UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER II
SESSION 2014/2015

COURSE NAME	:	INSTRUMENTATION AND CONTROL
COURSE CODE	:	BNR 20703
PROGRAMME	:	1 BND
EXAMINATION DATE	:	JUNE 2015 / JULY 2015
DURATION	:	2 ½ HOURS
INSTRUCTION	:	ANSWER **FOUR (4)** QUESTIONS ONLY

THIS QUESTION PAPER CONSISTS OF **ELEVEN (11)** PAGES

Q1 (a) Briefly discuss the advantages of control systems.

(3 marks)

(b) Two types of control system configurations are the open loop and the closed loop.

(i) Explain what is meant by the open loop control system and closed loop control system.

(ii) Draw the block diagram for the open loop control system and the closed loop control

(7 marks)

(c) A temperature control system operates by sensing the difference between the thermostat setting and the actual temperature, and then opening a fuel valve an amount proportional to this difference. Draw the functional block diagram identifying the input and output signals, the controller and the plant.

(7 marks)

(d) Water clock is possibly the oldest time-measuring instruments. **FIGURE Q1(d)** shows an automatic control of water level using a float level for a water clock. The water clock consists of three water tanks: Tank 1 - a tank for the water source, Tank 2 - a small tank which contains a float with valve, and Tank 3 - a big tank contains a float with a pointer. This clock measures the time by the weight of water flowing from Tank 2 to Tank 3. As the water flows, the float and the pointer, which shows the time will rise. Since the accuracy of this water clock depends heavily on the constant flow of water, it is important to control the water flow from Tank 1 to Tank 2. This can be achieved by the use of the float with the valve. If the water level in Tank 2 decreases, more water flows from Tank 1 to Tank 2 and the water level will increase. If the water level in Tank 2 increases, less water flows from Tank 1 to Tank 2 and the water level will decrease.

By considering the automatic water level control of the water clock, identify the input, the output, the sensor and the control variables of this control system.

(8 marks)

Q2 (a) **FIGURE Q2(a)** shows an electrical network consisting of resistors (R), an inductor (L) and a capacitor (C). $v(t)$ is the input voltage and $v_c(t)$ is the voltage across the capacitor. Derive the transfer function $G(s)=V_c(s)/V(s)$, of the system.

(6 marks)

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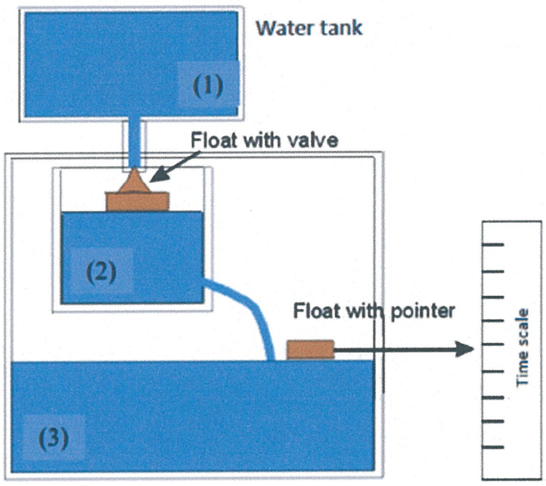

FIGURE Q1(d)

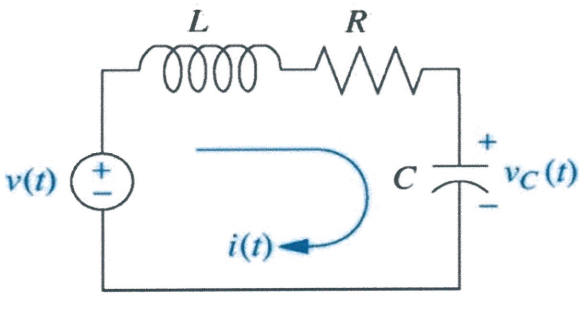

FIGURE Q2(a)

(b) The electrical network in **FIGURE Q2(a)** is used in a closed-loop system as shown in **FIGURE Q2(b)**, where *X(s)* is the input and *Y(s)* is the output of the system. Determine the transfer function of the system with R=1Ω, L = 2H and C = 1F. *G(s)* is the same as that in part (a).

(5 marks)

(c) For the system part (b), determine

(i) the system order;
(ii) the system type;
(iii) the damping ratio (ζ);
(iv) the natural frequency (ω_n);
(v) the type of response; and
(vi) the steady-state error (e_{ss}) to a step input.

(6 marks)

(d) A DC servomotor is designed to drive a rotational mechanical load as shown in **FIGURE Q2(d)**. Determine the transfer function, $\theta_2(s)/T(s)$.

(8 marks)

Q3 (a) Briefly explain the meaning of "step response of a system".

(2 marks)

(b) An open loop control system is shown in **FIGURE Q3(b)**, where the *R(s)* is a unit step input and C(s) is the system's output:

(i) identify the system order and type, plot the system's poles on an *s*-plane, and state the type of the output response; and
(ii) if a negative feedback with H(s) = 5s + 6 is added into the system, does the stability of the system change? Examine what would be the type of the output response now?

(10 marks)

(c) **FIGURE Q3(c)** shows the unit step response of an unknown open loop control system. From this response, determine the transfer function of the system.

(4 marks)

(d) For the system shown in **FIGURE Q3(d)**, determine K so that for an input of *2u(t)*, there will be a 0.01 error in the steady-state output response.

Note : $u(t) = 0$ for $t < 0$
$= 1$ for $t \geq 0$

(9 marks)

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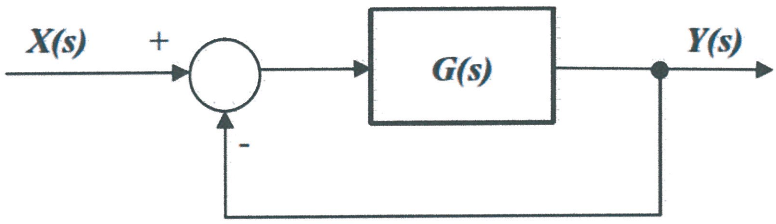

FIGURE Q2(b)

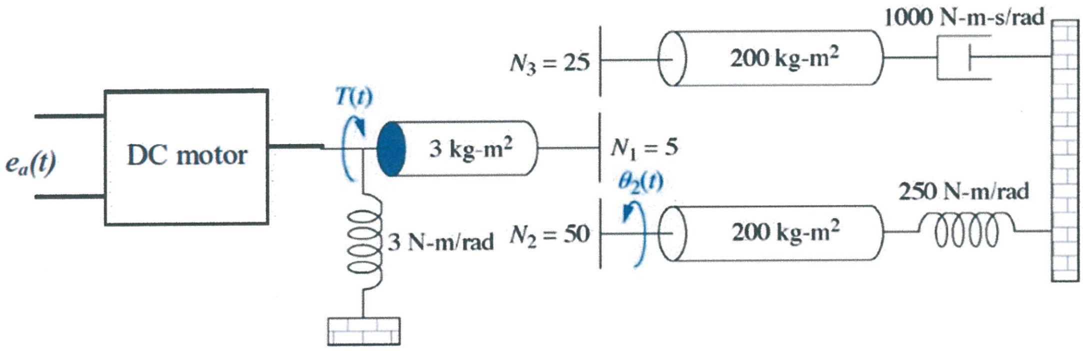

FIGURE Q2(d)

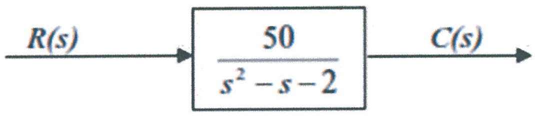

FIGURE Q3(b)

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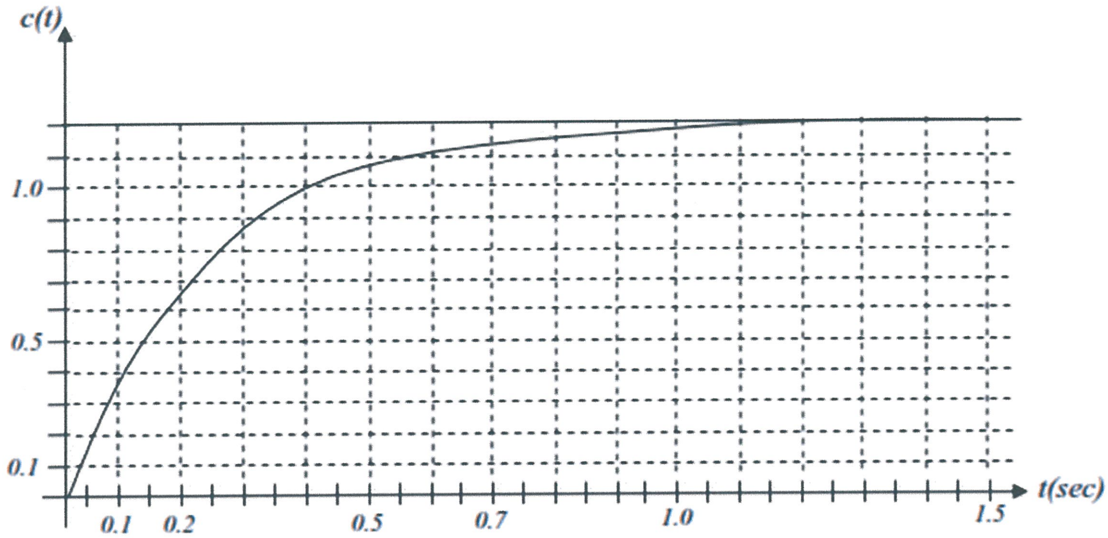

FIGURE Q3(c)

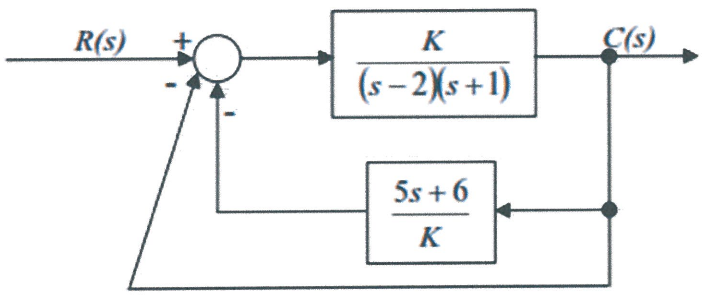

FIGURE Q3(d)

Q4 (a) Derive the overall transfer function for the system shown in **FIGURE Q4(a)** using the block diagram reduction method.

(9 marks)

(b) The motor, with torque-speed characteristics as shown in **FIGURE Q4(b)**, 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)

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

(c) A torsional mechanical system to test shaft elasticity is modeled and the transfer function can be represented:

$$G(s) = \frac{9}{Js^2 + (f+10)s + k}$$

(i) if the values $J = 3$ kg-m^2 and $k = 27$ N-m-s/rad are given, calculate the value of adjustable damper coefficient, f, such that critically damped response can be obtained for a unit step input; and

(5 marks)

(ii) determine the natural frequency, the final output value and the steady state error.

(3 marks)

Q5 (a) Describe the compensation in order to improve the steady-state error and transient response and list the test input used to evaluate steady-state error.

(4 marks)

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

(6 marks)

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

determine the range of K to ensure stability.

(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) Kp;
(ii) Ti ;
(iii) Td ; and
(iv) obtain the transfer function of PID controllers

(15 marks)

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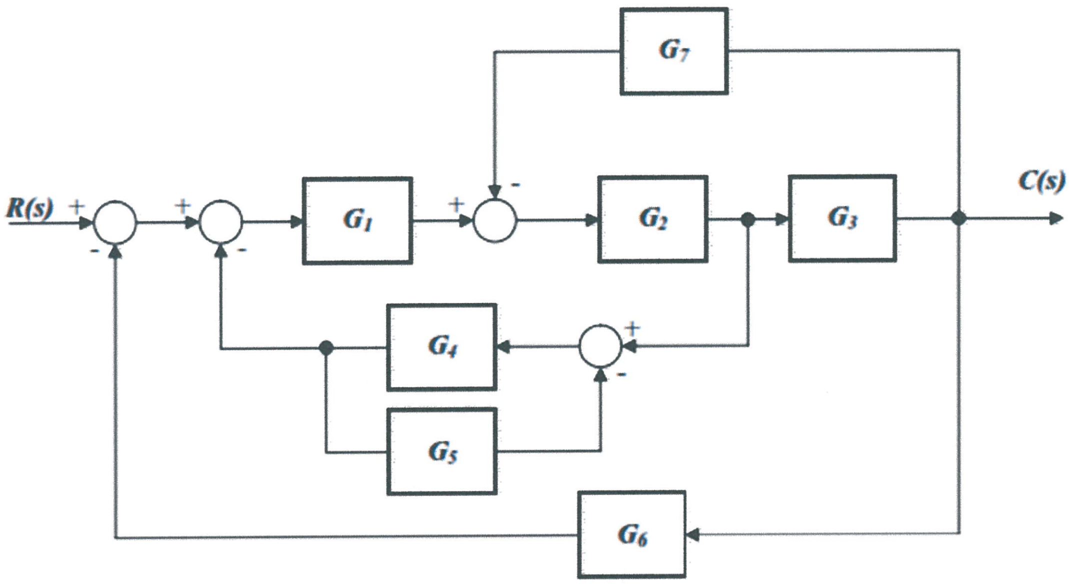

FIGURE Q4(a)

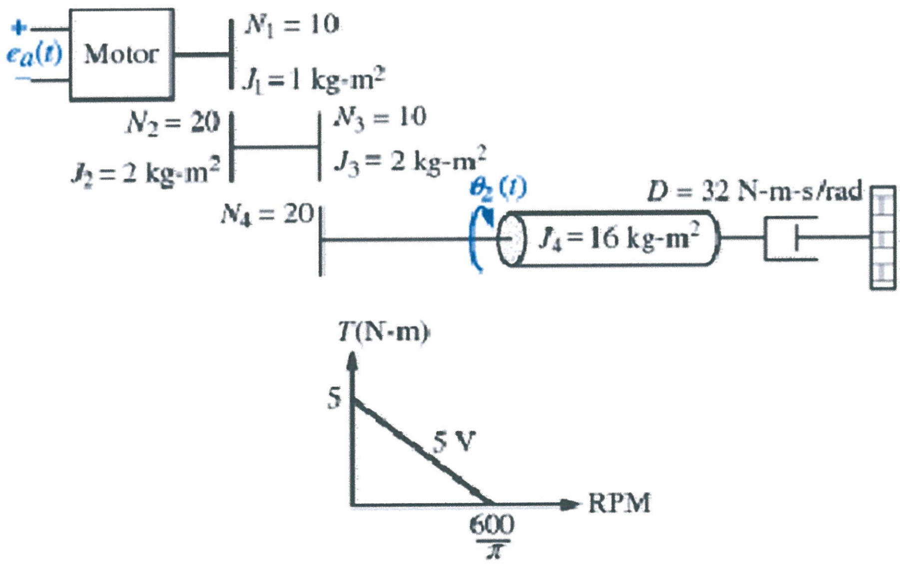

FIGURE Q4(b)

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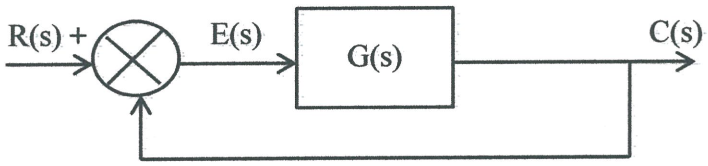

FIGURE Q5(b)

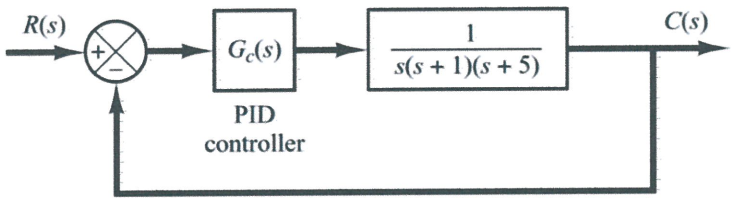

FIGURE Q5(c)

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

-- END OF QUESTION –

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Laplace Transform Table

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	$\mathcal{L}\left[\int_{0^-} f(\tau)d\tau\right]=\frac{F(s)}{s}$
Initial value	$\lim_{t\to 0} f(t)=\lim_{s\to\infty} sF(s)$
Final value	$\lim_{t\to\infty} f(t)=\lim_{s\to 0} sF(s)$