

## 2020–2021 Winter Break Math Challenges

Due Dec. 31. Submit to `vincent.chan@renertschool.ca` with the subject “MAHMC Solutions.”

### Challenge 1: Digit puzzle

To ring in the new year, make the number 2021 in 9 different ways, each time by using copies of the same digit and the following operations (in addition to parentheses):

- Standard operations:  $+$ ,  $-$ ,  $\times$ ,  $\div$
- Negation:  $-\square$
- Exponentiation of two numbers:  $\square^\square$
- Square root of a number:  $\sqrt{\square}$
- Factorial:  $\square!$  (Note: you may use iterated factorial but not multi-factorial, so that  $3!! = (3!)! = 6! = 720$ , and **not**  $3!! = 3 \times 1 = 3$ .)
- Concatenation (i.e. “glueing”) of digits (only of the original digit used):  $dd$

Your score for a particular digit is the number of copies you use, and your goal is to have the lowest score possible (**you will be competing against others in your division**).

For example, you can make 2021 by using copies of the digit “9” as follows:

$$2021 = \underbrace{\frac{9}{9} + \frac{9}{9} + \cdots + \frac{9}{9}}_{2021 \text{ times}}$$

If you do it like this, you are using 4042 copies of 9, which is not good for you. A far more efficient way to do it is

$$2021 = 9 \times \sqrt{9} \times \left( 99 - \left( \sqrt{9} + \frac{9}{9} \right)! \right) - \sqrt{9}! + \frac{9}{9} + \frac{9}{9}$$

which gets you there with only 12 copies (this is, of course, not optimal).

- (1) Using the digit 1
- (2) Using the digit 2
- (3) Using the digit 3
- (4) Using the digit 4
- (5) Using the digit 5
- (6) Using the digit 6
- (7) Using the digit 7
- (8) Using the digit 8
- (9) Using the digit 9

## Challenge 2: Approximations

To say goodbye to the last year, here is a puzzle about 2020. How close can you get to 2020 using the digits 2, 0, 2, 0 exactly once? You may use the following operations (in addition to parentheses):

- Standard operations:  $+$ ,  $-$ ,  $\times$ ,  $\div$
- Negation:  $-\square$
- Exponentiation of two numbers:  $\square^\square$
- Square root of a number:  $\sqrt{\square}$
- Factorial:  $\square!$ 
  - Note: you may use iterated factorial but not multi-factorial, so that  $3!! = (3!)! = 6! = 720$ , and **not**  $3!! = 3 \times 1 = 3$ .
  - Hint:  $0! = 1$
- Floor:  $\lfloor \square \rfloor$  (this is the largest integer less than or equal to the input, so  $\lfloor \pi \rfloor = 3$ )

Notice you CANNOT use "glueing"!

**(You will be competing against others in your division.)**

### **Challenge 3: Art**

Winter is a great time for beautiful images, especially in Calgary where we get so much sunlight. For this challenge, draw or paint a picture! It must be

- (1) winter-themed, and
- (2) math-related.

You must also write a short paragraph explaining how your art satisfies these two points. You will be judged on:

- (1) the aesthetic and technical quality of the art,
- (2) the depth of connection to mathematics, and
- (3) the quality of writing.

**(You will be competing against others in your division.)**



### Challenge 5: Suguru

In Suguru, you'll find "cages," which are denoted by the bold outlines. Each cage needs to be filled with unique digits counting up from 1, so that a 1-cell cage only has a 1, a 2-cell cage has a 1 and a 2, a 3-cell cage has a 1, 2, and a 3, and so forth. Cells that are adjacent (touching) cannot contain the same number, including diagonally. (Go to <https://krazydad.com/tablet/suguru/> to practice.) Solve the following Suguru!

		2			5		5							4
4														
								3			4			
4													2	
								5						
			5											
5														
	2										2			
										5	3			4
					4								3	1
2								3		5		4		