1) Why is there more improvement in steady-state error if a PI controller is used instead of a lag compensator?

2) Describe the conditions that must exist for all closed-loop poles and zeros in order to make a 2nd order approximation.

3) What is a root locus?

4) Given a closed loop transfer function \( \frac{C(s)}{R(s)} = \frac{3K}{s^2 + 4s + 7 + K} \), describe the effect on the following parameters (increase ↑, unchanged ↔, decrease ↓) of an increase in \( K \):
   a) natural frequency
   b) damping ratio
   c) system type number
   d) steady-state error (ramp input)
   e) %OS (step input)
   f) peak time (step input)
   g) steady-state error (step input)
   h) settling time (step input)
5) [35] The open-loop transfer function, $G(s)$, for a unity feedback control system is

$$
G(s) = \frac{K(s + 7)}{(s)(s + 2)(s + 4)} = \frac{K(s + 7)}{s^3 + 6s^2 + 8s}
$$

a) Determine the limits on $K$ for a stable closed-loop system.

b) Estimate and sketch the root locus for the system as $K$ varies from 0 to $\infty$. You MUST draw on the graph provided below. Show ALL important calculations.

c) Prove that the point $S = -2 + j 2.0$ is not on the root locus

d) Design a controller to force the system to have the dominant root of c) above.

e) Make a sketch of the time response of your closed-loop system to a unit step input.

f) How would you change your controller if you were required to make the steady-state error for a ramp input equal to 0?
6) [20] The open loop transfer function for a unity feedback control system is:

\[ G(s) = \frac{K}{(s+1)(s+4)} \]

and a root locus plot is shown at the right. Select a value K that will give the desired responses to a unit step input:

a) minimum \( e_{ss} \),

b) \( \%OS \leq 10\% \),

c) \( T_S \leq 1.8 \) seconds, and

d) \( T_P \) (peak time) \( \leq 0.9 \) seconds.

7) [20] Determine the number of roots with positive real parts (if any) and the location of any roots on the imaginary axis (if any) for the characteristic equations below:

a) \( s^4 + 14s^3 + 65s^2 + 112s + 60 = 0 \)

b) \( 4s^5 + 24s^4 + 93s^3 + 318s^2 + 539s + 294 = 0 \)