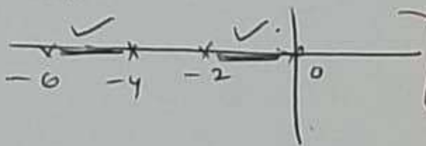
Ques. 1. $G(s) = \dfrac{1}{s(s+2)(s+4)(s+6)}$ $\quad K > 0$

① $\sigma_a = \dfrac{0-2-4-6}{4}$

$= -3$



(3).

② $\theta_a = \dfrac{(2K+1)\pi}{4}$ $\quad (K = 0, 1, 2, 3)$

$= 45°, 135°, 225°, 315°.$

② Calculation of Breakaway points (4).

(with / without symmetry)

$\left(\dfrac{dK}{ds} = 0\right)$

$$1 + \frac{K}{s(s+2)(s+4)(s+6)} = 0$$

$$K = -[s(s+2)(s+4)(s+6)]$$

$$\frac{dK}{ds} = -\frac{d}{ds}[s^4 + 12s^3 + 44s^2 + 48s] = 0$$

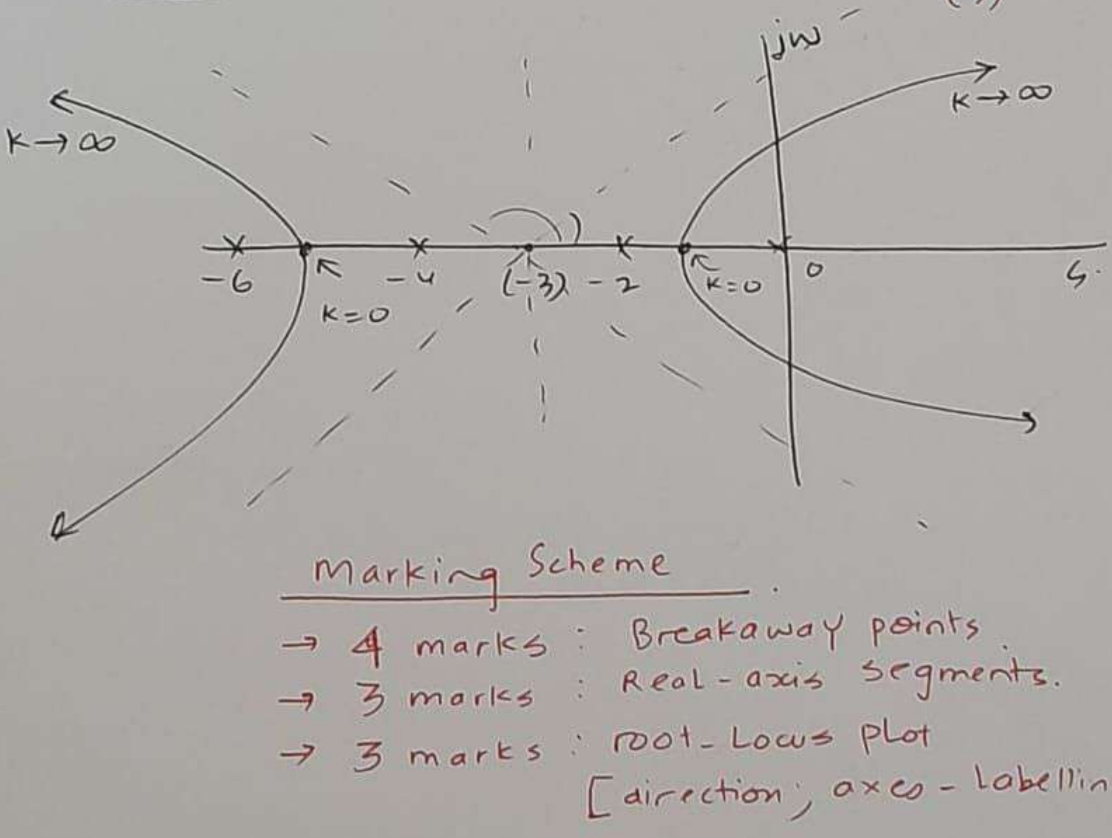
$$s = -5.255,\ -3,\ -0.780$$

valid pts. $s = -5.255,\ -0.780.$

$(-3-\sqrt{5}) \qquad (-3+\sqrt{5}).$

③ Plot.

(3)



Marking Scheme

→ 4 marks : Breakaway points.

→ 3 marks : Real-axis segments.

→ 3 marks : root-Locus plot [direction, axes-labelling, etc].

Q2

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

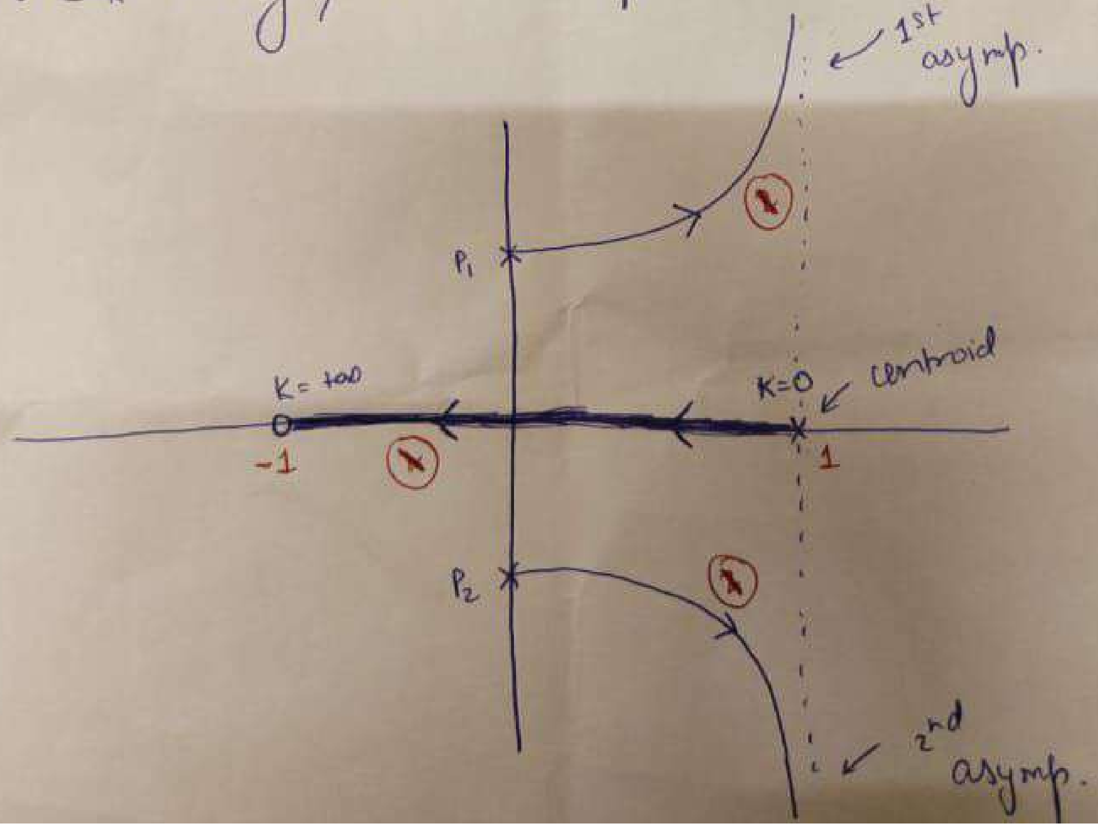
no. of asymp. line $= p - z$
$= 3 - 1$
$= 2$ (1)

angle of asymp. $= \dfrac{(2q+1)180^\circ}{p-z}$
$= (2q+1)90^\circ$ (x)
if $q = 0 = 90^\circ$
$q = 1 = 270^\circ$

angle of departure :→ (3)
for $P_1 = 180^\circ - (90^\circ + 135^\circ) + 45^\circ$
$= 0^\circ$
for $P_2 = -180^\circ - (-135^\circ - 90^\circ) - 45^\circ$
$= 0^\circ$

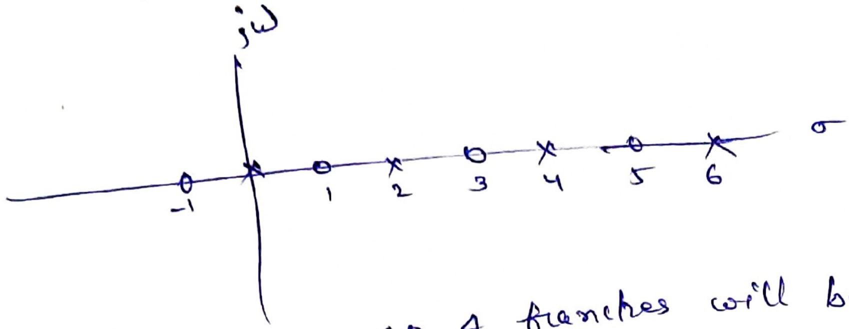
centroid $= \dfrac{\Sigma p - \Sigma z}{p - z} = \dfrac{(1 + (j) - (j)) - (-1)}{3-1} = 1$ (1)

(do calculations req. to show this ↓) (1)
⇒ no break away / break in points.



Q03 Case 1 for $K > 0$

Location of poles & zeroes in s-plane

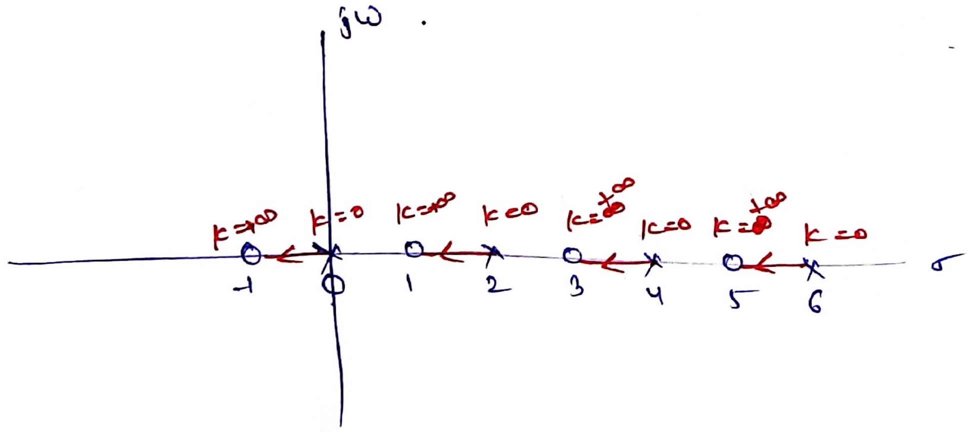


→ $N = P = 4$, so 4 branches will be there

→ ∴ $N = P$, all the root locus branches start at finite open loop poles & end at finite open loop zeroes

→ Left to odd no. of poles/zeros root locus branch exists (on real line)

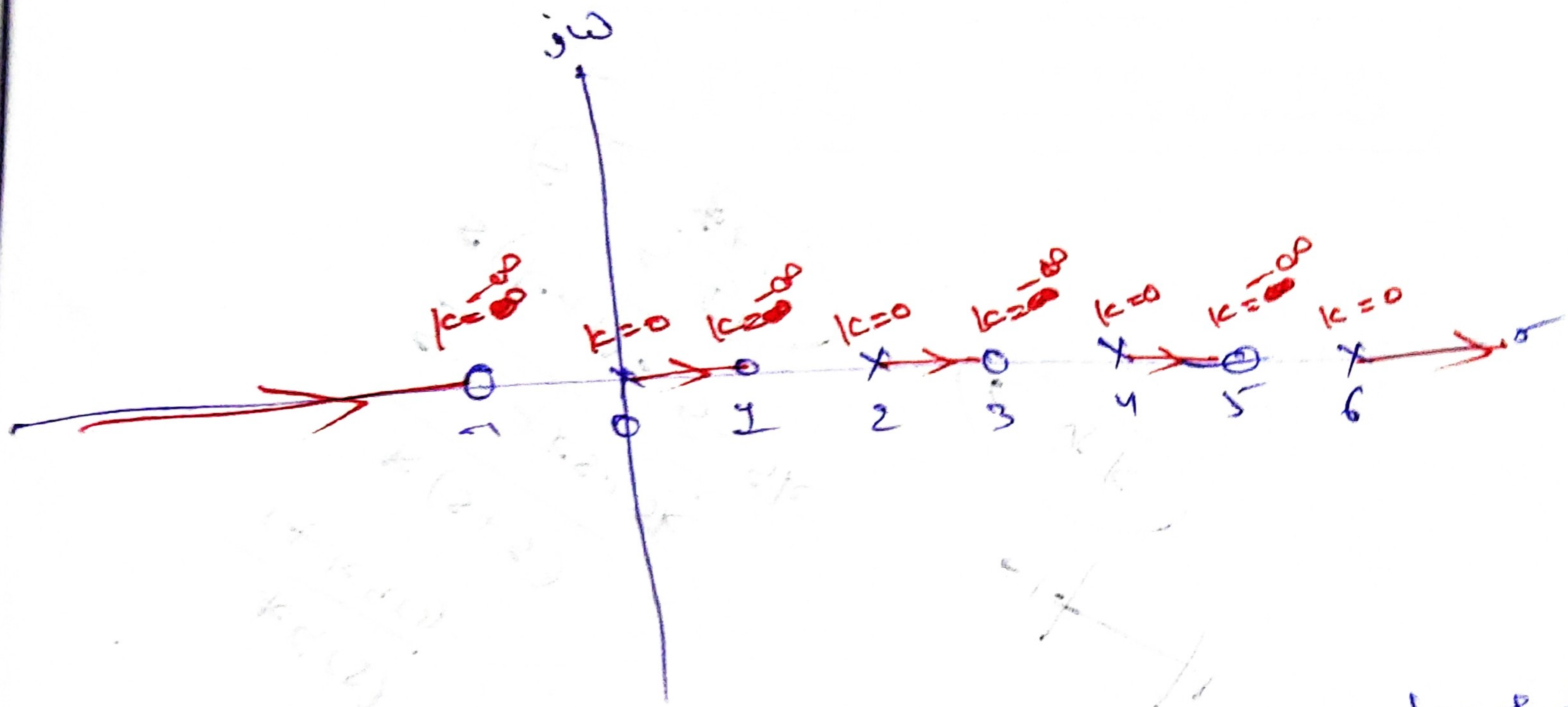
→ No 2 branches meeting towards each other (or exiting away from each other) on the real axis so no breakaway/break-in pts.



Case 2 for $K < 0$

~~System~~ root locus rule will be followed as same as positive feedback system

→ Left to even no. of poles/zeros root locus branch exists (on real line)



⇒ similar reason as above for no breakin & break-away pts.

Scanned with ACE Scanner

Marking scheme

$K > 0 \rightarrow$ 2 mark $\rightarrow$ reasoning behind root locus branches & ~~root~~ poles/zeros correct location

3 mark $\rightarrow$ correct root locus diagram.

$K < 0 \rightarrow$ same as above case.

Q4) (a) Initial rise rate - 4m (0.5 each)

(1) -1 (2) 1 (3) 1 (4) $-\frac{1}{2}$ (5) 0 (6) $\frac{4}{3}$ (7) 1 (8) $\frac{1}{2}$

(b) $C_1 \rightarrow$ (4)

$C_2 \rightarrow$ (8)

$C_4 \rightarrow$ (6)

$C_8 \rightarrow$ (1)

(2m - 0.5 each)

For $C_3, C_5, C_6, \boxed{C_7} \rightarrow$ no match

(4m) - 0.5 each

$C_7 \rightarrow$ (5) R.R - zero

* For C_7 marks given for both cases provided suitable assumption is used.

(c) $C_5 \rightarrow$ U.D, Initial value is non zero const ($\because$ T.F is biproper)

Rise rate $= 0$, F.V = 1.

$$G(s) = \frac{2.5(s+1)(s+2)}{s^2+2s+5}$$

$C_6, C_7 \rightarrow$ U.D, I.V = 0, F.V = 1. But rise rate of C_6 is higher than C_7

$$C_6 \rightarrow \frac{2s+5}{s^2+2s+5}$$

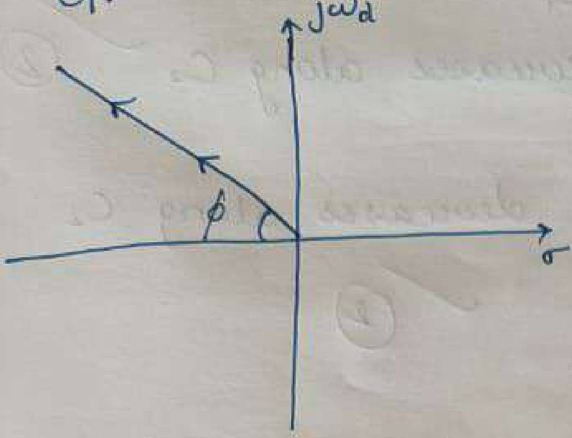
$$\boxed{C_7 \rightarrow \frac{s+5}{s^2+2s+5}}$$

(or) C_3

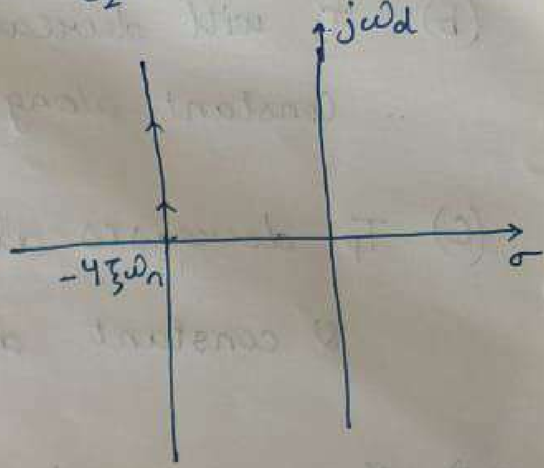
$$C_3 \rightarrow \frac{2}{s+2}$$

5 (a)

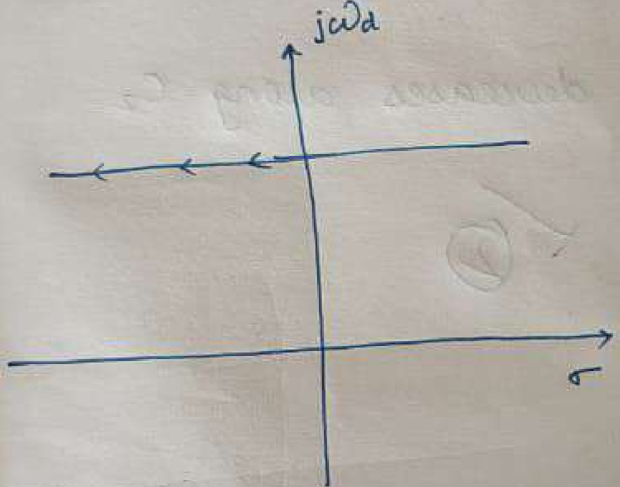
C_1:



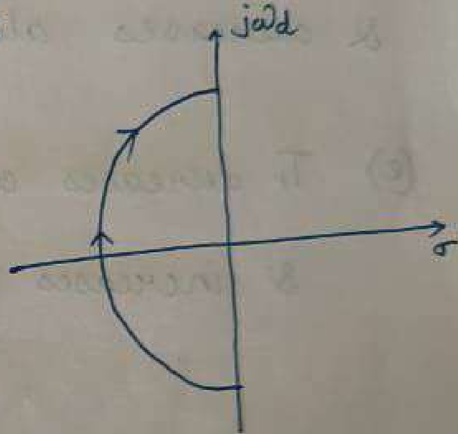
C_2:



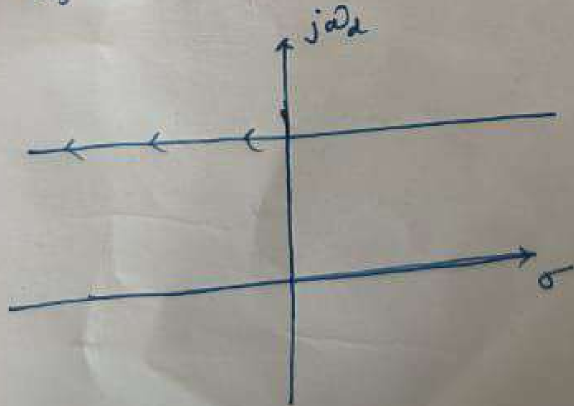
C_3:



C_4:



C_5:



2

3

(b) T_s will decrease along C_1

∴ Constant along C_2 & decreases along C_3 2

(c) T_p decreases along C_1, decreases along C_2

& constant along C_3 2

(d) % OS is constant along C_1, increases along C_2

& decreases along C_3 2

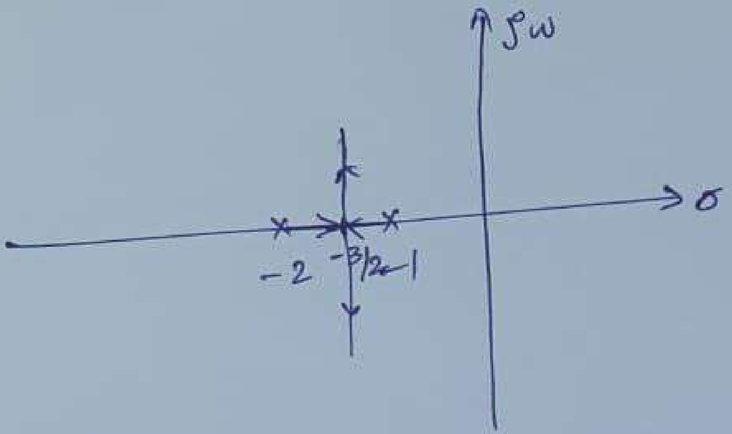
(e) T_r decreases along C_1, decreases along C_2

& increases along C_3 2

7

marking scheme for Q5:
Part(a) has 3 marks.
(b),(c),(d) and (e) have 2 marks each but if all are correct then will get 7 marks.

6) a) $G(s) = \dfrac{n(s)}{d(s)} = \dfrac{1}{s^2+3s+2} = \dfrac{1}{(s+1)(s+2)}$



Marks split

$\underbrace{4+3}+3 = 10$

Root locus → 2 marks
comments → 2/1 mark

$$\sigma_a = \frac{\sum \text{finite poles} - \sum \text{finite zeros}}{\#\text{finite poles} - \#\text{finite zeros}} = \frac{-2-1}{2} = -3/2$$

At $\sigma_a = -3/2$, we have $\xi\omega_n = \cancel{-3/2}\ 3/2$

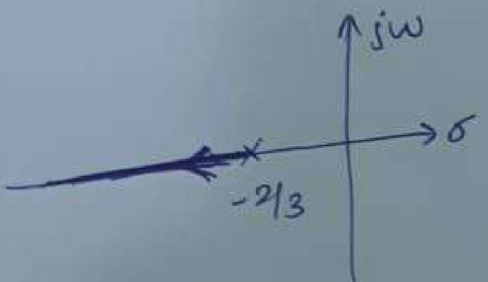
constant settling time at $-3/2$

$T_s = \dfrac{4}{\xi\omega_n} = \dfrac{4}{3/2} = 8/3 > 2$

$\therefore$ $T_s \leq 2$ and 2% overshoot not possible.

b) Same as previous, $T_s \leq 1 \Rightarrow$ not possible.

c) $G(s) = \dfrac{1}{3s+2} = \dfrac{1/3}{s+2/3}$



Not possible to have $T_p = 2s$ and %OS

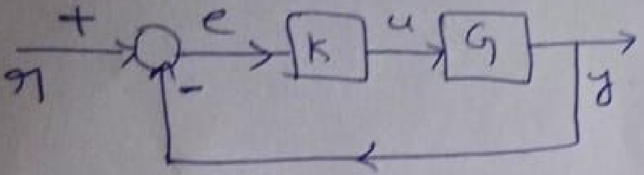
$T_s = 4/a$

$a = 2/3$

$= \dfrac{4}{2/3} = 6$

$T_s \leq 1$ ~~not~~ possible

Q7.



$$\boxed{\frac{Y(s)}{R(s)} = \frac{KG(s)}{1+KG(s)}} \quad , R(s) = \frac{1}{s}$$

$$E(s) = R(s) - Y(s)$$

$$= R(s) - \frac{KG(s)R(s)}{1+KG(s)}$$

$$= R(s)\left[1 - \frac{KG(s)}{1+KG(s)}\right]$$

$$E(s) = \frac{1}{s}\left[\frac{1+KG(s)-KG(s)}{1+KG(s)}\right]$$

$$= \frac{1}{s}\left[\frac{1}{1+KG(s)}\right]$$

marking scheme for Q7:
2.5 each for plots,
2.5 for cheking stability and
error transfer function

steady state error

$$SSE(\infty) = \lim_{s\to 0} sE(s) = \lim_{s\to 0} s \cdot \frac{1}{s}\left[\frac{1}{1+KG(s)}\right] = \lim_{s\to 0}\left[\frac{1}{1+KG(s)}\right]$$

a) $G(s) = \frac{5}{s+5}$

$$SSE = \lim_{s\to 0}\left[\frac{1}{1+K\frac{5}{s+5}}\right] = \lim_{s\to 0}\left[\frac{s+5}{s+5+5K}\right]$$

$$SSE = \frac{5}{5+5K}$$

b) $G(s) = \frac{s-5}{s+5}$

$$SSE = \lim_{s\to 0}\left[\frac{1}{1+K\frac{(s-5)}{s+5}}\right] = \lim_{s\to 0}\left[\frac{s+5}{s+5+(s-5)K}\right] = \lim_{s\to 0}\frac{s+5}{s(K+1)+5-5K}$$

$$= \frac{5}{5-5K}$$

c) $G(s) = \frac{s+5}{s-5}$

$$SSE = \lim_{s\to 0}\left[\frac{1}{1+K\frac{(s+5)}{s-5}}\right] = \lim_{s\to 0}\left[\frac{s-5}{s-5+Ks+5K}\right] = \frac{-5}{+5K-5} = \frac{5}{5-5K}$$ ///

- To plot the steady state error we need to check the stability of the closed loop system to have the range of k.

a) $G(s) = \dfrac{5}{s+5}$.

$1 + k\,G(s)H(s) = 0$

$1 + K \dfrac{5}{s+5} = 0$

$s + 5 + 5k = 0$

$\Rightarrow s = -(5 + 5k)$

for $5 + 5k > 0$

$\boxed{K > -1}$ stable.

b) $G(s) = \dfrac{s-5}{s+5}$.

$1 + K\,G(s)\,H(s) = 0$

$1 + k\dfrac{(s-5)}{s+5} = s + 5 + ks - 5k$

$\Rightarrow s(K+1) = 5K - 5$

$s = \dfrac{5K-5}{K+1}$

K values $\cancel{(K>1)} \cup \cancel{(K<-1)}$

$\underline{-1 < K < 1}$

for stability

c) $G(s) = \dfrac{s+5}{s-5}$.

$1 + k\left(\dfrac{s+5}{s-5}\right) = 0$

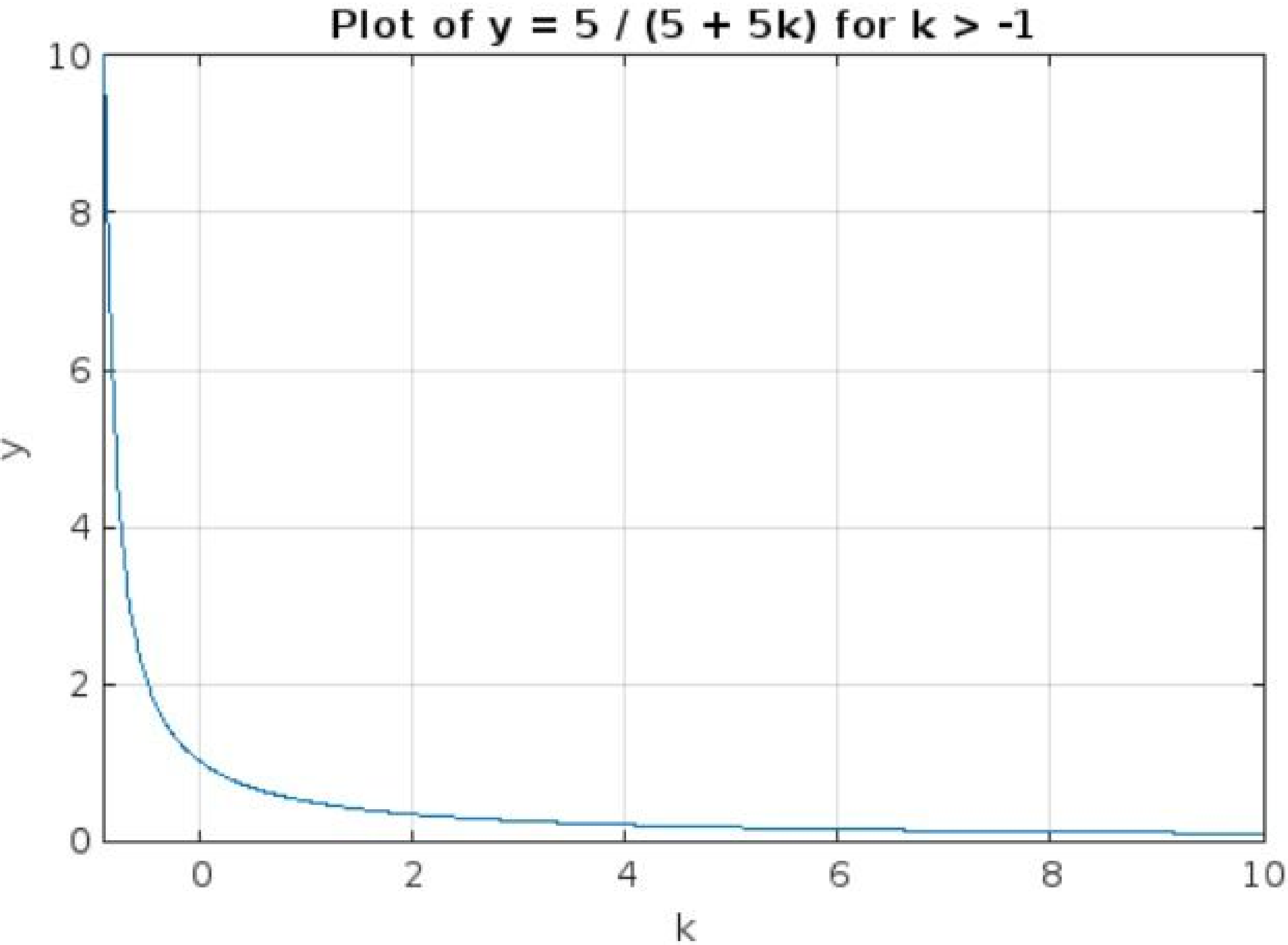
$s - 5 + ks + 5k = 0$

$s(k+1) + 5k - 5 = 0$

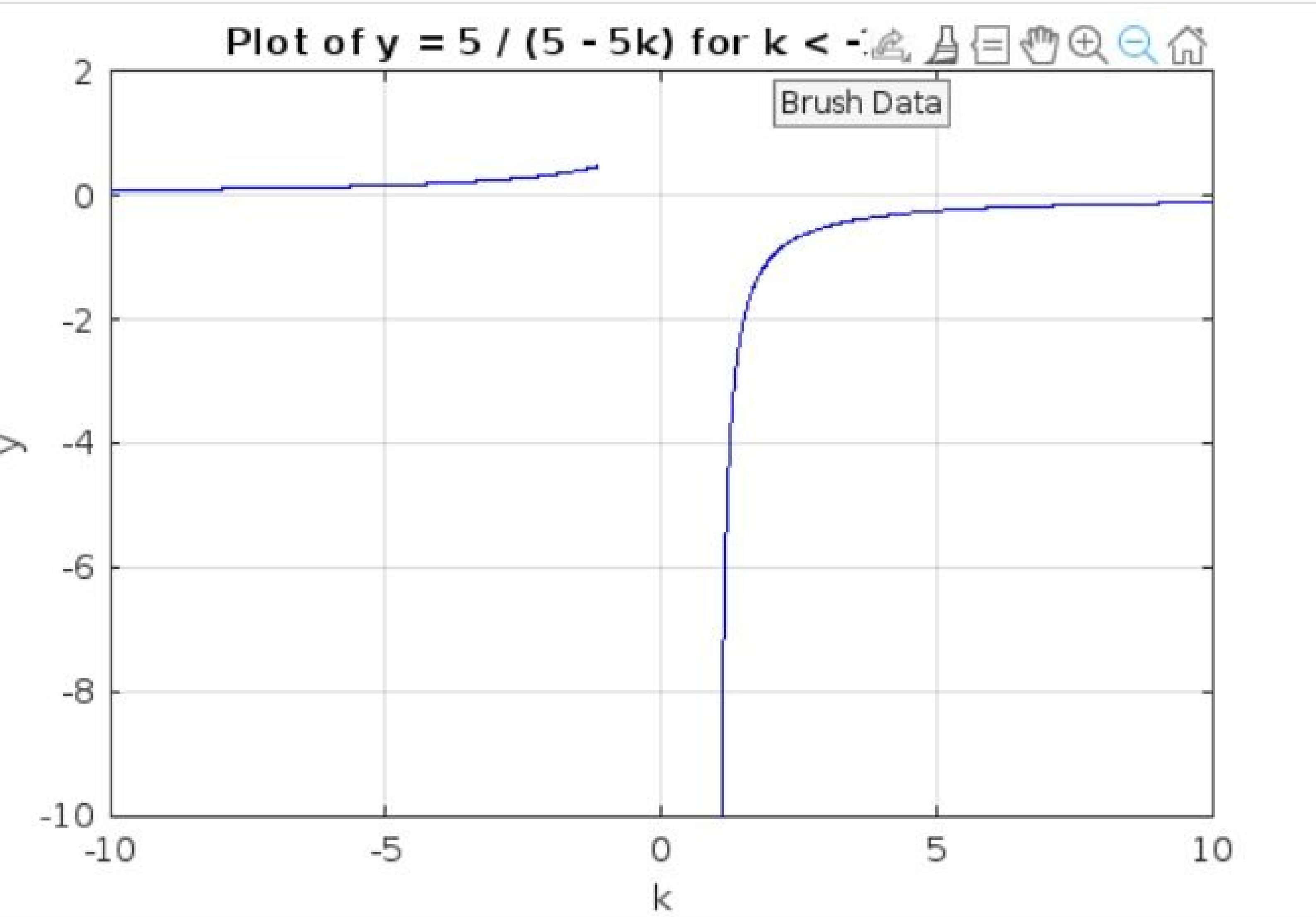
$s = \dfrac{5 - 5k}{k+1}$

K values $(k > 1) \cup (K < -1)$

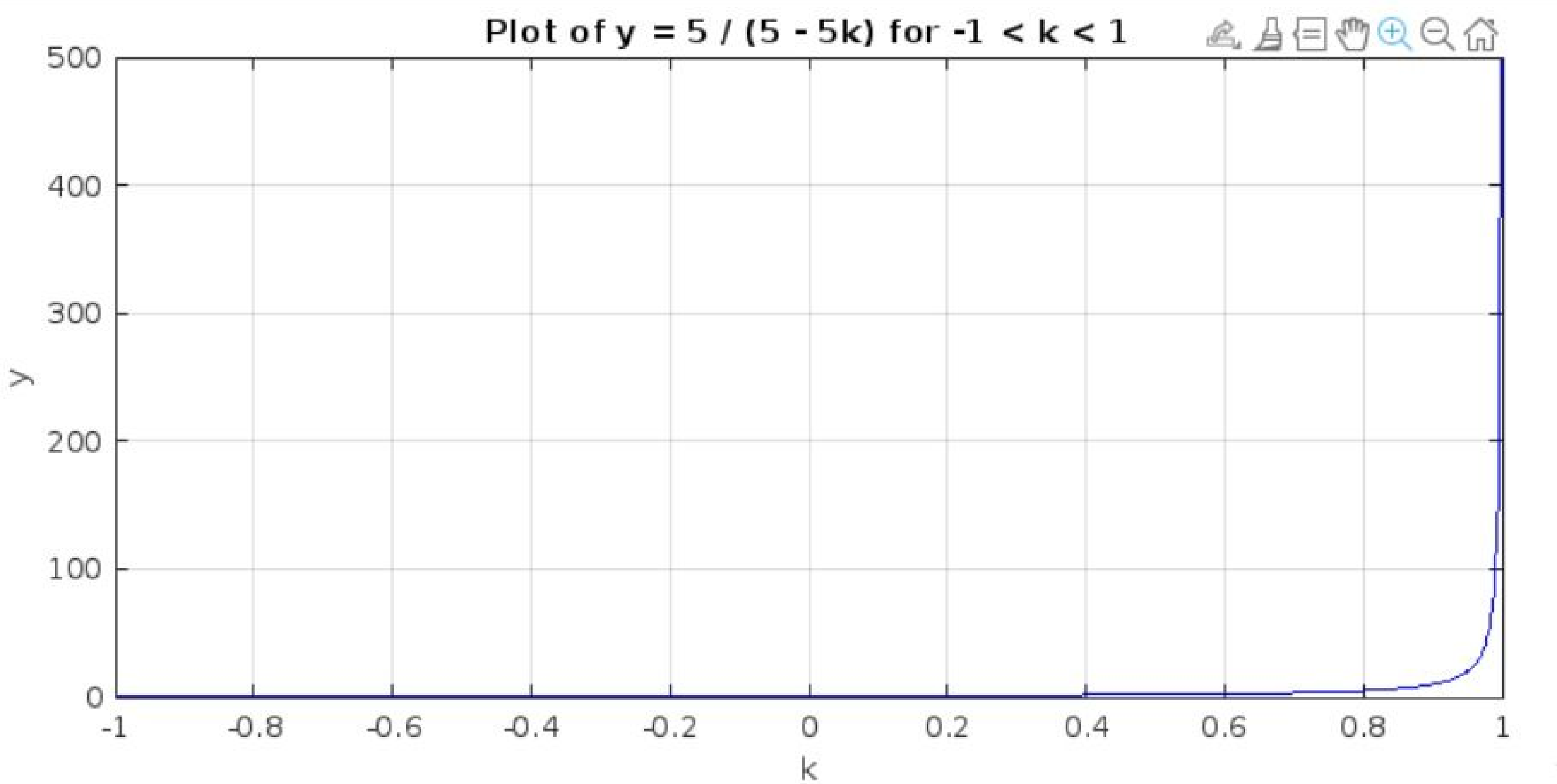
for stability.



Plot of y = 5 / (5 + 5k) for k > -1
10
8
6
4
2
0
y
0
2
4
6
8
10
k



Plot of y = 5 / (5 - 5k) for k < -
Brush Data
y
k
2
0
-2
-4
-6
-8
-10
-10
-5
0
5
10


Plot of y = 5 / (5 - 5k) for -1 < k < 1
500
400
300
200
100
0
y
-1
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1
k