

GOVERNING EQUATIONS

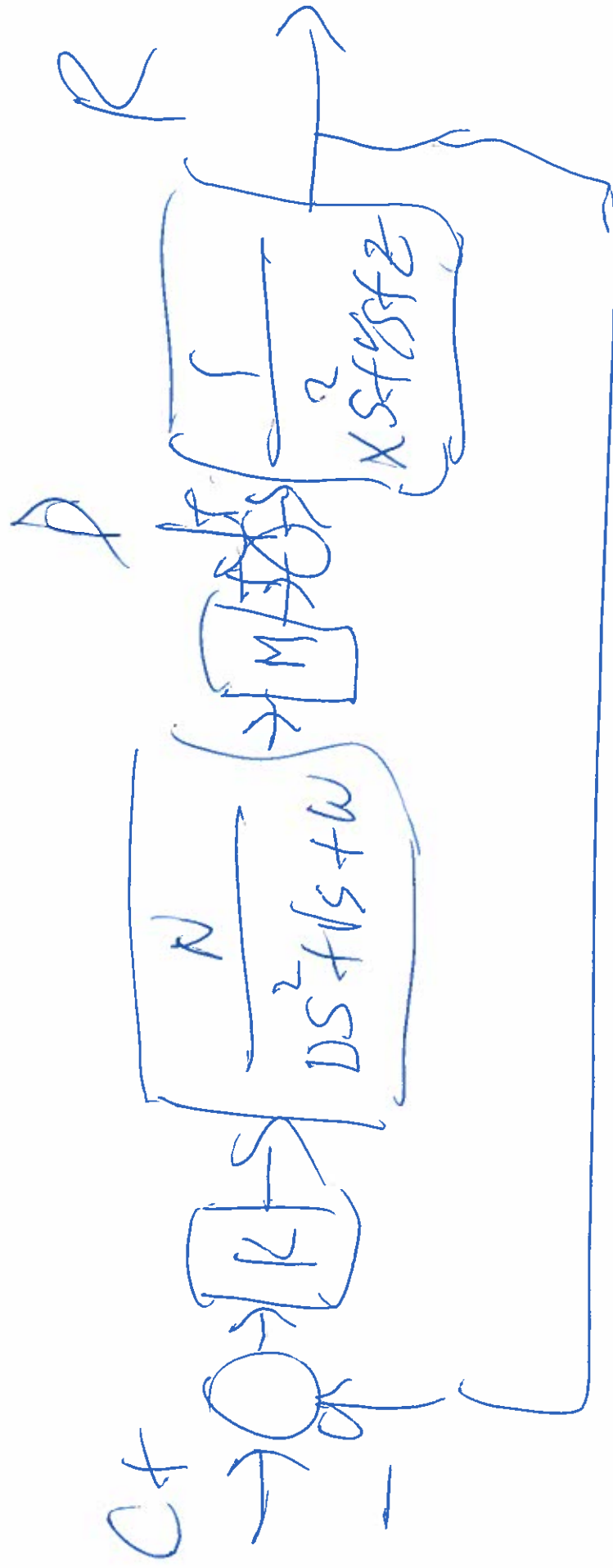
$$X \frac{d^2 c}{dt^2} + Y \frac{dc}{dt} + Z R = M P + D$$

$$U \frac{d^2 p}{dt^2} + V \frac{dp}{dt} + W P = N Q$$

$$Q = K E$$

$$E = C - R$$

CONTROLS EXAMPLE



OVERALL BLOCK DIAGRAM

GH FUNCTION

KRM

$$GH = \frac{KRM}{(s^2 + s + 1)(s^2 + 5s + 2)}$$

PARAMETERS

$$L = 1 \quad V = 2 \quad W = 1 \quad M = 4$$

$$X = 1 \quad Y = 4 \quad Z = 4 \quad N = 2$$

GA PNCZCN

8 K

GA₃

$$\frac{8K}{(s^2+4s+4)(s^2+2s+1)}$$

NYQVZ PLOT

$$K = \frac{3}{11} = 1.125$$

9

$$G = \frac{(S^2 + 4S + 4)(S^2 + 2S + 1)}{9}$$

9

==

$$S^4 + 6S^3 + 13S^2 + 12S + 4$$

Imaginary Axis

q

$$G_H = \frac{1}{\omega^4 - 6\omega^2 j - 13\omega^2 + 12\omega j + 4}$$

End of

$$As \omega \rightarrow 0 \quad GH \Rightarrow \frac{9}{4} \quad 2.25 \quad \textcircled{1}$$

$$As \omega \rightarrow \infty \quad GH \Rightarrow \frac{9}{\omega^4} \quad 0 \quad \textcircled{5}$$

REAL AXIS CROSSOVER

$$-6\omega^3 + 12\omega = 0$$

$$\omega^2 = 2$$

$$GH = \frac{9}{\omega^4 - 13\omega^2 + 4}$$

$$= \frac{9}{4 - 26 + 4} = -0.5 \quad \textcircled{3}$$

Find the roots of the equation

$$w^4 - 13w^2 + 4 = 0$$

$$w^2 = \frac{13 \pm \sqrt{13^2 - 16}}{2}$$

$$w \Rightarrow \frac{13 + 12.37}{2} = 12.68$$

$$w \Rightarrow \frac{13 - 12.37}{2} = 0.315$$

$$\textcircled{2} \quad \{65'1- = \frac{\{ (02'9 + 90'1-)}{b} =$$

$$\frac{\{ (95'0 \times 21 + 95'0 \times 51 \times 9-)}{b} = 49$$

$$55'0 = 3 \quad 518'0 = 23$$

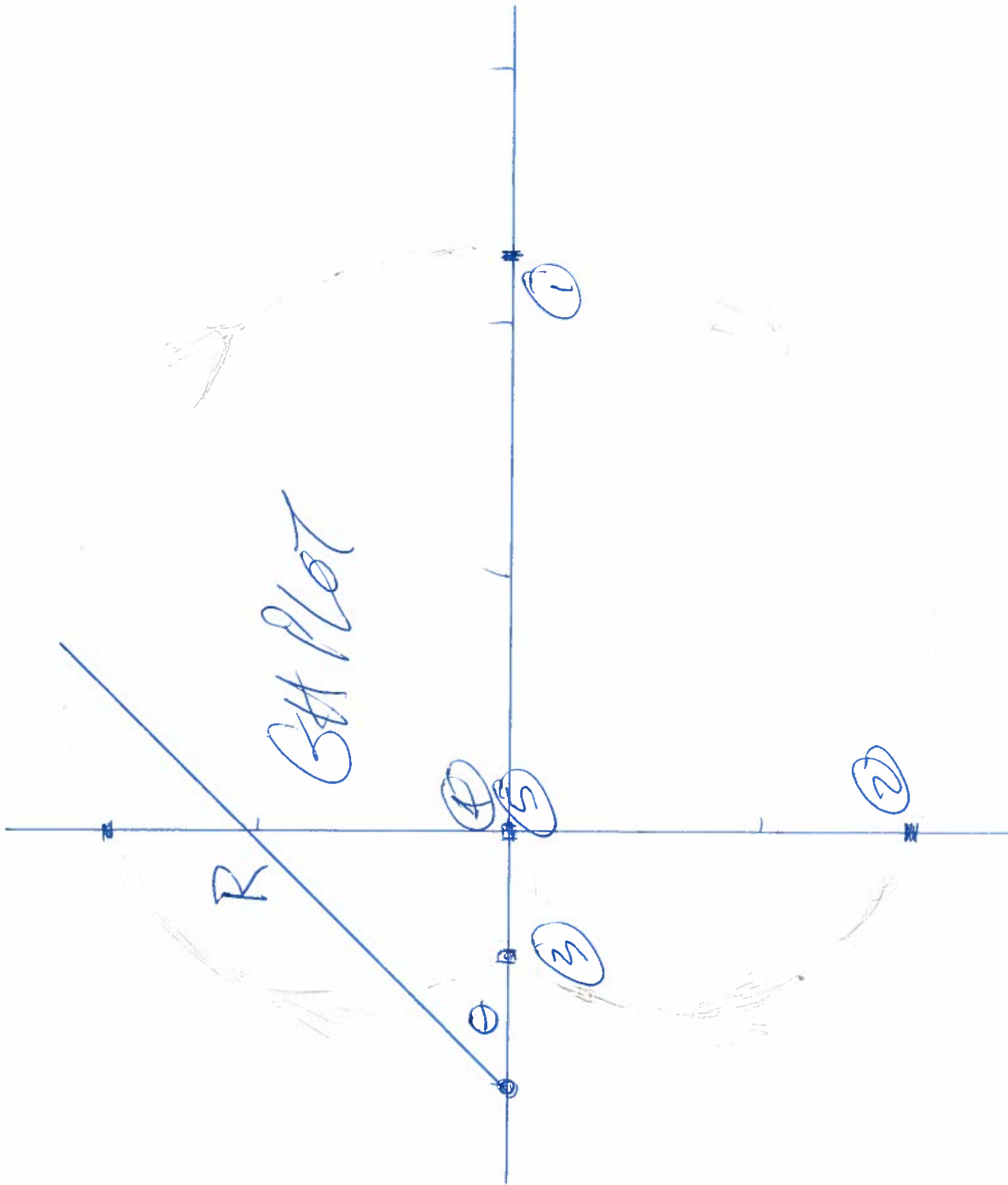
$$\frac{\{ 321 + \{ 809-}{b} = 49$$

$$b \quad \frac{9}{-6\omega^2 j + 12\omega j}$$

$$\omega = 12.68 \quad \omega = 3.56$$

$$b \quad \frac{9}{(-6 * 12.68 * 3.56 + 12 * 3.56 j)}$$

$$b \quad \frac{9}{(-270.8 + 42.7 j)} = +0.04 j \quad \textcircled{A}$$



GA Poles

$$\frac{8k}{(s^2 + 4s + 4)(s^2 + 2s + 1)} = \frac{8k}{(s+2)(s+2)(s+1)(s+1)}$$

$$\text{Poles } s = -1 \quad s = -1 \quad s = -2 \quad s = -2$$

NA Poles

Clockwise Rotations

$$N \equiv 0$$

UN32AB2E P02ES

$$Np \equiv 0$$

UN32AB2E 2E2ES

$$Nz \equiv 0$$

STABILITY MARGINS

GAIN MARGIN

$$GM = \frac{1}{1.051} = 2$$

PHASE MARGIN

$$PM = 22$$

$$1641 \approx 1320$$

9

$$\frac{\sqrt{(w^4 - 13w^2 + 4)^2 + (-6w^3 + 12w)^2}}{1}$$

Root locus check

8 (H)

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

8 (H)

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

Zero root

$$1 + GH = 0$$

$$GH = -1$$

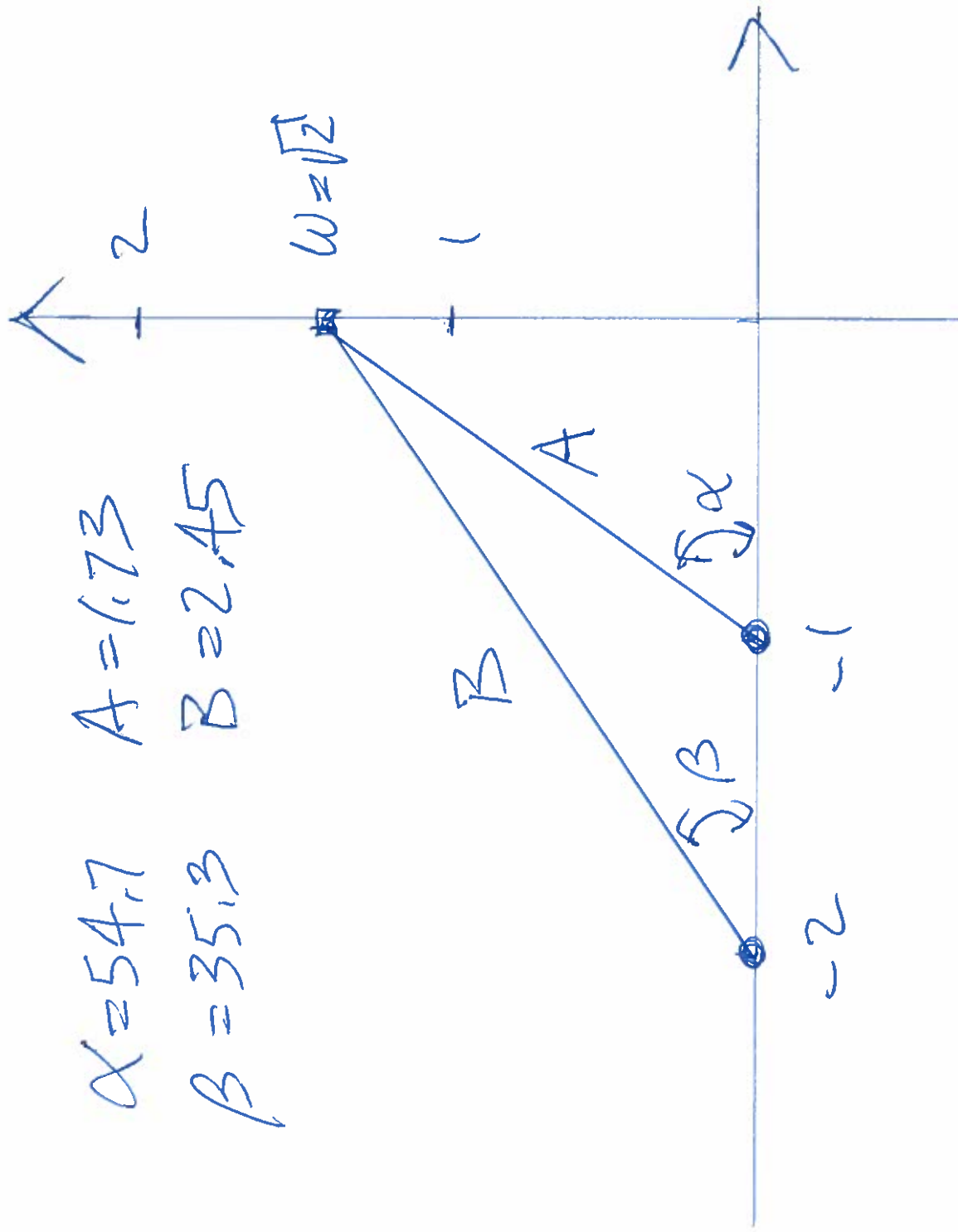
IMPLICATIONS

1) MAGNITUDE
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$$\alpha = 54.7 \quad A = 1.73$$

$$\beta = 35.3 \quad B = 2.45$$



MANCODE

$$\frac{8 * 2.25}{2.45 + 2.45 + 1.73 + 1.73} = 1 \quad \checkmark$$

PHASE

$$35.3 + 35.3 + 54.7 + 54.7 = 180 \quad \checkmark$$