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1. A crane hoists a load in Fig.1. The rope is considered to be stiff with a fixed length L.
   (a) Derive the nonlinear mathematical model of the system. (4%)
   (b) Assume ϕ is small. Simplify the model in (a) to a linear model. (3%)
   (c) Obtain the transfer function from cart velocity to rope angle $\frac{\Phi(s)}{V_T(s)}$. (3%)
   (d) Assume that the cart is driven at a constant velocity V_0. Solve the resulting $\phi(t)$. (3%)
   (e) Find the transfer function from the applied force to the cart's position, $\frac{X_T(s)}{F_T(s)}$. (3%)
   (f) If a constant force is applied to the cart, show what will happen as $t \to \infty$. (4%)

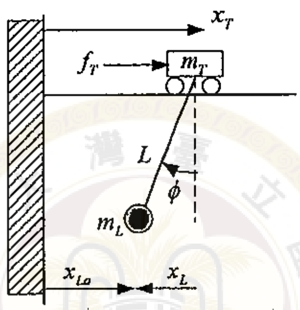

Fig.1

2. Consider the system in Fig.2 that has the specifications of velocity constant $K_v = 10$ and damping ratio $\zeta = 0.5$.

   Find the values of K_1 and K_f for meeting the specification. (20%)

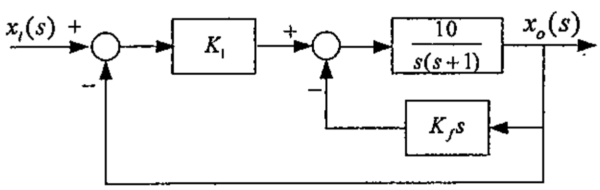

Fig.2

3. A position control system as shown in Fig.3.
   (a) Find K to yield a settling time of 0.1 sec. (5%)
   (b) Solve the resulting percentage of overshoot. (5%)
   (c) Find the range of K to keep the system stable. (5%)
   (d) Sketch the root-locus diagram. (5%)

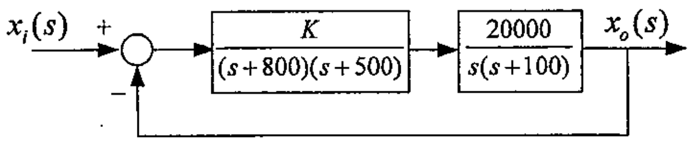

Fig.3

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4. A controlled plant which state space equations are described as

$$\dot{\mathbf{x}}(t) = \begin{bmatrix} 0 & 1 \\ -2 & 3 \end{bmatrix} \mathbf{x}(t) + \begin{bmatrix} 0 \\ 1 \end{bmatrix} u(t)$$
$$y(t) = \begin{bmatrix} 1 & 0 \end{bmatrix} \mathbf{x}(t)$$

and the block diagram of the closed-loop control system is shown in Fig.4. The closed-loop poles are given as -8, -2 and -1. Please find K_I and $\mathbf{K}_0 = [K_2 \quad K_3]^T$. (20%)

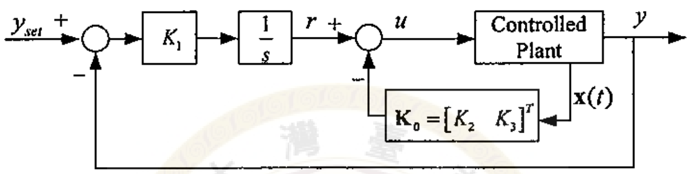

Fig.4

5. Consider a closed-loop system shown in Fig.5 with the open-loop transfer function as

$$G(s)H(s) = \frac{K}{s(s+1)(2s+1)}$$

(a) Is the closed-loop system stable while K=2? (10%)
(b) Find the critical value of K for stability. (10%)

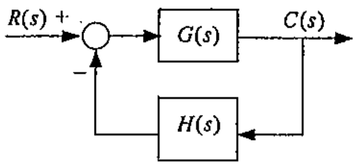

Fig.5

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