10

MATHEMATICS

Quarter 1 - Module 5: Performing Division of Polynomials Using Long Division and Synthetic Division

AIRs - LM

MATHEMATICS 10
Quarter 1 - Module 5: Performing Division of Polynomials Using Long Division and Synthetic Division
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10

MATHEMATICS

Quarter 1 - Module 5: Performing Division of Polynomials Using Long Division and Synthetic Division

Introductory Message

This Self-Learning Module (SLM) is prepared so that you, our dear learners, can continue your studies and learn while at home. Activities, questions, directions, exercises, and discussions are carefully stated for you to understand each lesson.

Each SLM is composed of different parts. Each part shall guide you step-by-step as you discover and understand the lesson prepared for you.

Pre-tests are provided to measure your prior knowledge on lessons in each SLM. This will tell you if you need to proceed on completing this module or if you need to ask your facilitator or your teacher's assistance for better understanding of the lesson. At the end of each module, you need to answer the post-test to self-check your learning. Answer keys are provided for each activity and test. We trust that you will be honest in using these.

In addition to the material in the main text, Notes to the Teacher are also provided to our facilitators and parents for strategies and reminders on how they can best help you on your home-based learning.

Please use this module with care. Do not put unnecessary marks on any part of this SLM. Use a separate sheet of paper in answering the exercises and tests. And read the instructions carefully before performing each task.

If you have any questions in using this SLM or any difficulty in answering the tasks in this module, do not hesitate to consult your teacher or facilitator.

Thank you.

Target

This module will assess your knowledge on operations on polynomials with emphasis on division.

As you go through this module, you will apply the different mathematical concepts studied and your skills in performing division on polynomials.

If you find any difficulty in answering the exercises, seek assistance from your teacher. Let's start and be prepared with the learnings that you will get along the way!

Learning Competency:

- Performs division of polynomials using long division and synthetic division. (***M10AL-Ig-1***)

After going through this module, you are expected to:

1. recall polynomial expressions
2. arrange polynomial expressions in standard form
3. divide polynomials using long division and synthetic division,

It's time to activate your prior knowledge!
Answer the pre-test to see how much you know about the topic.

Pre-assessment

Read and analyze each item carefully then select the letter that best corresponds to the question. Write your answer in a separate sheet of paper.

1. Which of the following expressions is **NOT** an example of a polynomial?
   A. $x^2 - 5$ B. $x^3 - y^3 + 4$ C. $3x^4 + 5x^2 - 8$ D. $2x^{-5} - 6x^2 + 1$
2. Which of the following polynomial expressions is in standard form?
   A. $3x^2 - 2x^5 + 7$ B. $5x^3 - 2x^2 + 8x^4$
   C. $x^5 - 2x^3 + 4x - 7$ D. $x^4 + 3x^3 - 9x^6 + 8x - 4$
3. In the division algorithm $\frac{P(x)}{d(x)} = Q(x) + \frac{r(x)}{d(x)}$, what is the dividend?
   A. P(x) B. d(x) C. r(x) D. Q(x)

For numbers 4 – 8, use the illustration of long division below:

Divide $(x^2 + 9x + 4)$ by $(x - 3)$

$$
\begin{array}{r|l}
 & x + 12 \\
\hline
x - 3 & x^2 + 9x + 4 \\
 & \underline{-(x^2 - 3x)} \\
 & 12x + 4 \\
 & \underline{-(12x - 36)} \\
 & 40
\end{array}
$$

4. What is the divisor?
   A. 40 B. $x - 3$ C. $x + 12$ D. $x^2 + 9x + 4$
5. What is the dividend?
   A. 40 B. $x - 3$ C. $x + 12$ D. $x^2 + 9x + 4$
6. What are the operations to be used?
   A. Division, Subtraction, Multiplication, Addition B. Multiplication, Addition
   C. Division, Multiplication, Subtraction, Addition D. Addition, Multiplication
7. What is the quotient?
   A. 40 B. $x - 3$ C. $x + 12$ D. $x^2 + 9x + 4$
8. What is the remainder?
   A. 0 B. 1 C. 12 D. 40

For numbers 9 – 11, refer to the synthetic division below:

-5	4	21	26	320
		-20	-5	-105
	4	1	21	215

9. What is the divisor?
   A. $x - 5$ B. $x + 5$ C. 5 D. -5

10. Which polynomial is the dividend?
   A. $4x^4 + 21x^3 + 26x + 320$ B. $4x^3 + 21x^2 + 26x + 320$
   C. $4x^3 + x + 21x + 215$ D. $4x^2 + x + 21 + 215$

11. Which polynomial is the quotient?
   A. $4x^3 + x + 21x + 215$ B. $4x^2 + x + 21 + 215$
   C. $4x^2 + x + 21 + 215/x - 5$ D. $4x^2 + x + 21 + 215/x + 5$
12. If $(7x^4 - 5x^5 - 7x^3 + 2x - 3)$ is divided by $(x + 3)$ using synthetic division, the numbers in the first row would be:
   A. $-7\ -7\ -5\ 0\ 2\ -3$ B. $-3\ 7\ -7\ 0\ 2\ -5$
   C. $-5\ 7\ -7\ 0\ 2\ -3$ D. $1\ 7\ -7\ 0\ 2\ -3$
13. What will be multiplied to $x^2 - 6x + 2$ to get $3x^3 - 19x^2 + 12x - 2$?
   A. $3x - 1$ B. $3x + 1$ C. $3x + 2$ D. $x + 3$
14. Louie used synthetic division to find the quotient if $(5x^2 - 16x + 4x^3 - 3)$ is divided by $(x - 2)$. He obtained – 19 as remainder. His solution is shown below.

2	5	-16	4	-3
		10	-12	-16
	5	-6	-8	-19

   What is the error?
   i. The sign of the divisor was not changed.
   ii. The terms of the polynomial were not arranged according to decreasing powers of x.
   iii. The sum entries in the third row are incorrect.
   iv. The numerical coefficients of the first row were not properly written.
   A. i only B. ii only C. ii and iv only D. I and iii only
15. The volume of a rectangular prism is $(2x^3 - 11x^2 + 13x - 4)cm^3$ and its height is $(x - 4)cm$. What is the area of its base?
   A. $(2x^2 - 3x + 1)cm^2$ B. $(2x^2 + 19x + 76)cm^2$
   C. $(2x^2 + 3x - 1)cm^2$ D. $(2x^2 - 19x - 76)cm^2$

Jumpstart

Before going through this module, let us have a recall on *Polynomial Expression* discussed in your grade 7 mathematics class which is a pre-requisite of the lesson we will be exploring.

You have learned that a **polynomial expression** *P(x)* is an algebraic expression of the form:

$$a_nx^n + a_{n-1}x^{n-1} + a_{n-2}x^{n-2} + \ldots + a_1x + a_0,\ a_n \neq 0.$$

where the nonnegative integer ***n*** is called the degree of the polynomial and coefficients $a_0, a_1, \ldots, a_n$ are real numbers.

The terms of a polynomial may be written in any order. However, we often follow the convention of writing the terms in decreasing powers of the variable x. In this case, the polynomial expression is said to be in ***standard form***.

Activity 1. Fill Me In!

Identify whether the given expressions below are polynomials or not. If yes, express each in standard form.

Expression	Polynomial (Yes or No)	Standard Form
$2x^4 - 4x^2 + 5x^3 - 7$		
$x^{-3} + 2x^2 - 7x^5 + 9$		
$2x^3 - 3x^{1/2} - 4 + x$		
$10x^2 + 2x^4 + 8 + 7x^3$		
$3x^6 - 8\sqrt{x} + 6 - 5x^4$		

How did you find the activity?
Did it help you recall polynomial expressions? Were you able to write the polynomial expressions in standard form?

Discover

*Long roads are often less traveled by, especially when you know there is an easier way to take. Just like in dividing polynomials, you may get confused about finding the quotient. But don't worry because in this module, you will discover two essential ways to learning "**Division of Polynomials**." So let your mind endure, and enjoy the path of Long Division and Synthetic Division.*

A. Dividing Polynomials using Long Division

The method used to divide a polynomial by a two- or three-termed polynomial is like long division of whole numbers in arithmetic.

Example 1. Divide $(9x^4 - 2 - 6x - x^2)$ by $(x - 1)$.

Solution:

Step 1. Rewrite the problem in long division form: $\boldsymbol{divisor)\overline{dividend}}$. See to it that both the dividend and the divisor are expressed in standard form. Insert **0** coefficients for any missing term.

$$x - 1 \overline{)\ 9x^4 + 0x^3 - x^2 - 6x - 2}$$

Step 2. Divide the first term of the dividend $(9x^4)$ by the first term of the divisor (x). Write the quotient above the similar term.

$$\begin{array}{r} 9x^3 \\ x - 1 \overline{)\ 9x^4 + 0x^3 - x^2 - 6x - 2} \end{array} \quad \Rightarrow \quad \boldsymbol{9x^4 \div x = 9x^3}$$

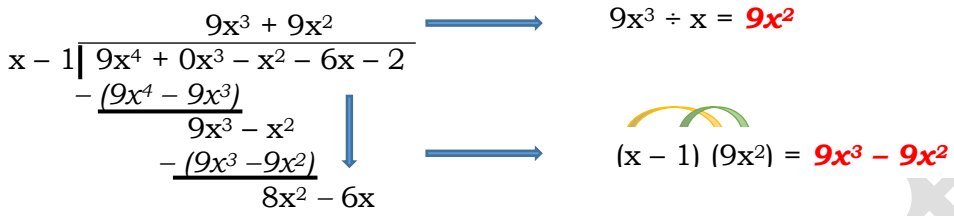
Step 3. Multiply the divisor by the first quotient. Write the terms of the product under similar terms.

$$\begin{array}{r} 9x^3 \\ x - 1 \overline{)\ 9x^4 + 0x^3 - x^2 - 6x - 2} \\ \underline{\boldsymbol{9x^4 - 9x^3}} \end{array} \quad \Rightarrow \quad (x - 1)(9x^3) = \boldsymbol{9x^4 - 9x^3}$$

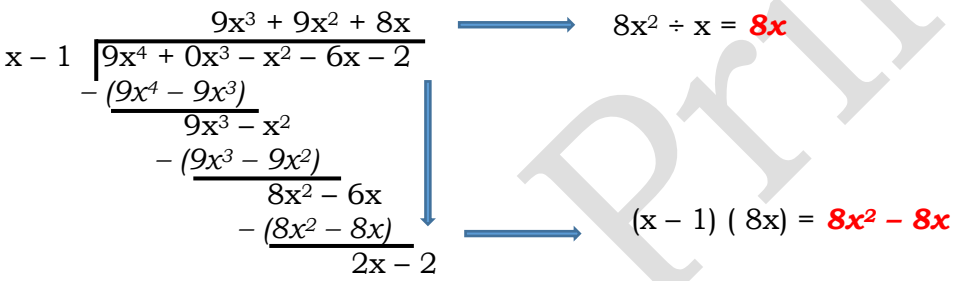
Step 4. Subtract the product from the dividend (*change the sign of the product which is the subtrahend*) then bring down the next term.

$$\begin{array}{r} 9x^3 \\ x - 1 \overline{)\ 9x^4 + 0x^3 - x^2 - 6x - 2} \\ \underline{-(9x^4 - 9x^3)} \\ 9x^3 - x^2 \end{array} \quad \Rightarrow \quad -(9x^4 - 9x^3) = \boldsymbol{-9x^4 + 9x^3}$$

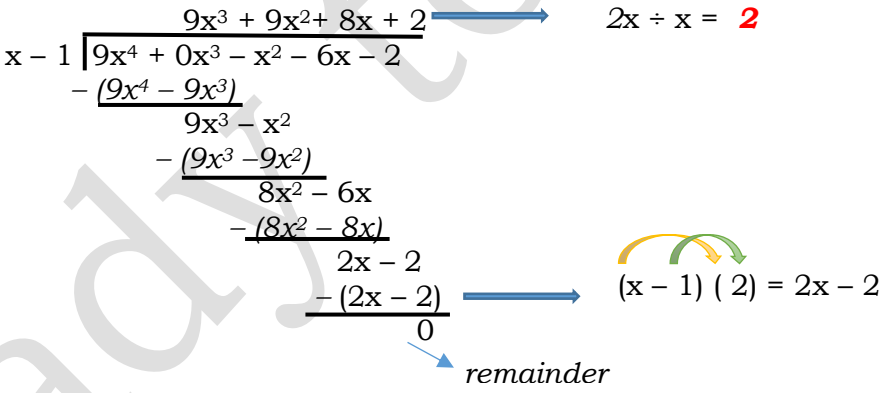
Step 5. Repeat steps 2 to 4. This time, the difference and the next term will be the new dividend.



Step 6. The steps 2 to 4 will be repeated with ***8x² – 6x*** as the new dividend.



Step 7. Continue the process until the degree of the remainder is less than that of the divisor, or the remainder is 0.



Therefore, the quotient is ***9x³ + 9x² + 8x + 2.***

In general, when a polynomial is divided by another polynomial, we express the result in the following form:

$$\frac{P(x)}{d(x)} = Q(x) + \frac{r(x)}{d(x)}$$

where ***P(x)*** is the dividend, ***d(x)*** ≠ 0 is the divisor, ***Q(x)*** is the quotient and ***r(x)*** is the remainder.

Example 2. **(**Divide $4x^5 - 16x + 40x^3 - 5 + 3x^2 - 25x^4$) by ($x^2 + 9 - 6x$)

Solution:

Follow the steps shown from example 1.

$$\frac{4x^5 - 25x^4 + 40x^3 + 3x^2 - 16x - 5}{x^2 - 6x + 9}$$

→ *dividend*
→ *divisor*

both must be in standard form

$$4x^3 - x^2 - 2x \quad \rightarrow \text{Quotient}$$

$$x^2 - 6x + 9 \;\overline{)\; 4x^5 - 25x^4 + 40x^3 + 3x^2 - 16x - 5}$$

$$-(4x^5 - 24x^4 + 36x^3) \quad \rightarrow \text{Multiply: } 4x^3(x^2 - 6x + 9)$$

$$-x^4 + 4x^3 + 3x^2 \quad \rightarrow \text{Subtract. Bring down } 3x^2$$

$$-(x^4 + 6x^3 - 9x^2) \quad \rightarrow \text{Multiply. } -x^2(x^2 - 6x + 9)$$

$$-2x^3 + 12x^2 - 16x \quad \rightarrow \text{Subtract. Bring down } -16x$$

$$-(-2x^3 + 12x^2 - 18x) \quad \rightarrow \text{Multiply. } -2x(x^2 - 6x + 9)$$

$$2x - 5 \quad \rightarrow$$

Subtract. Bring down -5
(2x – 5) is the ***remainder*** since the degree of $2x < x^2$.

Hence; $\dfrac{4x^5 - 25x^4 + 40x^3 + 3x^2 - 16x - 5}{x^2 - 6x + 9} = \mathbf{4x^3 - x^2 - 2x + \dfrac{2x - 5}{x^2 - 6x + 9}}$

B. Dividing Polynomials Using Synthetic Division

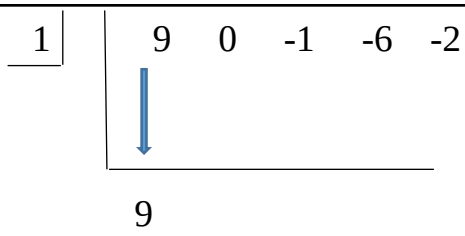
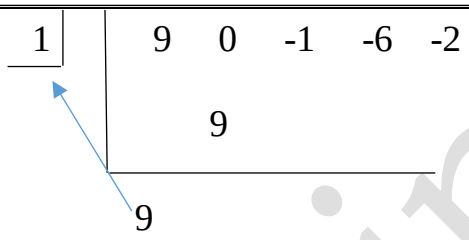
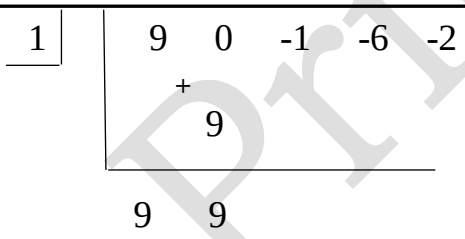
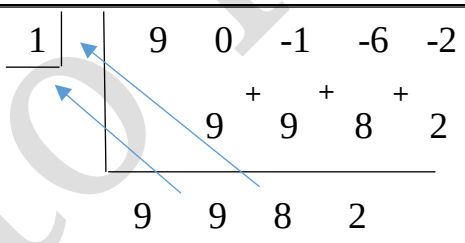
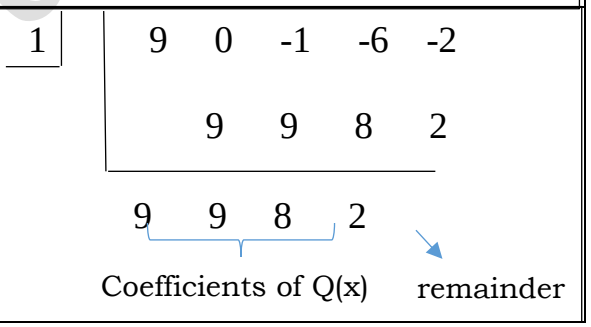
There is a well-known algorithm for dividing a polynomial **P(x)** by a binomial of the form **(x – r).** This method is called ***synthetic division*** which is a shorter procedure compared to that of long division. When you do long division, you are using the four operations, but in synthetic division, you can only use multiplication and addition operations.

Let us illustrate synthetic division through the steps outlined below. The process involves writing numbers in three rows.

Example 3. Use synthetic division to divide *($9x^4 - 2 - 6x - x^2$)* by *($x - 1$).*

(**NOTE:** *The dividend and divisor are the given polynomials in example 1 for us to check whether the same quotient will be obtained with both methods*).

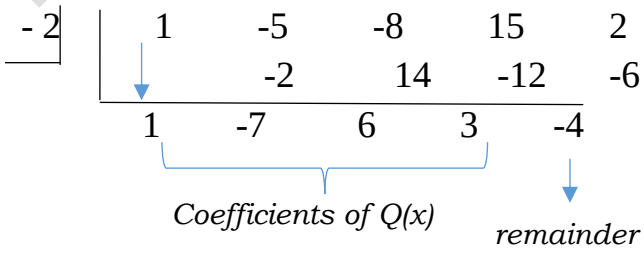
Step 1: *Set P(x) into its standard form*	P(x) = $9x^4 - x^2 - 6x - 2$
Step 2: *Arrange the coefficients of P(x) in descending order of power, replacing 0 with any missing term. (**There is no x^3 in P(x), so its coefficient is 0**).*	___ | 9 0 -1 -6 -2

Step 3: *Place the value of r in the upper left corner. Since the divisor is x – 1, then r = 1 then bring down the first coefficient which is 9. It will be the first entry of the third row.*	
Step 4: *Multiply 9 by 1 then write the result below 0. This becomes the first entry in the second row.*	
Step 5. *Add 0 and 9. The sum becomes the second entry in the third row.*	
Step 6. *Multiply 9(2nd entry in the third row) by 1 and write the answer below -1. Add -1 and 9, then the result will be multiplied to 1, to place below – 6. Afterwards, add -6 and 8. Repeat the process until all colums are filled.*	
Step 7. *The numbers 9, 9, 8, 2 in the third row represent the coefficients of Q(x) which must be one degree less than P(x) and the last number in the third row which is 0 is the remainder.* *∴ the quotient is* $\mathbf{9x^3 + 9x^2 + 8x + 2}$	

In this example, the same answer was obtained using long division and synthetic division.

Example 4. Divide ($x^4 - 5x^3 - 8x^2 + 15x + 2$) by (x + 2)

Solution: Since the dividend is already in standard form and there are no missing term, write the coefficients of the polynomial in the first row. Follow the steps described in example 3.



Therefore, the quotient is

$$\mathbf{x^3 - 7x^2 + 6x + 3 + \frac{-4}{x + 2}}$$

Example 5. Use synthetic division to find the quotient of *$(8x^3 - 2x^2 - 19x - 15)$* by *$(4x + 5)$*.

Solution:

The divisor is not in the form (x – r). However, note that 4x+5 = 4(x + $\frac{5}{4}$).

Hence, the problem can be restated as follows: $\frac{\mathbf{8x^3-2x^2-19x-15}}{\mathbf{4(x+\frac{5}{4})}}$.

Thus, we first use synthetic division to get the quotient then divide the result by 4 to get the final answer.

$\frac{-5}{4}$ | 8 -2 -19 -15

-10 15 5

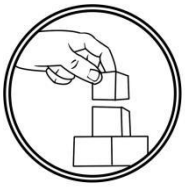
8 -12 - 4 - 10

Coefficients of Q(x) *remainder*

For the final answer, divide the result ($8x^2 - 12x - 4 + \frac{-10}{x+\frac{4}{5}}$) by 4.

Therefore, the quotient is $\mathbf{2x^2 - 3x - 1 + \frac{-10}{5x+4}}$.

How was your journey?
Which do you find easier, the long division or the synthetic division? Remember, whatever method you use, you will be arriving the same answer.
Now that you have learned about the division of polynomials, be ready to perform the preceding activities.



Explore

Here are some enrichment activities for you to work on to master and strengthen the concepts you have learned from this lesson.

Activity 2: *Divide and Write!*

Find the quotient of the following through:

A. Long Division

1. $(2x^3 + 9x^2 - 4 + 3x)$ by $(x + 4)$
2. $(x + 3x^4 - 2 - x^3)$ by $(x^2 + x + 1)$

B. Synthetic Division

3. $(4x^2 - 25 + x^3 - x)$ by $(x + 5)$
4. $(x^5 - 3x^3 - 2x - 4)$ by $(x + 1)$
5. $(2x^4 + 3x^2 + 12 + 5x^3 + 8x)$ by $(2x + 3)$

Activity 3: TRIVIA

TO WHICH ANIMAL FAMILY DOES THE IBEX BELONG

Directions: Match column **A** with column **B.** Place the letter that represents the quotient and the remainder in the box that corresponds to the number representing the given polynomials.

A	**B**
1. $(3x^3 - 5x + 4)$ by $(x + 2)$	**A.** $x^3 - x^2 + 2x + 4$; R = 7
2. $(2x^5 - 2x^3 + 4x^2 - 3)$ by $(x + 1)$	**L.** $2x^4 + 3x^3 + 6x^2 + 9x + 16$; R = 33
3. $(x^4 - 3x^3 + 4x^2 - 1)$ by $(x - 2)$	**D.** $2x^2 - 5x + 17$; R = - 54
4. $(x^4 - x^2 - x - 1)$ by $(x - 1)$	**W.** $3x^3 + x^2 + 4x + 7$; R = 13
5. $(2x^5 - x^4 - 3x^2 - 2x + 1)$ by $(x - 2)$	**T.** $3x^2 - 6x + 7$; R = - 10
6. $(2x^3 + x^2 + 2x - 3)$ by $(x + 3)$	**I.** $x^3 + x^2 - 1$; R = - 2
7. $(x^4 - 2x^3 - 3x + 3)$ by $(x - 3)$	**O.** $2x^4 - x^3 + x^2 - 2x + 5$; R = - 12
8. $(3x^4 - 5x^3 + 2x^2 - x - 1)$ by $(x - 2)$	**S.** $2x^4 - 2x^3 + 4x - 4$; R = 1
9. $(2x^5 + 3x^4 - x^3 + x - 2)$ by $(x + 2)$	**G.** $x^3 + x^2 + 3x + 6$; R = 21
	E. $3x^2 + 6x - 7$; R = 10

8	**4**	**5**	**6**		**7**	**9**	**3**	**1**	**2**

*Pascual, Ferdinand C, et al. (2004), Worktext in Advanced Algebra, Trigonometry and Statistics, Simplified Concepts and Structures, Sta Ana, Manila, **EIMI**(Innovative Educational Materials Inc).*

Deepen

Let's dig deeper by applying the concept on division of polynomials in solving real-life word problem.

Activity 4: ***Apply your Skills into the Real World!***

Solve the following problems by dividing the polynomials given. You may use the method you are most comfortable with. Show your complete solutions.

1. Johnny works for $(x + 5)$ hours as a contact tracer in the city of San Fernando. He earns $(2x^3 + 13x^2 + 21x + 30)$ pesos today. How much does Johnny earn per hour?

2. Jenny bought $(2x^4 + 5x^3 + 2x^2 - 7x - 21)$ pesos worth of canned goods for her scheduled community pantry. If each canned good costs $(2x - 3)$ pesos, how many canned goods did Jenny buy?

3. There are $(x^4 + 3x^3 - 4x^2)$ vaccines to be given in the province of La Union. If there are $(x + 4)$ municipalities to receive equal number of distributions, how many vaccines will be given to each municipality?

Rubric for Problem Solving

4	3	2	1
Used an appropriate strategy to come up with a correct solution and arrived at a correct answer	Used an appropriate strategy to come up with a solution, but a part of the solution led to an incorrect answer	Used an appropriate strategy but came up with an entirely wrong solution that led to an incorrect answer	Attempted to solve the problem but used an inappropriate strategy that led to a wrong solution

Gauge

Well done! You were able to reach this destination where you can measure your patience and understanding when taking the ***two different roads*** *–* ***methods in dividing polynomials****. Your final task is the assessment part! Good Luck!*

Post-assessment

Let us determine how much you have learned from this module. Read and understand each item carefully, then choose the letter of your answer and write it on your answer sheet.

1. Which of the following expressions is a polynomial?
   A. $\sqrt[3]{x} - 5$ B. $\frac{x+7}{x^2} + 4$ C. $8x^3 + 9x^5 + 6$ D. $2x^3 - 6x^{-2} + 1$
2. Which of the following polynomial expressions is **NOT** in standard form?
   A. $3x^2 - 2x^5 + 7$ B. $5x^4 - 2x^2 + 8x + 6$
   C. $x^5 - 2x^3 + 4x - 7$ D. $x^6 + 3x^3 - 9x^2 + 8x - 4$
3. In the division algorithm $\frac{P(x)}{d(x)} = Q(x) + \frac{r(x)}{d(x)}$, what is the divisor?
   A. P(x) B. d(x) C. r(x) D. Q(x)

For numbers 4 – 7, use the illustration of long division below:

Divide $(3x^3 + 5x^2 + x - 2)$ by $(x - 2)$

$$
\begin{array}{r|l}
 & 3x^2 - x + 3 \\
\hline
x + 2 & 3x^3 + 5x^2 + x - 2 \\
 & \underline{-(3x^3 + 6x^2)} \\
 & -x^2 + x \\
 & \underline{-(-x^2 - 2x)} \\
 & 3x - 2 \\
 & \underline{-(3x + 6)} \\
 & -8
\end{array}
$$

4. What is the dividend?
   A. – 8 B. x + 2 C. $3x^2 - x + 3$ D. $3x^3 + 5x^2 + x - 2$
5. What is the divisor?
   A. – 8 B. x + 2 C. $3x^2 - x + 3$ D. $3x^3 + 5x^2 + x - 2$
6. What is the quotient?
   A. – 8 B. x + 2 C. $3x^2 - x + 3$ D. $3x^3 + 5x^2 + x - 2$
7. What is the remainder?
   A. – 8 B. 0 C. 2 D. 8

For numbers 8 – 10, refer to the synthetic division below:

$$
\begin{array}{r|cccc}
-4 & -3 & 1 & 0 & -208 \\
 & & 12 & -52 & 208 \\
\hline
 & -3 & 13 & -52 & 0
\end{array}
$$

8. What is the divisor?
   A. $x - 4$ B. $x + 4$ C. -4 D. 4
9. Which polynomial is the quotient?
   A. $-3x^2 + 13x - 52$ B. $-3x^2 + 13x + 52$
   C. $-3x^3 + 13x - 52$ D. $-3x^3 + 13x^2 + 52$
10. Which polynomial is the dividend?
   A. $-3x^3 + x + 52x - 208$ B. $-3x^3 + x + 52x + 208$
   C. $-3x^3 + x - 208$ D. $-3x^3 + x + 208$
11. If $(7x^4 - 5x^5 + 27x^3 - 28x + 3)$ is divided by $(x - 3)$ using synthetic division, the numbers in the second row would be:
   A. $-15\ -24\ -9\ 27\ -3$ B. $-15\ -24\ 9\ 27\ 3$
   C. $-15\ 24\ -9\ 27\ -3$ D. $-15\ -24\ 9\ 27\ -3$
12. What will be multiplied to $x^2 - 6x + 2$ to get $3x^3 - 17x^2 + 2$?
   A. $x + 3$ B. $3x + 2$ C. $3x + 1$ D. $3x - 1$
13. Which polynomial gives a quotient of $(3x^2 + 2x + 4)$ and a remainder of 19 when divided by $(2x - 3)$?
   A. $6x^3 - 5x^2 + 2x$ B. $6x^3 - 5x^2 + 4x + 7$
   C. $6x^3 - 5x^2 + 2x + 7$ D. $6x^3 + 5x^2 + 2x + 7$
14. Leah used synthetic division to find the quotient if $(5x^2 - 16x + 4x^3 - 3)$ is divided by $(x - 2)$. She obtained -19 as remainder. Her solution is shown below.

-2	4	5	-16	-3
		-8	6	20
	4	-3	10	17

What is the error?
   i. The sign of the divisor was not changed.
   ii. The terms of the polynomial were not arranged according to decreasing powers of x.
   iii. The sum entries in the third row are incorrect.
   iv. The numerical coefficients of the first row were not properly written.

   A. i only B. ii only C. ii and iv only D. i and iii only
15. The volume of a rectangular prism is $(2x^3 + 11x^2 + 11x - 4)cm^3$ and its height is $(x + 4)cm$. What is the area of its base?
   A. $(2x^2 - 3x + 1)cm^2$ B. $(2x^2 + 19x + 76)cm^2$
   C. $(2x^2 + 3x - 1)cm^2$ D. $(2x^2 - 19x - 76)cm^2$

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