MHF 4U0 **Semester 2, 2008 - 2009**

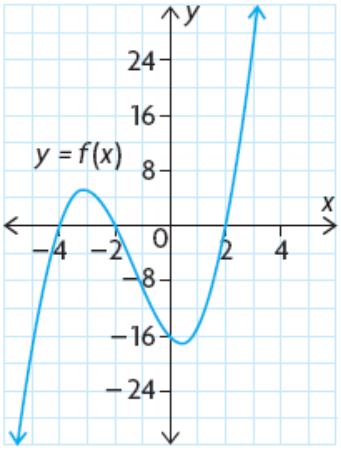
Grade 12 Advanced Functions (University Preparation)
Unit 3 – Major Test on Polynomial Functions

Mr. N. Nolfi

***Victim*: _____**

KU	APP	TIPS	COM
/7	/25	/18	/10

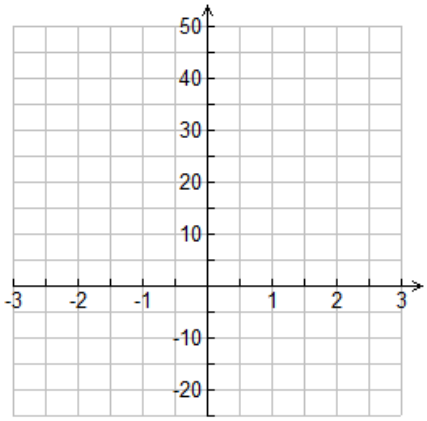
1. Determine an equation of the polynomial function $y = f(x)$ whose graph is shown at the right. Express the polynomial expression in your equation in ***factored form***. **(4 KU)**



2. Consider the quintic function $p(x) = 4x^5 + 32x^2$.

(a) Fully factor the polynomial. **(3 KU)**

(b) Use the factored form of the polynomial to sketch the graph of $y = p(x)$. **(3 APP)**



(c) Lisa took the graph of $y = p(x)$ and applied the following transformations to produce the function *g*.

1. Vertical stretch by a factor of 2.
2. Vertical translation one unit up.

How many zeros does *g* have? **(2 TIPS)**

3. The following transformations are applied to the function $y = x^4$.

(i) Vertical stretch by a factor of 3, reflection in the *x*-axis, vertical translation 2 units down.
(ii) Horizontal compression by a factor of 1/4, reflection in the *y*-axis, horizontal translation 5 units left.

(a) Write an equation of the transformed function. **(4 APP)**

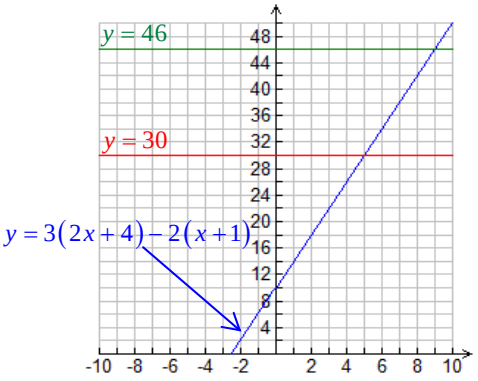
(b) State the image of the point $(1,1)$ under the transformation. **(3 APP)**

4. Solve the equation $3x^3 - 3x^2 - 7x + 5 = x^3 - 2x^2 - 1$. **(6 APP)**

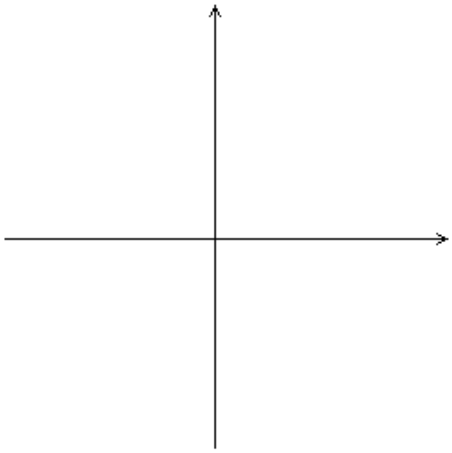
5. Solve the following inequalities. In both cases, express the solution both as a set and with the use of a number line.

(a) $-4 \le -3x - 3 \le 5$ **(4 APP)**	**(b)** $(2x-4)^2(x+3) \le 0$ **(5 APP)**

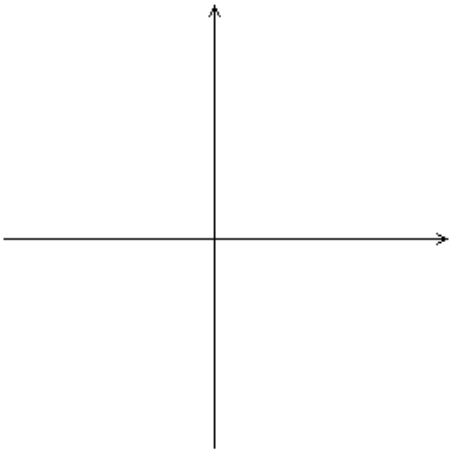
6. Write an inequality that corresponds to the diagram given at the right. In addition, state the solution set. (Do not solve the inequality. You should be able to see the solution just by looking at the graphs.) **(3 TIPS)**



7. Explain why the polynomial equation $2x^{10}+13x^8+5x^6+x^4+19x^2+1=0$ has ***no real roots***. In addition, sketch a possible graph of the polynomial function $f(x)=2x^{10}+13x^8+5x^6+x^4+19x^2+1$. **(4 TIPS)**



8. The function $f(x)=kx^4+8x^2$ has three turning points, an absolute (global) maximum value of 8 and a zero at $x=2$. Determine the value of *k* as well as the other zero(s) of *f*. Then sketch the graph of $y=f(x)$. **(4 TIPS)**



9. A box that holds an expensive pen has square ends and its length is 13 cm greater than its width. If the volume of the box is 60 cm^3, determine its dimensions. **(5 TIPS)**

MHF 4U0 **Semester 2, 2008 - 2009**

Grade 12 Advanced Functions (University Preparation)
Unit 3 – Major Test on Rational Functions

Mr. N. Nolfi

***Victim*: _____**

KU	APP	TIPS	COM
/14	/22	/17	/10

1. Match each function with its graph. **(4 KU)**

a) $h(x) = \dfrac{x+4}{2x+5}$

b) $m(x) = \dfrac{2x-4}{x-2}$

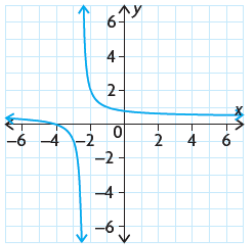
c) $f(x) = \dfrac{3}{x-1}$

d) $g(x) = \dfrac{2x-3}{x+2}$

a) _____ **b)** _____

c) _____ **d)** _____

A



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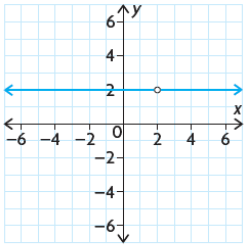
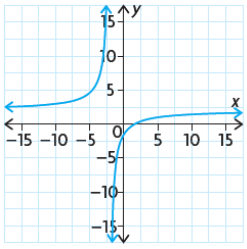
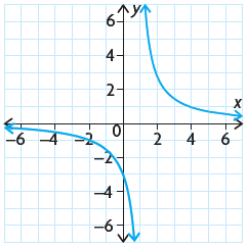


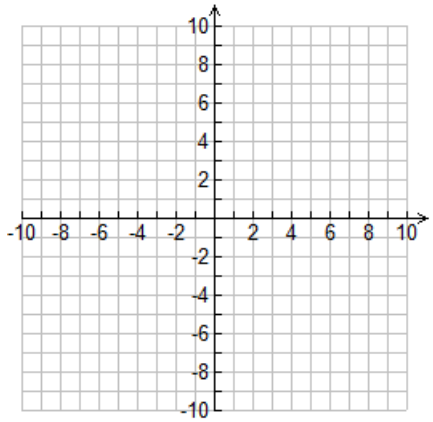
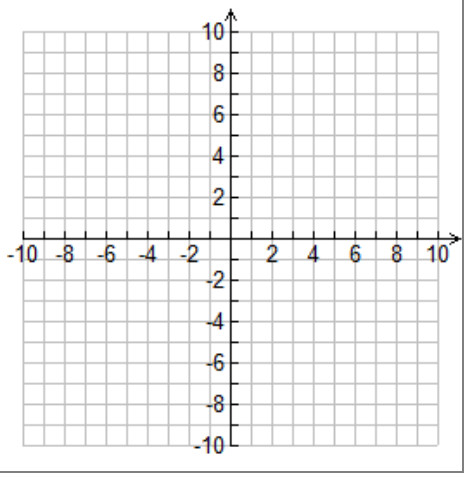
B



D



2. Complete the following table. **(10 KU, 6 APP)**

Equation of Function	*Characteristics of Function*	*Graph*
$f(x) = \dfrac{x+2}{x^2-x-6}$	Zeros: _____ *y*-intercept: _____ Domain: _____ Range: _____ Asymptote(s): _____ _____ As $x \to \infty$, $f(x) \to$ _____ As $x \to -\infty$, $f(x) \to$ _____ As $x \to 3^-$, $f(x) \to$ _____ As $x \to 3^+$, $f(x) \to$ _____ As $x \to -1^-$, $f(x) \to$ _____ As $x \to -1^+$, $f(x) \to$ _____	
$f(x) = \dfrac{-12x-3}{6x-6}$	Zeros: _____ *y*-intercept: _____ Domain: _____ Range: _____ Asymptote(s): _____ _____ As $x \to \infty$, $f(x) \to$ _____ As $x \to -\infty$, $f(x) \to$ _____ As $x \to 1^-$, $f(x) \to$ _____ As $x \to 1^+$, $f(x) \to$ _____	

Ku	–
App	–
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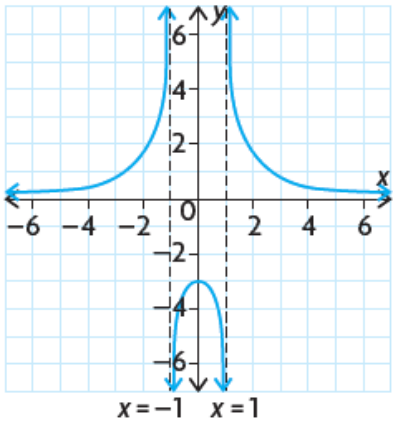
Com	–

3. Solve.

(c) $\frac{-b}{b-1}=\frac{-3}{b+7}$ **(5 APP)**	**(d)** $\frac{2}{c+5}>\frac{3c}{c+10}$ **(6 APP)**

4. The graph of the rational function f is shown at the right. If the equation of f has the form $f(x)=\frac{m}{x^2+kx+n}$, determine the values of k, m and n. **(5 TIPS)**



Ku	–
App	–
Tips	–
Com	–

5. As the date of the MHF4U0 exam drew nearer, Manavjot and Niroj became increasingly nervous. To help relieve their stress, they decided to walk along a straight line on which Mr. Nolfi had marked an origin.

At the time t seconds,

Niroj's distance from the origin is given by the function $s_N(t) = \dfrac{7t}{t^2+1}$ and

Manavjot's distance from the origin is given by the function $s_M(t) = t + \dfrac{5}{t+2}$.

(a) At what time(s) do Niroj and Manavjot collide? **(4 TIPS)**

(b) When is Niroj closer to the origin than Manavjot? **(4 TIPS)**

Ku	–
App	–
Tips	–
Com	–

6. Three employees work at a shipping warehouse. Paco can fill an order two minutes faster than Tom but Carl fills an order one minute slower than Tom. When Tom and Paco work together they can fill an order in one minute and twenty seconds. When Paco and Carl work together, they take one minute and thirty seconds to fill an order.

(a) How long does each person take to fill an order? **(5 APP)**

(b) How long would it take all three of them working together to fill an order? **(4 TIPS)**

Ku	–
App	–
Tips	–
Com	–

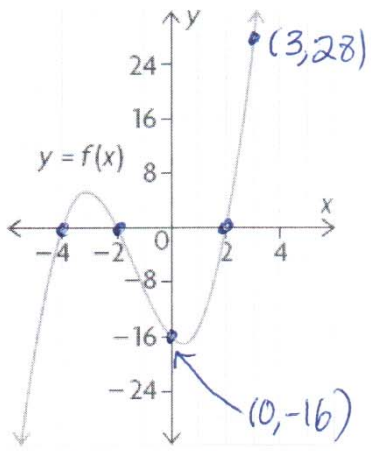
MHF 4U0 — **Semester 2, 2008 - 2009**

Grade 12 Advanced Functions (University Preparation)
Unit 3 – Major Test on Polynomial Functions

Mr. N. Nolfi
Victim: Mr. Solutions. Your work is thorough and clean Mr. S. !!

KU	APP	TIPS	COM
7 /7	25 /25	18 /18	10 /10

1. Determine an equation of the polynomial function $y = f(x)$ whose graph is shown at the right. Express the polynomial expression in your equation in *factored form*. **(4 KU)**



Assume that the given polynomial function has degree 3 (opposite end behaviours → degree must be odd)

∴ the equation of f has the form

$f(x) = a(x+4)(x+2)(x-2)$ (∵ zeros are $-4, -2, 2$)

Since the point $(3,28)$ lies on the curve, $f(3) = 28$

$\therefore a(3+4)(3+2)(3-2) = 28$

$\therefore a = \frac{28}{35} = \frac{4}{5}$

$\therefore f(x) = \frac{4}{5}(x+4)(x+2)(x-2)$

Can also use the point $(0,-16)$, in which case the equation is found to be $f(x) = (x+4)(x+2)(x-2)$

2. Consider the quintic function $p(x) = 4x^5 + 32x^2$.

(a) Fully factor the polynomial. **(3 KU)**

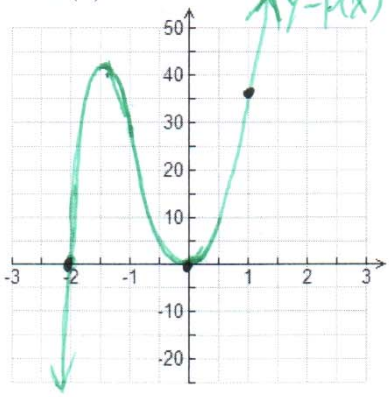
$4x^5 + 32x^2$

$= 4x^2(x^3 + 8)$

$= 4x^2(x+2)(x^2-2x+4)$ (order 2 → tangent)

zeros are $0, -2$ | does not factor because $b^2 - 4ac < 0$

(b) Use the factored form of the polynomial to sketch the graph of $y = p(x)$. **(3 APP)**



(c) Lisa took the graph of $y = p(x)$ and applied the following transformations to produce the function g.

1. Vertical stretch by a factor of 2.
2. Vertical translation one unit up.

How many zeros does g have? **(2 TIPS)**

The function g should have only one zero. The vertical stretch has no effect on the zeros because any point on the x-axis has a y-co-ordinate of zero. The vertical shift, however, causes the point $(0,0)$ to move up, which means that the function g only intersects the x-axis at one point.

3. The following transformations are applied to the function $y = x^4$ → $\frac{1}{4}$

(i) Vertical stretch by a factor of 3, reflection in the x-axis, vertical translation 2 units down.
(ii) Horizontal compression by a factor of $\frac{1}{4}$, reflection in the y-axis, horizontal translation 5 units left.

(a) Write an equation of the transformed function. **(4 APP)**

$y = -3(-4(x+5))^4 - 2$

$\therefore y = -768(x+5)^4 - 2$

(b) State the image of the point $(1,1)$ under the transformation. **(3 APP)**

$(x,y) \to (-\frac{1}{4}x - 5, -3y - 2)$

$\therefore (1,1) \to (-\frac{1}{4}(1) - 5, -3(1) - 2)$

$\therefore (1,1) \to (-\frac{21}{4}, -5)$

4. Solve the equation $3x^3 - 3x^2 - 7x + 5 = x^3 - 2x^2 - 1$. **(6 APP)**

$\therefore 2x^3 - x^2 - 7x + 6 = 0$

$\therefore (x-1)(2x^2 + x - 6) = 0$

$\therefore (x-1)(2x-3)(x+2) = 0$

$\therefore x - 1 = 0$ or $2x - 3 = 0$ or $x + 2 = 0$

$\therefore x = 1$ or $x = \frac{3}{2}$ or $x = -2$

Let $f(x) = 2x^3 - x^2 - 7x + 6$

$\because f(1) = 0$, $x-1$ must be a factor of $f(x)$ (factor theorem)

$$
\begin{array}{r}
2x^2 + x - 6 \\
x-1 \overline{)\,2x^3 - x^2 - 7x + 6} \\
2x^3 - 2x^2 \\
\hline
x^2 - 7x \\
x^2 - x \\
\hline
-6x + 6 \\
-6x + 6 \\
\hline
0
\end{array}
$$

5. Solve the following inequalities. In both cases, express the solution both as a set and with the use of a number line.

(a) $-4 \le -3x - 3 \le 5$ **(4 APP)**

$\therefore -4 + 3 \le -3x - 3 + 3 \le 5 + 3$

$\therefore -1 \le -3x \le 8$

$\therefore \frac{-1}{-3} \ge \frac{-3x}{-3} \ge \frac{8}{-3}$

$\therefore \frac{1}{3} \ge x \ge -\frac{8}{3}$

Solution set

$\{x \in \mathbb{R} \mid -\frac{8}{3} \le x \le \frac{1}{3}\}$

(interval notation: $[-\frac{8}{3}, \frac{1}{3}]$)

(b) $(2x-4)^2(x+3) \le 0$ **(5 APP)**

only $x = 2$ satisfies this

$\therefore (2x-4)^2 \ge 0$ and $x + 3 \le 0$ or $(2x-4)^2 \le 0$ and $x + 3 \ge 0$

$\therefore (2x-4)^2 \ge 0$ for all $x \in \mathbb{R}$,

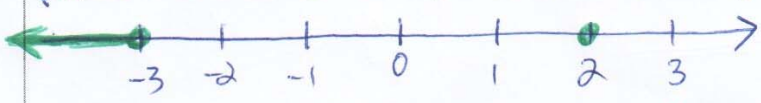
$\therefore x + 3 \le 0$ or $(2x-4)^2 = 0$ and $x + 3 \ge 0$

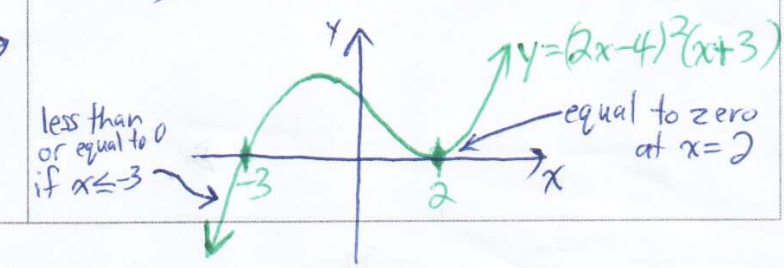
$\therefore x \le -3$ or $x = 2$ and $x \ge -3$

$\therefore x \le -3$ or $x = 2$

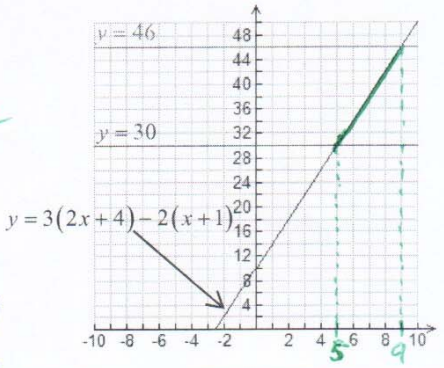
Solution Set: $\{x \in \mathbb{R} \mid x \le -3 \text{ or } x = 2\}$

(interval notation: $(-\infty, -3] \cup [2, 2]$)





6. Write an inequality that corresponds to the diagram given at the right. In addition, state the solution set. (Do not solve the inequality. You should be able to see the solution just by looking at the graphs.) **(3 TIPS)**



May also use $<$

$30 \leq 3(2x+4)-2(x+1) \leq 46$

Solution Set

$\{x \in \mathbb{R} \mid 5 \leq x \leq 9\}$ or $[5,9]$ in interval notation

7. Explain why the polynomial equation $2x^{10}+13x^8+5x^6+x^4+19x^2+1=0$ has *no real roots*. In addition, sketch a possible graph of the polynomial function $f(x)=2x^{10}+13x^8+5x^6+x^4+19x^2+1$. **(4 TIPS)**

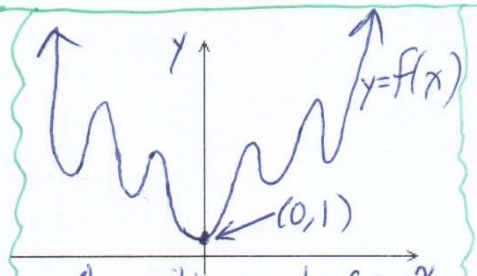
Since all the coefficients are positive and all the powers are even powers of x,

$2x^{10}+13x^8+5x^6+x^4+19x^2 \geq 0$ for all $x \in \mathbb{R}$

$\therefore 2x^{10}+13x^8+5x^6+x^4+19x^2+1 \geq 1$ for all $x \in \mathbb{R}$

$\therefore f(x) \geq 1$ for all $x \in \mathbb{R}$

That is, no matter what value of x is chosen, the value of $f(x)$ must be at least 1. Therefore, the graph of $y=f(x)$ cannot cross the x-axis, which means that the equation cannot have any real roots



A possible graph of $y=f(x)$

The graph must lie entirely above the x-axis, have same end behaviours and up to 9 turning points.

8. The function $f(x)=kx^4+8x^2$ has three turning points, an absolute (global) maximum value of 8 and a zero at $x=2$. Determine the value of k as well as the other zero(s) of f. Then sketch the graph of $y=f(x)$. **(4 TIPS)**

$f(2)=0$

Since f has a zero at $x=2$, $f(2)=0$

$\therefore k(2^4)+8(2^2)=0$

$\therefore 16k+32=0$

$\therefore 16k=-32$

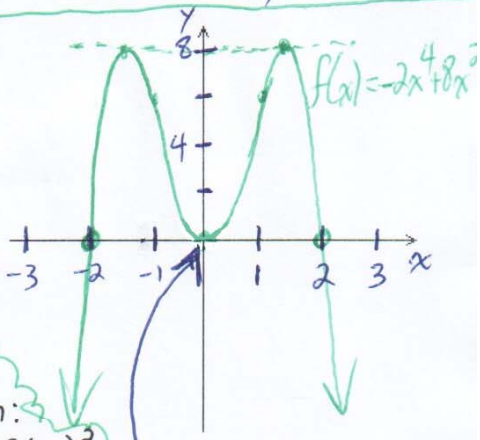
$\therefore k=-2$

$\therefore f(x)=-2x^4+8x^2$

$=-2x^2(x^2-4)$

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

$\therefore$ the other zeros are 0 and -2.



Note that f is an EVEN function:

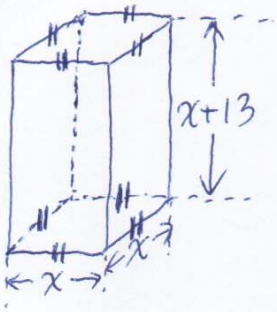
$f(-x)=-2(-x)^4+8(-x)^2$

$=-2x^4+8x^2=f(x)$

$\therefore f$ is symmetric in the y-axis

Since the order (also called multiplicity) of this zero is 2, the graph looks like a parabola in the vicinity of $x=0$ and is tangent to the x-axis.

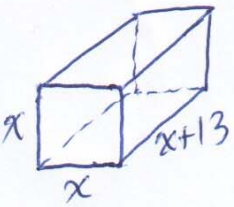
9. A box that holds an expensive pen has square ends and its length is 13 cm greater than its width. If the volume of the box is 60 cm^3, determine its dimensions. **(5 TIPS)**



Let $V(x)$ represent the volume of the box

$\therefore V(x) = x(x)(x+13)$

$\therefore V(x) = x^2(x+13)$



Since the volume of the box is 60 cm^3,

$V(x) = 60$

$\therefore x^2(x+13) = 60$

$\therefore x^3 + 13x^2 = 60$

$\therefore x^3 + 13x^2 - 60 = 0$

$\therefore (x-2)(x^2+15x+30) = 0$

$\therefore x-2 = 0$ or $x^2+15x+30 = 0$

$\therefore x = 2$ or $x = \frac{-15 \pm \sqrt{15^2-4(1)(30)}}{2}$

$= \frac{-15 \pm \sqrt{105}}{2} < 0$ → inadmissable since a length cannot be negative

Let $f(x) = x^3+13x^2-60$

$\because f(2) = 0$

$\therefore x-2$ must be a factor of $f(x)$ (factor theorem)

$$\begin{array}{r} x^2+15x+30 \\ x-2 \overline{)\, x^3+13x^2+0x-60} \\ x^3-2x^2 \\ \hline 15x^2+0x \\ 15x^2-30x \\ \hline +30x-60 \\ 30x-60 \\ \hline 0 \end{array}$$

The dimensions of the box are

2 cm × 2 cm × 15 cm. //

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Grade 12 Advanced Functions (University Preparation)
Unit 3 – Major Test on Rational Functions

Mr. N. Nolfi
Victim: Mr. Solutions Well done Mr. S. !!

KU	APP	TIPS	COM
14/14	22/22	17/17	10/10

1. Match each function with its graph. **(4 KU)**

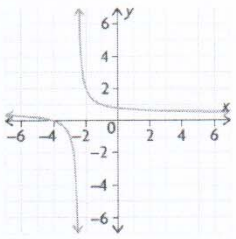
a) $h(x) = \dfrac{x+4}{2x+5}$ VA: $x = -\frac{5}{2}$, HA: $y = \frac{1}{2}$

b) $m(x) = \dfrac{2x-4}{x-2} = \dfrac{2(x-2)}{x-2} = 2,\ x \neq 2$ (hole)

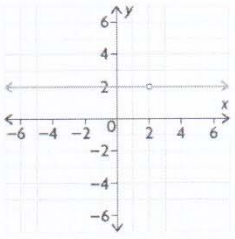
c) $f(x) = \dfrac{3}{x-1}$ VA: $x=1$, HA: $y=0$

d) $g(x) = \dfrac{2x-3}{x+2}$ VA: $x=-2$, HA: $y=2$

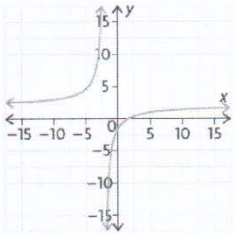
A



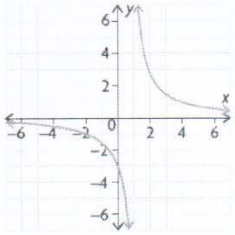
C



B



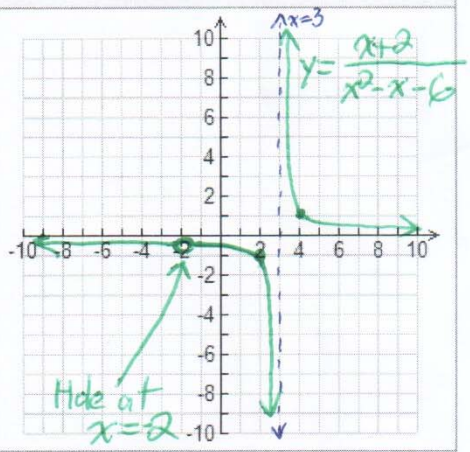
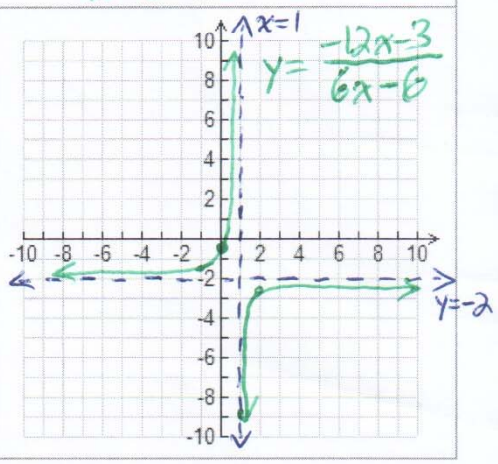
D



a) A b) C

c) D d) B

2. Complete the following table. **(10 KU, 6 APP)**

Equation of Function	*Characteristics of Function*	*Graph*
$f(x) = \dfrac{x+2}{x^2-x-6}$ $= \dfrac{(x+2)}{(x+2)(x-3)}$ $= \dfrac{1}{x-3},\ x \neq -2,\ x \neq 3$	Zeros: none y-intercept: $-\frac{1}{3}$ Domain: $\{x \in \mathbb{R};\ x \neq -2$ and $x \neq 3\}$ Range: $\{y \in \mathbb{R};\ y \neq 0\}$ Asymptote(s): $x=3$ $y=0$ As $x \to \infty$, $f(x) \to 0$ As $x \to -\infty$, $f(x) \to 0$ As $x \to 3^-$, $f(x) \to -\infty$ As $x \to 3^+$, $f(x) \to +\infty$ As $x \to -1^-$, $f(x) \to -\frac{1}{4}$ As $x \to -1^+$, $f(x) \to -\frac{1}{5}$	
$f(x) = \dfrac{-12x-3}{6x-6}$	Zeros: $-\frac{1}{4}$ y-intercept: $\frac{1}{2}$ Domain: $\{x \in \mathbb{R};\ x \neq 1\}$ Range: $\{y \in \mathbb{R};\ y \neq -2\}$ Asymptote(s): $x=1$, $y=-2$ As $x \to \infty$, $f(x) \to -2$ As $x \to -\infty$, $f(x) \to -2$ As $x \to 1^-$, $f(x) \to +\infty$ As $x \to 1^+$, $f(x) \to -\infty$	

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3. Solve.

(a) $\frac{-b}{b-1}=\frac{-3}{b+7}$ **(5 APP)** (Multiply B.S. by $(b-1)(b-7)$)

$\therefore -b(b+7)=-3(b-1)$

$\therefore -b^2-7b=-3b+3$

$\therefore -b^2-7b+3b-3=0$

$\therefore -b^2-4b-3=0$

$\therefore b^2+4b+3=0$

$\therefore (b+1)(b+3)=0$

$\therefore b+1=0$ or $b+3=0$

$\therefore b=-1$ or $b=-3$

(b) $\frac{2}{c+5}>\frac{3c}{c+10}$ **(6 APP)**

Don't multiply B.S. by $(c+5)(c+10)$ because a number of cases would need to be considered to decide if inequality needs to be reversed.

$\therefore \frac{2}{c+5}-\frac{3c}{c+10}>0$

$\therefore \frac{2(c+10)}{(c+5)(c+10)}-\frac{3c(c+5)}{(c+5)(c+10)}>0$

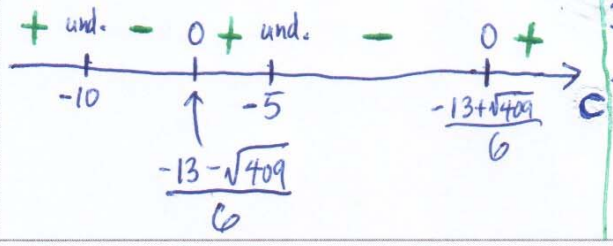
$\therefore \frac{2c+20-(3c^2+15c)}{(c+5)(c+10)}>0$

$\therefore \frac{-3c^2-13c+20}{(c+5)(c+10)}>0$

$\therefore \frac{3c^2+13c-20}{(c+5)(c+10)}<0$ (Both sides multiplied by -1)

The solution set is

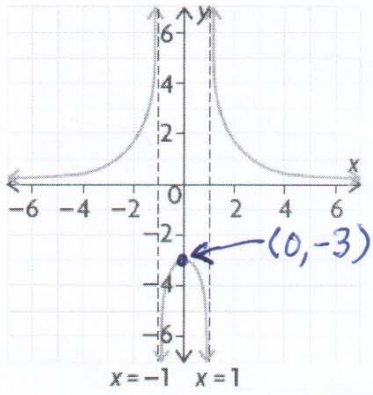
$\{c\in\mathbb{R} \mid -10<c<\frac{-13-\sqrt{409}}{6}$ or $-5<c<\frac{-13+\sqrt{409}}{6}\}$



$3c^2+13c-20=0$

$\therefore c=\frac{-13\pm\sqrt{409}}{6}$

4. The graph of the rational function f is shown at the right. If the equation of f has the form $f(x)=\frac{m}{x^2+kx+n}$, determine the values of k, m and n. **(5 TIPS)**



Since f has vertical asymptotes $x=-1$ and $x=1$

$\therefore x^2+kx+n=(x+1)(x-1)$

$\therefore x^2+kx+n=x^2-1$

$\therefore k=0$ and $n=-1$

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

Since $(0,-3)$ lies on the graph of f, $f(0)=-3$

$\therefore \frac{m}{0^2-1}=-3$

$\therefore \frac{m}{-1}=-3$

$\therefore m=3$

Therefore, $k=0$, $n=-1$ and $m=3$

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5. As the date of the MHF4U0 exam drew nearer, Manavjot and Niroj became increasingly nervous. To help relieve their stress, they decided to walk along a straight line on which Mr. Nolfi had marked an origin.

At the time t seconds,

Niroj's distance from the origin is given by the function $s_N(t) = \frac{7t}{t^2+1}$ and

Manavjot's distance from the origin is given by the function $s_M(t) = t + \frac{5}{t+2}$.

(a) At what time(s) do Niroj and Manavjot collide? **(4 TIPS)**

Niroj and Manavjot collide when their distances from the origin are the same at a particular time. That is, they collide whenever

$$S_N(t) = S_M(t)$$

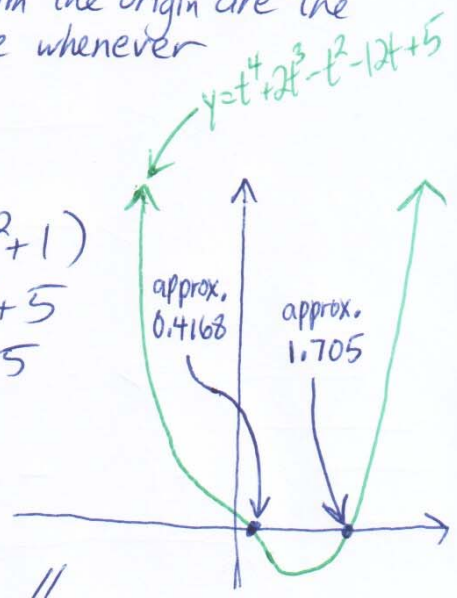
$$\therefore \frac{7t}{t^2+1} = t + \frac{5}{t+2}$$

$$\therefore 7t(t+2) = t(t+2)(t^2+1) + 5(t^2+1)$$

$$\therefore 7t^2+14t = t(t^3+2t^2+t+2) + 5t^2+5$$

$$\therefore 7t^2+14t = t^4+2t^3+t^2+2t+5t^2+5$$

$$\therefore t^4+2t^3-t^2-12t+5 = 0$$



By using a graphing calculator or graphing software, we find that $t \doteq 0.4168$ or $t \doteq 1.705$. Therefore, Manavjot and Niroj collide at about 0.42s and 1.7s. //

(b) When is Niroj closer to the origin than Manavjot? **(4 TIPS)**

Niroj is closer to the origin than Manavjot whenever

$$\frac{7t}{t^2+1} < t + \frac{5}{t+2}$$

Since $t^2+1 > 0$ for all $t \in \mathbb{R}$ and $t+2 > 0$ for all $t > 0$, we can multiply both sides by $(t+2)(t^2+1)$ without reversing the inequality. ($t+2 > 0$ since negative times are meaningless in this context). Following the same steps as in 5(a), we obtain

$$t^4+2t^3-t^2-12t+5 < 0.$$

From the graph in 5(a), we can conclude that t must lie between about 0.4168s and 1.705s. Therefore, Niroj is closer to the origin than Manavjot roughly between 0.4s and 1.7s.

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6. Three employees work at a shipping warehouse. Paco can fill an order two minutes faster than Tom but Carl fills an order one minute slower than Tom. When Tom and Paco work together they can fill an order in one minute and twenty seconds. When Paco and Carl work together, they take one minute and thirty seconds to fill an order.

(a) How long does each person take to fill an order? **(5 APP)**

80 s

$t \rightarrow$ time that it takes Tom to fill an order (in seconds)

$t-120 \rightarrow$ " " " " Paco to " " " (" ")

$t+60 \rightarrow$ " " " " Carl to " " " (" ")

fraction of order completed by Tom when working alone (in one second)

fraction of order completed by Paco in one second when working alone

fraction of order completed in one second (by Tom and Paco together)

$$\therefore \frac{1}{t} + \frac{1}{t-120} = \frac{1}{80}$$

$$\therefore 80(t-120) + 80t = t(t-120)$$

$$\therefore 160t - 9600 = t^2 - 120t$$

$$\therefore t^2 - 280t + 9600 = 0$$

$$\therefore (t-240)(t-40) = 0$$

$$\therefore t = 240 \text{ or } t = 40$$

inadmissable because this would mean that it Paco could fill an order in $40-120 = -80$ s.

Therefore, it takes Tom 4 minutes, Paco 2 minutes and Carl 5 minutes to fill an order.

(b) How long would it take all three of them working together to fill an order? **(4 TIPS)**

In one minute,

Tom completes $\frac{1}{4}$ of an order

Paco " $\frac{1}{2}$ of an order

Carl " $\frac{1}{5}$ of an order

Working together, the three of them can complete

$$\frac{1}{4} + \frac{1}{2} + \frac{1}{5} = \frac{5}{20} + \frac{10}{20} + \frac{4}{20} = \frac{19}{20} \text{ of an order}$$

in one minute.

Therefore, it takes them $\frac{20}{19} \doteq 1.05$ minutes to complete an order when working together. //

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