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UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER II
SESSION 2017/2018

COURSE NAME	:	INSTRUMENTATION AND PROCESS CONTROL
COURSE CODE	:	BNL 30603
PROGRAMME CODE	:	BNL
EXAMINATION DATE	:	JUNE / JULY 2018
DURATION	:	3 HOURS
INSTRUCTION	:	ANSWER **ALL** QUESTIONS

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THIS QUESTION PAPER CONSISTS OF **SEVEN (7)** PAGES

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Q1 (a) There are two types of control strategy. By giving a suitable examples accordingly, briefly explain the two types of the control strategy.

(4 marks)

(b) Control system is a group of components which maintains desired results (goals) by manipulating the value of another variable in the system. Describe the desired results (goals) of control system.

(3 marks)

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

(7 marks)

(d) The dynamic responses of second order system depend on the ζ value. Sketch and describe **FOUR (4)** different second order responses with their respective ζ value with the input of step input function. Explain the definition of Maximum overshoot (M_p) in the transient response characteristics.

(6 marks)

Q2 (a) Given the following differential equations, analyze the system by obtaining the response $y(t)$ subject to the given initial condition.

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

(5 marks)

(ii) $y'' + 3y' + 2y = 0 \qquad where \; y(0) = 0.1 \;\; and \;\; y'(0) = 0.05$

(5 marks)

(b) An electrical motor is applied to balance a ball as shown in **Figure Q2(b)**. Motor input current, i_m controls the torque of the motor at negligible friction. Assume the beam balance at $\phi = 0$, calculate transfer function of the system. Draw the block diagram to represent the transfer function.

(10 marks)

Q3 (a) Describe the following basic elements of electronic instrument.

(i) Transducer

(ii) Signal modifier

(iii) Sensor

(6 marks)

(b) Explain briefly the working principles of control valves. Sketch their instrumentation schematic.

(10 marks)

(c) Discuss the concept of interacting and non-interacting system with appropriate examples.

(4 marks)

Q4 (a) The open loop transfer function of a robot arm control system for a process control tank manipulation system is given by:

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

Referring to robot arm control system,

(i) Clearly locate all poles and zeros on a linear graph paper. Calculate 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. Then determine the operational point, S_m (poles) from damping ratio, ζ = 0.5, natural frequencies (ω_n and ω_d) and gain K at this operational point.

(8 marks)

(b) Differentiate the concept of control strategies (P, PI and PID controllers).

(6 marks)

Q5 (a) Define the concept of cascade control system and describe **TWO (2)** rules in designing cascade control.

(5 marks)

(b) **Figure Q5(b)** shows the translation mechanical system of a robotic control system. Force, $f(t)$ is an input; $x_1$and x_2 are the output displacements. Formulate the transfer function, $X(s)/F(s)$ of the system.

(15 marks)

–END OF QUESTION –

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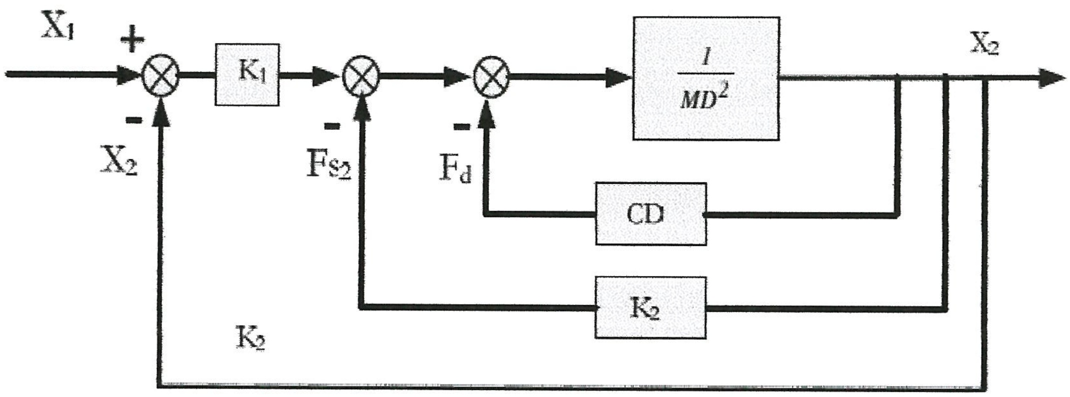

Figure Q1(c)

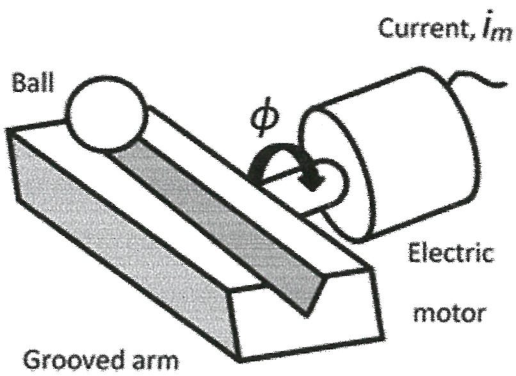

Figure Q2(b)

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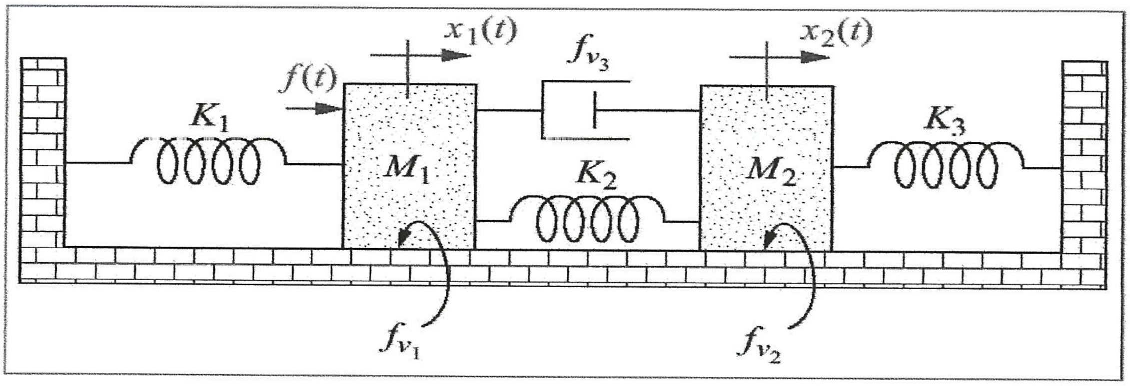

Figure Q5(b)

REFERENCES;

Laplace Transform

Original	Image
a	$\frac{a}{s}$
t	$\frac{1}{s^2}$
t^2	$\frac{2}{s^3}$
$t^n, n \in N$	$\frac{n!}{s^{n+1}}$
e^{at}	$\frac{1}{s-a}$
te^{at}	$\frac{1}{(s-a)^2}$
t^2e^{at}	$\frac{2}{(s-a)^3}$
$t^n e^{at}, n \in N$	$\frac{n!}{(s-a)^{n+1}}$

Original	Image
$\sin(\omega t)$	$\frac{\omega}{s^2+\omega^2}$
$\cos(\omega t)$	$\frac{s}{s^2+\omega^2}$
$\sinh(\omega t)$	$\frac{\omega}{s^2-\omega^2}$
$\cosh(\omega t)$	$\frac{s}{s^2-\omega^2}$
$t\sin(\omega t)$	$\frac{2s\omega}{(s^2+\omega^2)^2}$
$t\cos(\omega t)$	$\frac{s^2-\omega}{(s^2+\omega^2)^2}$
$e^{at}\sin(\omega t)$	$\frac{\omega}{(s-a)^2+\omega^2}$
$e^{at}\cos(\omega t)$	$\frac{s-a}{(s-a)^2+\omega^2}$

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Time Response

$$C(s)=\frac{\omega_n^2}{s^2+2\zeta\omega_n s+\omega_n^2}\qquad \zeta=\frac{-\ln(\%OS/100)}{\sqrt{\pi^2+\ln^2(\%OS/100)}}\qquad \%OS=100e^{-\left(\frac{\zeta\pi}{\sqrt{1-\xi^2}}\right)}$$

$$T_p=\frac{\pi}{\omega_n\sqrt{1-\zeta^2}}=\frac{\pi}{\omega_d}\qquad T_s=\frac{4}{\zeta\omega_n}=\frac{4}{\sigma_d}\qquad T_f=\frac{1.321}{\omega_k}$$

Test waveforms

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

Root Locus

$$K=\frac{1}{|G(s)H(s)|}=\frac{\prod polelength}{\prod zerolength}$$

$$\sigma_c=\frac{(p_1+p_2+\text{L}\ +p_n)-(z_1+z_2+\text{L}\ +z_m)}{n\ \ m}$$

$$\theta_a=\frac{(2k+1)\pi}{\#\,finite\_poles-\#\,finite\_zeroes}$$

$$\theta=\sum finite\_zero\_angles-\sum finite\_pole$$

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

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

$K_p=\lim_{s\to 0}G(s)$
Position Constant

$$e(\infty)=e_{ramp}(\infty)=\lim_{s\to 0}\frac{s(1/s^2)}{1+G(s)}=\lim_{s\to 0}\frac{1}{s+sG(s)}=\frac{1}{\lim_{s\to 0}sG(s)}$$

$K_v=\lim_{s\to 0}s\,sG(s)$
Velocity Constant

$$e(\infty)=e_{parabola}(\infty)=\lim_{s\to 0}\frac{s(1/s^3)}{1+G(s)}=\lim_{s\to 0}\frac{1}{s^2+s^2G(s)}=\frac{1}{\lim_{s\to 0}s^2G(s)}$$

$K_a=\lim_{s\to 0}s^2G(s)$
Acceleration Constant