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UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER I
SESSION 2019/2020

COURSE NAME	:	INSTRUMENTATION AND CONTROL SYSTEMS
COURSE CODE	:	BNT 20403
PROGRAMME CODE	:	BNT
EXAMINATION DATE	:	DECEMBER 2019/JANUARY 2020
DURATION	:	THREE (3) HOURS
INSTRUCTION	:	ANSWER **ALL** QUESTIONS

THIS QUESTION PAPER CONSISTS OF **NINE (9)** PAGES

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Q1 (a) With your own words, define static and dynamic characteristics of measuring instruments.

(4 marks)

(b) Compare accuracy and precision in an instrument with the aid of diagrams.

(5 marks)

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

(i) absolute error.

(1 mark)

(ii) percentage of error.

(2 marks)

(iii) relative accuracy.

(1 mark)

(iv) percentage of accuracy.

(1 mark)

(d) Investigate the importance of sensor in the application of the Internet-of-Things (IoT). Give **TWO (2)** examples of sensor commonly used in the IoT and describe their functions.

(6 marks)

Q2 (a) Two types of control system configurations are the open loop and closed-loop. Explain what is meant by the open loop control system and open loop control system.

(4 marks)

(b) Identify **THREE (3)** reasons for using feedback control systems and **ONE (1)** reason for not using them

(4 marks)

(c) Some high speed rail systems are powered by electricity supplied to a pantograph on the train's roof from a catenary overhead as shown in **Figure Q2(c).** The force applied by the pantograph to the catenary is regulated to avoid loss of contact due to excessive transient motion. A proposed method to regulate the force uses a closed-loop feedback system, whereby a force, F_{up} is applied to the bottom of the pantograph, resulting in an output force applied to the catenary at the top. The contact between the head of the pantograph and the catenary is represented by a spring. The output force is proportional to the displacement of this spring, which is the difference between the catenary and pantograph head vertical position. Draw a functional block diagram and distinguish following signals:

(i) the desired output force as the input
(ii) the force, F_{up}, applied to the bottom of the pantograph
(iii) the difference in displacement between the catenary and pantograph head
(iv) the output contact force

(12 marks)

Q3 (a) Given

$$G(s) = \frac{\frac{1}{LC}}{s^2 + \frac{R}{L}s + \frac{1}{LC}}$$

Determine the transfer function of the closed-loop system as shown in **Figure Q3(a)** with R=1Ω, L = 2H and C = 1F.

(4 marks)

(b) For the system in question **Q3(a),** calculate;

(i) the system order.

(1 mark)

(ii) the system type.

(1 mark)

(iii) the damping ratio (ζ).

(1 mark)

(iv) the natural frequency (ω_n).

(1 mark)

(v) the type of response.

(1 mark)

(vi) the steady-state error (ess) to a step input.

(3 marks)

(c) A DC servomotor is designed to drive a rotational mechanical load as shown in **Figure Q3(c).** Demonstrate the transfer function, $\theta_2(s)/T(s)$.

(8 marks)

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Q4 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(a)** shows their responses to step input

(a) Compare the performance of the three DC motor in terms of their overshoot, rise time, settling time and steady state error with the aid of a table.

(12 marks)

(b) 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.

(6 marks)

(c) In your opinion, which system (either A, B or C) gives the best performance and justify your answer.

(2 marks)

Q5 (a) For the unity feedback system of **Figure Q5(a)** with

$$G(s) = \frac{K(s+6)}{s(s+1)(s+4)}$$

Determine the range of K to ensure stability.

(5 marks)

(b) Consider the control system shown in **Figure Q5(b).** Apply a Ziegler-Nicholas tuning rule with the aid from **Table Q5(b)** for the determination of the K_p, T_i, T_d and the transfer function of the PID controllers

(15 marks)

- END OF QUESTIONS –

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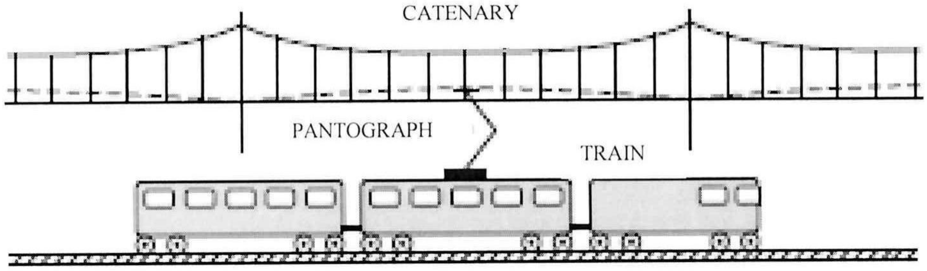

Figure Q2(c)

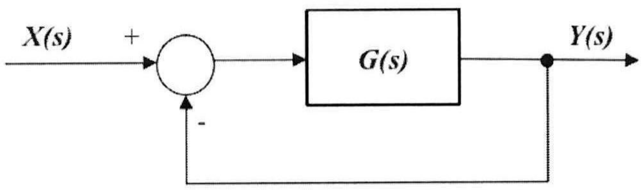

Figure Q3(a)

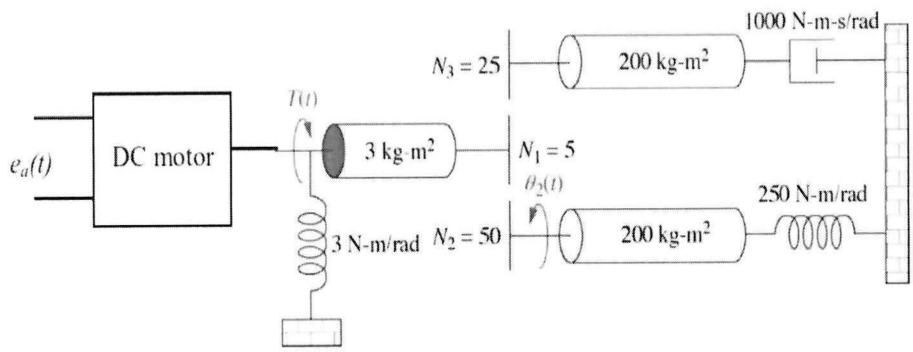

Figure Q3(c)

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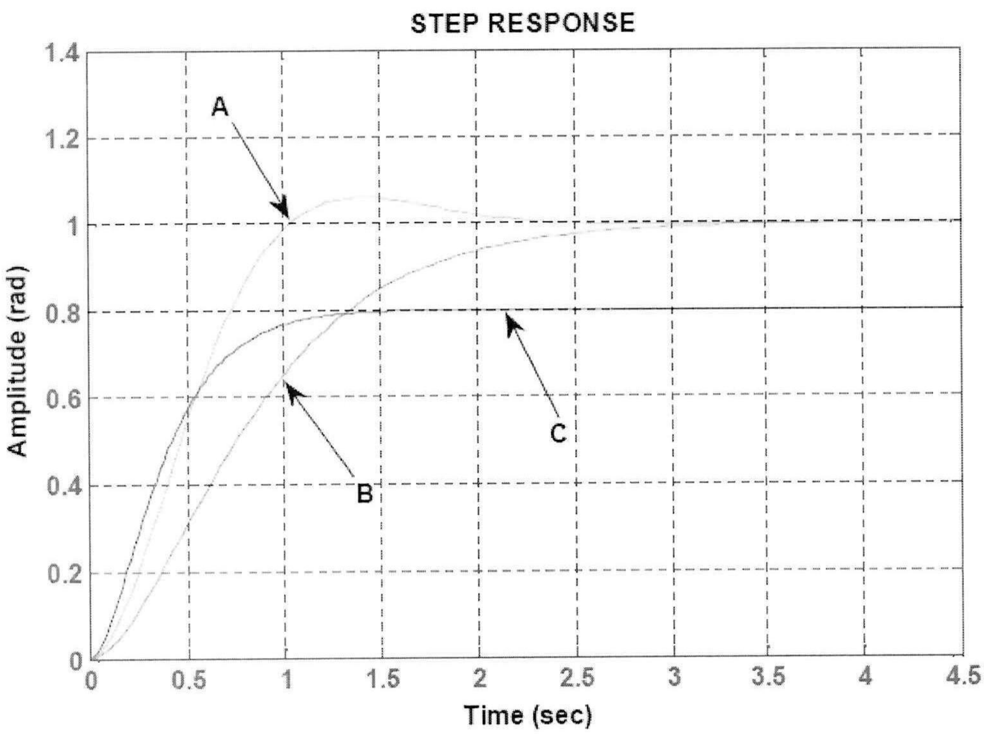

Figure Q4(a)

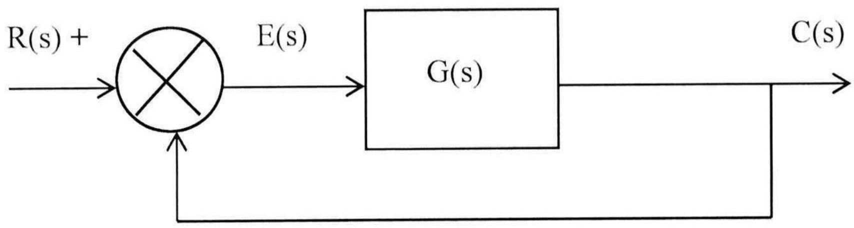

Figure Q5(a)

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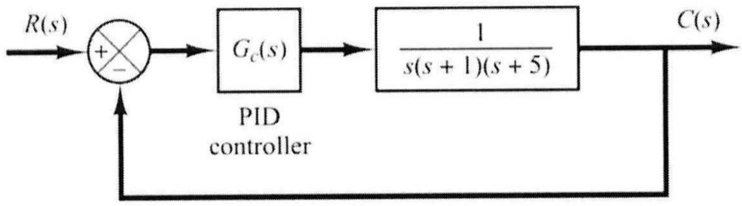

Figure Q5(b)

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

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	$0.6K_{cr}$	$0.5P_{cr}$	$0.125P_{cr}$

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Formula

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]