DUBLIN CITY UNIVERSITY

SEMESTER 1 IN-CLASS TEST 2017/2018

MODULE: EE458 – Control Systems Analysis

PROGRAMME(S):

ECE	BEng Electronic & Computer Engineering
ME	B.Eng. in Mechatronic Engineering
ECSAO	Study Abroad (Engineering & Computing)
ECSA	Study Abroad (Engineering & Computing)

YEAR OF STUDY: 4,O,X

EXAMINER(S):

Jennifer Bruton	(Ext:5034)
Prof. Gerard Parr	External
Dr. Simon Watson	External

TIME ALLOWED: 1 Hour

INSTRUCTIONS: Answer Question 1.

PLEASE DO NOT TURN OVER THIS PAGE UNTIL YOU ARE INSTRUCTED TO DO SO.
The use of programmable or text storing calculators is expressly forbidden.
Please note that where a candidate answers more than the required number of questions, the examiner will mark all questions attempted and then select the highest scoring ones.

Requirements for this paper:

INSTRUCTIONS FOR COMPUTER-BASED WORK

IMPORTANT: PLEASE READ THIS SHEET CAREFULLY BEFORE COMMENCING THIS EXAM.

GENERAL:

- Set up your own directory (called your student exam number) in `c:\temp` as saving to `c:\temp` is faster than saving to the USB flash drive.
- All m-files, script files, SIMULINK files, plot files and diary files (with extension `txt`) must be saved to the network drive `Q:\` and to the USB flash drive.
- Save your work regularly. No credit is given for work that has been 'lost'.
- At the end of the exam, it is your responsibility to ensure that all your work has been saved successfully to the network drive `Q:\` and to the USB flash drive.

SAVING PLOTS:

- The plot must be generated to your satisfaction in the Figure window. Do not minimize this window.
- Save your plot as type `*.fig` only. Other formats are not acceptable.
- **N.B.** Make sure that you save your plot to `c:\temp\....` Make sure that you use a unique name for the plots.

DIARY FILES:

- It is recommended that you use a separate diary file for each part of a question.
- To open/start a diary file, at the MATLAB Command Prompt, type:

```
>> diary c:\temp\examnum\diary1.txt
>> diary on
```

- To close a diary file, at the MATLAB Command Prompt, type:

```
>> diary off
```

USEFUL MATLAB FUNCTIONS:

abs	acos	angle	asin	atan	axis
bandwidth	bode	break	c2d	cd	clear
clf	close	conv	cos	det	eig
else	evalfr	exit	exp	feedback	figure
find	for	function	grid	help	if
imag	impulse	inv	isstable	label	length
log	log10	logspace	lsim	margin	max
mean	min	norm	nyquist	ones	open
ode45	pi	pinv	plot	pole	poly
print	pzmap	quit	rand	rank	real
residue	rlocfind	rlocus	roots	round	semilogx
series	sign	sim	sin	size	sqrt
ss	ssdata	step	subplot	sum	tan
text	tf	tf2ss	tfdata	title	while
who	xlabel	ylabel	zeros	zgrid	zpk
zpkdata	zoom				

- **Please note:** the use of *solve()*, *stepinfo()*, *sisotool()*, *rltool()*, *sgrid()* or any of their related functions is not allowed as part of this assessment.

QUESTION 1 (COMPULSORY) ***[TOTAL MARKS: 25]***

[See Appendix for applicable formulae]

Q 1(a) **[6 Marks]**

A closed-loop control system is described by the block diagram in **Figure Q1.**

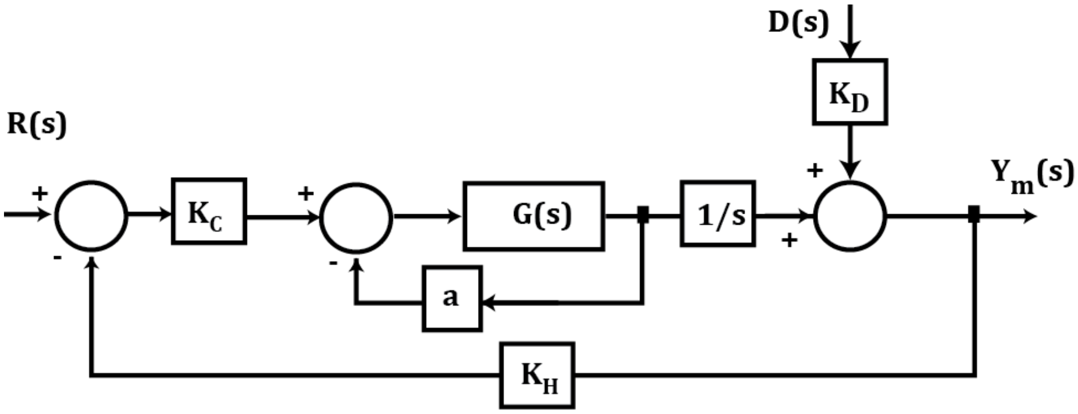

Figure Q1

(i) find an expression for the output $Y_m(s)$ in terms of $D(s)$ and $R(s)$,

(ii) find an expression for the transfer function between the measured output $Y_m(s)$ and the disturbance input $D(s)$ when $R(s) = 0$,

(iii) find a more detailed expression for the transfer function in terms of $\mathrm{K_C}$ in **Q 1(a)(ii)** if:

$$G(s) = \frac{0.5s + 1}{s}, \quad a = 5, \quad K_H = 10, \quad K_\mathrm{D} = 0.2$$

Q 1(b) **[7 Marks]**

(i) Derive an expression for the error signal, $\mathrm{E}(s) = \mathrm{R}(s) - \mathrm{Y_m}(s)$, for the system in **Figure Q1**.

(ii) Present the Final Value Theorem (FVT) formula for the steady-state error.

(iii) Use the FVT to design the gain, $\mathrm{K_C}$, to give a disturbance steady state error of $\mathbf{-0.04}$ when $\mathrm{R}(s) = 0/s$, and $\mathrm{D}(s) = 1/\mathrm{s}^2$.

(iv) Use **MATLAB** to predict the overall steady-state error when $\mathrm{R}(s) = 2/s$ and $\mathrm{D}(s) = 1/\mathrm{s}^2$.

Q 1(c) **[7 Marks]**

(i) Use **SIMULINK** to simulate the system in **Figure Q1** for the value of K_C designed in **Q 1(b)(iii)** in response to both of the inputs described in **Q 1(b)(iii)** for 7 seconds; the inner loop containing $G(s)$ and the gain a should be implemented using a single **SIMULINK** *Zero-Pole* block.

(ii) Plot the error response signal and then save this plot.

(iii) Use **MATLAB** to measure the steady-state error value. Does this value match the value designed for in **part 1(b)**? Briefly comment on why they do/do not match.

Q 1(d) **[5 Marks]**

(i) Present the formula for the Sensitivity of a function to variations in a parameter.

(ii) For the system in **Figure Q1**, find the sensitivity of the transfer function between the measured output and the disturbance (found in **Q 1(a)(iii)**) to variations in the gain, K_C.

[End of Question1]

APPENDIX

Please note: the use of `solve`, `stepinfo()`, `sisotool()`, `rltool()`, `sgrid()` or any of their related functions is not allowed as part of this assessment.

Selection of Laplace and Z-Transforms

f(t)	*F(s)*	*F(z),*
1	$\frac{1}{s}$	$\frac{T}{1-z^{-1}}$
t	$\frac{1}{s^2}$	$\frac{Tz^{-1}}{(1-z^{-1})^2}$
t^2	$\frac{2}{s^3}$	$\frac{T^2z^{-1}(1+z^{-1})}{(1-z^{-1})^3}$
e^{-aT}	$\frac{1}{s+a}$	$\frac{1}{1-e^{-aT}z^{-1}}$
te^{-aT}	$\frac{1}{(s+a)^2}$	$\frac{Te^{-aT}z^{-1}}{(1-e^{-aT}z^{-1})^2}$

Transient Performance formulae - 1st order system:

$$s = -a$$
$$\tau = \frac{1}{a}, \quad t_s = \frac{4}{a} \quad t_r = \frac{2.2}{a}$$

Transient Performance formulae - 2nd order under-damped system:

$$\boldsymbol{s = -\zeta\omega_n \pm j\omega_n\sqrt{1-\zeta^2}}$$
$$\%\ \boldsymbol{Overshoot = 100e^{\frac{-\pi\zeta}{\sqrt{1-\zeta^2}}}}\%, \quad \boldsymbol{t_p = \frac{\pi}{\omega_n\sqrt{1-\zeta^2}}}$$
$$\boldsymbol{t_s = \frac{4}{\zeta\omega_n}}, \qquad \boldsymbol{t_r = \frac{\pi - \tan^{-1}\left(\sqrt{1-\zeta^2}/\zeta\right)}{\omega_n\sqrt{1-\zeta^2}}}$$

2nd order under-damped transient performance – frequency domain formulae:

$$Phase\ Margin = \ tan^{-1}\left[2\zeta\left\{\frac{1}{(4\zeta^4+1)^{1/2}-2\zeta^2}\right\}^{1/2}\right]$$
$$M_P = \frac{1}{2\zeta\sqrt{1-\zeta^2}}$$
$$\omega_b = \frac{4}{\zeta t_s}\sqrt{(1-2\zeta^2)+\sqrt{4\zeta^4-4\zeta^2+2}}$$
$$\omega_b = \frac{\pi}{t_p\sqrt{1-\zeta^2}}\sqrt{(1-2\zeta^2)+\sqrt{4\zeta^4-4\zeta^2+2}}$$

Continued on Next Page…

Ziegler-Nichols Transient Response method PID Parameters:
(parameter symbols below have their usual meanings)

	K_P	T_I	T_D
P	1 / RL		
PI	0.9 / RL	3 L	
PID	1.2 / RL	2 L	0.5 L

Ziegler-Nichols Ultimate Cycle method PID Parameters:
(parameter symbols below have their usual meanings)

	K_P	T_I	T_D
P	$0.5\ K_C$		
PI	$0.45\ K_C$	$T_C / 1.2$	
PID	$0.6\ K_C$	$T_C / 2$	$T_C / 8$

ITAE Optimum Coefficients for Step Input:

$$s + \omega_n$$
$$s^2+1.4\,\omega_n s + \omega_n^2$$
$$s^3+1.75\,\omega_n s^2+2.5\,\omega_n^2 s+ \omega_n^3$$
$$s^4+2.1\,\omega_n s^3+3.4\,\omega_n^2 s^2+2.7\,\omega_n^3 s+ \omega_n^4$$
$$s^5+2.8\,\omega_n s^4+5.0\,\omega_n^2 s^3+5.5\,\omega_n^3 s^2+3.4\,\omega_n^4 s+ \omega_n^5$$

ITAE Optimum Coefficients for Ramp Input:

$$s^2+3.2\,\omega_n s + \omega_n^2$$
$$s^3+1.75\,\omega_n s^2+3.25\,\omega_n^2 s+ \omega_n^3$$
$$s^4+2.41\,\omega_n s^3+4.93\,\omega_n^2 s^2+5.14\,\omega_n^3 s+ \omega_n^4$$
$$s^5+2.19\,\omega_n s^4+6.50\,\omega_n^2 s^3+6.30\,\omega_n^3 s^2+5.24\,\omega_n^4 s+ \omega_n^5$$

[END OF APPENDICES]

[END OF EXAM]