32^{nd} United States of America Mathematical Olympiad

Day I 12:30 PM – 5 PM

April 29, 2003

1. Prove that for every positive integer n there exists an n-digit number divisible by 5^n all of whose digits are odd.

2. A convex polygon $\mathcal{P}$ in the plane is dissected into smaller convex polygons by drawing all of its diagonals. The lengths of all sides and all diagonals of the polygon $\mathcal{P}$ are rational numbers. Prove that the lengths of all sides of all polygons in the dissection are also rational numbers.

3. Let $n \neq 0$. For every sequence of integers

$$A = a_0, a_1, a_2, \ldots, a_n$$

satisfying $0 \leq a_i \leq i$, for $i = 0, \ldots, n$, define another sequence

$$t(A) = t(a_0), t(a_1), t(a_2), \ldots, t(a_n)$$

by setting $t(a_i)$ to be the number of terms in the sequence A that precede the term a_i and are different from a_i. Show that, starting from any sequence A as above, fewer than n applications of the transformation t lead to a sequence b such that $t(b) = b$.

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4. Let ABC be a triangle. A circle passing through A and B intersects segments AC and BC at D and E, respectively. Lines AB and DE intersect at F while lines BD and CF intersect at M. Prove that $MF = MC$ if and only if $MB \cdot MD = MC^2$.

5. Let a, b, c be positive real numbers. Prove that

$$\frac{(2a+b+c)^2}{2a^2+(b+c)^2} + \frac{(2b+c+a)^2}{2b^2+(c+a)^2} + \frac{(2c+a+b)^2}{2c^2+(a+b)^2} \le 8.$$

6. A positive integer is written at each vertex of a regular hexagon so that the sum of all numbers written is 2003^{2003}. Bert makes a sequence of moves of the following form: Bert picks a vertex and replaces the number written there by the absolute value of the difference between the numbers written at the two neighboring vertices. Prove that Bert can always make a sequence of moves ending at the position with all six numbers equal to zero.