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Some Puzzles for Brainstorming

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Abstract: For superior performance in IOI or IMO, it is important that students develop their logic and analytical skills. The advent of powerful LLMs is creating an opportunity for students to avoid spending time in brainstorming over problems. This paper provides students with an opportunity to sharpen their analytical skills and logic by solving problems, most of which are drawn from existing resources and are often modified/generalized to challenge their presence of mind. References to some related topics have also been included. At the end of the paper, some hints for the solution have been provided.

Keywords: Logic problems, problems for analytical skill development.

There has been a lot of literature (1, 3-8) published and in online repositories (9-11) that challenge young people with puzzles and mathematical problems for solution. This article compiles some of the interesting puzzles, especially for our young people, to brainstorm over. Some of these puzzles are available in published materials and on different websites. These puzzles are either logic-based or require some analytical skill for their solution. These problems have been listed in random order to test real examinations/tests. The author posed these problems to pre-university students, who found them challenging and interesting.

1. Four students were standing face to face, and a teacher had many red and white caps. The teacher put one cap on each one's head, and we now have only four caps. The teacher asked for raising hands if anyone had seen two red caps. Immediately, all of them raised their hands. Then he said if someone can figure out the color of her own hat, she should put down her hands and tell the color. Nobody was putting down hands for a long time. Then at long last Alice put down her hands and told the right color. Tell the color and present logic behind your answer.
2. A couple invited 6 couples to a dinner party. Assume 'knowing' and 'not knowing' are symmetric relations. Those who did not know each other got to know each other and shook hands. You can assume that husband and wife know each other. After dinner, at the time of departure, the host husband asked everyone else how many people they had shaken hands with. Everybody answered with a different number. How many people did the host husband shake hands with?

3. Somebody starting at point A on Earth's surface walked to the north for 20 kms to reach point B, and then walked 20 kms to the south to reach point C. Is it possible that the distance between A and C is 30 kms?
4. There are 50 coins, sides not recognizable by touch, on the table, of which 16 coins are heads up. You are blindfolded. You can flip as many coins as you wish. Then you should divide them into two piles, not necessarily of equal size, so that each pile has the same number of heads up.
5. Adam and Bill met after a long time to learn that both of them became mathematicians and married. Adam asked Bill how many children he had, to which Bill responded, 'three'. When asked about their ages, Bill said the sum of their ages is 13, and the product of their ages equals the number of windows in the adjacent building. Then Adam said that he needed a little more information to figure out their individual ages. Then Bill said that the youngest child's birthday can be celebrated only once every four years. What are their ages?
6. How can you divide four similar cakes among 63 students so that the smallest cake piece is as large as possible? What about replacing numbers respectively by (2,15), (3,35), (4,63), (5,99)?
7. A jail super decided to set free as many of the 10 long-serving prisoners as could tell the color of the hat he would be given by the jailer. He asked all of them to come to the playground the next day in the morning. He also said that he would have plenty of white and black hats. He would also place the prisoners in a queue at his discretion. Starting with the last person in the queue, he would ask what color the hat he was wearing on. Those who could tell the right color would be freed. Prisoners went to the cell and chalked out a plan to set the largest number of them free. In telling the color of the hat, they cannot say anything other than color, and no other codes can be transmitted any other way. Find the strategy in which the largest number can reach freedom.

   Supplementary question: If there are m known colors and n persons, how many people can get to freedom?
8. You are walking on a road that has been divided into two roads, one of which leads to the post office and the other to the university. You want to go to university, but you do not know which road leads to university. There is a guard standing near the fork who knows which road leads to which destination. It is not known whether the guard is truthful or a liar. The guard can be asked only one question to find the right path. What is the question? If the guard alternates on speaking the truth and telling lies what would be the question?
9. There are 30 marbles on the table. Two players play the game. The first player, in his first turn, cannot remove all the marbles. Any player in his move can take at most double the number of marbles his opponent took in his last turn, and should take at least one. The player emptying the table wins the game. How are you going to play the game as the first player? How about starting with n marbles and removing at most k times as much as the opponent's last turn?

10. Four dogs were standing on the corners of a square field of one square mile. Every dog runs exactly to the dog on the right, covering half the distance with its eyes closed, and then stops. Again, run to the dog on the right and stop after half the distance has been covered. What happened to the dogs at the end? How much distance could each dog cross? If the dogs opened after covering 1/3, 1/4, or 1/n of the distance, what would the answers be?
11. Two brothers had some goats. Each goat was sold at a price equal to the number of goats they had. They started sharing the money, removing 20 euro bills in turn, with the elder brother taking the first bill. In his turn, after a while, the elder brother saw that if he took another 20-euro bill, there would not be enough to share equally with the younger brother. So he gave his younger brother his knife, which cost an integer Euro. What was the price of the knife?
12. It is said that the following problem was posed to an ailing Einstein in the hospital by his journalist friend with the hope that, by thinking about a solution to the problem, Einstein would forget his pain, and Einstein proved his friend wrong. In how many different places can swapping the hour and minute hands of a clock result in a valid time?
13. A robot is standing by the side of an infinite wall with a single door that can be discovered only when the robot is at step exactly in front of the door. Devise an algorithm for the robot that, in the worst case, discovers the door in the minimum number of steps.
14. Supplementary problem: Assume you are lost in a forest at a junction with 3 emanating roads, one of which has a treasure at an unknown distance, which you can recognize only if you are just in front of it. Design an algorithm that will lead you to the treasure in the minimum number of steps in the worst case.
15. Charlie is a new friend of Alex and Ben. They want to know Charlie's date of birth. Charlie tells the following possible dates: 15 May, 16 May, 19 May, 17 June, 18 June, 14 July, 16 July, 14 August, 15 August, and 18 August. Charlie whispered her month of birth to Alex and the date to Ben. Alex said, "I do not know Charlie's date of birth. But I am sure neither does Ben." Ben said," At first I did not know Charlie's birthday, but now I know." Alex said," Then I also know." Find Charlie's date of birth.
16. You are in a dense convex forest of S sq.km area. You have an instrument that will allow you to follow any trajectory you wish. What is the minimum distance in the worst case you need to cross to come out of the dense forest?
17. A hard-working father called his idle son to his deathbed and said he had bought gold with all his earnings and hidden it in the forest. The son wanted to know the location of gold, to which the father said, "There are two identical trees, A and B, in the forest, and a stone S. You must walk from S to A and then walk an equal distance perpendicularly towards the other tree to find point C. You should again walk from S to B, and an equal distance perpendicularly to find D. Gold is at the midpoint of A and B." The son went to the forest and found trees A and B, but failed to find S. Can you help him find gold?
18. A pure, unrealistic mathematical problem. Five friends caught some fish and fell asleep. The first friend woke up at night, divided the fish into five equal shares, and

threw the remaining two into the river. He took his share, gathered the remaining fish, and went to sleep. In this way, each friend did exactly the same as the first friend. In the morning, all five woke up at the same time and found exactly the number of fish they caught. What was the minimum number of fish caught?

19. Find a ten-digit number whose leftmost digit is the number of 0's in it, next digit is the number of 1's, and in this way, the rightmost digit is the number of 9's in it. What is the number?
20. Find a method of representing any integer using three 2's and known functions (no use of $+$, $-$, $\times$, $/$ signs and no other digits).
21. A boy went to buy a pen, a pencil, a notebook, and a eraser. Then the shopkeeper told the amount to pay. The boy asked how the shopkeeper found the total amount, and the shopkeeper answered that he multiplied all the prices. The boy said the shopkeeper was wrong, to which the shopkeeper remarked, even adding the values gave the same answer. What were the prices?
22. If two students are to undertake a journey of d kilometers using a very well-trained horse that can carry one of the friends at a time. Assuming horse speed $v_h \gg v_{m-}$ (speed of man), what will be the minimum time required to complete the journey for the friends to start their journey together and end it in the minimum time? What about if there were n men and m horses and each horse could carry c men at a time?
23. Given two straight lines in 3D space, how do you find their distance? What is the answer if you are given two straight line segments?
24. If you invest 100 euro at a rate of interest euro 100/per year. You can get an interest rate based on the time you invest: 3 months will give you 25 euros, and 1 month, 100/12 euros. You can invest for any small time period you wish and will receive interest proportionate to the period. What is the maximum amount of interest you can earn in a year?
25. Given a directed graph G = (V, E) with nonnegative weights on edges. By spanning tree, we mean the spanning tree of the underlying graph (without directions). Every edge (a, b) of the spanning tree uniquely determines a fundamental cut set and partitions the vertex set V into V_a and V_b. Weight of cut set $[V_a, V_b]$= weight of edges of the cut set in the orientation of edge (a, b) minus weight in the reverse direction. Is it always possible to have a spanning tree for which the weight of every cut set is nonnegative? (Kaykobad, 1986).
26. A pen, an eraser, and a notebook cost US$100. The price of two pens is less than the price of a notebook. The price of four erasers is less than the price of three pens, and the price of a notebook is less than the price of three erasers. If all the prices are integers, find each price.
27. Is it possible that in a race, a pair of legs of a 27-foot-long, 9-foot-high, and 7-foot-wide elephant ran 27 feet more than the other two legs?
28. In the month of January of a year, there were 4 Sundays and 4 Wednesdays. Which day was the 10^{th} of January?

29. Mr. Johnson is now as old as the ages of his twin sons and three daughters taken together. In year 20xx, he will be as old as the sum of his daughters' ages. What will be the ages of twin sons in year 20xx compared to their current ages?
30. Grandpa and grandma are together 140 now. What is grandma's current age if grandpa's age was twice grandma's when grandpa was as old as grandma now?
31. If the sum of the digits of a pair of numbers is divisible by k, what is their smallest difference?
32. John said, "The day before yesterday I was 10, but I will turn 13 next year." What is the birthday of John?
33. How can I cut the 3X8 cm^2 board into only two pieces so that they will fill inside the 2X12 cm^2 hole exactly?
34. A girl, a boy, and a dog are walking down a road together. The boy walks at 5 km/h, and is just behind the girl who walks at 6 km/h. The dog runs from boy to girl and back again with a constant speed of 10 km/h. The dog does not slow down on the turn. How far does the dog travel in 1 hour?
35. If I drive halfway to the city at 40 km/hour, how fast do I have to go for the rest of the way to make the average speed 80 km/hour for the entire journey?
36. If $x^{x^{\cdot^{\cdot^{x}}}} = a$, then what is the value of x?
37. Find $\frac{1}{60} = \frac{1}{A} + \frac{1}{B} + \frac{1}{C}$. What about solutions to $\frac{1}{60} = \frac{1}{A} + \frac{1}{B} + \frac{1}{C} + \frac{1}{D}$ or $\frac{1}{60} = \frac{1}{A} + \frac{1}{B} + \frac{1}{C} + \frac{1}{D} + \frac{1}{E}$? All denominators are positive integers.
38. What is the minimum number of comparisons for sorting 5 numbers when the result of each comparison is known immediately, and can be used for the decision for the next comparison?
39. A pen, two erasers, and 3 workbooks cost euro 170, 3 pens, an eraser, and two workbooks cost euro 180, and two pens, 3 erasers, and a workbook cost eur 190. How much does a pen cost?
40. There are 3100 coins laid out in a row. For some positive integer x at least $\frac{3}{4}$ of the first x coins are heads, and at least $\frac{4}{5}$ of the last x coins are tails. What is the maximum possible value of x?
41. N mixed, and messed-up electrical wires are hanging from a skyscraper. You need to determine their heads and tails by tying some of them in one end and testing connectivity at the other. If there are two, you cannot properly identify the ends. If 3, tie two and name the other as 1. Go to the roof to identify the other end of the untied wire and so on. What is the minimum number of times you need to go up and down to identify heads and tails of all wires?

Hints: 2. Draw a graph in which edges indicate familiarity 4. Figures are important 5. Ties need to be broken, 7. a) the last person should answer depending upon the parity of the color of the white/black hats in front of him. b)You can use the EXOR operation 8. Ask a question to which the guard's answer will be the same whether he speaks the truth or lies. Double-positive or double-negative statements give the same answer. 9. Start developing solutions for smaller figures, 11. Study remainders 12. Figure out the smallest interval after which swapping hands give right time. 13, 14. Analyze complexity based on strategy. 15. Hint: Use the method of elimination. 16. Hint: Follow the boundary covering a given area but of minimum length. 17. Hint: The gold can only be discovered if its position is independent of the position of the stone.

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Dr. Kaykobad was the organizing chair of the first-ever international computer conference, ICCIT, held in Bangladesh. He also served as the chair of the steering committee for the Workshop on Algorithms (WALCOM), with proceedings published in Lecture Notes in Computer Science by Springer. He has mentored more than a dozen undergraduate students whose research was published in reputable international journals. He is a frequent columnist in national newspapers, authoring over 300 articles, most of which focus on the country's education. He was a pioneer in introducing Mathematics Olympiad, Informatics Olympiad, and Science Olympiad in Bangladesh. He has led or served as deputy leader of the Bangladesh IOI team since 2008, which has won a gold medal, seven silver medals, and twenty-five bronze medals. Currently, he is the president of the Bangladesh Mathematical Olympiad Committee and the Bangladesh Informatics Olympiad Committee. He was the director of the ICPC Asia Region Dhaka site from 2001 to 2003. He served as the chief judge of the IIT Kanpur Asia Region site of ICPC in 2010, 2011, and 2013. He received the Outstanding Coach Award from ICPC in 2002 in Honolulu, Hawaii, the Senior Coach Award at the ICPC World Finals held in St. Petersburg, Russia, in 2013, and the ICPC Lifetime Coach Award in 2019 in Porto, Portugal. He was also awarded a gold medal by the Bangladesh Physics Olympiad Committee.

Dr. Kaykobad was a Visiting Professor in the CSE Department at the Chinese University of Hong Kong, Kyung Hee University in Korea, ANU, Monash University in Australia, and Amritapuri University in India. In 2005, the country's president awarded him a Gold Medal from the Bangladesh Computer Society in recognition of his contribution to the country's computer programming culture. In 2006, he received the BAS Gold Medal in the physical sciences senior category, which was presented by the country's Prime Minister.