DUBLIN CITY UNIVERSITY

SEMESTER 1 IN-CLASS TEST 2015/2016

MODULE: EE406 – Systems Analysis

PROGRAMME(S):

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

YEAR OF STUDY: 4,O,X

EXAMINERS:

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Prof. Sakir Sezer
Prof. Matilde Santos Penas

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 (Please mark (X) as appropriate)

- [ ] *Log Tables*
- [ ] *Graph Paper*
- [ ] *Dictionaries*
- [ ] *Statistical Tables*
- [ ] *Bible*
- [ ] *Thermodynamic Tables*
- [ ] *Actuarial Tables*
- [ ] *MCQ Only – Do not publish*
- [ ] *Attached Answer Sheet*

INSTRUCTIONS FOR COMPUTER-BASED WORK

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

GENERAL:

- Set up your own directory (called your student ID 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\IDnum\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 *`stepinfo()`* and related functions, *`sisotool()`*, *`rltool()`* and *`sgrid()`* is not allowed as part of this assessment.

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

[See Appendix for applicable formulae]

Q 1(a) **[3 Marks]**

A closed loop control system, **Figure Q1**, consists of the process, $G(s)$, a forward path controller, $C(s)$, and a feedback sensor $H(s)$. The process input is affected by a disturbance, $D(s)$.

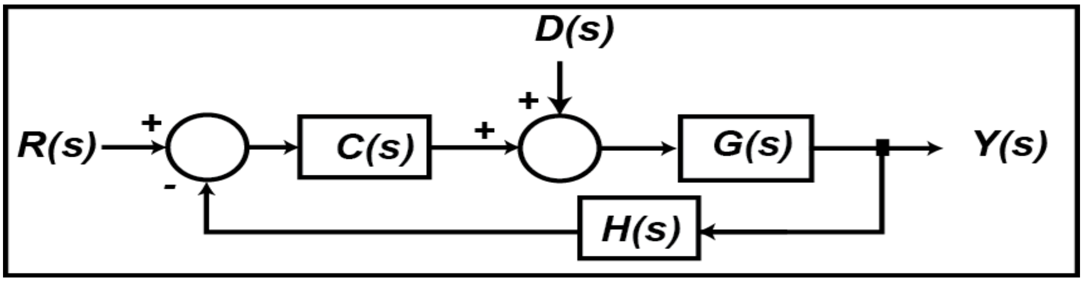

Figure Q1

Given the expression for the output, $Y(s)$:

$$Y(s) = G(s).D(s) + C(s).G(s).R(s) - C(s).G(s).H(s).Y(s)$$

Find an expression for the error, $E(s)$.

Q 1(b) **[8 Marks]**

(i) Present the Final Value Theorem (FVT) relating the time-domain steady-state error to the frequency-domain steady-state error; the theorem must feature $e(t)$ and $E(s)$.

(ii) Using the result of **Q 1(a)** and the FVT, design the controller gain K_C to give an overall steady-state error of $^2/_3$ when $r(t) = 2u(t)$ and $d(t) = 0.5u(t)$, given the following transfer functions for the elements in **Figure Q1**:

$$G(s) = \frac{1}{(0.01s+1)} \quad C(s) = \frac{K_C}{(s+4)} \quad H(s) = \frac{2}{(s+2)}$$

Q 1(c) **[3 Marks]**

For the system in **Figure Q1** with the value of K_C and the transfer functions given in **Q 1(b)**, use **MATLAB** commands to predict the steady-state error when the reference and disturbance inputs in **Q 1(b)(ii)** are applied.

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

(i) Use **SIMULINK** to simulate the system in **Figure Q1** for the value of K_C designed in **Q 1(b)** in response to the reference and disturbance inputs give in **Q 1(b)** for 4 seconds; $C(s)$, $G(s)$ and $H(s)$ should be implemented as separate **SIMULINK** blocks and each block should be of a different format (e.g. LTI, Transfer Function, etc.).

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

(iii) Use **MATLAB** to measure the steady-state error.

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

(i) Present the formula for the sensitivity of the transfer function ($T_{ED}(s)$) between the error signal, $E(s)$, and the disturbance input, $D(s)$, to changes in the controller gain if $C(s) = K_C$.

(ii) Using the appropriate part of the result for $E(s)$ from **Q 1(a)** above, find an expression for this sensitivity function with respect to K_C, based on the configuration shown in **Figure Q1**. Your final expression should not feature the terms, $C(s)$, $G(s)$ and $H(s)$ but you do not have to multiply all terms out.

[End of Question 1]

APPENDIX

Please note: the use of *stepinfo()* and related functions, *sisotool()*, *rltool()* and *sgrid()* 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	$\frac{1}{s^3}$	$\frac{T^2z^{-1}(1+z^{-1})}{(1-z^{-1})^3}$
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:

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

[End of Appendix]

[End of Examination]