UTHM
Universiti Tun Hussein Onn Malaysia

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER II
SESSION 2014/2015

COURSE NAME	:	INSTRUMENTATION AND CONTROL SYSTEM
COURSE CODE	:	BEH22003
PROGRAMME	:	BACHELOR OF ELECTRONIC ENGINEERING WITH HONOURS
EXAMINATION DATE	:	JUNE 2015 / JULY 2015
DURATION	:	3 HOURS
INSTRUCTION	:	ANSWER **ALL** QUESTIONS

THIS QUESTION PAPER CONSISTS OF FIVE (9) PAGES

Q1 (a) List two advantages of closed loop system.

(2 marks)

(b) **Figure Q1(b)** shows the valve control system, where the system uses human operator as a part of the control system.

(i) Categorize either the system is open loop or closed loop system and justify your answer.

(2 marks)

(ii) Explain the operation of the system.

(4 marks)

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

(12 marks)

Q2 (a) Name two methods of controlling DC motor.

(2 marks)

(b) Give components required for adding velocity feedback on position control of DC motor.

(4 marks)

(c) Ahmad needs to buy the DC motor for his final year project. At the shop, the dealer gives Ahmad two types of DC motors which have similar size and price. However, both of the motors have different speed characteristic as shown in **Table Q2(c)**.

(i) Calculate the percentage of speed regulation for each motor.

(4 marks)

(ii) Based on the results obtained in Q2(c)(i), point out which motor Ahmad should buy.

(2 marks)

(d) The schematic diagram of DC motor is as given in **Figure Q2(d)**. Determine the transfer function $\frac{\theta_m(s)}{V_a(s)}$ for the system where $\theta_m(s)$ is referred as motor angular displacement while $V_a(s)$ is referred as armature voltage. Given that:

Moment inertia of the motor,	$J_m = 2$ kg-m^2
Moment inertia of the load,	$J_L = 12$ kg-m^2
Viscous fractional constant of motor,	$B_m = 2$ N-m-s/rad
Viscous fractional of load,	$B_L = 2$ N-m-s/rad
Back emf constant,	$K_b = 2$
Motor torque constant,	$K_t = 4$
Armature resistance,	$R = 5\ \Omega$
Armature inductance,	$L = 100$ mH

(8 marks)

Q3 (a) State the definition of stable and unstable system based on s-plane poles location.

(2 marks)

(b) Discuss the behavior of responses when:

(i) Damping ratio, $\zeta = 1$.

(2 marks)

(i) Damping ratio, $\zeta > 1$.

(2 marks)

(c) Based on the s-plane poles location of closed loop system shown in **Figure Q3(c)(i)**.

(i) Determine the transfer function of the system and calculate the peak time, T_p, settling time, T_s, rise time, T_r, and the percentages overshoot, $\%\mu_s$ of the system.

(12 marks)

(ii) Based on the value of damping ratio, obtained in Q3(c)(i), categorize the response for the system.

(2 marks)

Q4 (a) The system in **Figure Q4** is at steady state where the liquid level is at the desired level. The system is now disturbed permanently by adjusting the valve B manually in such a way that the flow rate of the liquid through valve B is increased significantly. Discuss clearly the effect of this disturbance on the liquid level when a proportional mode controller is being used.

(8 marks)

(b) The minimum and maximum levels of the liquid in the tank shown in **Figure Q4** are 0m and 10m respectively. Valve A is linear, with a flow scale factor of $10m^3/h$ per percent controller output. The controller output is nominally 50% with a constant of K_p = 10% per percent and the liquid level steady state is nominally at 5m. The valve B is adjusted in such a way that flow rate through valve B changes permanently from $500m^3/h$ to $600\ m^3/h$. Determine the new steady state liquid level.

(12 marks)

Q5 (a) Describe clearly how a thermistor differs from a resistance temperature detector (RTD).

(8 marks)

(b) Explain what is meant by self-heating in a resistance based temperature sensor.

(4 marks)

(c) A RTD has $\alpha_o = 0.005/°C$, $R = 500\Omega$, and dissipation constant of $P_D = 30mW/°C$ at 20°C. The RTD is used as R_4 in a bridge circuit as shown in **Figure Q5(c)** with $R_1=R_2=500\Omega$, R_3 is a variable resistor to balance the bridge. If the supply voltage is 10 V and the RTD is placed in a bath at 0°C, determine the value of R_3 to balance the bridge.

(8 marks)

- END OF QUESTION -

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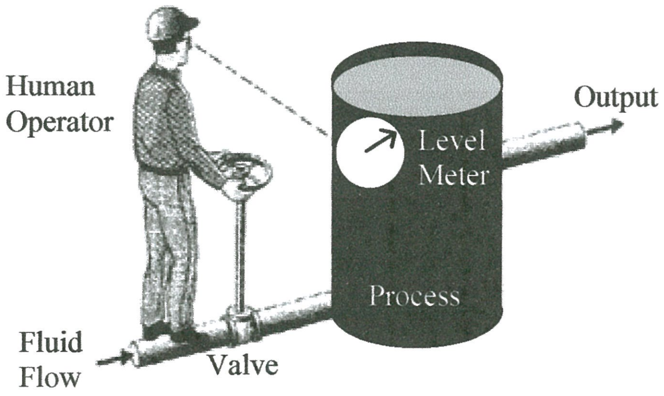

FIGURE Q1(b)

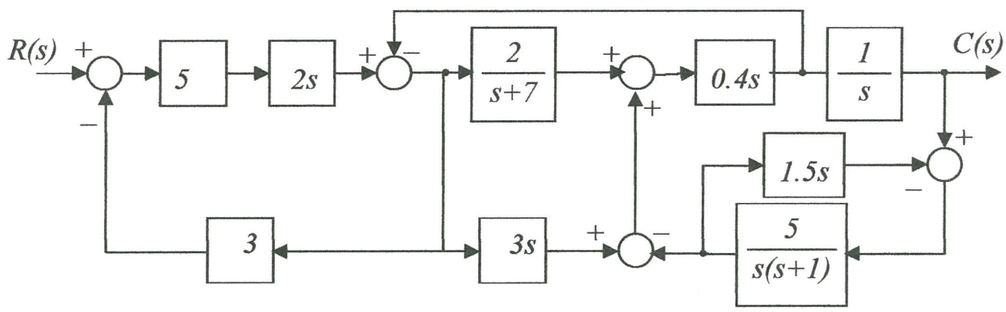

FIGURE Q1(c)

TABLE Q2(c)

No	DC motor	Speed Specification	
		Speed with No Load (W_{NL})(rpm)	Speed with Load, (W_L) (rpm)
1	DC motor A	2000	1900
2	DC motor B	2000	1700

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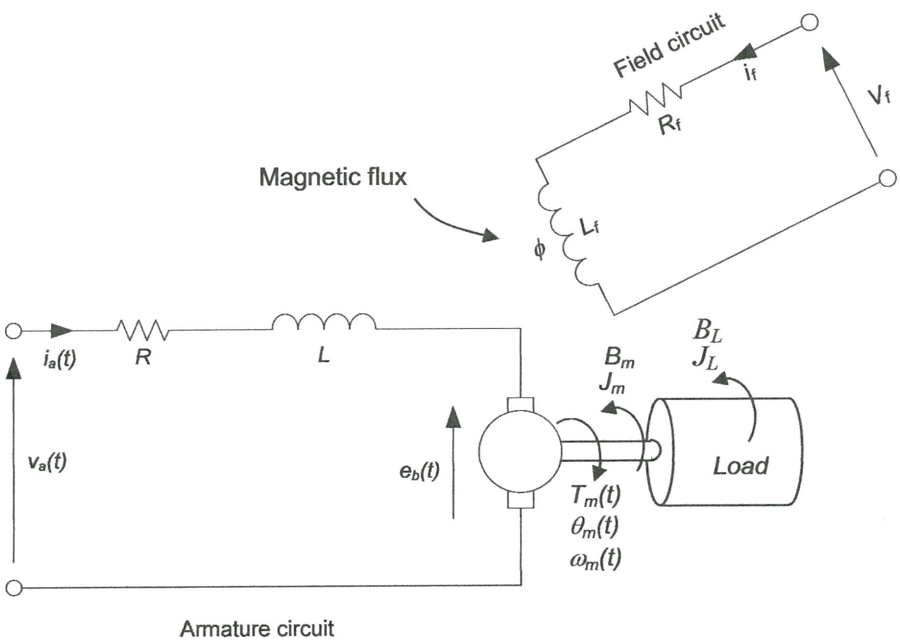

FIGURE Q2(d)

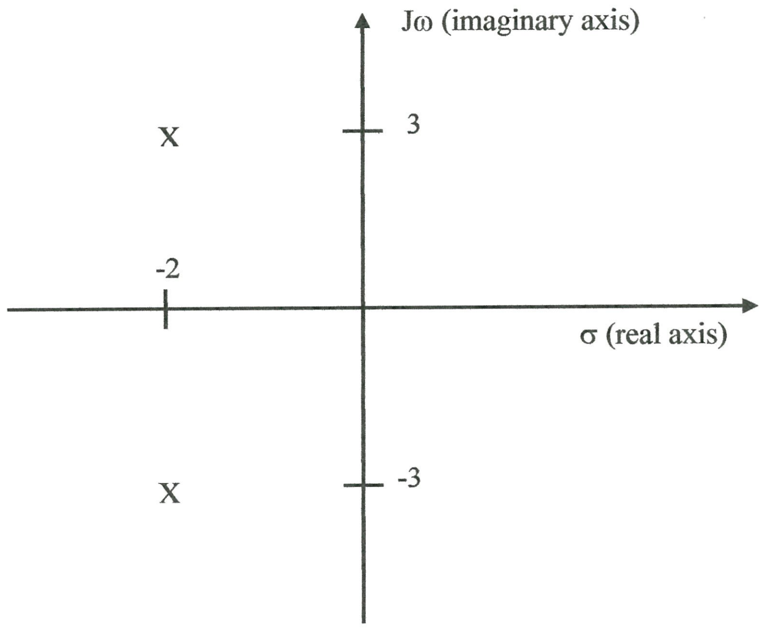

FIGURE Q3(c)(i)

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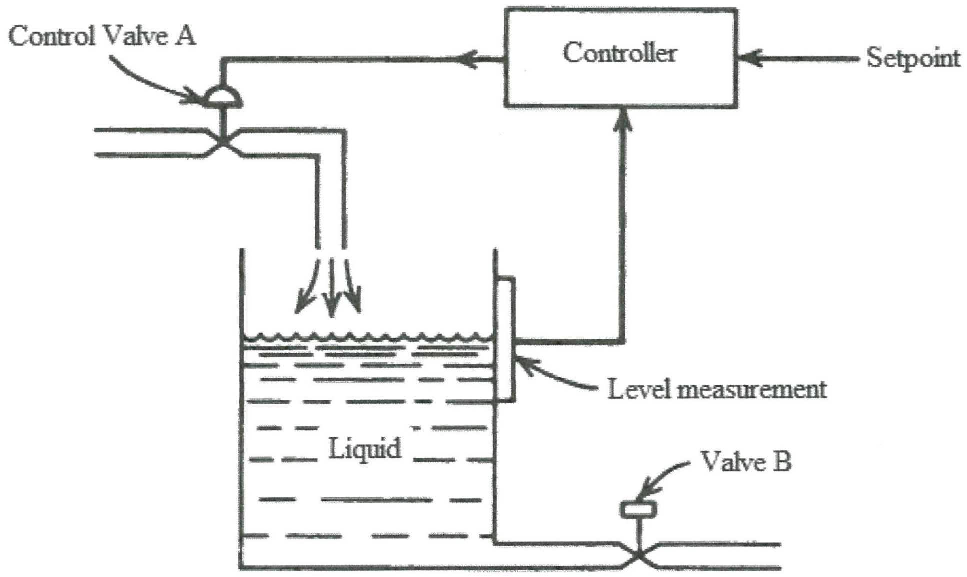

FIGURE Q4

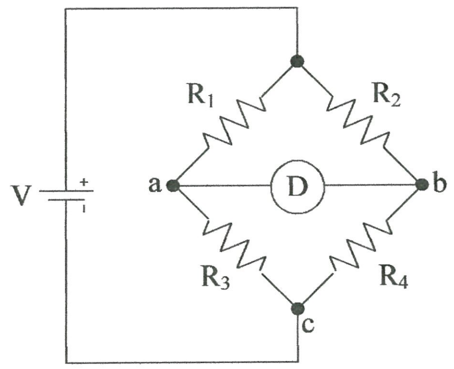

FIGURE Q5(c)

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FORMULA

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	$\lim_{t\to\infty} f(t) = \lim_{s\to 0} sF(s)$

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TABLE C

2nd Order prototype system equations

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