$\boxed{F.6}$ (a)

$\dot{\tilde{x}} = A\tilde{x} + B\tilde{u}$ where $\tilde{x}_{Lon} = \begin{bmatrix} \tilde{h} \\ \dot{\tilde{h}} \end{bmatrix}$ $\tilde{y}_{Lon} = [\tilde{h}]$ $\tilde{u}_{Lon} = [\tilde{F}]$

$\tilde{y} = C\tilde{x} + B\tilde{u}$

$$\begin{bmatrix} \dot{\tilde{h}} \\ \ddot{\tilde{h}} \end{bmatrix} = \begin{bmatrix} 0 & 1 \\ 0 & 0 \end{bmatrix} \begin{bmatrix} \tilde{h} \\ \dot{\tilde{h}} \end{bmatrix} + \begin{bmatrix} 0 \\ 1/m \end{bmatrix} [\tilde{F}]$$

where $m = 2m_r + m_c$

$$[\tilde{h}] = [1 \;\; 0] \begin{bmatrix} \tilde{h} \\ \dot{\tilde{h}} \end{bmatrix} + [0][\tilde{F}]$$

$$\dot{\tilde{x}}_{Lon} = \begin{bmatrix} 0 & 1 \\ 0 & 0 \end{bmatrix} \tilde{x}_{Lon} + \begin{bmatrix} 0 \\ 1/m \end{bmatrix} \tilde{u}_{Lon}$$

$$\tilde{y}_{Lon} = [1 \;\; 0] \tilde{x}_{Lon} + [0] \tilde{u}_{Lon}$$

(b)

$\dot{\tilde{x}} = A\tilde{x} + B\tilde{u}$ where $\tilde{x}_{Lat} = \begin{bmatrix} \tilde{z} \\ \tilde{\theta} \\ \dot{\tilde{z}} \\ \dot{\tilde{\theta}} \end{bmatrix}$ $\tilde{y}_{Lat} = \begin{bmatrix} \tilde{z} \\ \tilde{\theta} \end{bmatrix}$ $\tilde{u}_{Lat} = [\tilde{\tau}]$

$\tilde{y} = C\tilde{x} + B\tilde{u}$

$$\begin{bmatrix} \dot{\tilde{z}} \\ \dot{\tilde{\theta}} \\ \ddot{\tilde{z}} \\ \ddot{\tilde{\theta}} \end{bmatrix} = \begin{bmatrix} 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & -\frac{F_e}{m} & \frac{\mu}{m} & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} \tilde{z} \\ \tilde{\theta} \\ \dot{\tilde{z}} \\ \dot{\tilde{\theta}} \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \\ 0 \\ 1/J \end{bmatrix} [\tilde{\tau}]$$

where $J = (2m_r d^2 + J_c)$

$$\begin{bmatrix} \tilde{z} \\ \tilde{\theta} \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \end{bmatrix} \begin{bmatrix} \tilde{z} \\ \tilde{\theta} \\ \dot{\tilde{z}} \\ \dot{\tilde{\theta}} \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \end{bmatrix} [\tilde{\tau}]$$

$$\dot{\tilde{x}}_{Lat} = \begin{bmatrix} 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & \frac{-F_e}{m} & \frac{-\mu}{m} & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix} \tilde{x}_{Lat} + \begin{bmatrix} 0 \\ 0 \\ 0 \\ 1/J \end{bmatrix} \tilde{u}_{Lat}$$

$$\tilde{y}_{Lat} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \end{bmatrix} \tilde{x}_{Lat} + \begin{bmatrix} 0 \\ 0 \end{bmatrix} \tilde{u}_{Lat}$$

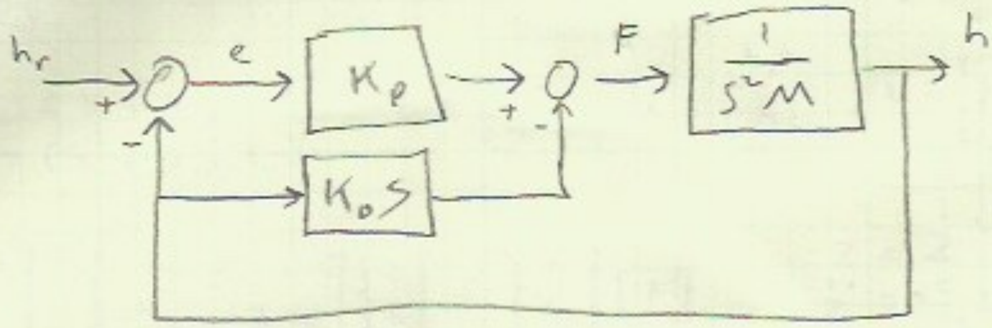
$\boxed{F.7}$ (a)

given

$$\frac{1}{s^2 M} = H(s) \qquad P_{1,2} = \frac{1}{2M}\left(-0 \pm \sqrt{0^2 - 4(M)0}\right) = \frac{0}{2M} = 0$$

$$P_{1,2} = 0$$

(b)



$$\left.\begin{aligned} e &= h_r - h \\ F &= K_p e - s K_D h \\ h &= F \frac{1}{s^2 M} \end{aligned}\right\} \quad h = (K_p(h_r - h) - s K_D h) \frac{1}{s^2 M}$$

$$h s^2 M = K_p h_r - K_p h - s K_D h$$

$$h(s^2 M + s K_D + K_p) = K_p h_r$$

$$h = \frac{K_p}{s^2 M + s K_D + K_p} h_r$$

$$\Delta(s) = s^2 M + s K_D + K_p$$

$$p_{1,2} = \frac{1}{2M}\left(-K_D \pm \sqrt{K_D^2 - 4(M)K_p}\right)$$

$$p_{1,2} = \frac{1}{3}\left(-K_D \pm \sqrt{K_D^2 - 6 K_p}\right)$$