國立臺灣科技大學102學年度碩士班招生試題

系所組別：機械工程系碩士班丁組

科　　目：系統控制

(總分為100分)

題目共四題，總分 100 分，每小題有標示所占分數

1. The transfer function between rotational angle θ and input voltage V of a third order servo mechanical system is: $\dfrac{\theta(s)}{V(s)} = \dfrac{20(s+2)}{(s+8)(s^2+2s+5)}$

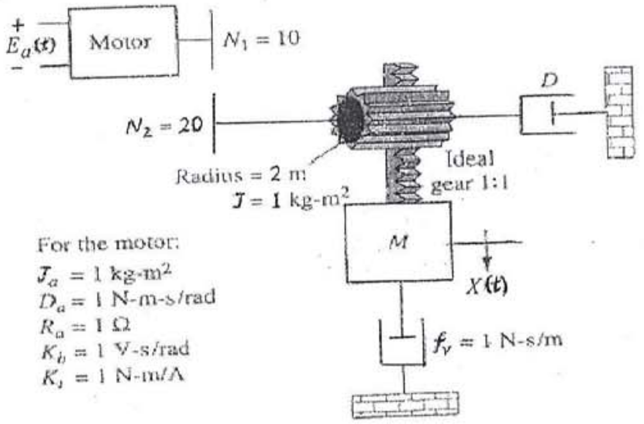
(a) Using inverse Laplace transform scheme, find the analytical expression for the rotational angle time domain response with respect to a unit step voltage input. (10%)

(b) Can this third order system response be described by a second order system approximately with roughly explanation? Then what is the damping ratio and natural frequency? (8%)

(c) Using its dominated second order poles shown in the transfer function, predict the approximate percentage overshoot and peak time values. (7%)

2. The mechanical system shown in following figure, if mass M is 3.75 kg and shaft 2 damping coefficient D is 4 N-m-s/rad ,

(a) Please find the transfer function $G(s) = \dfrac{X(s)}{E_a(s)}$ (10 %)



(b) Using this open loop transfer function of part (a) result to plot a unity feedback closed loop system block diagram with a cascade PD controller. (5 %)

(c) If this cascade PD controller is designed for this unity feedback servo mechanical system to yield 16.3% overshoot and 2 second settling time, find the K_p and K_d values of this PD controller. (10%)

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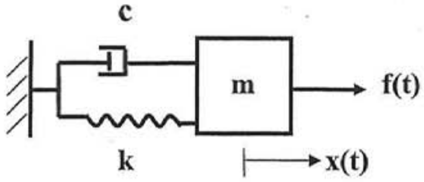
3. Consider a mass m connected to a spring (spring constant k) and a damper (damping coefficient c) slides on a smooth horizontal table. An external force $f(t)$ is applied resulting in displacement $x(t)$ from the equilibrium point.



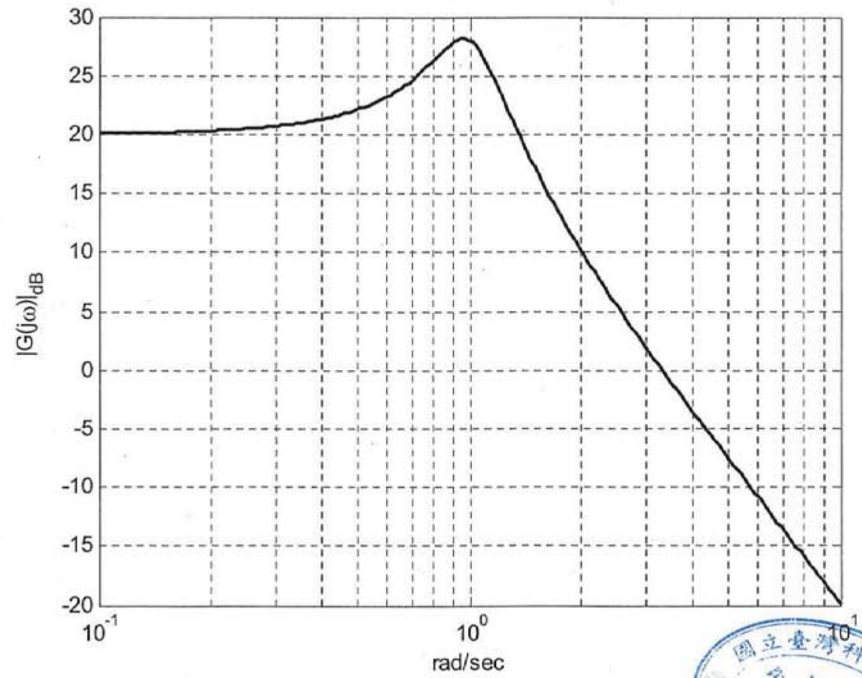
(a) Draw a free body diagram (FBD) of mass m for arbitrary displacement $x(t)$ and show that the equation of motion:

$$m\ddot{x}(t)+c\dot{x}(t)+kx(t)=f(t)$$

Clearly state which rule is used. (5%)

(b) Find the transfer function $G(s)=\dfrac{X(s)}{F(s)}$. (5%)

(c) Determine the values of the mass m, spring constant k, and damping coefficient c based on the frequency response of $G(s)$ shown in the figure below. (5%)



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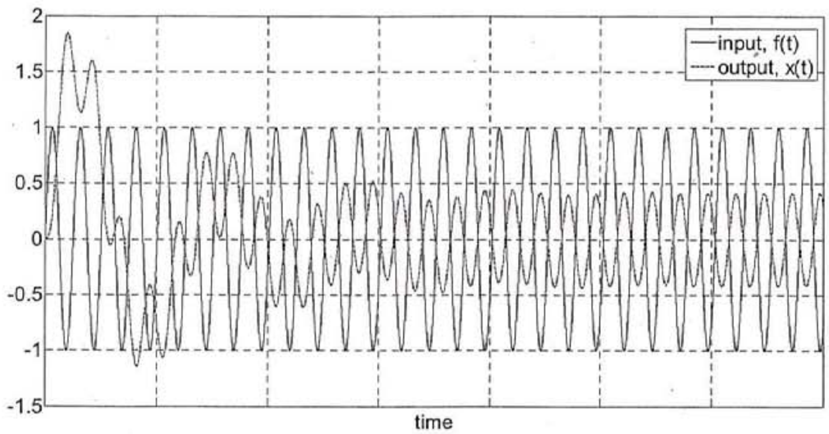
(d) Sketch the corresponding unit-step response of the system $G(s)$ described with the Gain Bode plot in (c). Indicate in your drawing the maximum overshoot, peak time, and final value of the displacement $x(t)$. (5%)

(e) A unit-amplitude sinusoidal force $f(t)$ of unknown frequency excites the system described with the Gain Bode plot in (c). Given the input $f(t)$ (solid) and the output $x(t)$ (dashed) graph shown below find the frequency of the input sinusoidal excitation. Note that you SHOULD NOT guess the time-stamps for the x-axis in the graph below, but use other information to deduct your answer. (5%)



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4. Assume that a linear model of the open-loop engine speed dynamics is given by

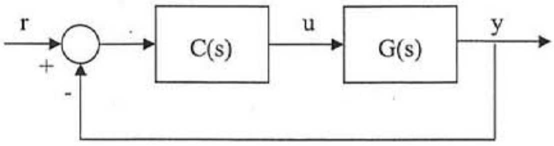
$$\frac{d}{dt}\begin{bmatrix} x_1 \\ x_2 \end{bmatrix} = \begin{bmatrix} -2 & -5 \\ 1 & 0 \end{bmatrix}\begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} 1 \\ 0 \end{bmatrix} u(t)$$

$$y(t) = \begin{bmatrix} 0 & 10 \end{bmatrix}\begin{bmatrix} x_1 \\ x_2 \end{bmatrix}$$

where the input $\boldsymbol{u(t)}$ is the throttle position and output $\boldsymbol{y(t)}$ is the engine speed.

(a) Find the transfer function $\boldsymbol{G(s)} = \frac{\boldsymbol{Y(s)}}{\boldsymbol{U(s)}}$. (5%)

(b) Assume that a unity feedback configuration is used for the engine speed control:



If the controller C(s) is of proportional type (i.e. C(s)=K, a constant), please analytically show how the proportional (P) gain affects the closed-loop performance both at steady-state and during transient and the closed-loop stability. Please use root-locus and indicate what other control design tools are used. (5%)

(c) If a PI controller is used, given a fixed P gain please analytically show how the integral (I) gain affects the closed-loop performance both at steady-state and during transient and the closed-loop stability. Please use root-locus and indicate what other control design tools are used. (5%)

(d) If the throttle motor dynamic is considered and thus another pole at s=-5 is added to the open loop system $G(s)$, how will that affect your conclusions in the design of the P controller in (b)? (5%)

(e) If instead the Induction-to-Power (IP) delay is considered and is modeled as a pure time delay $e^{-0.075s}$ in the open loop path, how will that affect your conclusions in the design of the PI controller in (c)? (Hint: approximate the delay with a 1st order Pade approximation). (5%)