1. How many functions $f : \{1, 2, 3, 4, 5\} \to \{1, 2, 3, 4, 5\}$ take on exactly 3 distinct values?

2. Let i be one of the numbers $0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11$. Suppose that for all positive integers n, the number n^n ***never*** has remainder i upon division by 12. List all possible values of i.

3. A plane in 3-dimensional space passes through the point (a_1, a_2, a_3), with a_1, a_2, and a_3 all positive. For each plane that intersect the three coordinate axes with intercepts greater than zero (i.e. there exist positive numbers b_1, b_2, b_3 such that $(b_1, 0, 0)$, $(0, b_2, 0)$, and $(0, 0, b_3)$ all lie on this plane), consider the volume of the tetrahedron formed by the origin and these three intercepts. Find, in terms of a_1, a_2, and a_3, the minimum possible volume for such a tetrahedron.

4. Let y be in a k-tangent pair if there exists a positive integer $x < y$ such that $\arctan \frac{1}{k} = \arctan \frac{1}{x} + \arctan \frac{1}{y}$. Compute the second largest integer that is in a 2012-tangent pair.

5. Regular hexagon $A_1A_2A_3A_4A_5A_6$ has side length 1. For $i = 1, \ldots, 6$, choose B_i to be a point on the segment A_iA_{i+1} uniformly at random, assuming the convention that $A_{j+6} = A_j$ for all integers j. What is the expected value of the area of hexagon $B_1B_2B_3B_4B_5B_6$?

6. Evaluate
$$\sum_{n=1}^{\infty} \sum_{m=1}^{\infty} \frac{1}{nm(n+m+1)}.$$

7. A *card* is an ordered 4-tuple (a_1, a_2, a_3, a_4) where each a_i is chosen from $\{0, 1, 2\}$. A *line* is an (unordered) set of three cards $\{(a_1, a_2, a_3, a_4), (b_1, b_2, b_3, b_4), (c_1, c_2, c_3, c_4)\}$ such that for each i, the numbers a_i, b_i, c_i are either all the same or all different. How many different lines are there?

8. The left end of a rubber band $100e$ centimeters long is attached to a wall and a slightly sadistic child holds on to the right end. A point-sized ant starts at the left end of the rubber band. At time $t = 0$, the ant begins walking to the right along the rubber band as the child begins stretching it. The increasingly tired ant walks at a rate of $1/(\ln(t + e))$ centimeters per second, while the child uniformly stretches the rubber band at a rate of 100 centimeters per second. The rubber band is infinitely stretchable and the ant and child are immortal. Compute the time in seconds, if it exists, at which the ant reaches the right end of the rubber band and bites the obnoxious child. If the ant never reaches the right end, answer $+\infty$.

9. We say that two lattice points are *neighboring* if the distance between them is 1. We say that a point lies at distance d from a line segment if d is the minimum distance between the point and any point on the line segment. Finally, we say that a lattice point A is *nearby* a line segment if the distance between A and the line segment is no greater than the distance between the line segment and any neighbor of A. Find the number of lattice points that are nearby the line segment connecting the origin and the point $(1984, 2012)$.

10. A permutation of the first n positive integers is *valid* if, for all $i > 1$, i comes after $\left\lfloor \frac{i}{2} \right\rfloor$ in the permutation. What is the probability that a random permutation of the first 14 integers is valid?

11. Given that $x, y, z > 0$ and $xyz = 1$, find the range of
$$\frac{x^3 + y^3 + z^3 - x^{-3} - y^{-3} - z^{-3}}{x + y + z - x^{-1} - y^{-1} - z^{-1}}.$$

12. A triangle has sides of length $\sqrt{2}$, $3 + \sqrt{3}$, and $2\sqrt{2} + \sqrt{6}$. Compute the area of the smallest regular polygon that has three vertices coinciding with the vertices of the given triangle.

13. How many positive integers n are there such that for any natural numbers a, b, we have $n \mid (a^2b + 1)$ implies $n \mid (a^2 + b)$? (Note: The symbol $\mid$ means "divides"; if $x \mid y$ then y is a multiple of x.)

14. Find constants α and c such that the following limit exists and is nonzero:

$$c = \lim_{n\to\infty} \frac{e\left(1-\frac{1}{n}\right)^n - 1}{n^\alpha}.$$

Give your answer in the form (α, c).

15. Sean thinks packing is hard, so he decides to do math instead. He has a rectangular sheet that he wants to fold so that it fits in a given rectangular box. He is curious to know what the optimal size of a rectangular sheet is so that it's expected to fit well in any given box. Let a and b be positive reals with $a \leq b$, and let m and n be independently and uniformly distributed random variables in the interval $(0, a)$. For the ordered 4-tuple (a, b, m, n), let $f(a, b, m, n)$ denote the ratio between the area of a *folded sheet* (with original dimensions $a \times b$) and the area of the horizontal cross-section of the box with dimension $m \times n$. Sean defines a folded sheet as the original $a \times b$ sheet folded in halves along each dimension (keeping its sides parallel to the sides of the box) until it occupies the largest possible area that will still fit in the box. Compute the smallest value of $\frac{b}{a}$ that maximizes the expectation f.