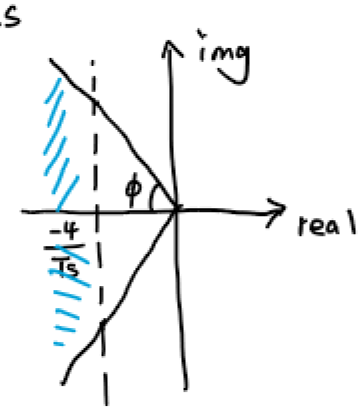
Q1 : P.O. = 30% $T_s = 0.75$ s

$$\zeta = \frac{-\ln\left(\frac{P.O.}{100}\right)}{\sqrt{\pi^2 + \ln\left(\frac{P.O.}{100}\right)^2}} = 0.358$$

$$\phi = \cos^{-1}(\zeta) = 69.02 \text{ degrees}$$



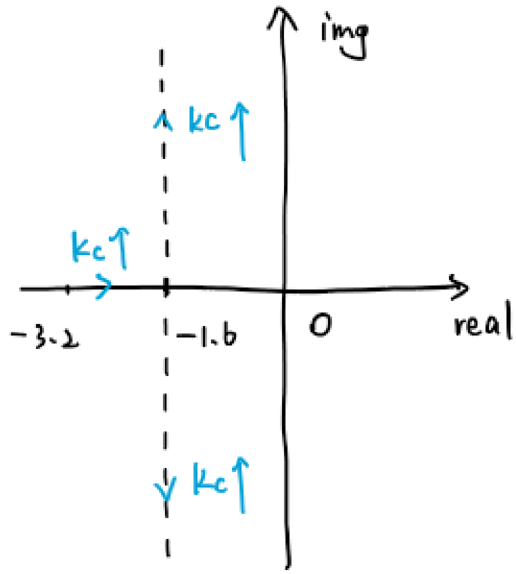
real part $= \frac{-4}{T_s} = -5.33 = a$

img part $= a\tan\phi = 2.608a$

To meet the constraint, we will need the poles at the blue part.

So we choose $-5.5 \pm j14$ for our desired poles.

Q2 :



Because k_c is a positive value, as we can see from the graph, the tendancy is drawn for increasing k_c.

Thus, we can not place the closed loop poles at $-5.5 \pm j4$.

Q3: Assume $s_0 = -5.5 + j14$

$$\angle G(s_0) = -\angle(s_0 - 0) - \angle(s_0 + 3.2)$$
$$= -\tan^{-1}\left(\frac{-14}{5.5}\right) - \tan^{-1}\left(\frac{-14}{2.3}\right)$$
$$= -111.45^\circ - 99.33^\circ = -210.78^\circ$$

Because $\angle G(s_0) + \angle G_c(s_0) = 180^\circ + l\,360^\circ$

$$\therefore \angle G_c(s_0) = 30.78^\circ + l\,360^\circ = \phi_c$$

The phase lead compensator can help provide the required phase because it can give us a zero and a pole to adjust.

Q4: To meet the requirement, we will need to place the zero at the blue region as shown in Q1.

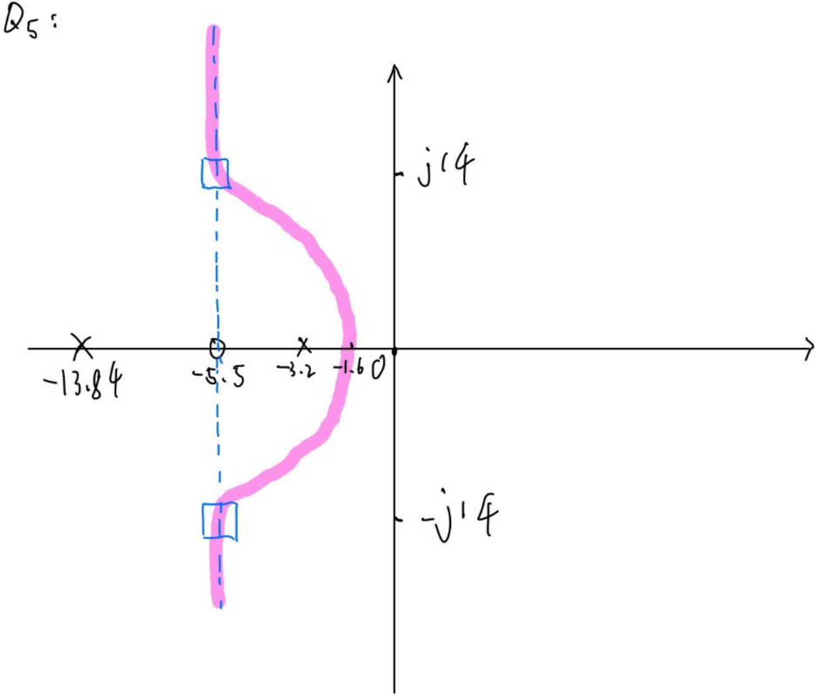
We choose $z = -5.5$.

$$\angle(s_0 + p) = \angle(s_0 + z) - \phi_c$$
$$= 90^\circ - 30.78^\circ + l\,360^\circ$$
$$= 59.22^\circ + l\,360^\circ$$

$$p = z - b\tan\phi_c$$
$$= -5.5 - 14\tan 30.78^\circ$$
$$= -13.84$$

$$\therefore z = -5.5, \quad p = -13.84$$

Q_5:



Q_6:

$$|G_c(s_0)\, G(s_0)| = 1$$

$$|k_c k_a| \cdot \frac{\pi\,|s_0+z_i|}{\pi\,|s_0+p_j|} = 1$$

$$|k_c k_a| = \frac{\pi\,|s_0+p_j|}{\pi\,|s_0+z_i|} = \frac{d_0 \cdot d_1 \cdot d_p}{d_z}$$

$$\Rightarrow 4.7 k_c = \frac{\sqrt{5.5^2+14^2} \cdot \sqrt{(5.5-3.2)^2+14^2} \cdot \sqrt{(13.84-5.5)^2+14^2}}{14}$$

$$k_c = 52.85$$

Q_7 : $K_c = 52.85$ $z = 5.5$ $p = 13.84$

Substitute into $T(s) = \dfrac{G_c(s)\,G(s)}{1+G_c(s)\,G(s)}$

$$T(s) = \frac{4.7 \times 52.85 \times (s+5.5)}{s(s+3.2)(s+13.84) + 4.7 \times 52.85 \times (s+5.5)}$$

$$= \frac{248.39s + 1366.17}{s^3 + 17.04s^2 + 292.68s + 1366.17}$$

From above, we can see that the transfer function has 1 zero and 3 poles. We do expect deviation from the design objectives, as we calculate the poles based on the overshoot and settling time using the formula for second order transfer function. But we use the formula provided in the lab 4 document to calculate the dominant poles, so the p and z value with extra pole will be approximately equal to the theoretical values with deviation.

Q_8:

$$K_v = \lim_{s \to 0} s \cdot G_c(s) G(s)$$

$$= \lim_{s \to 0} s \cdot \frac{s+5.5}{s+13.84} \cdot \frac{4.7 \times 52.85}{s(s+3.2)}$$

$$= \frac{5.5}{13.84} \cdot \frac{4.7 \times 52.85}{3.2}$$

$$= 30.85$$

$$\Rightarrow e_{ss} = \frac{1}{K_v} = 0.032.$$