NATIONAL UNIVERSITY OF SCIENCE AND TECHNOLOGY

FACULTY OF INDUSTRIAL TECHNOLOGY
DEPARTMENT OF ELECTONIC ENGINEERING
BACHELOR OF ENGINEERING (HONS) DEGREE

Final Examination May 2013

TEE 3241 CONTROL ENGINEERING

Duration of Examination – 3 Hours

INSTRUCTIONS TO CANDIDATES

1. Answer any **FOUR**questions.
2. Each question carries 25 marks.
3. Show all your steps clearly in any calculations.
4. Start each new question on a fresh page.

Question 1

a) Willowvale Mazda Motor Corporation (WMMC) has asked you to design the cruise control system for their new Chauteng range of passenger vehicles. A conventional cruise control system works by sensing the speed of the vehicle based on sensing the turning rate of the tail shaft. The tail shaft is the shaft between the shifting gearbox (driven by the engine) and the differential gearbox (which drives the wheels). The cruise control system adjusts the throttle setting of the engine (which is measured as an angle) so that the vehicle maintains the set speed. The cruise control system is activated by the driver pressing a switch once the car is travelling at the desired speed. Draw the functional block diagram for the cruise control system, stating any assumptions. [10 marks]

b) A system has the transfer function:

$$G(s) = \frac{25a}{(s^2+6s+25)(s+a)}.$$

Find the approximate transient response when $a=30$. Plot the pole-zero map and sketch the approximate response. [10 marks]

c) Give the general formats of first order and second order systems. In your own opinion, why is it important to study such systems? [5 marks]

Question 2

a) Figure Q2(a) shows a dc shunt wound generator rotating at constant speed, with a signal voltage applied to its field winding. Derive the transfer function. [6 marks]

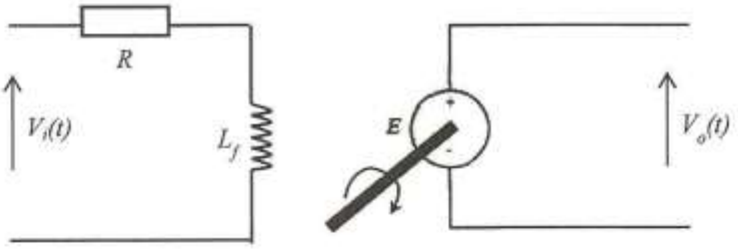

Figure Q2(a)

b) The diagram in figure Q2 (b) shows a simplified servo. Obtain *c(t)* if *r(t)* is unit step input, K=2 and $G(s) = \frac{1}{s(s+4)}$. [10 marks]

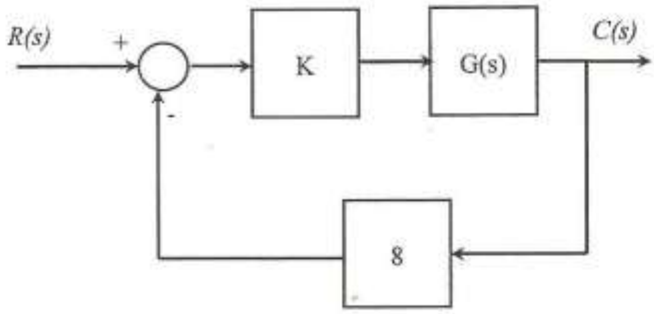

Figure Q2 (b)

c) Use the Routh-Hurtwitz criterion to investigate for stability of the system shown in figure Q2 Verify the number of unstable poles. [9 marks]

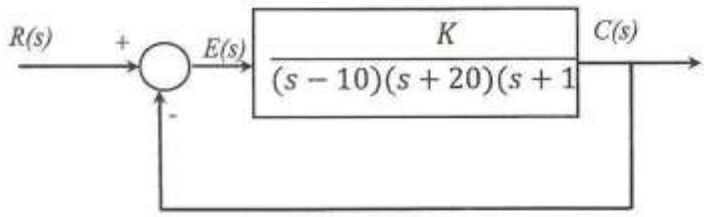

Figure Q2 (c)

Question 3

a) The lag circuit shown in figure Q3(a) is often used as a compensator in feedback control systems. Obtain the transfer function of the circuit. [8 marks]

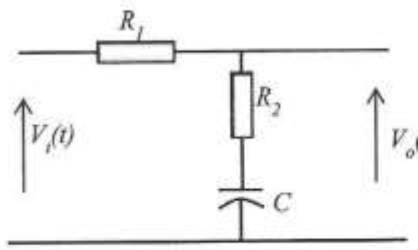

Figure Q3(a)

b) The open loop transfer function of a unity feedback control system is given by

$$G(s) = \frac{K}{s(As+B)}.$$

Derive the steady state error and error coefficients for a step, ramp and parabolic input. [9 marks]

c) Outline what you understand by the terms P, I and D in PID control. Why are PID controllers widely applied in industry? [8 marks]

Question 4

a) Obtain $\frac{C(s)}{R(s)}$ in the block diagram of figure Q4 (a). [8 marks]

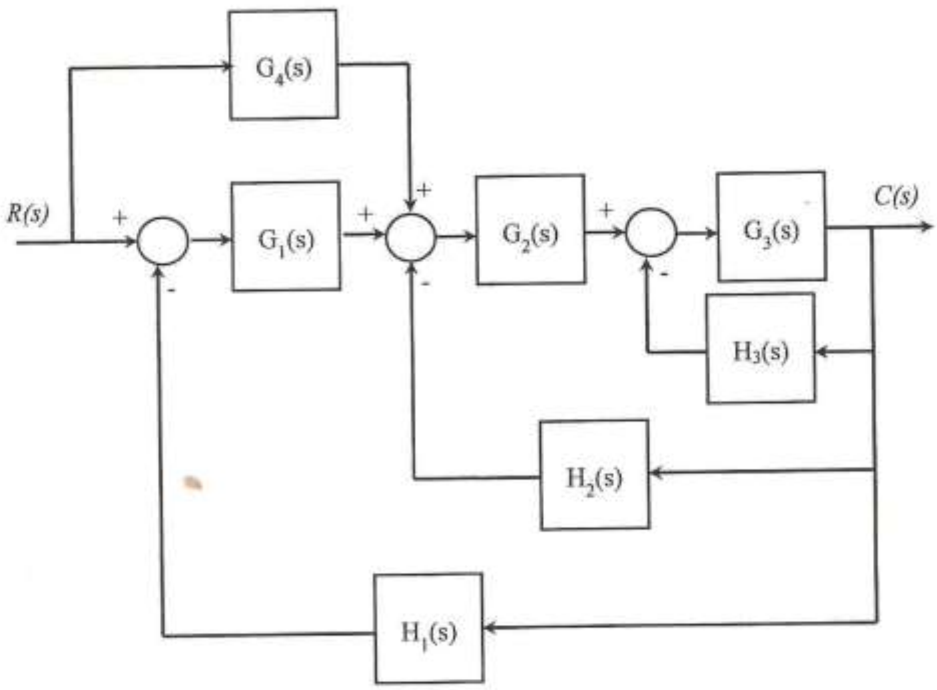

Figure 4 (a)

b) A system has the transfer function:

$$G(s) = \frac{10(s+10)}{(s+20+j15)(s+20-j15)}$$

Find the magnitude and phase responses for the frequency response function $G(j\omega)$. Sketch the bode plots. [11 marks]

c) The forward loop of a unity feedback control system is given by $G(s) = \frac{K}{s(s+6)}$. For what values of K does the system become unstable? For what values of K does the system begin to oscillate? [6 marks]

Question 5

a) Define the terms: ***delay time, rise time and settling time***. [6 marks]

b) A control system with unity feedback has a forward path transfer function given by $\frac{K}{s(s+1)(s+3)}$. Sketch the root locus diagram for the system and hence determine the value of K when the system damping ratio is 0.5. Comment on the stability of the system. [19 marks]

Question 6

a) Describe the steps followed when modeling systems using the mechanistic approach. [5 marks]

b) A system is specified by the following transfer function:

$$G(s) = \frac{s^2 - 7s + 10}{(s+3)(s^2+2s+2)(s^2+4s+3)}$$

Plot the pole-zero map. Determine the stability of the system. [10 marks]

c) A stirred tank for a chemical process uses feed forward control to maintaintemperature of contents at some specified level. Sketch a schematic diagram showing the arrangement of the components. Describe the operation of the system. [10 marks]

END OF PAPER

National University of Science and Technology
Department of Electronic Engineering

Table of Laplace Transform Pairs

f(t)	F(s)
1. impulse, $\delta(t)$	1
2. unit step, $u(t)$	$\frac{1}{s}$
3. shifted impulse, $\delta(t-nT)$	e^{-nsT}
4. unit ramp, t	$\frac{1}{s^2}$
5. parabola, t^2	$\frac{2}{s^3}$
6. exponential, $e^{\pm at}$	$\frac{1}{s \mp a}$
7. $e^{-at} f(t)$	$F(s+a)$
8.	
9. $t\,f(t)$	$\frac{-dF(s)}{ds}$
10. $\frac{1}{t} f(t)$	$\int_s^{\infty} F(s')\,ds'$
11. $\sin\omega t$	$\frac{\omega}{s^2+\omega^2}$
12. $\cos\omega t$	$\frac{s}{s^2+\omega^2}$
13. $e^{-at}\sin\omega t$	$\frac{\omega}{(s+a)^2+\omega^2}$
14. $e^{-at}\cos\omega t$	$\frac{s+a}{(s+a)^2+\omega^2}$
15. $\frac{e^{-at}-e^{-bt}}{b-a}$	$\frac{1}{(s+a)(s+b)}$
16. $\frac{\omega}{\sqrt{(1-\zeta^2)}} e^{-\zeta\omega t}\sin\left[\omega\sqrt{(1-\zeta^2)}\,t\right]$	$\frac{\omega^2}{s^2+2\zeta\zeta\, s+\omega^2}$