1 (a) $G_1 \Rightarrow$ Not possible as all the three conditions won't satisfy at the same time.

(2)

(b) 10% OS , $T_s = 20$

$$\exp\left(\frac{-\pi \xi_1}{\sqrt{1-\xi_1^2}}\right) = 0.1$$

$$\xi_1 = 0.5911$$

for 2% tolerence , $T_s = 20 = 4\tau$

$$\frac{4}{\omega_{n_1}\xi_1} = 20 \Rightarrow \omega_{n_1} = 0.3383$$

(1)

$$G_2 = \frac{\omega_{n_1}^2}{s^2 + 2\xi_1\omega_{n_1}s + \omega_{n_1}^2}$$

10% OS , $T_p = 3$ sec

$$\xi_2 = 0.5911$$

$$T_p = \frac{\pi}{\omega_{n_2}\sqrt{1-\xi_2^2}} = 3$$

$$\omega_{n_2} = 1.298$$

(1)

$$G_3 = \frac{\omega_{n_2}^2}{s^2 + 2\xi_2\omega_{n_2}s + \omega_{n_2}^2}$$

$T_p = 3$ sec , $T_s = 20$ sec

$$\frac{4}{\xi_3 \omega_{n3}} = 20 \Rightarrow \omega_{n3} = \frac{1}{5\xi_3}$$

$$T_p = \frac{\pi}{\omega_{n3}\sqrt{1-\xi_3^2}} = 3$$

$$\frac{5\pi\xi_3}{\sqrt{1-\xi_3^2}} = 3$$

1

$$\xi_3 = 0.1875$$

$$\omega_{n3} = 1.0661$$

$$G_4 = \frac{\omega_{n3}^2}{s^2 + 2\xi_3\omega_{n3}s + \omega_{n3}^2}$$

2.(a)

① $\frac{8}{s^2+2s+8} \rightarrow \underline{\underline{f}} \rightarrow$ - system underdamped
- Simple 2nd Order system

② $\frac{s+8}{s^2+2s+8} \rightarrow \underline{\underline{d}} \rightarrow$ - system underdamped
- addition of zero with +ve coeff.
- rise time decreases

③ $\frac{-s+8}{s^2+2s+8} \rightarrow \underline{\underline{a}} \rightarrow$ - system underdamped
- addition of zero with -ve coeff.
- rise time increases initially goes below zero & comes up

④ $\frac{s+8}{s^2+30s+8} \rightarrow \underline{\underline{e}} \rightarrow$ - 2nd order system
- overdamped system (no peak)

⑤ $\frac{3s+2}{2s+2} \rightarrow \underline{\underline{b}} \rightarrow$ - 1st order system
- unit step + decaying exponential
$u(t) + \frac{1}{2}e^{-t}$

⑥ $\frac{s+2}{2s+2} \rightarrow \underline{\underline{c}} \rightarrow$ - 1st order system
- unit step - decaying exponential
$u(t) - \frac{1}{2}e^{-t}$

⑦ $\frac{s+8}{s-8} \rightarrow$ NA $\rightarrow$ - 1st order
- unstable system

a) $\frac{s+8}{s^2+2s+8}$ b) $\frac{s+8}{s^2+70s+8}$ c) $\frac{3s+2}{2s+2}$ d) $\frac{s+2}{2s+2}$ e) $\frac{-s+8}{s^2+2s+8}$

f) $\frac{8}{s^2+2s+8}$ g) $\frac{s+8}{s-8}$

IVT

$\lim_{s\to\infty} sF(s)$.

$= \lim_{s\to\infty} \frac{1}{s} \cdot s \cdot F(s)$.

a) 0

b) 0

c) 3/2

d) 1/2

e) 0

f) = 0

g) 1

FVT

$\lim_{s\to 0} F(s)$

a) 1

b) 1

c) 1

d) 1

e) 1

f) 1

g) NA

IRR.

$\lim_{s\to\infty} sF(s)$

a) 1

b) 1

c) $\frac{3}{2} + \frac{-1}{(2s+2)}$

$L^{-1}\left(\frac{1}{2s+2}\right)\Big|_{t=0} = -\frac{1}{2}$

d) $\frac{1}{2} + L^{-1}\left(\frac{1}{2(s+1)}\right)\Big|_{t=0} = \frac{1}{2}$

e) -1

f) 0

g) 16.

Mark

Q.2 (a)

Sub-parts	Marks
6	2
4	1.5
2	0.5
1	0.5
0	0

if all subparts are correct

(b)

Subparts	Marks
7	3
4	2
2	1
1	0.5
0	0

Q3) $G(s) = \dfrac{\omega_n^2}{s^2 + 2\xi\omega_n s + \omega_n^2}$ $\quad 0 < \xi < 1$

a) constant % overshoot curve (C_1)

1 mark

b) constant T_s curve (C_2)

Real part of root is constant.

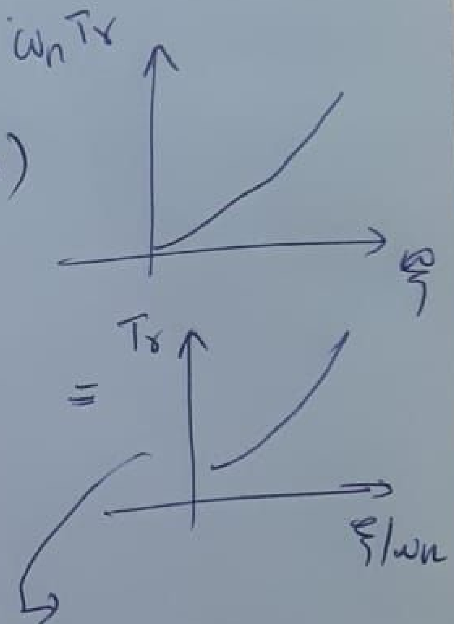
1 mark

b) Along C_2 ⟹ T_p decreases (since $\omega_d \uparrow$)

1.5 mark

% OS increases

T_r decreases



=

Along C_1 :⟹ T_p decreases

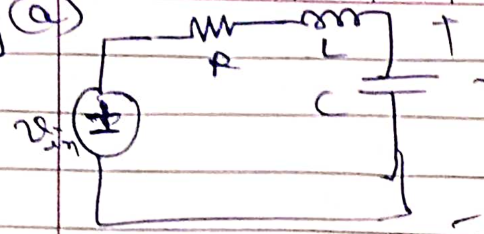
1.5 mark

T_s decreases

T_r decreases

ξ decreases, ω_n increases ⟹ T_r decreases

Q04 (a)



$$\frac{v_o}{v_{in}} = \frac{1/sC}{1/sC + R + sL}$$

$$\frac{v_o}{v_{in}} = \frac{1}{s^2LC + RCs + 1}$$

$$\frac{v_o}{v_{in}} = \frac{1/LC}{s^2 + \frac{R}{L}s + 1/LC}$$

$$\omega_n = \frac{1}{\sqrt{LC}}, \quad 2\xi\omega_n = \frac{R}{L}$$

$$\xi = \frac{R\sqrt{LC}}{2L} \Rightarrow$$

$$\boxed{\xi = \frac{R}{2}\sqrt{\frac{C}{L}}}$$

taking $C = 10^{-8}F$, $L = 10^{-6}H$ ~~R=10~~

$R = 10\Omega$.

$$\xi = \frac{10}{2}\sqrt{\frac{10^{-8}}{10^{-6}}} \Rightarrow = 0.5$$

$\Rightarrow$ Underdamped.

(b) Same circuit with large R value can be an overdamped system

Let take $R = 10K$.

$C = 10^{-8}F$, $L = 10^{-6}H$

$$\xi = \frac{10 \times 10^3}{2} 10^{-1}$$

$$\xi = 500$$

$\hookrightarrow$ hence overdamped for large R.

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YOUVA

(c) In both the above cases (a) & (b) input is taken Voltage source & output is ~~taken~~ voltage across capacitor (V_0).

Marking pattern

a) 1 marks → Circuit with transfer fn.
1 marks → choosing R, L, C s.t. it is ~~overdamped~~ Underdamped & R is small.

b) 1 marks → ckt with transfer fn.
1 marks → choosing R, L, C, s.t. it is overdamped & R is Large.

c) ~~1 marks~~ 0.5 mark for part (a) i/p & o/p
0.5 mark for part (b) i/p & o/p.

Q5

(a) $$G(s) = \frac{1}{s^2+2\zeta s+1}$$

Transfer function after addition of pole and taking the step response will look like:→

$$C(s) = \frac{a}{s(s^2+2\zeta s+1)(s+a)}$$ ← to handle steady state value

taking partial fraction of C(s)

$$C(s) = \frac{A}{s} + \frac{Bs-C}{s^2+2\zeta s+1} + \frac{D}{(s+a)}$$

here we assumed that the nondominant pole a is located at $-c$ on the real axis

After calculation for A, B, C and D, we get:→

$$A = 1$$

$$C = \frac{4\zeta^2 a - 2\zeta a^2 - a}{a^2 - 2\zeta a + 1}$$

$$B = \frac{2\zeta a - a^2}{a^2 - 2\zeta a + 1}$$

$$D = \frac{-1}{a^2 - 2\zeta a + 1}$$

now as the nondominant pole $a \to \infty$;

$$\lim_{a \to \infty} D = \lim_{a \to \infty} \frac{-1}{a^2 - 2\rho a + 1} = 0$$

$$\therefore D = 0$$

$$\lim_{a \to \infty} C = \lim_{a \to \infty} \frac{4\rho^2 a - 2\rho a^2 - a}{a^2 - 2\rho a + 1} = -2\rho$$

$$\therefore C = -2\rho$$

$$\lim_{a \to \infty} B = \lim_{a \to \infty} \frac{2\rho a - a^2}{a^2 - 2\rho a + 1} = -1$$

$$\therefore B = -1$$

$$\lim_{a \to \infty} A = \lim_{a \to \infty} (1) = 1 \qquad \therefore A = 1$$

Thus we observed the residue (i.e. D) of the nondominant pole and its response becomes zero as the nondominant pole approaches infinity.

(b) $$G(s) = \frac{1}{s^2+2\xi s+1}$$

adding a pole to $G(s)$ "such that steady state gain is not disturbed":→

But here two cases may happen zero can lie on left half plane or on right half plane too.

Case 1:→ on left half plane

$$G(s) = \frac{(s/a+1)}{s^2+2\xi s+1}$$

step response:→

$$C(s) = \frac{(s/a+1)}{s(s^2+2\xi s+1}$$

$$C(s) = \frac{1}{s(s^2+2\xi s+1)}(s/a) + \frac{1}{s(s^2+2\xi s+1)}$$

if $a \to \infty$ then

$$C(s) = \frac{1}{s(s^2+2\rho s+1)}\cancelto{0}{\left(\frac{s}{a}\right)} + \frac{1}{s(s^2+2\rho s+1)}$$

$$\therefore\ C(s) = \frac{1}{s(s^2+2\rho s+1)}$$

<u>case 2:-</u> when zero added on right half plane

$$C(s) = \frac{(1 - s/a)}{s(s^2+2\rho s+1)}$$

$$C(s) = \frac{1}{s(s^2+2\rho s+1)} - \left(\frac{s}{a}\right)\left(\frac{1}{s(s^2+2\rho s+1)}\right)$$

if $a \to \infty$

$$C(s) = \frac{1}{s(s^2+2\rho s+1)} - \cancelto{0}{\left(\frac{s}{a}\right)\frac{1}{s(s^2+2\rho s+1)}}$$

$$\therefore\ C(s) = \frac{1}{s(s^2+2\rho s+1)}$$

method 2:→

For additional zero to be neglected

take zero as:→

$$s = -\frac{1}{\epsilon}$$

$$TF = \frac{\epsilon s + 1}{s^2 + 2\rho s + 1}$$

now proceed further.