編號： 197

國立成功大學 109 學年度碩士班招生考試試題

系　　所：製造資訊與系統研究所

考試科目：自動控制

考試日期：0210，節次：1

※ 考生請注意：本試題不可使用計算機。　請於答案卷(卡)作答，於本試題紙上作答者，不予計分。

1. (20%) Consider the inverted pendulum system shown in Figure 1. Assume that the mass of the mobile base is m_1 and the inverted pendulum is m_2 with a massless rod of the length l. The angle of the rod to the vertical axis is θ. For the system, $y(t)$, the horizontal movement, is considered as the output with the input $u(t)$ as the driving force on the mobile base.
   (1) Derive the dynamic model of the inverted pendulum system.
   (2) Find out the transfer function of the inverted pendulum system with y(t) as the output and u(t) as the input if θ is large.
   (3) If θ(t) is very small, find out the transfer of the system with θ(t) as the output and u(t) as the input.

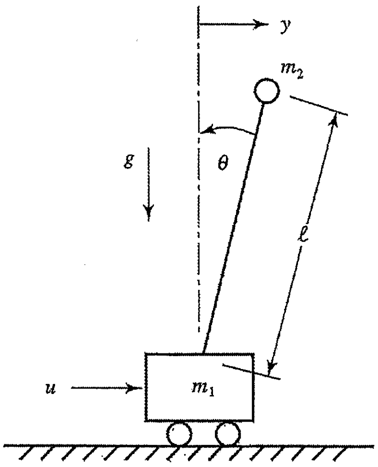

Figure 1. Inverted pendulum system.

2. (15%) The mechanical system shown in Figure 2 (a) is used as part of the unity feedback system shown in Figure 2 (b). Find the values of M and D to yield 20% overshoot and 2 seconds settling time.

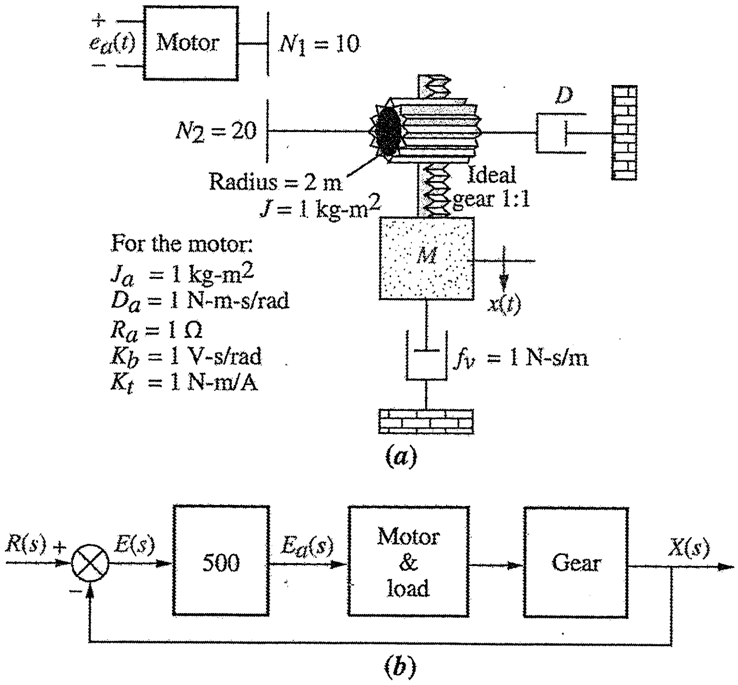

Figure 2. Motor and load in a feedback control system

3. (30%) An example of an automated highway system is shown in Figure 3. A velocity control system for maintaining the *velocity* between vehicles is illustrated in Figure 4. The output *Y(s)* is the relative velocity of the two automobiles; the input *R(s)* is the desired relative velocity between the two vehicles. Our design goal is to develop a controller that can maintain the prescribed velocity between the vehicles and maneuver the active vehicle as commanded.

The **CONTROL GOAL** of the system is to maintain the prescribed velocity between the two vehicles, and maneuver the active vehicle as commanded. Design a controller with your choice from a PD or PI controller to satisfy the following **SPECIFICATIONS**.

(1) Zero steady-state error to a step input
(2) Steady-state error due to a ramp input of $e_{ss}<25\%$ of the input magnitude
(3) Percent overshoot of $< 5\%$ to a step input
(4) Settling time of $T_s<1.5$ *sec* to a step input (using a 2% criterion to establish settling time)
Hint: you can use the root locus technique for second-order approximation of transient response.

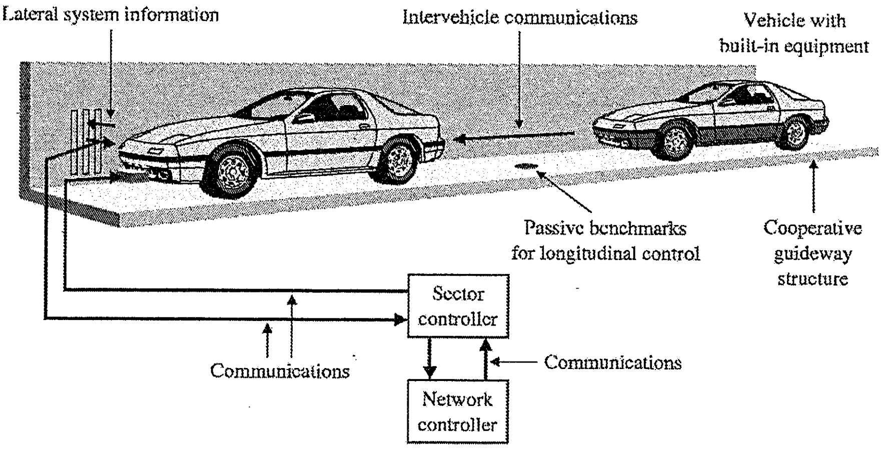

Figure 3. Automated highway system.

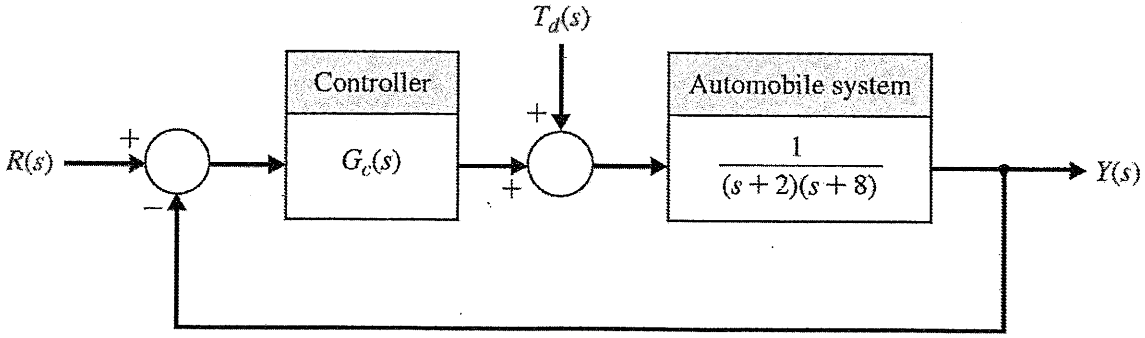

Figure 4. Vehicle velocity control system.

4. (20%) A ship's roll can be stabilized with a control system. A voltage applied to the fins' actuators creates a roll torque that is applied to the ship. The ship, in response to the roll torque, yields a roll angle. Assuming that block diagram for the roll control system shown in Figure 5, answer the followings
   (1) Find out the range of gain for stability, and the oscillation frequency by using the root locus technique.
   (2) If K=5, determine the gain and phase margins for the system via plotting the Nyquist diagram.

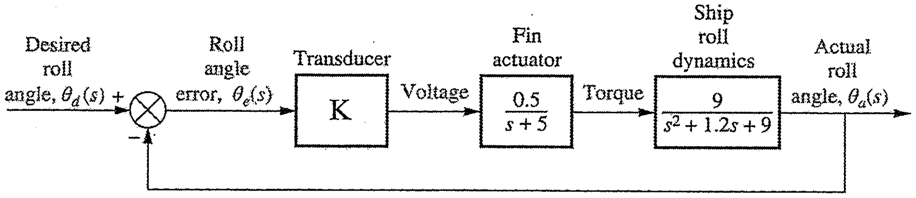

Figure 5. Block diagram of a ship's roll-stabilizing system.

5. (15%) Consider a unity feedback control system with the transfer function

$$\text{System 1: } G(s)=\frac{(s+2)(s+4)}{s(s+1)(s+3)} \qquad \text{System 2: } G(s)=\frac{50(s+3)}{s(s+2)(s+4)}$$

   (1) Find the analytical expressions for the magnitude and phase response.
   (2) Plot the Bode plot and answer the gain and phase margins.