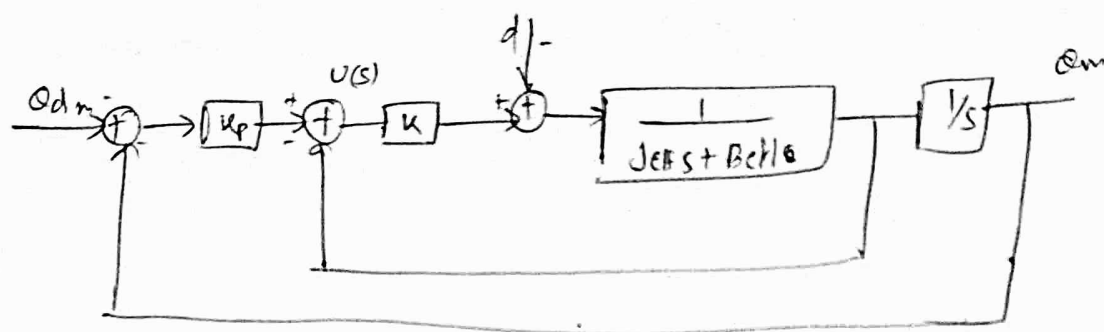


Q3

(a) PD control.



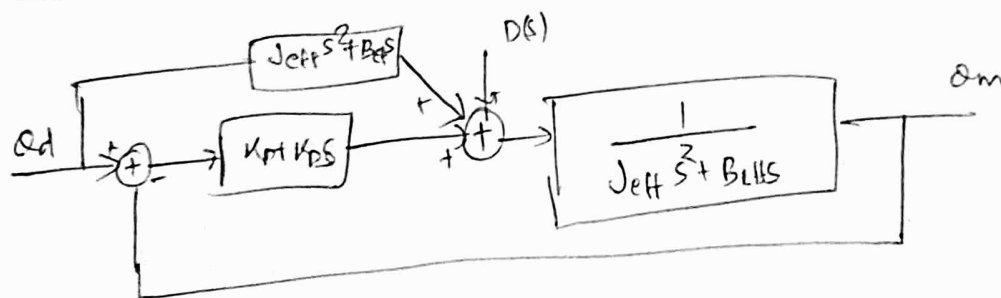
Control equation is

$$U(s) = K_p (O_d - O_m) + K_d (\dot{O}_d - \dot{O}_m)$$

$$K_p = 10, 3, 1$$

$$K_d = 5, 1.25, 1$$

(b) Same PD with feed forward model



Control equation is

$$U(s) = K_p (O_d - O_m) + K_d (\dot{O}_d - \dot{O}_m) + J_{eff} \ddot{O}_d + B_{ct} \dot{O}_d$$

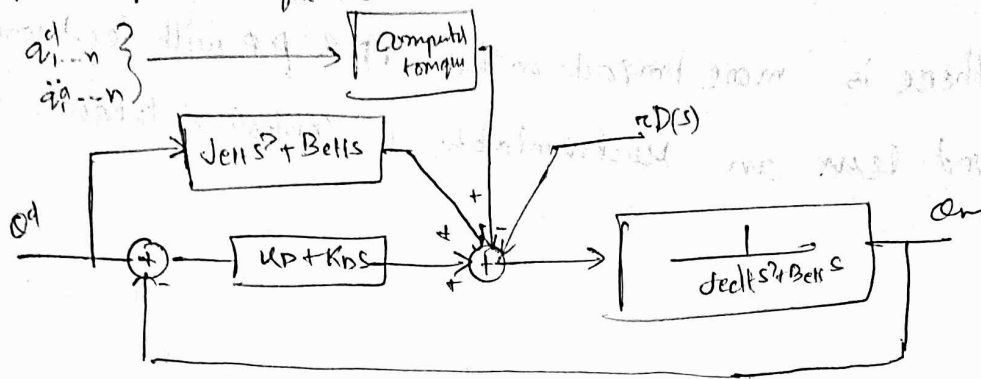
$$K_p = 10, 3, 1$$

$$K_d = 5, 1.25, 1$$

$$J_{eff} = 10$$

$$B_{ct} = 10$$

(c) Same PD control along with a feed forward disturbance compensation using computed torque method.



$$U(\phi) = \kappa_d (Q_d - Q_m) + \kappa_o (\dot{Q}_d - \dot{Q}_m) + J_{eff} \ddot{Q}_d + B_{eff} \dot{Q}_d + M(\eta) \ddot{Q}_d + B(Q, \dot{Q}) \dot{Q}_d + G(Q)$$

Same as before  $M(2)$ ,  $(2, 2)$ ,  $G(2)$  is calculated

(d) Multivariable control



$$u \in M(\mathbb{Q}) q_1 + C(\mathbb{Q}^1 \mathbb{Q}^1) q_1 + G(\mathbb{Q})$$

$$q_q = \ddot{Q}a + k_e(e) + n_e(\ddot{e})$$

$$e = Q_d - Q_m$$

Observation! =>

Q 4, 5, 6,

There is more impact on the PD, & PP with lead forward and less on multivariable & Controlled to ram.



$$m\ddot{x} + c\dot{x} + kx = (m\ddot{x}_d + c\dot{x}_d + kx_d) + (m\ddot{x}_d + c\dot{x}_d + kx_d) \quad (1)$$

$$m\ddot{x} + c\dot{x} + kx = m\ddot{x}_d + c\dot{x}_d + kx_d \quad (2)$$

substitution of (1) in (2) gives

substitution of (1) in (2) gives (b)



$$m\ddot{x} + c\dot{x} + kx = m\ddot{x}_d + c\dot{x}_d + kx_d \quad (3)$$

$$m\ddot{x} + c\dot{x} + kx = m\ddot{x}_d + c\dot{x}_d + kx_d \quad (4)$$

$$m\ddot{x} + c\dot{x} + kx = m\ddot{x}_d + c\dot{x}_d + kx_d \quad (5)$$