Universiti Tun Hussein Onn Malaysia

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER I
SESSION 2016/2017

COURSE NAME	:	INSTRUMENTATION AND CONTROL SYSTEM
COURSE CODE	:	BEH22003
PROGRAMME CODE	:	BEJ
EXAMINATION DATE	:	DECEMBER 2016 /JANUARY 2017
DURATION	:	3 HOURS
INSTRUCTION	:	ANSWER **ALL** QUESTIONS

THIS QUESTION PAPER CONSISTS OF EIGHT (8) PAGES

Q1 (a) Give **one (1)** advantage of open loop system.

(2 marks)

(b) Describe each of the control system classification listed below;

(i) Single input single output (SISO) system.

(2 marks)

(ii) Time-Invariant system.

(2 marks)

(c) Determine the transfer function $\frac{C(s)}{R(s)}$ of the system shown in **Figure Q1(c)**.

(14 marks)

Q2 (a) Describe the meaning of mechanical gearing system.

(4 marks)

(b) The schematic diagram of DC motor is as given in **Figure Q2(b).** Determine the transfer function $\frac{\theta_m(s)}{V_a(s)}$ for the system where $\theta_m(s)$ is referred as angular position while $V_a(s)$ is referred as armature voltage. Assume that the DC motor is on "Load" condition.

(8 marks)

(c) The DC motor shown in **Figure Q2(b)** operating in open-loop condition and does not provide precise angular positioning regulation. As an engineer, you are required to design a closed loop system for the DC motor so that a precise angular positioning regulation can be achieved.

(i) Identify the additional component required for controlling the angular positioning of the DC motor.

(3 marks)

(ii) Sketch the schematic and block diagram of the modified system.

(5 marks)

Q3 (a) The closed loop transfer function of a system is given as below.

$$G(s) = \frac{C(s)}{R(s)} = \frac{(s+1)}{(s+5)(s^2+9)}$$

Classify the system stability based on zeros and poles plot of the system on s-plane.

(6 marks)

(b) The block diagram of a positioning system is shown in **Figure Q3(b)** ;

(i) Find the closed loop transfer function of the system.

(1 marks)

(ii) Determine the damping ratio, ζ and natural frequency, ω_n of the system.

(3 marks)

(iii) Calculate the peak time, T_p.

(1 marks)

(iv) Calculate the rise time, T_r.

(2 marks)

(v) Calculate the settling time, T_s with 5% band.

(1 marks)

(vi) Calculate the percentage of overshoot, %μs.

(2 marks)

(vii) Determine the new value of damping ratio, ζ, for the system, if the percentage of overshoot obtained in question Q3(b)(iv) is reduce by 60%.

(4 marks)

Q4 (a) Explain clearly the difference between *offset* and *neutral zone*.

(6 marks)

(b) Based on the characteristics of open loop test for temperature of chemical reactor shown in **Figure Q4(b),** you are required to design the Proportional Integral Derivative (PID) controller to regulate the temperature of the reactor at 80°C.

(i) Determine the parameter of Proportional Gain (K_p), Integral Gain (K_i) and Derivative Gain (K_d) for the PID controller using Cohen Coon tuning formula.

(6 marks)

(ii) Based on **Q4(b)(i),** sketch the complete block diagram of the PID controller for regulating temperature of the chemical reactor. Assume that the transfer function of the heating process of the chemical reactor is as given below;

$$G(s) = \frac{0.07}{s + 0.002}$$

(8 marks)

Q5 (a) List two (2) types of sensor that widely used in industry for measuring the temperature.

(3 marks)

(b) Explain in detail the working principles of Resistance Temperature Detectors (RTD).

(7 marks)

(c) One of the major problem in steam distillation column industry is to ensure that the water contained in the column tank maintain around the minimum and maximum level so that the effective overall distillating process can be achieved. As a process engineer in distillation column industry, you are required to design a level control system for the distillation column.

(i) Choose suitable sensor for this application

(2 marks)

(ii) With proper sketching, illustrate the operation of level control system that you proposed in question Q5(c)(i).

(8 marks)

- END OF QUESTIONS –

FINAL EXAMINATION

SEMESTER / SESSION : SEM I/ 2016/2017
COURSE NAME : INSTRUMENTATION AND CONTROL SYSTEM
PROGRAMME : BEJ
COURSE CODE : BEH22003

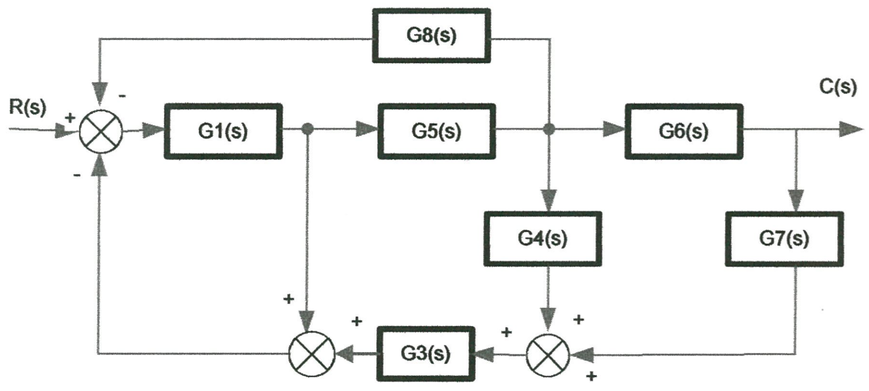

Figure Q1(c)

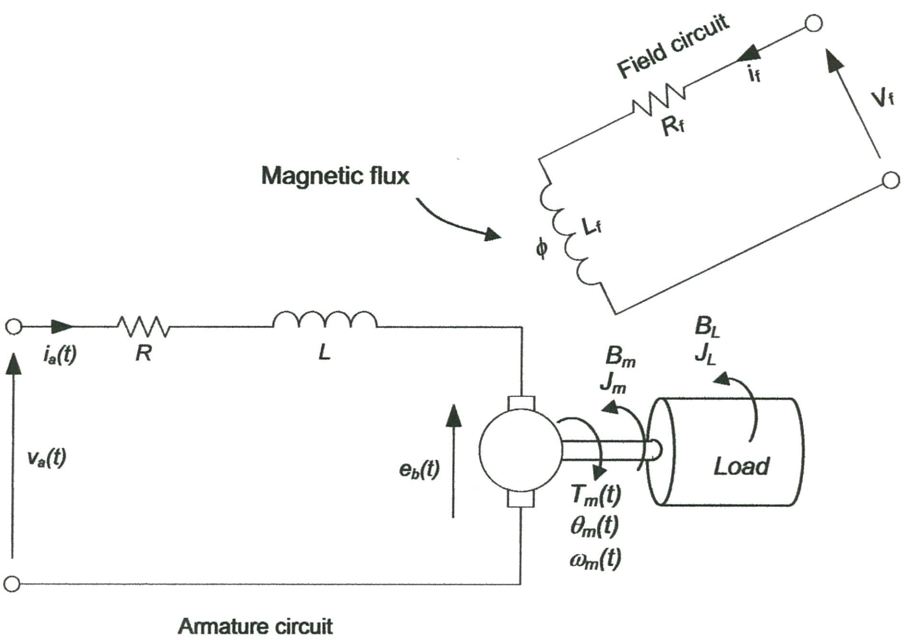

Figure Q2(b)

FINAL EXAMINATION

SEMESTER / SESSION : SEM I/ 2016/2017
COURSE NAME : INSTRUMENTATION AND CONTROL SYSTEM
PROGRAMME : BEJ
COURSE CODE : BEH22003

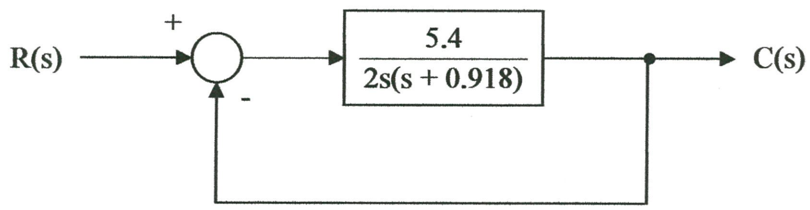

Figure Q3(b)

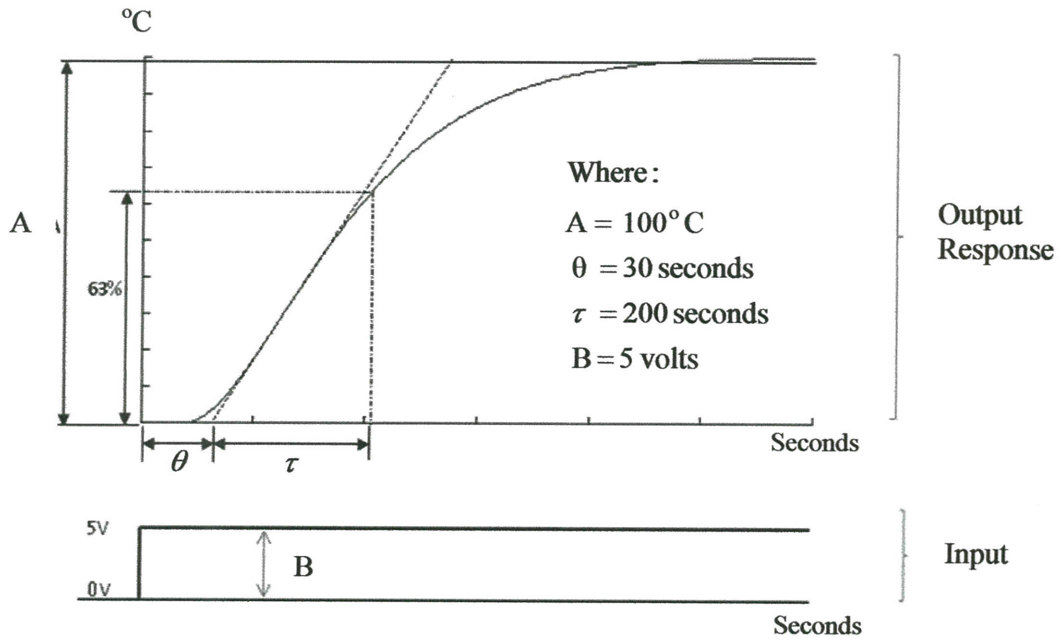

Figure Q4(b)

FINAL EXAMINATION

SEMESTER / SESSION : SEM I/ 2016/2017
COURSE NAME : INSTRUMENTATION AND CONTROL SYSTEM
PROGRAMME : BEJ
COURSE CODE : BEH22003

FORMULAE

Table A
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 B
Laplace transform theorems

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

FINAL EXAMINATION

SEMESTER / SESSION	: SEM I/ 2016/2017	PROGRAMME	: BEJ
COURSE NAME	: INSTRUMENTATION AND CONTROL SYSTEM	COURSE CODE	: BEH22003

Table C

2nd Order prototype system equations

$\dfrac{C(s)}{R(s)} = \dfrac{\omega_n^{\;2}}{s^2 + 2\zeta\omega_n s + \omega_n^{\;2}}$	$T_r = \dfrac{\pi - \cos^{-1}\zeta}{\omega_n\sqrt{1-\zeta^2}}$
$\mu_p = e^{\frac{-\zeta\pi}{\sqrt{1-\zeta^2}}}$	$T_p = \dfrac{\pi}{\omega_n\sqrt{1-\zeta^2}}$
$T_s = \dfrac{4}{\zeta\omega_n}$ (2% criterion)	$T_s = \dfrac{3}{\zeta\omega_n}$ (5% criterion)

Table D

Cohen Coon Tuning Formula

Controller	K_p	T_i	T_d
P	$\dfrac{\tau}{K\theta}\left(1 + \dfrac{\theta}{3\tau}\right)$		
PI	$\dfrac{\tau}{K\theta}\left(0.9 + \dfrac{\theta}{12\tau}\right)$	$\theta\left(\dfrac{30 + 3\left(\frac{\theta}{\tau}\right)}{9 + 20\left(\frac{\theta}{\tau}\right)}\right)$	
PID	$\dfrac{\tau}{K\theta}\left(\dfrac{4}{3} + \dfrac{\theta}{4\tau}\right)$	$\theta\left(\dfrac{32 + 6\left(\frac{\theta}{\tau}\right)}{13 + 8\left(\frac{\theta}{\tau}\right)}\right)$	$\theta\left(\dfrac{4}{11 + 2\left(\frac{\theta}{\tau}\right)}\right)$