UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER I
SESSION 2014/2015

COURSE NAME	:	INSTRUMENTATION AND CONTROL
COURSE CODE	:	BNR 20703
PROGRAMME	:	BND/ BNF
EXAMINATION DATE	:	DECEMBER 2014/JANUARY 2015
DURATION	:	2 HOURS 30 MINUTES
INSTRUCTION	:	ANSWER **FOUR (4)** QUESTIONS ONLY

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

Q1 (a) Briefly explain 3 advantages of control systems.

(3 marks)

(b) Illustrate an open loop control system and a closed loop control system. Briefly explain its operation, the function of its components, and draw the system block diagram which includes the stated components.

(6 marks)

(c) For the following control systems, analyze whether the system is an open loop or a closed loop system and state whether the system is a kinetic control or a process control:

(i) air-conditioner;
(ii) electric toaster;
(iii) escalator; and
(iv) a solar panel tracking the sun movement.

(6 marks)

(d) A university wants to establish a control system model that represents the student population as an output and the desired student population as an input. The administration determines the rate of admission by comparing the current and desired student population. The admissions office then uses this rate to admit students.

i) draw a functional block diagram showing the administration and the admissions office as blocks of the system; and

ii) show the following signals: the desired student population, the actual student population, the desired student rate as determined by the administration, the actual student rate as generated by the admissions office, the dropout rate, and the net of entry rate.

(10 marks)

Q2 (a) Explain the meaning of "*step response of a system*".

(1 mark)

(b) For the following systems transfer function, categorize the system order, plot the poles on s-plane and sketch the output response.

(i) $$G(s) = \frac{20}{s^2 + 14s + 100}$$

(ii) $$G(s) = \frac{18}{s^2 + 9s + 9}$$

(iii) $$G(s) = \frac{2}{s + 4}$$

(6 marks)

(c) Figure Q2(c) shows the unit steps responses for the systems A, B and C. Based on the 3 criteria, the transient response, the steady state response and the stability, analyze the performance of each system. Hence, which system has the best performance? Give reason to support your choice.

(8 marks)

(d) Determine the transfer function, $\theta_i(s)/T(s)$, for the rotational system shown in Figure Q2(d).

(10 marks)

Q3 (a) Briefly explain the definition of the transfer function of a system.

(2 marks)

(b) Illustrate the following control terminologies with the aid of respective plotting:

i) stability;
ii) steady-state error;
iii) time constant for a first order step response; and
(iv) settling time for a second order step response.

(6 marks)

(c) Figure Q3(c) shows an electrical network consisting of resistors, an inductor, and a capacitor. $v_i(t)$ is the input voltage and $v_o(t)$ is the voltage across the capacitor. Determine the transfer function, $G(s) = V_o(s)/V_i(s)$ of the system.

(7 marks)

(d) Given the motor, load and torque-speed curve shown in Figure Q3(d)(i) and Q3(d)(ii). The transfer function of system is:

$$\frac{\theta_m(s)}{E_a(s)} = \frac{\dfrac{K_t}{R_a J_m}}{s\left[s + \dfrac{1}{J_m}\left(D_m + \dfrac{K_t K_b}{R_a}\right)\right]}$$

Using the transfer function given above, determine the transfer function, $G(s) = \theta_L(s)/E_a(s)$.

(10 marks)

Q4 (a) Explain all the performance specifications for a second order system.

(5 marks)

(b) Consider the block diagram of the position servomechanism used in an antenna tracking system shown in Figure Q4(b). This system uses an electric dc motor to rotate the radar antenna, which automatically tracks an aircraft. A unit step input is used to investigate the performance of the antenna's tracking capability.

(i) determine the closed-loop transfer function of the system;
(ii) calculate the value of the damping ratio (ζ) for the system if a critically damped response is required;
(iii) for the damping ratio found in part (ii), determine the value of gain K and the undamped natural frequency (ω_n);
(iv) determine the steady-state error (e_{ss}) of the system using the value of gain K obtained in part (iii);
(v) suggest on how the steady-state error (e_{ss}) of the system can be reduced; and
(vi) determine the settling time (T_s) of the system.

(16 marks)

(c) It is noted that the rotation of a radar antenna is very slow and the electric motor needs to be changed in order to achieve a fast tracking response. The modified system is shown in Figure Q4(c). If the settling time required for the system is 0.5 s and the damping ratio is equal to 1, determine the values for K_I and τ.

(4 marks)

Q5 (a) i) Explain the advantage of the design using Root Locus.
ii) Describe the compensation in order to improve the steady-state error.
iii) Describe the compensation in order to improve transient response.
iv) Describe the compensation in order to improve both steady-state error and transient response.

(4 marks)

(b) In the system of Figure Q5(b), let

$$G(s) = \frac{K(s+2)}{s(s-1)(s+3)}$$

Determine the range of K for closed-loop stability.

(6 marks)

(c) Consider the control system shown in Figure Q5(c). Apply a Ziegler-Nicholas tuning rule with the aid from Table Q5(c) for the determination of the values parameters:
(i) K_p;
(ii) T_i;
(iii) T_d; and
(iv) obtain the transfer function of PID controllers

(15 marks)

-- END OF QUESTION –

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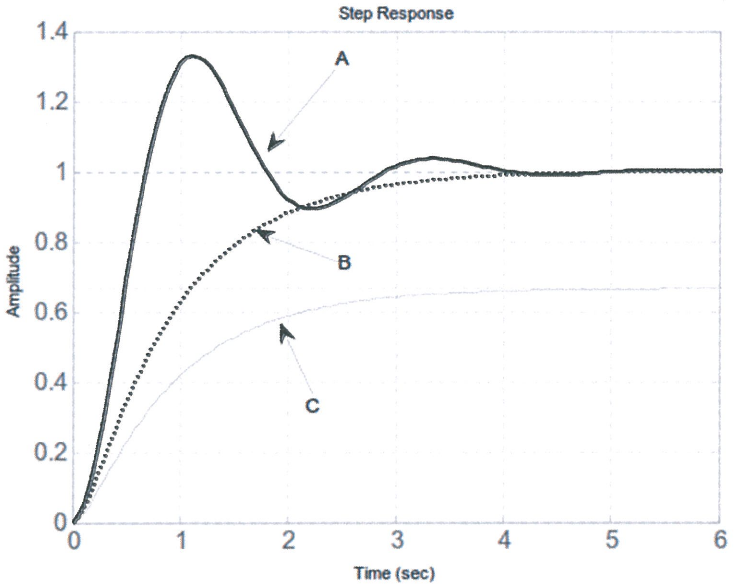

Figure Q2(c)

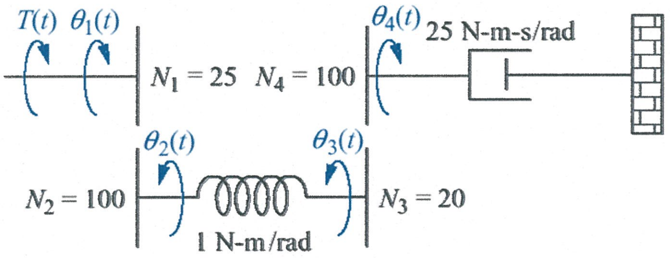

Figure Q2(d)

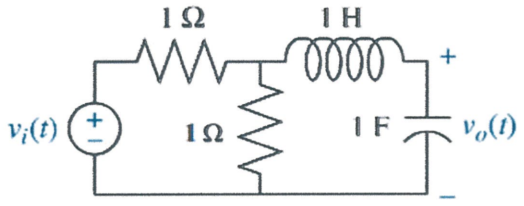

Figure Q3(c)

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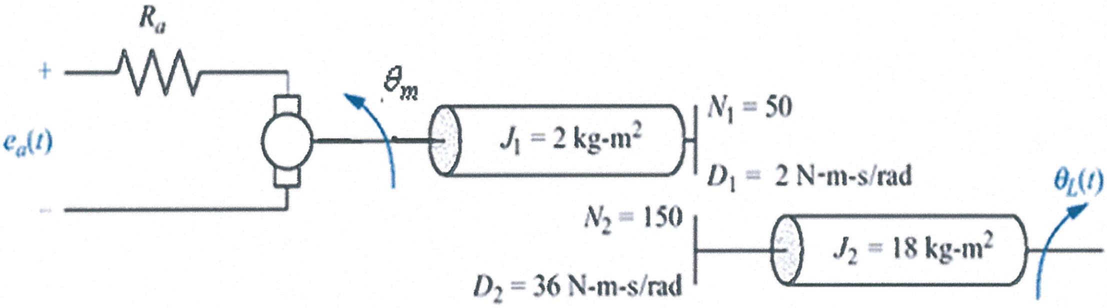

Figure Q3(d)(i)

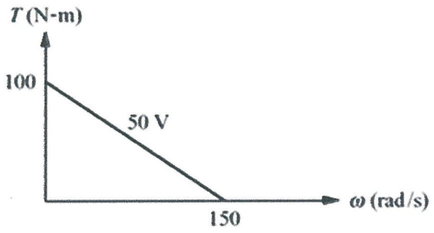

Figure Q3(d)(ii)

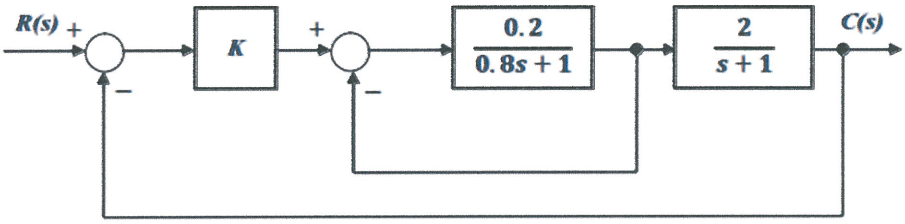

Figure Q4(b)

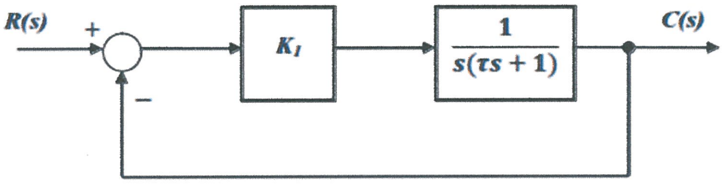

Figure Q4(c)

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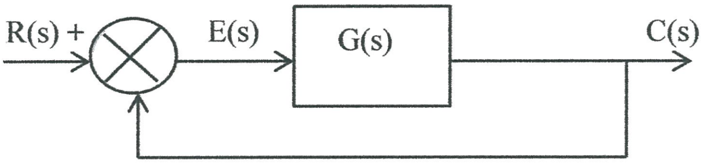

Figure Q5(b)

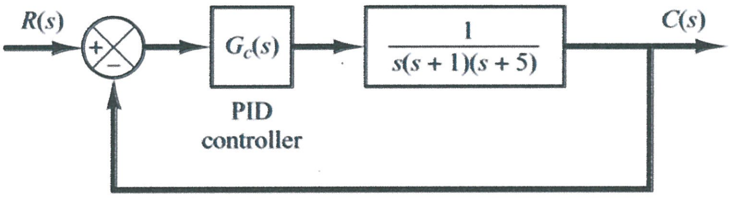

Figure Q5(c)

Type of Controller	K_p	T_i	T_d
P	$0.5K_{cr}$	∞	0
PI	$0.45K_{cr}$	$\frac{1}{1.2}P_{cr}$	0
PID	$0.6K_{cr}$	$0.5P_{cr}$	$0.125P_{cr}$

Table Q5(c): QDR tuning formulas on ultimate gain and period

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TABLE 1
Laplace Transform Table

$f(t)$	$F(s)$
$\delta(t)$	1
$u(t)$	$\frac{1}{s}$
$tu(t)$	$\frac{1}{s^2}$
$t^n u(t)$	$\frac{n!}{s^{n+1}}$
$e^{-at}u(t)$	$\frac{1}{s+a}$
$\sin \omega t u(t)$	$\frac{\omega}{s^2+\omega^2}$
$\cos \omega t u(t)$	$\frac{s}{s^2+\omega^2}$

TABLE 2
Laplace Transform Theorems

Name	Theorem
Frequency shift	$\mathcal{L}\left[e^{-at}f(t)\right] = F(s+a)$
Time shift	$\mathcal{L}\left[f(t-T)\right] = e^{-sT}F(s)$
Differentiation	$\mathcal{L}\left[\frac{d^n f}{dt^n}\right] = s^n F(s) - \sum_{k=1}^{n} s^{n-k} f^{k-1}(0^-)$
Integration	$\mathcal{L}\left[\int_{0^-}^{t} f(\tau)d\tau\right] = \frac{F(s)}{s}$
Initial value	$\lim_{t\to 0} f(t) = \lim_{s\to\infty} sF(s)$
Final value	$\lim_{t\to\infty} f(t) = \lim_{s\to 0} sF(s)$