*Note: 請將題號及答案標示清楚

1. (20%) Consider the mechanical system of Fig. 1, where m_1 and m_2 are masses, K is a spring and C is a damper. F is the applied force. y_1 and y_2 are the displacements of m_1 and m_2, respectively.

   (1) (5%) Write the dynamic equations of m_1 and m_2.

   (2) (5%) Find the transfer function $T_{F\to y_1}$ from F to y_1.

   (3) (5%) Consider the closed-loop system of Fig. 2 with $G(s)=T_{F\to y_1}$ and a PD-control $C(s)=K_P+\dfrac{K_D s}{\tau s+1}$ where $\tau \ll 1$, calculate the steady-state error to a step input $R(s)=\dfrac{1}{s}$.

   (4) (5%) Set the state as $x=[y_1\ \ \dot{y}_1\ \ y_2\ \ \dot{y}_2]^T$ with input of F and outputs of $[y_1\ \ y_2]^T$, please derive the corresponding state-space model.

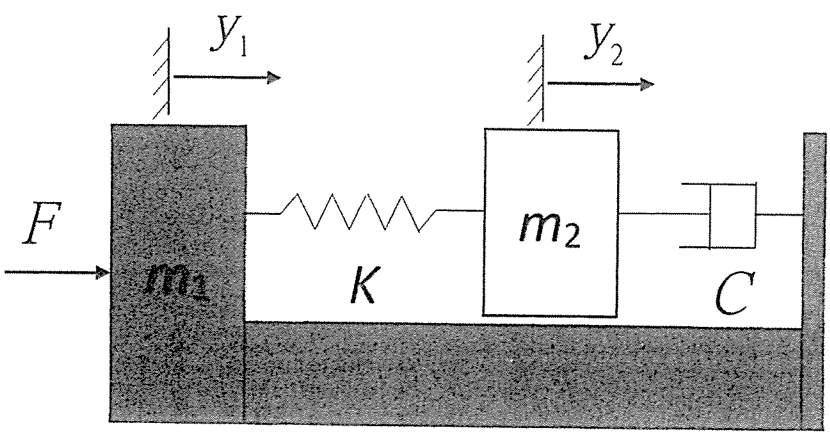

Fig. 1

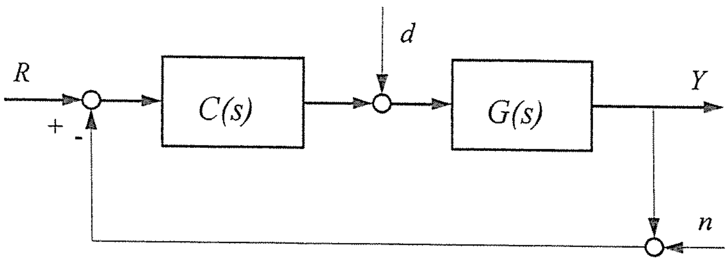

Fig. 2

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2. (30%) Consider the closed-loop of Fig. 2 with $G(s)=\dfrac{1}{s^3+3s^2+2s}$,

(1) (5%) Applying a P-control $C(s)=K_P$, please sketch the root-loci of the closed-loop poles as $K_P:0\to\infty$.

(2) (5%) Find the value of K_P that would give the fast settling time to step commands.

(3) (5%) Estimate the setting time (within 2% error) to step commands by the K_P found in (2).

(4) (5%) What is the range of K_P such that the closed-loop system is stable?

(5) (5%) What is the value of K_P so that the closed-loop system has a damping ratio of $\dfrac{1}{\sqrt{2}}$?

(6) (5%) What is the natural frequency of the closed-loop system by the K_P found in (5).

3. (12%) What are the objectives of the approaches of root locus, Nyquist plot, Bode diagram, and Nichols chart? (6%) Why can they determine the closed-loop characteristics of a system based on the open loop transfer function? (6%)

4. (25%) For a unity feedback system, the open loop transfer function $G(s)$ is given as

$$G(s)=\frac{K(s+3)}{s(s^2+4s+25)}$$

The closed-loop system performance requires 5% steady-state error for a ramp input, and 45^0 phase margin. Use the Bode diagram approach to design a cascade compensator to achieve the requirements. (Hint: the semi-log diagrams are given in Fig.3.)

5. (13%) A system has the transfer function shown as $G(s)=\dfrac{40}{(s+2)(s+10)}$.

(1) (7%) Find the bandwidth of the system.

(2) (6%) For a 20Hz input signal, how does the system react to the signal? Why?

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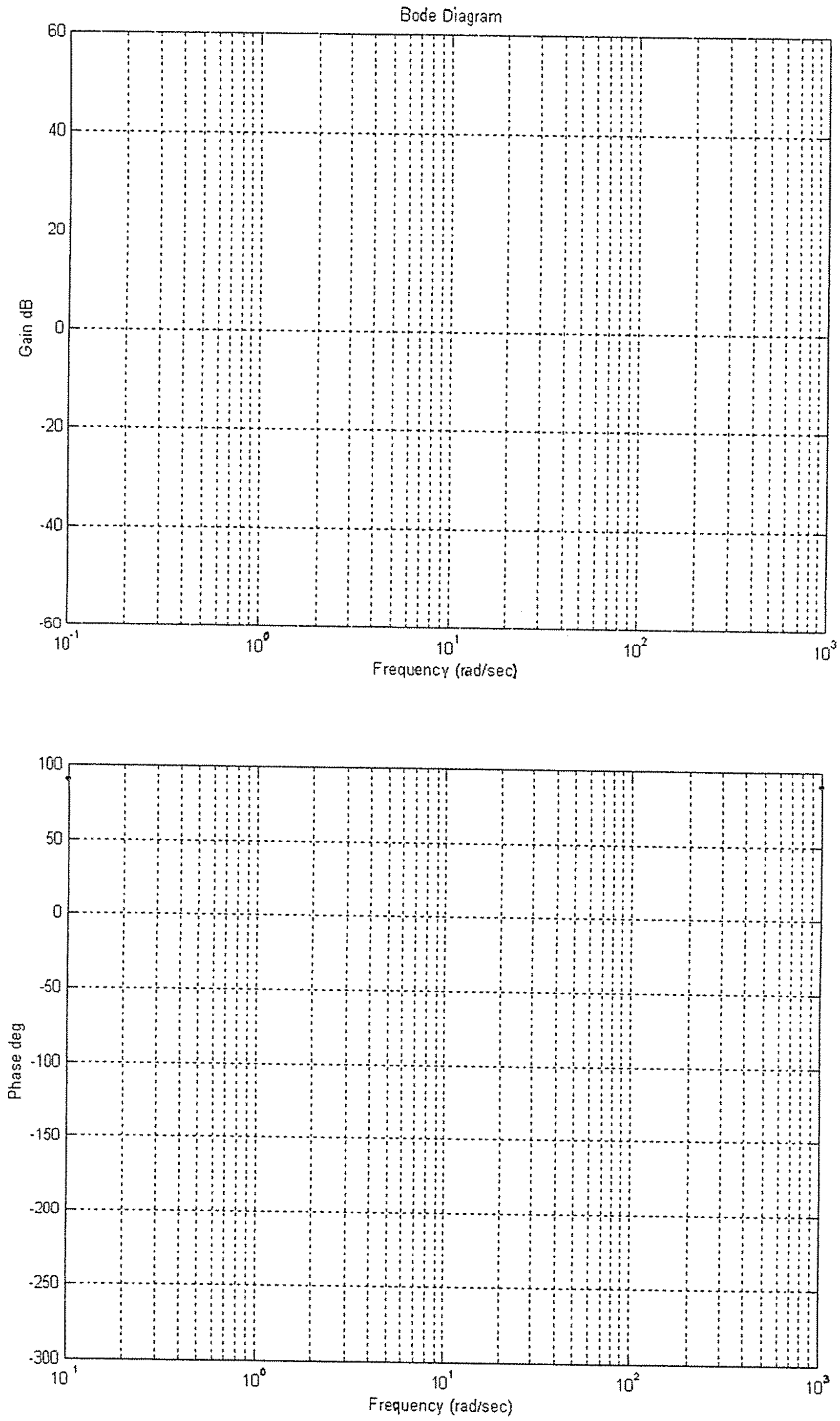
Bode Diagram
60
40
20
0
-20
-40
-60
Gain dB
10^{-1}
10^{0}
10^{1}
10^{2}
10^{3}
Frequency (rad/sec)
100
50
0
-50
-100
-150
-200
-250
-300
Phase deg
Frequency (rad/sec)

Fig. 3

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