UNIVERSITY COLLEGE LONDON

EXAMINATION FOR INTERNAL STUDENTS

MODULE CODE	:	**ELEC216P**
ASSESSMENT PATTERN	:	**ELEC216PA**
MODULE NAME	:	**Programming and Control Systems**
DATE	:	**Thursday 10 May 2018**
TIME	:	**10:00**
TIME ALLOWED	:	**3 hrs**

This paper is suitable for candidates who attended classes for this module in the following academic year(s):

Year

<u>Suitable for all candidates</u>

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2016/17-ELEC216PA-001-EXAM-Electronic and Electrical Engineering *116*

TURN OVER

Rubric for ELEC216P: Answer FOUR questions. TWO questions must be selected from Section A and TWO questions must be selected from Section B.

Section A

1.

(a) Explain how the feedforward control structure in Figure 1.1 enables a control system to reject disturbances. Your answer should compare the time-domain responses of the controlled variable and the manipulated variable in the case when feedforward control is present to the same responses when no controller is applied.

Why might disturbance rejection with a feedforward system result in a small residual in the controlled variable?

[10 marks]

(b) Using Figure 1.1 as a basis, draw an enhanced block diagram that shows a feedforward-feedback control structure. Figure 1.2 suggests additional blocks and signals that might be useful for this task.

[5 marks]

(c) With the use of suitable sketches of the time-domain responses, explain why the disturbance rejection of a combined feedforward-feedback control system is generally better than that of a feedforward-only system or a feedback-only system.

[5 marks]

(d) By considering the response of the controlled variable to a step change in the set point, explain why integral action is needed in the forward path of a feedback system if the steady state error is to be zero.

[5 marks]

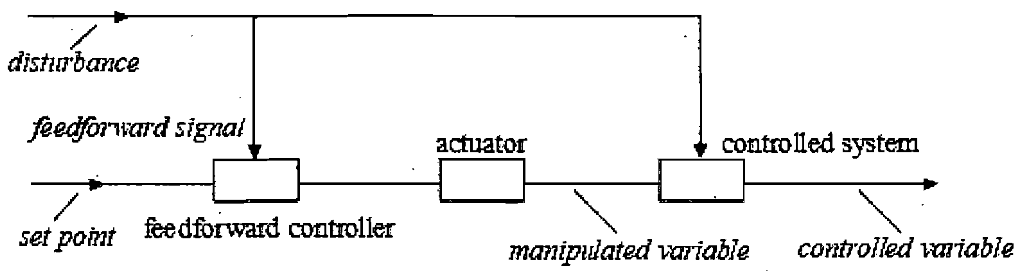

Figure 1.1. The block diagram of a feedforward control structure.

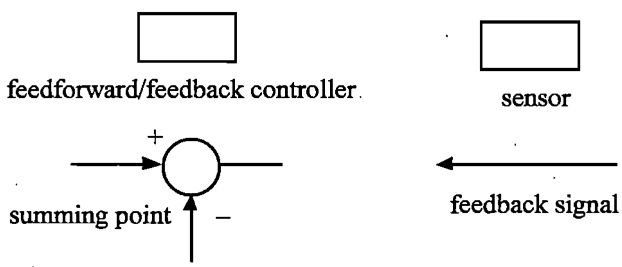

Figure 1.2. Blocks and signals for constructing the block diagram of a feedforward-feedback control structure.

2.

(a) State how the class of a control system may be determined from an inspection of the system block diagram, if the transfer functions of its components are known. In what way is a class 1 system better than a class 0 system?

[5 marks]

(b) The positions of three cars on a road are denoted by x_1, x_2 and x_3 and their velocities are dx_1/dt, dx_2/dt and dx_3/dt. A mathematical model for the traffic flow assumes a driver's acceleration is proportional to the distance from the car in front and to the velocity of his or her own car. There is no overtaking and the acceleration of the front car (number 1) is zero. Hence:

$$\frac{d^2x_1}{dt^2} = 0$$
$$\frac{d^2x_2}{dt^2} = k_2\left[(x_1 - x_2) - \tau_2\frac{dx_2}{dt}\right]$$
$$\frac{d^2x_3}{dt^2} = k_3\left[(x_2 - x_3) - \tau_3\frac{dx_3}{dt}\right]$$

Note that the steady-state case of zero acceleration has all the cars covering the distance at the same constant velocity.

Define a system state vector $z = \begin{pmatrix} z_1 & z_2 & z_3 & z_4 & z_5 & z_6 \end{pmatrix}^T$ where:

$$\begin{aligned} z_1 &= x_1 & z_4 &= dx_1/dt \\ z_2 &= x_2 & z_5 &= dx_2/dt \\ z_3 &= x_3 & z_6 &= dx_3/dt \end{aligned}$$

and find the matrix $\boldsymbol{A}$ in the state-space representation $\dfrac{dz}{dt} = \boldsymbol{A}\,z$.

[10 marks]

(c) The poles of the system of part (b) are the values of s that satisfy the state space characteristic equation $\det(s\boldsymbol{I} - \boldsymbol{A}) = 0$. By calculating this determinant, it can be shown that the characteristic equation of the system of part (b) is:

$$s^2\left(s^2 + k_2\tau_2 s + k_2\right)\left(s^2 + k_3\tau_3 s + k_3\right) = 0$$

(i) The factor s^2 in the characteristic equation gives a double pole at $s = 0$, which means that the traffic dynamics contain ramp-like and step-like behaviour in the time domain. What behaviour of the traffic is captured by the ramp and step signals?

(ii) Beyond the double pole at $s = 0$, determine the conditions that ensure the system is stable.

(iii) Assuming the system has parameters that ensure stability, due to the double pole at $s = 0$, neither the positions nor the velocities are zero in the steady state. Suggest what behaviour of the traffic might be captured by the other poles of the system, corresponding to exponentially decaying signals. Only qualitative, not quantitative, analysis is required.

[10 marks]

3.

(a) Consider $G_c(s)$ to be the closed-loop transfer function of a unity negative feedback system with controller $C(s)$ and transfer function $G_o(s)$ in the forward path, where $G_o(s)$ and $C(s)$ are given by,

$$G_o(s) = \frac{1}{s(s-1)}$$
$$C(s) = K\frac{s+1}{s+5}$$

By using the Routh Hurwitz or any other method, find the range of values K that stabilizes the closed loop transfer function.

[10 marks]

(b) (i) Sketch the phase part of the Bode diagram of the first order system below:

$$G_l(s) = \frac{1}{\tau s + 1}$$

Assume $\tau > 0$.

(ii) Sketch the phase part of the Bode diagram of the time delay system below:

$$G_d(s) = e^{-sT_d}$$

Assume $T_d > 0$.

(iii) sketch the phase part of the Bode diagram of the FOPTD (first order plus time delay) system, which is defined by,

$$G(s) = \frac{e^{-sT_d}}{\tau s + 1}$$

By combining the phase part of the Bode diagrams in parts (i), (ii). Discuss the reason why a FOPTD system can be unstable in closed loop control system.

[10 marks]

(c) The Nyquist diagram of an open loop system, denoted by $KH(s)G_0(s)$, is shown in Figure 3.1. We know that $KH(s)G_0(s)$ has no pole in right hand side of the complex plane. By using these information and the Cauchy's principle of the argument, find the number of unstable poles of closed loop system, which are the zeros of $1 + KH(s)G_0(s)$.

[5 marks]

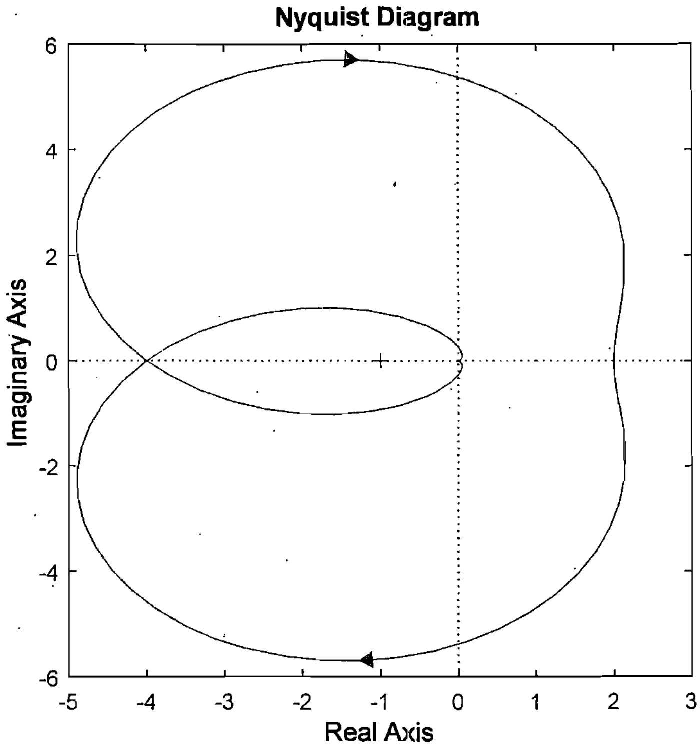

Figure 3.1. Nyquist diagram of $G(s)$

Section B

Questions should be answered using code in Java, where appropriate, as the relevant Object-Oriented Language.

4. (a) Explain what is meant by exception handling in modern programming languages and outline how it is supported in Java. Why is language support for exceptions important?

[8 marks]

(b) List four common examples of unchecked exceptions that can occur in Java programs, explaining what can cause them.

[7 marks]

(c) Write a *coinThrower* method that emulates the throwing of a coin. The number of times to throw it should be passed as an argument and the method should print out the outcome and return a value that signifies if it succeeded or not. The coin should only be allowed to be thrown for an even number of times, if the argument is an odd or negative number the method should return a suitable value signifying that it failed.

[10 marks]

5. (a) What is a linked list data structure and what operations does it provide? Explain briefly how a *List* class can be implemented through a *ListNode* class.

[8 marks]

(b) Write the *concatenate* method of a *ConcatenateList* class that inherits from *List*. The *concatenate* method should take as argument an external list object and merge it with the list instance variable, concatenating the two lists.

[9 marks]

(c) What is a queue data structure? Show how a *Queue* class can be implemented through composition by using the *List* class.

[8 marks]

6. (a) Write a piece of code that will print a number at random from the following set: 2, 4, 6, 8, 10.

[5 marks]

(b) What is the Fibonacci series? Write the *fibonacci* method of a *FibonacciCalculator* class which calculates the Fibonacci value of a given positive integer. How could we measure how much time it takes to execute this method? Write an excerpt of code that does this.

[11 marks]

(c) Explain what a selection sort algorithm is, and calculate its complexity.

[9 marks]

END OF PAPER