Characteristic eqn. : $1 + 9.81 K_d L(s)$

e) $L(s) = \left(\frac{K_p}{K_d} + \frac{K_i}{K_d s} + s\right) \cdot \frac{9.81}{s^2}$

$$\frac{s^2 + \frac{K_p}{K_d}s + \frac{K_i}{K_d}}{s^3}$$

$$s = \frac{-\frac{K_p}{K_d} \pm \sqrt{\frac{K_p^2}{K_d^2} - 4\frac{K_i}{K_d}}}{2} = \frac{-\frac{K_p}{K_d} \pm \sqrt{\frac{K_p^2 - 4K_iK_d}{K_d^2}}}{2}$$

$$= -\frac{K_p \pm \sqrt{K_p - 4K_iK_d}}{2K_d}$$

Zeroes at $\frac{K_p}{2K_d} \mp \frac{\sqrt{K_p - 4K_iK_d}}{2K_d}$

In RLTool, I set the transfer function as $\frac{1}{s^3}$, and placed two real zeroes. I manipulated and tuned these zeroes such that 0.7 times the largest gain within the region was also in the region. I got:

$$9.81 K_d = 3.63, \quad \frac{K_p}{2K_d} + \frac{\sqrt{K_p - 4K_iK_d}}{2K_d} = 1.076$$

$$, \quad \frac{K_p}{2K_d} - \frac{\sqrt{K_p - 4K_iK_d}}{2K_d} = 0.2068$$

$\boxed{K_d = 0.370}$

$\Rightarrow K_p + \sqrt{K_p - 1.48K_i} = 1.076 \cdot 0.74$

$\Rightarrow K_p - 1.48K_i = (0.796 - K_p)^2$

$\Rightarrow K_p - 1.48K_i = 0.634 - 1.59K_p + K_p^2$

$\Rightarrow -1.48K_i = 0.634 - 2.59K_p + K_p^2$

$-K_i = 0.428 - 1.75K_p + 0.676K_p^2$

$K_p - \sqrt{K_p - 1.48K_i} = 0.2068 \cdot 0.74$

$\Rightarrow K_p - 1.48K_i = (K_p - 0.153)^2$

$\Rightarrow K_p - 1.48K_i = K_p^2 - .306K_p + .023$

$K_i = 0.676K_p^2 + 0.878K_p - 0.016$