Ohio Automobile License Plate Mathematics

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Bill *and his family have recently relocated to Orlando, Florida, from NE Ohio, where he taught fourth graders. He is in his eighth year of teaching, and now has a sixth grade class at the Lake Highland Preparatory School in Orlando.* ***Vin*** *is in his forty-first year of school work, and has been a teacher, coach, administrator and headmaster. For ten of the past 29 years he has been a math specialist in grades 5 & 6 at University School in Cleveland OH. Vin has presented math workshops at numerous GCCTM, OCTM, and NCTM regional conferences in Ohio.*

Let's continue to celebrate the Bicentennial of Ohio and Geauga County, the Centennial of the invention of the automobile, and the Golden Anniversary of the Eisenhower Interstate Highway System in a mathematical manner! To honor these milestone accomplishments, and in particular our school's Centennial, our sixth grade math classes decided to collect a "one-per-state" automobile license plate grouping. Ohio became a state on March 1, 1803. There were only forty-four states in the USA during the year our school was founded. Can you discover what year University School first opened its doors in Cleveland, Ohio? (Hint: It was in the late nineteenth century.)

It took us an entire academic school year to complete our mission of collecting one auto license plate in excellent condition from each state depicting our school's centennial year celebration. Each automobile license plate had to have clear and legible documentation including a year sticker that coincided with our school's centennial year. We wrote to the Bureau of Motor Vehicle (BMV) departments in all 50 states requesting their assistance. In the course of our explorations, we discovered an invaluable resource: ALPCA, The Automobile License Plate Collectors' Association at www.alpca.org. Many helpful members provided us with assistance.

We proudly displayed our collection prominently on a wall in a central hallway. The framed display measures five feet square, and has become a source of pride and interest among students, teachers, and school visitors. All license plates in the USA now have a common dimension. Each state license plate is uniform in size and measures six inches in height by twelve inches in length. We also displayed a collection in our math classrooms. A license plate collection mounted on the wall above the frontal smart board always captures the attention of those persons entering our math classroom.


Have you ever "collected states" by counting license plates on long automobile trips? Vincent Fiordalis (above, right, with four of his students) did—and still does. He literally collects them and uses them in his fifth and sixth grade classes at University School (Shaker Heights, Ohio) in a variety of math games. Fiordalis' hobby is useful in another way: the license plates cover up some of that bare wall space!

Let's now take a moment to consider some important initial alphabetic and numerical possibilities and permutations as they pertain to auto license plates. We will use **Ø** for the digit zero, and, use **O** for the letter in all of our examples. Some states omit the letter **O** because it can easily be confused with the digit **Ø** written as **O.**

- If a license plate used only one letter there would be 26 possibilities: **A–Z**. A, B, C. . . X, Y, Z.
- Two letters together: in a pattern like **AA, AB, AC**, **ZZ** will increase the possibilities to 26^2 or 676. If you then reverse the alphabetic pattern **ZZ, ZY, ZW**, etc., double this to 1,352, less any letter duplication or commonality. In this example it is necessary to subtract 26 from the total, for **AA, BB, CC** reversed look the same. This makes 1,326 the total.
- If only one of the ten digits is used there would be 10 possibilities **Ø – 9**. Ø, 1, 2…7, 8, 9.
- Two digits would provide 100 possibilities, 10^2 . **ØØ – 99.**   ØØ, Ø1, Ø2 … 97, 98, 99.
- Three digits would provide 1,000 possibilities, 10^3. **ØØØ – 999.**   ØØØ, ØØ1, ØØ3. . . 997, 998, 999.

This is the basic pattern foundation for further license plate mathematical discovery. Now, different possibilities can be investigated. It is an interesting and worthwhile project for your students to compute many of the potential math permutation possibilities depending on the specific placement of numbers and letters. We use the theoretical maximum number of possibilities, ignoring duplications and those questionable permutations that might be censored by the registration officials in the BMV License Plate office.
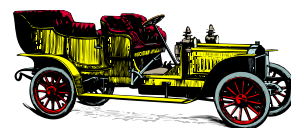
- Using one letter and one number: There would be 260 different letter/number possibilities (10 × 26), if the letter preceded the number **AØ** – **Z9**. If the pattern were reversed with number-letter **ØA** – **9Z** the number of possibilities would double to a total of 520, minus any that look alike.
- A combination of two letters and two numbers in this sequence: **AA** – **ØØ** through **ZZ** – **99** would allow for 67,600 possibilities ($10^2 \times 26^2$). Again, the letter **O** and digit **Ø** are not to be confused.

Changing the alphanumeric configuration order from **AA**–**11** to: **A**–**11**–**A**, and then further changing the order to: **11**–**AA**, etc., will also increase the possibilities of two letters and two number combinations. There would be three times the original "two letter and two number" example shown above, to a total of 201,000 total possibilities ($10^2 \times 26^2 \times 3$). Historically in Ohio, all license plates with the pattern of "**AA**–**11**" were traditionally assigned to cars in the northern region of the state. "**A**–**11**–**A**" patterned plates were then designated for central Ohio, and, "**11**–**AA**" plates were allocated to the southern Ohio counties.

As the number of cars has increased, each state BMV needed to find new methods to increase the number of license plate registrations. The population of the United States surpassed 300,000,000 people in October of 2006. Additional auto registrations are required to meet future registration needs. Numerous unique and creative number and letter combinations have been formulated throughout the different states, particularly during the past thirty years. Today, most states offer consumers a variety of options. These include different plate choices, often with colorful base plate graphics displaying the official state bird, flower, motto, universities, professional teams, or other unique item. In Ohio, the red cardinal "Wildlife" plate is the most popular license plate. Other favorite Ohio base plates include the Fairport Harbor Lighthouse with the "Great Lake State" quote and The Ohio State University "O-Buckeye-logo" plate.

- Some states presently display three letters followed by three numbers. Example: **HIT** – **401**, this allows for 17,576,000 possibilities ($26^3 \times 10^3$) or, the reverse number–letter configuration: e.g., **123** – **ASK** for an additional 17,576,000 possibilities. This generates a total of 35,152,000 different combinations, minus any duplication ($26^3 \times 10^3 \times 2$).
- A three letter - four number alignment like **RUN** – **5280**: ($26^3 \times 10^4$). 26 cubed times 10 to the fourth power equals 175,760,000 different combinations. This is doubled when reversed to four numbers followed by three letters, and totaling together 35,152,000 ($26^3 \times 10^4 \times 2$).
- Plates with a two letter-two number-two letter combination like **IM**– **96**–**YR** ($26^4 \times 10^2$), would total 45,697,600 plates. Rearrange this pattern to two numbers followed by two letters and then followed by two additional numbers, eg. **76**–**BG**–**89** extends the total another 6,760,000 ($26^2 \times 10^4$).

What are the total possibilities for plates with one to seven numbers? "**Ø**" through "**9,999,999.**" Compute the number of differences for a plate with one to seven letters "**A**" through "**ZZZZZZZ.**"

By utilizing alphanumeric combinations, states can provide creativity, variety, and geographical identity while satisfying the number of vehicles which need to be registered. The possibilities seem endless. Now, it is possible to have more than an adequate number of license plate combinations to cover all required automobile registrations.

Consider some additional research projects, addressing these questions?
- When was Ohio's first official state automobile registration? Why was it needed?
- How many years did Ohio use porcelain plates? (Hint, the first one was in 1908)
- What different materials have been used to make license plates in Ohio?
- Where are license plates physically manufactured in Ohio?
- How many cars are now registered in the state of Ohio? (hint, over seven million)
- Was there a color rotation in Ohio of base plate colors and letter/number colors?
- Which five states require the most auto registrations, and which have the fewest?
- How many states require dual license plates per vehicle? Police organizations prefer both a front and back plate on all automobiles for ease in registration identification.
- What is a personalized "vanity" license plate and why does Ohio permit them?

Some recent "vanity" plates that we have seen here in Ohio include: **PL8S, PI R SQR, 9 LYVES, RUN4US, U NEEK, 10S NE1, STR TRK 3, CALM DN, BIONIC, NO WHO UR, LA 1 DAY, DEBT FRE, SMCH 2 DO, RU FUN 2, 1 ON MARS, LAWMAN**, **TEACH 1**, etc.

We often take a few minutes at the beginning of each math class to focus and compute some mental numerical calculations to warm up our brains. Sometimes we use the license plate display for a data base. Almost any basic arithmetic operation; addition, subtraction, multiplication, and division, can be easily reinforced using the numbers found on the license plates. Potentially, there are an infinite number of mathematical permutations to reinforce all basic computational operations and concepts.

Examples of problems utilizing our "one-per-state" license plate display might include:
- Find the sum, using the numbers only, add:

OH: **V 26 F,** FL: **WF 73,** NY: **65 KEY,** HI: **X 643,** & TX: **KMA 618**

V26F + WF 73 + 65 KEY + X 643 + KMA 618 = 1,425

- What is the difference between: Delaware: **383837** and New Hampshire: **106464**?

$$383837 - 106464 = 277{,}373$$

- Using numbers only, what is the product of: Arizona: **748–GCN** and Wyoming: **GK–359**?

$$\underline{748} \text{ GCN} \times \text{GK } \underline{359} = 268{,}532$$

- What is the quotient when you divide KY: **RBF 1944** by VT: **432 XYZ**?

$$\text{RBF } \underline{1944} \div \underline{432} \text{ XYZ} = 4.5$$

Students make up individual problems to share, by inventing an original license plate, then personalizing and codifying it to represent: names, initials, birthdays, phone numbers, and addresses. Examples: using **A = 1, B = 2, C = 3, D = 4,** with **J = Ø**. Negative integers are also possible.

- **AIDB – 321 = 1942 – CBA** = ?   **(1,621)**

- **BFG – 839** might transfer to: **267 – HCI** = ?   **(–572)**

- **HDEF + CBA** could become **8456 + 321** = ?   **(8,777)**

- **(1210 + 1944) – (1124 + 1942)** = ?   These letter code applications now become:

  (ABAJ + AIDD) – (AABD + AIDB) or **3154 – 3066 = ?**   **(88 or HH)**

Our math students then challenge their peers to decipher these new plates. Afterwards they would explain mathematically how they came up with their personalized cipher code.

Here are some additional potential queries and research ideas for your student's consideration.

- If the United States government decided to cancel all individual state auto registrations and then required only one inclusive federal system, what alpha-numeric system(s) might be adopted to successfully register all the operating vehicles in the USA?
- What if there was a Global registration requirement for all auto vehicle identification numbers (VINs) and all license plate registrations? How could they all be individually recorded? Remember that there are now over six billion inhabitants on planet Earth!
- Are there more permutations possible with seven digit phone numbers (**321 – 8260**) or seven place auto tags (**ABC – 1234**) using an alphanumeric system? The popular use of cell phones during the past decade requires a great deal of additional new phone numbers
- Will we run out of possible phone number combinations before we run out of license plate numbers? If so, when and how would that occur?
- If you pick a license plate at random from a 3-letter 4-number configuration, what is the probability of choosing one with at least one vowel and also a number divisible by three?
- How many plates can you find that are divisible by a prime number: 2, 3, 5, 7, 11 . . . etc.?
- Are their any "twin primes" or palindromes displayed in the license plate collection?
- How many license plates have either an even number or a vowel occurring at least one time?

Some more curriculum related integrated classroom academic and geographic activities and questions might include: (Hint: Utilize the internet, *World Almanac* and other research tools here.)

- Ask each of your students to learn all of the state capitals using the displayed license plate "one-per-state" collection in your classroom as a "key" for their memory associations.
- Discover the most Southern State in the USA? (Northern, Eastern, Western)
- Which four states collectively share one common border vertex? (Hint: "4 corners")
- What is your Governor's state license plate number?
- What official license plates do your US congress representatives utilize?
- How do our neighbors across the borders in Canada and Mexico register automobiles?
- What procedure does the European Common Union use to keep track of all their vehicles?
- How do India and China register their vehicles? Both countries now have more than one billion inhabitants each and annually the number of potential car owners increases?

Summertime is a favorite family vacation time in America! Many parents make extensive travel plans with their children and look forward to an annual auto adventure. Stimulating games involving states, geography, license plates, colors and numbers can be played during these trips to provide stimulation. There are so many different alphanumeric possibilities available on license plates that game possibilities are endless. Many excellent car travel games are also commercially available. Won't you consider license plate collecting now? Discover how it might enhance your math curriculum. Most of our students have enjoyed their experiences with "Ohio Automobile License Plate Mathematics." Assembling materials for our "Ohio Automobile License Plate Mathematical Adventure" has been a most rewarding experience for us at University School and we recommend it.

Happy Collecting!

The authors pictured in 1976 working on Bill's first "one-per-state" license plate collection.

FYI. University School was founded in 1890 in Cleveland, Ohio.