UNIVERSITY OF GHANA

BACHELOR OF SCIENCE IN COMPUTER ENGINEERING
FIRST SEMESTER EXAMINATIONS: 2017/2018
SCHOOL OF ENGINEERING SCIENCES
CPEN 401: CONTROL SYSTEMS ANALYSIS AND DESIGN (3 CREDITS)

INSTRUCTIONS: **ATTEMPT ALL QUESTIONS**

TIME ALLOWED: **THREE HOURS**

1. (a) Find the inverse Laplace Transform of the below expression:

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

State and indicate the Region of Convergence.

[2 marks]

(b) The figure below shows a schematic diagram of an automobile suspension system. As the car moves along the road, the vertical displacements at the tires act as the motion excitation to the automobile suspension system. The motion of this system consists of a translational motion of the center of mass and a rotational motion about the center of mass. The mathematical modeling of the complete system is quite complicated but a simplified version of the suspension system is shown in the fig 1b. Assuming that the motion x_i at the point P is the input to the system and the vertical motion x_o of the body is the output. Determine the transfer function $X_o(s)/X_i(s)$.

[Hint: Consider the motion of the body only in the vertical direction]

Displacement x_o is measured from the equilibrium position in the absence of input x_i

[3 marks]

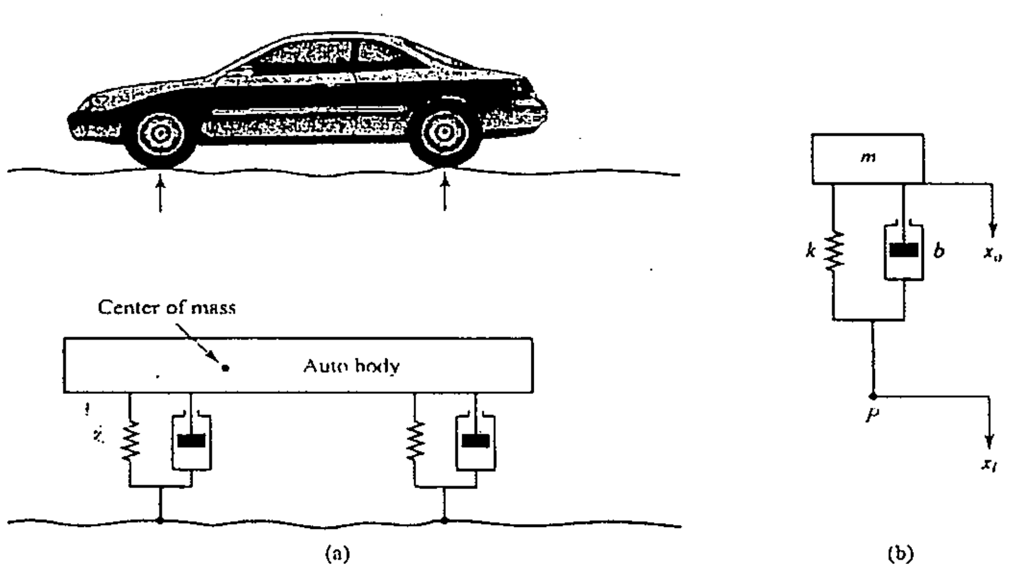

Fig. 1

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c. The system shown below is a simplified version of a motorcycle suspension system, the input u is a displacement input. Determine the transfer function $Y(s)/U(s)$.

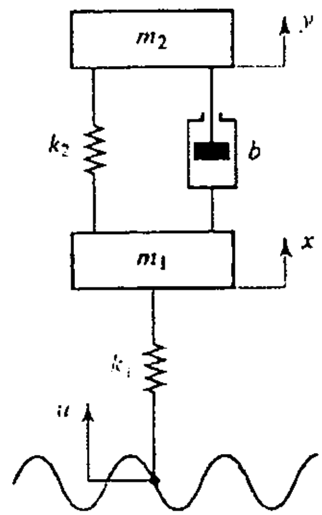

Fig 1c.

[5 marks]

2. 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

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

[6 marks]

C. Determine the transfer function of the system. [8 marks]

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

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

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

[8 marks]

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

[3 marks]

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

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

Construct the *state model* of the system.

[12 marks]

5. 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. [6 marks]

6. For the system 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:

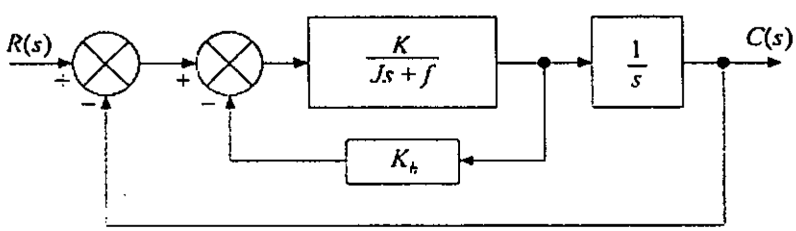
i. The value of gain, K [3 marks]

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



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7. A. What is a *PID controller*?

[1 mark]

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

[5 marks]

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

[2 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:

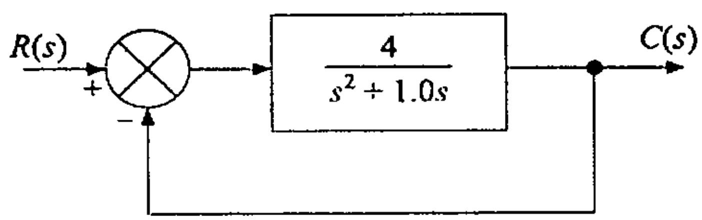
i. the derivative constant, T_d [3 marks]

Without derivative control, determine:

ii. The rise time [2 marks]

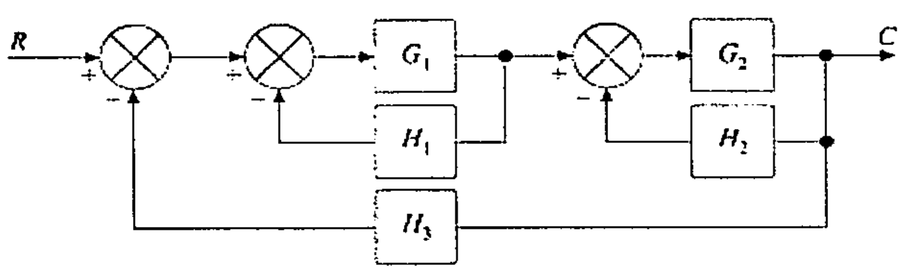
iii. The peak time [1 marks]

iv. The peak overshoot [1 marks]



8. Determine the transfer function of the block diagrams below by using either the *block diagram reduction technique* or the *signal flow graph* method.

A.



[5 marks]

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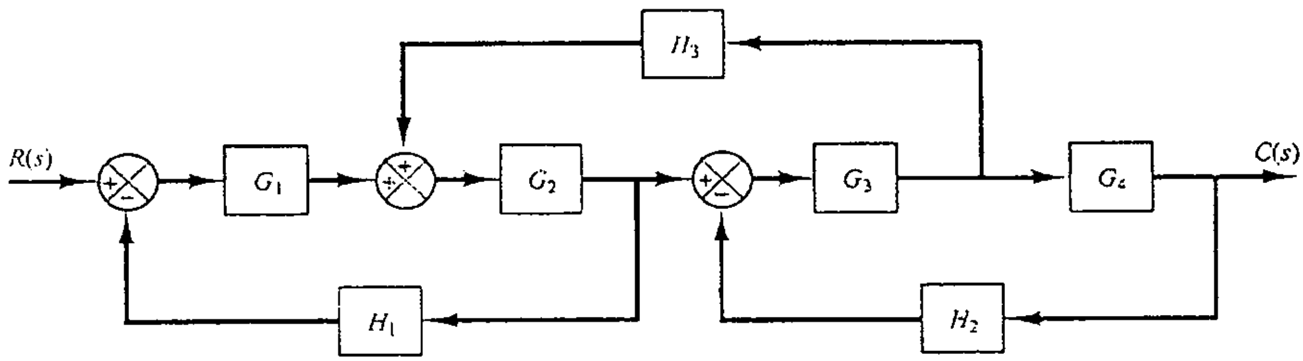
B.



[5 marks]

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