MATHCOUNTS® Problem of the Week Archive

Congrats National Winners! — May 11, 2015

Problems & Solutions

Congratulations to all the Mathletes® who participated in the 2015 Raytheon MATHCOUNTS National Competition, especially to the National Champion, Kevin Liu of Indiana and the Written Competition Champion, Andy Xu of South Carolina, as well as their coaches. Here are just a few of the problems they had to solve during last week's competition.

If six people randomly sit down at a table with six chairs, and they do not notice that there are name tags marking assigned seats, what is the probability that exactly three of them will sit in the seat he or she was assigned? Express your answer as a common fraction.

[Sprint #22]

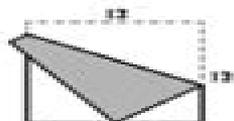Let's label the six seats A through F as follows:

$$\overline{A\ B\ C\ D\ E\ F}$$

We are asked to determine the probability that exactly three of the six individuals sit in the correctly assigned seat. There are $_6C_3 = 6!/(3! \cdot 3!) = 20$ ways to choose which three of the six seats are occupied by the correctly assigned individual. Then there are only two ways to arrange the other three individuals so that none of the remaining three seats is occupied by the individual assigned to sit there. For example, if individuals are seated correctly in A, B and C, these are the only two options for the remaining three seats to be filled so that exactly three seats are occupied by the individual assigned to sit there:

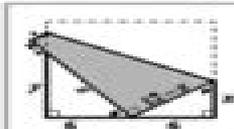$$\frac{A\ B\ C\ F\ D\ E}{A\ B\ C\ D\ E\ F} \qquad \frac{A\ B\ C\ E\ F\ D}{A\ B\ C\ D\ E\ F}$$

That's $20 \times 2 = 40$ total ways for the six people to be arranged in the seats so that exactly three seats are occupied by the individual assigned to sit there. Since there are $6! = 720$ different ways for six people to be seated in six distinctly labeled chairs, that gives us a probability of $40/720 = \mathbf{1/18}$.

One corner of a square of side length 12 units is folded down to meet the midpoint of a side as shown. What is the area of the shaded trapezoid?

[Target #4]

We are asked to find the area of the shaded trapezoid. We know its height is 12 units, the side length of the square, but we need to determine the lengths of the top and bottom bases in order to calculate the area of the trapezoid. As the figure indicates, three right triangles created when the square is folded as described are similar. The right triangle in the lower right corner has sides of length x, $12 - x$ and 6 units. Using the Pythagorean Theorem, we can write an equation that relates these side lengths: $x^2 + 6^2 = (12 - x)^2$. Solving for x, we get $x^2 + 36 = 144 - 24x + x^2 \rightarrow 24x = 108 \rightarrow x = 4.5$ units. So the hypotenuse of this triangle, which also is the bottom base of the trapezoid, has length $12 - 4.5 = 7.5$ units. You might notice that this triangle has side lengths that are a multiple of the primitive Pythagorean Triple 3-4-5. That means the similar triangle in the bottom left corner has sides of length 6, $y = 8$ and $z = 10$ units. Since the hypotenuse of this triangle together with the longer leg of the third similar triangle are a side of the square, it follows that this longer leg of the triangle must have length $12 - 10 = 2$ units. Since we know the ratio of the legs of this triangle must be 3:4, we can use the proportion $3/4 = w/2$ to determine that the shorter leg of the third triangle, which also is the top base of the trapezoid, has length $w = 1.5$ units. We now can calculate the area of the trapezoid to be $\frac{1}{2}(1.5 + 7.5)(12) = (9)(9) = \mathbf{54}$ units^2.

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WJ Hussar

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