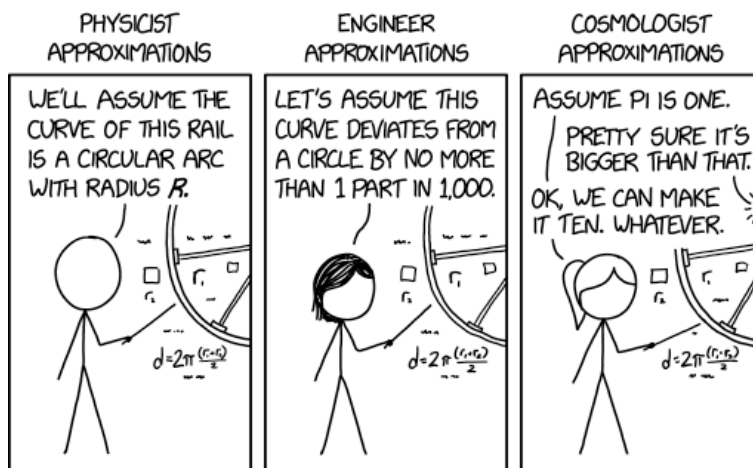# Columbia Science Olympiad
2023 Fermi SOLUTIONS

January 28, 2023

Student Name(s): SOLUTIONS _____

Team Name: SOLUTIONS _____**Team Number**: _____

School Name: SOLUTIONS _____

INSTRUCTIONS

- You have **50 minutes** to complete this exam. There are **35 questions** total. The questions are not in any particular order of difficulty. You are not expected to finish.

- No additional resources are allowed other than **pencils and scratch paper**.

- **Only the answer sheet will be graded.** It is the last page. Please fill out the identification information on the answer sheet as well. It is okay to detach the answer sheet, as you will need to when turning in your exam anyways.

- Recall that answers should just be the degree of the exponent (power of ten). Round your answers (e.g. if you calculate 499, your round your answer to 100, and you should write down 2. If you estimate 500, then you should write down 3).

- Incorrectly formatted answers may not be graded (e.g. 10^5, 4000)

- Scoring will work as normal – you will be awarded 1 point for a ± 2 order of magnitude, 3 points for ± 1, and 5 points for the correct order of magnitude approximation.

1

Section 1. Real-world cases

1. (5 points) In honor of me eating at Cracker Barrel for the first time in my life this year, **what is the annual revenue (in USD) of Cracker Barrel in 2022?**

   > **Solution:** In 2022, Cracker barrel's revenue was 3.32 billion USD, or **9**.

2. (5 points) We had to Google a ton of research to create this exam. **How many Google searches are done every day?**

   > **Solution:** There are about 8.5 billion searches every day, or **10**.

3. (5 points) As a Midwest local, one of my favorite pastimes is sitting in cornfields...doing nothing. **About how many pounds of corn are grown and harvested in Indiana each year?**

   > **Solution:** In 2021, there were 5.4 million acres of corn in Indiana. One acre gives about 159 bushels of corn, and one bushel of corn is 56 pounds. You get $4.8 * 10^{10}$ pounds of corn, so **10**.

4. (5 points) Why do ice cubes always come as...cubes? Why aren't there ice spheres? or ice cylinders? **If you froze all the freshwater (include *all* sources, not just surface lakes, ponds, etc.) on Earth into an ice cube, what would the side length of the cube be in meters?**

   > **Solution:** There is 1.3 billion cubic kilometers of water total on Earth, with 2.5% of that being freshwater. Also, water is 1.086 as dense as ice. Ultimately, you should get 328km side length for the cube, which is $\approx 10^5$ meters, so **5**.

5. (5 points) In the wise words of Albus Dumbledore, "Fermi Questions is the best Scioly event!" **Directly after worldwide release, how many seconds did J.K. Rowling have to wait until she sold enough copies of *Harry Potter and the Deathly Hallows* to be able to stack them to the International Space Station?**

> **Solution:** ISS is on average 250 miles above the Earth's surface, or $1.584 * 10^7$ inches. *The Deathly Hallows* is about 2 inches thick, so we'd need 7920000 books. This is very close to the books sold in the first 24 hours (8.3 million to be exact). So, we get 10^5 seconds, or **5**.

6. (5 points) One of my favorite songs is Bruno Mars' *Talking to the Moon.* Unfortunately, sound does not travel through space, so Bruno's words never made it to the moon :(. Assuming the sound does not decay, and assuming we use the speed of sound through *air*, **How many seconds would it take your voice to travel the equivalent distance from the Earth's surface to the moon?**

> **Solution:** $382,500$ km is the average distance to the moon. The speed of sound is 343 m/s. You get $1,115,160$ seconds total, or **6**.

7. (5 points) Do you ever see those funny graphs Apple presents to show how much better their devices are than their competitors? It got me thinking about Apple's new computer chips. **Intel 4004 was the first ever commercially produced microprocessor. How many times more transistors are on the new Apple M2 chip, compared to the Intel 4004 chip?**

> **Solution:** The Apple M2 chip has 20 billion transistors. Intel 4004 had 2300 transistors. This is about 10^7 times as many transistors, so **7.** You can also use Moore's Law (the number of transistors in chips doubles every 2 years). It's been ∼50 years since Intel 4004 came out, meaning 25 "doublings". $2^{25} \approx 10^7$.

8. (5 points) Did you know that capsaicinoids are the active chemical compound found in peppers that make them spicy? **How many times hotter is the hottest capsaicinoid compared to the hottest jalapeno peppers, on the scoville scale?**

> **Solution:** Resiniferatoxin is the hottest capsaicinoid, at 16 billion scoville units! The hottest jalapeno peppers are around 8000 scoville units, so the ratio is $2 * 10^6$, or **6**.

9. (5 points) Sometimes, I spend more time looking for a show than actually watching a show on Netflix. **How many days would it take to watch all of Netflix (assume Netflix US)?**

> **Solution:** There are 2.2 million minutes on Netflix US in total, which is 1500 days, or **3**.

10. (5 points) Wow, that's a lot of days! **How many megabytes of data would it take to stream all of Netflix (assume Netflix US) in HD?**

> **Solution:** Netflix says they use up to 3GB per hour, while Disney+ says about 2GB per hour. We use 2GB as an average. Use the 2.2 million minutes from last question, to get $7.4 * 10^7$ MB, or **8**.

11. (5 points) Speaking of streaming services, have you made your Spotify "playlist in a bottle"? **On average, how many hours would it take for you to listen to all of the songs Spotify adds to its collection in a single day?**

> **Solution:** Spotify adds about 40 thousand songs every day, and the average song on spotify is 3 minutes long, so you get 2000 hours, or **3**.

12. (5 points) Fermi Questions are usually solved by what people often call "back of a napkin" calculations. **If you used a BIC ballpoint pen to draw a continuous straight line, how many paper napkins would you need to draw on until the pen ran out of ink? In other words, if you used the pen to draw one single horizontal line on each napkin, where the line is equal to the side length of the square napkin, how many napkins could you draw on until the pen ran out of ink?** Assume the napkin is NOT unfolded (how a paper napkin looks in its packaging).

> **Solution:** BIC ballpoint pens can write about 2.5km. A paper napkin, when unfolded, is about 0.125 meters. You get $2 * 10^5$ napkins, or **5**.

13. (5 points) Something I miss from high school is competing against my classmates in Kahoots. College professors should use them more often! **How many Kahoot sets have been created since the inception of the site?**

> **Solution:** According to Kahoot, about 100 million kahoot sets, so **8**.

14. (5 points) The Wiki Game is where you try to jump from one Wikipedia page to another by only using the hyperlinks on the pages. **Across all Wikipedia articles, how many hyperlinks are there to the "United States" Wikipedia page?**

> **Solution:** According to Wikipedia's own stats pages, about $484,000$, so **5**.

15. (5 points) One of the most popular drinks amongst my friends these days is bubble tea. Did you know bubble tea originated in Taiwan? **What is the global bubble tea market value, in New Taiwan Dollars?**

> **Solution:** The global market value was 2.1 billion in 2020 (slightly more now, but this is good enough). At this time (Jan 20, 2023), 1 USD is worth about 30.5 new taiwan dollars. So, it's $6 * 10^{10}$, or **11**.

Section 2. NYC-related questions

16. (5 points) The New York Federal Reserve is one the most important institutions for the U.S. economy. **How many Lydian stater gold coins (the first gold coin ever used for currency in the world) would equal the amount of gold stored in the New York Federal Reserve?**

> **Solution:** There are 5620 metric tons in the bank. A gold stater was about 8g of gold. This equates to $7 * 10^8$ gold coins, or **9**.

17. (5 points) A famous icon of NYC is its squadron of yellow taxi cabs. **How many miles do all of the taxi cabs drive in a day, cumulatively?**

> **Solution:** A NYC taxi cab drives about 70,000 miles in a year. There are currently 13,500 taxis in NYC. You can divide by 365 to get the average mileage per day, and calculate to get $2.5 * 10^6$ miles each day, so **6**.

18. (5 points) You may have seen this one coming. It's the classic interview question to test your analytical skills! **How many windows are in NYC?** Don't forget that all windows count: homes, cars, boats, you name it.

> **Solution:** This famous question took us a long time to solve, so we created a google doc to explain our final solution. Short answer: 10^8, or **8**.

19. (5 points) One of my favorite experiences in NYC has been celebrating 4th of July here. **In 2022, how many shells were set off for "Macy's 4th of July Fireworks" celebration?**

> **Solution:** Based on this news article, there were $1,920$ shells a minute, and it was a 25-minute show, so about 48,000 total. So, **4**.

20. (5 points) We couldn't get through the NYC section without talking about Columbia! Recently, Columbia has been under public scrutiny due to it giving inaccurate information to U.S. News national university rankings. As such, Columbia's ranking dropped to 18th in 2023, compared to 2nd in 2022. **If you multiplied Columbia University's rankings in the "U.S. News Rankings of best national universities" over all years from 1988 to 2023 (inclusive), what would your answer be?**

> **Solution:** You can find the data here. You obtain $8 * 10^{30}$, so **31**. This is about 8th place on average over the years.

Section 3. Scientific questions

21. (5 points) I wanted to ask this question about t-rexes but unfortunately I couldn't find any concrete data on them :(. **How many genes does a fruit fly have?**

> **Solution:** Fruit flies have approximately $14,000$ genes, so the answer is **4**.

22. (5 points) "Mexican Coke" is a special form of Coca Cola where all the sugar in it is purely real cane sugar (i.e. only sucrose). **How many molecules of sucrose are there in a 12 oz. Mexican Coca Cola bottle?**

> **Solution:** There are 39 g of sugar in a 12 oz. coca cola bottle and sucrose weighs 342.3 g / mol. Thus, there are 0.114 mol of sugar. Multiplying by Avogadro's number, there are 6.9×10^{22} molecules of sugar, so the answer is **23**.

23. (5 points) Did you know that a parsec is not a unit of time, but rather a unit of distance? **How many hours would it take the Saturn V rocket, traveling constantly at its top speed, to finish Han Solo's famous 12-parsec Kessel Run?**

> **Solution:** 12 parsecs $= 3.7 * 10^{14}$ kilometers. Saturn V's top speed was $15,500$ mph, or $25,000$ km/h. This would be about 10^{10} hours, so **10**.

24. (5 points) In *Mission Impossible: Rogue Nation*, Tom Cruises' character, Ethan Hunt, holds onto the side of a plane as it takes off. **Assuming that the plane took off at a constant velocity of** 200 **mph, and that Ethan is holding the plane such that his body is aligned with the wind ("diver position"), how many Newtons of force are exerted on Ethan Hunt by air resistance?**

> **Solution:** Drag Force is calculated as: $F_D = \frac{1}{2} C_D \rho A V^2$. The drag coefficient C_D of a human moving through air in "diver position" is 0.7, ρ of air $= 1.2$, and we assume the cross-sectional area of a human is 0.18 m^2. Plug into the equation (also convert velocity to m/s) to get 612 N, or **3**.

25. (5 points) We take for granted that when we charge up our batteries, they don't get heavier... or do they? **Assuming that an iPhone 14 has a 3000 mAh battery that is rated at 3.7 volts, how many more kilograms does an iPhone 14 weigh when fully charged, compared to when its battery is completely empty, all else equal?** Assume for simplicity that all electrons in the battery have zero kinetic motion, regardless of the battery being charged or not.

> **Solution:** Energy in Wh = mAh * V / 1000. You get 11.1 Wh. Now, use $E = mc^2$ to find the mass difference based on the energy. Remember to convert Wh to Joules (factor of 3600), the SI unit for energy. You get $m = 4.7 * 10^{-13}$, so the answer is **-13**.

Section 4. Mathematical questions

26. (5 points) We like to call this question the Power Tower. **What is 3^{3^3}?**

> **Solution:** $3^{3^3} = 3^{27} = 3 \cdot 9^{13} < 3 \times 10^{13}$ and $3^{3^3} = 3 \cdot 9^{13} > 3 \cdot 8^{13} > 2^{40} = 1024^4 > 1000^4 = 10^{12}$. The answer is between 10^{12} and 3×10^{13}. Since we did more estimations on the lower bound, it should be closer to 3×10^{13}. The real answer is 7.6×10^{12}, thus the answer is **13**.

27. (5 points) We like to call this question the ᴚǝʍoꓕ ᴚǝʍoԀ.**What is $0.2^{0.2^{0.2^{\cdots}}}$?**

> **Solution:** Let s be the solution. Then, $s = 0.2^s \implies s5^s = 1$. Let $f(x) = x5^x$. Note $f(0) < f(0.1) < 1 < f(0.5)$, so the answer is between 0.1 and 0.5. The real answer is 4.7×10^{-1}, thus the answer is **-1**.

28. (5 points) Interestingly, the largest prime number ever found was discovered in 2018. For the past 4 years, nobody has cared enough to look for the next; and neither do we! Just tell us: **what is the ten millionth prime number?**

> **Solution:** The ten millionth prime number is $160,481,183$. So, the answer is **8**.

29. (5 points) A tetromino is a geometric shape composed of four squares, connected orthogonally (think Tetris pieces). **How many distinct ways are there to tile a 2×100 board with tetrominoes of any shape?**

> **Solution:** The number of ways to tile a $2 \times 2N$ board with tetrominoes is F_{n+1}^2, where F_{n+1} is the $(n+1)$-th Fibonacci number. $F_{51} = 20365011074$ and $F_{51}^2 = 4.1 \times 10^{20}$, so the answer is **20**.

30. (5 points) A childhood card game I loved to play with my brother is "War." You always start your hand with half the cards in a standard 54-card deck. **Assuming order does not matter, what are the total unique hands you can start out with in "War"?**

> **Solution:** Each hand has 27 cards, so there are $\binom{54}{27}$ ways to choose the two hands. This evaluates to 1.9×10^{15}, so the answer is **15**.

Section 5. Meta questions

Important: Remember that your *actual answer* is the number you write down to the power of 10. For example, if you write "4", your actual answer is $10,000$. "4" is just the format that we wish for you to record your answers as. Whenever we ask for the max, mean, etc. of answers, we mean an operation defined upon the *actual answers*.

31. (5 points) Let's start off with a simple, yet classic one. **If P is the number of points you received on this exam (EXCLUDING section 5), what is P^2?**

> **Solution:** Answer depends on the test taker's score.

32. (5 points) Perhaps you struggled on each individual question, but maybe you're better at seeing the bigger picture. **EXCLUDING section 5, what is the geometric mean of all the (correct) answers on this exam?**

> **Solution:** The geometric mean is very close to 10^8, or **8**.

33. (5 points) Let's see how well you think you fared against the other competitors. **If we ranked all teams' test scores (based JUST on your performances in sections 1-4), and you placed in k-th place, what is k?**

> **Solution:** Answer to be seen. This question is actually not too bad, since the top 1-4 teams round to 10^0, while pretty much all other places round to 10^1. We really just wanted to see who was confident enough to say they were in the top 4 teams.

Note: For the next two questions, your answer will influence the correct answer; choose wisely!

34. (5 points) **What is the median of the answers to this question?**

> **Solution:** Answer to be seen. We chose to use the median so that one team writing an absurdly large or small answer would not greatly change the correct answer. Post-test commentary: Overall, teams helped each other out by generally writing down very small numbers. The few that put absurdly large numbers did not alter the median.

35. (5 points) Are you tired of these paradoxical questions? Okay, okay, this is the last one. **The correct answer to this question will be the max of all answers to this question divided by the minimum of all answers to this question. Your answer must be between 10^0 and 10^{10}, inclusive.**

> **Solution:** Answer to be seen. Post-test commentary: Due to at least one team putting 10^0 and at least one team putting 10^{10}, the answer becomes 10. Unfortunately, any other answer in-between this range is in vain as it does not alter the outcome.

36. (1 point) **Please rate this exam on a scale from 10^0 to 10^{10}.** Any answer (or even no answer) will be rewarded 1 free point. You can leave feedback below as well!

Congratulations on finishing the test! Regardless of how well you think you did, know that we designed this to be a difficult exam; you should be proud of even completing such a challenge! :)

Answer Sheet

Student Name(s): SOLUTIONS _____

Team Name: SOLUTIONS _____Team Number: _____

School Name: SOLUTIONS _____

1. ____ **9** ____   2. ____ **10** ____   3. ____ **10** ____   4. ____ **5** ____   5. ____ **5** ____

6. ____ **6** ____   7. ____ **7** ____   8. ____ **6** ____   9. ____ **3** ____   10. ____ **8** ____

11. ____ **3** ____   12. ____ **5** ____   13. ____ **8** ____   14. ____ **5** ____   15. ____ **11** ____

16. ____ **9** ____   17. ____ **6** ____   18. ____ **8** ____   19. ____ **4** ____   20. ____ **31** ____

21. ____ **4** ____   22. ____ **23** ____   23. ____ **10** ____   24. ____ **3** ____   25. ____ **-13** ____

26. ____ **13** ____   27. ____ **-1** ____   28. ____ **8** ____   29. ____ **20** ____   30. ____ **15** ____

31. ____ **3** ____ 32. ____ **8** ____   33. ____ **1** ____ 34. ____ **2** ____   35. ____ **10** ____

36. Feedback appreciated as well!

> **Solution:** SOLUTIONS