

**UNIVERSITY COLLEGE TATI (UC TATI)****FINAL EXAMINATION QUESTION BOOKLET**

COURSE CODE	: DEI 2113 / DEE 3143
COURSE	: CONTROL SYSTEMS
SEMESTER/SESSION	: 1-2023/2024
DURATION	: 3 HOURS

**Instructions:**

- a) Answer all **4** questions.
- b) All answers should be written in answer booklet.
- c) Write legibly and draw sketches wherever required.
- d) If in doubt, raise your hands and ask the invigilator.

**DO NOT OPEN THIS BOOKLET UNTIL YOU ARE TOLD TO DO SO****THIS BOOKLET CONTAINS 8 PRINTED PAGES INCLUDING COVER PAGE**

**QUESTION 1**

a) Define terms below:

- i. Control system (1 mark)
- ii. Input (1 mark)
- iii. Output (1 mark)

b) Control systems are important and present almost everywhere in our daily lives. State two (2) examples of:

- i. God-created control systems (2 marks)
- ii. Man-made control systems (2 marks)

c) There are three main elements exist in any control systems. Produce a block diagram of a basic control system that has all those elements.

(3 marks)

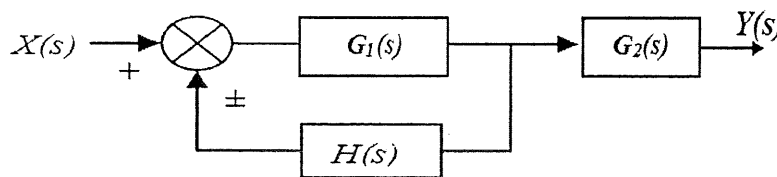
d) Describe two (2) disadvantages of open-loop system.

(2 marks)

e) Describe three (3) main objectives of control systems analysis and design

**QUESTION 2**

- a) Define the transfer function of a system. (1 mark)
- b) Illustrate summing junction, blocks and take off point. (3 marks)
- c) Draw the block diagram for forward path and feedback path. (3 marks)
- d) An open loop system consists of three elements in series, the elements having transfer functions of  $\frac{1}{2s}$ ,  $\frac{(s+1)}{(s+3)}$  and  $\frac{6}{(s+2)}$ .
- i. Produce the block diagram of this system (3 marks)
- ii. Determine the overall transfer function of the system. (4 marks)
- e) Find the equivalent transfer function for Figure 1 below. (4 marks)

**Figure 1**

**QUESTION 3**

a) Define the following terms:

i. Laplace transform. (1 mark)

ii. Inverse Laplace transform (1 mark)

b) Determine the Laplace transformation of these functions using table Laplace transformation.

i.  $f(t) = 5t^2$  (2 marks)

ii.  $f(t) = e^{2t}\sin 3t$  (3 marks)

c) Determine the Inverse Laplace transformation of these functions using table Laplace transformation.

i.  $G(s) = (e^{-3s} - e^{-4s})$  (3 marks)

ii.  $G(s) = \frac{s}{s^2+9}$  (3 marks)

iii.  $G(s) = \frac{5}{(s-2)^2+25}$  (4 marks)

d) Given  $G(s) = \frac{(s+2)}{(s+1)(s+4)}$  find  $g(t)$  using partial fraction expansion.

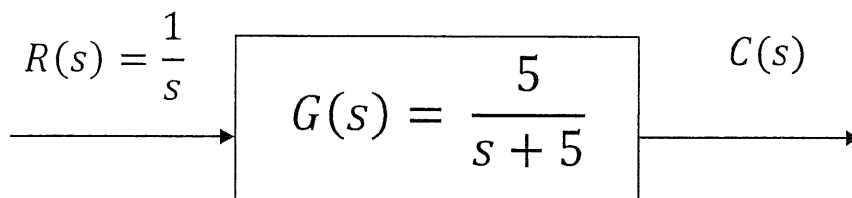
(10 marks)

**QUESTION 4**

- a) State and sketch two (2) types of input in transfer function (4 marks)
- b) Plot the system pole and zero based on the transfer function below:

$$G(s) = \frac{s + 4}{(s + 2)(s + 5)} \quad (3 \text{ marks})$$

- c) Figure 2 show the transfer function of first order system is given as:

**Figure 2**

- i. Find time constant,  $T_c$ . (2 marks)
- ii. Find rise time time,  $T_r$ . (2 marks)
- iii. Find settling time,  $T_s$  (2 marks)
- iv. Determine output time response,  $c(t)$ . (7 marks)
- v. Based on answer in (i), identify forced and natural response. (2 marks)

d) The transfer function of second order system is given:

$$G(s) = \frac{0.04}{s^2 + 0.02s + 0.04}$$

Determine the:

- |      |                               |           |
|------|-------------------------------|-----------|
| i.   | Natural frequency, $\omega_n$ | (1 mark)  |
| ii.  | Damping ratio, $\xi$          | (2 marks) |
| iii. | Peak time, $T_p$              | (3 marks) |
| iv.  | Settling time, $T_s$          | (3 marks) |
| v.   | Rise time, $T_r$              | (3 marks) |
| vi.  | Overshoot, %OS                | (3 marks) |

-----End of question-----

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**FORMULA**

1.  $A = \pi r^2 s_{1,2} = -\zeta\omega_n \pm \omega_n\sqrt{\zeta^2 - 1}$
2.  $\zeta = \frac{a}{2\omega_n}$
3.  $j^2 = -1$
4.  $\omega = \omega_n\sqrt{1 - \zeta^2}$
5.  $T_r = \frac{\pi}{2\omega_n\sqrt{1-\zeta}}$
6.  $T_p = \frac{\pi}{\omega_n\sqrt{1-\zeta}} = \frac{\pi}{\omega_d}$
7.  $T_s = \frac{4}{\zeta\omega_n} = \frac{4}{\sigma_d}$
8.  $\%OS = e^{-\left(\zeta\pi/\sqrt{1-\zeta^2}\right)} \times 100\%$
9.  $T_c = \frac{1}{a}$
10.  $T_r = \frac{2.2}{a}$
11.  $T_s = \frac{4}{a}$

CONTROL SYSTEMS (DEI 2113 / DEE 3143)

Table of Laplace Transforms

$f(t) = \mathcal{L}^{-1}\{F(s)\}$	$F(s) = \mathcal{L}\{f(t)\}$	$f(t) = \mathcal{L}^{-1}\{F(s)\}$	$F(s) = \mathcal{L}\{f(t)\}$
1. 1	$\frac{1}{s}$	2. $e^{at}$	$\frac{1}{s-a}$
3. $t^n, n=1,2,3,\dots$	$\frac{n!}{s^{n+1}}$	4. $t^p, p > -1$	$\frac{\Gamma(p+1)}{s^{p+1}}$
5. $\sqrt{t}$	$\frac{\sqrt{\pi}}{2s^{3/2}}$	6. $t^{n-1/2}, n=1,2,3,\dots$	$\frac{1 \cdot 3 \cdot 5 \cdots (2n-1)\sqrt{\pi}}{2^n s^{n+1/2}}$
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. $t^n e^{at}, n=1,2,3,\dots$	$\frac{n!}{(s-a)^{n+1}}$	24. $f(ct)$	$\frac{1}{c} F\left(\frac{s}{c}\right)$
25. $u_c(t) = u(t-c)$ <u>Heaviside Function</u>	$\frac{e^{-cs}}{s}$	26. $\delta(t-c)$ <u>Dirac Delta Function</u>	$e^{-cs}$
27. $u_c(t) f(t-c)$	$e^{-cs} F(s)$	28. $u_c(t) g(t)$	$e^{-cs} \mathcal{L}\{g(t+c)\}$
29. $e^{ct} f(t)$	$F(s-c)$	30. $t^n f(t), n=1,2,3,\dots$	$(-1)^n F^{(n)}(s)$
31. $\frac{1}{t} f(t)$	$\int_s^\infty F(u) du$	32. $\int_0^t f(v) dv$	$\frac{F(s)}{s}$
33. $\int_0^t f(t-\tau) g(\tau) d\tau$	$F(s)G(s)$	34. $f(t+T) = f(t)$	$\frac{\int_0^T e^{-st} f(t) dt}{1-e^{-sT}}$
35. $f'(t)$	$sF(s) - f(0)$	36. $f''(t)$	$s^2 F(s) - sf(0) - f'(0)$
37. $f^{(n)}(t)$	$s^n F(s) - s^{n-1} f(0) - s^{n-2} f'(0) \cdots - sf^{(n-2)}(0) - f^{(n-1)}(0)$		