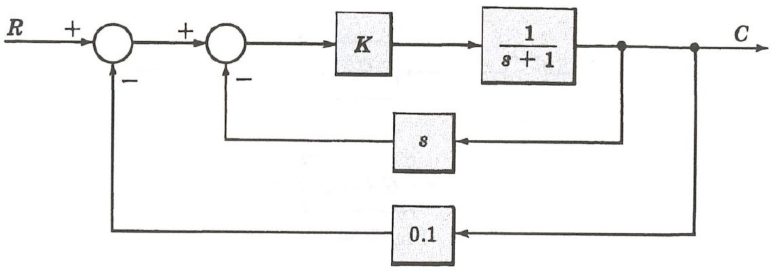
DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING

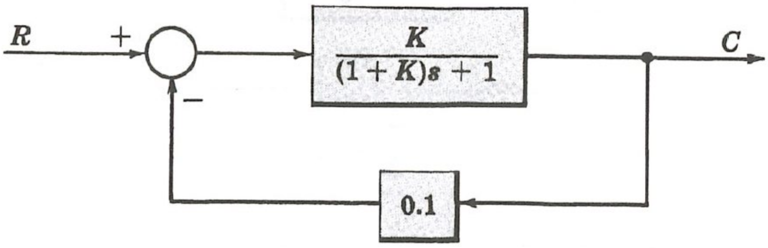
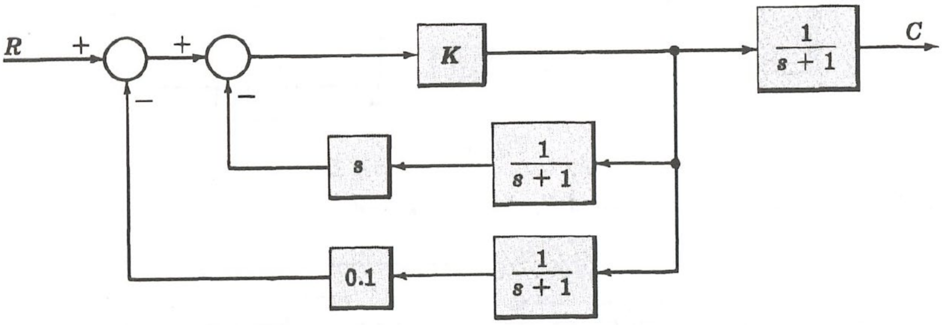
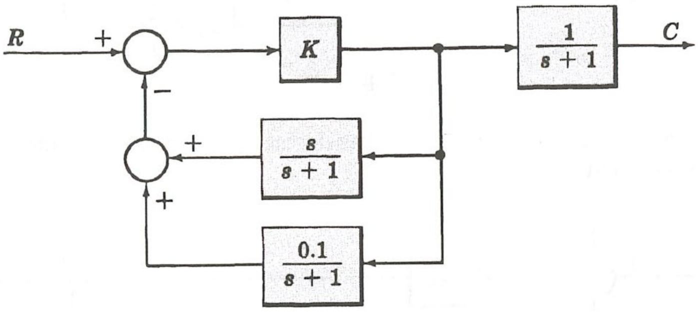
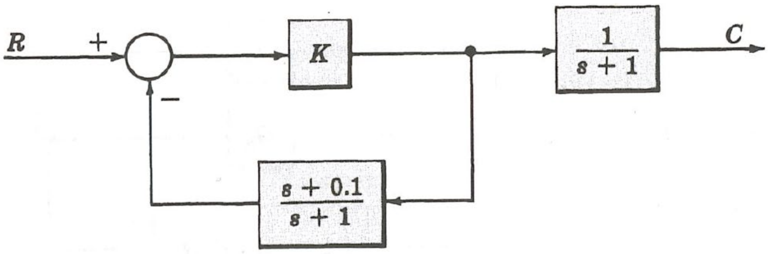
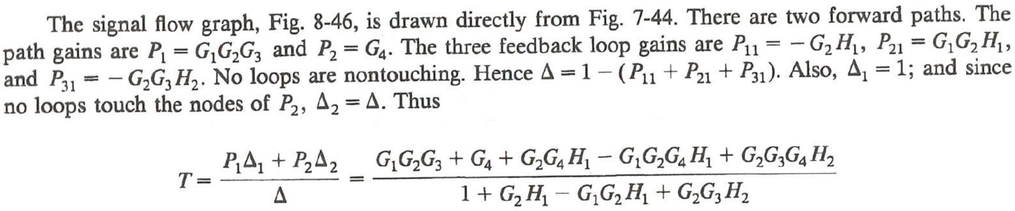
SOLUTION & MARKING SCHEME

(Semester 1, 2023/24)

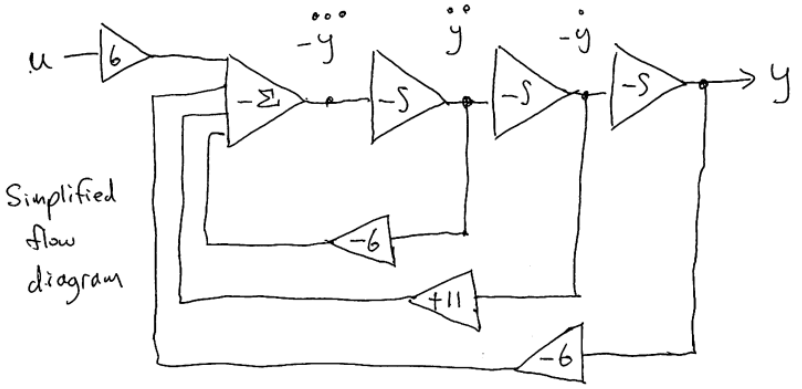
SUBJECT (Code & Title)	EE3005/EE3005A/EE3005B Systems and Control

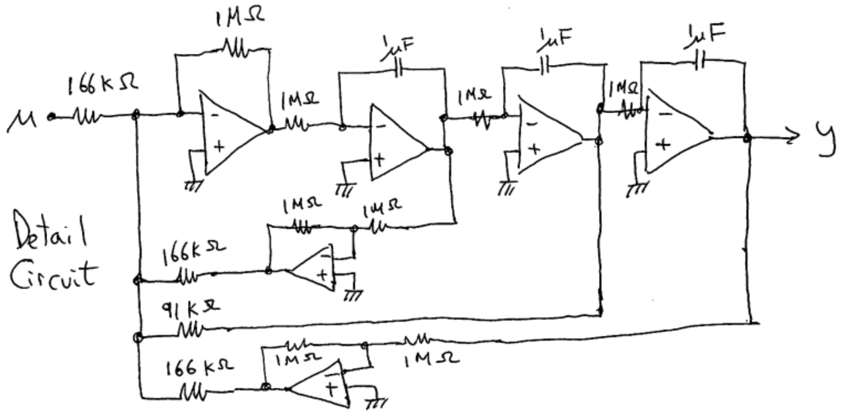
SUBJECT EXAMINER	Dr N.C. Cheung
SUBJECT MODERATOR	Dr W.H. Gu

QUESTION NO.	SOLUTION	MARKS
Q1	$$Y(s) = b_3 + \frac{c_{11}}{s+1} + \frac{c_{21}}{s+2} + \frac{c_{31}}{s+4}$$ where $b_3 = 0$, $$c_{11} = \left.\frac{s^2+9s+19}{(s+2)(s+4)}\right\vert_{s=-1} = \frac{11}{3} \qquad c_{21} = \left.\frac{s^2+9s+19}{(s+1)(s+4)}\right\vert_{s=-2} = -\frac{5}{2}$$ $$c_{31} = \left.\frac{s^2+9s+19}{(s+1)(s+2)}\right\vert_{s=-4} = -\frac{1}{6}$$ Thus $$Y(s) = \frac{11}{3(s+1)} - \frac{5}{2(s+2)} - \frac{1}{6(s+4)}$$ $$\mathscr{L}[y(t)] \equiv Y(s) = \frac{1}{2s} - \frac{1}{s+1} - \frac{1}{2(s+2)}$$ Therefore $$y(t) = \frac{1}{2}\mathscr{L}^{-1}\left[\frac{1}{s}\right] - \mathscr{L}^{-1}\left[\frac{1}{s+1}\right] - \frac{1}{2}\mathscr{L}^{-1}\left[\frac{1}{s+2}\right] = \frac{1}{2}[1 - 2e^{-t} - e^{-2t}] \qquad t > 0$$ $$\mathscr{L}[y(t)] = Y(s) = \frac{11}{3(s+1)} - \frac{5}{2(s+2)} - \frac{1}{6(s+4)}$$ Therefore $$y(t) = \frac{11}{3}e^{-t} - \frac{5}{2}e^{-2t} - \frac{1}{6}e^{-4t}$$	10
Q2		

QUESTION NO.	SOLUTION	MARKS
Q2 cont.	    X(s)and Y(s) can be found	10
Q3	 The signal flow graph, Fig. 8-46, is drawn directly from Fig. 7-44. There are two forward paths. The path gains are $P_1 = G_1G_2G_3$ and $P_2 = G_4$. The three feedback loop gains are $P_{11} = -G_2H_1$, $P_{21} = G_1G_2H_1$, and $P_{31} = -G_2G_3H_2$. No loops are nontouching. Hence $\Delta = 1 - (P_{11} + P_{21} + P_{31})$. Also, $\Delta_1 = 1$; and since no loops touch the nodes of P_2, $\Delta_2 = \Delta$. Thus $$T = \frac{P_1\Delta_1 + P_2\Delta_2}{\Delta} = \frac{G_1G_2G_3 + G_4 + G_2G_4H_1 - G_1G_2G_4H_1 + G_2G_3G_4H_2}{1 + G_2H_1 - G_1G_2H_1 + G_2G_3H_2}$$	10
Q4		10

QUESTION NO. | SOLUTION | MARKS





Q5

System equations:

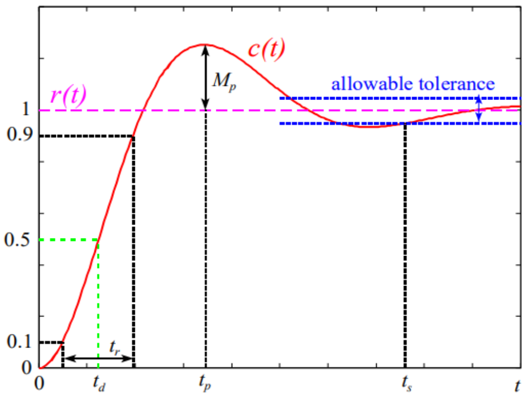
Mechanical: $$m\frac{d^2x}{dt^2}+b\frac{dx}{dt}+kx=p$$

Electrical: $$L\frac{di}{dt}+Ri+\frac{1}{C}\int idt=e$$

$$L\frac{d^2q}{dt^2}+R\frac{dq}{dt}+\frac{1}{C}q=e$$ (in terms of electric charge, $i=dq/dt$)

Translational Mechanical Systems	**Rotational Mechanical Systems**	**Electrical Systems**
Force (p)	Torque (T)	Voltage (e)
Mass (m)	Moment of inertia (J)	Inductance (L)
Viscous friction coeff. (b)	Viscous friction coeff. (b)	Resistance (R)
Spring constant (k)	Spring constant (k)	1/capacitance (1/C)
Displacement (x)	Angular displacement (θ)	Charge (q)
Velocity (dx/dt)	Angular velocity (ω)	Current (i)

10

<table>
<tr><th>QUESTION NO.</th><th>SOLUTION</th><th>MARKS</th></tr>
<tr><td>Q6</td><td>Definition of transient response specifications


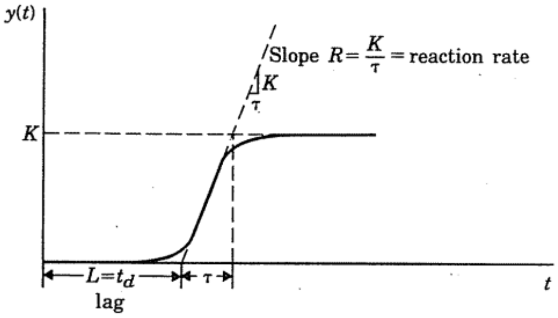
1. Delay time *td* : Time required for the response to reach half the final value.
2. Rise time *tr* : Time required to rise from 10% to 90% (overdamped) and 0 to 100% (underdamped) of its final value.
3. Peak time *tp* : Time required to reach the first peak of the overshoot.
4. Maximum overshoot *Mp* : Occur at the peak time *tp* .
5. Settling time *ts* : Time required to reach and stay within a range about the final value of size specified by absolute percentage of final value. (usually 5% or 2%)</td><td>10</td></tr>
<tr><td>Q7</td><td>**Summary: Transient Response Method**
1. Measure the open loop step response of the plant
2. Obtain L and R
3. Calculate the P, I, and D values according to the table below.


Figure 5.30 Process open-loop step response.

Table 5.2 Ziegler-Nichols tuning parameters using transient response.
<table><tr><th></th><th>K_p</th><th>T_I</th><th>T_D</th></tr><tr><td>P</td><td>$1/RL$</td><td></td><td></td></tr><tr><td>PI</td><td>$0.9/RL$</td><td>$3L$</td><td></td></tr><tr><td>PID</td><td>$1.2/RL$</td><td>$2L$</td><td>$0.5L$</td></tr></table></td><td>10</td></tr>
<tr><td></td><td></td><td></td></tr>
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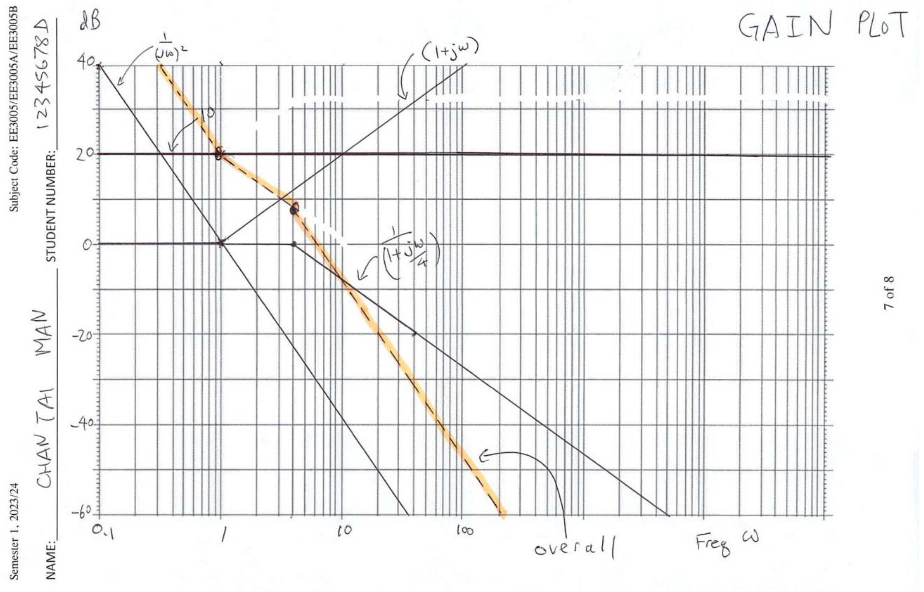
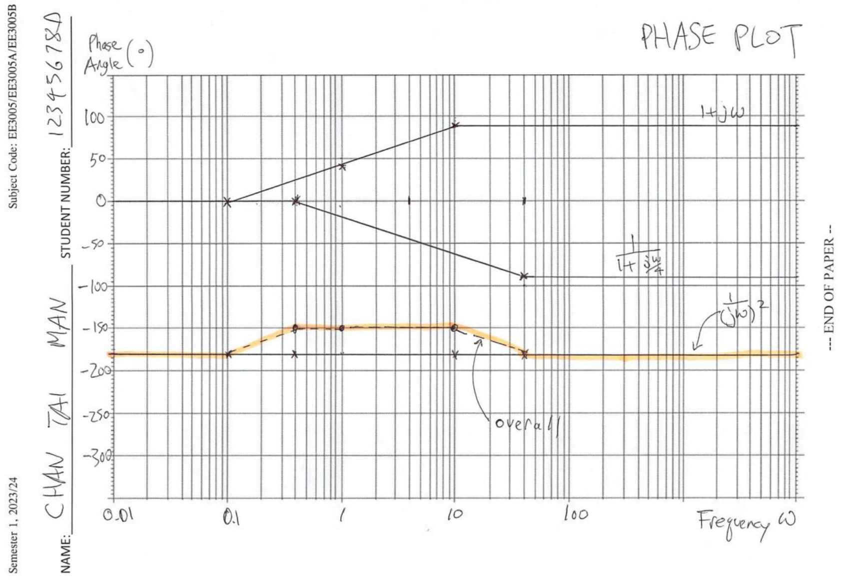
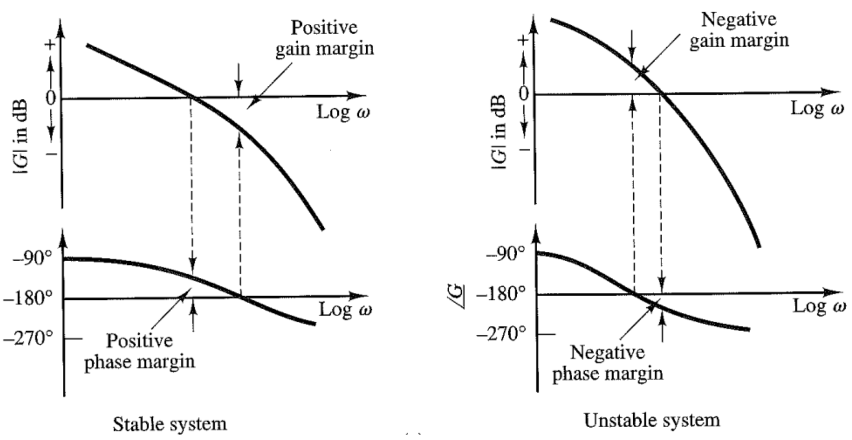
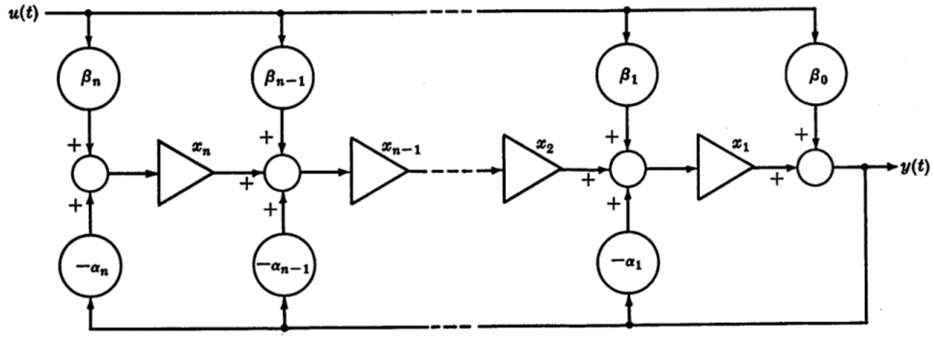
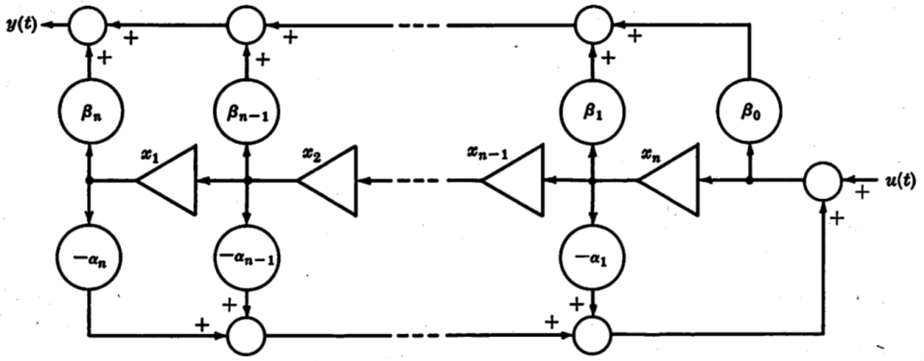
QUESTION NO.	SOLUTION	MARKS
Q8	 	10
Q9		10

QUESTION NO.	SOLUTION	MARKS
Q10	 Observable canonical form  Controllable canonical form Relationship (swap between the two canonical form) 1. Swap the input and the output 2. Change the direction (input/output) of the integrators 3. Change the direction of the signal lines 4. Swap the nodes with the adders	10