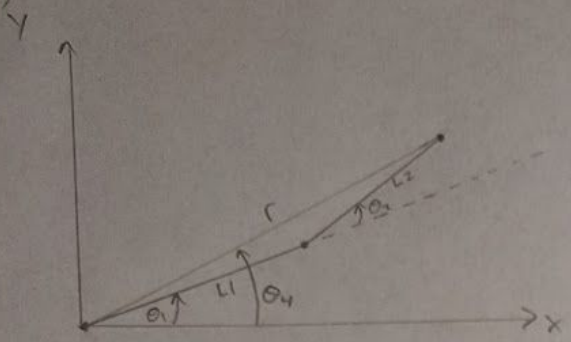
9.)



arm 1

$x = L1 \cos\theta_1$

$y = L1 \sin\theta_1$

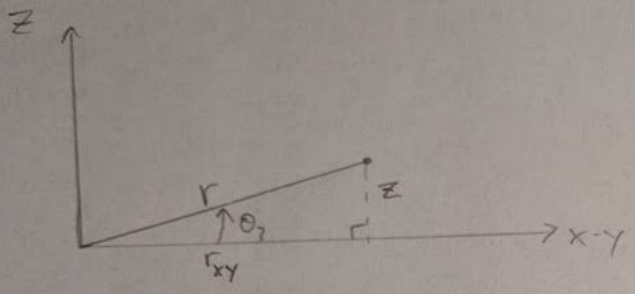
arm 2

$x = L2 \cos(\theta_1 + \theta_2)$

$y = L2 \sin(\theta_1 + \theta_2)$

$r = \text{arm1} + \text{arm2}$

$\theta_4 = \tan^{-1}\left(\frac{r_y}{r_x}\right)$



$x = r\cos\theta_4$

$y = r\sin\theta_4$

$z = r\sin\theta_3$

} Forward Kinematic equations

b.) $r = \sqrt{x^2 + y^2}$

$r_{xy} = \sqrt{r^2 - z^2}$

$\therefore \theta_3 = \tan^{-1}\left(\frac{z}{r_{xy}}\right)$

From the book:

$D \equiv \frac{x^2 + y^2 - a_1^2 - a_2^2}{2a_1a_2}$

$\theta_2 = \tan^{-1}\left(\frac{\pm\sqrt{1 - D^2}}{D}\right)$

± Because of the joint types. A two link manipulator with something like spherical joints could have "infinite" for each θ_i

Also from the book: $\gamma = \tan^{-1}\left(\frac{a_2 \sin\theta_2}{a_1 + a_2 \sin\theta_2}\right)$

$\theta_1 = \text{Tan}^{-1}\left(\frac{y}{x}\right) - \gamma$