國立臺灣科技大學
九十四學年度碩士班招生考試試題
系所組別：自動化及控制研究所碩士班丙組
科　　目：控制系統

總分為 100 分，題號請標示清楚。

1. Obtain a linearized expression for the following function, valid near the given reference value.

$$w = y_1^2 \sin y_2,\ \ y_{10} = 1, \quad y_{20} = \pi/4. \qquad (5\%)$$

2. If Fig. 2 models a position servo with G(s) = 1/[s(s+3)], choose p and K in the controller G_C = K(s+1)/(s+p) such that: (10%)
   (1) The steady-state unit ramp following error is zero, and
   (2) The damped natural frequency of oscillatory components in the transient response is 4 rad/sec.

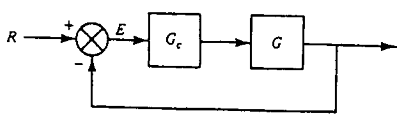
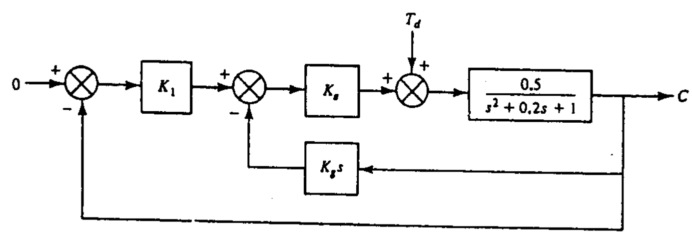


Fig. 2

3. The block diagram of a roll stabilizer for a ship is shown below. Minor loop rate feedback is included because of the low damping associated with the ship dynamics.
   (a) Express the transfer function for the effect of wave disturbance torque T_d on ship roll angle C. (5%)
   (b) Find the equations that must be satisfied by K_a, K_1, and K_g to ensure both a steady-state value of no more than 0.1 for C in response to a unit step T_d and a system damping ratio 0.5. (5%)
   (c) Which of K_1, and K_a must be adjustable to enable both specifications in part (b) to be met? (5%)



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4. The linearized model of a robot arm system driven by a DC motor is shown below. The system parameters and variables are given as follows:

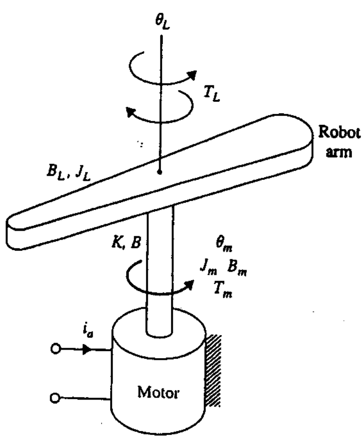
In DC motor, where T_m = motor torque $= K_i i_a$,
K_i = torque constant,
i_a = armature current of motor,
J_m =motor inertia,
B_m = motor viscous-friction coefficient,
θ_m = motor-shaft displacement.

In robot arm, where J_L = inertia of arm,
T_L = disturbance torque on arm,
θ_L = arm displacement,
K= torsional spring constant,
B= viscous-friction coefficient of shaft between the motor and arm,
B_L = viscous-friction coefficient of the robot arm shaft.

(a) Write the differential equations for the system with $i_a(t)$ and $T_L(t)$ as input and $\theta_m(t)$ and $\theta_L(t)$ as outputs. (10%)

(b) Express the transfer function relations as

$$\begin{bmatrix} \Theta_m(s) \\ \Theta_L(s) \end{bmatrix} = G(s) \begin{bmatrix} I_a(s) \\ -T_L(s) \end{bmatrix}$$ Find G(s). (10%)



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5. Figure 5(a), shows a well-known "broom-balancing" system in control systems. The objective of the control system is to maintain the broom in the upright position by means of the force u(t) applied to the car as shown. In practical applications, the system is analogous to a one-dimensional control problem of the balancing of a unicycle or a missile immediately after launching. The free-body diagram of the system is shown in Figure 5(b), where

f_x = force at broom base in horizontal direction,

f_y = force at broom base in vertical direction,

M_b = mass of broom,

g = gravitational acceleration,

M_c = mass of car,

J_b = moment of inertia of broom about center of gravity CG= $M_b L^2/3$

(a) Write the force equations in the x and y directions at the pivot point of the broom. Write the torque equation about the center of gravity (CG) of the broom. Write the force equation of the car in the horizontal direction. (10%)

(b) Express the equations obtained in part (a) as state equations by assigning the state variables as $x_1 = \theta$, $x_2 = d\theta/dt$, $x_3 = x$, and $x_4 = dx/dt$. Simplify these equations for small θ by taking the approximations: $\sin\theta \cong \theta$ and $\cos\theta \cong 1$. (10%)

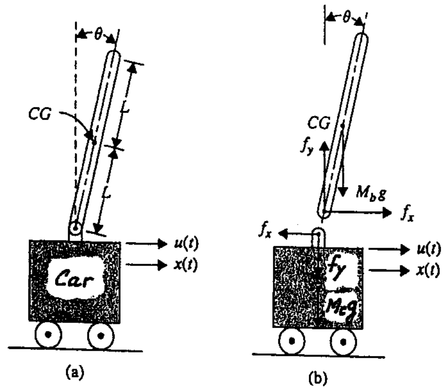

Figure 5

6. Determine the steady-forced response of a system with transfer function

$$T(s) = \frac{1}{(s+1)(0.1s+1)}$$ to the sinusoidal input r(t) = 2sin 0.5t. (10%)

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7. In Figure 7, a plant transfer function $G(s)=\frac{0.5}{s^2}$ may represent a satellite.

(a) Design a PD controller that places the two complex poles of the closed-loop transfer function at $s=-2\pm 2j$. (5%)

(b) Sketch the root locus for the compensated system of (a). (5%)

(c) A unit step function is applied to the compensated system input of (a). Give the time required for the system to reach steady state. (5%)

(d) Find the transfer function of a PD compensator that results in a critically damped system with a time constant of $\tau = 0.25s$. (5%)

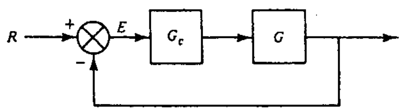

Figure 7