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(To be filled by candidate)

Name of Candidate : ADITYA SRIVASTAVA

Roll No. : ....

Registration Number : .... Date of Examination : 18/08/22

CSE 2022 : MAIN TEST SERIES

ELECTRICAL ENGINEERING

Test -6
Full Syllabus Test
Paper-II

Time Allowed : Three Hours

Maximum Marks: 250

GENERAL INSTRUCTIONS

There are EIGHT questions divided in TWO SECTIONS. Candidate has to attempt FIVE questions in all. Question no. 1 and 5 are compulsory and out of remaining, THREE are to be attempted choosing at least ONE from each section.
This Question-cum Answer Booklet (QCAB) contains 73 pages. Immediately on receipt of the booklet, please check that this booklet does not have any misprint or torn or missing pages etc. If so, get it replaced by a fresh booklet.
Candidates must read the instructions on this page and the following pages carefully before attempting the paper.
Candidates should attempt the questions strictly in accordance with the instructions specified in the question paper and in the space prescribed under each question in the booklet. Any answer written outside the space allotted will not be given credit.
Question paper will be provided separately and can be taken by the candidates after conclusion of the exam.

SUBJECT/PAPER
ELECTRICAL ENGINEERING | Invigilator's Sign. : . . . .

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Name of Candidate : ADITYA SRIVASTAVA

Test : Test 6 (Paper 2)

Stream : Electrical Engineering

Centre :

Online ☑

Offline ☐

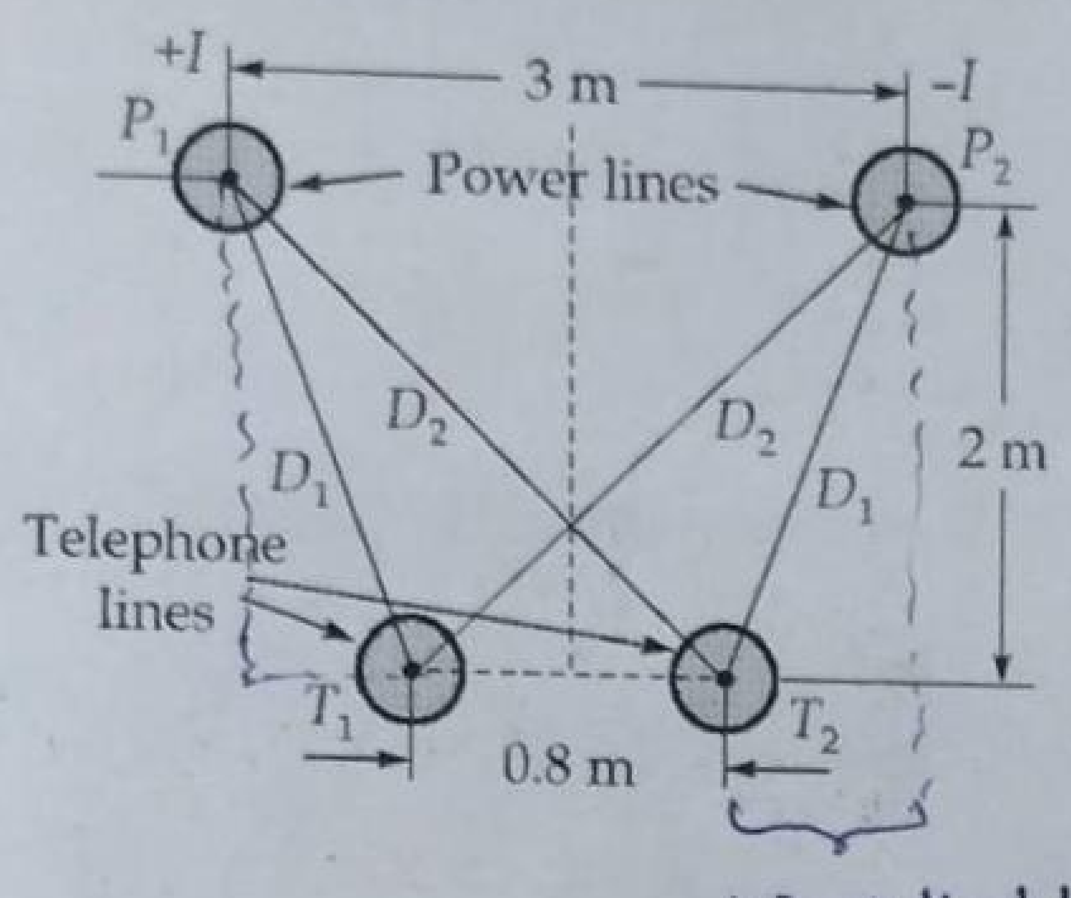
Q. No.	Page No.	Marks	Total	Signature	Q. No.	Page No.	Marks	Total	Signature
1	1				5	38			
2	11				6	48			
3	20				7	56			
4	29				8	65			
GRAND TOTAL									

EVALUATION INDICATORS	Remarks			
	Excellent	Good	Average	Needs Improvement
1. Clarity of Concepts				
2. Relevance to question				
3. Illustration - Diagram/Graphs/ Flow chart/Formula				
4. Presentation				
5. Accuracy				

Observations:

Section A

(a) A single-phase 50 Hz power line is supported on a horizontal cross-arm. The spacing between the conductors is 3 m. A telephone line is supported symmetrically below the power line as shown in figure below. Calculate the mutual inductance between the two circuits and the voltage induced per kilometer in the telephone line if the current in the power line is 100 A. Assume the telephone line current to be zero.



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$$D_1 = \sqrt{2^2 + (1.1)^2} = 2.2825\text{ m}$$

$$D_2 = \sqrt{2^2 + (1.1+0.8)^2} = 2.7586\text{ m}$$

Now mutual inductance is given by

$$L = 2\times10^{-7} \ln\left(\frac{\text{mutual GMD}}{\text{GMR}}\right)$$

Here +I and −I are opposing currents

$$\Rightarrow M = 4\times10^{-7} \ln\left(\frac{D_2}{D_1}\right) \text{ H/m}$$

$$= 75.78\times10^{-9} \text{ H/m}$$

or $\boxed{M = 75.78\ \mu\text{H/km}}$

Now voltage induced $= I \times \omega L$ V/km

$$= 100\times100\pi\times75.78\times10^{-6} \text{ V/km}$$

$$= 2.3807 \text{ V/km}$$

Design a syndrome calculator for a (7, 4) cyclic Hamming code generated by the polynomial $G(p) = p^3 + p + 1$. Evaluate the syndrome for $Y = (1001101)$. 10

Now $p^6 \div (p^3+p+1)$

gives remainder $p^2+1 = [0101]$

$p^7 \div (p^3+p+1)$ gives remainder $1 = [0001]$

$p^5 \div (p^3+p+1)$ gives remainder

$p^2+p+1 = [0111]$

$p^4 \div (p^3+p+1)$ gives remainder p^2+p

$= [0110]$

So Matrix $P = \begin{bmatrix} 0 & 0 & 1 \\ 1 & 0 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 0 \end{bmatrix}$

$\therefore$ $G = [I_k | P]$ & $H = [P^T | I_{n-k}]$

$\Rightarrow H = \begin{bmatrix} 0 & 1 & 1 & 1 & 1 & 0 & 0 \\ 0 & 0 & 1 & 1 & 0 & 1 & 0 \\ 1 & 1 & 1 & 0 & 0 & 0 & 1 \end{bmatrix}$

$\Rightarrow$ Now syndrome calculator is $Y \cdot H^T \Rightarrow$ $H^T = \begin{bmatrix} 0 & 0 & 1 \\ 1 & 0 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 0 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$

Now $Y \cdot H^T = [1001101] \begin{bmatrix} 0 & 0 & 1 \\ 1 & 0 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 0 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$

$\boxed{S = [010]}$

$$\begin{array}{l} p^3+p+1 \overline{)\, p^6 \,(} \; p^3+p+1 \\ \quad p^6+p^4+p^3 \\ \hline \quad p^4+p^3 \\ \quad p^4+p^2+p \\ \hline \quad p^3+p^2+p \\ \quad p^3+p+1 \\ \hline \quad p^2+1 \end{array}$$

$$\begin{array}{l} p^3+p+1 \overline{)\, p^7 \,(} \; p^4+p^2+p+1 \\ \quad p^7+p^5+p^4 \\ \hline \quad p^5+p^4 \\ \quad p^5+p^3+p^2 \\ \hline \quad p^4+p^3+p^2 \\ \quad p^4+p^2+p \\ \hline \quad p^3+p \\ \quad p^3+p+1 \\ \hline \quad 1 \end{array}$$

$$\begin{array}{l} p^3+p+1 \overline{)\, p^5 \,(} \; p^2+1 \\ \quad p^5+p^3+p^2 \\ \hline \quad p^3+p^2 \\ \quad p^3+p+1 \\ \hline \quad p^2+p+1 \end{array}$$

$$\begin{array}{l} p^3+p+1 \overline{)\, p^4 \,(} \; p \\ \quad p^4+p^2+p \\ \hline \quad p^2+p \end{array}$$

(i) How can insulation resistance of the cable be measured by loss of charge method?

(ii) A length of cable is tested for insulation resistance by the loss of charge method. An electrostatic voltmeter of infinite resistance is connected between the cable conductor and earth, forming there with a joint capacitance of 600 pF. If is observed that after charging the voltage falls from 250 V to 92 V in 1 minute. Calculate the insulation resistance of the cable.

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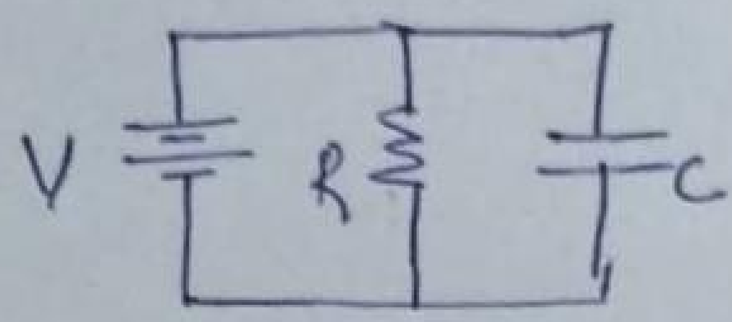
Insulation resistance of the cable can be measured



by studying the decay of voltage and hence charge $(Q = CV)$ on the capacitor of cable.

We know that time constant $\tau = RC$ and charge decay equation is

$$V = V_0 e^{-t/RC}$$

Now $92 = 250 \times e^{-60s/RC}$

$$\Rightarrow e^{60/RC} = \frac{250}{92}$$

$$\frac{60}{RC} = 0.9997 \approx 1$$

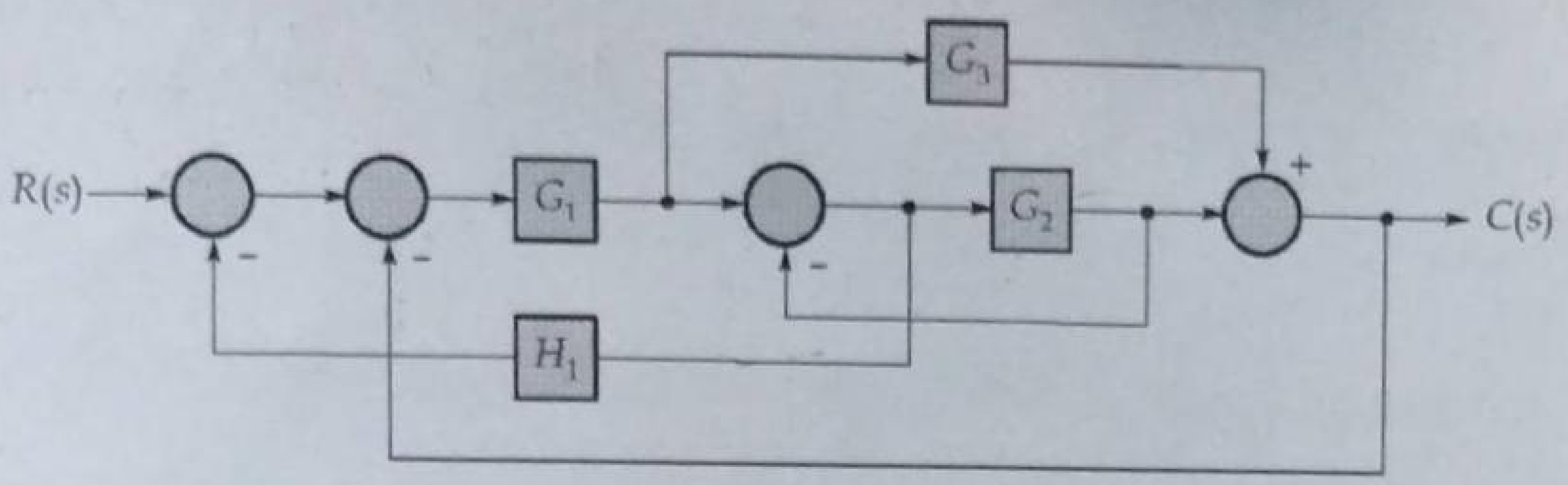
$$\Rightarrow R = \frac{60}{600 \times 10^{-12}} \Omega$$

$\boxed{R = 100\ G\Omega}$ or $100 \times 10^9\ \Omega$

Distinguish between the three modes of 8255.

10

A system is represented by the block diagram shown in figure below. Draw the signal flow graph (SFG) and determine the overall transmittance $\frac{C(s)}{R(s)}$ by using Mason's gain formula.



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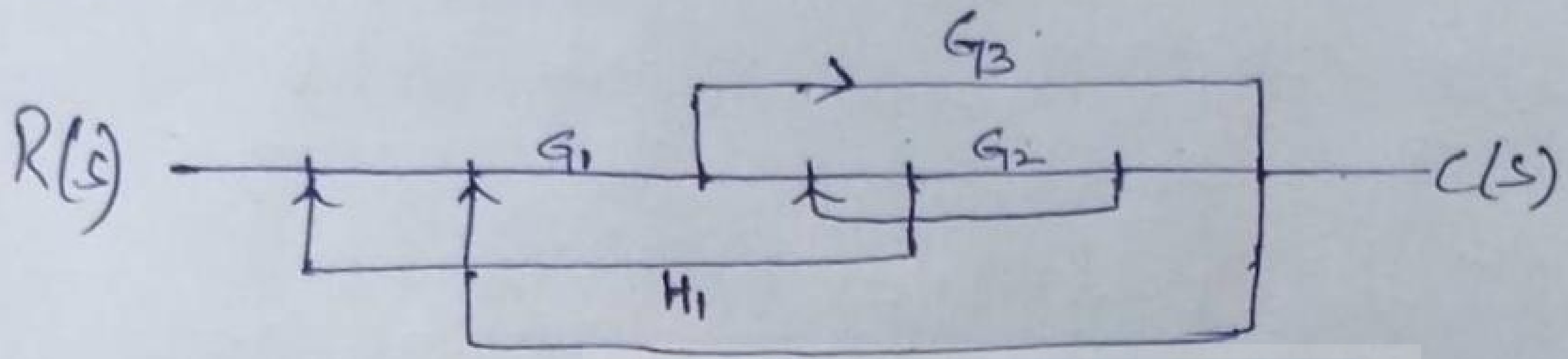
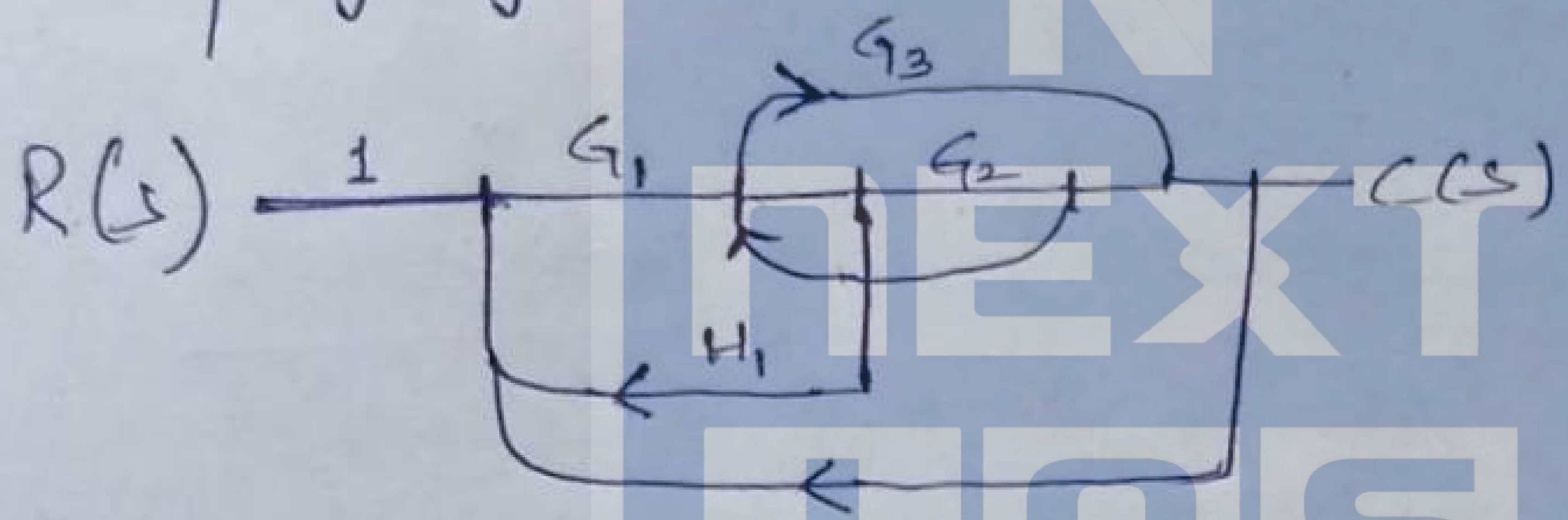


Simplifying -



Forward paths = G_1G_2 & G_1G_3

Loops = $-G_1H_1$, $-G_2$, $-G_1G_2$, $-G_1G_3$ non touching.

Non touching loops dont exist for any path.

So; By Mason's formula:-

$$\text{Transfer fn} = \frac{G_1G_2 + G_1G_3}{1 + G_1H_1 + G_2 + G_1G_2 + G_1G_3 + G_1G_2G_3}$$

or
$$\boxed{\frac{C(s)}{R(s)} = \frac{G_1(G_2+G_3)}{1+G_1H_1+G_2+G_1G_2+G_1G_3+G_1G_2G_3}}$$

(i) Mention advantages and disadvantages of numerical relay.

(ii) In a 132 kV system, the inductance and capacitance up to the location of the circuit breaker are 0.4 H and 0.015 μF respectively. Determine

1. the maximum value of the restriking voltage.
2. frequency of transient oscillation, and
3. the maximum value of RRRV.

10 + 10

Numerical relay has following advantages :-

1) Compactness in size and reliability in operation.
2) Flexibility offered since they are programmable
3) Adaptable by monitoring operating values from digital input.
4) Lower cost per function compared to electromechanical & static counterparts.

Disadvantages

1) Short life cycle due to fast pace of change and advancements in each generation
2) Difficult to maintain expertise as changes take place frequently.
3) Transient susceptibility leading to incorrect operations.

(ii) $V_{ph} = \frac{132}{\sqrt{3}} kV$ or $V_m = \frac{132}{\sqrt{3}} \times \sqrt{2}\, kV = 107.78 kV$

$L = 0.4H$; $C = 0.015 \mu F$.

⇒ Max value of restriking voltage $= 2 \times V_{ar}$

$= 2 \times K \times V_m \times \sin\phi$

Here $\phi = 90°$ & $K = 1.0$

$= 2 \times 107.78 kV$

$= \boxed{215.56 kV}$

⇒ Freq. of transient oscillation $= \frac{1}{2\pi\sqrt{LC}}$

$= \frac{1}{2\pi\sqrt{0.4 \times 0.015 \times 10^{-6}}}$

$= \boxed{2.054 kHz}$

⇒ $(RRRV)_{max} = \frac{V_m}{\sqrt{LC}}$

$= \frac{107.78 \times 10^3}{\sqrt{0.4 \times 0.015 \times 10^{-6}}}$

$= \boxed{1.39 kV/\mu s}$

So, max value of restriking voltage = 215.56 kV

freq. of transient oscillation = 2.054 kHz

max value of rate of restriking voltage = 1.39 kV/μs

Q 2 (b) (i) The open loop transfer function of a unity feedback system is $G(s) = \frac{K(s+\alpha)}{s(s^2+12s+32)}$.

Find the value of K and α so that the velocity error constant is 6.25 and the second-order response has a natural frequency of 5 rad/sec. Assume that the system is stable. 10

$$K_v = \lim_{s\to 0} sG(s)$$

$$= \lim_{s\to 0} \frac{K(s+\alpha)\times \cancel{s}}{\cancel{s}(s^2+12s+32)}$$

$$= \lim_{s\to 0} \frac{K(s+\alpha)}{s^2+12s+32} = \frac{K\alpha}{\cancel{28}\,32}$$

$$\Rightarrow K\alpha = 32\times 6.25 = 200 \longrightarrow (1)$$

Now given $\omega_n = 5$ rad/s

From the $G(s)$; we get characteristic eq^n :-

$$s^3+12s^2+32s+Ks+K\alpha = 0$$

or $$s^3+12s^2+(32+K)s+200=0 \longrightarrow (ii)$$

comparing with $(s+P)(s^2+2\xi\omega_n s+\omega_n^2)$

$$= s^3+2\xi\omega_n s^2+\omega_n^2 s+Ps^2+2\xi\omega_n P s+P\omega_n^2$$

$$= s^3+(2\xi\omega_n+P)s^2+(\omega_n^2+2\xi\omega_n P)s+P\omega_n^2$$

Now $2\xi\omega_n+P = 12$

$\omega_n^2 P = 200$

& $\omega_n^2+2\xi\omega_n P = 32+K$

We know $\omega_n = 5$ rad/s $\Rightarrow P = \frac{200}{25} = 8$

$\Rightarrow 2\times\xi\times 5+8 = 12 \Rightarrow \xi = 0.4$

Now $K = (5)^2+2\times 0.4\times 5\times 8-32$

Candidates must not write on this margin

or $\boxed{K = 25}$

$\Rightarrow \alpha = \frac{200}{25} = 8$

$\boxed{\alpha = 8}$

Q.2 (b) (ii) The transfer function of the forward path and feedback path of a control system are:

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

Determine the values K, a and b if the phase margin is 45°, the gain crossover frequency is 2 rad/sec and the phase crossover frequency is 6 rad/sec.

10

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

$$\Rightarrow G(j\omega)H(j\omega) = \frac{K}{j\omega(-\omega^2+aj\omega+b)} \quad \text{——— (I)}$$

$$= \frac{K}{j\omega((b-\omega^2)+ja\omega)}$$

$$= \frac{K((b-\omega^2)-ja\omega)\times -j}{(-j)\times j\omega[(b-\omega^2)^2+a^2\omega^2]}$$

$$= \frac{-jK(b-\omega^2-ja\omega)}{\omega[(b-\omega^2)^2+a^2\omega^2]}$$

$$= \frac{K(-a\omega-j(b-\omega^2))}{\omega[(b-\omega^2)^2+a^2\omega^2]} \quad \text{——— (II)}$$

from (I) :– $\angle G(j\omega)H(j\omega) = -90 - \tan^{-1}\left(\frac{a\omega}{b-\omega^2}\right)$

Now for $\omega = 6$ rad/s ; $\angle G(j\omega)H(j\omega) = -180°$

$$\Rightarrow \cancel{-}90° = \cancel{-}\tan^{-1}\left(\frac{a\times 6}{b-6^2}\right)$$

$$\Rightarrow \tan 90° = \frac{a\times 6}{b-6^2}$$

$$\Rightarrow b = 6^2 \text{ or } \boxed{b = 36}$$

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Now at $\omega = 2\,rad/s$

$$\angle G(j\omega)H(j\omega) = -180 + 45 = -135^\circ$$

$$\Rightarrow -135^\circ = -90^\circ - \tan^{-1}\left(\frac{a\times 2}{36-4}\right)$$

$$45^\circ = \tan^{-1}\left(\frac{a\times 2}{32}\right)$$

$$\Rightarrow a\times 2 = 32 \text{ or } \boxed{a = 16}$$

Now from (II):—

$$\frac{K \times \sqrt{a^2\omega^2 + (b-\omega^2)^2}}{\omega \times \left(a^2\omega^2 + (b-\omega^2)^2\right)} = 1 \text{ for } \omega = 2\,rad/s$$

$$\Rightarrow \frac{K}{2\times\sqrt{16^2\times 2^2 + (36-2^2)^2}} = 1$$

$$\Rightarrow \boxed{K = 90.51}$$

Q.2 (c) A (7, 4) linear block code is generated according to the following parity check matrix H :

$$[H] = \begin{bmatrix} 1 & 1 & 1 & 0 & 1 & 0 & 0 \\ 1 & 1 & 0 & 1 & 0 & 1 & 0 \\ 1 & 0 & 1 & 1 & 0 & 0 & 1 \end{bmatrix}$$

The received codeword Y is 1000011 for a transmitted code word X. Find the corresponding data transmitted.

10

$$H^T = \begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 0 \\ 1 & 0 & 1 \\ 0 & 1 & 1 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

Now finding syndrome $= Y \cdot H^T$

$$= [1000011] \begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 0 \\ 1 & 0 & 1 \\ 0 & 1 & 1 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

$$= [100]$$

Looking at syndrome, it matches column 5 from the left of the [H] matrix

$\Rightarrow$ by max likelihood decoder; $e = [0000100]$

$\Rightarrow$ transmitted $XG = Y + e$

$$= [1000011] + [0000100]$$

$$\boxed{XG = [1000111]}$$

Now considering G in systematic form of $[I_k | P]$ $\Rightarrow$ $\boxed{X = [1000]}$

Section B

Q.5 (a) Explain the followings things :

(i) Memory mapped I/O.

(ii) Machine cycles of 8085 microprocessor.

10

(i) This is a type of microprocessor mapping which uses I/o device as a memory register; thereby assigning 16 bit address.

Eg: Instructions like LDA, STA use this form of mapping.

(ii) Machine cycle refers to the number of t-states which make up one part of the execution of a statement or command — whether accessing memory or acknowledging input/output.

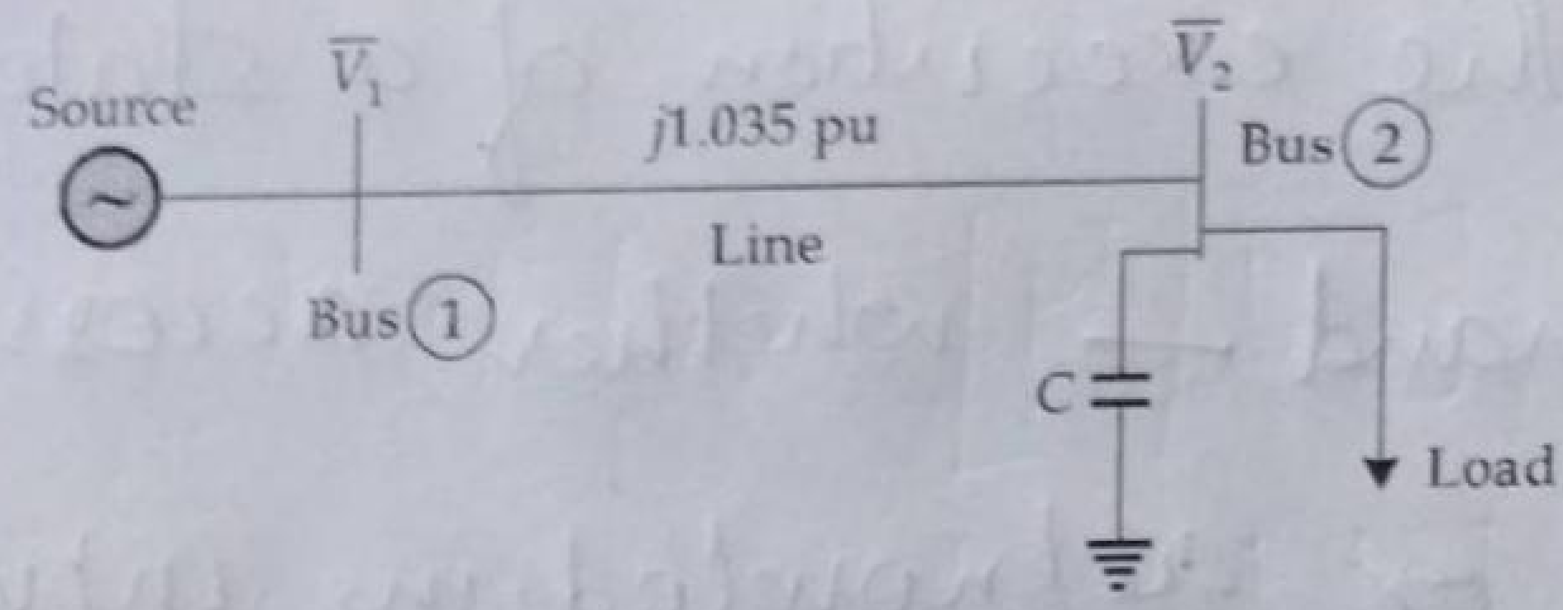
Eg: For MOV A, B;
first 4-tstates go into opcode fetch which forms one machine cycle.

Q.5 (b) Consider the following single line diagram consisting a source, transmission line, shunt capacitor and load. Magnitude of bus voltage $|V_1|$ and $|\overline{V_2}| = 1$ pu. $\overline{V_1}$ leads $\overline{V_2}$ by 30°. The admittance of capacitor bank is 0.8 pu.

Determine:

(i) the source power factor.

(ii) the load power factor.



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Given $V_2 = 1\angle 0°$ pu; $V_1 = 1\angle 30°$ pu

Power delivered to bus $P = \frac{1 \times 1}{1.035} \sin 30°$

$= 0.483$ pu

current in the line $= \frac{1\angle 30° - 1\angle 0°}{j1.035}$

$= 0.5\angle 15°$ pu

$\Rightarrow$ Source power factor $= \cos(30-15)$

$= \boxed{0.966 \text{ lag}}$

Now for the load; $S_2 = V_2 \times I^*$

$= 1 \times 0.5\angle -15°$

$S_2 = 0.5\angle -15°$ pu

But ~~Pload~~ $S_{Load} = S_2 - Y_c \times V_2^2$

$= 0.5\angle -15° - 0.8 \times 1\angle 90°$

$= 1.047\angle -62.54°$ pu

$\Rightarrow$ load power factor $= \cos(62.54°)$

$= \boxed{0.461 \text{ lag}}$

Q.5 (c) For the (7, 4) Hamming code, the parity-check matrix H is given by

$$H = \begin{bmatrix} 1 & 0 & 1 & 1 & 1 & 0 & 0 \\ 1 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 1 & 1 & 0 & 0 & 1 \end{bmatrix}$$

(i) Construct the generator matrix.

(ii) The code word that begins with 1010.

(iii) If the received code word Y is 0111100, then decode this received code word.

10

Given H of form $\left[P^T \mid I_{n-k}\right]$

we see $P^T = \begin{bmatrix} 1 & 0 & 1 & 1 \\ 1 & 1 & 0 & 1 \\ 0 & 1 & 1 & 1 \end{bmatrix}$

$\Rightarrow P = \begin{bmatrix} 1 & 1 & 0 \\ 0 & 1 & 1 \\ 1 & 0 & 1 \\ 1 & 1 & 1 \end{bmatrix}$

(i) $\Rightarrow G = \left[I_k \mid P\right] = \begin{bmatrix} 1 & 0 & 0 & 0 & 1 & 1 & 0 \\ 0 & 1 & 0 & 0 & 0 & 1 & 1 \\ 0 & 0 & 1 & 0 & 1 & 0 & 1 \\ 0 & 0 & 0 & 1 & 1 & 1 & 1 \end{bmatrix}$

For code word $= XG$

$= [1010] \begin{bmatrix} 1 & 0 & 0 & 0 & 1 & 1 & 0 \\ 0 & 1 & 0 & 0 & 0 & 1 & 1 \\ 0 & 0 & 1 & 0 & 1 & 0 & 1 \\ 0 & 0 & 0 & 1 & 1 & 1 & 1 \end{bmatrix}$

(ii) code word $= [1010011]$

(iii) $Y = [0111100]$ & $H^T = \begin{bmatrix} 1 & 1 & 0 \\ 0 & 1 & 1 \\ 1 & 0 & 1 \\ 1 & 1 & 1 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$

$\Rightarrow$ syndrome $YH^T = [101]$

This matches with third column of H

$\Rightarrow e = [0010000]$

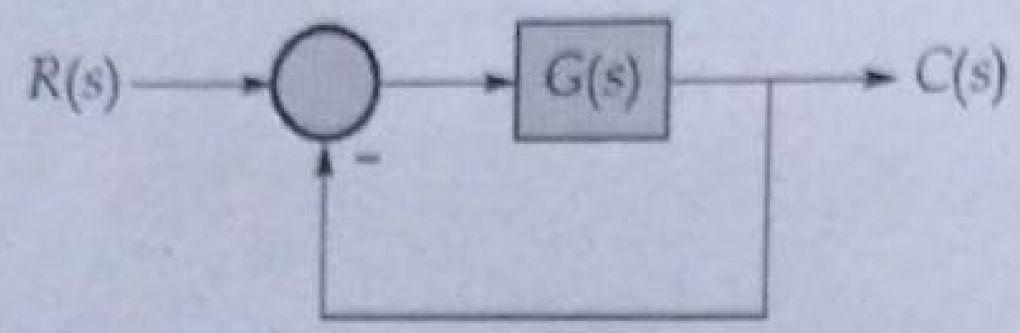
$\Rightarrow$ code word $= [0111100] + [0010000]$

$\boxed{\text{code word} = [0101100]}$

Q.5 (d) The system shown in figure below, has open loop transfer function,

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

Find the range of K for which the system is stable. Show that the system response can oscillate at two different frequencies. Apply Routh-Hurwitz criterion.



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$$1+G(s)H(s) = s(s-1)(s^2+4s+20) + Ks + K$$
$$= (s^2-s)(s^2+4s+20) + Ks + K$$
$$= s^4+4s^3+20s^2-s^3-4s^2-20s+Ks+K$$
$$= s^4+3s^3+16s^2+(K-20)s+K$$

Using Routh Hurwitz table:—

s^4	1	16	K
s^3	3	K−20	0
s^2	$\frac{68-K}{3}$	K	
s^1	$\frac{-K^2+79K-1360}{68-K}$	0	
s^0	K		

$$\frac{\frac{68-K}{3}\times(K-20)-3K}{\frac{68-K}{3}}$$

$$\Rightarrow \frac{\frac{68K-1360-K^2+20K-9K}{3}}{\frac{68-K}{3}}$$

$$\Rightarrow \frac{-K^2+79K-1360}{68-K}$$

Now for stability:—

$K>0$; $68-K>0 \Rightarrow K<68$

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

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

$$\boxed{25.35<K<53.65}$$

Now for oscillation:— at $K=25.35$

$\Rightarrow$ system oscillates at $-\left(\frac{68-25.35}{3}\right)\omega^2+25.35=0$

$\Rightarrow \boxed{\omega = 1.335 \text{ rad/s}}$

& at $k=53.65$; $-\left(\frac{68-53.65}{3}\right)\omega^2+53.65=0$

$\Rightarrow \boxed{\omega = 3.349 \text{ rad/s}}$

Q.5 (e) A capacitance of 250 pF produces resonance with a coil at a frequency of $\left(\frac{2}{\pi}\right) \times 10^6$ Hz, while at the second harmonics of this frequency resonance is produced by a capacitance of 50 pF.

Calculate:

(i) the self-capacitance, and

(ii) the inductance of the coil.

Neglect the effect of voltmeter capacitor and also other stray capacitance.

10

$$C_1 = 250\,pF \;;\; f_1 = \frac{2}{\pi} \times 10^6 \,Hz$$

$$C_2 = 50\,pF \;;\; f_2 = \frac{4}{\pi} \times 10^6 \,Hz$$

$$\Rightarrow n = \frac{f_2}{f_1} = 2$$

$$\Rightarrow C_d = \frac{C_1 - n^2 C_2}{n^2 - 1} = \frac{250 - 4 \times 50}{4 - 1}$$

$$\text{or } \boxed{C_d = 16.67\,pF}$$

$$\text{Now } f_1 = \frac{1}{2\pi\sqrt{L(C_1 + C_d)}} \Rightarrow \sqrt{L} = \frac{1}{2\pi\sqrt{C_1 + C_d} \times f_1}$$

$$\text{or } L = \frac{1}{4\pi^2 (C_1 + C_d) f_1^2} = 0.234 \times 10^{-15} H \times 10^{12}$$

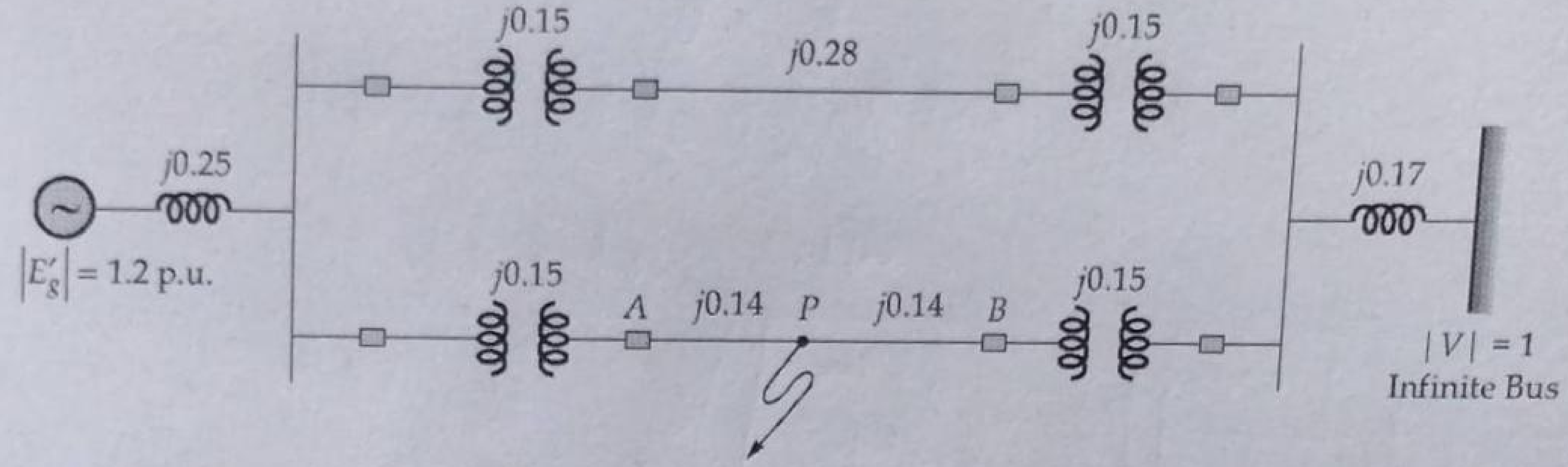
$$\text{or } \boxed{L = 234.38\,\mu H}$$

Q.6 (a) A generator is connected by a double line to an infinite bus, the voltage of which is $V = 1$ pu as shown in the figure. Per unit values of reactances and voltages are indicated in the figure. A three-phase short circuit occurs at the point P. The circuit breaker A and B open simultaneously and remain open. The mechanical power supplied to the generator before fault is $P_m = 1$ pu.

(i) Determine the electrical power P_{e1}, P_{e2} and P_{e3} before, during and post the fault respectively.

(ii) Draw on the same graph, power angle curves for P_{e1}, P_{e2} and P_{e3}.

(iii) Calculate the critical clearing angle δ_c.



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Before Fault

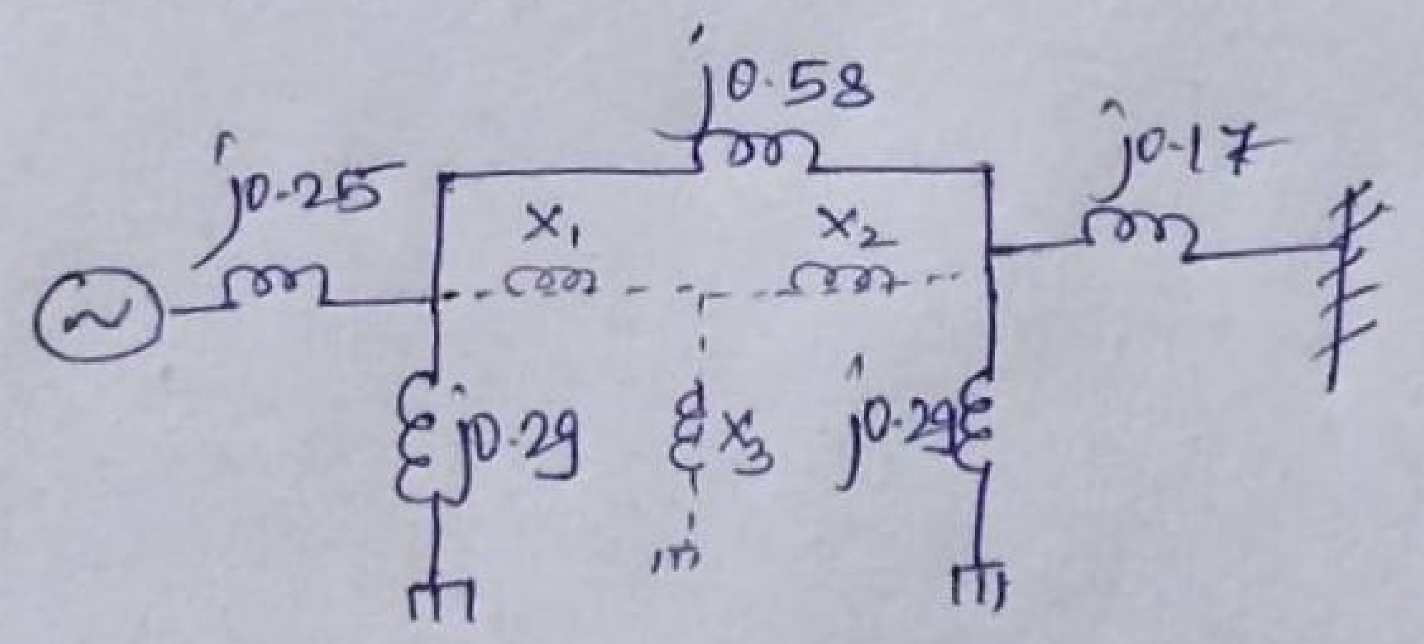
$|E_g| = 1.2\,pu\ ;\ |V| = 1\,pu$

Now $X_{eq} = j0.25 + (j0.58) \| (j0.58) + j0.17$

$= j0.71$

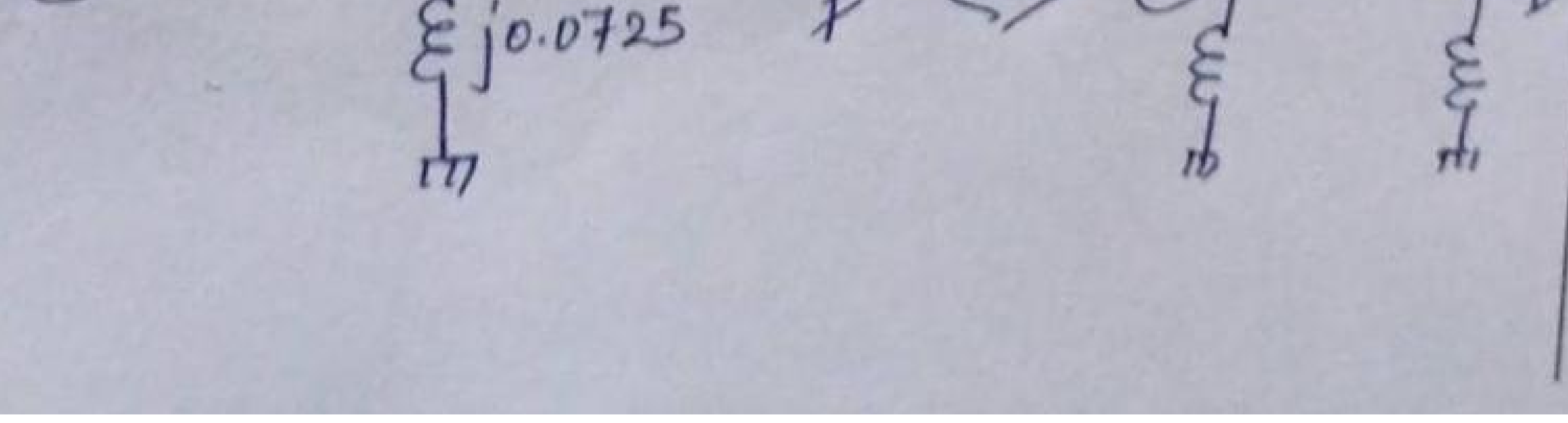
$\Rightarrow P_{e_1} = \dfrac{1.2 \times 1}{0.71} \sin\delta \Rightarrow \boxed{P_{e_1} = 1.69 \sin\delta}$

During fault



$X_1 = \dfrac{j0.29 \times \cancel{j0.58}}{2 \times \cancel{j0.58}} = j0.145 = X_2$

$X_3 = \dfrac{\cancel{j0.29} \times j0.29}{2 \times \cancel{j0.58}_{\,2}} = j0.0725$



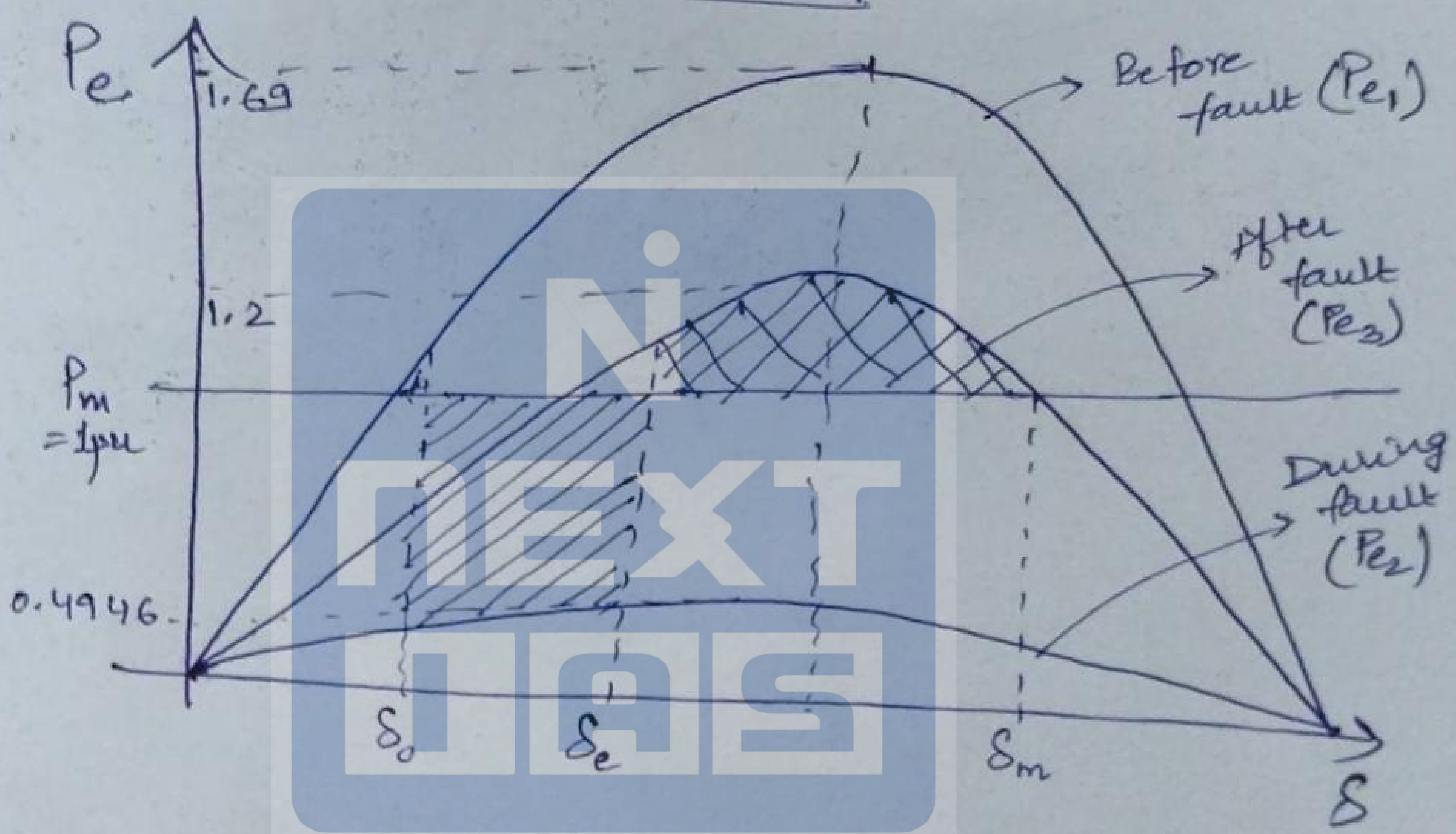
Now $X_{11} = j0.395 + j0.315 + j\frac{0.395 \times 0.315}{0.0725}$
$= j2.426$

$\Rightarrow P_{e_2} = \frac{1.2 \times 1}{2.426} \sin\delta = \boxed{0.4946 \sin\delta}$

$\boxed{\text{After fault}}$:- $X_{eq} = j0.25 + j0.58 + j0.17$
$= j1$

$\Rightarrow P_{e_3} = \boxed{1.2 \sin\delta}$

(ii)



(iii) $r_1 = \frac{0.4946}{1.69} = 0.2927$; $r_2 = \frac{1.2}{1.69} = 0.71$

$\Rightarrow \cos\delta_c = \frac{\sin\delta_0(\delta_m - \delta_0) - r_1\cos\delta_0 + r_2\cos\delta_m}{r_2 - r_1}$

where $\delta_m = \pi - \sin^{-1}\left(\frac{\sin\delta_0}{r_2}\right) = \pi - \sin^{-1}\left(\frac{0.5917}{0.71}\right) = 123.55°$ or 2.156 rad

& $\sin\delta_0 = \frac{1}{1.69} \Rightarrow \delta_0 = 0.6332$ rad or $36.28°$

$\Rightarrow \cos\delta_c = \frac{\frac{1}{1.69} \times (2.156 - 0.633) - 0.2927 \times 0.806 - 0.71 \times 0.553}{0.71 - 0.2927}$

$= 0.6531 \Rightarrow \boxed{\delta_c = 49.23°}$

critical angle

Candidates must not write on this margin

(b) A 1 Mbps BPSK receiver detects waveforms $s_1(t) = A\cos\omega_0 t$ or $s_2(t) = -A\cos\omega_0 t$ with a matched filter.

(i) If $A = 1$ mV, what will be the average bit error probability?

(ii) What should be the average received signal power to maintain an error probability of 2×10^{-3}? Assume single-sided noise power spectral density to be $N_0 = 10^{-11}$ W/Hz.

(iii) Binary antipodal signals are used in another scheme with amplitudes of ± 100 V to transmit information over an AWGN channel at a rate of 10^5 bps. The psd $\frac{N_0}{2} = 0.5 \times 10^{-2}$ W/Hz. Determine the error probability achieved. Assume that the system employs rectangular pulses.

Given, $Q(2.9) = 2 \times 10^{-3}$, $Q(4.47) = 10^{-5}$ and $Q(0.316) = 0.38$.

20

(i) $$E_b = \frac{1}{2} \times A^2 \times E_p + \frac{1}{2} \times A^2 \times E_p = A^2 \times E_p$$

$$= (10^{-3})^2 \times \left(\frac{2\pi}{\omega_0}\right) \times \frac{1}{2}$$

T_b

$$= 10^{-6} \times 10^{-6} \times \frac{1}{2} = 5 \times 10^{-13} \text{ J}$$

Now $$P_e = Q\left(\sqrt{\frac{2E_b}{N_0}}\right) = Q\left(\sqrt{\frac{5\times10^{-13}\times 2}{1\times 10^{-11}}}\right)$$

$$= Q\left(\frac{1}{\sqrt{10}}\right) = Q(0.316) = \boxed{0.38}$$

(ii) For given case $\sqrt{\frac{2E_b}{N_0}} = 2.9$ for $P_e = \frac{2}{1000}$

$$\Rightarrow \frac{2E_b}{10^{-11}} = (2.9)^2 \Rightarrow E_b = 4.205 \times 10^{-11} \text{ J}$$

Now $$A^2 \times E_p = 4.205 \times 10^{-11} \text{ J}$$

$$\Rightarrow E_p = \frac{4.205 \times 10^{-11}}{10^{-6}} \text{ W}$$

$$\boxed{E_p = 0.4205 \mu W}$$

or $$A = \sqrt{2 \times 0.4205 \times 10^{-6}} = \underline{9.17 mV}$$

(iii) For the rectangular pulses:-

$$E_p = A^2 \times T_b$$
$$= (100)^2 \times \frac{1}{10^5} = 0.1 W$$

Now For binary signalling

$$E_b = \frac{1}{2} \times A^2 T_b + \frac{1}{2} \times A^2 T_b = A^2 T_b$$

or $E_b = E_p = 0.1 W$

Now $P_e = Q\left(\sqrt{\frac{2 \times E_b}{N_0}}\right) = Q\left(\sqrt{\frac{2 \times 0.1}{1 \times 10^{-2}}}\right)$

$$= Q(4.47) = \boxed{10^{-5}}$$

Ans

Q.6 (c) The open-loop transfer function of a unity feedback system is $G(s) = \frac{K}{s(s+15)}$. If $K = 225$, what change must be made in the system to reduce the peak overshoot by 50%, keeping the settling time same? Also, determine the new transfer function.

10

Characteristic equation –

$$s^2 + 15s + 225$$

$$\Rightarrow (\omega_n)_1 = \sqrt{225} = 15 \text{ rad/s}$$

$$\xi_1 = \frac{15}{2 \times 15} = 0.5$$

Now $M_{p_1} = e^{-\pi\xi_1/\sqrt{1-\xi_1^2}} = 0.163$ or 16.3%

Now Reducing M_p by $50\% \Rightarrow M_{p_2} = 0.0815$

$$\Rightarrow \frac{\pi\xi_2}{\sqrt{1-\xi_2^2}} = \ln\frac{1}{0.0815} \Rightarrow \frac{\xi_2^2}{1-\xi_2^2} = 0.6368$$

$$\Rightarrow \xi_2^2 = 0.389 \text{ or } \boxed{\xi_2 = 0.624}$$

Now for settling time to be same $\Rightarrow$

$$\xi_1(\omega_n)_1 = \xi_2(\omega_n)_2 \Rightarrow (\omega_n)_2 = \frac{0.5}{0.624} \times 15$$

$$\boxed{(\omega_n)_2 = 12.024 \text{ rad/s}}$$

So, change required is to use a proportional gain of $\boxed{0.6426}$ in forward path to make

$$K_2 = (12.024)^2 = 144.58$$

New transfer f^n:– $\boxed{G(s) = \frac{144.58}{s(s+15)}}$.

Candidates must not write on this margin

a) Sketch the root locus of a closed-loop system the open-loop transfer function of which is,

$G(s)H(s) = \dfrac{K}{(s+3)(s+5)(s^2+2s+2)}$ and determine the following:

(i) The angles of departure from complex poles.

(ii) The break-away points.

(iii) The intersection with imaginary axis.

(iv) The stability conduction.

(v) gain margin of K = 20.

20

$s^2+2s+2 \Rightarrow (s^2+2s+1)+1 \Rightarrow s = -1 \pm j$

So, poles are $-3, -5, -1 \pm j$

$\Rightarrow \Sigma \text{poles} = -10 \; ; \; \# \text{poles} = 4$

Now $\sigma = \dfrac{\Sigma \text{poles} - \Sigma \text{zeros}}{\# \text{poles} - \# \text{zeros}} = -\dfrac{10}{4} = -2.5$

asymptote angles $= \dfrac{(2q+1)\pi}{4} = \dfrac{\pi}{4}, \dfrac{3\pi}{4}, \dfrac{5\pi}{4}, \dfrac{7\pi}{4}$

(ii) For breakaway points :—

$\dfrac{d}{ds}\left[(s+3)(s+5)(s^2+2s+2)\right] = 0$

$\dfrac{d}{ds}\left[(s^2+8s+15)(s^2+2s+2)\right] = 0$

$(s^2+8s+15)(2s+2) + (2s+8)(s^2+2s+2) = 0$

$(s^2+8s+15)(s+1) + (s+4)(s^2+2s+2) = 0$

$s^3+8s^2+15s+s^2+8s+15 + s^3+2s^2+2s+4s^2+8s+8 = 0$

$2s^3+15s^2+33s+23 = 0$

$s = -4.26, \; -1.619 \pm j0.276$

valid breakaway pt.

(iii) Characteristic eqⁿ :– $(s^2+8s+15)(s^2+2s+2)+K$

$= s^4 + 2s^3 + 2s^2 + 8s^3 + 16s^2 + 16s + 15s^2 + 30s + 30 + K$

$= s^4 + 10s^3 + 33s^2 + 46s + (30+K)$.

Using Routh Hurwitz criteria:–

s^4	1	33	30+K
s^3	10	46	
s^2	$\cancel{30+K}$ 28.4	30+K	
s^1	$\frac{1006.4 - 10K}{28.4}$	0	
s^0	30+K		

Now for stability $1006.4 - 10K > 0$

$\Rightarrow \boxed{K < 100.64} \Rightarrow$ (iv) $\boxed{0 < K < 100.64}$

for oscillation:– $K = 100.64$

$\Rightarrow -28.4\omega^2 + 30 + 100.64 = 0$

$\omega^2 = 4.6$ or $\boxed{\omega = 2.145 \text{ rad/s}}$

(i) angle of departure for pole $-1+j$:–

$\phi = -90° - \tan^{-1}\left(\frac{1}{2}\right) - \tan^{-1}\left(\frac{1}{4}\right)$

$= -130.6°$

$\Rightarrow$ angle of departure for $(-1+j)$ $= 180 + \phi$ $= 49.4°$

angle of departure for $(-1-j)$ $= -49.4°$ by symmetry.

(v) For $K = 20$; gain margin $= \frac{100.64}{20} = 5.032$

or $(\text{gain margin})_{dB} = 20\log_{10} 5.032 = \boxed{14.03 dB}$

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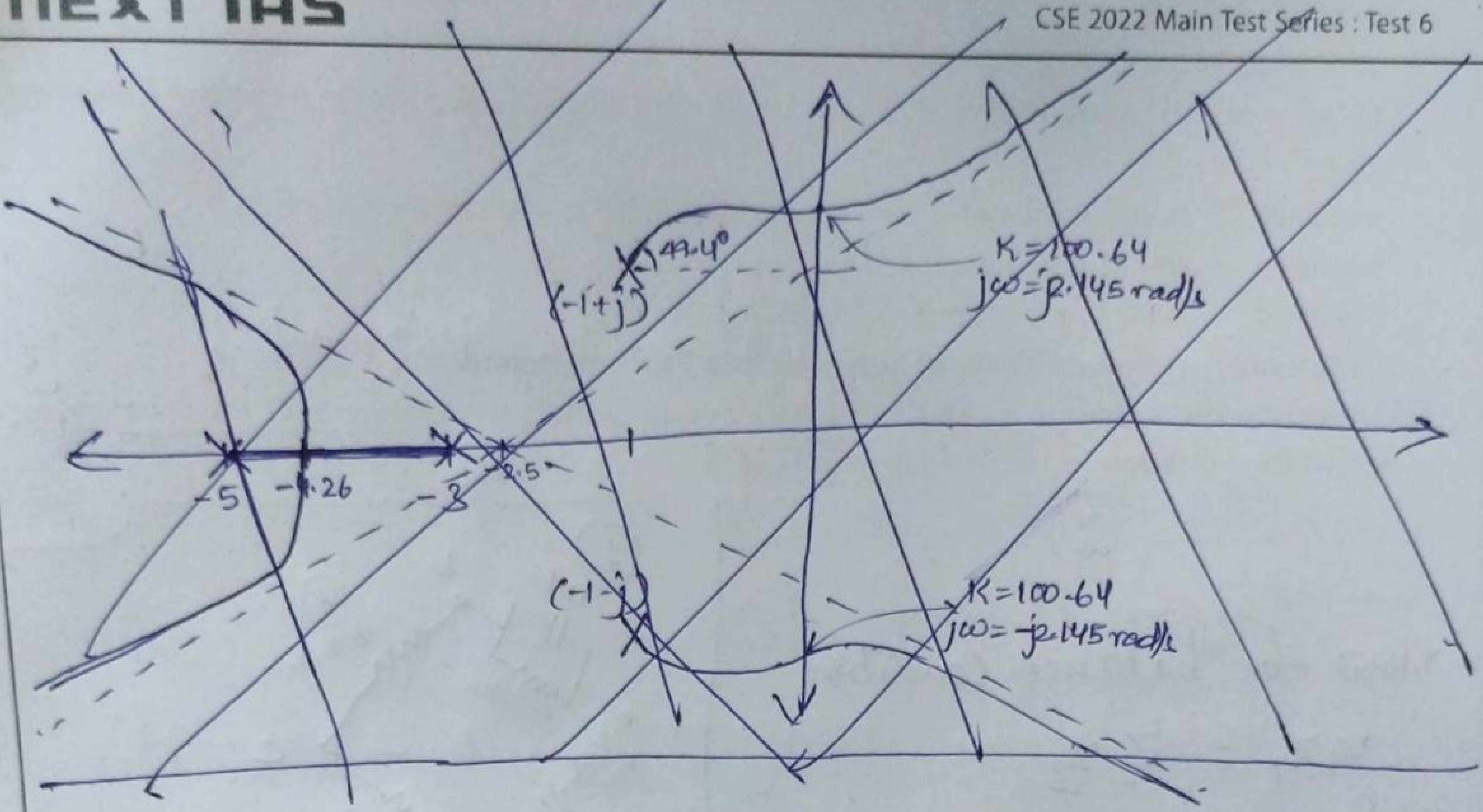
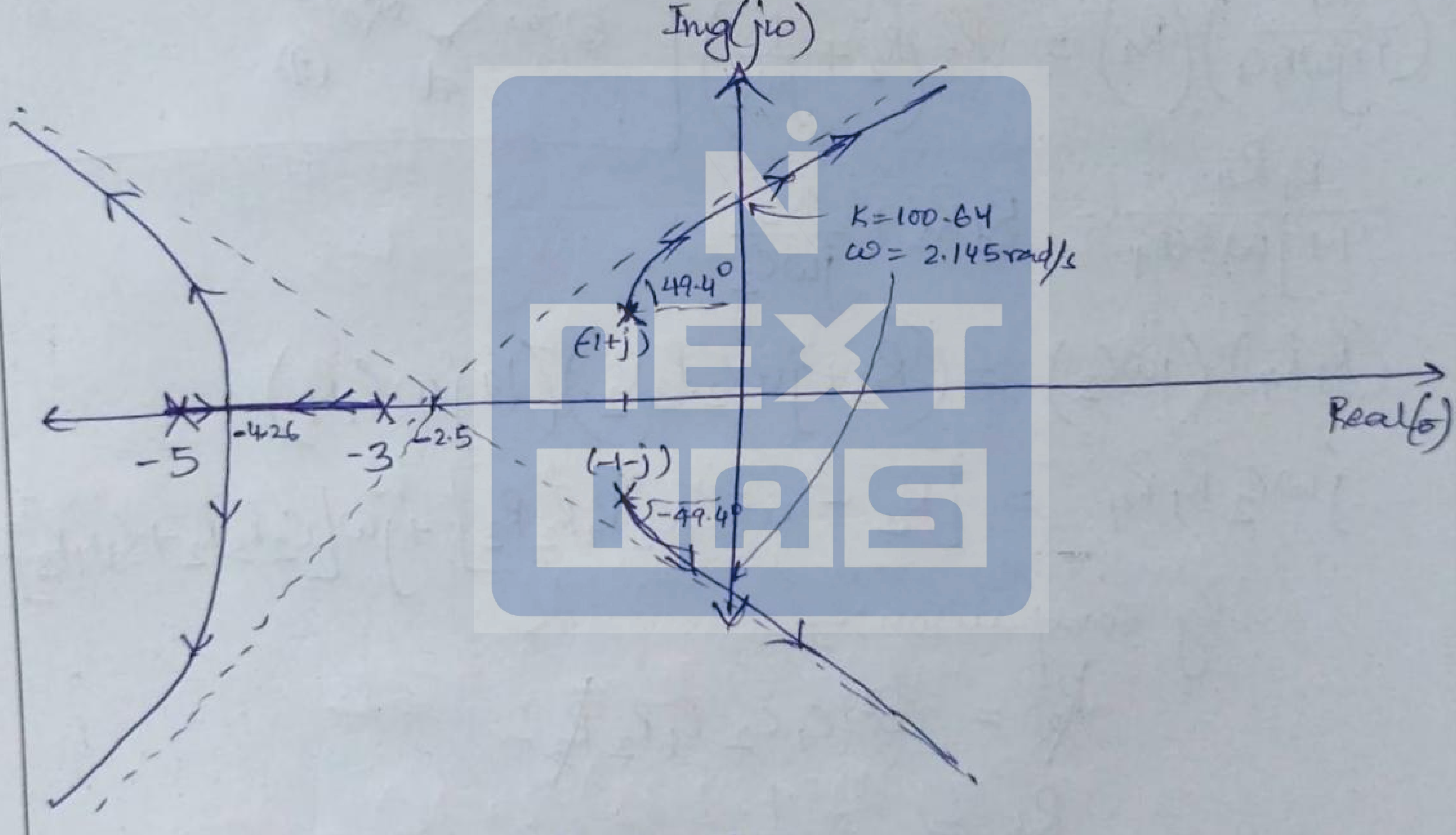

44.4°
(-1+j)
K=100.64
jω=j2.145 rad/s
-5
-4.26
-3
-2.5
(-1-j)
K=100.64
jω=-j2.145 rad/s

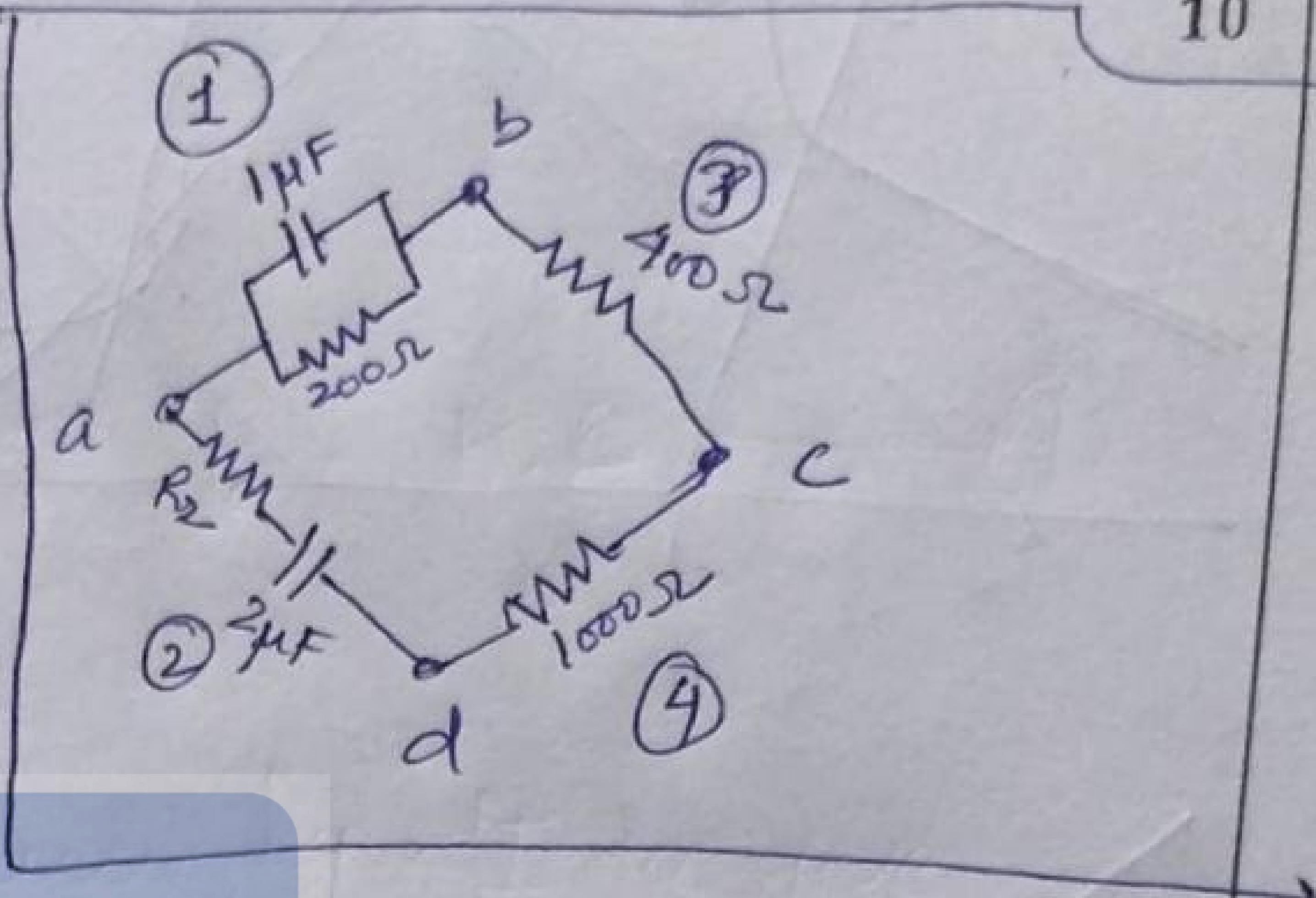

Img(jω)
K=100.64
ω= 2.145 rad/s
49.4°
(-1+j)
-5
-4.26
-3
-2.5
Real(σ)
(-1-j)
-49.4°

Root locus

Q.8 (b) (i) The arms of a four arm bridge *abcd*, supplied with sinusoidal voltage, have the following values :

arm *ab* : A resistance of 200 Ω in parallel with a capacitance 1 μF.
arm *bc* : 400 Ω resistance,
arm *cd* : 1000 Ω resistance
arm *da* : A resistance R_2 in series with a 2 μF capacitance.

Determine the value of R_2 and the frequency at which the bridge will balance. Also derive the equation of balance, if any. **10**



Now for balance condition

$$Z_1 Z_4 = Z_2 Z_3$$

$$\left(\frac{R_1}{1+j\omega R_1 C_1}\right)(R_4) = R_3\left(R_2 + \frac{1}{j\omega C_2}\right)$$

$$\frac{R_1 R_4}{1+j\omega C_1 R_1} = R_3 R_2 + \frac{R_3}{j\omega C_2}$$

$$(R_1 R_4)(j\omega C_2) = (R_3 + j\omega C_2 R_3 R_2)(1+j\omega C_1 R_1)$$

$$j\omega C_2 R_1 R_4 = [R_3 - \omega^2 C_1 C_2 R_1 R_2 R_3] + j\omega[C_2 R_3 R_2 + C_1 R_1 R_3]$$

By comparison :—

$$\cancel{R_3} = \omega^2 C_1 C_2 R_1 R_2 \cancel{R_3}$$

$$R_2 = \frac{1}{\omega^2 C_1 C_2 R_1} \quad \text{——— } (1)$$

also $\cancel{\omega} C_2 R_1 R_4 = C_2 R_3 R_2 + C_1 R_1 R_3$

$$\frac{C_2 R_1 R_4 - C_1 R_1 R_3}{C_2 R_3} = R_2$$

$$\Rightarrow R_2 = \frac{2\times10^{-6}\times 200\times10^{3} - 1\times10^{-6}\times 200\times 400}{2\times10^{-6}\times 400}$$

$$\boxed{R_2 = 400\,\Omega}$$

Now Putting back in ① ⇒

$$400 = \frac{1}{\omega^2 \times 2\times10^{-12} \times 200}$$

$$\Rightarrow \omega^2 = \frac{1}{400\times400\times10^{-12}}$$

$$\Rightarrow \boxed{\omega = 2500 \text{ rad/s}} \text{ or } \boxed{f = 398 \text{ Hz}}$$

.8 (b) (ii) Derive general torque equation of moving iron instruments. Also derive deflection (θ) for the current I flowing in the instrument. Write any four advantages of moving iron instruments. 10

For a moving iron instruments;
we have $T_d = T_c$ at the balance condition

where from spring; $T_c = K.\theta$ —— (I)

and for $\boxed{T_d:}$

Let current increases by dI to give change in inductance by dL
& change in θ by $d\theta$

$\Rightarrow eI\,dt = I^2 dL + IL\,dI$ $\left[\text{since } e = I\frac{dL}{dt} + L\frac{dI}{dt}\right]$

change in stored energy

$= \frac{1}{2}(I+dI)^2(L+dL) - \frac{1}{2}I^2L$

$= \frac{1}{2}(I^2 + dI^2 + 2I\,dI)(L+dL) - \frac{1}{2}I^2L$

Neglecting higher order terms;

$IL\,dI + \frac{1}{2}I^2 dL$

Now by conservation of energy:-

$I^2dL + \cancel{IL\,dI} = \cancel{IL\,dI} + \frac{1}{2}I^2dL + T_d\,d\theta$

$\Rightarrow T_d\,d\theta = \frac{1}{2}I^2 dL$

or $T_d = \frac{1}{2}I^2\frac{dL}{d\theta}$ —— (II)

Combining (I) & (II) :-

at balance $\boxed{\theta = \frac{1}{2} \frac{I^2}{K} \cdot \frac{dL}{d\theta}}$

Advantages

1) Universality — usable for dc and ac
2) Less friction error ⇒ high weight ratio
3) Robustness due to no moving parts unlike electrodynamometer instruments.
4) Cheap to build.

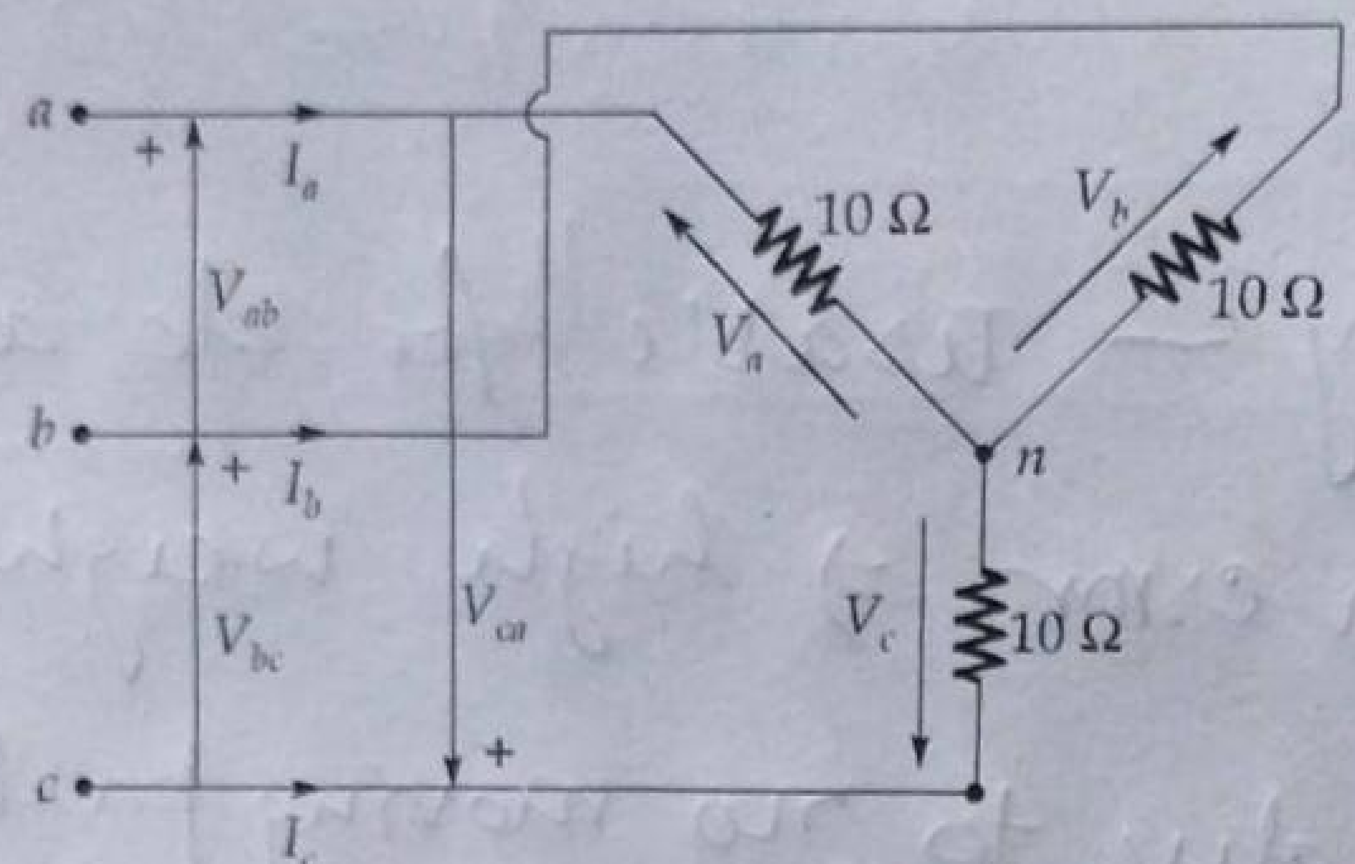
Q.8 (c) The line voltages across a three-phase, wye-connected load, consisting of a 10 ohm resistance in each phase as shown in figure, are unbalanced such that

$V_{ab} = 220\angle 131.70°$ V, $V_{bc} = 252\angle 0°$ V and $V_{ca} = 195.30\angle -122.75°$ V

(i) Determine the sequence phase voltage. Then find the voltage across the 10 Ω resistances, and

(ii) Calculate line currents.

(Assume *abc* phase sequence)



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$$V_{ab} = V_a - V_b = (V_{a_0} + V_{a_1} + V_{a_2}) - (V_{a_0} + \lambda^2 V_{a_1} + \lambda V_{a_2})$$
$$V_{bc} = V_b - V_c = (V_{a_0} + \lambda^2 V_{a_1} + \lambda V_{a_2}) - (V_{a_0} + \lambda V_{a_1} + \lambda^2 V_{a_2})$$
$$V_{ca} = V_c - V_a = (V_{a_0} + \lambda V_{a_1} + \lambda^2 V_{a_2}) - (V_{a_0} + V_{a_1} + V_{a_2})$$

$$\Rightarrow \begin{bmatrix} V_{ab} \\ V_{bc} \\ V_{ca} \end{bmatrix} = \begin{bmatrix} 0 & (1-\lambda^2) & (1-\lambda) \\ 0 & (\lambda^2-\lambda) & (\lambda-\lambda^2) \\ 0 & (\lambda-1) & (\lambda^2-1) \end{bmatrix} \begin{bmatrix} V_{a_0} \\ V_{a_1} \\ V_{a_2} \end{bmatrix}$$

Taking it to domain of V_{ab_0}, V_{ab_1}, V_{ab_2} :-

$$\begin{bmatrix} V_{ab_0} \\ V_{ab_1} \\ V_{ab_2} \end{bmatrix} = \frac{1}{3} \begin{bmatrix} 1 & 1 & 1 \\ 1 & \lambda & \lambda^2 \\ 1 & \lambda^2 & \lambda \end{bmatrix} \begin{bmatrix} V_{ab} \\ V_{bc} \\ V_{ca} \end{bmatrix}$$

$$V_{ab_0} = \frac{1}{3}(V_{ab} + V_{bc} + V_{ca}) = 2.08 \angle 118.63° \text{ mV} \approx 0 \text{ V}$$
$$V_{ab_1} = \frac{1}{3}(V_{ab} + \lambda V_{bc} + \lambda^2 V_{ca}) = 221.15 \angle 123.04° \text{ V}$$
$$V_{ab_2} = \frac{1}{3}(V_{ab} + \lambda^2 V_{bc} + \lambda V_{ca}) = 33.71 \angle -140.66 \text{ V}$$

So; $V_{a_1} = \dfrac{V_{ab1}}{\sqrt{3}\angle 30^\circ} = \dfrac{221.15 \angle 123.04}{\sqrt{3}\angle 30^\circ}$

$$\boxed{V_{a_1} = 127.68 \angle 93.04^\circ \, V}$$

$V_{a_2} = \dfrac{V_{ab2}}{\sqrt{3}\angle -30^\circ} = \dfrac{33.31 \angle -140.66}{\sqrt{3}\angle -30}$

$$\boxed{V_{a_2} = 19.23 \angle -110.66^\circ \, V}$$

Now $\boxed{V_{a_0} = 0}$

Finding voltages

$V_a = V_{a_0} + V_{a_1} + V_{a_2} = 110.343 \angle 97.06^\circ \, V$

$V_b = V_{a_0} + \lambda^2 V_{a_1} + \lambda V_{a_2} = 143.63 \angle -22.41^\circ \, V$

$V_c = V_{a_0} + \lambda V_{a_1} + \lambda^2 V_{a_2} = 131.19 \angle -155.34^\circ \, V$

→ currents

$$\left.\begin{aligned} I_a &= 11.03 \angle 97.06^\circ \, A \\ I_b &= 14.36 \angle -22.41^\circ \, A \\ I_c &= 13.12 \angle -155.34^\circ \, A \end{aligned}\right\} \text{since } I = \frac{V}{10} \text{ for each phase}$$