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Universiti Tun Hussein Onn Malaysia

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER II
SESSION 2015/2016

COURSE NAME	:	CONTROL ENGINEERING AND INSTRUMENTATION
COURSE CODE	:	BNJ 20403
PROGRAMME	:	BNL
EXAMINATION DATE	:	JUNE / JULY 2016
DURATION	:	3 HOURS
INSTRUCTION	:	**ANSWER ALL QUESTIONS**

THIS QUESTION PAPER CONSISTS OF **SIX (6)** PAGES

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Q1 (a) State if the following sentences are **TRUE (T)** or **FALSE (F)**

(i) A closed-loop control system uses a measurement of the output and feedback of the signal to compare it with the desired input.
(ii) The ability to obtain linear approximations of physical systems allows the analyst to consider the use of Laplace transformation.
(iii) The outputs of a linear system can be related to the state variables and the input signals by the state differential equation.
(iv) Root locus methods are not applicable to digital control system design and analysis.
(v) The arrangement of the system and the selection of suitable components and parameters is part of the process of control design.

(5 marks)

(b) Match the term with the definition shown below:

- Sampling period
- Microcomputer
- Z-transform
- PID controller
- Digital control system

(i) A controller with three terms in which the output is the sum of a proportional term, an integral term, and a differentiating term.
(ii) A conformal mapping from the s-plane to the z-plane by the relation $z=e^{st}$.
(iii) The periods when all the numbers leave or enter the computer.
(iv) A control system using digital signals and a digital computer to control a process.
(v) A small personal computer (PC) based on microprocessor.

(5 marks)

(c) Illustrates the following three elementary block diagram into block diagram algebra:-

(i) Series connection
(ii) Parallel connection
(iii) Negative feedback connection

(9 marks)

(d) Explain **TWO (2)** differences between sensitivity, precision and accuracy in an instrument.

(6 marks)

Q2 A feedback control system is represented as the block diagram shown in **FIGURE Q2**.

(a) Plot the coordinate of finite open-loop poles and finite open-loop zeros on linear graph paper. Represent the zeros using symbol 'O' and poles using symbol 'X'.

(3 marks)

(b) Determine the following:

(i) The asymptotes, the real-axis intercept, σ_a and the angles of the lines that intersect at σ_a.
(ii) The exact point and gain, K where the locus crosses the imaginary- axis
(iii) The breakaway point on the real axis.

(12 marks)

(c) Sketch the root locus for the system

(10 marks)

Q3 (a) Illustrate the general phase and gain stability margins in Nyquist Plot

(4 marks)

(b) An open-loop transfer function for the system of servo motor 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

(15 marks)

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

(3 marks)

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

(3 marks)

Q4 (a) Explain the increasing effect of:

(i) the proportional gain of a PID controller
(ii) the integral gain of a PID controller
(iii) the derivative gain of a PID controller

in terms of system damping effect, steady state error and stability.

(9 marks)

(b) Sketch all the time reponse showing the effect of the introduction of P, PI, PD and PID controllers to a system that initially has 10% overshoot, 10% steady-state error and 10 seconds settling time.

(9 marks)

(c) Construct and analyze a block diagram of a closed-loop system having a PID controller with *Kp*, *Ki* and *Kd* as the proportional, integral and derivate gains respectively. The open-loop transfer function of the system is shown below.

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

Assume the system is having unity feedback.

(5 marks)

(d) Determine the closed loop transfer function of part (c) system in polynomial form.

(2 marks)

-END OF QUESTIONS-

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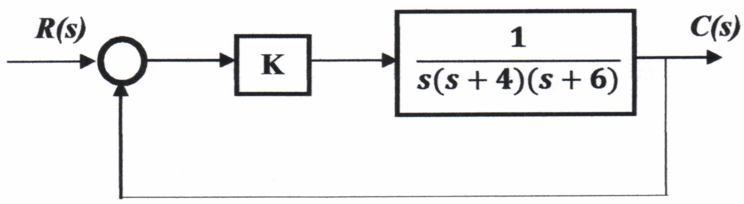

FIGURE Q2

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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REFERENCES:

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	$\sin\omega t u(t)$	$\frac{\omega}{s^2+\omega^2}$
Cosine	$\cos\omega t u(t)$	$\frac{s}{s^2+\omega^2}$

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

$$e(\infty)=e_{step}(\infty)=\frac{1}{1+\lim_{s\to 0}G(s)};\quad K_p=\lim_{s\to 0}G(s)$$

$$e(\infty)=e_{ramp}(\infty)=\frac{1}{\lim_{s\to 0}sG(s)};\quad K_V=\lim_{s\to 0}sG(s)$$

$$e(\infty)=e_{parabola}(\infty)=\frac{1}{\lim_{s\to 0}s^2G(s)};\quad K_a=\lim_{s\to 0}s^2G(s)$$