UNIVERSITY OF ESWATINI

SIT/RESIT EXAMINATION, FIRST SEMESTER

JANUARY 2019

FACULTY OF SCIENCE AND ENGINEERING

DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING

TITLE OF PAPER: CONTROL ENGINEERING I

COURSE CODE : EEE431 / EE431

TIME ALLOWED: THREE HOURS

INSTRUCTIONS:

1. **There are four questions in this paper. Answer all questions. Each question carries 25 marks.**
2. **Useful information is provided at end of this paper.**
3. **If you think not enough data has been given in any question you may assume any reasonable values.**

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THIS PAPER CONTAINS SEVEN (7) PAGES INCLUDING THIS PAGE

Question 1

(a) Briefly compare and contrast open-loop control system versus closed loop control system. [4]

(b) Draw the block diagram of a closed loop control system for a disk drive. [4]

(c) For the electric circuit shown below determine the transfer function if the output is the voltage across R_2 *and* C_2 as shown in Fig Q. 1(c), give that $R_1 = R_2 = 1\Omega$ *and* $C_1 = C_2 = 1\,F$ [6]

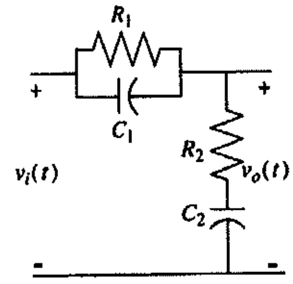


Fig Q.1 (c)

(d) Given the pole plot shown in figure 1(d) , find $\xi, \omega_n, T_p, \%OS$ *and* T_s [5]

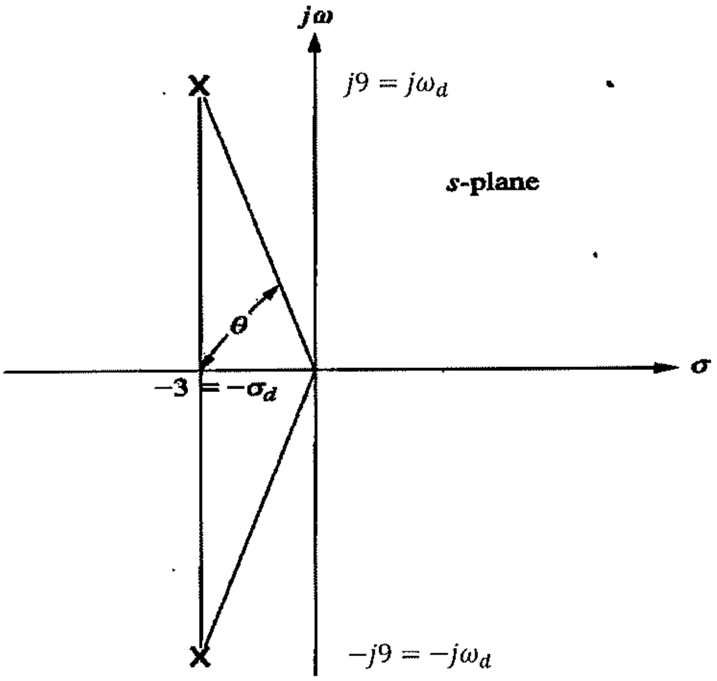


Fig. Q.1 (d)

(e) Given the system defined below, find the transfer function, $T(s) = \frac{Y(s)}{U(s)}$, *where* $U(s)$ is the input and Y(s) is the output. [6]

$$\dot{x} = \begin{bmatrix} 0 & 1 \\ -9 & -7 \end{bmatrix} x + \begin{bmatrix} 0 \\ 1 \end{bmatrix} u$$

$$y = \begin{bmatrix} 1 & 2 \end{bmatrix} x$$

Question 2

(a) Based on the natural response definition of stability, explain for the close-loop system case, the terms *stable, unstable* and *marginally stable.* [6]

(b) Find the state equations for the translational mechanical system shown Fig. Q.2 (b) below [13]

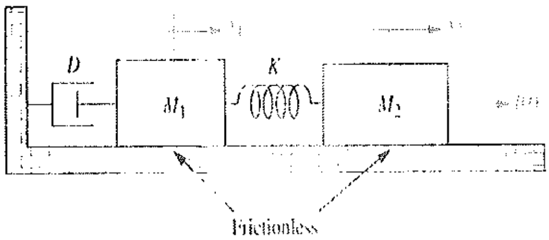


Fig. Q.2(b)

(c) Find the state-space representation in phase variable form for the system shown in Fig. Q.2 (c) [6]

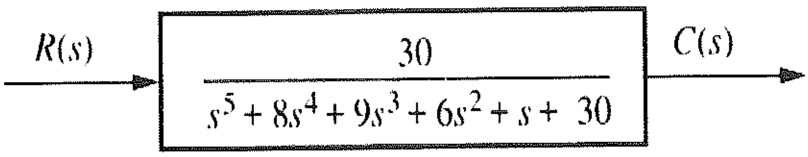


Fig. Q.2(c)

Question 3

(a) Given the transfer function below, Find the sampled time function, $f^*(t)$ [13]

$$F(z) = \frac{0.8z}{(z-0.9)(z-0.3)(z-0.5)}$$

(b) Investigate the effect of T on the steady state error on the following system by assume a fixed gain K = 2 [12]

$$G(z) = \frac{Kz(1-e^{-T})}{(z-1)(z-e^{-T})}$$

For T = 0.5 sec, 1 sec and 2 sec

Question 4

(a) What information is contained in the specification $K_p = 100$? [4]

(b) Find the number of poles in the left half-plane, the right half-plane, and on the $j\omega$-axis for the system of Fig. Q.4 (b) [6]

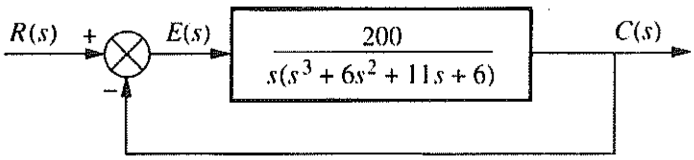


Fig.Q4 (b)

(c) Given the system

$$\dot{\mathbf{x}} = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ -1 & -2 & -3 \end{bmatrix}\mathbf{x} + \begin{bmatrix} 10 \\ 0 \\ 0 \end{bmatrix}u$$

$$y = [1 \quad 0 \quad 0]\mathbf{x}$$

Find out how many poles are in the left half-plane, in the half-plane, and on the $j\omega$-axis. [5]

(d) Consider the system shown in Fig. Q.4(d)

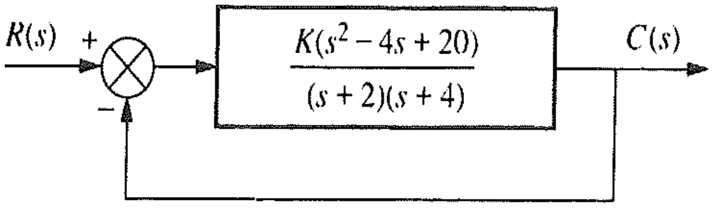
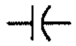


Fig.Q. 4 (d)

(i) The exact point and gain where the locus crosses the 0.45 damping ratio line
(ii) The exact point and gain where the locus crosses the $j\omega$- axis
(iii) The breakaway point on the real axis
(iv) The range of K within which the system is stable

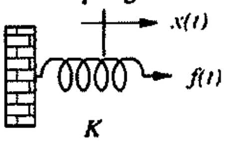
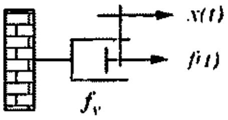
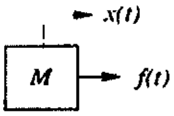
[10]

Table 1

Component	Voltage-current	Current-voltage	Voltage-charge	Impedance $Z(s) = V(s)/I(s)$	Admittance $Y(s) = I(s)/V(s)$
 Capacitor	$v(t) = \frac{1}{C}\int_0^t i(\tau)\,d\tau$	$i(t) = C\frac{dv(t)}{dt}$	$v(t) = \frac{1}{C}q(t)$	$\frac{1}{Cs}$	Cs
 Resistor	$v(t) = Ri(t)$	$i(t) = \frac{1}{R}v(t)$	$v(t) = R\frac{dq(t)}{dt}$	R	$\frac{1}{R} = G$
 Inductor	$v(t) = L\frac{di(t)}{dt}$	$i(t) = \frac{1}{L}\int_0^t v(\tau)\,d\tau$	$v(t) = L\frac{d^2q(t)}{dt^2}$	Ls	$\frac{1}{Ls}$

Note: The following set of symbols and units is used throughout this book: $v(t)$ = V (volts), $i(t)$ = A (amps), $q(t)$ = Q (coulombs), C = F (farads), R = Ω (ohms), G = ℧ (mhos), L = H (henries).

Table 2

Component	Force-velocity	Force-displacement	Impedance $Z_M(s) = F(s)/X(s)$
Spring  K	$f(t) = K\int_0^t v(\tau)\,d\tau$	$f(t) = Kx(t)$	K
Viscous damper  f_v	$f(t) = f_v v(t)$	$f(t) = f_v\frac{dx(t)}{dt}$	$f_v s$
Mass 	$f(t) = M\frac{dv(t)}{dt}$	$f(t) = M\frac{d^2x(t)}{dt^2}$	Ms^2

Note: The following set of symbols and units is used throughout this book: $f(t)$ = N (newtons), $x(t)$ = m (meters), $v(t)$ = m/s (meters/second), K = N/m (newtons/meter), f_v = N-s/m (newton-seconds/meter), M = kg (kilograms = newton-seconds²/meter).

Table 3

Input	Steady-state error formula	Type 0 Static error constant	Type 0 Error	Type 1 Static error constant	Type 1 Error	Type 2 Static error constant	Type 2 Error
Step, $u(t)$	$\frac{1}{1+K_p}$	$K_p =$ Constant	$\frac{1}{1+K_p}$	$K_p = \infty$	0	$K_p = \infty$	0
Ramp, $tu(t)$	$\frac{1}{K_v}$	$K_v = 0$	∞	$K_v =$ Constant	$\frac{1}{K_v}$	$K_v = \infty$	0
Parabola, $\frac{1}{2}t^2u(t)$	$\frac{1}{K_a}$	$K_a = 0$	∞	$K_a = 0$	∞	$K_a =$ Constant	$\frac{1}{K_a}$

Static Error Constants

For a step input, $u(t)$,

$$e(\infty) = e_{\text{step}}(\infty) = \frac{1}{1 + \lim_{s\to 0} G(s)}$$

For a ramp input, $tu(t)$,

$$e(\infty) = e_{\text{ramp}}(\infty) = \frac{1}{\lim_{s\to 0} sG(s)}$$

For a parabolic input, $\frac{1}{2}t^2u(t)$,

$$e(\infty) = e_{\text{parabola}}(\infty) = \frac{1}{\lim_{s\to 0} s^2G(s)}$$

Position constant, K_p, where

$$K_p = \lim_{s\to 0} G(s)$$

Velocity constant, K_v, where

$$K_v = \lim_{s\to 0} sG(s)$$

Acceleration constant, K_a, where

$$K_a = \lim_{s\to 0} s^2G(s)$$

$$f^*(t) = \sum_{k=0}^{\infty} kT\delta(t - kT)$$

$$F^*(s) = \sum_{k=0}^{\infty} kTe^{-kTs}$$

$$e^{-kTs} = Z^{-k}$$