RW 6.15

6.15. A high-performance hydraulic actuator is shown in Fig. 6.36. The dc motor, with the torque/current relationship $T = -K_a i$, is controlled from a voltage source V_s, and has winding resistance R and inductance L. The positive displacement pump displaces D m^3 of fluid per radian of shaft rotation. The mass m is driven through a ram of area A. A bypass valve, with fluid resistance R_1, returns the fluid to the reservoir tank.

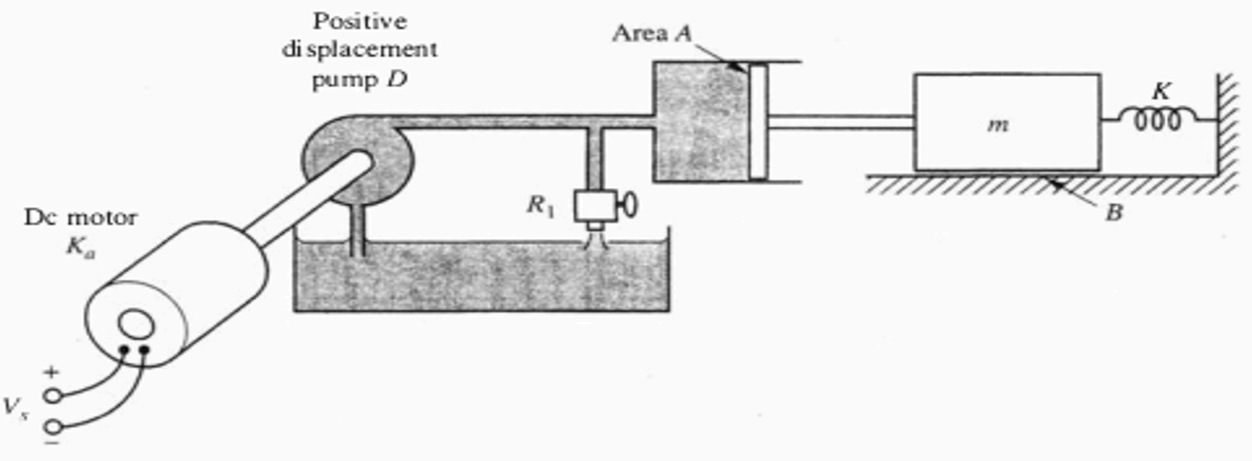


Figure 6.36: A high-performance hydraulic drive system.

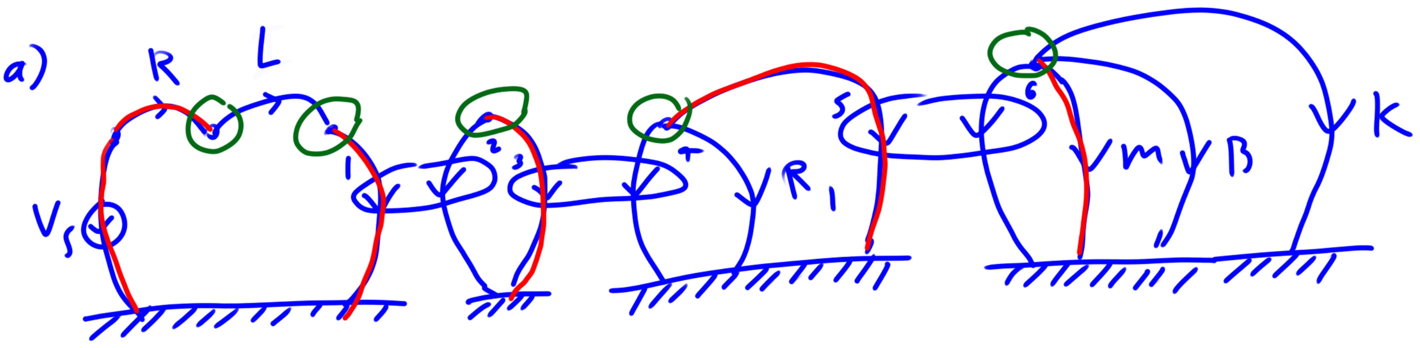
(a) Construct the system linear graph and identify the state variables.

(b) Derive the state equations.

(c) Write an output equation for the displacement of the mass.

(d) Determine the relationship between the ram force on the mass to the motor torque for the case when the mass is clamped so that it cannot move.

a)



State: V_m $\quad i_L$ $\quad f_K$ $\quad n=3$

b)

	elemental	continuity	compatibility
R	$V_R = R I_R$	$I_R = I_L$	
L	$\frac{dI_L}{dt} = \frac{1}{L} V_L$		$V_L = V_s - V_R - V_1$
K_a	$T_2 = -K_a I_1$	$I_1 = I_L$	
	$V_1 = \frac{1}{K_a} \Omega_2$		$\Omega_2 = \Omega_3$
D	$Q_4 = D\,\Omega_3$		
	$T_3 = \frac{-1}{D} P_4$	$T_3 = -T_2$	$P_4 = P_5$
R_1	$Q_{R_1} = \frac{1}{R_1} P_{R_1}$		$P_{R_1} = P_5$
A	$f_6 = \frac{1}{A} P_5$		
	$Q_5 = A V_6$	$Q_5 = -Q_4 - Q_{R_1}$	$V_6 = V_m$
m	$\frac{dv_m}{dt} = \frac{1}{m} f_m$	$f_m = -f_6 - f_B - f_K$	
B	$f_B = B V_B$		$V_B = V_m$
K	$\frac{df_K}{dt} = K V_K$		$V_K = V_m$

$$\frac{dI_L}{dt} = \frac{1}{L} V_L = \frac{1}{L}(V_s - V_R - V_1)$$

$$= \frac{1}{L}\left(V_s - R I_R - \frac{1}{K_a}\Omega_2\right)$$

$$= \frac{1}{L}\left(V_s - R I_L - \frac{1}{K_a}\Omega_3\right)$$

$$= \frac{1}{L}\left(V_s - R I_L - \frac{1}{K_a D} Q_4\right)$$