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UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER II
SESSION 2016/2017

COURSE NAME	:	CONTROL ENGINEERING
COURSE CODE	:	BDA 30703
PROGRAMME	:	3 BDD
EXAMINATION DATE	:	JUNE 2017
DURATION	:	3 HOURS
INSTRUCTION	:	1. PART A (COMPULSORY): ANSWER **ALL** QUESTIONS 2. PART B (OPTIONAL) : ANSWER **ONE(1)** QUESTION ONLY

THIS QUESTION PAPER CONSISTS OF **EIGHT (8)** PAGES

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PART A: ANSWER ALL QUESTIONS

Q1. (a) Define the dynamic characteristics of a measuring instrument?

(3 marks)

(b) Describe three types of dynamic characteristics of measuring instruments. Use suitable figures to support your answer

(9 marks)

(c) One of the applications of operational amplifier (op-amp) in control systems is to be used as a summing node. **Figure Q1** shows an op-amp circuit used for the aforementioned purpose. Calculate the output V_0 if the circuit is subject to the inputs V_{11}, V_{12}, V_{13}, V_{21}, V_{22}, and V_{23}?

(8 marks)

Q2 **Figure Q2** shows a translational mechanical system of two rigid bodies of mass 'm_1' and 'm_2'. Let the displacement of the bodies of mass 'm_1' and 'm_2' be equal to 'x_1' and 'x_2' respectively. The system is given with the input F; and the desired output is x_2.

(i) Draw the free body diagram of the system.

(ii) Derive governing differential equation of motions of the system.

(iii) From equations derived in part Q2(b), develop a block diagram.

(iv) Without solving for the transfer function convert the block diagram into signal flow graph.

(20 marks)

Q3 Precision control of the angular velocity $\omega_m(t)$ of an inertia load driven directly by an armature controlled DC motor can be achieved by comparing an input voltage from potentiometer with feedback voltage derived from a tachometer coupled to the motor shaft. **Figure Q3** shows the speed control system circuitry

(a) Determine the Laplace transform equation for potentiometer, op-amp and tachometer.

(3 marks)

(b) Determine Laplace transform equation for the armature control DC motor circuit.

(8 marks)

(c) Using equation from Q3(a) and Q3(b), construct block diagram model for the speed control system in **Figure Q3**.

(9 marks)

Q4 Consider the system with an open loop transfer function as:

$$KG(s) = \frac{K}{s\left(s^2 + 4s + 5\right)}$$

(a) Sketch the root locus for the system.

(13 marks)

(b) Observe that for small or large values of *K*, the system is underdamped and for medium values of *K* it is overdamped.

(7 marks)

PART B: ANSWER ONE (1) OUT OF TWO QUESTIONS

Q5 (a) Stability of a system can be accessed by its pole and zeros location on a complex plane. Can Bode Diagram be used to determine system's stability? If yes, explain how to do that.

(4 marks)

(b) Draw the Bode diagram for the transfer function below;

$$H(s) = 10\frac{s+10}{s^2+3s}$$

(10 marks)

(c) Based on the block diagram drawn, what is the value of Gain Margin and the Phase Margin of the system. Is the system stable?

(6 marks)

Q6 We want to control the temperature of an unstable chemical reactor. The transfer function is

$$G(s) = \frac{1}{(s+1)(s-1)(s+5)}$$

(a) Use a proportional controller and draw a root locus with respect to the amplification K. Calculate which K in the compensator that stabilizes the system.

(10 marks)

(b) Use a PD controller. The control law is given by

$$u = K(e + TD\frac{de}{dt})$$

where e is the error. Let $TD = 0.5$ and draw a root locus with respect to K. For which values of K does the controller stabilize the system?

(10 marks)

- END OF QUESTIONS –

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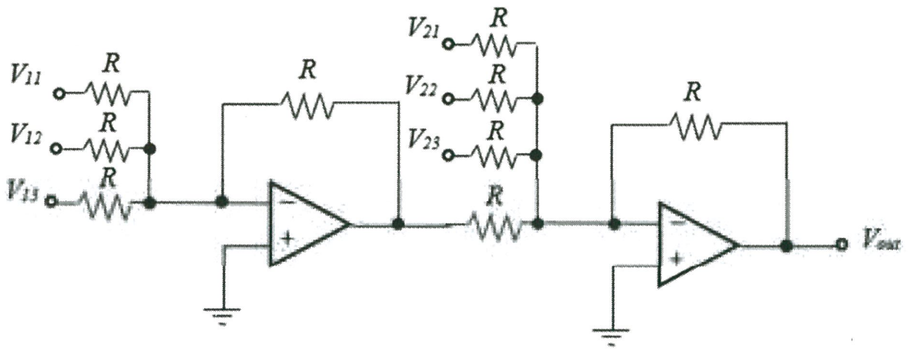

Figure Q1

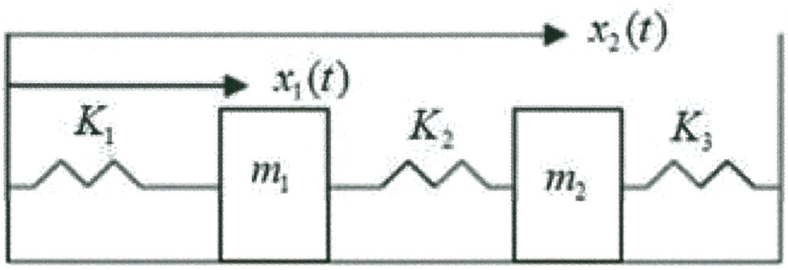

Figure Q2

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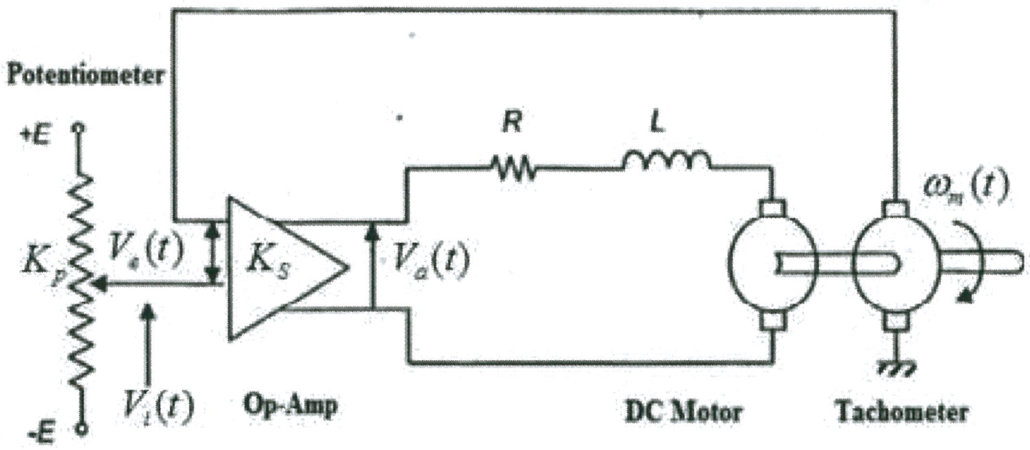

Figure Q3

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REFERENCE

Laplace Transformation:

$\mathcal{L}[1] = 1/s$

$\mathcal{L}[t] = 1/s^2$

$\mathcal{L}[At^n] = An!/S^{n+1}$

$\mathcal{L}[e^{-at}] = 1/(s+a)$

$\mathcal{L}[\sin \omega t] = \omega/(s^2+\omega^2)$

$\mathcal{L}[\text{kos } \omega t] = s/(s^2+\omega^2)$

$\mathcal{L}[e^{-at}\sin \omega t] = \omega/((s+a)^2+\omega^2)$

$\mathcal{L}[e^{-at}\text{kos } \omega t] = (s+a)/((s+a)^2+\omega^2)$

$\mathcal{L}[d^2y/dt^2] = s^2y(s) - sy(0) - dy(0)/dt$

$\mathcal{L}[dy/dt] = sy(s) - y(0)$

Final Value Theorem;

$$\text{had}_{t\to\infty} f(t) = \text{had}_{s\to 0} sF(s)$$

Time Response Function :

$$G(s) = \frac{\omega_n^2}{s^2 + 2\zeta\omega_n s + \omega_n^2}$$

$$T_p = \frac{\pi}{\omega_n\sqrt{1-\zeta^2}}$$

$$s_1, s_2 = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$$\zeta = \frac{-\ln(\%OS/100)}{\sqrt{\pi^2 + \ln^2(\%OS/100)}}$$

$$\%OS = 100\,e^{-(\zeta\pi/\sqrt{1-\zeta^2})}$$

$$T_s = \frac{4}{\zeta\omega_n}$$