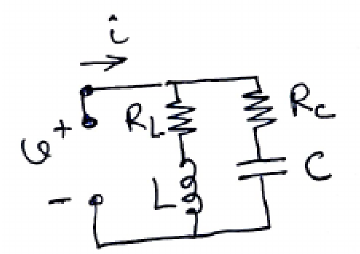
EE302-S1, Control Systems, Quiz-2 (26th March 2025)

Notes & instructions: read these very carefully and then read all questions before starting to attempt:

- Attempt all questions: each question carries 10 marks. Unnecessarily long, convolved, redundant or irrelevant text could attract marks-reduction. Show intermediate steps briefly for all calculations.
- Unless otherwise explicitly specified, k is real and positive, and feedback configuration is always the standard negative unity feedback configuration, with the constant gain k, compensator $C(s)$ (if any), and the open loop transfer function $G(s)$ all in the forward path.
- For Bode plot, mark corner frequencies clearly in both gain and phase plots and mark 0 dB line, DC-gain value line, high-frequency roll-off rates (or high-frequency gain, in dB). For Nyquist plot, mark $\omega = 0$, $\omega = \infty$ and show orientation clearly. Mark real-axis intersection values.
- Some questions might not have the sought answer (by intent). In such a case, give reasons why the sought answer is not possible. (Read next point.)
- If you feel a question has ambiguity and/or needs clarification, then assume yourself appropriately, state and justify your assumption and then solve the problem with that assumption. Do not call any TA or instructor for your query.

Ques 1: Sketch the root-locus of $G(s) = \dfrac{1}{s(s+1)(s+3)(s+4)}$ for $\boldsymbol{k < 0}$. (Need you to mark explicitly breakaway/breakin points, angles of departure/arrival, real-axis segments, $j\mathbb{R}$ intersection (k and ω_c), and direction of each branch as k increases from $-\infty$ to 0. If some of these are not relevant, say so explicitly. Note again the specification of direction of the branches.)

Ques 2: (a) Consider the RLC circuit shown. Find the transfer function $Z(s)$ from input source $i(t)$ to output voltage $v(t)$. Assume $C = 1$, $R_C = 1$ and $L = 1$.
(b) For the transfer function $Z(s)$ from i to v, obtain a state space realization.



Ques 3: (a) For the Bode magnitude plot shown below in Figure-(a), suggest two different transfer functions that have this magnitude plot. Draw the phase-plots for each of the two different transfer functions you suggest.

Figure-(a)

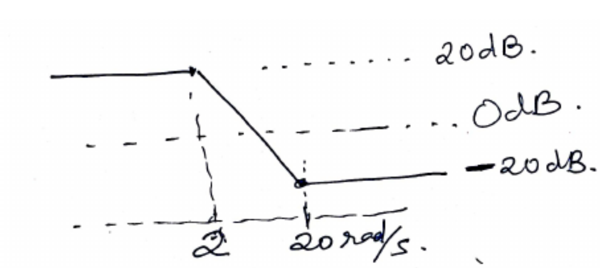
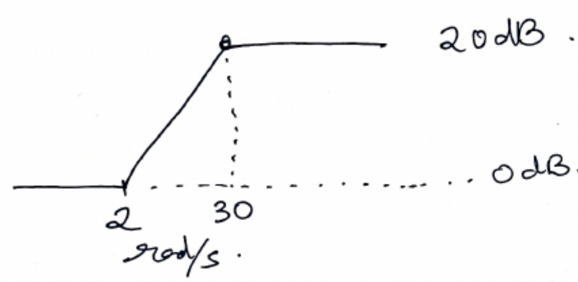


Figure-(b)



(b) Same is to be done for Figure-(b).

Ques 4: Draw the Nyquist plot of $G(s) = \frac{s-1}{s+4}$ and use the plot to obtain range of (positive) k for stability. Give justification.

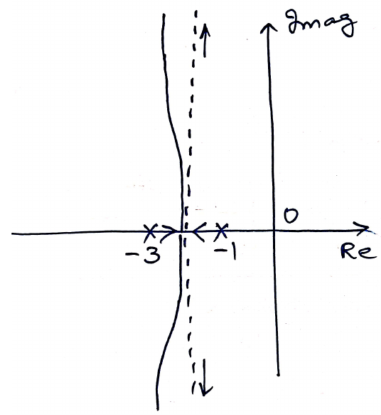
Ques 5: For the open loop transfer function $G(s) = \frac{1}{(s+1)(s+10)(s+100)}$, obtain the value of (positive) k that makes closed the closed loop system unstable by each of the three methods below. Also calculate (by each of the three methods below) the frequency ω_c at which one or more branches of the root-locus cross into the right-half plane.

(a) drawing the Nyquist plot, and using necessary arguments briefly,

(b) using Routh-Hurwitz criteria,

(c) drawing Bode plot (only approximate value of k and of ω_c).

Ques 6: (Assumption:) The root locus of an open loop transfer function $G(s)$ is shown (but not to scale). $G(s)$ is proper and open loop stable with $0 < G(0) < \infty$. The dotted line in the root-locus is of $G(s)$, while the regular-line is the root-locus of $C_1(s)G(s)$ (the desired/changed one).



(a) Which **one** of the following transfer functions $C_1(s)$ is most appropriate to change the root-locus from the dotted-line to the regular-line? Give reasons briefly.

$$\frac{s+3}{s+6}, \quad \frac{s+6}{s+3}, \quad \frac{s+8}{s+10}, \quad \frac{s+10}{s+8}, \quad \frac{s+0.09}{s+0.01}, \quad \frac{s+0.01}{s+0.09}, \quad \frac{s+0.12}{s+0.01}, \quad \frac{s+0.01}{s+0.12},$$

(b) Once suitable poles on the regular-line root-locus (of $C_1(s)G(s)$) are chosen by appropriate value of k (and $k > 0$), suppose the steady state error for step-input is e_1. Which **one** of the following transfer functions $C_2(s)$ would be most appropriate to reduce the steady state error to one-tenth of e_1? Give reasons briefly.

$$\frac{s+3}{s+6}, \quad \frac{s+6}{s+3}, \quad \frac{s+8}{s+10}, \quad \frac{s+10}{s+8}, \quad \frac{s+0.09}{s+0.01}, \quad \frac{s+0.01}{s+0.09}, \quad \frac{s+0.12}{s+0.01}, \quad \frac{s+0.01}{s+0.12},$$

(c) Write briefly about the relevance of statements within "Assumption" above for solving (a) and (b).