UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER I
SESSION 2009/2010

SUBJECT NAME	:	CONTROL SYSTEM
SUBJECT CODE	:	BEE 3143
COURSE	:	3 BEE
EXAMINATION DATE	:	NOVEMBER 2009
DURATION	:	2 ½ HOURS
INSTRUCTION	:	ANSWER FOUR (4) QUESTIONS ONLY

THIS PAPER CONSISTS OF 9 PAGES

Q1 (a) Many modern devices use turntable to rotate a disk at a constant speed. For example, a CD player, a computer disk drive , and a phonograph record player, all require a constant speed of rotation in spite of motor wear and variation and other component changes. Name three reasons for using feedback control systems to design a system for turntable speed control and at least one reason for not using them.

(4 marks)

(b) A high-speed proportional solenoid valve is shown in Figure Q1(b). A voltage propotional to the desired position of the spool is applied to the coil.The resulting magnetic field produced by the current in the coil causes the armature to move the spool. A linear voltage differential transformer (LVDT) that outputs a voltage propotional to displacement senses the spool's position.This voltage can be used in a feedback path to implement closed loop operation. Draw a functional block diagram of the valve, showing input and output positions, coil voltage, coil current and spool force.

(10 marks)

(c) An Automatic refrigerator is a cooling appliance comprising a thermally insulated compartment and a heat pump to cooling the contents to a temperature below ambient.

(i) Is the automatic refrigerator an open loop or closed loop system? Why?

(ii) Identify each component in the automatic refrigerator temperature control system.

(iii) Draw the block diagram of the automatic refrigerator temperature control system.

(11 marks)

Q2 Determine transfer function (C(s)/R(s)) for block diagram shown in Figure Q2 by using block diagram reduction method.

(25 marks)

Q3 Figure Q3 shows a printer mechanism without any motor attached to the system.

(a) Produce a schematic diagram for the physical system shown in the Side View of Figure Q3.

(7 marks)

(b) If the input $\theta_i(s)$ and the output is $\theta_o(s)$, determine the transfer function, $G(s) = \theta_o(s)/ T(s)$ from the schematic diagram.

(8 marks)

(c) If a closed-loop position control system is to be attached to the rotational mechanical system, calculate the transfer function of the system. Given $\frac{\theta_o}{\theta_i}$:

$$\frac{\theta_o}{\theta_i} = \frac{K}{T_m s^2 + s + K}$$ where $K = K_p K_s K_m$ and T_m is a motor time constant

The parameters for the motor are as follow

Motor inertia, $J_a = 0.04$ kg-m^2
Motor viscous friction, $B_a = 0.02$ Nm-s/ rad
Load inertia, $J_L = 0.3$ kg-m^2
Load viscous friction, $B_L = 0.18$ Nms/ rad
Potentiomater constant, $K_p = 2$ V/ rad
Amplifier constant, $K_s = 4$
Motor torque constant, $K_t = 10$ N-m/ A
Back e.m.f. constant, $K_B = 0.2$ V-s/ rad
Motor armature resistance, R = 15 Ω

(10 marks)

Q4 The DC motor will be used in three-axis pick and place robot for flexible manufacturing system (FMS). The robot are simultaneously controlled and driven by DC motor in movement of each axis with fast acceleration, deceleration and reasonable precision. A robot which has a block diagram as shown in Figure Q4 has to be design.

(a) Determine the range of K_I for the system to be stable if $K_f = \frac{1}{(s+1)(s+5)}$.

(7 marks)

(b) If the system has unity feedback, categorize the system type and calculate steady state error for inputs of 4 $u(t)$, 4 $tu(t)$ and 4 $t^2u(t)$.

(5 marks)

(c) If the system has unity feedback for a unit step input and require to obtain system response with 10% of maximum overshoot, determine:

(i) Possible value for gain, K_I
(ii) The rise-time, T_r
(iii) The settling-time, T_s for ±2%
(iv) The peak-time, T_p
(v) System transient response (sketch).

(13 marks)

Q5 Consider the simplified form of the transfer function for position servomechanism used in an antenna tracking system as shown in Figure Q5. By using root locus technique:

(a) Construct its root locus.

(17 marks)

(b) (i) From the root locus calculate the value of K so that the damping ratio is $\zeta =$ 0.342.

(ii) Determine all the closed loop poles for the value of K determined in Q5 b(i).

(8 marks)

Q6 The unity feedback of an open loop transfer function, G(s) is attached with a lead compensator, $G_c(s)$ as shown in Figure Q6. The system settling time is 1.25s for ±2% band and 4.6% of maximum overshoot.

(a) Obtain the closed loop poles of the original system and calculate the angle which will be contributed by the system.

(7 marks)

(b) Calculate Z_c and P_c by using bisect angle method

(7 marks)

(c) Find K_c and obtain the transfer function of the compensator.

(5 marks)

(d) Determine the value of R_1 and R_2, then sketch the phase lead compensator circuit if the given capacitor value is 1μF

(6 marks)

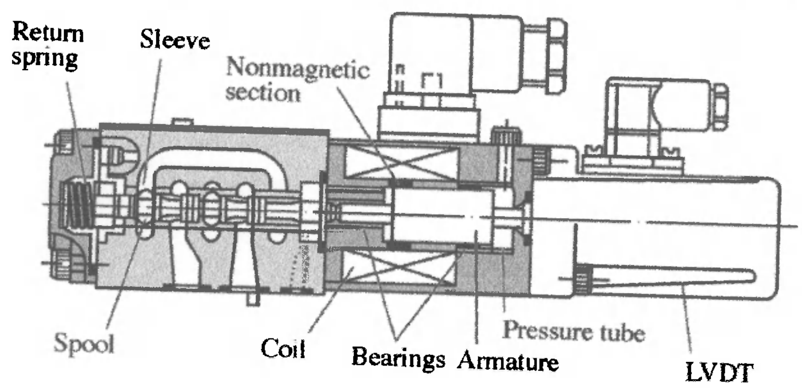

Figure Q1(b)

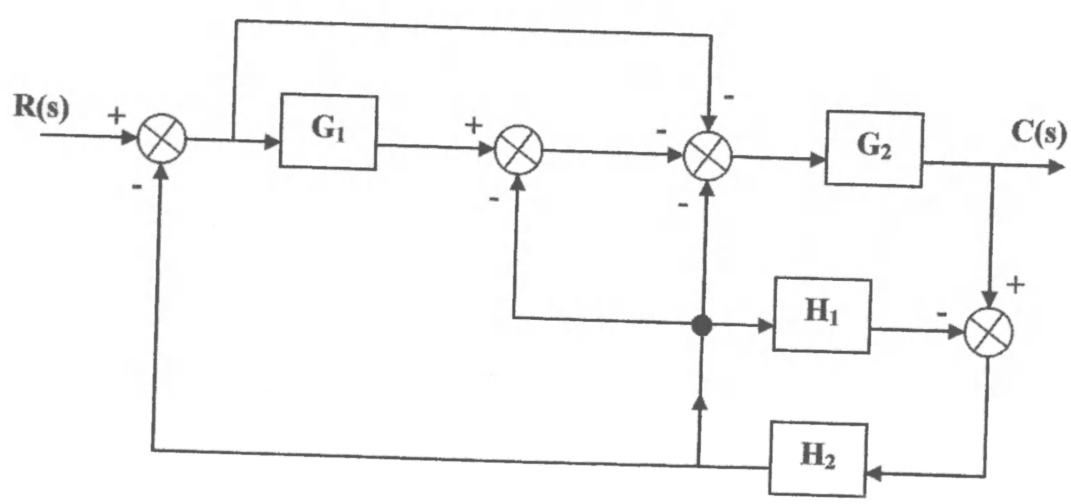

Figure Q2

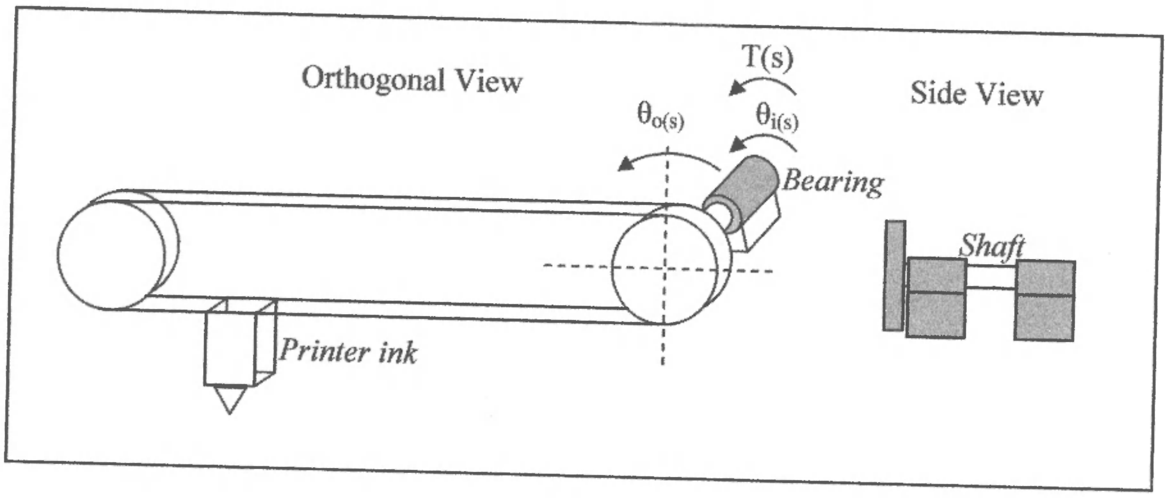

Figure Q3

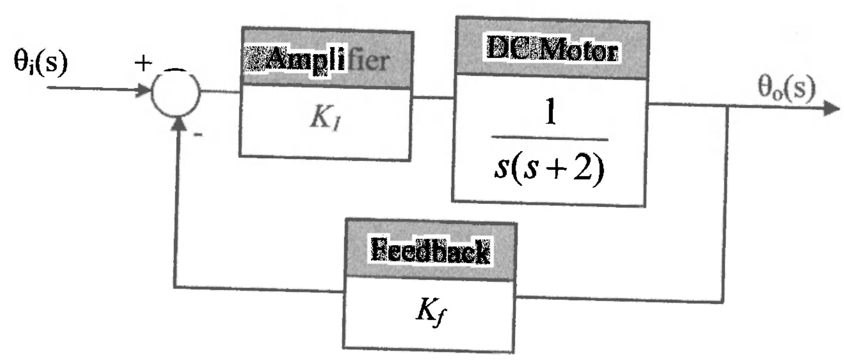

Figure Q4

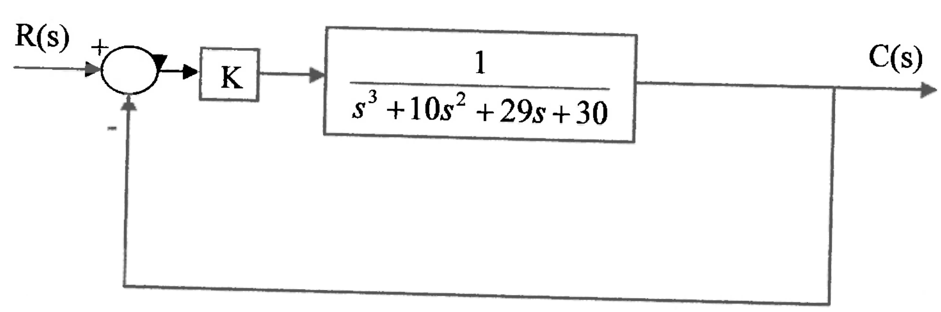

Figure Q5

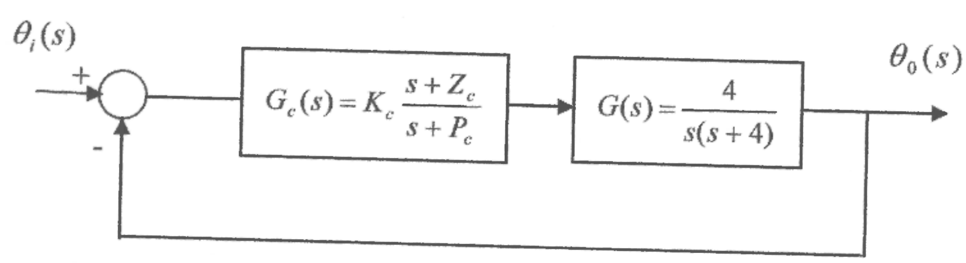

Figure Q6

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

TABLE 3

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)