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UNIVERSITY OF BOLTON

SCHOOL OF THE BUILT ENVIRONMENT AND ENGINEERING

BSc (HONS) MECHATRONICS

SEMESTER 2 EXAMINATIONS 2008/2009

MECHATRONICS SYSTEMS 2

MODULE NO: MEC3001

Date: Monday, 1 June 2009 **Time: 10.00 a.m. – 12.00 noon**

INSTRUCTIONS TO CANDIDATES:

There are SIX questions.

Answer ANY FOUR questions.

All questions carry equal marks.

Marks for parts of questions are shown in brackets

This examination paper carries a total of 100 marks

All working must be shown

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Q1. (a) An automobile suspension system is shown in Figure Q1. It is assumed that the wheel is a spring. The input of the system is the force F(t) and the output is the displacement $y_1(t)$.

Determine the transfer function $G(s) = y_1(s) / F(s)$ for the quarter – automobile model.

(25 marks)

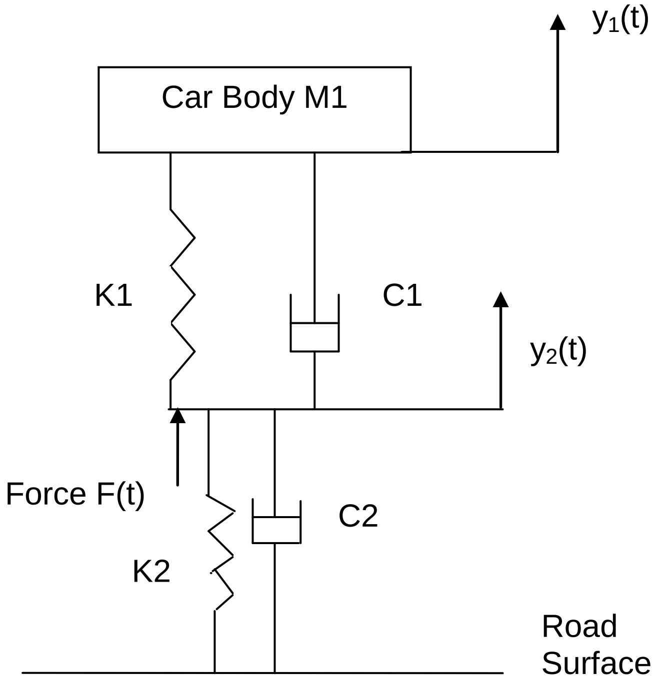

Figure Q1 Schematic Diagram of a Quarter Automobile Model

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2. (a) A control system has the transfer function as:

$$G(s) = \frac{18}{3s+6}$$

and the system is subject to a unit step input.

i) Calculate the time taken for the system to reach 85% of its final position. (4 marks)

ii) Calculate the percentage of the system's position after 1.1 seconds, and determine its position value at that time (1.1 seconds). (6 marks)

(b) Figure Q2 shows a block diagram for a hydraulic control system.

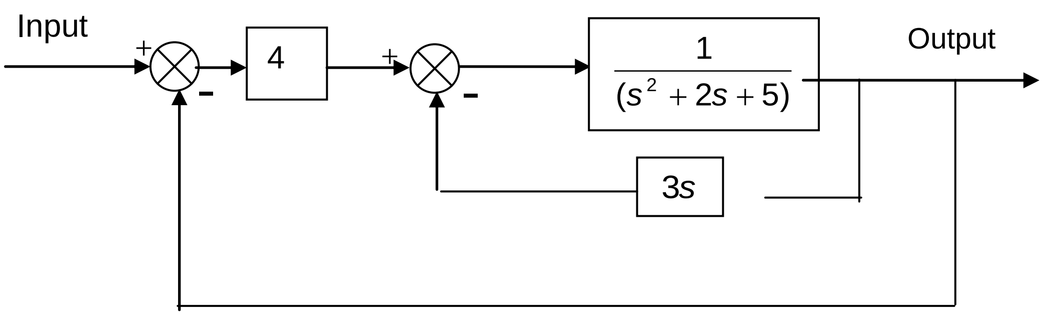

Figure Q2 A Hydraulic Control System

Determine the closed loop system's

(i) natural angular frequency (the undamped angular frequency) ω_n
(ii) the damped angular frequency ω_d
(iii) damping factor ζ
(iv) the 100% rise time t_r
(v) the percentage maximum overshoot
(vi) the 2% settling time t_s, and
(vii) the peak time t_p

(15 marks)

Total 25 marks

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3. Consider the control system shown in Figure Q3 with its closed loop form.

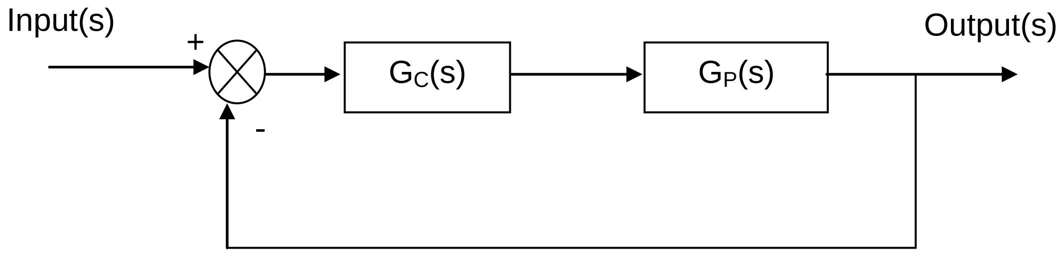

Figure Q3

Where $G_p(s) = \dfrac{1}{s(s^2+7s+12)}$

(a) If $G_c(s)$ is a proportional controller, find the range of the gain K_p where the system is stable.

(7 marks)

(b) Find the K_i for a unit parabolic input ($\theta_i = \dfrac{1}{s^3}$) If $G_c(s)$ is a PI controller and the steady state error is less than 0.02. (8 marks)

(c) The designer needs to achieve 10% overshoot. Design a derivative controller to satisfy these requirements. (10 marks)

Total 25 marks

Please turn the page

4. (a) Figure Q4 (a) illustrates a rotational mechanical system with a compound gear train.

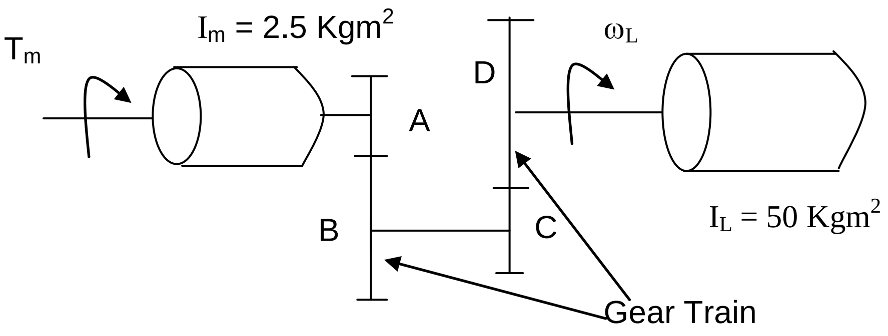

Figure Q4 (a) A rotational mechanical system

Where the first driver Gear A has 12 teeth, Gear B 24 teeth, Gear C 16 teeth and Gear D 32 teeth.

(i) If the maximum angular acceleration of the load needs to be 15 rad/s^2, determine the maximum torque of the motor. (6 marks)

(ii) Determine the power needed to accelerate the whole system from rest so that the final angular velocity of the load ω_L is 30 rad/s. (4 marks)

(b) A DC motor has an inertia I_m of 0.02 kgm^2. The nominal speed of motor is 2000 rpm and can generate a maximum torque of 30 Nm. It is connected to a uniformly distributed arm.

Figure Q4 (b) shows the motor power system. The inertia of the load I_L is 2 Kgm^2, and the torque required by the load is 50 Nm.

Question 4 continued over

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Question 4 continued

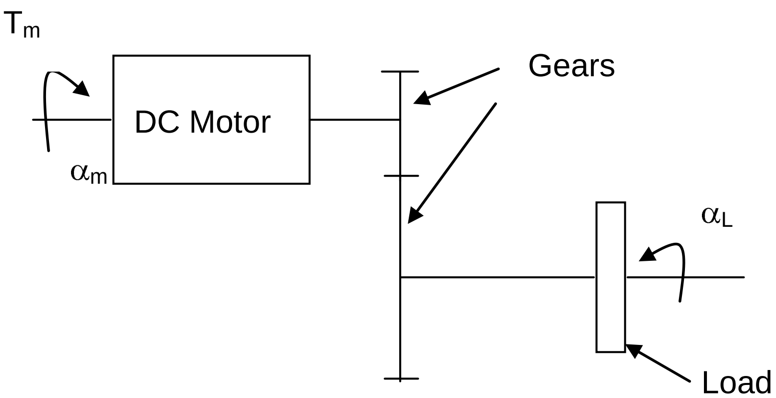

Figure Q4 (b) The motor power system

(i) Ignoring the viscous friction in the system, determine the gear ratio for the system. (7 marks)

(ii) If the viscous friction has been measured as b_m = 0.1 Kgm/s and b_L = 0.2 Kgm/s, and using the gear ratio determined by (a) above, what is the maximum torque of the motor required for the system? (8 marks)

Total 25 marks

5. (a) Explain five main features of hydraulic actuation systems and describe the practical applications for using the hydraulic systems. (10 marks)

(b) Describe, using the valve symbols, the basic principles of

(i) a Poppet valve, and
(ii) a Pressure limiting valve

(7 marks)

(c) Design a simple pneumatic up and down lift system by using valve symbols and explain its operation sequence. (8 marks)

Total 25 marks

Please turn the page

6. (a) Briefly explain six main areas demanded for artificial intelligence.

(6 marks)

(b) Identify the differences between "supervised learning" and "unsupervised learning", and describe how the neural networks can be used to achieve the supervised learning and unsupervised learning.

(10 marks)

(c) (i) Explain what fuzzy logic is and why fuzzy logic is used.

(4 marks)

(iii) Give one example for using fuzzy logic control in a mechatronics system or product. Include the design of a fuzzy linguistic rule to describe the relationship between the input and the output variables.

(5 marks)

Total 25 marks

END OF QUESTIONS

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FORMULA SHEET

DC Motors (Dynamic Equations)

$$G = \frac{\alpha_L}{\alpha_M} = \frac{\omega_L}{\omega_M}$$

$$\text{Power} = (I_m + G^2 I_L)\alpha_m \omega_m$$

$$T_L = I_L \alpha_L$$

$$T_m = (I_m + G^2 I_L)\alpha_m + (b_m + G^2 b_L)\omega_m$$

Blocks with feedback loop

$$G(s) = \frac{Go(s)}{1 + Go(s)H(s)}$$ (for a negative feedback)

$$G(s) = \frac{Go(s)}{1 - Go(s)H(s)}$$ (for a positive feedback)

Steady-State Errors

$$e_{ss} = \lim_{s \to 0}[s(1 - G_O(s))\theta_i(s)]$$ (for an open-loop system)

$$e_{ss} = \lim_{s \to 0}[s \frac{1}{1 + G_o(s)} \theta_i(s)]$$ (for the closed-loop system with a unity feedback)

$$e_{ss} = \lim_{s \to 0}[s \frac{1}{1 + \frac{G_1(s)}{1 + G_1(s)[H(s) - 1]}} \theta_i(s)]$$ (if the feedback H(s) ≠ 1)

$$e_{ss} = \lim_{s \to 0}[-s \cdot \frac{G_2(s)}{1 + G_2(G_1(s) + 1)} \cdot \theta_d]$$ (if the system subjects to a disturbance input)

Laplace Transforms

A unit impulsefunction	1
A unit step function	$\frac{1}{s}$
A unit ramp function	$\frac{1}{s^2}$

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First order Systems

$\theta_O = G_{ss}(1 - e^{-t/\tau})$ (for a unit step input)

$\theta_O = AG_{ss}(1 - e^{-t/\tau})$ (for a step input with size A)

Performance measures for second-order systems

$\omega_d t_r = 1/2\pi$; $\omega_d t_p = \pi$; $t_s = \dfrac{4}{\zeta\omega_n}$; $\omega_d = \omega_n\sqrt{(1-\zeta^2)}$

$$\text{P.O.} = \exp\left(\frac{-\zeta\pi}{\sqrt{(1-\zeta^2)}}\right) \times 100\%$$