September 20, 2020

Baseline revue test. Algebra.

1. Open brackets and expand the following expressions
   a. $(a+b)^2 =$
   b. $(a-b)^2 =$
   c. $(a+b)^3 =$
   d. $(a-b)^3 =$
2. Factor the following expressions
   a. $a^2 - b^2 =$
   b. $a^2 + b^2 =$
   c. $a^3 - b^3 =$
   d. $a^3 + b^3 =$
   e. $1 + a + a^2 + a^3 =$
3. For a quadratic equation $ax^2 + bx + c = 0$ the roots are,
   $x_{1,2} =$
   and they have the following properties,
   $x_1 + x_2 =$
   $x_1 \cdot x_2 =$
4. Open brackets and expand the following expression

   $(a+b)^{10} =$

5. What is the number of permutations of n objects?
6. How many ways is there to select k objects out of n if,
   a. order does matter?
   b. order does not matter?
7. Write the formula for a binomial coefficient

   $${}_nC_k \equiv C_n^k \equiv \binom{n}{k} =$$

   and explain its relation to combinatorics and certain counting problems.

Solutions to the baseline revue test. Algebra.

1. Open brackets and expand the following expressions
   a. $(a+b)^2 = a^2 + 2ab + b^2$
   b. $(a-b)^2 = a^2 - 2ab + b^2$
   c. $(a+b)^3 = a^3 + 3a^2b + 3ab^2 + b^3$
   d. $(a-b)^3 = a^3 - 3a^2b + 3ab^2 - b^3$
2. Factor the following expressions
   a. $a^2 - b^2 = (a-b)(a+b)$
   b. $a^2 + b^2 = \ldots$
   c. $a^3 - b^3 = (a-b)(a^2 + ab + b^2)$
   d. $a^3 + b^3 = (a+b)(a^2 - ab + b^2)$
   e. $1 + a + a^2 + a^3 = (1+a)(1+a^2) = \frac{1-a^4}{1-a}$

   The last example was a particular case of a geometric progression, whose sum is one of the most important expressions in algebra,

$$1 + a + a^2 + \cdots + a^n = \frac{1-a^{n+1}}{1-a}$$

   A simple heuristic way to prove this result is to multiply both sides with $(1-a)$ and then open the brackets,

$$(1 + a + a^2 + \cdots + a^n)(1-a) = 1 - a + a - a^2 + a^2 - \cdots - a^n + a^n - a^{n+1} = 1 - a^{n+1}$$

3. For a quadratic equation $ax^2 + bx + c = 0$ the roots are,
   $x_{1,2} = \frac{-b \pm \sqrt{b^2-4ac}}{2a}$
   and they have the following properties,
   $x_1 + x_2 = -\frac{b}{a}$
   $x_1 \cdot x_2 = \frac{c}{a}$

Although this can be checked by direct substitution of the formula for $x_{1,2}$, the easiest way to see this is by rewriting the equation in the reduced form and identifying it with the product of the two brackets,

$$ax^2 + bx + c = 0 \Leftrightarrow x^2 + \frac{b}{a}x + \frac{c}{a} = 0 \Leftrightarrow (x-x_1)(x-x_2) = 0 \Leftrightarrow x^2 - (x_1+x_2)x + x_1x_2 = 0$$

This is an example of the polynomial factorization, which we will be studying in significant detail this year.

4. Open brackets and expand the following expression,

$$(a+b)^n = a^n + na^{n-1}b + {}_nC_k a^{n-2}b^2 + {}_nC_k a^{n-k}b^k + \cdots + {}_nC_1 a\, b^{n-1} + b^n$$

This is the Newton's binomial formula, and we will be reviewing and re-deriving it later this year using the mathematical induction.

5. What is the number of permutations of n objects? Answer: $n!$

This is the number of ways that n different objects (or subjects) can be placed into n different places.

Examples:

- How many ways is there to sit n people in a movie theater with n numbered chairs?
- How many ways is there to hand out n different books to n students?
- How many ways is there to place n numbered billiard balls into n numbered spots?

There is n ways to select a place for the first object (subject), for each of these n choices there is $n-1$ choice to place the second one, so there are $n(n-1)$ in total different choices to fill the first two spots, and so on. Hence, there are $n! = n(n-1)(n-2)\ldots\cdot 2\cdot 1$.

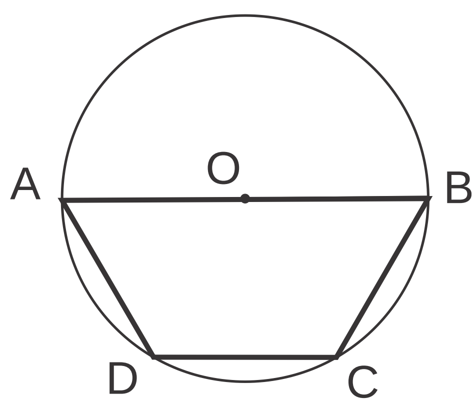
6. How many ways is there to select k objects out of n if,
    a. order does matter? Answer: ${}_nP_k = \frac{n!}{(n-k)!}$
    b. order does not matter? Answer: ${}_nC_k = \frac{n!}{k!(n-k)!}$

Math 9 placement test 2020

1. Open brackets and expand the following expressions
    a. $(a+b)^2 =$
    b. $(a-b)^3 =$
2. Factor the following expressions
    a. $a^2 - b^2 =$
    b. $a^3 - b^3 =$
    c. $a^3 + b^3 =$
    d. $1 + a + a^2 + a^3 =$
3. Find the remainder of 2020^{2020} upon division by 3.
4. Solve the equation

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

5. Eight teams have reached the quarter-finals of the soccer World Cup.
    a. How many ways are there for these teams to be paired to play the quarter-final games?
    b. How many different outcomes of which team wins which medal (gold, silver, bronze) are possible?
6. Trapezoid $ABCD$ is inscribed in a circle of radius r as shown in the Figure. The longer base of the trapezoid is equal to diameter, $|AB| = 2r$, while the shorter bas equals r. Find the area of the trapezoid $ABCD$.



Math 9 placement test 2019

1. Factor the following expressions
    a. $a^2 - b^2 =$
    b. $a^3 - b^3 =$
    c. $a^3 + b^3 =$
    d. $1 + a + a^2 + a^3 =$

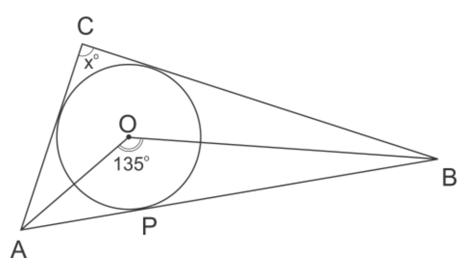
2. Find the coefficient of x^7 in the polynomial $(1 + 2x)^9$.
3. Let x_1, x_2 be roots of the equation $x^2 = x + 1$. Find $\frac{1}{x_1} + \frac{1}{x_2}$.
4. Find the remainder of 2^{2019} upon division by 7.
5. Let $ABCD$ be a trapezoid, with bases AD and BC, and let E, F be midpoints of sides AB, CD respectively. If $BC = 2$ cm, $AD = 6$ cm, then what is EF? Can you prove your answer?

Math 9 placement test 2018

6. Open brackets and expand the following expressions
   a. $(a + b)^2 =$
   b. $(a - b)^3 =$
7. Factor the following expressions
   a. $a^2 - b^2 =$
   b. $a^3 - b^3 =$
   c. $a^3 + b^3 =$
   d. $1 + a + a^2 + a^3 =$
8. Solve the following inequality. Write your answer as a set of possible values for x.

$$\frac{(x + 2)^2(x - 7)}{x + 3} \leq 0$$

9. Find the remainder of 2^{2019} upon division by 7.
10. Let x_1, x_2 be roots of the equation $x^2 = x + 1$. Find $\frac{1}{x_1} + \frac{1}{x_2}$.
11. Find the remainder upon division of 2^{2019} by 7.
12. O is the center of the inscribed circle in triangle ABC. The angle AOB is 135 degrees. Find the angle ACB.



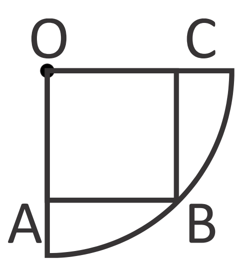
Math 9 placement test 2017

1. Open brackets and expand the following expressions
   a. $(a+b)^2 =$
   b. $(a-b)^3 =$
2. Factor the following expressions
   a. $a^2 - b^2 =$
   b. $a^3 - b^3 =$
   c. $a^3 + b^3 =$
   d. $1 + a + a^2 + a^3 =$
3. Find the remainder of 3^{2017} upon division by 4.
4. Solve the equation

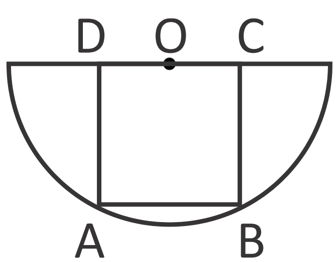
$$x + \frac{1}{x} = 7\frac{1}{7}$$

5. Eight teams have reached the quarter-finals of the soccer World Cup.
   a. How many ways are there for these teams to be paired to play the quarter-final games?
   b. How many different outcomes of which team wins which medal (gold, silver, bronze) are possible?
6. Find the area of a square inscribed in

   a. a quarter circle of radius r, as shown in the Figure below,



   b. a semicircle circle of radius r as shown in the Figure below.



Math 9 placement test 2016

1. Open brackets and expand the following expressions
    a. $(a+b)^2 =$
    b. $(a-b)^3 =$
2. Factor the following expressions
    a. $a^2 - b^2 =$
    b. $a^3 - b^3 =$
    c. $a^3 + b^3 =$
    d. $1 + a + a^2 + a^3 =$
3. Find the remainder of 3^{2016} upon division by 5.
4. Solve the equation

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

5. Eight teams have reached the quarter-finals of the soccer World Cup.
    a. How many ways are there for these teams to be paired to play the quarter-final games?
    b. How many different outcomes of which team wins which medal (gold, silver, bronze) are possible?
6. Four equal segments are cut off a circle of radius r so that a square is obtained. Find the area of each of these segments.

Math 8-9 placement test 2015

1. How many ways are there to choose a team captain and 6 team members out of 15 candidates?
2. If x_1, x_2 are roots of the square equation $x^2 + 2x - 7$, what is $x_1 x_2$? $\frac{1}{x_1} + \frac{1}{x_2}$?
3. Simplify the following expression

$$\frac{(a^2 - b^2)^3}{(a-b)(a+b)^2}$$

4. How many “words” can you form by permuting the letters of the word “letter”? (A “word” is any combination of letters, not necessarily meaningful)
5. Points $A = (0,0)$, $B = (2,0)$, and C on the coordinate plane form an equilateral triangle. What are the coordinates of point C?
6. Factor $a^4 - b^4$.
7. Corners of a square with the side a are cut off so that a regular octagon is obtained. Find the area of this octagon.
8. Solve the inequality

$$\frac{x+5}{x^2 - 2x - 3} > 0$$

9. If we write the polynomial $(x+2)^{10}$ in the usual form $x^{10} + a_1 x^9 + a_2 x^8 + \ldots$, what would be the coefficient of x^6?
10. Find all integer numbers which give remainder 2 upon division by 7 and remainder 5 upon division by 13.
11. Given triangle ABC, explain how to construct (using ruler and compass) a point which is at equal distance from points A, B, and C.

Math 8-9 placement test 2015: solutions to selected problems

(1) $15 \cdot C_{14}^{6} = 15 \cdot \frac{14!}{6! \cdot 8!} = \frac{15 \cdot 14 \cdot 13 \cdot 12 \cdot 11 \cdot 10 \cdot 9}{6 \cdot 5 \cdot 4 \cdot 3 \cdot 2}$

$= 15 \cdot 7 \cdot 13 \cdot 11 \cdot 3 = \boxed{45045}$

(2) $x_1 + x_2 = -2$

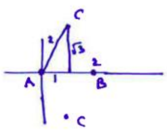
$\boxed{x_1 \cdot x_2 = -7}$

$\frac{x_1 + x_2}{x_1 \cdot x_2} = \frac{1}{x_1} + \frac{1}{x_2} = \frac{-2}{-7} = \boxed{\frac{2}{7}}$

(3) $\frac{(a-b)^3 (a+b)^3}{(a-b)(a+b)^2} = \boxed{(a-b)^2 (a+b)}$

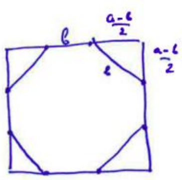
(4) letter

$\boxed{\frac{6!}{2! \cdot 2!}} = \frac{120 \cdot 6}{2 \cdot 2} = 60 \cdot 3 = \boxed{180}$

(5) 

$\boxed{C = (1, \sqrt{3}) \quad \text{or} \quad (1, -\sqrt{3})}$

(6) $a^4 - b^4 = (a^2 - b^2)(a^2 + b^2) = \boxed{(a-b)(a+b)(a^2+b^2)}$

(7) 

$b^2 = 2\left(\frac{a-b}{2}\right)^2$

$2b^2 = (a-b)^2$

$b^2 + 2ab - a^2 = 0 \qquad b = -a \pm \sqrt{a^2 + a^2}$

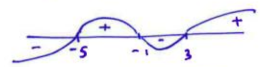
$b = (\sqrt{2} - 1)a$

$\text{Area} = a^2 - 4 \cdot \left(\frac{a-b}{2}\right)^2 \cdot \frac{1}{2} = a^2 - \frac{(a-b)^2}{2}$

$= a^2 - \frac{a^2}{2}(2 - \sqrt{2})^2 = a^2 - a^2[2 - 2\sqrt{2} + 1] = a^2[2\sqrt{2} - 2]$

$\boxed{\text{Area} = 2(\sqrt{2} - 1)a^2}$

(8) $\frac{x+5}{x^2 - 2x - 3} > 0 \qquad \frac{x+5}{(x-3)(x+1)} > 0 \qquad x \neq 3, \ x \neq -1$



$\boxed{x \in (-5, -1) \cup (3, +\infty)}$

(9) $(x+2)^{10} = x^{10} + \ldots + a_4 x^6 + \ldots \qquad a_4 = C_{10}^{4} = \frac{10!}{6! \cdot 4!}$

$a_4 = \frac{10 \cdot 9 \cdot 8 \cdot 7}{4 \cdot 3 \cdot 2} = 210 \qquad \boxed{a_4 = 210}$

alternatively by Pascal's triangle

(10) $n = 7k + 2 = 13m + 5$

$7k = 3 \mod 13 \qquad 7k' = 1 \mod 13$

$k' = 2$

$k = 6 + 13l \quad (m = 7l + 3) \qquad 7 \cdot 6 = 3 \mod 13$

$n = 7(6 + 13l) + 2 = 7 \cdot 13\, l + 44$

$\boxed{n = 91l + 44 \qquad l = 0, \pm 1, \pm 2 \ldots}$

12.

Math 9 placement test 2014

1. Open brackets and expand the following expressions
    a. $(a+b)^2 =$
    b. $(a-b)^3 =$
2. Factor the following expressions
    a. $a^2 - b^2 =$
    b. $a^3 - b^3 =$
    c. $a^3 + b^3 =$
    d. $1 + a + a^2 + a^3 =$
3. Find the coefficient of x^5 in the expression $(1+2x)^8$
4. Find the remainder of 3^{2014} upon division by 7.
5. Solve the equation

$$\frac{x^2+1}{2x} + \frac{2x}{x^2+1} = 2$$

6. Eight teams have reached the quarter-finals of the soccer World Cup.
    a. How many ways are there for these teams to be paired to play the quarter-final games?
    b. How many different outcomes of which team wins which medal (gold, silver, bronze) are possible?
7. Corners of a square with the side a are cut off so that a regular octagon is obtained. Find the area of this octagon.

Math 9 placement test 2014: solutions to selected problems

1. Open brackets and expand the following expressions
    a. $(a+b)^2 =$
    b. $(a-b)^3 =$
2. Factor the following expressions
    a. $a^2 - b^2 =$
    b. $a^3 - b^3 =$
    c. $a^3 + b^3 =$
    d. $1 + a + a^2 + a^3 =$
3. Find the coefficient of x^5 in the expression $(1+2x)^8$

$$(1+2x)^8 = \cdots + C_8^3(2x)^5 + \cdots = \cdots + \frac{8!}{5!\cdot 3!}\cdot 2^5 \cdot x^5 + \cdots = \cdots + 7\cdot 8\cdot 32\cdot x^5 + \cdots$$

4. Find the remainder of 3^{2014} upon division by 7.

$3^{2014} = (7+2)^{1007} = (\ldots)\cdot 7 + 2^{1007} = (\ldots)\cdot 7 + 4\cdot(7+1)^{335} = (\ldots)\cdot 7 + 4$

5. Solve the equation

$$\frac{x^2+1}{2x} + \frac{2x}{x^2+1} = 2$$

$\frac{x^2+1}{2x} = t$, then $\frac{x^2+1}{2x} + \frac{2x}{x^2+1} = 2 \Leftrightarrow t + \frac{1}{t} = 2 \Leftrightarrow t^2 - 2t + 1 = 0 \Leftrightarrow t = 1 \Leftrightarrow \frac{x^2+1}{2x} = 1 \Leftrightarrow x^2 - 2x + 1 = 0 \Leftrightarrow x = 1.$

8. Eight teams have reached the quarter-finals of the soccer World Cup.
    a. How many ways are there for these teams to be paired to play the quarter-final games?

For 2n teams, let the number of pairings be P_n. There is 2n-1 ways to pair the first team and thus select the first pair. For the remaining 2n-2 teams, there will be 2n-3 ways to select the second pair, and so on. Hence, $P_n = (2n-1)\cdot P_{n-1} = (2n-1)\cdot(2n-3)\cdot \ldots \cdot 3\cdot 1$. For the case of 8 teams, $P_4 = 7\cdot 5\cdot 3 = 105$.

    b. How many different outcomes of which team wins which medal (gold, silver, bronze) are possible?

This is given by the number of possible ways to select 3 out of 8, where order matters. The answer is $A_8^3 = \frac{8!}{5!} = 6\cdot 7\cdot 8 = 336$.

9. Corners of a square with the side a are cut off so that a regular octagon is obtained. Find the area of this octagon.