THE RAMANUJAN CHALLENGE FOR AI

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ABSTRACT

To help evaluate the mathematical skills of current AI systems, we present a set of formulas for fundamental mathematical constants. These problems are attractive for AI evaluation because they are concrete and can be checked numerically to arbitrary precision, yet proving them may require non-obvious mathematics. Mathematical constants such as π, e, Catalan's constant, and special values of the Riemann zeta function have fascinated mathematicians for centuries. The search for formulas evaluating mathematical constants has produced some of the most beautiful mathematics in the field, especially in cases that yield irrationality proofs or fast convergence rates. Ramanujan's legacy is emblematic of this tradition. The list we provide contains two types of problems: formulas whose proofs are known to the authors but will remain encrypted for a short initial period; and formulas that are not yet proven. We are curious to see the achievements of AI in both cases.

Problem	**Name**	**Contributor**
2.1	Polynomial continued fraction for π	Michael Shalyt[1]
2.2	Euler's constant γ as an Apéry limit	Rotem Kalisch[1]
2.3	The sum $\pi + e$ as an Apéry limit	
2.4	A series of harmonic numbers converging to a polylogarithm combined with zeta values	Carsten Schneider[2]
2.5	Efficient rational approximation of Catalan's constant G	Hila Barkan[1]
2.6	A series for $\zeta(2) + \zeta(3)$	
2.7	Efficient four-term recurrence for $\zeta(2) + \zeta(3)$	Elyasheev Leibtag[3]
2.8	Very fast rational approximation of $\sqrt{10005}/\pi$	
3.1	An integral over knot polynomial roots expressing π^2	John Campbell[4]
3.2	Optimality of Apéry's irrationality-measure bound for $\zeta(3)$	Shachar Weinbaum[1]

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1 INTRODUCTION

Recent progress in AI for mathematics has made quantitative evaluation increasingly urgent. We increasingly need university-level and research-level questions that test whether AI systems can contribute to genuine mathematical work. Several recent benchmarks address this need from different directions. RealMath and LemmaBench study mathematical questions drawn from research papers and mathematical forums [Zhang et al. 2025; Peyronnet et al. 2026]. A central difficulty is contamination: if a problem or its solution appears in the AI training data, success may reflect retrieval rather than reasoning. One response is to perturb existing problems, as in GSM-Symbolic [Mirzadeh et al. 2025] and ASyMOB [Shalyt et al. 2025], reducing dependence on uncontaminated original questions. A stronger response is to use authentic research problems that have not yet appeared publicly. FrontierMath [Glazer et al. 2024], Riemann-Bench [Garre et al. 2026], and part of Humanity's Last Exam [Phan et al. 2025] emphasize original difficult questions with structured verification, while First Proof [Abouzaid et al. 2026] focuses on unpublished research problems whose answers were known to experts.

The present manuscript follows the spirit of First Proof, but concentrates on a more focused domain with a long mathematical tradition: explicit formulas involving fundamental mathematical constants, presented as recurrences, continued fractions, series, and integrals. The most interesting formulas often point to hidden structures (algebraic, group-theoretic, etc.). Historically, such formulas have been signatures of mathematical inspiration, from Ramanujan's "dreams" to Apéry's "garden".

This domain is well suited to quantitative evaluation of AI abilities. On the one hand, candidate formulas for constants can often be tested to thousands of digits, so numerical validation is immediate and objective. On the other hand, converting such evidence into proof may require a wide variety of mathematical tools from various domains. It is often hard to know in advance which approach will be best suited for each formula.

The historical examples are iconic. Ramanujan's formulas for π remain a model of unexpected structure in special values [Ramanujan 1914]. Apéry's proof of the irrationality of $\zeta(3)$, together with the reinterpretation by Beukers via multiple integrals, showed how recurrence relations and arithmetic estimates can turn an experimental pattern into a theorem [Apéry 1979; Beukers 1979]. Subsequent work and continued ongoing efforts extend this perspective to odd zeta values, Catalan's constant, Euler's constant, and a wide range of Apéry limits and related special values [Ball et al. 2001; Zudilin 2001; Rivoal et al. 2003; Lagarias 2013; Chamberland et al. 2021; Raayoni et al. 2021; Elimelech et al. 2023; Weinbaum et al. 2025].

Many of the questions collected here lie in or near the modern Apéry-style tradition. Some ask for polynomial continued fractions or holonomic recurrences converging to constants such as π, $\log 2$, γ, $\pi + \mathrm{e}$, or combinations of zeta values. Others concern efficient recurrences with a conjectural exponential rate of convergence, or integrals whose closed forms appear to encode deeper arithmetic structure. At a broader conceptual level, these identities also belong to the world of periods and special values, where numerical discovery frequently precedes structural explanation [Kontsevich et al. 2001].

A few remarks

The present list is split into two categories. The first category consists of formulas for which a proof (in the classic sense or as the result of an algorithmic procedure, see discussion below) is known to the authors but has not yet been made public. These questions are intended to test whether an AI system, or a human participant, can independently structure a valid proof. The second category consists of formulas and hypotheses that have been numerically validated to high precision, but for which the authors do not currently have a proof. These are posed as open problems.

Why are the formulas so complex? Mostly because AI got so good, and can immediately prove most simple forms. Nevertheless, some of the most interesting formulas presented below are complex because no simpler forms are known, as in the example of the recurrence that produces $\pi + e$. We will see whether/when AI can provide new insight into these classic questions.

2 The Questions

This section contains proven problems, presented here for the first time. The proofs or computational procedures for the proofs are known to the authors but are not yet public. Their level of difficulty varies. Some may be tackled using existing literature or folklore, while others appear to require additional novelty. In each case, the statement is written in the form of an explicit formula so that it can be checked numerically.

2.1 Polynomial continued fraction for π

Let:

$$a_n = -220n^3 - 484n^2 - 301n - 42, \qquad b_n = 4n^2(2n+1)^2(5n-4)(5n+6).$$

Prove:

$$a_0 + \cfrac{b_1}{a_1 + \cfrac{b_2}{a_2 + \cfrac{b_3}{a_3 + \ddots}}} = \frac{6}{3-\pi}.$$

2.2 Euler's constant γ as an Apéry limit

For $n \geq 0$, define:

$$\begin{aligned} 0 = &\left(-8n^3 - 51n^2 - 105n - 68\right) u_n \\ &+ \left(24n^5 + 337n^4 + 1833n^3 + 4818n^2 + 6092n + 2928\right) u_{n-1} \\ &- (n+2)(n+3)\left(24n^5 + 273n^4 + 1150n^3 + 2154n^2 + 1635n + 268\right) u_{n-2} \\ &+ (n+1)(n+2)^4 (n+3)\left(8n^3 + 75n^2 + 231n + 232\right) u_{n-3} \end{aligned}$$

Let p_n, q_n be two solutions of the recurrence, defined by the initial values:

$$p_{-3} = 0, \quad p_{-2} = 7, \quad p_{-1} = 179$$

$$q_{-3} = 1, \quad q_{-2} = 12, \quad q_{-1} = 306$$

Prove:

$$\lim_{n\to\infty} \frac{p_n}{q_n} = \gamma,$$

where γ is Euler's constant.

2.3 The sum $\pi + e$ as an Apéry limit

For $n \geq 1$, define

$$\begin{aligned} 0 = &\left(-n^3 + 2n^2 + 7n + 3\right) u_n \\ &+ (n+2)\left(2n^4 + n^3 - 26n^2 - 48n - 19\right) u_{n-1} \\ &+ (n+2)\left(n^6 + 9n^5 + 8n^4 - 87n^3 - 249n^2 - 234n - 68\right) u_{n-2} \\ &+ (n+1)^2 (n+2)\left(2n^5 + 3n^4 - 13n^3 - 21n^2 + 4\right) u_{n-3} \\ &- n^3 (n+1)^2 (n+2)\left(n^3 + n^2 - 8n - 11\right) u_{n-4}. \end{aligned}$$

Let p_n, q_n be two solutions of the recurrence, defined by the initial values:

$$p_{-3} = 1, \quad p_{-2} = 1, \quad p_{-1} = 20, \quad p_0 = 296$$

$$q_{-3} = 1, \quad q_{-2} = 0, \quad q_{-1} = 4, \quad q_0 = 48$$

Prove:

$$\lim_{n\to\infty} \frac{p_n}{q_n} = \pi + e.$$

2.4 A SERIES OF HARMONIC NUMBERS CONVERGING TO A POLYLOGARITHM COMBINED WITH ZETA VALUES

Prove:

$$\sum_{m=0}^{\infty}\sum_{k=0}^{m}\frac{\binom{m}{k}^2 H_k^2}{(m+1)^2\binom{2m}{m}} =$$

$$20\,\mathrm{Li}_4\left(\frac{1}{2}\right)+\frac{5}{6}\log^4(2)+10\zeta(2)-\frac{65}{9}\zeta(2)^2-\log^2(2)(12+5\zeta(2))+\frac{1}{2}\zeta(3)+\log(2)\left(\frac{35}{2}\zeta(3)-16\right),$$

where $H_0=0$ and for $k\geq 1$, H_k is the k-th harmonic number.

2.5 EFFICIENT RATIONAL APPROXIMATION OF CATALAN'S CONSTANT G

For $n\geq 0$, let

$$M(n)=\big(m_{ij}(n)\big)_{1\leq i,j\leq 3},$$

where

$$\begin{aligned}
m_{11}(n)&=(-2n-5)(n+3)^2(136n^4+1424n^3+5548n^2+9551n+6141),\\
m_{12}(n)&=384n^6+6384n^5+44168n^4+162698n^3+336377n^2+369933n+169011,\\
m_{13}(n)&=-480n^4-4980n^3-19210n^2-32690n-20730,\\
m_{21}(n)&=(n+2)^2(n+3)^2(4n+10)(48n^3+386n^2+1017n+879),\\
m_{22}(n)&=(n+2)^2(-272n^5-3848n^4-21732n^3-61184n^2-85761n-47808),\\
m_{23}(n)&=(n+2)^2(320n^3+2540n^2+6610n+5640),\\
m_{31}(n)&=(-4n-10)(n+2)^2(n+3)^2(32n^4+302n^3+1037n^2+1530n+813),\\
m_{32}(n)&=(n+2)^2(192n^6+2984n^5+19116n^4+64452n^3+120256n^2+117279n+46476),\\
m_{33}(n)&=(n+2)^2(-16n^5-408n^4-2912n^3-8884n^2-12254n-6240).
\end{aligned}$$

For $N\geq 0$, define

$$\mathcal{M}_N=M(0)M(1)\cdots M(N-1).$$

Choose initial conditions

$$A=\begin{pmatrix}30921 & -32972 & 8240\\ 33750 & -36000 & 9000\end{pmatrix}.$$

Write

$$A\mathcal{M}_N=\begin{pmatrix}P_{N,1} & P_{N,2} & P_{N,3}\\ Q_{N,1} & Q_{N,2} & Q_{N,3}\end{pmatrix}.$$

Then, for each $j=1,2,3$, prove:

$$\lim_{N\to\infty}\frac{P_{N,j}}{Q_{N,j}}=G,$$

where

$$G=\sum_{k=0}^{\infty}\frac{(-1)^k}{(2k+1)^2}$$

is Catalan's constant.

2.6 A SERIES FOR $\zeta(2)+\zeta(3)$

Let $(u_n)_{n\geq 1}$ be the sequence defined by

$$u_1=-\frac{93}{4480},\qquad u_2=-\frac{117}{14000},$$

and, for $n\geq 3$, by the recurrence

$$
\begin{aligned}
0 = &-2(n+3)^3(2n+5)(3n+5)u_n \\
&+(n+2)^2(15n^3+85n^2+155n+93)u_{n-1} \\
&-(n+1)^3(n+2)(3n+8)u_{n-2}.
\end{aligned}
$$

Prove:

$$\frac{2077}{720}+\sum_{j=1}^{\infty} u_j = \zeta(2)+\zeta(3).$$

2.7 Efficient four-term recurrence for $\zeta(2)+\zeta(3)$

For $n \geq 0$, define

$A_n = 1024(2n+5)^4(2n+7)^3(2n+9)^3\big(946n^2+6407n+10860\big)$,
$B_n = 128(2n{+}7)^3(2n{+}9)^3\big(104060n^6{+}1745370n^5{+}12145238n^4{+}44886481n^3{+}92943995n^2{+}102256019n+46709052\big)$,
$C_n = 16(n+3)^4(2n+9)^3\big(3784n^5+57792n^4+351019n^3+1059230n^2+1587211n+944620\big)$,
$D_n = (n+3)^4(n+4)^6\big(946n^2+4515n+5399\big)$.

Let $(p_n)_{n\geq 0}$ and $(q_n)_{n\geq 0}$ be the two solutions of the recurrence

$$u_{n+1} = \frac{B_n}{A_n}\,u_n - \frac{C_{n-1}}{A_{n-1}}\,u_{n-1} + \frac{D_{n-2}}{A_{n-2}}\,u_{n-2}, \qquad n \geq 2,$$

with initial conditions

$$p_0 = -612218384750, \qquad p_1 = -\frac{9525021973931919}{18100}, \qquad p_2 = -\frac{29561828382772029}{65380},$$

and

$$q_0 = -215040420000, \qquad q_1 = -\frac{167282265043404}{905}, \qquad q_2 = -\frac{964185327658080}{6071}.$$

Prove:

$$\lim_{n\to\infty}\frac{p_n}{q_n} = \zeta(2)+\zeta(3).$$

2.8 Very fast rational approximation of $\sqrt{10005}/\pi$

Let

$$R = 151931373056001, \qquad u = 2n+3, \qquad w = u(3u-2)(3u+2).$$

For $n \geq 0$, let

$$M(n) = \begin{pmatrix} \dfrac{a_1}{w} & \dfrac{a_2}{w} & \dfrac{a_3}{w} & \dfrac{144R(u-1)^2}{w} \\ -u^3 & -3u^2 & -3u & -1 \\ \dfrac{b_1}{144R} & -\dfrac{b_2}{72R} & -\dfrac{b_3}{36R} & -\dfrac{2u+2R-7}{2R} \\ \dfrac{c_1}{288R^2} & \dfrac{c_2}{144R^2} & \dfrac{c_3}{72R^2} & \dfrac{c_4}{4R^2} \end{pmatrix},$$

where

$$
\begin{aligned}
a_1 &= (144R-99)u^5-(288R-333)u^4+(144R-229)u^3-114u^2+40u+64, \\
a_2 &= (432R-243)u^4-(864R-909)u^3+(432R-868)u^2-80u+272, \\
a_3 &= (432R-153)u^3-(864R-648)u^2+(432R-860)u+360,
\end{aligned}
$$

$$
\begin{aligned}
b_1 &= 9u^4-(144R-63)u^3+158u^2+168u+64, \\
b_2 &= 36u^3+(216R-189)u^2-316u-168, \\
b_3 &= 54u^2+(108R-189)u-158,
\end{aligned}
$$

and

$$\begin{aligned} c_1 &= 18u^5 + (54R+45)u^4 - (288R^2 - 378R + 251)u^3 \\ &\qquad + (948R - 1086)u^2 + (1008R - 1384)u + (384R - 576), \\ c_2 &= (153R - 72)u^4 - (657R - 702)u^3 - (432R^2 - 1292R + 1069)u^2 \\ &\qquad + (2064R - 2508)u + (1072R - 1512), \\ c_3 &= (180R - 108)u^3 - (891R - 864)u^2 - (216R^2 - 1450R + 1385)u \\ &\qquad + (1116R - 1422), \\ c_4 &= (6R-4)u^2 - (33R - 32)u - (4R^2 - 58R - 236337691420383). \end{aligned}$$

For $N \geq 0$, define

$$\mathcal{M}_N = M(0)M(1)\cdots M(N-1),$$

with the convention that $\mathcal{M}_0 = I$.

Choose initial conditions

$$A = \begin{pmatrix} A_1 & A_2 & A_3 & A_4 \\ B_1 & B_2 & B_3 & B_4 \end{pmatrix},$$

where

$$\begin{aligned} (A_1, A_2, A_3, A_4) = (&37169305760442252761441,\ 111507917281327441564208, \\ &111507917281327599720129,\ 37169305760442410917362), \end{aligned}$$

and

$$\begin{aligned} (B_1, B_2, B_3, B_4) = (&1167416361542639692320,\ 3502249084627896132160, \\ &3502249084627879697280,\ 1167416361542622723840). \end{aligned}$$

Write

$$A\mathcal{M}_N = \begin{pmatrix} P_{N,1} & P_{N,2} & P_{N,3} & P_{N,4} \\ Q_{N,1} & Q_{N,2} & Q_{N,3} & Q_{N,4} \end{pmatrix}.$$

Then, for each $j = 1, 2, 3, 4$, we conjecture that

$$\lim_{N\to\infty} \frac{P_{N,j}}{Q_{N,j}} = \frac{\sqrt{10005}}{\pi}.$$

3 THE CONJECTURES

This section contains open problems, presented here for the first time. In each case, the statement is written in the form of an explicit formula so that it can be checked numerically.

3.1 AN INTEGRAL OVER KNOT POLYNOMIAL ROOTS EXPRESSING π^2

Let $A_{7_2}(M, L)$ denote the A-polynomial for the prime knot 7_2.

$$\begin{aligned} A_{7_2}(M,L) = L^5 &+ L^4\left(M^{14} - M^{12} + 3M^4 + 4M^2 - 2\right) \\ &+ L^3\left(-2M^{18} + 5M^{16} + M^{14} - 4M^{12} + 6M^8 + 5M^6 + 2M^4 - 4M^2 + 1\right) \\ &+ L^2\left(M^{22} - 4M^{20} + 2M^{18} + 5M^{16} + 6M^{14} - 4M^{10} + M^8 + 5M^6 - 2M^4\right) \\ &+ L\left(-2M^{22} + 4M^{20} + 3M^{18} - M^{10} + M^8\right) + M^{22}. \end{aligned}$$

Let $\alpha \approx 0.349269\ldots$ denote the real solution of $A_{7_2}\left(\alpha, \alpha^{1/2}\right) = 0$ closest to 0.349269. Let $\beta \approx 0.406813\ldots$ denote the real solution of $A_{7_2}(\beta, \beta) = 0$ closest to 0.406813 Let $y = y(x)$ denote the curve satisfying $A(x, y(x)) = 0$ for $\alpha \leq x \leq \beta$ and such that $y(x)$ is positive and decreasing with $y'(x) \leq -2$. Prove the following formula, which was discovered empirically:

$$\frac{4\pi^2}{85} = \int_\alpha^\beta \left(\log x \frac{dy}{y} - \log y \frac{dx}{x}\right).$$

Context. This result is a surprisingly simple conjectural closed form of a Godbillon–Vey type Knot invariant [Khoi 2008].

3.2 Optimality of Apéry's irrationality-measure bound for $\zeta(3)$

The sequences $(a_n)_{n\geq 0}$ and $(b_n)_{n\geq 0}$ are solutions of Apéry's recurrence

$$(n+1)^3 u_{n+1} - \big(34n^3 + 51n^2 + 27n + 5\big) u_n + n^3 u_{n-1} = 0 \qquad (n \geq 1),$$

with initial values

$$a_0 = 0, \quad a_1 = 6, \qquad b_0 = 1, \quad b_1 = 5.$$

Define $d_n \coloneqq \operatorname{lcm}(1, \ldots, n)^3$. Note that $d_n a_n, d_n b_n \in \mathbb{Z}$ as shown in [Apéry 1979].

Prove:

$$\gcd(d_n a_n, d_n b_n) = e^{o(n)}.$$

Context. The a_n, b_n sequences were generated by Apéry in his proof of the irrationality of $\zeta(3)$ [Apéry 1979]. Specifically, considering the linear forms $a_n - \zeta(3) b_n$ gives a bound on the irrationality measure of $\zeta(3)$, by demonstrating that $d_n a_n, d_n b_n \in \mathbb{Z}$.

The above conjecture shows that the irrationality-measure bound found by Apéry is tight for his particular formula.

4 Discussion - proof in the age of AI

The process of collecting these examples has resurfaced a broader question: what should count as a sufficient proof in the era of AI? Interactive theorem provers (such as Lean [Moura et al. 2015]) are expected to be the gold standard for trust in AI output. In practice, however, many recent AI achievements in mathematics are considered complete without this formalization (e.g., [OpenAI 2026; Alon et al. 2026]). The problems in this challenge sharpen this tension: many are computational in nature, and therefore provide a concrete setting in which algorithmic derivations carried out by computer algebra systems can be evaluated as candidates for mathematical proof.

For the purpose of this challenge, we consider a derivation carried out using symbolic libraries within established computer algebra systems as sufficient evidence of a valid solution. This convention should not be interpreted as replacing the strict standards required for a rigorous published proof. It is motivated by common practice in experimental mathematics, and by the computational nature of the results. For this reason, problems of the kind presented here may serve as a useful test case for how AI can help create the missing link between numerical discovery, symbolic computation, and rigorous proof.

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