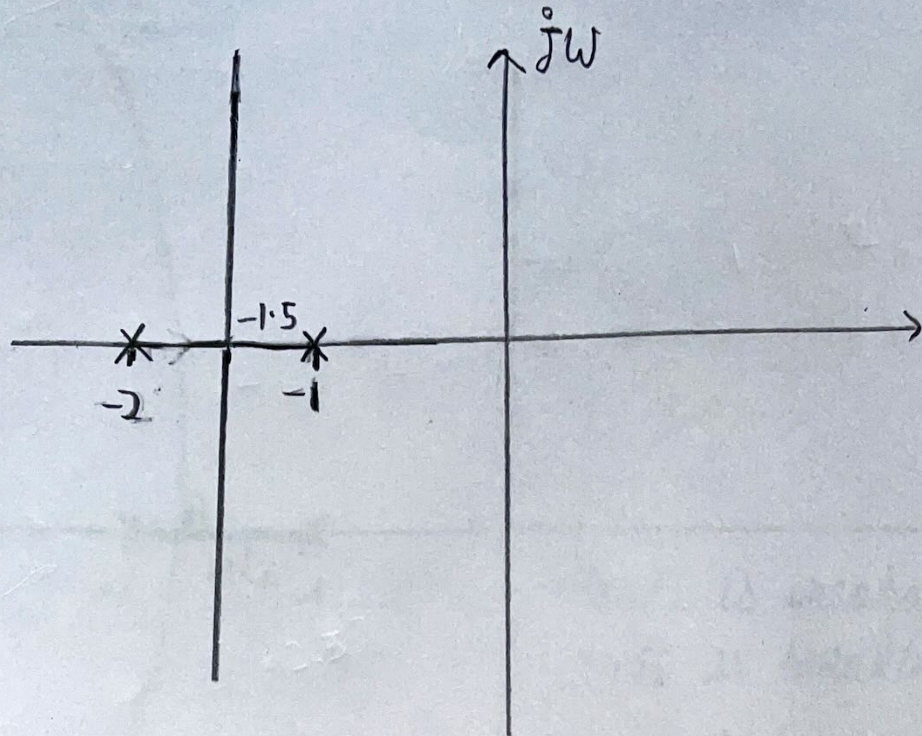
A)



Breakaway Point = -1.5

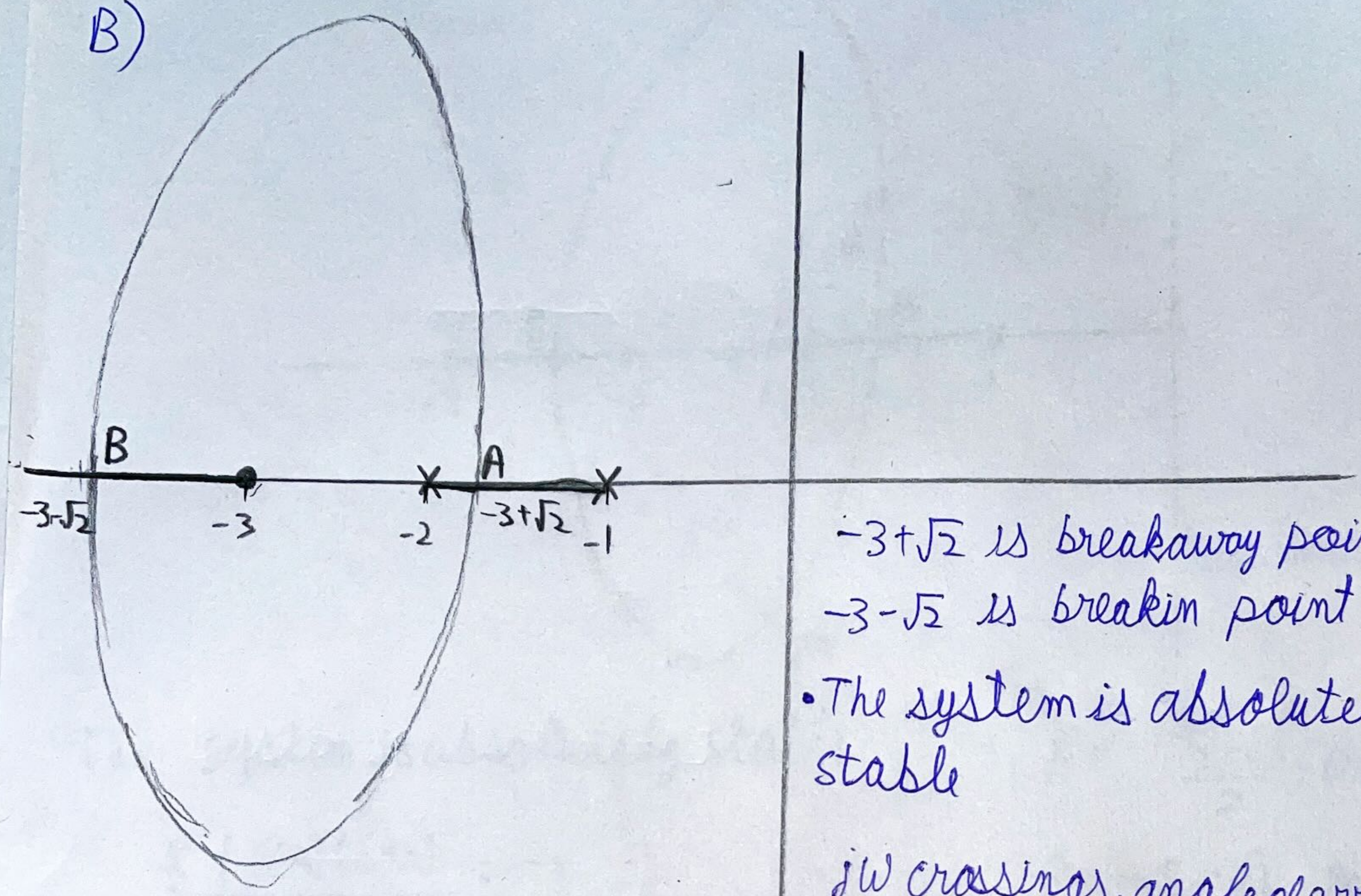
At $s = -1.5$

$$\frac{K}{(-0.5)(0.5)} = -1 \Rightarrow K = 0.25$$

$\Rightarrow K > 0.25$

$\because$ $\forall K \in (0, \infty)$ poles are in left half of plane system is absolutely stable

B)



$-3+\sqrt{2}$ is breakaway point ie. A

$-3-\sqrt{2}$ is breakin point ie. B

- The system is absolutely stable

$j\omega$ crossings, angle of arrival, departure are NA

$$\frac{K(s+3)}{s^2+3s+2}+1=0$$

For Breakaway

$$\frac{dK}{ds}=0$$

$$K=-\frac{(s^2+3s+2)}{s+3}$$

$$\frac{dK}{ds}=\frac{-(2s+3)(s+3)+(s^2+3s+2)}{(s+3)^2}=0$$

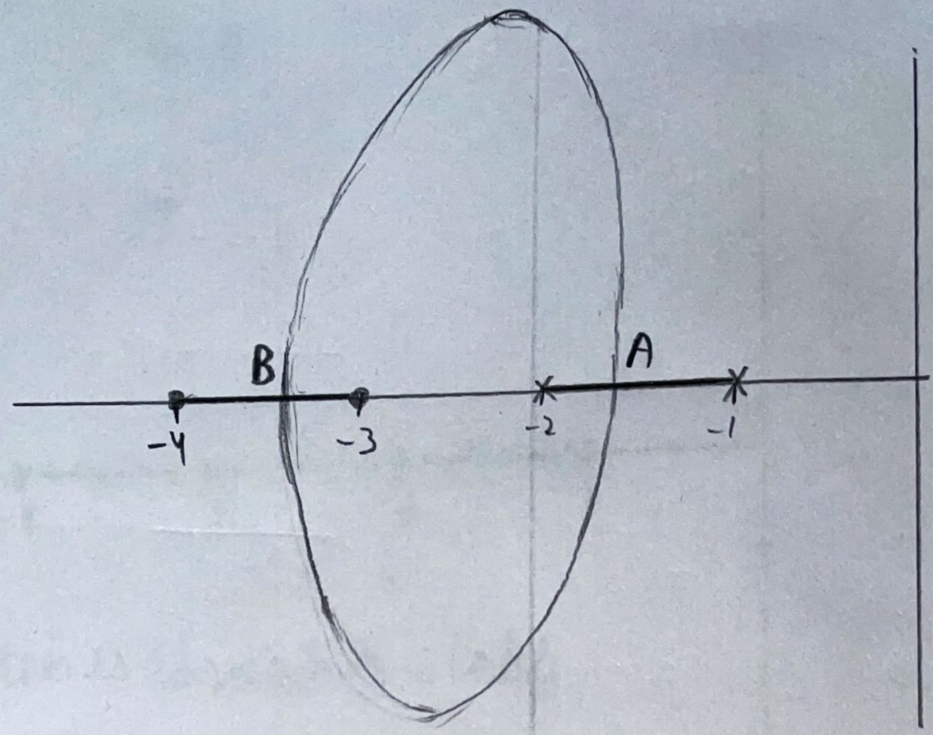
$$\Rightarrow s^2+3s+2=2s^2+9s+9$$

$$s^2+6s+7=0$$

$$s=-3-\sqrt{2},\ -3+\sqrt{2}$$

For both $K>0 \Rightarrow$ Valid

c)



The system is absolutely stable

$$\frac{K(s+3)(s+4)}{(s+1)(s+2)} = -1$$

$$K = \frac{-(s+1)(s+2)}{(s+3)(s+4)}$$

$\frac{dK}{ds} = 0$, $K > 0 \Rightarrow s \in (-2,-1) \cup (-4,-3)$

$$K = \frac{-(s^2+3s+2)}{(s^2+7s+12)}$$

$$\frac{dK}{ds} = \frac{-\left[(2s+3)(s^2+7s+12) - (2s+7)(s^2+3s+2)\right]}{(s^2+7s+12)^2} = 0$$

$$2s^3 + 17s^2 + 45s + 36 = 2s^3 + 13s^2 + 25s + 14$$

$$4s^2 + 20s + 22 = 0$$

$$2s^2 + 10s + 11 = 0$$

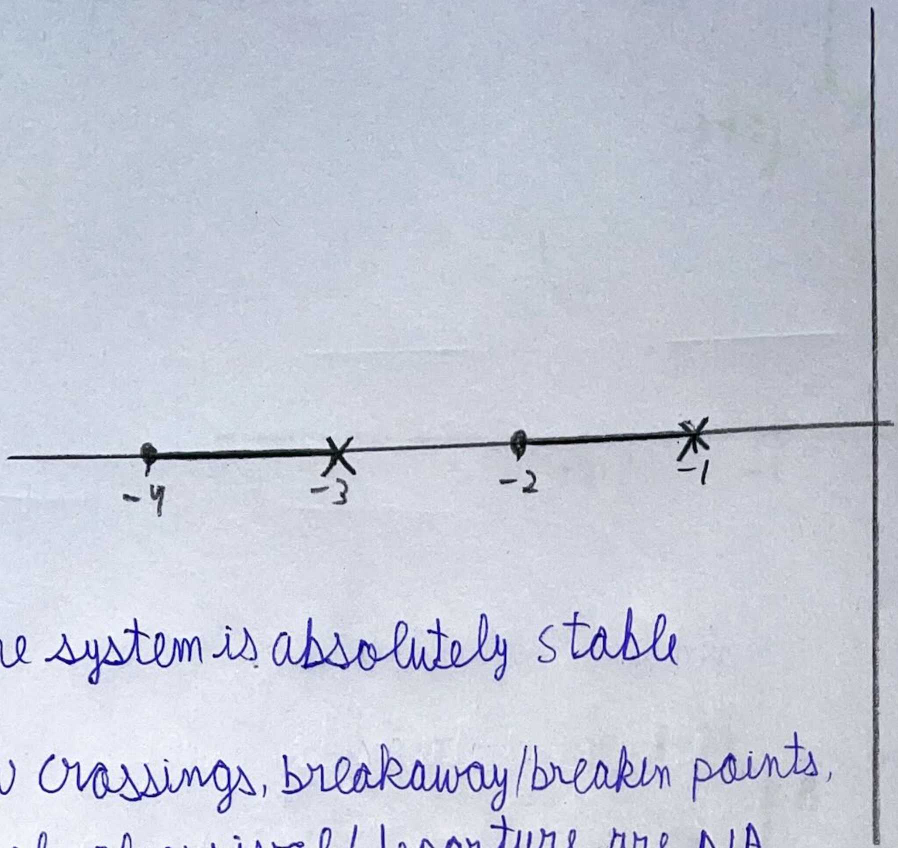
$s = \frac{-5-\sqrt{3}}{2}, \frac{-5+\sqrt{3}}{2}$

$A = \frac{-5+\sqrt{3}}{2}$, Breakaway

$B = \frac{-5-\sqrt{3}}{2}$, Breakin

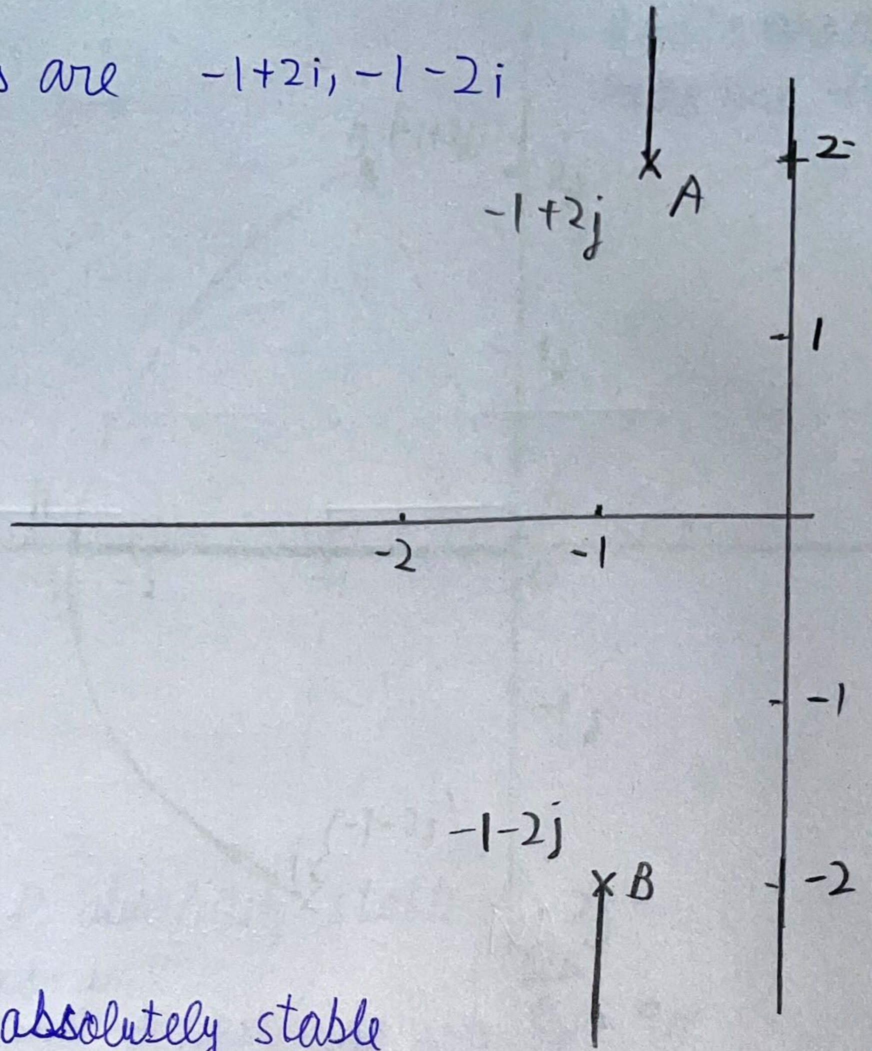
$j\omega$-crossing, angle of arrival/departure is NA

D)



- The system is absolutely stable
- jw crossings, breakaway/breakin points, angle of arrival/departure are NA.

E) The poles are $-1+2i, -1-2i$



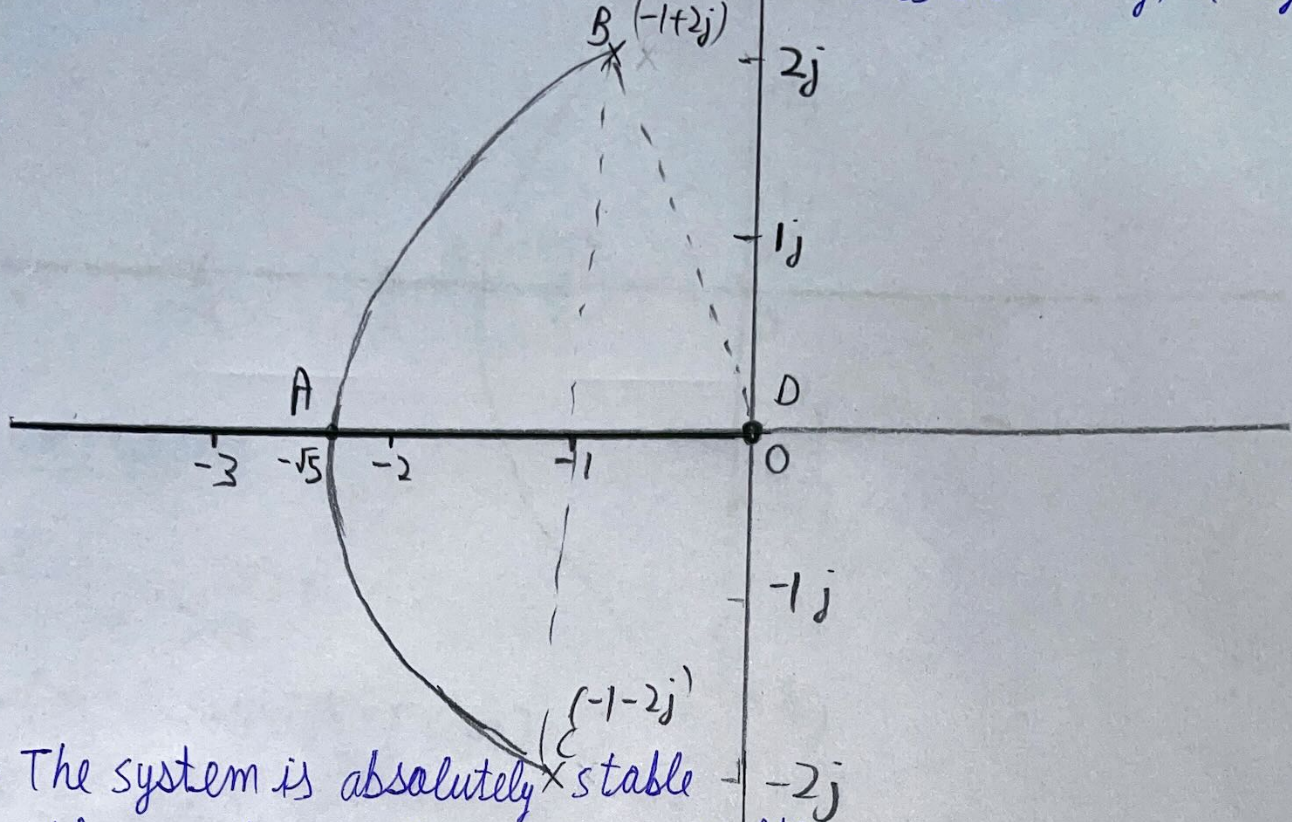
- The system is absolutely stable
- $j\omega$-crossings, breakaway / breakin points ~~angle~~ are NA
- ϕ_d for A: 90°

  ϕ_d for B: -90°

F)

Roots are 0

Poles are $-1+2j, -1-2j$



- The system is absolutely stable with variation in K
- $j\omega$-crossings are not there
- $\frac{KS}{s^2+2s+5} = -1 \Rightarrow K = -\frac{(s^2+2s+5)}{s}$

$$K = -\left(s + \frac{5}{s} + 2\right)$$

$$\frac{dK}{ds} = 0, \; K > 0$$

$$-\left(1 - \frac{5}{s^2}\right) = 0$$

$$\Rightarrow s^2 = 5$$

$$s = \sqrt{5}, -\sqrt{5}$$

$s = \sqrt{5}$, $K < 0$

$s = -\sqrt{5}$, $K > 0 \Rightarrow$ ✓

$A = -\sqrt{5}$

At B

$$\phi_p = 90°$$

$$\phi_z = 180° - \tan^{-1}(2)$$

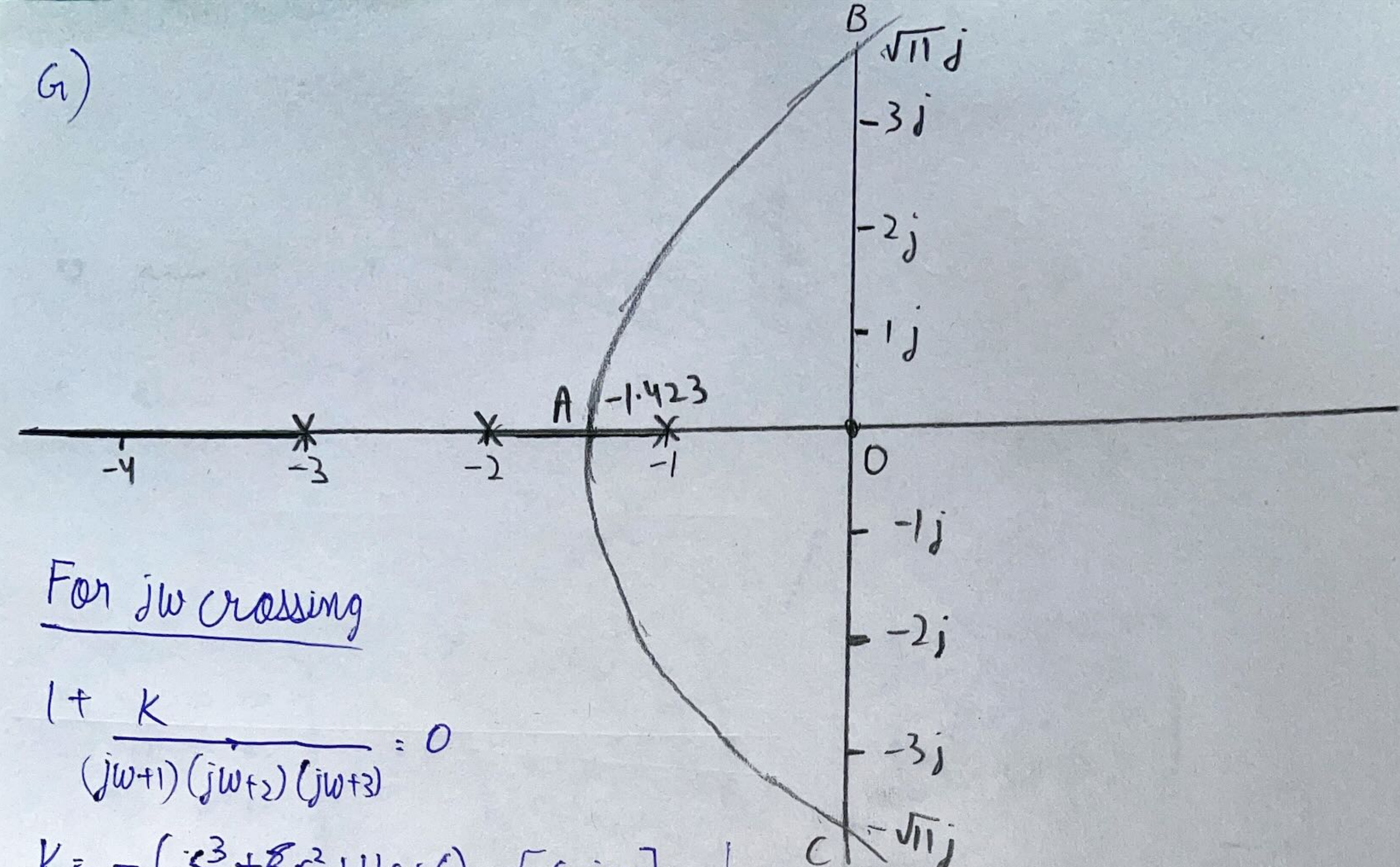
$$\phi = 90° - 180° + \tan^{-1}(2) = \tan^{-1}(2) - 90°$$

$$\phi_d = 180° - \phi$$
$$= 270° - \tan^{-1}(2)$$
$$= 270° - 63.43$$
$$= 206.56°$$

$\Rightarrow \phi_d$ at C $= 360° - 205.56°$
$= 153.44°$

$\because$ B & C are complex conjugates

G)



<u>For jw crossing</u>

$$1+\frac{K}{(j\omega+1)(j\omega+2)(j\omega+3)}=0$$

$$K=-(s^3+6s^2+11s+6) \quad [s=j\omega]$$

$$-K=-j\omega^3-6\omega^2+11j\omega+6$$

$$(11\omega-\omega^3)j+(6-6\omega^2+K)=0$$

$$\omega(11-\omega^2)=0$$

$$\Rightarrow \omega=\sqrt{11},\ -\sqrt{11}$$

$$6-6\omega^2+K=0$$

$$6-6(11)+K=0$$

$$K=60$$

$\Rightarrow$ jw crossing at $\sqrt{11}j$ & $-\sqrt{11}j$
(B) (C)

- The system is conditionally stable for $\underline{K<60}$

$$K=-(s^3+6s^2+11s+6)$$

$$\frac{dK}{ds}=0, \quad K>0$$

$$-(3s^2+12s+11)=0$$

$$s=\frac{-6\pm\sqrt{3}}{3}=-2\pm\frac{1}{\sqrt{3}}$$

$$A=-2+\frac{1}{\sqrt{3}}\approx-1.423$$; Breakaway Points