Universiti Tun Hussein Onn Malaysia

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER I
SESSION 2016/2017

COURSE NAME	:	CONTROL ENGINEERING AND INSTRUMENTATION
COURSE CODE	:	BNJ 30703
PROGRAMME	:	BNL
EXAMINATION DATE	:	DECEMBER 2016 / JANUARY 2017
DURATION	:	3 HOURS
INSTRUCTION	:	ANSWER **ALL** QUESTIONS

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THIS QUESTION PAPER CONSISTS OF **NINE (9)** PAGES

Q1 (a) Define the following terms:

(i) Control system
(ii) Open loop system

(4 marks)

(b) Explain briefly the comparison between non-feedback and feedback system.

(4 marks)

(c) Determine the transfer function $C(s)/R(s)$ of the block diagram shown in **FIGURE Q1(c)** using block diagram reduction method.

(6 marks)

(d) Apply Mason's Rule to calculate the transfer function of the system represented by signal flow graph in **FIGURE Q1(d).** Given:

$$\frac{Y(s)}{R(s)} = \frac{\sum P_k \Delta_k}{\Delta}$$

(6 marks)

Q2 (a) **FIGURE Q2(a)** shows the translation mechanical system. Force, f is an input; x_1 and x_2 are the output displacements.

(i) Draw the free body diagram of the system

(2 marks)

(ii) Derive the equation of motion using Newton's Law of Motion

(4 marks)

(iii) Interpret the equation in (ii) into the s-domain using the Laplace transform assuming zero initial condition.

(2 marks)

(iv) Determine the transfer function model, $F(s)/X(s)$ of the system.

(6 marks)

(b) Given the following differential equation, solve for $y(t)$ if initial condition for $y(0) = 10$. Use the Laplace transform.

$$\frac{dy}{dt} + 2y = 12 \qquad where \;\; y(0) = 10$$

(6 marks)

Q3 (a) Give a brief explanation on the purpose of constructing a root locus.

(4 marks)

(b) The open loop transfer function of a humanoid's arm control system is given as:

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

(i) Clearly locate all poles and zeros on a linear graph paper. Provide calculations for the following: asymptote angles, centroid for asymptotes, and departure angle from complex pole.

(6 marks)

(ii) Plot the complete root locus, with the locus on the real axis is clearly shown.

(5 marks)

(iii) Then determine the operational point, S_m (poles) for damping ratio, $\zeta = 0.5$. Also determine natural frequencies (ω_n and ω_d) and gain K at this operational point.

(5 marks)

[**Instruction:** Use the scale of **4 cm : 1** unit for both axes and choose the longer side of the graph paper as the real exis]

Q4 (a) Illustrate the general phase and gain stability margins in Nyquist Plot.

(4 marks)

(b) An open-loop transfer function for the system of an electric shredding machine is given as follows:

$$G(s) = \frac{10K}{s(1 + 0.1s)(1 + 0.02s)}$$

(i) Construct the Bode diagram on the semi log graph paper for the system if K = 1

(10 marks)

(ii) Evaluate phase margin, gain margin, frequency of phase margin and frequency of gain margin from your Bode diagram.

(3 marks)

(iii) Evaluate the range of K for stability form your Bode diagrams.

(3 marks)

Q5 (a) Describe the following terms:

(i) Transducer
(ii) Sensor

(2 marks)

(b) Given expected voltage value across a resistor is 80V. The measurement is 79V. Calculate.

(i) the absolute error
(ii) the percentage (%) of error
(iii) the relative accuracy
(iv) the percentage (%) of accuracy

(4 marks)

(c) A Standard is a known accurate measure of physical quantity which determine the values by comparison method.

(i) List **FOUR (4)** categories of Standard
(ii) Briefly explain your answer in (i)

(8 marks)

(d) Explain the differences between sensitivity, precision and accuracy in an instrumentation.

(6 marks)

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-END OF QUESTIONS-

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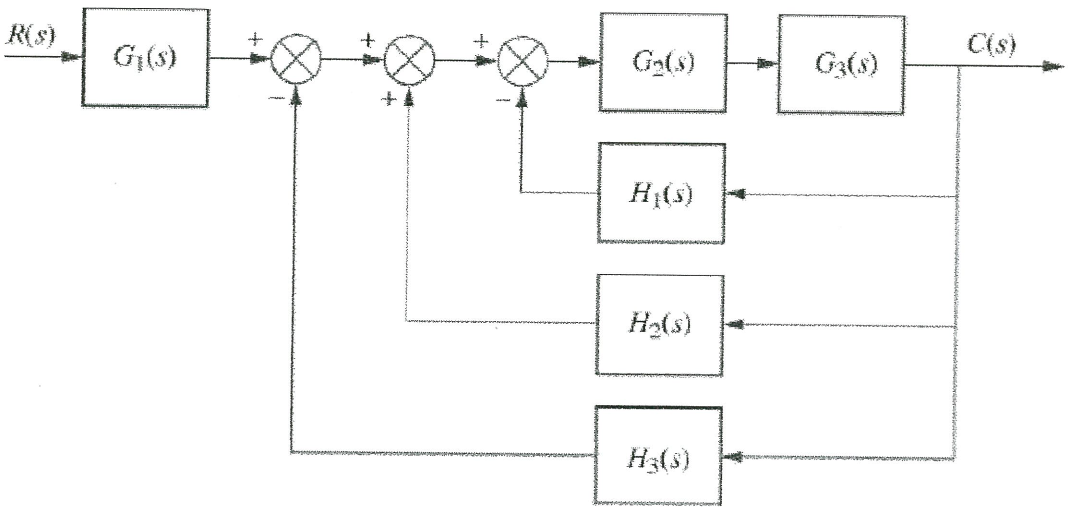

FIGURE Q1(c)

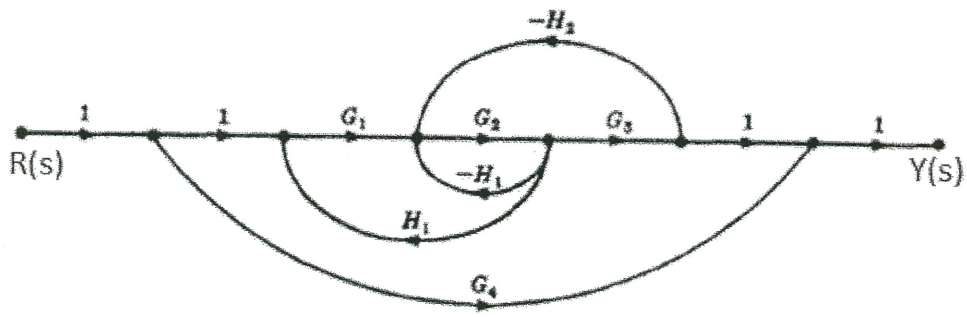

FIGURE Q1(d)

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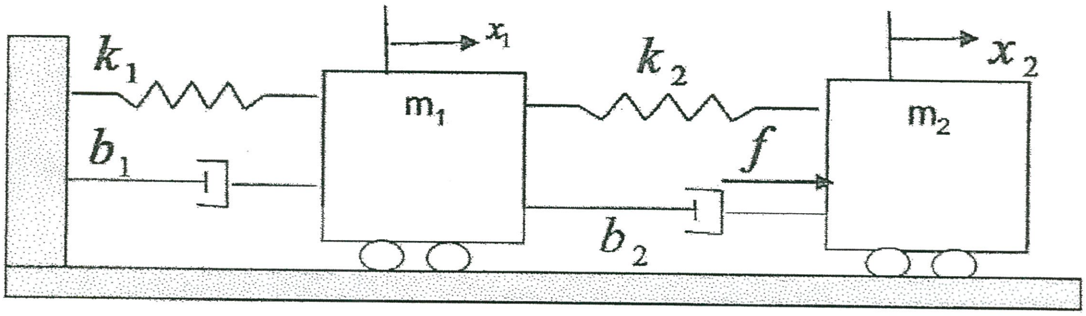

FIGURE Q2(a)

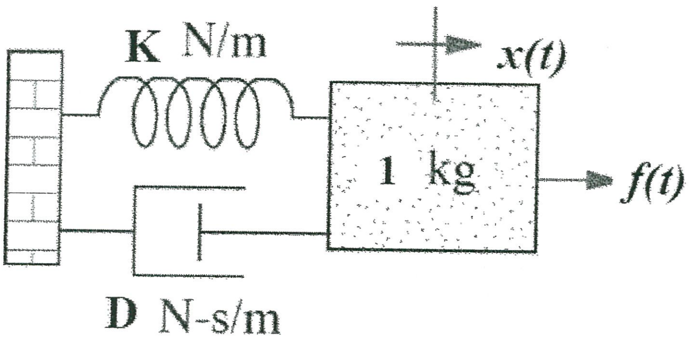

FIGURE Q3(a)

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REFERENCES:

Table 1: Laplace Transform Pairs

	$f(t)$	$F(s)$
1.	Unit impulse $\delta(t)$	1
2.	Unit step $1(t)$	$1/s$
3.	t	$1/s^2$
4.	$\frac{t^{n-1}}{(n-1)!}\quad(n-1,2,3,\ldots)$	$\frac{1}{s^n}$
5.	$t^n\,(n=1,2,3,\ldots)$	$\frac{n!}{s^{n+1}}$
6.	e^{-at}	$\frac{1}{s+a}$
7.	te^{-at}	$\frac{1}{(s+a)^2}$
8.	$\frac{1}{(n-1)!}t^{n-1}e^{-at}\quad(n=1,2,3,\ldots)$	$\frac{1}{(s+a)^n}$
9.	$t^n e^{-at}\quad(n=1,2,3,\ldots)$	$\frac{n!}{(s+a)^{n+1}}$
10.	$\sin\omega t$	$\frac{\omega}{s^2+\omega^2}$
11.	$\cos\omega t$	$\frac{s}{s^2+\omega^2}$
12.	$\sinh\omega t$	$\frac{\omega}{s^2-\omega^2}$
13.	$\cosh\omega t$	$\frac{s}{s^2-\omega^2}$
14.	$\frac{1}{a}\left(1-e^{-at}\right)$	$\frac{1}{s(s+a)}$
15.	$\frac{1}{b-a}\left(e^{-at}-e^{-bt}\right)$	$\frac{1}{(s+b)(s+a)}$
16.	$\frac{1}{b-a}\left(be^{-bt}-ae^{-at}\right)$	$\frac{s}{(s+b)(s+a)}$

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REFERENCES:

Item no.	Theorem	Name
1.	$\mathcal{L}[f(t)] = F(s) = \int_{0-}^{\infty} f(t)e^{-st}dt$	Definition
2.	$\mathcal{L}[kf(t)] = kF(s)$	Linearity theorem
3.	$\mathcal{L}[f_1(t)+f_2(t)] = F_1(s)+F_2(s)$	Linearity theorem
4.	$\mathcal{L}[e^{-at}f(t)] = F(s+a)$	Frequency shift theorem
5.	$\mathcal{L}[f(t-T)] = e^{-sT}F(s)$	Time shift theorem
6.	$\mathcal{L}[f(at)] = \frac{1}{a}F\left(\frac{s}{a}\right)$	Scaling theorem
7.	$\mathcal{L}\left[\frac{df}{dt}\right] = sF(s)-f(0-)$	Differentiation theorem
8.	$\mathcal{L}\left[\frac{d^2f}{dt^2}\right] = s^2F(s)-sf(0-)-\dot{f}(0-)$	Differentiation theorem
9.	$\mathcal{L}\left[\frac{d^nf}{dt^n}\right] = s^nF(s)-\sum_{k=1}^{n} s^{n-k}f^{k-1}(0-)$	Differentiation theorem
10.	$\mathcal{L}\left[\int_{0-}^{t} f(\tau)\,d\tau\right] = \frac{F(s)}{s}$	Integration theorem
11.	$f(\infty) = \lim_{s\to 0} sF(s)$	Final value theorem[1]
12.	$f(0+) = \lim_{s\to\infty} sF(s)$	Initial value theorem[2]

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Time Response

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

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

$$\%OS=100e^{-\left(\frac{\zeta\pi}{\sqrt{1-\zeta^2}}\right)}$$

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

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

$$T_r=\frac{1.321}{\omega_n}$$

Table 2: Test waveforms used in control systems

Name	Time function	Laplace transform
Step	$u(t)$	$\frac{1}{s}$
Ramp	$tu(t)$	$\frac{1}{s^2}$
Parabola	$\frac{1}{s}t^2$	$\frac{1}{s^3}$
Impulse	$\delta(t)$	1
Sinusoid	$\sin\omega tu(t)$	$\frac{\omega}{s^2+\omega^2}$
Cosine	$\cos\omega tu(t)$	$\frac{s}{s^2+\omega^2}$

Root Locus

$$K=\frac{1}{|G(s)H(s)|}=\frac{\prod \text{pole lengths}}{\prod \text{zero lengths}}$$

$$\sigma_a=\frac{\sum \text{finite poles}-\sum \text{finite zeros}}{\#\text{finite poles}-\#\text{finite zeros}}$$

$$\theta_a=\frac{(2k+1)\pi}{\#\text{finite poles}-\#\text{finite zeros}}$$

$$KG(s)H(s)=-1=1\angle(2k+1)180^\circ$$

$$\theta=\sum \text{finite zero angles}-\sum \text{finite pole}$$

Differentiation (quotient rule)

If $u=f(x)$ and $v=g(x)$ then

$$\frac{d}{dx}\left(\frac{u}{v}\right)=\frac{v(du/dx)-u(dv/dx)}{v^2}=\frac{g(x)f'(x)-f(x)g'(x)}{[g(x)]^2}$$

Steady-state Error

$$e(\infty)=e_{step}(\infty)=\frac{1}{1+\lim_{s\to0}G(s)};\quad K_p=\lim_{s\to0}G(s)$$

$$e(\infty)=e_{ramp}(\infty)=\frac{1}{\lim_{s\to0}sG(s)};\quad K_v=\lim_{s\to0}sG(s)$$

$$e(\infty)=e_{parabola}(\infty)=\frac{1}{\lim_{s\to0}s^2G(s)};\quad K_a=\lim_{s\to0}s^2G(s)$$