UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER I
SESSION 2010/2011

COURSE	:	CONTROL SYSTEM
COURSE CODE	:	BEE 3143
PROGRAMME	:	3 BEE
EXAMINATION DATE	:	NOVEMBER/DECEMBER 2010
DURATION	:	2 ½ HOURS
INSTRUCTION	:	ANSWER FOUR (4) QUESTIONS ONLY

THIS PAPER CONSISTS OF NINE (9) PAGES

Q1 (a) Explain what is meant by the open loop system and the closed loop system and draw the block diagram for open loop system and closed loop system.

(5 marks)

(b) List down three (3) advantages and three (3) disadvantages closed loop system.

(6 marks)

(c) List and describe three (3) primary objectives of control system analysis and design focuses.

(6 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 of the water clock, identify input, output, sensor and the control variables of this control system.

(8 marks)

Q2 The lateral control of a space shuttle with a gimbaled engine is shown in Figure Q2(a). During ascent the space shuttle is steered by commands generated by the computer's guidance calculations. These commands are in the form of vehicle attitude, attitude rates, and attitude accelerations obtained through measurements made by the vehicle's inertial measuring unit, rate gyro assembly, and accelerometer assembly, respectively. The ascent digital autopilot uses the errors between the actual and commanded attitude, rates and accelerations to gimbal the space shuttle main engine and the solid rocket boosters to effect the desired vehicle attitude. A simplified model of the pitch control system is shown in Figure Q2(b).

(a) Determine the closed-loop transfer function relating actual pitch to commanded pitch. Assume all other inputs are zero

(8 marks)

(b) Determine the closed-loop transfer function relating actual pitch rate to commanded pitch rate. Assume all other inputs are zero.

(10 marks)

(c) Determine the closed-loop transfer function relating actual acceleration rate to commanded pitch rate. Assume all other inputs are zero

(7 marks)

Q3 (a) Figure Q3(a) shows a mechanism of an auto-gate system.

(i) Write down the transfer function of a motor.

(1.5 marks)

(ii) Give the definition of seven (7) parameters involved in Q3(a)(i).

(3.5 marks)

(iii) Write down the equation of motor inertia, J_M and motor damping, B_M when gears and load are applied to the motor?

(2 marks)

(iv) Determine the transfer function for the complete auto-gate system.

(2 marks)

(b) As a Control Engineer, you are asked to design a lift system for a 10 storey building with following specifications, 10% overshoot and 0.5 second settling time for 2% band.

(i) Determine the lift system stability based on s-plane.

(10 marks)

(ii) Obtain the system response complete with the parameters and its value.

(6 marks)

Q4 (a) Large welding robots are used in today's auto plants. The welding head is moved to different positions on the auto body and a rapid, accurate response is required. A block diagram of a welding head positioning system is shown in Figure Q4(a). Determine the range of K and a for which the system is stable.

(10 marks)

(b) Figure Q4(b) shows a block diagram with unity feedback where;

$$G(s) = \frac{200}{(s+2)(s+4)(s+5)}$$

(i) Draw a Bode plot for the system.

(11 marks)

(ii) Find the gain margin and phase margin of the system and determine system stability.

(4 marks)

Q5 (a) List at least one (1) difference between starting points and ending points on sketching the root locus.

(2 marks)

(b) A simplified block diagram of the meter used to measure oxygen concentration is shown in Figure Q5(b). By using root locus techniques,

(i) Construct its root locus.

(15.5 marks)

(ii) From the root locus calculate the value of K so that the damping ratio is $\zeta = 0.17$.

(4 marks)

(iii) Determine all the closed loop poles for the value of K obtained in Q4 b(ii).

(3.5 marks)

Q6 Figure Q6 shows a simplified control system of a robot arm for transferring radioactive materials in a nuclear power plant. Due to safety reason, it is necessary that for a unity step input the system response is not allowed to overshoot more than 5%, the settling time for 2% criterion is less than 15 seconds and the steady state error is less than 0.05. A compensator cascading with the process will be added to improve the performance of the system to meet the specifications.

(a) Investigate whether system agrees with the specifications and find which parameters need to be improved.

(8 marks)

(b) What kind of compensator is suitable for this purpose? Why?

(2 marks)

(c) Design the compensator and its transfer function.

(15 marks)

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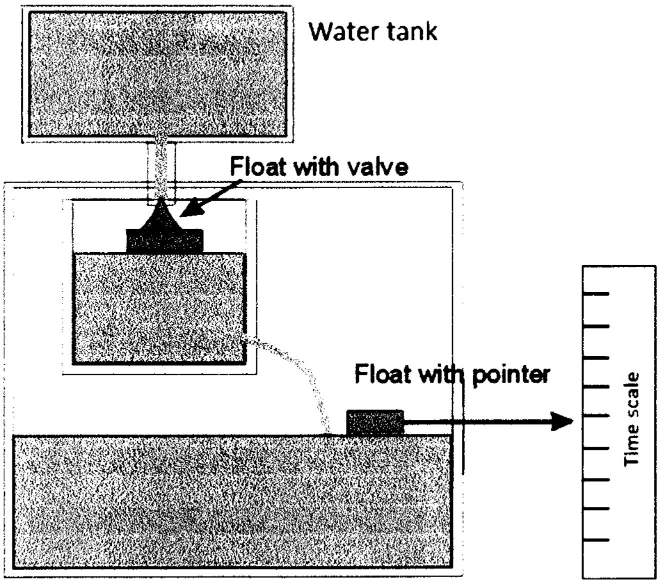

Figure Q1(d)

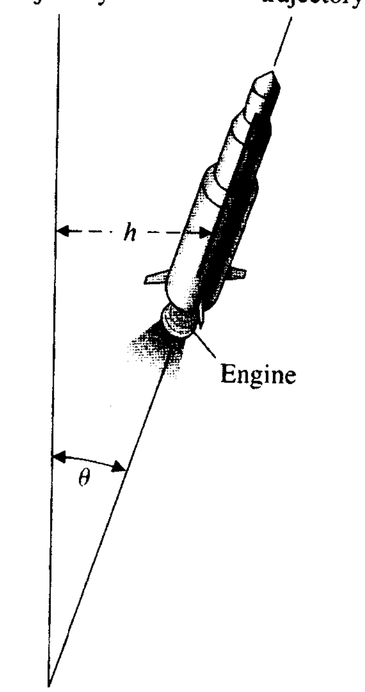

Figure Q2(a)

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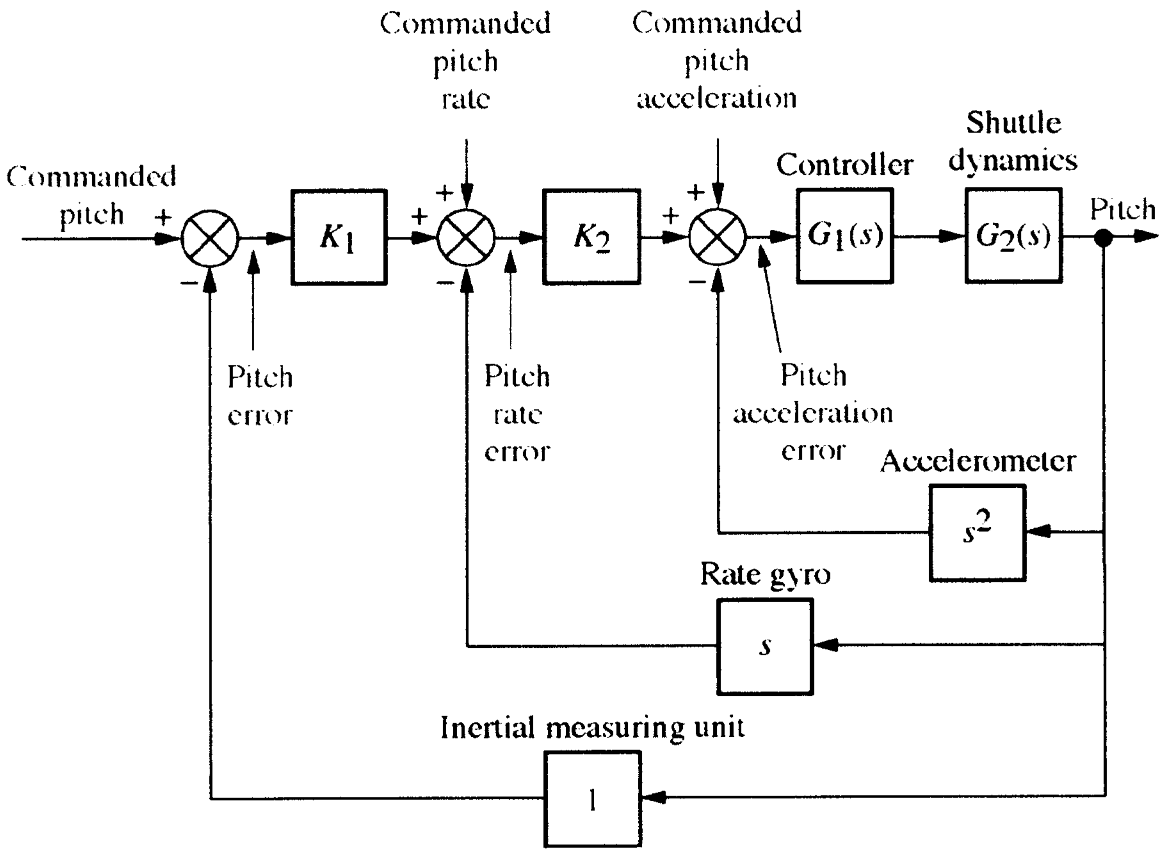

Figure Q2(b)

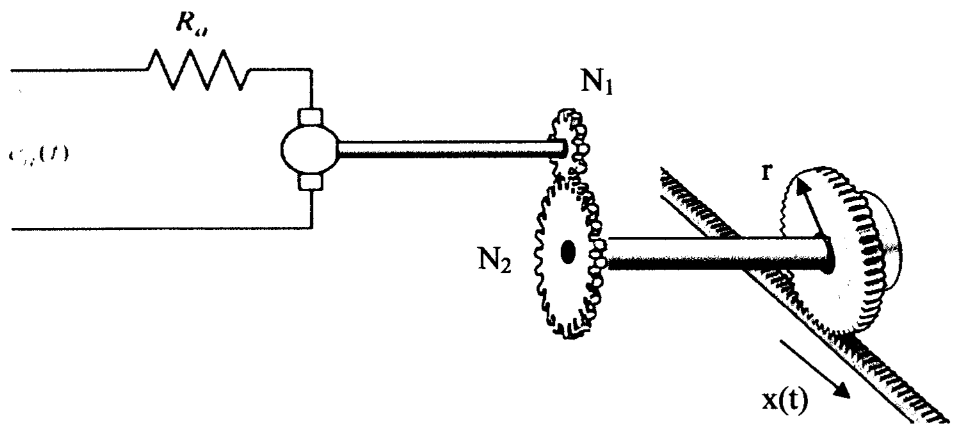

Figure Q3(a)

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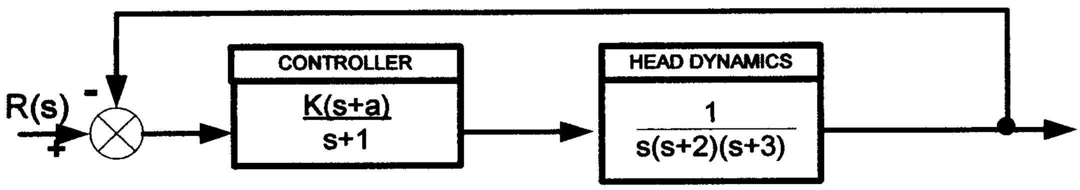

Figure Q4(a)

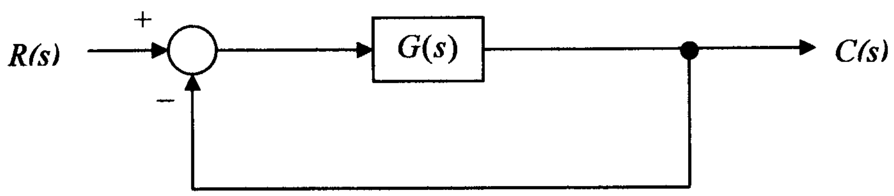

Figure Q4(b)

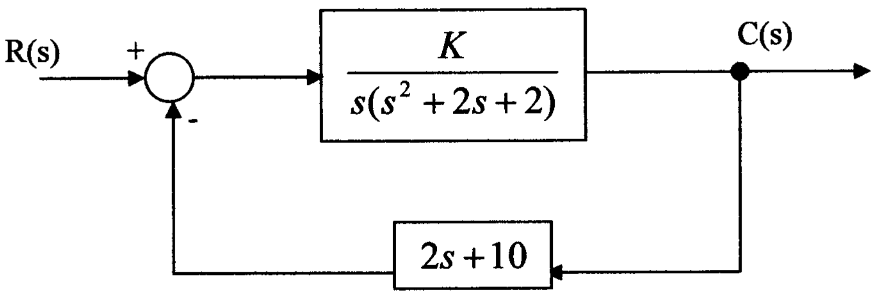

Figure Q5(b)

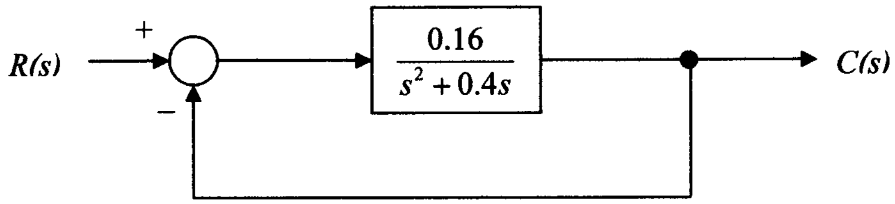

Figure Q6

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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	$\mathscr{L}\left[e^{-at}f(t)\right]=F(s+a)$
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 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)