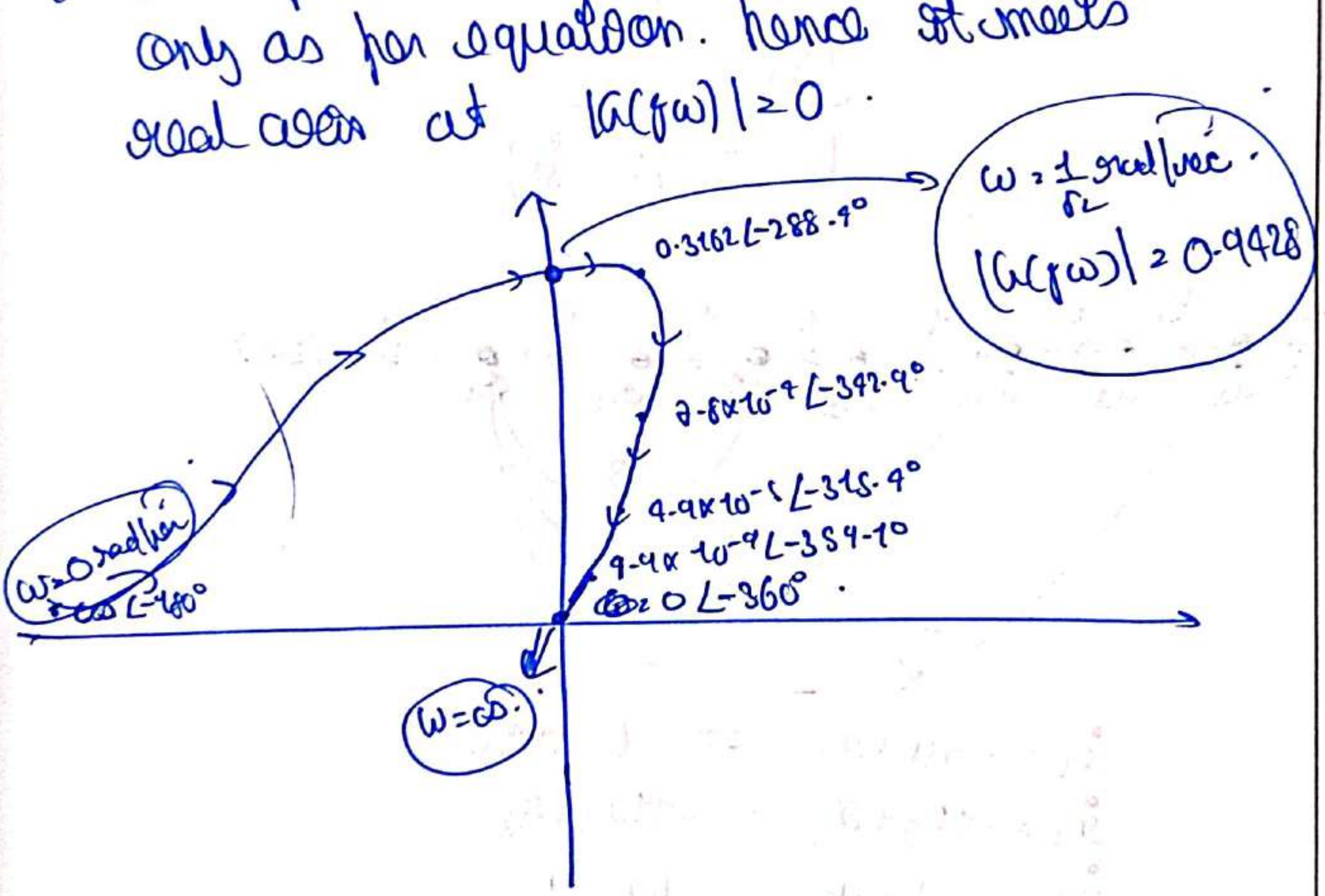
$$= \frac{(2\omega^2-1)+j(3\omega)}{\omega^2(4\omega^4+5\omega^2+1)}$$

Now, to cross real axes, imaginary part = 0

$$\Rightarrow \frac{3\omega}{\omega^2(4\omega^4+5\omega^2+1)} = 0$$

$$\Rightarrow \frac{3}{\omega(4\omega^4+5\omega^2+1)} = 0$$

∴ it is possible to cross real axis at $\omega=\infty$ only as per equation. hence it meets real axis at $|G(j\omega)|=0$.



Q.7 (c) Construct the state model for a system characterised by the differential equation :

$$\frac{d^3y}{dt^3} + \frac{6d^2y}{dt^2} + \frac{11dy}{dt} + 6y = u$$

Give the block diagram representation of the state model.

[15 + 5 = 20 mar

(Ans.) we have, $\dddot{y} + 6\ddot{y} + 11\dot{y} + 6y = u$.

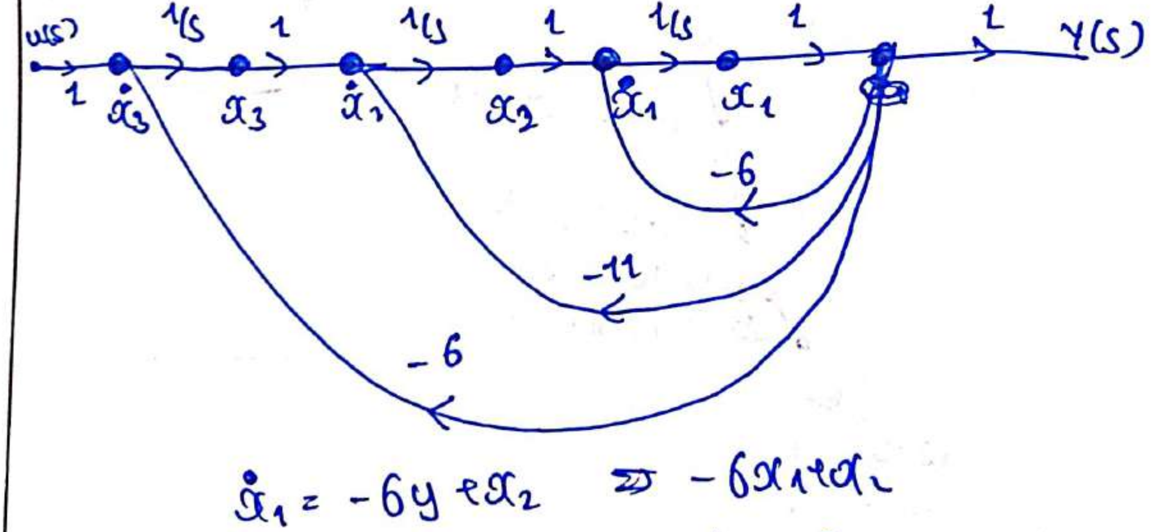
Now taking laplace tranform, we have

$$(s^3 + 6s^2 + 11s + 6)Y(s) = U(s)$$

$$\frac{Y(s)}{U(s)} = \frac{1}{s^3 + 6s^2 + 11s + 6}$$

$$= \frac{1/s^3}{1 + \frac{6}{s} + \frac{11}{s^2} + \frac{6}{s^3}} = \cancel{\frac{1}{s^3}}$$

$$= \frac{\left(\frac{1}{s^3}\right)}{1 - \left(-\frac{6}{s} - \frac{11}{s^2} - \frac{6}{s^3}\right)}$$



$\dot{x}_1 = -6y + x_2 \Rightarrow -6x_1 + x_2$

$\dot{x}_2 = -11y + x_3 = -11x_1 + x_3$

$\dot{x}_3 = -6y + u. = -6x_1 + u$

$y = x_1$

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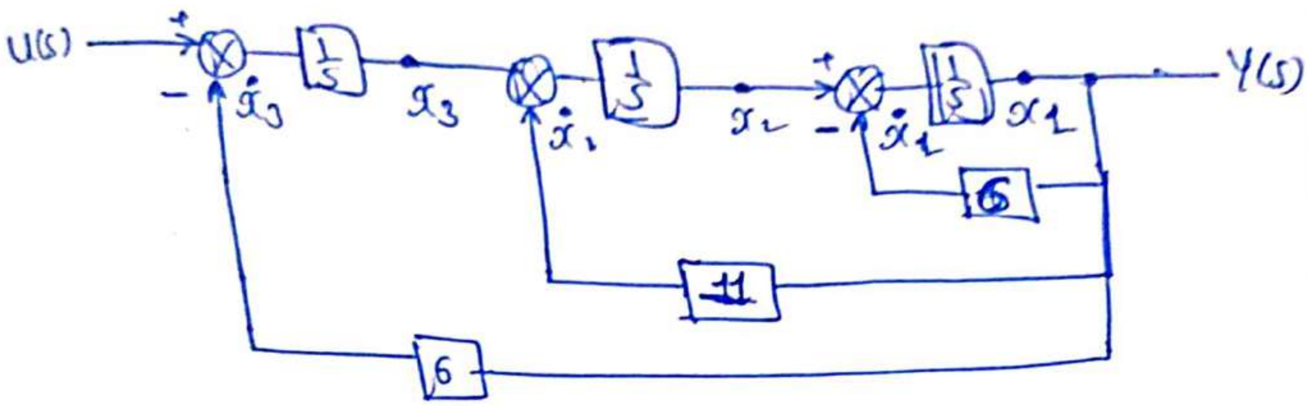
$$\therefore \begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \\ \dot{x}_3 \end{bmatrix} = \begin{bmatrix} -6 & 1 & 0 \\ -11 & 0 & 1 \\ -6 & 0 & 0 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix} u$$

$$y = \begin{bmatrix} 1 & 0 & 0 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix}$$



Q.8 (a) The open-loop transfer function of a unity feedback control system is given below:

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

Plot the root locus and determine the value of K at the breakaway point.

[20 marks]

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(b) The open loop transfer function of a feedback control system is

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

Find the restriction on K for stability. Find the value of K for the system to have a gain margin of 3 dB. With this value of K, find the gain cross over frequency and phase margin. Use Nyquist Approach.

[20 marks]

(d) The state space model of a second order system given below is designed using feedback control system.

$$\dot{x} = \begin{bmatrix} 2 & 3 \\ -1 & 4 \end{bmatrix} x + \begin{bmatrix} 0 \\ 1 \end{bmatrix} u$$

$$y = \begin{bmatrix} 1 & 0 \end{bmatrix} x$$

(i) What are the conditions for the desired response? Also check whether desired response is possible or not.

(ii) Design an observer system such that the above system has settling time of 0.5 sec and damping frequency of 6 rad/sec.

[8 + 12 marks]

OOOO

Space for Rough Work

Space for Rough Work

Space for Rough Work