**THE OPEN UNIVERSITY OF SRI LANKA**
**FACULTY OF ENGINEERING TECHNOLOGY**
**DIPLOMA IN TECHNOLOGY – LEVEL 4**
**FINAL EXAMINATION – ACADEMIC YEAR 2013/2014**
**MEX4243 - CONTROL SYSTEMS ENGINEERING**

**Date : 31st August, 2014** **Time: 0930 - 1230 hrs**

**Important:**

1. This question paper consists of **eight** questions.
2. Write the answers for the **Section A** and **Section B** in separate answer books.
3. Answer **Q1, which is compulsory,** and FOUR other questions selecting **at least ONE from SECTION A and TWO from SECTION B.**
4. Present important but relevant facts and information briefly. Any missing information can be sensibly and reasonably assumed provided that you state them clearly. Wherever necessary, use neatly drawn sketches to explain answers.

## SECTION A

**Q1**

(a) A servo motor is a motor combined with a position sensing device used to control angular position, velocity and acceleration. Fig.Q1(a) shows a diagram of a servo motor control system. The function of the servo is to receive a control signal that represents a desired output position of the servo shaft, and apply power to its DC motor until its shaft turns to that position.

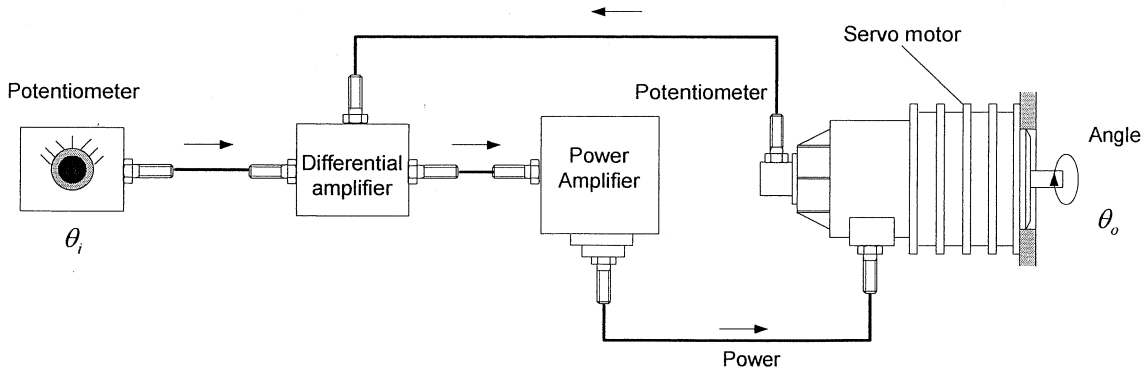



**Fig.Q1(a)**

(i) By studying the diagram in Fig.Q1(a), draw a complete block diagram of this control system showing all necessary parameters and state the functions of each block.

(ii) Using this block diagram explain how the complete system works.

[08 marks]

(b) A dynamic vibration absorber is shown in Fig. Q1(b).

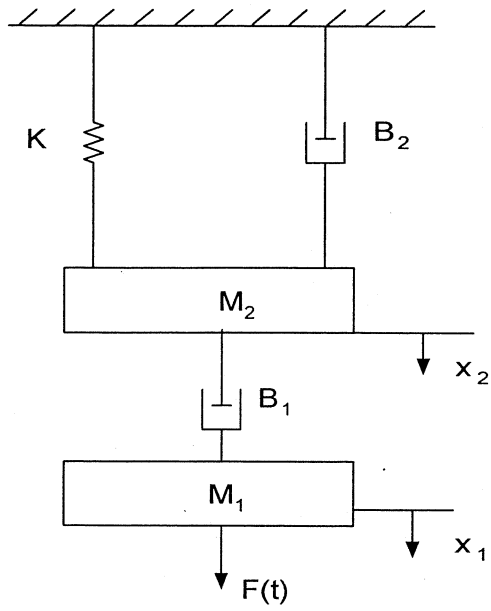



Fig. Q1(b)

(i) Draw the free body diagram for masses $M_1$ and $M_2$.

(ii) Now write the balancing equations for each of these free body diagrams.

(iii) Develop the analogous electrical circuit based on the force-current analogy.

[12 marks]

**Q2**

(a) (i) Define the parameters required to describe a first order control system and sketch the output response. You need to mark all necessary parameters.

(ii) Find the output response, C(t) for the system shown in Fig.Q2(a).

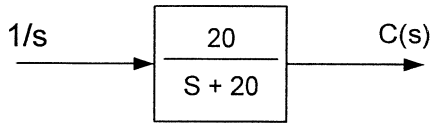



Fig.Q2(a)

(iii) Calculate the parameters you described in (a)(i) and mark them on a figure which shows the output response described above. [08 marks]

(b) Measurements conducted on a servomechanism show the system response to be $C(t) = 1 - 2.5e^{-3t} + 1.5e^{-5t}$, when subjected to a unit step input.

(i) Find an expression for the closed loop transfer function. You need to show all steps for the calculation.

(ii) Identify the poles and zeros of the system and mark them in a pole zero diagram.

(iii) Briefly describe the nature of the unit step response of this system using a diagram.

(iv) Analyze the effect of adding a zero to the above system. [12 marks]

**Q3**

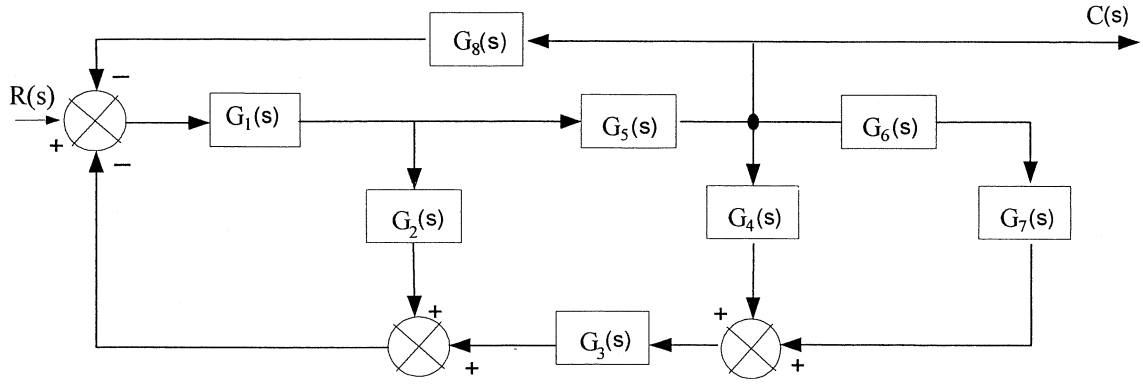



Fig.Q3

(a) Reduce the block diagram shown in Fig.Q3 to a single transfer function.

(b) Use Mason's Gain Formula to obtain the transfer function C(s)/R(s) of the system. (**You must clearly show all steps.**)

[20 marks]

**Q4**

(a) What are the 3 main standard signals used in time domain analysis? [03 marks]

(b) Derive steady state errors and static error coefficients for type 0, type 1 and type 2 systems. [09 marks]

(c) For a unity feedback control system, the open loop transfer function is,

$$G(s) = \frac{10/(s+2)}{s^2(s+1)}$$

Find,

(i) position, velocity and acceleration error constants.

(ii) the steady state error when the input is

$$R(s) = \frac{3}{s} - \frac{2}{s^2} + \frac{1}{3s^3}$$

[08 marks]

## SECTION B

**Q5**

(a) Obtain a bode plot of the following transfer function

$$G(s) = \frac{(s+3)}{s(s^2+11.2s+64)}$$

[12 marks]

(b) If a simple gain $K$ is incorporated into the design, determine the value of $K$ for the system to have a phase margin of $60^0$ [04 marks]

(c) What is the gain margin of the system for the above value of $K$? [04 marks]

**Q6**

(a) A system has a characteristic equation

$$(q) = s^3 + 2s^2 + 4s + k = 0$$

(i) Use Routh-Hurwitz criterion to determine the range of $k$ that makes the system stable

(ii) Determine the value of $k$, so that there are two symmetric poles of the system about the origin. Hence determine the poles of the system

[13 marks]

(b) Draw a Nyquist diagram for the following system and determine the range of $k$ for the system to be stable.

$$L(s) = \frac{k}{(s+1)(0.1s+1)}$$

[07 marks]

**Q7**

A closed loop negative unity feedback system is used to control the roll motion of a strike-fighter jet.

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

(a) Sketch the root locus of the system [10 marks]

(b) Calculate the minimum value of K that results in a complex pole pair of the closed loop system [04 marks]

(c) If a zero at -3 is introduced to the system, sketch the root locus of the new system [06 marks]

**Q8**

Design a lead compensator for the open loop system,

$$G(s) = \frac{4}{s(s+4)}$$

so that the closed loop system static error constant $K_v$ is 20 $sec^{-1}$, the phase margin is at least $50^0$, and the gain margin is at least 10 dB.

[20 marks]

---------- The End ----------