DUBLIN CITY UNIVERSITY

SEMESTER 1 IN-CLASS TEST 2018/2019

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):

Dr. Brendan Hayes	(Ext:7984)
Dr. Simon Watson	External

TIME ALLOWED: 1 Hour

INSTRUCTIONS: Answer Question 1.

Marks will be lost if all necessary work is not clearly shown.

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) **[7 Marks]**

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

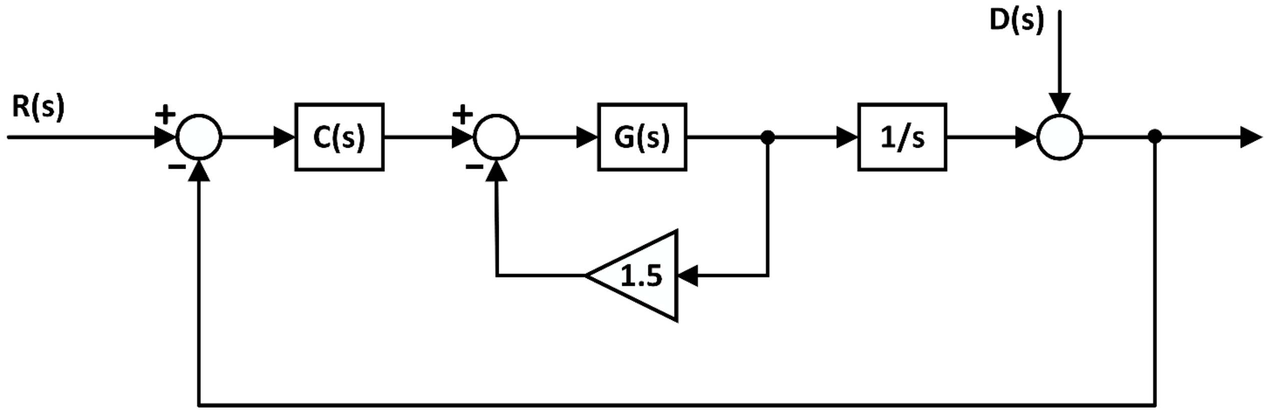

Figure Q1

where $G(s) = \dfrac{0.25s + 1}{s}$ and $C(s) = \dfrac{k_C}{0.2s + 1}$,

(i) determine the **type** of the system in **Figure Q1** and hence comment on the steady-state error caused by an input $R(s) = 2/s$ when $D(s) = 0$.

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

Q 1(b) **[5 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 steady-state error of $-\mathbf{15}\%$ when $\mathrm{R(s)} = 2/\mathrm{s}$, and $\mathrm{D(s)} = 1/\mathrm{s}^2$.

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

(i) Use **SIMULINK** to simulate the system in **Figure Q1** for the value of $\mathrm{K_C}$ designed in **Q 1(b)(iii)** in response to both of the inputs described in **Q 1(b)(iii)** for 15 seconds; $\mathrm{C}(s)$ should be implemented using a **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.

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

(i) Present the formula for the Sensitivity of a closed-loop system to a parameter of the open-loop system.

(ii) Present the appropriate **chain-rule** version of this formula when the parameter to be varied is k_C and the open loop system containing k_C is $C(s)$.

(iii) Hence, use the chain rule version of the sensitivity formula to find an expression for the sensitivity of the closed-loop system in **Figure Q1** to variations in the parameter k_C when $D(s) = 0$.

[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	$\frac{1}{s^2}$	$\frac{Tz^{-1}}{(1-z^{-1})^2}$
t²	$\frac{2}{s^3}$	$\frac{T^2z^{-1}(1+z^{-1})}{(1-z^{-1})^3}$
e^{-aT}	$\frac{1}{s+a}$	$\frac{1}{1-e^{-aT}z^{-1}}$
te^{-aT}	$\frac{1}{(s+a)^2}$	$\frac{Te^{-aT}z^{-1}}{(1-e^{-aT}z^{-1})^2}$

Product rule:

$$y = uv \Rightarrow \frac{dy}{dx} = u\frac{dv}{dx} + v\frac{du}{dx}$$

Quotient Rule:

$$y = \frac{u}{v} \Rightarrow \frac{dy}{dx} = \frac{v\frac{du}{dx} - u\frac{dv}{dx}}{v^2}$$

Chain Rule:

$$y = u\big(v(x)\big) \Rightarrow \frac{dy}{dx} = \frac{du}{dv}\frac{dv}{dx}$$

[END OF APPENDICES]

[END OF EXAM]