

4.322) Find $P_5(x)$ given, zeros: 1, $1+i$
(mult=3) $\rightarrow 1 \pm i$

zero	mult	factors
$x=1$	3	$(x-1)^3$

$x=1+i$	1	$[x - (1+i)] \rightarrow [x-1-i][x-1+i]$
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$x=1-i$	1	$[x - (1-i)] \rightarrow [x-1+i][x-1-i]$
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$$(a-b)(a+b) = a^2 - b^2$$

$$(x-1)^2 - (i)^2$$

$$x^2 - 2x + 1 - i^2$$

$$i^2 = -1$$

$$x^2 - 2x + 1 + 1$$

$$(x^2 - 2x + 2)$$

$$P_5(x) = (x-1)^3(x^2 - 2x + 2)$$

$$(A-B)^3 = A^3 + 3AB^2 - 3A^2B - B^3$$

$$= (x^3 + 3x - 3x^2 - 1)(x^2 - 2x + 2)$$

4.3p2

24) $f(x) = x^3 + 3x^2 + 25x + 75$

given, $x = -5i$

Find all zeros.

$$\frac{6}{2} = 3$$

zero

$$x = -5i \rightarrow (x + 5i)$$

$$x = 5i \rightarrow (x - 5i)$$

$$\left. \begin{array}{l} (x)^2 - (5i)^2 \\ x^2 - 25i^2 \\ (x^2 + 25) \end{array} \right\}$$

$$\begin{array}{r} \overline{x^2 + 25} \overline{) x^3 + 3x^2 + 25x + 75} \\ \underline{-x^3} \\ 3x^2 \\ \underline{-3x^2} \\ 0 \end{array}$$

Remaining factor:

$$x + 3 = 0$$

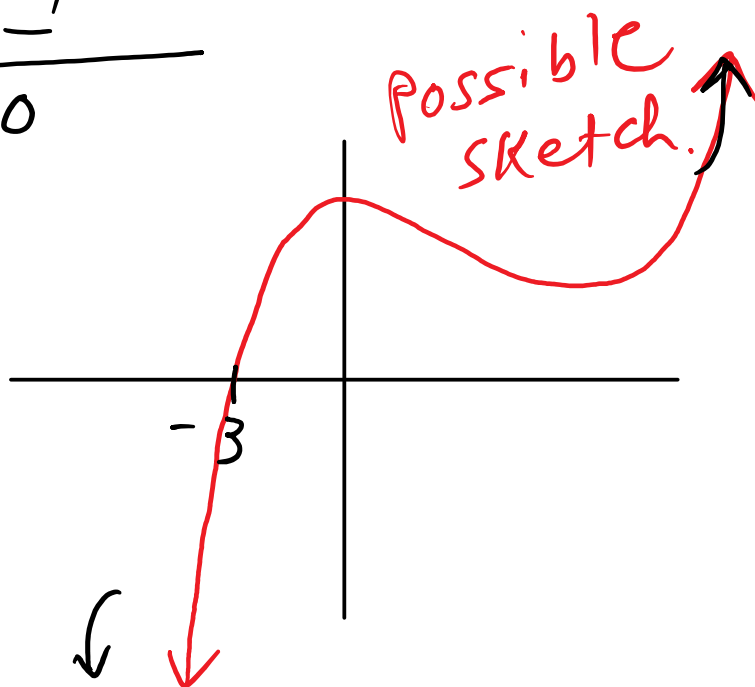
remaining zero

$$x = -3$$

$$P_3(x); a_n = 1 > 0$$

$$n = 3$$

$$x = 3, \pm 5i$$



4.3 try this...

In Problems 23–30, use the given zero to find the remaining zeros of each function.

23. $f(x) = x^3 - 4x^2 + 4x - 16$; zero: $2i$

24. $g(x) = x^3 + 3x^2 + 25x + 75$; zero: $-5i$

25. $f(x) = 2x^4 + 5x^3 + 5x^2 + 20x - 12$; zero: $-2i$

26. $h(x) = 3x^4 + 5x^3 + 25x^2 + 45x - 18$; zero: $3i$

27. $h(x) = x^4 - 9x^3 + 21x^2 + 21x - 130$; zero: $3 - 2i$

28. $f(x) = x^4 - 7x^3 + 14x^2 - 38x - 60$; zero: $1 + 3i$

29. $h(x) = 3x^5 + 2x^4 + 15x^3 + 10x^2 - 528x - 352$; zero: $-4i$

30. $g(x) = 2x^5 - 3x^4 - 5x^3 - 15x^2 - 207x + 108$; zero: $3i$

28) given $x = 1 + 3i$ is a zero,
 $x = 1 - 3i$ must also be a zero (conjugate pairs)

So, zero $\longrightarrow$ factor

$$x = 1 + 3i \longrightarrow [x - (1 + 3i)]$$

$$x = 1 - 3i \longrightarrow [x - (1 - 3i)]$$

The **Rational Function**: $R(x) = \frac{N(x)}{D(x)}$, is a quotient of
 Two polynomial functions

$\nearrow$ poly
 $\nwarrow$ poly

Rational Functions are different from polynomial in a significant way: They are rarely continuous, and the graphs will have

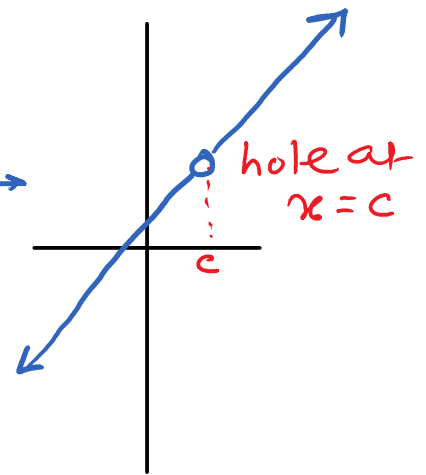
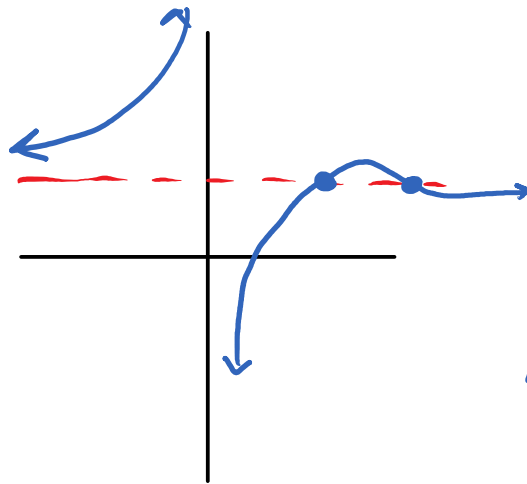
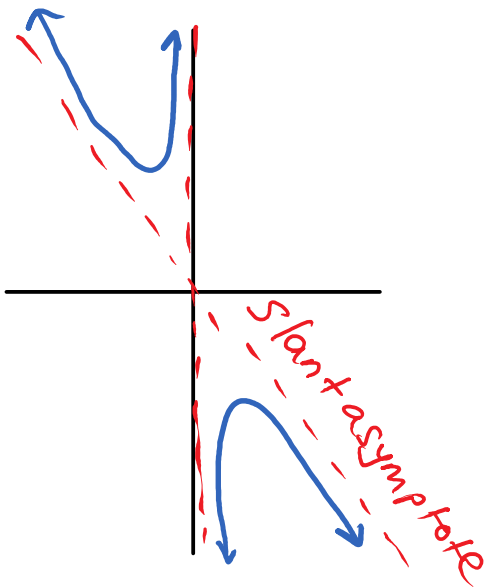
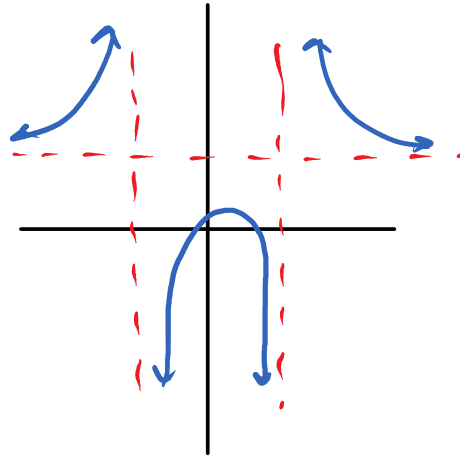
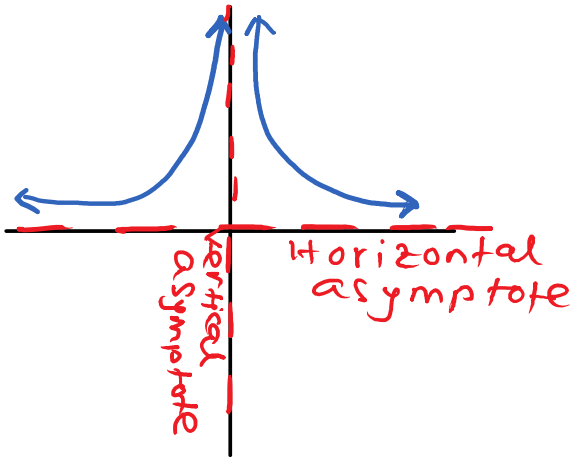
- a) Vertical asymptotes (vertical lines where the graphs will "approach" but never touch)
- b) Horizontal asymptotes (horizontal lines the graphs tend to "approach" far to the left and right $x \rightarrow \pm \infty$). The graph MAY or MAY NOT touch the horizontal asymptotes
- c) Slant asymptotes (slant lines $y = mx + b$ that the graph "approach" as right $x \rightarrow \pm \infty$)
- d) The graphs may have "holes" at certain x-values

$x \rightarrow +\infty$ (right)
 $x \rightarrow -\infty$ (left)

Let's see some examples in the next page...

Rational Functions and their Graphs

$$R(x) = \frac{N(x)}{D(x)} = \frac{a_n x^n + \dots + a_1 x + a_0}{b_m x^m + \dots + b_1 x + b_0}$$



4.4,4.5p3

From what we already know we can find its...

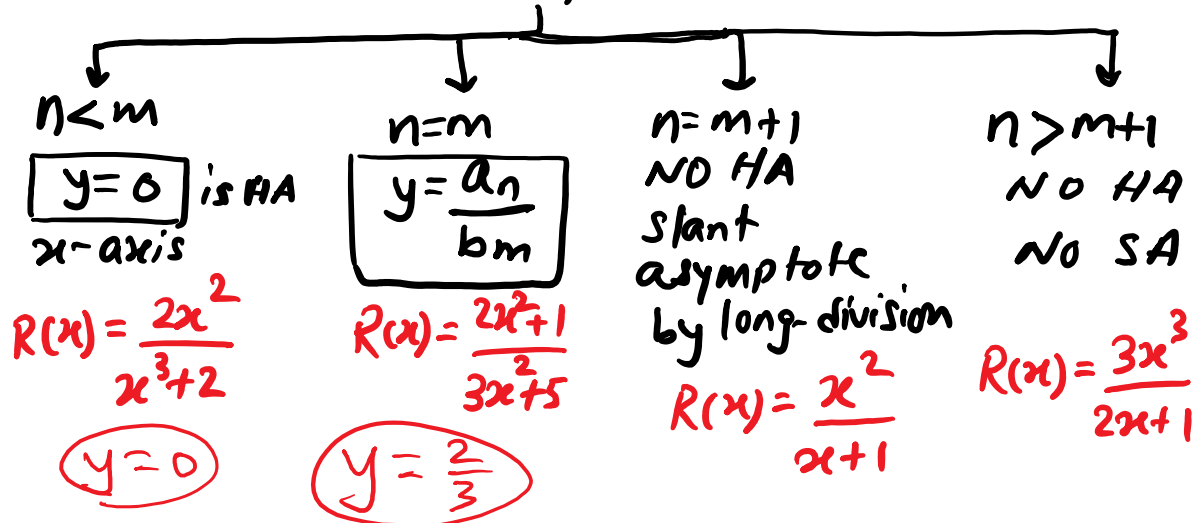
- Domain (set $D(x) \neq 0$ and solve, say $x \neq a$ and $x \neq b$)
- x- and y-int (ordered pairs)
- Equations of the vertical asymptotes (copy the vertical lines from part I above: $x = a$ and $x = b$)
- Test for symmetry as usual
- To find the equations of the horizontal asymptotes we can follow the flow-chart below:
- Test whether function touches its HA/SA by setting original function = equation of its asymptotes and try to solve for x.

chart for horizontal asymptote of rational functions

$$R(x) = \frac{a_n x^n + a_{n-1} x^{n-1} + \dots + a_0}{b_m x^m + b_{m-1} x^{m-1} + \dots + b_0}$$

n = degree of numerator Poly
 m = degree of denominator Poly

If



4.5 sketch the graphs of Rational Functions

#8) $R(x) = \frac{x}{(x-1)(x+2)} = \frac{x^1}{x^2}$

i) Domain: $(x-1)(x+2) \neq 0$ $\left\{ \begin{array}{l} x-1 \neq 0 \\ x \neq 1 \end{array} \right. \left\{ \begin{array}{l} x+2 \neq 0 \\ x \neq -2 \end{array} \right. \left\{ \begin{array}{l} (-\infty, -2) \cup (-2, 1) \cup (1, \infty) \end{array} \right.$

~~$VA = 1, -2$~~

ii) v. asymptote: $\boxed{x=1}$ $\boxed{x=-2}$

iii) x-int: $y=0 \rightarrow \text{top}=0 \rightarrow x=0 \rightarrow \boxed{(0,0)}$
 $\downarrow$
 y-int

iv) HA/SA: $\left. \begin{array}{l} n=1 \\ m=2 \end{array} \right\} n < m \rightarrow \boxed{y=0}$ is HA.

v) Does it touch HA? $\frac{x}{(x-1)(x+2)} = \frac{0}{1} \rightarrow x=0$
 $\downarrow$
 $\boxed{\text{at } (0,0)}$

vi) **Test for symmetry**
 $x \rightarrow -x$
 (i) $f(-x) = f(x)$
 y-axis symm
 (ii) $f(-x) = -f(x)$
 origin symm
 (iii) No symmetry

$x=5$

$f(5) = \frac{5}{(4)(7)} = \frac{5}{28}$

$f(-5) = \frac{-5}{(-6)(-3)} = \frac{-5}{18}$

$\boxed{\text{No Symmetry}}$

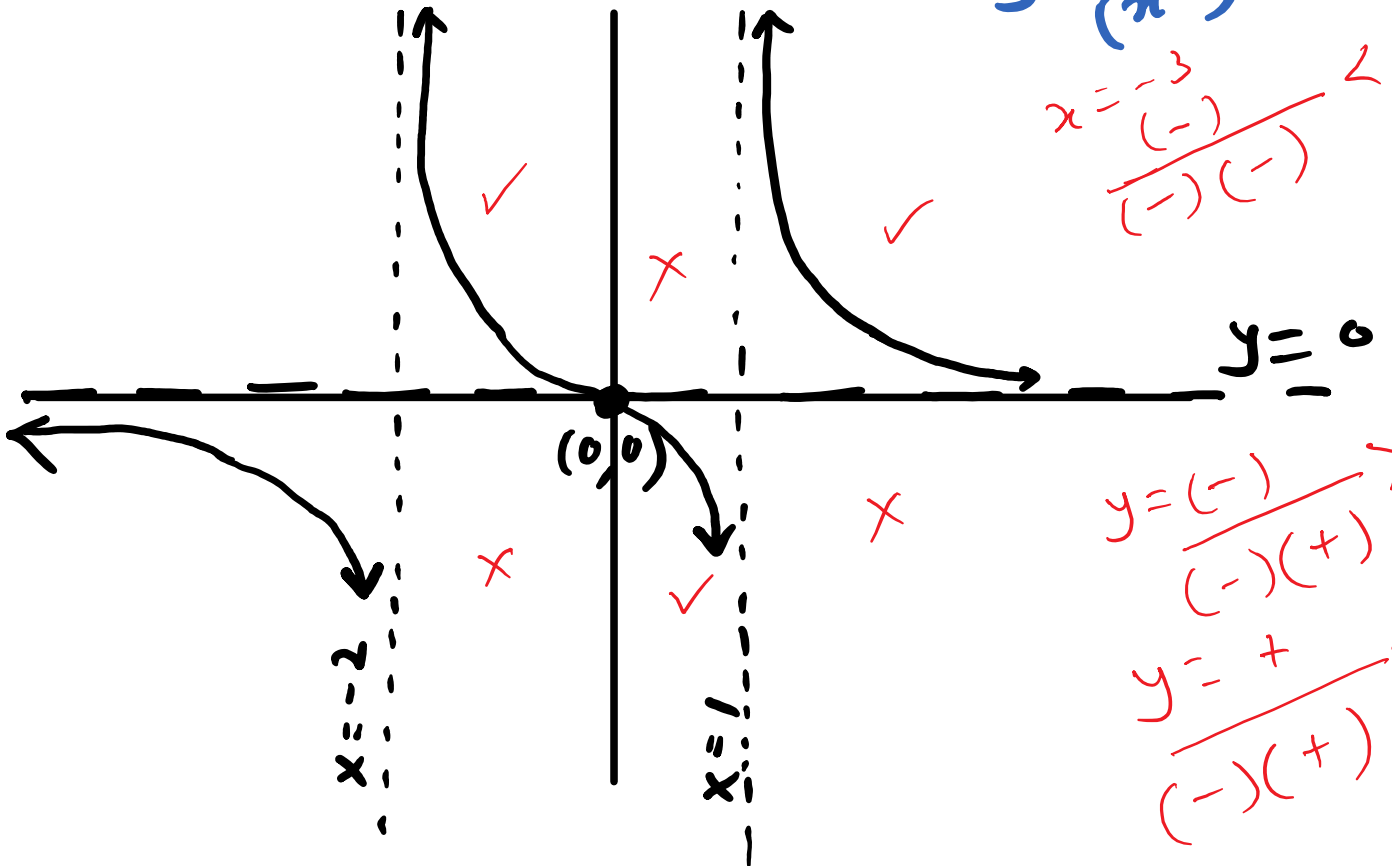
$f(x) = \frac{x}{(x-1)(x+2)}$
 $f(-x) = \frac{-x}{(-x-1)(-x+2)}$

no symmetry.

4.5p5

$$y = \frac{x}{(x-1)(x+2)}$$

$$x = -3 \quad \frac{(-)}{(-)(-)} < 0$$



$$y = \frac{(-)}{(-)(+)} > 0$$

$$y = \frac{+}{(-)(+)} < 0$$

$$x = 2 \quad \frac{+}{(+)(+)} > 0$$

$$10) R(x) = \frac{2x+4}{x-1}$$

i) Domain: $D(x) \neq 0 \rightarrow x-1 \neq 0 \rightarrow x \neq 1 \rightarrow \boxed{(-\infty, 1) \cup (1, \infty)}$

ii) VA: $\boxed{x=1}$

iii) x-int: $y=0 \rightarrow 2x+4=0 \rightarrow x=-2 \rightarrow \boxed{(-2, 0)}$

y-int: $x=0 \rightarrow y = \frac{0+4}{0-1} \rightarrow y=-4 \rightarrow \boxed{(0, -4)}$

iv) HA/SA: $\left. \begin{matrix} n=1 \\ m=1 \end{matrix} \right\} n=m \rightarrow y = \frac{2}{1} \rightarrow \boxed{y=2}$

v) Does it touch HA:

$$\frac{2x+4}{x-1} = \frac{2}{1} \rightarrow 2x+4 = 2(x-1)$$

$$\begin{array}{r} 2x+4 = 2x-2 \\ -2x \quad -2x \\ \hline 4 = -2 \text{ impossible} \end{array}$$

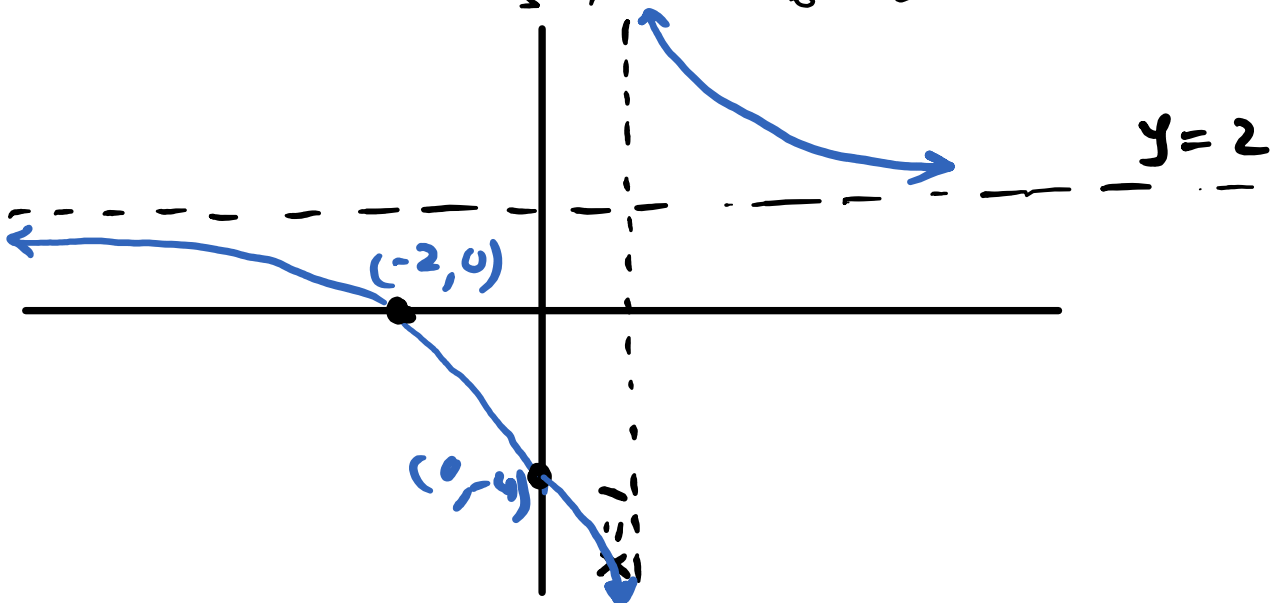
Does Not touch!

vi) Test for Symmetry:

$$x=5: f(5) = \frac{2(5)+4}{5-1} = \frac{14}{4} = \frac{7}{2}$$

$$x=-5: f(-5) = \frac{2(-5)+4}{-5-1} = \frac{-6}{-6} = 1$$

No Symmetry



$$26) F(x) = \frac{x^2 + 3x + 2}{x-1} = \frac{(x+2)(x+1)}{(x-1)}$$

$$\frac{2}{-2} \cdot \frac{1}{-1} = 2$$

$$\frac{2}{-2} + \frac{1}{-1} = 3$$

i) Domain: $x-1 \neq 0 \rightarrow x \neq 1 \rightarrow \boxed{(-\infty, 1) \cup (1, \infty)}$

ii) VA: $\boxed{x=1}$ ~~VA = 1~~

iii) x-int: $y=0 \rightarrow x+2=0 \rightarrow x=-2 \rightarrow \boxed{(-2, 0)}$
 $x+1=0 \rightarrow x=-1 \rightarrow \boxed{(-1, 0)}$

y-int: $x=0 \rightarrow y = \frac{2}{-1} \rightarrow y=-2 \rightarrow \boxed{(0, -2)}$

iv) HA/SA $\left. \begin{matrix} n=2 \\ m=1 \end{matrix} \right\} n=m+1 \rightarrow \text{NO HA} \rightarrow \text{SA:}$

SD:

	x^2	x	C
$x=1$	1	3	2
		1	4

$\boxed{y = 1x + 4}$

$\boxed{6=R}$

$y = \underline{x+4} + \frac{6}{x-1}$
 $x \rightarrow \infty$

$$\begin{array}{r} x+4 \\ x-1 \overline{) x^2 + 3x + 2} \\ \underline{x^2 - x} \\ 4x + 2 \\ \underline{4x - 4} \\ 6 \end{array}$$

$\boxed{y = x+4}$

v) Does it touch?

$$\frac{x^2 + 3x + 2}{x-1} \neq \frac{x+4}{1} \rightarrow x^2 + 3x + 2 = (x-1)(x+4)$$

$$x^2 + 3x + 2 = x^2 + 3x - 4$$

$\boxed{\text{Does not touch SA}}$

$2 = 4$ impossible

Does not
touch SA

$2 = 4$ impossible

4.5p8

vi) Test for symmetry

$$f(5) = \frac{(7)(\cancel{5})}{\cancel{4} \cdot 2} = \frac{21}{2}$$

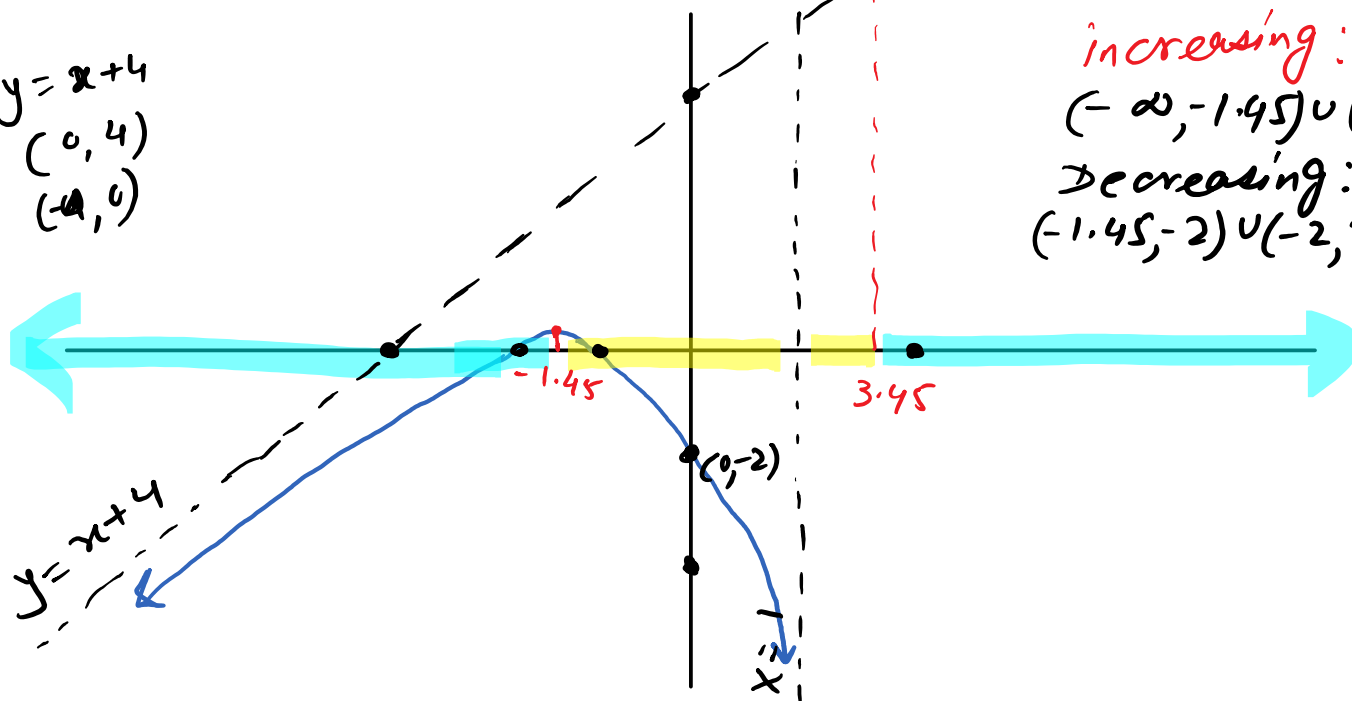
$$f(-5) = \frac{(-3)(\cancel{-4})^2}{(\cancel{-6})^3} = -2$$

No symmetry

$$y = x + 4$$

(0, 4)
(-4, 0)

increasing:
 $(-\infty, -1.45) \cup (3.45, \infty)$
decreasing:
 $(-1.45, -2) \cup (-2, 3.45)$



$$30) R(x) = \frac{x^2 - x - 12}{x+1} = \frac{(x-4)(x+3)}{(x+1)} \checkmark$$

i) Domain: $x+1 \neq 0 \rightarrow x \neq -1 \rightarrow \boxed{(-\infty, -1) \cup (-1, \infty)}$

ii) VA: $\boxed{x = -1}$

iii) x -int: $\rightarrow x-4=0 \rightarrow x=4 \rightarrow \boxed{(4, 0)}$
 $x+3=0 \rightarrow x=-3 \rightarrow \boxed{(-3, 0)}$

y -int $\rightarrow x=0 \rightarrow y = \frac{-12}{1} \rightarrow \boxed{(0, -12)}$

iv) $\left. \begin{matrix} n=2 \\ m=1 \end{matrix} \right\} \begin{matrix} n=m+1 \\ \text{NO HA} \\ \text{SA} \checkmark \end{matrix}$

$$x = -1 \begin{array}{r} 1 \quad -1 \quad -12 \\ \quad \quad -1 \quad 2 \\ \hline 1 \quad -2 \quad -10 = R \end{array}$$

$$\boxed{y = x - 2}$$

v) Touch? $\frac{x^2 - x - 12}{x+1} \stackrel{?}{=} \frac{x-2}{1}$

$$x^2 - x - 12 = (x+1)(x-2)$$

Does not touch

$$\cancel{x^2} - \cancel{x} - 12 = \cancel{x^2} - \cancel{x} - 2$$

$-12 = 2$ impossible

vi) Test for symmetry.

$$f(5) = \frac{8}{6} = \underline{\underline{\frac{4}{3}}}$$

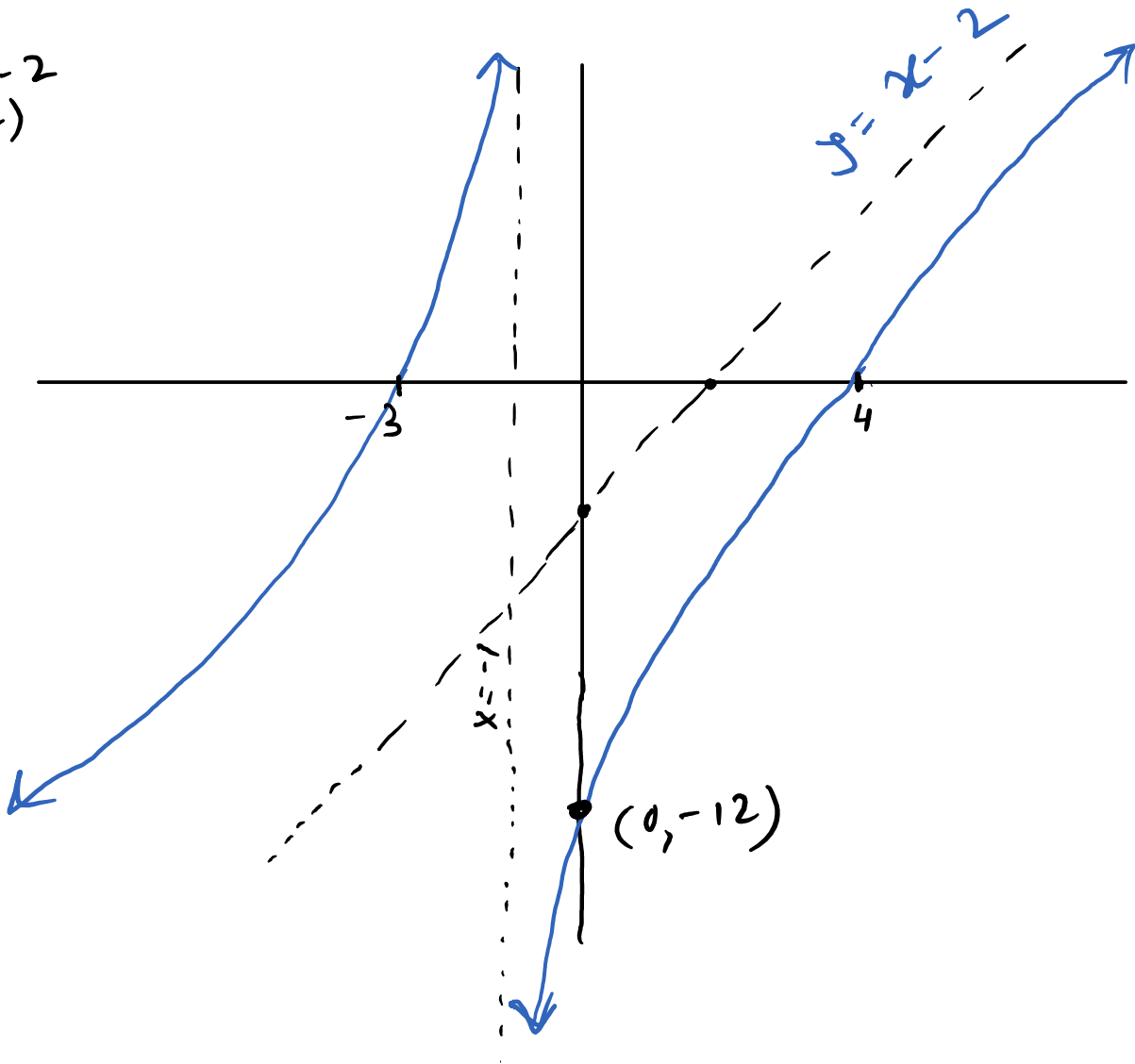
No symmetry

$$f(-5) = \frac{(-9)(-2)}{-42} = -\underline{\underline{\frac{9}{2}}}$$

4.5p10

$$y = x - 2$$

$(0, -2)$
 $(2, 0)$



52)

$$\frac{x}{(x+1)(x-1)}$$

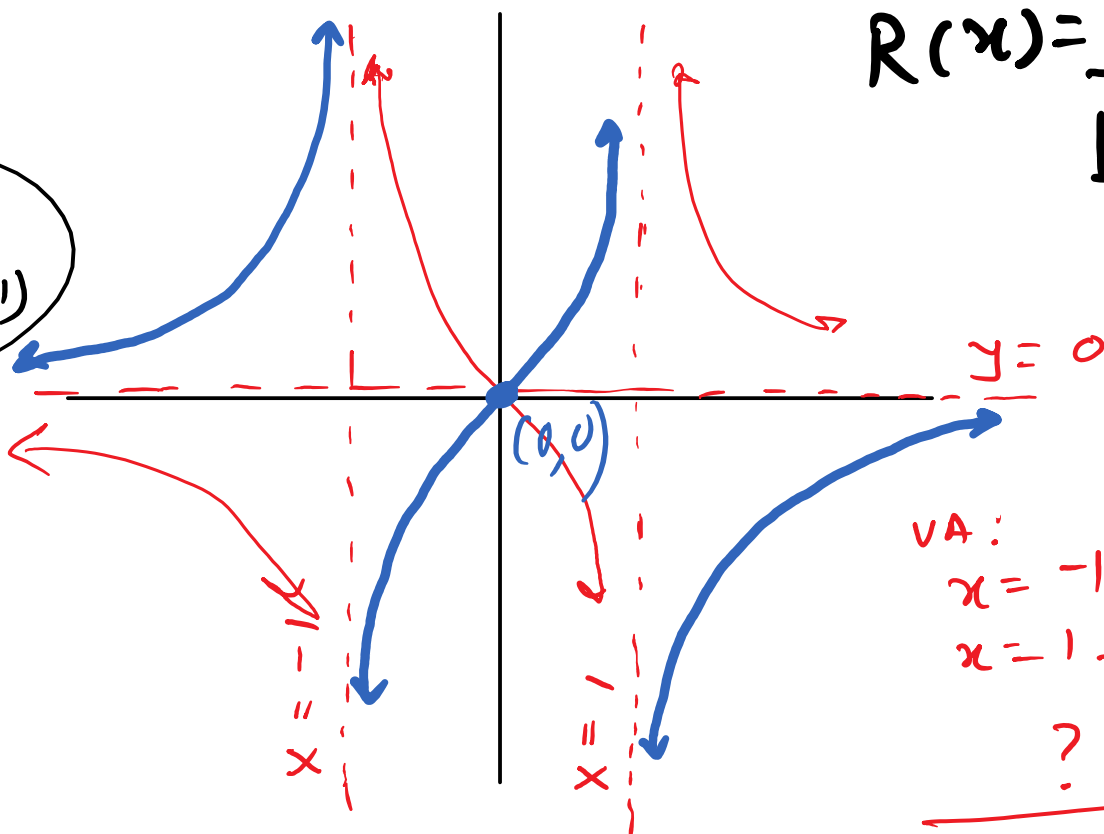
$$\frac{x-4}{x-4+5}$$

$$\frac{x-4}{x+1}$$

~~$$\frac{x}{(x+1)(x-1)}$$~~

$$-\frac{x}{x^2-1}$$

$$R(x) = \frac{\boxed{x - \text{int}}}{\boxed{VA}}$$



$$VA: \\ x = -1 \rightarrow (x+1) \\ x = 1 \rightarrow (x-1)$$

$$\frac{?}{(x+1)(x-1)}$$

$$x - \text{int}: \\ x = 0 \rightarrow (x-0) \\ \checkmark \frac{x-0}{(x+1)(x-1)}$$

$$25) R(x) = \frac{x^2 - 3x - 4}{x+2} = \frac{(x-4)(x+1)}{(x+2)}$$

(i) Domain: $x+2 \neq 0 \rightarrow x \neq -2 \rightarrow \boxed{(-\infty, -2) \cup (-2, \infty)}$

ii) VA: $\boxed{x = -2}$ ~~VA $x = -2$~~

iii) x-int: $y=0 \rightarrow (x-4)(x+1)=0$
 $\downarrow$
 $x=4; x=-1 \rightarrow \boxed{(4, 0); (-1, 0)}$

y-int: $x=0 \rightarrow y = \frac{0-0-4}{0+2} = -2 \rightarrow \boxed{(0, -2)}$

iv) HA/SA: $\left. \begin{matrix} n=2 \\ m=1 \end{matrix} \right\} n=m+1 \rightarrow \text{No HA} \rightarrow \text{SA} \checkmark$

$$\begin{array}{r} \overline{x+2} \overline{\overbrace{x^2-3x-4}^{x-5}} \\ \underline{x^2+2x} \\ -5x-4 \\ \underline{-5x-10} \\ 6=R \end{array}$$

OR $x = -2$

$$\begin{array}{r} x^2 \quad x \quad c \\ 1 \quad -3 \quad -4 \\ \underline{-2 10} \\ 1 \quad -5 \quad 6=R \end{array}$$

$\boxed{y = x-5} + \frac{6}{x+2} \rightarrow 0$
 $x \rightarrow \infty$

v) Does it touch?

$$\frac{x^2-3x-4}{x+2} \stackrel{?}{=} x-5 \rightarrow x^2-3x-4 = (x+2)(x-5)$$

$$\cancel{x^2-3x-4} = \cancel{x^2-3x-10}$$

$$-4 \neq -10$$

impossible

$\boxed{\text{Does not touch}}$

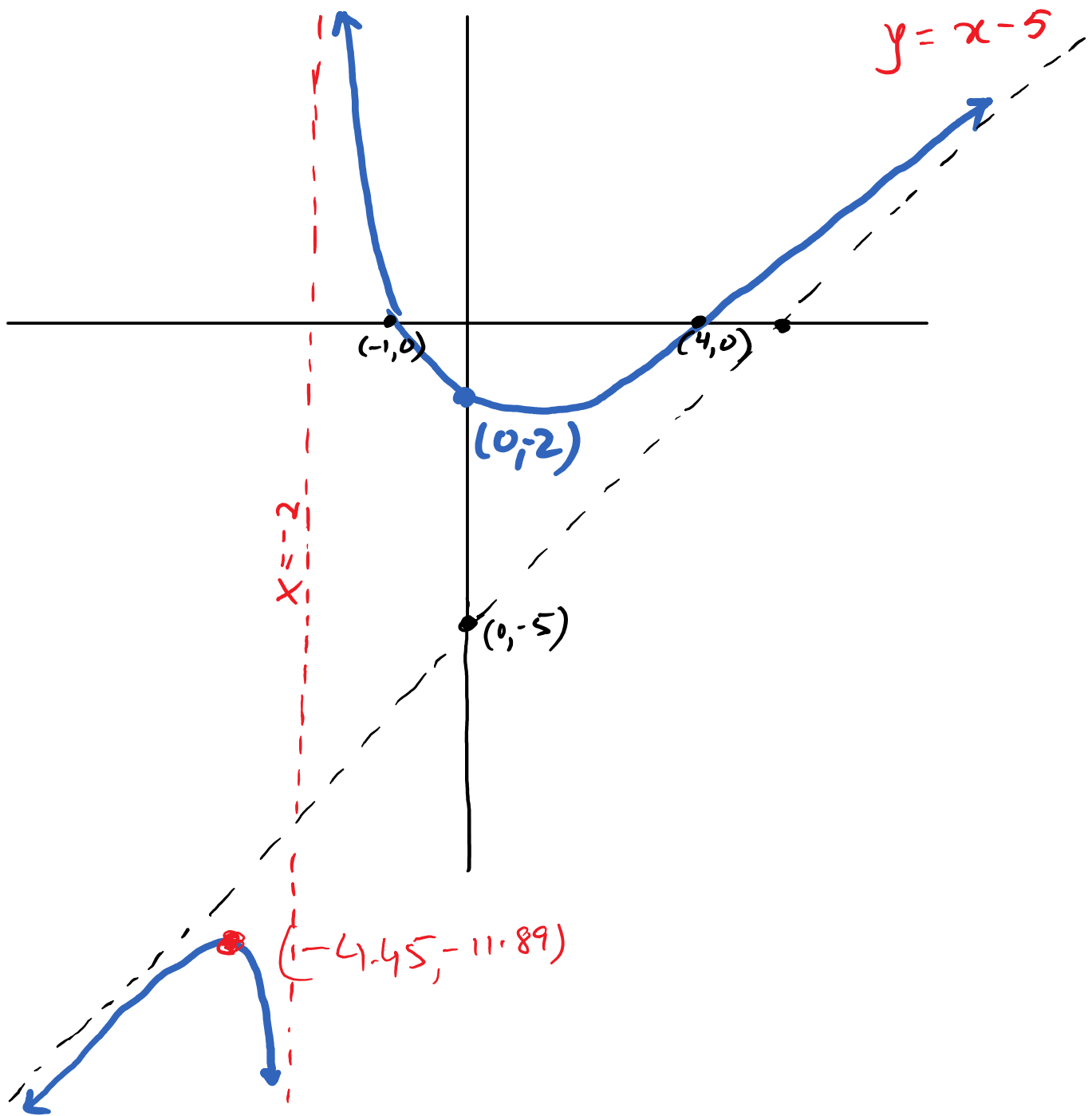
vi) Test for Symmetry:

$$f(10) = \frac{100-30-4}{12} = \frac{66}{12} = \frac{33}{6} = \left(\frac{11}{2}\right)$$

$$f(-10) = \frac{100+30-4}{-8} = \frac{126}{-8} = -\frac{63}{4}$$

$\boxed{\text{No symmetry}}$

4.5p13(NEW)



$$14) Q(x) = \frac{x^4 - 1}{x^2 - 4} = \frac{(x^2)^2 - (1)^2}{(x)^2 - (2)^2} = \frac{(x^2 + 1)(x^2 - 1)}{(x - 2)(x + 2)} = \frac{(x^2 + 1)(x + 1)(x - 1)}{(x - 2)(x + 2)}$$

$$i) D: \left. \begin{array}{l} x - 2 \neq 0 \rightarrow x \neq 2 \\ x + 2 \neq 0 \rightarrow x \neq -2 \end{array} \right\} \boxed{(-\infty, -2) \cup (-2, 2) \cup (2, \infty)}$$

$$ii) VA: \boxed{x = 2}; \boxed{x = -2}$$

$$iii) x\text{-int: } y = 0 \rightarrow (x^2 + 1)(x^2 - 1) = 0$$

$$\left. \begin{array}{l} x^2 + 1 \neq 0 \\ x = 1 \\ x = -1 \end{array} \right\} \boxed{\begin{array}{l} (1, 0) \\ (-1, 0) \end{array}}$$

$$y\text{-int: } x = 0 \rightarrow y = \frac{-1}{-4} = \frac{1}{4} \rightarrow \boxed{(0, \frac{1}{4})}$$

$$iv) HA/SA: \left. \begin{array}{l} n = 4 \\ m = 2 \end{array} \right\} n > m + 1 \rightarrow \boxed{\begin{array}{l} \text{No HA} \\ \text{No SA} \end{array}}$$

v) Test for Symmetry

$$f(5) = \frac{625 - 1}{25 - 4} = \frac{624}{21}$$

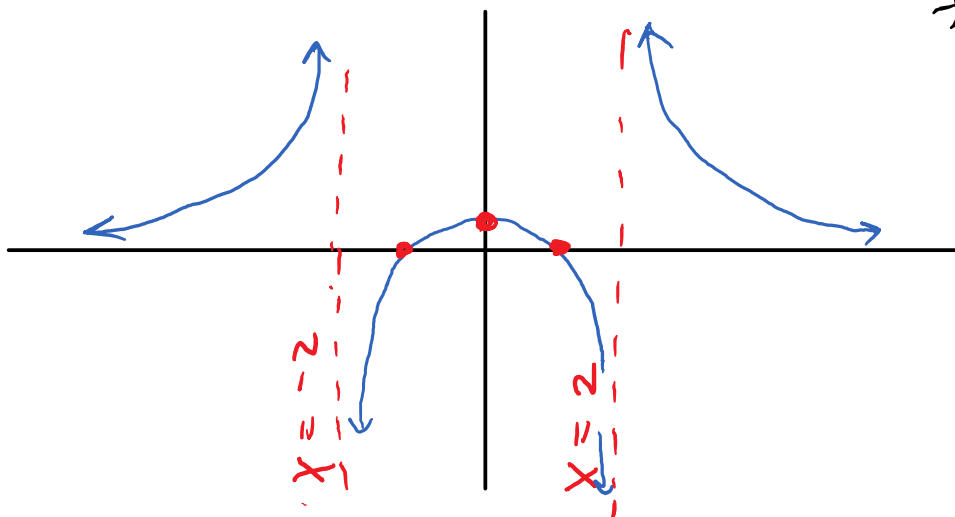
$$f(-5) = \frac{625 - 1}{25 - 4} = \frac{624}{21}$$

y -axis
Symm

$$f(x) = \frac{x^4 - 1}{x^2 - 4}$$

$$f(-x) = \frac{(-x)^4 - 1}{(-x)^2 - 4}$$

$$f(-x) = \frac{x^4 - 1}{x^2 - 4}$$



$$x = 3$$

$$\frac{3^4 - 1}{9 - 4} > 0$$

$$\#38) R(x) = \frac{x^2 + x - 30}{x + 6} = \frac{(x+6)(x-5)}{(x+6)}$$

i) Domain: $x+6 \neq 0$
 $x \neq -6$ $(-\infty, -6) \cup (-6, \infty)$

ii) VA: None $\rightarrow$ a hole at $x = -6$
 $y = x - 5$ at $x = -6$ $\left. \begin{array}{l} y = -11 \end{array} \right\} \boxed{(-6, -11)}$

iii) No slant-asymptote since $y = x - 5$ is already an oblique line.

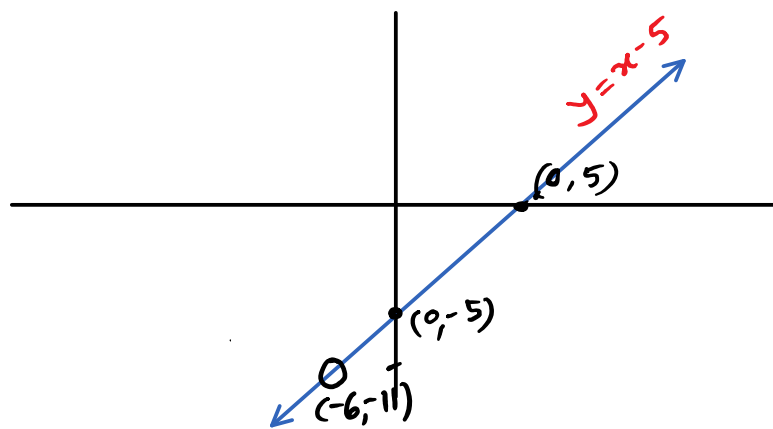
iv) x-int: $y = 0 \rightarrow 0 = x - 5 \rightarrow x = 5 \rightarrow \boxed{(5, 0)}$
 y-int: $x = 0 \rightarrow y = -5 \rightarrow \boxed{(0, -5)}$

v) Test for symm:

$$x = 10 \rightarrow f(10) = \underline{\underline{5}}$$

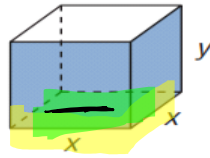
$$x = -10 \rightarrow f(-10) = \underline{\underline{-15}}$$

No symmetry



Application#62

- 62. Minimizing Surface Area** United Parcel Service has contracted you to design an **open box** with a square base that has a volume of 5000 cubic inches. See the illustration.

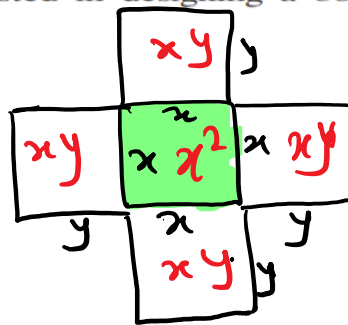


vol = capacity
 $\downarrow$ wh
 $x \cdot x \cdot y \rightarrow x^2 y = 5000$
 constraint

- Express the surface area S of the box as a function of x .
- Using a graphing utility, graph the function found in part (a).
- What is the minimum amount of cardboard that can be used to construct the box?
- What are the dimensions of the box that minimize the surface area?
- Why might UPS be interested in designing a box that **minimizes the surface area**?

Primary : surface
 function : area

$$S(x, y) = x^2 + 4xy$$



constraint:

$$x^2 y = 5000$$

$$y = \frac{5000}{x^2}$$

$$S(x) = x^2 + 4x \left(\frac{5000}{x^2} \right)$$

$$S(x) = x^2 + \frac{20000}{x}$$

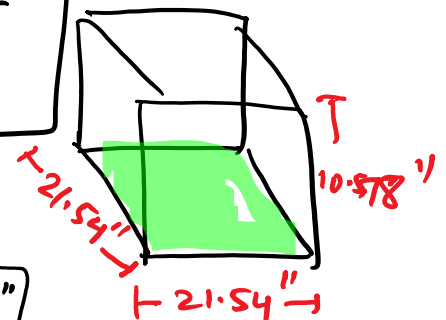
implied
 domain $x > 0$

$$S(10) = 100 + 2000 = 2100$$

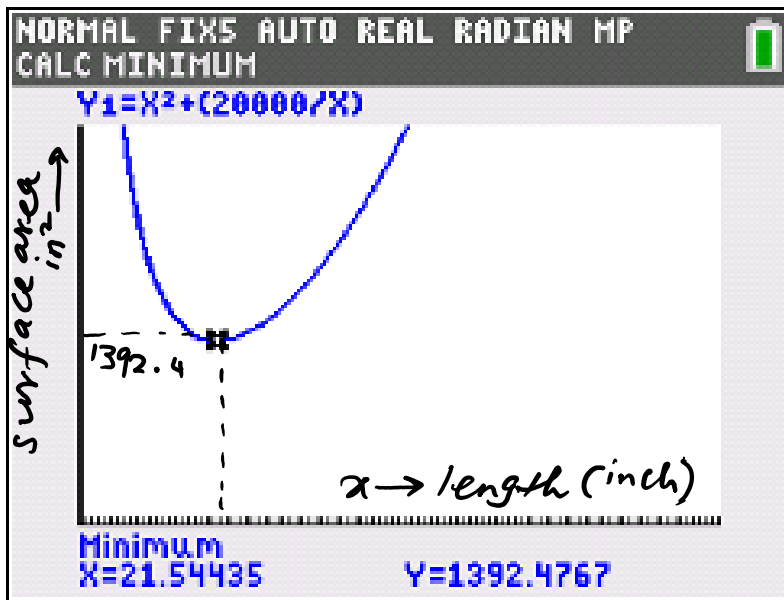
Minimum
 Surface area $\approx 1392.48 \text{ in}^2$

$$\rightarrow \frac{5000}{(21.54)^2} \approx 10.78''$$

Dimension: $l \times w \times h \rightarrow 21.54'' \times 21.54'' \times 10.78''$



#62



#58(NEW)

58. Drug Concentration The concentration C of a certain drug in a patient's bloodstream t minutes after injection is given by

$$C(t) = \frac{50t}{t^2 + 25}$$

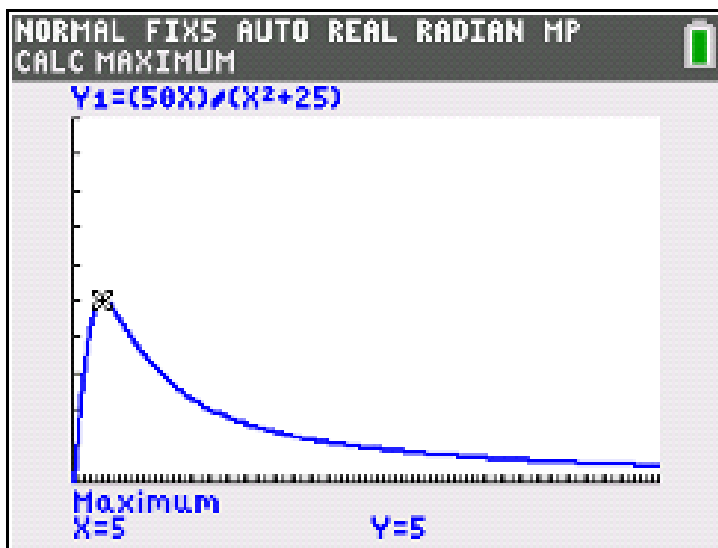
- (a) Find the horizontal asymptote of $C(t)$. What happens to the concentration of the drug as t increases?
- (b) Using your graphing utility, graph $C = C(t)$.
- (c) Determine the time at which the concentration is highest.

$t =$ indep. var: minutes after injection

$C(t) =$ concentration of drug in the bloodstream

a) concentration spikes, then decreases gradually with time

b)



try values
 $C(5) = \frac{50(5)}{50} = 5$

$$x_{\min} = 0$$

$$x_{\max} = 100$$

$$y_{\min} = 0$$

$$y_{\max} = 10$$

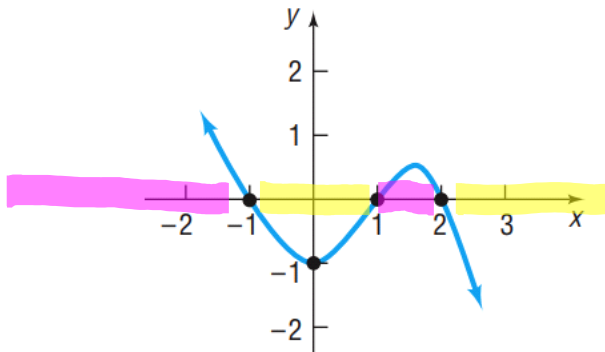
c) $t = 5$ mins $C(t)$ is maximum

4.6p1

✓ ✓ ✓ ✓ ✓

▣ To solve Polynomial and Rational Inequalities ($\leq$, $\geq$, $<$, $>$, $\neq$)

- | | | | | |
|-------------------------|--|--|--|-----------------------|
| • Polynomial Inequality | | | | • Rational Inequality |
|-------------------------|--|--|--|-----------------------|

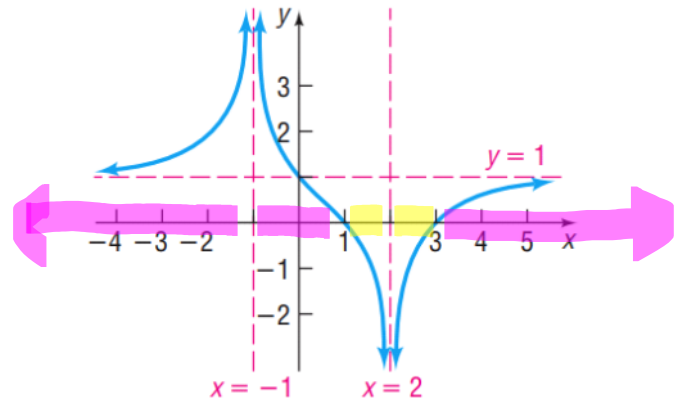


Solve: $p(x) \geq 0$

■ Solution: $(-\infty, -1] \cup [1, 2]$

Solve: $p(x) < 0$

■ Solution: $(-1, 1) \cup (2, \infty)$



Solve: $R(x) > 0$

■ Sol: $(-\infty, -1) \cup (-1, 1) \cup (3, \infty)$

Solve $R(x) \leq 0$

■ Sol: $[1, 2) \cup (2, 3]$

4.6 (Steps)

 To solve Polynomial and Rational Inequalities ($\leq$, $\geq$, $<$, $>$, $\neq$)

• Polynomial Inequality

• Rational Inequality

Steps:

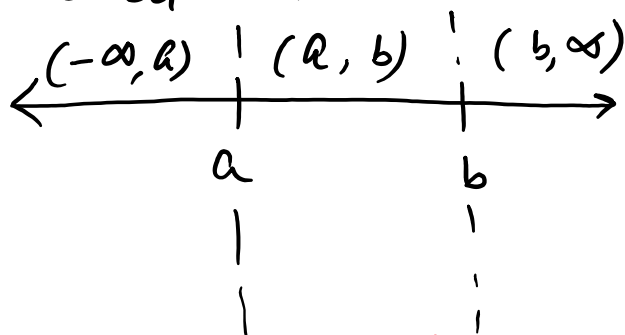
- ① factor
- ② Add/subtract to have 0 on one side

$$P(x) > 0 \quad \text{or}$$

$$P(x) < 0$$

- ③ Find zeros and $x=a, x=b$

Create intervals



- ④ Take any x -value in each interval and
Test even # of negs: > 0
 $\geq$ odd # of negs: < 0

- ⑤ Put $\checkmark$ if it solves the inequality and $\times$ if it doesn't.

- ⑥ put all " $\checkmark$ " in solution

Steps:

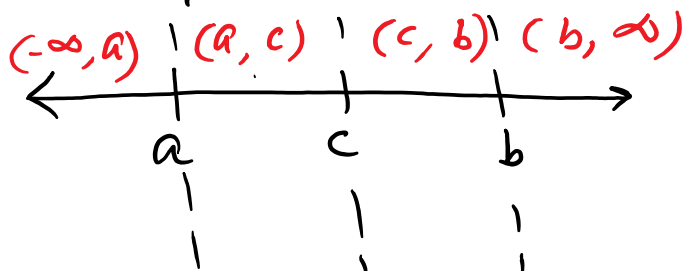
- ① factor
- ② Add/subtract to have 0 on one side

$$P(x) > 0 \quad \text{or}$$

$$P(x) < 0$$

- ③ Find zeros and $\forall x=a, x=b, x=c$

Create intervals



- ④ Take any x -value in each interval and
Test even # of negs: > 0
 $\geq$ odd # of negs: < 0

- ⑤ Put $\checkmark$ if it solves the inequality and $\times$ if it doesn't.

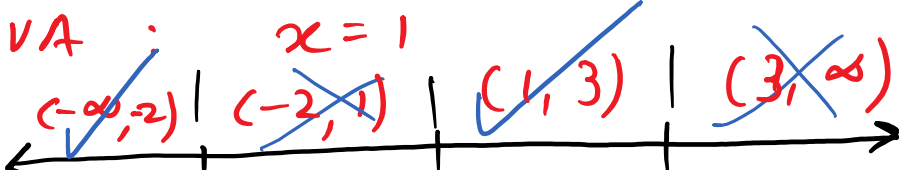
- ⑥ put all " $\checkmark$ " in solution
NEVER include $x=c$ inside solution.

4.6
36) Solve: $\frac{(x-3)(x+2)}{x-1} \leq 0$

step 1: factor, set $R(x) \leq 0$

step 2: x-int: $x=3$; $x=-2$

VA: $x=1$

* step 3: 

Testing: $x=-3$ $x=0$ $x=2$ $x=4$

$\frac{(-)(-)}{(-)} < 0$	$\frac{(-)(+)}{(-)} > 0$	$\frac{(-)(+)}{(+)} < 0$	$\frac{(+)(+)}{(+)} > 0$
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Step 4:

solution: $[-\infty, -2] \cup (1, 3]$

solve Polynomial inequality

solve

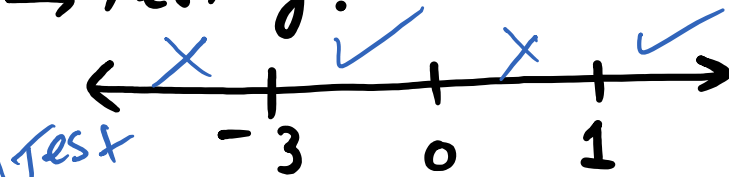
$$x^3 + 2x^2 - 3x > 0$$

$$\rightarrow x(x^2 + 2x - 3) > 0$$

$$x(x+3)(x-1) > 0$$

$$\rightarrow x=0; x=-3; x=1$$

→ Testing:



$$\text{sol: } (-3, 0) \cup (1, \infty)$$

solve Rational inequality

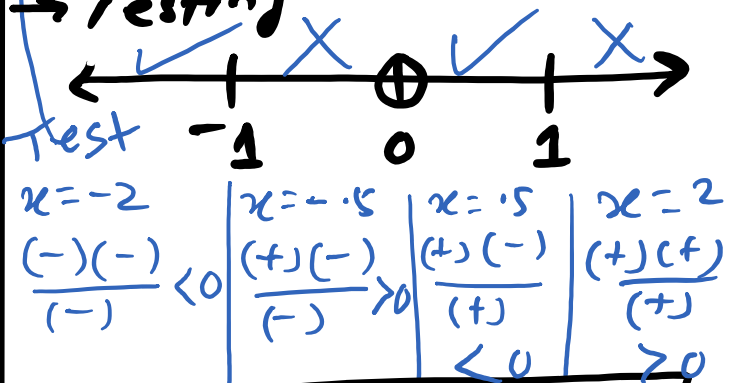
solve:

$$\frac{x^2 - 1}{x} \leq 0$$

$$\rightarrow \frac{(x+1)(x-1)}{x} \leq 0$$

$$\rightarrow \begin{array}{l|l} x\text{-int:} & \vee \wedge: \\ x = -1 & x = 0 \\ x = 1 & \end{array}$$

→ Testing



$$\rightarrow \text{sol: } (-\infty, -1] \cup (0, 1]$$