UNIVERSITY OF JOHANNESBURG

PROGRAM		BACCALAUREUS TECHNOLOGIAE
		CHEMICAL ENGINEERING
SUBJECT		**PROCESS CONTROL**
CODE		**ICP411**
DATE	:	SUMMER SSA EXAMINATION 2017 11 JANUARY 2017
DURATION	:	(SESSION 2) 11:30 - 14:30

TOTAL MARKS	100
FULL MARKS	100

EXAMINER	MRS MASHIFANA
MODERATOR	PROF. M.S. ONYANGO
NUMBER OF PAGES	SIX (6) INCLUDING THIS COVER PAGE

INSTRUCTIONS

THIS IS A CLOSED BOOK EXAM
NON-PROGRAMMABLE CALCULATORS PERMITTED (ONLY ONE PER CANDIDATE)
SHOW ALL UNITS IN CALCULATIONS!!!
ANSWER ALL THE QUESTIONS
NO ELECTRONIC DEVICES ALLOWED.

QUESTION 1: Process Dynamics and Mathematical Models

A force momentum balance on a mercury manometer results in the following equation: $4x'' + 0.8x' + x = p(t)$
where x is the displacement of the mercury column from its equilibrium position and p(t) is the time varying pressure acting on the manometer.

1.1. Find the transfer function relating x to p, assuming that the system initially is in equilibrium. (6)
1.2. Determine the response time of the manometer? (4)
1.3. Determine the response time damping characteristics and develop the equation for the system? (15)

[25]

QUESTION 2: General feedback control loop stability criterion

Use the testing criteria to assess the stability of processes with the following characteristics:

(a) $CE = -s^2 - 3s - 5$ (5)

(b) $CE = s^2 + 5s + 6$ (7.5)

(c) $CE = 2s^2 + 7s - 15$ (7.5)

[20]

QUESTION 3: Routh-Hurwitz criterion for stability

Consider a system whose closed-loop transfer function is given by:

$$G(s) = \frac{K}{s(s^2 + s + 1)(s + 2) + K}$$

Analyse the system stability using the Routh-Hurwitz criterion by;

(a) Deriving the R-H array
(b) Determining the values of K required for the system to be stable

[20]

QUESTION 4: Controller tuning - Ziegler-Nichols tuning method

For the control system shown in Figure 4.1 below, determine the controller settings for PI controller using Ziegler-Nichols tuning method,

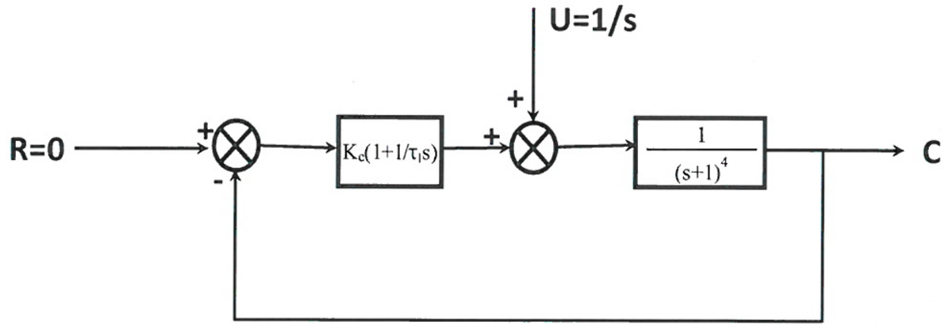

Figure 4.1: Closed loop block diagram for a feedback control system

The supplementary data given below can be used if necessary.
Use $\pi = 3.14$.

	ω=0.6	ω=0.8	ω=1	ω=1.2	ω=1.4	ω=1.6
$\tan^{-1}(-0.5\omega)$	-0.29	-0.38	-0.46	-0.54	-0.61	-0.67
$\tan^{-1}(-\omega)$	-0.54	-0.67	-0.78	-0.88	-0.95	-1.01
$\tan^{-1}(-1.5\omega)$	-0.73	-0.88	-0.98	-1.06	-1.13	-1.18
$\tan^{-1}(-2\omega)$	-0.88	-1.01	-1.11	-1.18	-1.23	-1.27
$\tan^{-1}(-2.5\omega)$	-0.98	-1.11	-1.19	-1.25	-1.29	-1.33
$\tan^{-1}(-3\omega)$	-1.06	-1.18	-1.25	-1.30	-1.34	-1.37
$\tan^{-1}(-3.5\omega)$	-1.13	-1.23	-1.29	-1.34	-1.37	-1.39
$\tan^{-1}(-4\omega)$	-1.18	-1.27	-1.33	-1.37	-1.39	-1.42
$\tan^{-1}(-4.5\omega)$	-1.22	-1.30	-1.35	-1.39	-1.41	-1.43
$\tan^{-1}(-5\omega)$	-1.25	-1.33	-1.37	-1.41	-1.43	-1.45

Ziegler and Nichols recommended the following settings for feedback controllers:

	K_c	τ_I min)	τ_D (min)
Proportional (P)	$K_u/2$	-	-
Proportional-integral (PI)	$K_u/2.2$	$P_u/1.2$	-
Proportionall-integral-derivative (PID)	$K_u/1.7$	$P_u/2$	$P_u/8$

$$K_u = \frac{1}{M} = Ultimate\ \ gain$$

M is the amplitude ratio of the system's response at the crossover frequency ω_{co};

$$Ultimate\ \ period\ \ of\ \ sustained\ \ cycling = P_u = \frac{2\pi}{\omega_{co}} \qquad \text{min}/\,cycle$$

[25]

QUESTION 5: Advanced control system

With the aid of a diagram explain the operation of an override control system using Lower Selector Switch (LSS). Use a boiler as your unit operation equipment.

[10]

TOTAL MARKS = 100

FULL MARKS = 100

Laplace transforms table

Table of Laplace Transforms

	$f(t)=\mathfrak{L}^{-1}\{F(s)\}$	$F(s)=\mathfrak{L}\{f(t)\}$		$f(t)=\mathfrak{L}^{-1}\{F(s)\}$	$F(s)=\mathfrak{L}\{f(t)\}$
1.	1	$\frac{1}{s}$	2.	e^{at}	$\frac{1}{s-a}$
3.	$t^n,\quad n=1,2,3,\ldots$	$\frac{n!}{s^{n+1}}$	4.	$t^p,\ p>-1$	$\frac{\Gamma(p+1)}{s^{p+1}}$
5.	$\sqrt{t}$	$\frac{\sqrt{\pi}}{2s^{\frac{3}{2}}}$	6.	$t^{n-\frac{1}{2}},\quad n=1,2,3,\ldots$	$\frac{1\cdot 3\cdot 5\cdots(2n-1)\sqrt{\pi}}{2^n s^{n+\frac{1}{2}}}$
7.	$\sin(at)$	$\frac{a}{s^2+a^2}$	8.	$\cos(at)$	$\frac{s}{s^2+a^2}$
9.	$t\sin(at)$	$\frac{2as}{(s^2+a^2)^2}$	10.	$t\cos(at)$	$\frac{s^2-a^2}{(s^2+a^2)^2}$
11.	$\sin(at)-at\cos(at)$	$\frac{2a^3}{(s^2+a^2)^2}$	12.	$\sin(at)+at\cos(at)$	$\frac{2as^2}{(s^2+a^2)^2}$
13.	$\cos(at)-at\sin(at)$	$\frac{s(s^2-a^2)}{(s^2+a^2)^2}$	14.	$\cos(at)+at\sin(at)$	$\frac{s(s^2+3a^2)}{(s^2+a^2)^2}$
15.	$\sin(at+b)$	$\frac{s\sin(b)+a\cos(b)}{s^2+a^2}$	16.	$\cos(at+b)$	$\frac{s\cos(b)-a\sin(b)}{s^2+a^2}$
17.	$\sinh(at)$	$\frac{a}{s^2-a^2}$	18.	$\cosh(at)$	$\frac{s}{s^2-a^2}$
19.	$e^{at}\sin(bt)$	$\frac{b}{(s-a)^2+b^2}$	20.	$e^{at}\cos(bt)$	$\frac{s-a}{(s-a)^2+b^2}$
21.	$e^{at}\sinh(bt)$	$\frac{b}{(s-a)^2-b^2}$	22.	$e^{at}\cosh(bt)$	$\frac{s-a}{(s-a)^2-b^2}$
23.	$t^n e^{at},\quad n=1,2,3,\ldots$	$\frac{n!}{(s-a)^{n+1}}$	24.	$f(ct)$	$\frac{1}{c}F\left(\frac{s}{c}\right)$
25.	$u_c(t)=u(t-c)$	e^{-cs}	26.	$\delta(t-c)$	e^{-cs}