UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER I
SESSION 2016/2017

COURSE NAME	:	INSTRUMENTATION AND CONTROL
COURSE CODE	:	BNR 20703
PROGRAMME	:	2 BND/2 BNF
EXAMINATION DATE	:	DECEMBER 2016 / JANUARY 2017
DURATION	:	2 HOURS 30 MINUTES
INSTRUCTION	:	ANSWER **FOUR (4)** QUESTIONS ONLY

THIS QUESTION PAPER CONSISTS OF **TEN (10)** PAGES

Q1 (a) (i) Describe the differences between static and dynamic characteristics of measuring instruments.

(ii) Briefly explain the differences between accuracy and precision in an instrument.

(6 marks)

(b) The expected value of the current through a resistor is 20 mA. However the measurement yields a current value of 18mA. Calculate:

(i) absolute error;
(ii) percentage of error;
(iii) relative accuracy; and
(iv) percentage of accuracy.

(4 marks)

(c) In a calibration test, 10 measurements using a digital voltmeter have been made of the battery voltage that is known to have a true voltage of 6.11 V. The results are shown in **TABLE Q1(c)**. Calculate:

(i) arithmetic mean;
(ii) deviation of each reading;
(iii) average deviation;
(iv) standard deviation; and
(v) calculate the accuracy of the 3rd experiment.

(10 marks)

(d) Sketch the diagram and explain briefly the working principle of galvanometric chart recorder.

(5 marks)

Q2 (a) Briefly explain **FOUR** advantages of control systems.

(4 marks)

(b) For the following control systems, determine 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 across the sky.

(8 marks)

(c) A car equipped with cruise control system can maintain its speed according to a driver's set speed, despite of presence any disturbances (for example, different road condition, etc.):

(i) explain whether this is an open loop or a closed loop control systems; and

(ii) draw the corresponding block diagram describing its operation.

(7 marks)

(d) 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)

Q3 (a) Briefly explain what is meant by a transfer function.

(2 marks)

(b) Determine the transfer function, $G(s) = V_L(s)/V(s)$ for network shown in **FIGURE Q3(b)**.

(7 marks)

(c) Determine the transfer function, $G(s)=\theta_2(s)/T(s)$, for the translational mechanical system shown in **FIGURE Q3(c).**

(8 marks)

(d) The motor, with torque-speed characteristics as shown in **FIGURE Q3(d),** drives the load shown in the figure. Determine the transfer function, $G(s)=\theta_2(s)/E_a(s)$. Please note that the gears have inertia and the general transfer function of the motor is given by:

(8 marks)

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

Q4 (a) As an engineer, you are given two control systems to be analyzed. The systems are the air purifier system and the air conditioner system:

(i) determine the type of control strategy (open loop or closed loop) for each system;
(ii) draw the functional block diagram; and
(iii) compare the important characteristics in both systems.

(6 marks)

(b) For precise control of a robot arm, a DC motor is required to rotate 1 radian from an initial position. Three DC motors (A, B and C) are tested and **FIGURE Q4(b)** shows their responses to step input:

(i) analyze the performance of each motor in terms of time response specifications and stability. Your discussion should relate to the rotation of DC motor in practical; and
(ii) hence, in your opinion which system gives the best performance and **WHY**?

(9 marks)

(c) When the system shown in **FIGURE Q4(c)(i)** is subjected to a unit-step input, the system output response is as shown in **FIGURE Q4(c)(ii)**. Determine:

(i) peak time, T_p , settling time, T_s , rise time, T_r ;
(ii) percentage overshoot, %OS;
(iii) damping ratio, ζ
(iv) natural frequency, ω_n ; and
(v) The values of K and T.

(10 marks)

Q5 (a) Identify **THREE** familiar forms that subsystems are normally connected in a block diagram?

(3 marks)

(b) Derive the overall transfer function for the system shown in **FIGURE Q5(b)** using the block diagram reduction method.

(10 marks)

(c) For the unity feedback system of **FIGURE Q5(c)** with

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

determine the range of K to ensure stability.

(6 marks)

(d) A unity feedback system of **FIGURE Q5(c)** has the following forward transfer function:

$$G(s) = \frac{1000(s+8)}{(s+7)(s+9)}$$

(i) evaluate system type Kp, Kv, and Ka; and

(ii) use your answer in (i) to find the steady-state errors for the standard step, ramp, and parabolic inputs.

(6 marks)

- END OF QUESTIONS -

FINAL EXAMINATION

SEMESTER/SESSION: SEM I/2016/2017
COURSE NAME: INSTRUMENTATION AND CONTROL

PROGRAMME : 2 BND & 2 BNF
COURSE CODE: BNR20703

No of measurement	Reading (V)
1	5.98
2	6.05
3	6.10
4	6.06
5	5.99
6	5.96
7	6.02
8	6.09
9	6.03
10	5.99

TABLE Q1(c)

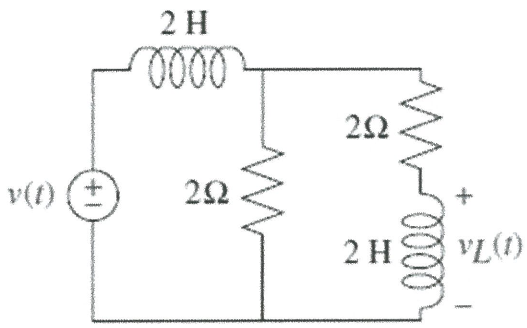

FIGURE Q3(b)

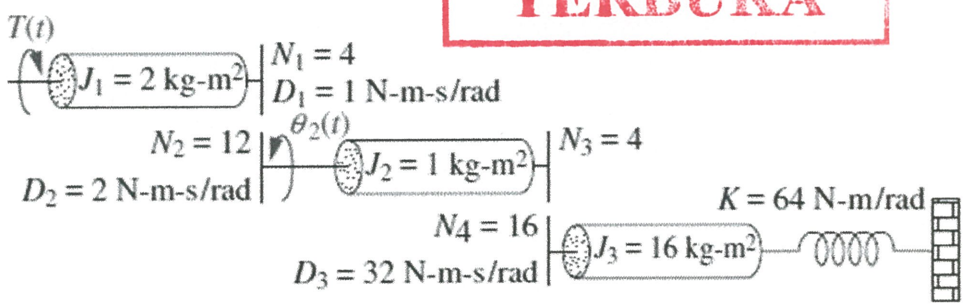

FIGURE Q3(c)

FINAL EXAMINATION

SEMESTER/SESSION: SEM I/2016/2017
COURSE NAME: INSTRUMENTATION AND CONTROL

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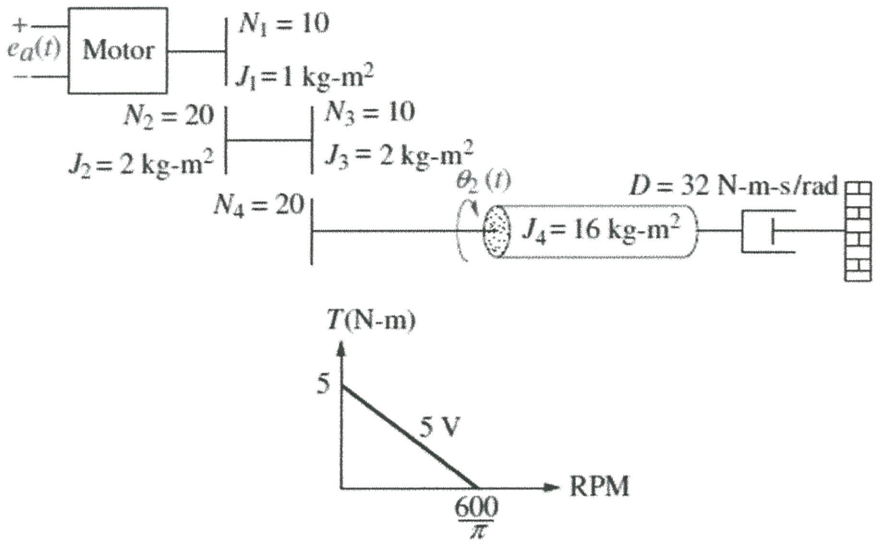

FIGURE Q3(d)

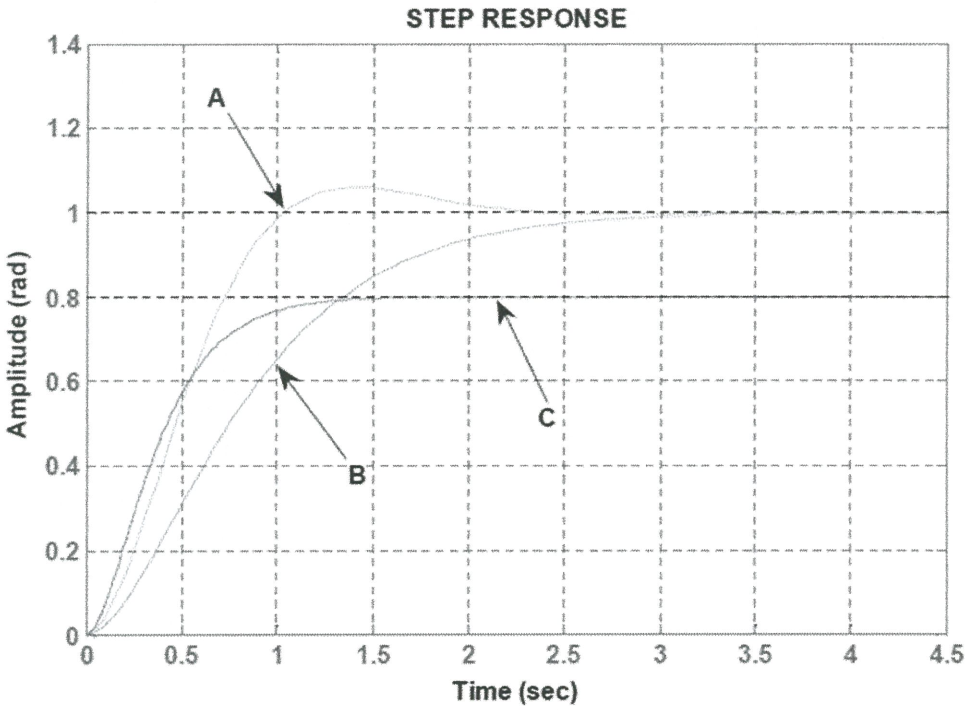

FIGURE Q4(b)

FINAL EXAMINATION

SEMESTER/SESSION: SEM I/2016/2017
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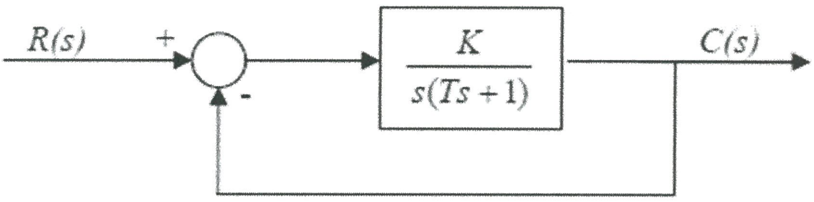

FIGURE Q4(c)(i)

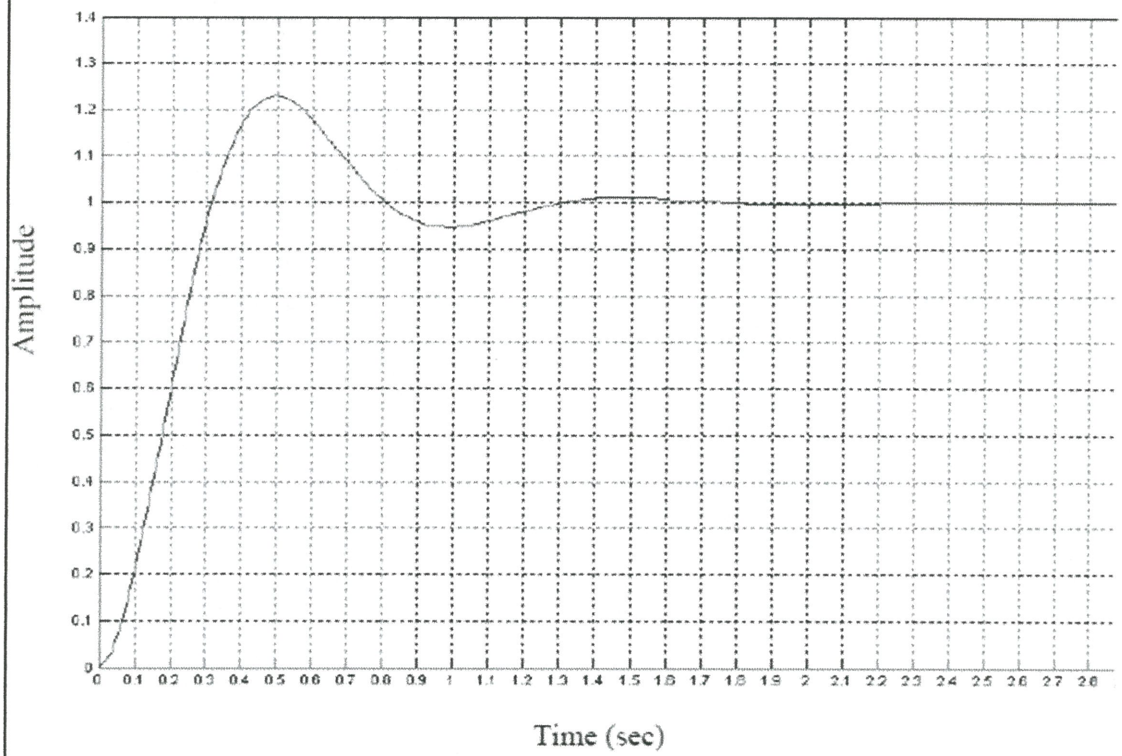

FIGURE Q4(c)(ii)

FINAL EXAMINATION

SEMESTER/SESSION: SEM I/2016/2017 PROGRAMME : 2 BND & 2 BNF
COURSE NAME: INSTRUMENTATION AND CONTROL COURSE CODE: BNR20703

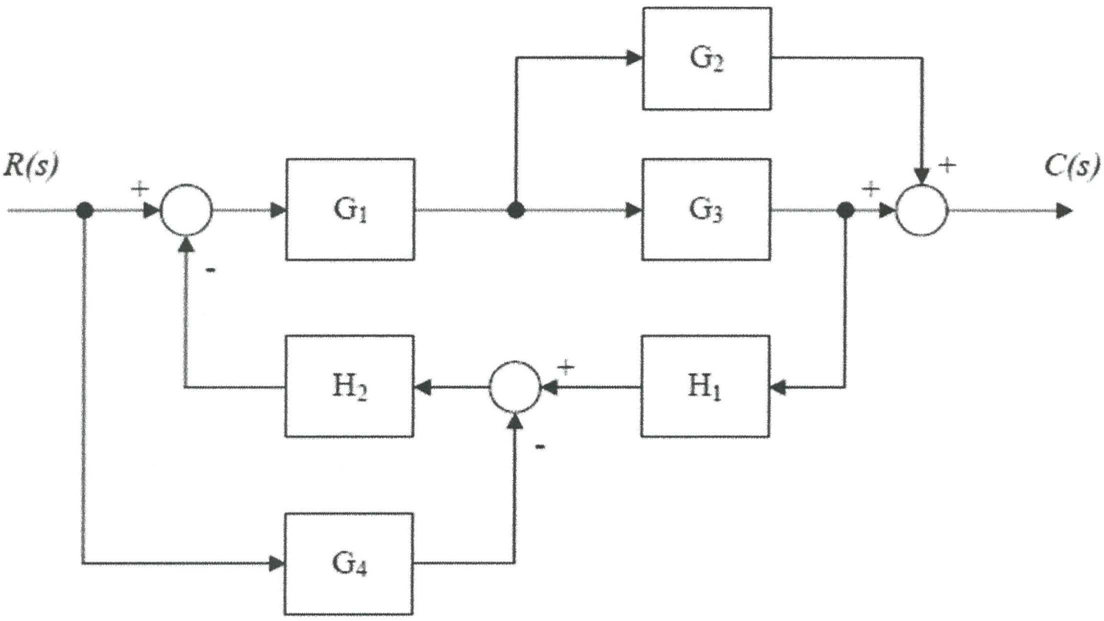

FIGURE Q5(b)

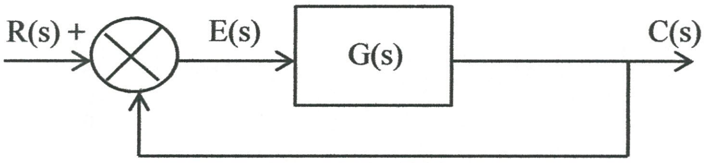

FIGURE Q5(c)

FINAL EXAMINATION

SEMESTER/SESSION: SEM I/2016/2017 | PROGRAMME : 2 BND & 2 BNF
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Laplace Transform Table

Item no.	$f(t)$	$F(s)$
1.	$\delta(t)$	1
2.	$u(t)$	$\frac{1}{s}$
3.	$tu(t)$	$\frac{1}{s^2}$
4.	$t^n u(t)$	$\frac{n!}{s^n + 1}$
5.	$e^{-at}u(t)$	$\frac{1}{s+a}$
6.	$\sin \omega t u(t)$	$\frac{\omega}{s^2+\omega^2}$
7.	$\cos \omega t u(t)$	$\frac{s}{s^2+\omega^2}$

Laplace Transform Theorem

Item no.	Theorem		Name
1.	$\mathscr{L}[f(t)] = F(s)$	$= \int_{0-}^{\infty} f(t)e^{-st}dt$	Definition
2.	$\mathscr{L}[kf(t)]$	$= kF(s)$	Linearity theorem
3.	$\mathscr{L}[f_1(t)+f_2(t)]$	$= F_1(s)+F_2(s)$	Linearity theorem
4.	$\mathscr{L}[e^{-at}f(t)]$	$= F(s+a)$	Frequency shift theorem
5.	$\mathscr{L}[f(t-T)]$	$= e^{-sT}F(s)$	Time shift theorem
6.	$\mathscr{L}[f(at)]$	$= \frac{1}{a}F\left(\frac{s}{a}\right)$	Scaling theorem
7.	$\mathscr{L}\left[\frac{df}{dt}\right]$	$= sF(s) - f(0-)$	Differentiation theorem
8.	$\mathscr{L}\left[\frac{d^2f}{dt^2}\right]$	$= s^2F(s) - sf(0-) - f'(0-)$	Differentiation theorem
9.	$\mathscr{L}\left[\frac{d^nf}{dt^n}\right]$	$= s^nF(s) - \sum_{k=1}^{n} s^{n-k}f^{k-1}(0-)$	Differentiation theorem
10.	$\mathscr{L}\left[\int_{0-}^{t} f(\tau)d\tau\right]$	$= \frac{F(s)}{s}$	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]