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1.

A pendulum with a ball and a uniform rod is shown in Fig.1, where *T* is the applied torque in the ϕ direction; *Mg* is the weight of ball; *mg* is the weight of rod; *L* is the length of rod. The mass center of rod is at *L*/2. The overall moment of inertia of ball and rod around the rotational point is *J*.

(a) Derive the nonlinear differential equation of the system. (8%)

(b) Transform (a) into state space model with the state variables: $x_1 = \phi$, $x_2 = d\phi/dt$. (7%)

(c) Linearize the state equations in (b) about the pendulum equilibrium point of the vertical position with zero angular velocity ($x_1 = 0, x_2 = 0$). (10%)

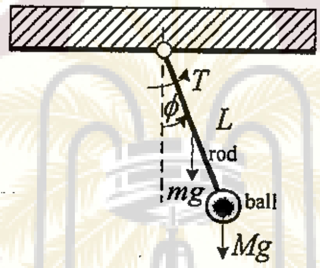

Fig.1

2.

Wind turbines are becoming popular as a way of green energy. Feedback control loops are designed to control the output power of the turbine. Blade-pitch control may be used for a constant rotational speed of generator. The pitch control system can be derived as

$G(s) = \dfrac{48500}{s^2 + 2.89s}$ with a PI controller as $G_c(s) = (K_p + \dfrac{K_I}{s})$, as shown in Fig.2.

(a) Please find the value of K_I that yields to a steady state error $e_{ss} = 2\%$ for a parabolic input. (7%)

(b) Plot the root locus of the system as a function of K_p by using the value of K_I found in (a). (8%)

(c) Please find the value of K_p that will result in a real pole at -1, and also find the location of the other two poles. (10%)

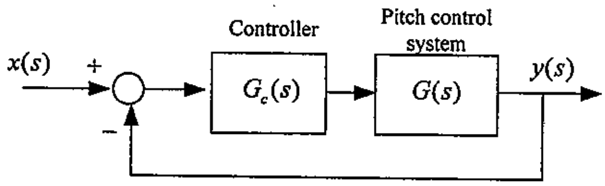

Fig.2

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3.
A car active suspension system uses an active hydraulic actuator to create a dynamic impedance that responds to road variations. The suspension system can be described as

$$\dot{\mathbf{X}}(t)=\begin{bmatrix}0 & 1 & 0\\ 0 & 0 & 1\\ -5 & -2K & -3\end{bmatrix}\mathbf{X}(t)+\begin{bmatrix}0\\ 0\\ K\end{bmatrix}u(t)$$

$$y(t)=\begin{bmatrix}1 & 0 & 0\end{bmatrix}\mathbf{X}(t)$$

(a) Please derive the characteristic equation of the system. (5%)
(b) Please find the range of K to make the system stable. (5%)
(c) To make the system marginally stable, please find the gain K and the oscillation frequency. (8%)
(d) Please find the steady-state value of $y(t)$ for a unit-step input as K=1. (7%)

4.
A floppy disc drive is a position control system in which a read/write head is positioned over a magnetic disk. The system responds to a command from a computer to position itself at a particular track on the disk. As shown in Fig.3, the model of motor and load is described as $G(s)=\dfrac{21K}{s(s+1)(s+3)}$. Please design a phase-lead compensator $G_c(s)=K_c\dfrac{s+z}{s+p}$ to satisfy the following conditions: (1) DC gain of compensator: 0.5; (2) Phase margin: 40°; (3) Settling time: T_s< 4 sec. (25%)

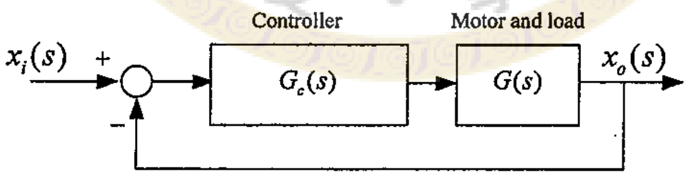

Fig.3

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