

Time limit: 15 minutes.

Instructions: This tiebreaker contains 3 short answer questions. All answers must be expressed in simplest form unless specified otherwise. You will submit answers to the problem as you solve them, and may solve problems in any order. You will not be informed whether your answer is correct until the end of the tiebreaker. You may submit multiple times for any of the problems, but **only the last submission for a given problem will be graded**. The participant who correctly answers the most problems wins the tiebreaker, with ties broken by the time of the last correct submission.

No calculators.

1. x is a base-10 number such that when the digits of x are interpreted as a base-20 number, the resulting number is twice the value as when they are interpreted as a base-13 number. Find the sum of all possible values of x .
2. If f is a monic cubic polynomial with $f(0) = -64$, and all roots of f are non-negative real numbers, what is the largest possible value of $f(-1)$? (A polynomial is monic if it has a leading coefficient of 1.)
3. Find the minimum of $f(x, y, z) = x^3 + 12\frac{yz}{x} + 16\left(\frac{1}{yz}\right)^{\frac{3}{2}}$ where x, y , and z are all positive. ¹

¹The problem as given in the tiebreaker did not specify that each of x, y , and z had to be positive. Without this constraint, the answer is $-\infty$, as x^3 can be an arbitrarily large negative value and dominate the expression.