UNIVERSITY OF GHANA
SCHOOL OF ENGINEERING SCIENCES
FIRST SEMESTER EXAMINATIONS: 2016/2017
LEVEL 400: BACHELOR OF SCIENCE IN ENGINEERING
CPEN 401: CONTROL SYSTEMS ANALYSIS AND DESIGN

INSTRUCTIONS: **ATTEMPT ALL QUESTIONS**

TIME ALLOWED: THREE HOURS

1. A. Explain the following terms

   i. State controllability [2 marks]
   ii. State observability [2 marks]
   iii. Output controllability [2 marks]

   B. Determine the state controllability matrix and state observability matrix of the system given below:

$$\dot{x}(t) = Ax(t) + Bu(t) \quad \text{and} \quad y(t) = Cx(t)$$

Where

$$A = \begin{bmatrix} 0 & 2 & 0 \\ 1 & 3 & 0 \\ -1 & 0 & 1 \end{bmatrix} \quad B = \begin{bmatrix} 0 \\ 1 \\ 1 \end{bmatrix} \quad C = [1 \quad 0 \quad 1]$$

[8 marks]

C. Determine the transfer function of the above system.

2. A. State two difficulties that may arise during the formulation of the *Routh Table* and describe how to overcome them.

[6 marks]

B. The characteristic equations for certain feedback control systems are given below. Determine the range of values of K for which the systems are to be stable and the frequency of sustained oscillations.

i. $s^3 + 2Ks^2 + (K+2)s + 7 = 0$

ii. $s^3 + 20s^2 + 5s + 9K = 0$

[8 marks]

3. A. State three advantages the *modern control design* approach have over the classical approach.

[6 marks]

B. A feedback system has a closed-loop transfer function:

$$T(s) = \frac{Y(s)}{U(s)} = \frac{7}{(s+1)(s+2)(s+3)}$$

i. Construct the *state space model* of the system. [8 marks]

ii. Determine the observability and controllability of the system. [8 marks]

4. A. Explain the terms *BIBO stability* and *asymptotic stability* [4 marks]

B. Show that the notion of *BIBO stability* is satisfied for a linear time invariant system if the impulse response of the system is absolutely integrable. [8 marks]

5. The control system of the Volta River Authority electricity generation plant in Akuse is depicted in the diagram below. If the maximum tolerable overshoot in the unit-step is 0.2 and the peak time is 1 second, Determine the following:

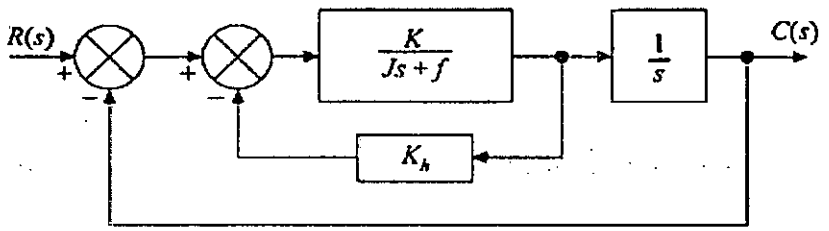
i. The value of gain, K [3 marks]

ii. The value of the velocity feedback, K_h [3 marks]

iii. The rise time [2 marks]

iv. The settling time [2 marks]

Assume that J=1kg-m^2 and f=1N-m/rad/s



6. A. Explain the operation of *PID* controllers.

[4 marks]

B. Derive the transfer function of a *PID controller* and draw the corresponding block diagram.

[8 marks]

C. Briefly explain the impact a derivative control has on the damping ratio and peak overshoot in a control system.

[4 marks]

D. A closed loop control system with unity feedback is shown below. By using the derivative control, the damping ratio is made to be 0.95.The input to the system is unit step.

Determine the following:

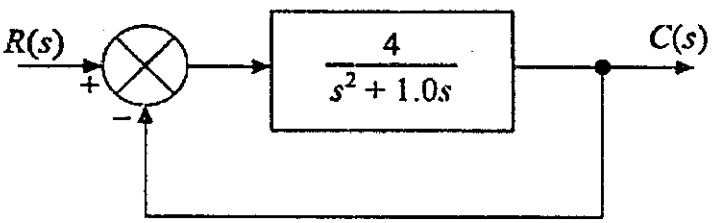
i. the derivative constant, T_d [4 marks]

Without derivative control, determine:

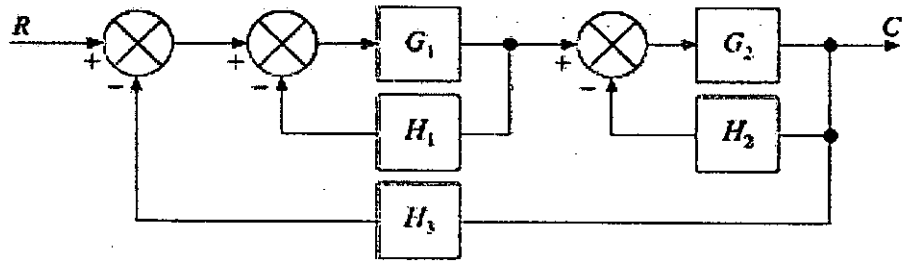
ii. The rise time [2 marks]

iii. The peak time [2 marks]

iv. The peak overshoot [2 marks]

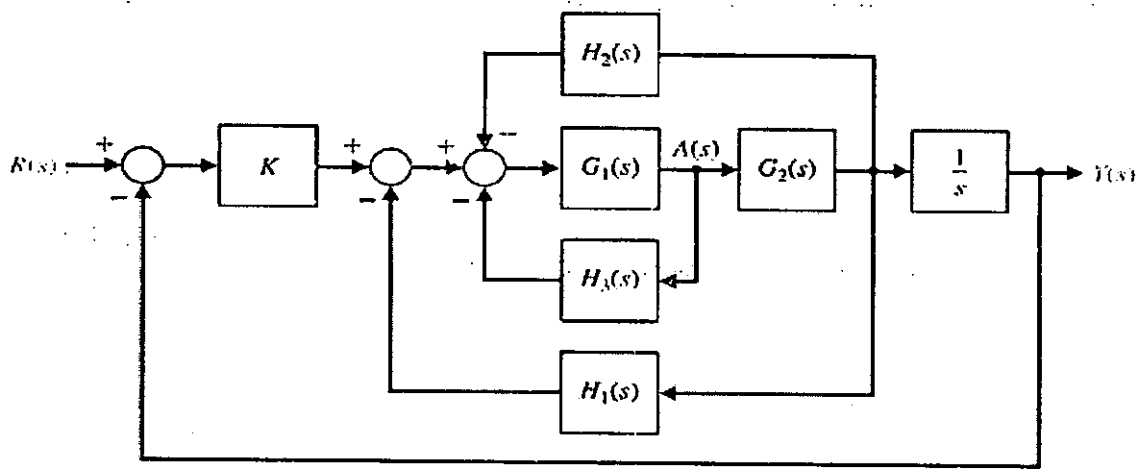


7. (A) Determine the transfer function of the block diagram below by using the *block diagram reduction technique.*



[10 marks]

(B) Determine the transfer function *Y(s)/R(s)* of the block diagram below by using the *signal flow graph* method with Mason formula.



[10 marks]