1a

$$\begin{cases} \cos(z_1)(m+M)\dot{z}_3 - md\cos^2(z_1)\dot{z}_2 + md\cos(z_1)\sin(z_1)z_2^2 = \cos(z_1)\,T_d/r \\ \cos(z_1)(m+M)\dot{z}_3 - d(m+M)\dot{z}_2 + g(m+M)\sin(z_1) = 0 \end{cases}$$

$$\begin{cases} (m+M)\dot{z}_3 - md\cos(z_1)\dot{z}_2 + md\sin(z_1)z_2^2 = T_d/r \\ \cos(z_1)\dot{z}_3 - d\dot{z}_2 + g\sin(z_1) = 0 \end{cases} \longrightarrow \frac{1}{(M+m\sin^2(z_1))}\left(-md\sin(z_1)z_2^2 + gm\cos(z_1)\sin(z_1) + T_d/r\right)$$

$$m\cos^2(z_1)\dot{z}_3 - md\cos(z_1)\dot{z}_2 + mg\cos(z_1)\sin(z_1) = 0$$

$$\dot{z}_3\underbrace{(m+M-m\cos^2(z_1))}_{(m(1-\cos^2(z_1))+M)} + md\sin(z_1)z_2^2 - mg\cos(z_1)\sin(z_1) = T_d/r$$

$$\dot{z}_3\left(M+\sin^2(z_1)m\right) \Longrightarrow \dot{z}_3 = \frac{1}{(M+\sin^2(z_1)m)}\left(-md\sin(z_1)z_2^2 + mg\cos(z_1)\sin(z_1) + T_d/r\right)$$

1b)

$$z_4 = i_a$$

$$\dot{z}_4 = i_a' \Rightarrow -u + R_a z_4 + L_a\dot{z}_4 + K_u w_a = 0$$

$$T_d = K_m i_a \qquad w_a = \frac{V}{r} = \frac{z_3}{r}$$

$$z_4 = i_a = \frac{T_d}{K_m}$$

$$\boxed{\dot{z}_4 = \frac{1}{L_a}\left(u - \frac{R_a T_d}{K_m} - \frac{K_u z_3}{r}\right)}\ ?$$

2a)

$\dot{z}_1$: $z_{20} = 0 \pm n\pi$

$\dot{z}_2$: $\frac{1}{d(M+\sin^2(z_{10}))}\left(g(M+m)\sin(z_{10}) + \cos(z_{10}) z_4 K_m/r\right) = 0$

$\dot{z}_3$: $\frac{1}{(M+m\sin^2(z_{10}))}\left(\underbrace{gm\cos(z_{10})\sin(z_{10}) + z_4 K_m/r}_{z_1}\right) = 0$

$= \begin{cases} (g(M+m)\sin(z_{10}) + \cos(z_{10}) z_4 K_m/r) & (1) \\ (gm\cos(z_{10})\sin(z_{10}) + z_4 K_m/r) \end{cases}$

$z_{10} = \cancel{2\arcsin\left(\frac{2 z_a}{rgm}\right)}$

$z_4 = \left(-gm\frac{\sin(2z_{10})}{2}\right)\frac{r}{K_m}$ in i (1)

(1): $g(M+m)\sin(z_{10}) + \cos(z_{10}) \cdot \frac{K_m}{r} \cdot \frac{r}{K_m} \frac{1}{2}(-gm\sin(2z_{10})) \Rightarrow z_{10} = 0$

$\dot{z}_4$: $\frac{1}{L_a}\left(\underbrace{u - R_a z_{40} - \frac{K_u z_{30}}{r}}\right) = 0 \Rightarrow$

$\frac{K_u}{L_a r}\left(\frac{ur}{K_u} - z_{30}\right) \Rightarrow z_{30} = \frac{u_0 r}{K_u}$

$\Rightarrow z_{40} = 0$

$T_a = u_0$?

$\sin x \sin x = \cos x \sin x + -\cos x \sin x$

2 b) $\dot{z}_1 = 0$ säger när roboten står stilla i upprätt läge

$\dot{z}_3 = 0$ är när hastigheten är noll (förändringen är 0)

$\dot{z}_4 = 0$ när induktansen 0

3. $\dot{z}_1 = z_2 = [0 \quad 1 \quad 0 \quad 0]$

Kring Jmv-pkter

$\dot{z}_2 = \frac{1}{d(M+m z_1^2)}\left(-\frac{md}{2} \cdot 2z_1 z_2^2 + g(m+M) z_1 + \frac{z_4 K_m}{r}\right) \Rightarrow \Bigg[\frac{(-md z_2^2 + g(m+M))(d(M+m z_1^2)) -}{}$

$\frac{-(-md z_1 z_2^2 + g(m+M) z_1 + \frac{z_4 K_m}{r})(dM + 2dm z_1)}{(d(M+m z_1^2))^2}, \frac{-md z_1}{d(M+m z_1^2)} \cdot 2z_2, 0, \frac{K_m}{r} \cdot \frac{1}{d(M+m z_1^2)}\Bigg]$

$\left[\frac{(-md(n\pi)^2 + g(m+M))(dM)}{(dM)^2}, 0, 0, \frac{K_m}{r dM}\right]$

$$A = \begin{bmatrix} 0 & 1 & 0 & 0 \\ \frac{\left(-md(n\pi)^2 + g(M+m)\right)}{dM} & 0 & 0 & \frac{K_m}{rdM} \\ \frac{\left(gm - md\,n\pi\right)}{M} & 0 & 0 & \frac{K_m}{rM} \\ 0 & 0 & -\frac{K_e}{rL_a} & -\frac{R_a}{L_a} \end{bmatrix}$$

$$B = \begin{bmatrix} 0 \\ 0 \\ 0 \\ \frac{1}{L_a} \end{bmatrix}$$

$$y_* = \theta = z_1$$

$$\Delta y = \underbrace{\begin{bmatrix} 1 & 0 & 0 & 0 \end{bmatrix}}_{C} \begin{bmatrix} z_1 \\ z_2 \\ z_3 \\ z_4 \end{bmatrix}$$