

King of Dumbs

Level: ♠ Technical

How much is 7×10^{27} ? Huge numbers without fear

Scientific notation, SI prefixes from kilo to quetta, orders of magnitude, log scales and Fermi estimates, explained with grains of sand, in three levels.

English Published October 13, 2026 Updated October 15, 2026



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<https://kingofdumbs.com/en/lessons/huge-numbers>

What you'll learn

- Scientific notation
- SI prefixes, from quecto to quetta
- Orders of magnitude and log scales
- Billion versus the Spanish billón
- Fermi estimation

Symbols you'll meet

E_a subscript: the label underneath (♠) · Σ sum: add them all up (♠) · x_i index i: item number i (♠) · Π product: multiply them all (♠) · $\approx$ approximately equal (♦♦) · $\leq \geq$ less or equal / greater or equal (♠) · $\neq$ not equal to (♠) · $|x|$ absolute value: drop the sign (♠) · $\cdot$ dot: multiply (or dot product) (♠) · $\Rightarrow \Leftrightarrow$ implies / is equivalent to (♠) · 10^{-3} negative exponent: divide (♦♦) · $\log$ logarithm: how many times do I multiply? (♠) · $\lfloor x \rfloor$ floor: round down (♠) · μ mu: micro (a millionth) or mean (♦♦) · $\in$ belongs to (♠) · $\mathbb{R} \mathbb{Z}$ sets of numbers (♠)

Your body holds about **7×10^{27} atoms**. You read it “seven times ten to the twenty-seventh”, and it’s a 7 followed by 27 zeros. The dumb question of this lesson is: **how much is that?**

Don’t worry if the number means nothing to you: it means nothing to almost anyone. In an experiment with adults, nearly half put “a million” right in the middle between a thousand and a billion, as if those words were evenly spaced. They aren’t, not even close. This lesson gives you four tools to make huge numbers mean something again: count the zeros, give them names, compare them on the right scale, and estimate them without a calculator.

Pick your card: ♠ if you’re starting from scratch, ♦ if a simple formula doesn’t scare you, ♠ if you want the notation. You can switch at any time.



Counting zeros: scientific notation

♦ → ♠ From intermediate to technical

In ♦ we said	In ♠ we write
number in front	mantissa a , with $1 \leq a < 10$
exponent	$n \in \mathbb{Z}$ (an integer)
how many places the decimal point moves	$n = \lfloor \log_{10} x \rfloor$
multiplying adds the exponents	$10^m \cdot 10^n = 10^{m+n}$
how much you know	significant figures
with an E	E notation; IEEE 754 floating point (double)

$$x = a \cdot 10^n, \quad 1 \leq |a| < 10, \quad n \in \mathbb{Z}$$

$$(a \cdot 10^m)(b \cdot 10^n) = ab \cdot 10^{m+n}$$

$$\log_{10} x = n + \log_{10} a, \quad 0 \leq \log_{10} a < 1$$

$$7 \times 10^{27} \equiv 7e27 \quad (\text{double: } \max \approx 1.8e308)$$

Every real $x \neq 0$ can be written uniquely as $x = a \cdot 10^n$ with $1 \leq |a| < 10$ and $n \in \mathbb{Z}$. Taking logs, $\log_{10}|x| = n + \log_{10}|a|$, with $0 \leq \log_{10}|a| < 1$: the exponent is the integer part of the logarithm, $n = \lfloor \log_{10}|x| \rfloor$, and the mantissa holds the fractional part. Scientific notation is a pocket table of logarithms, which is why a product reduces to adding exponents.

Significant figures live in the mantissa: 7×10^{27} claims one figure and 7.0×10^{27} claims two. Writing 7,000,000,000,000,000,000,000,000 seems to claim 28 exact figures, and nobody knows them.

Computers use the same idea in base 2. A double (IEEE 754) stores a 53-bit binary mantissa and an exponent: its maximum is $2^{1024} - 2^{971} \approx 1.8 \times 10^{308}$, and integers are only exact up to $2^{53} - 1$ (MDN). 10^{27} fits easily, but in JavaScript `7e27 + 1 === 7e27` is true: the 1 falls below the precision.

Giving them names: prefixes

♦ → ♠ From intermediate to technical

In ♦ we said	In ♠ we write
prefix, symbol	$k = 10^3$, $M = 10^6$, $G = 10^9$... $Q = 10^{30}$
lower case and upper case	$m = 10^{-3} \neq M = 10^6$
kibi, 1,024	$Ki = 2^{10}$ (IEC 80000-13)
gibibyte versus a gigabyte	$GiB / GB = 2^{30} / 10^9 \approx 1.074$
stuck in front of a unit	inseparable symbol: $km^2 = (10^3 \text{ m})^2 = 10^6 \text{ m}^2$

$$k = 10^3 = 1000 \neq Ki = 2^{10} = 1024$$

$$GiB / GB = 2^{30} / 10^9 \approx 1.074$$

$$m = 10^{-3} \neq M = 10^6$$

nm, not mμm (no compound prefixes)

kg: the prefix sits on the gram

The 24 SI prefixes are powers of 10^3 , except hecto, deca, deci and centi (10^2 , 10^1 , 10^{-1} , 10^{-2}), which survive through use. The 27th General Conference on Weights and Measures (2022) added R, Q, r and q, for two stated reasons: data science will soon need to express quantities beyond 10^{24} , and unofficial names had to be headed off before they caught on.

The SI Brochure sets three rules that are often broken:

- The prefix symbol and the unit symbol form an **inseparable symbol**, and a power applies to both: $1 \text{ km}^2 = (10^3 \text{ m})^2 = 10^6 \text{ m}^2$, not 10^3 m^2 . Likewise, $2.3 \text{ cm}^3 = 2.3 \times 10^{-6} \text{ m}^3$.
- **Prefixes don't stack**: nm, not mμm.
- **The kilogram** is the only base unit that already has a prefix, so multiples are formed on the gram: 10^{-6} kg is mg, not μkg.

SI prefixes are strictly powers of 10: “one kilobit represents 1000 bits and not 1024 bits”. Powers of 2 get their own prefixes, from kibi (2^{10}) to quebi (2^{100}), defined in IEC 80000-13. The gap grows with size: 2.4% for kibi versus kilo, 7.4% for gibi versus giga and 26.8% for quebi versus quetta... although nobody runs into that last one yet.

The King of Dumbs says:

If a translated story says “un billón de dólares”, count the zeros before panicking. It’s a trillion, not a billion.



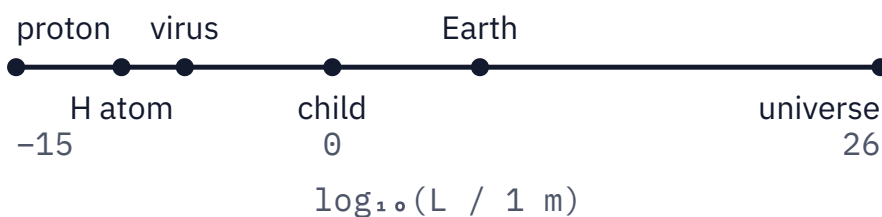
Comparing: orders of magnitude and log scales

♦ → ♠ From intermediate to technical

In ♦ we said	In ♠ we write
the nearest power of 10	<code>order(x) = round(log₁₀ x)</code>
each step multiplies by the same amount	axis $u = \log_{10} x$: constant ratio $\Rightarrow$ constant distance
differ by a factor of ten	$\Delta = \log_{10}(x_2 / x_1)$
as if a thousand, a million and a billion were evenly spaced	segmented linear heuristic (Landy et al., 2013)

$$\text{order}(x) = \text{round}(\log_{10} x)$$

$$\log_{10}(10^{26} \text{ m} / 10^{-15} \text{ m}) = 41$$



With $u = \log_{10} x$, multiplying by k shifts by a fixed distance $\log_{10} k$. A log scale turns ratios into differences and powers into slopes: on log-log axes, $y \propto x^p$ is a straight line of slope p .

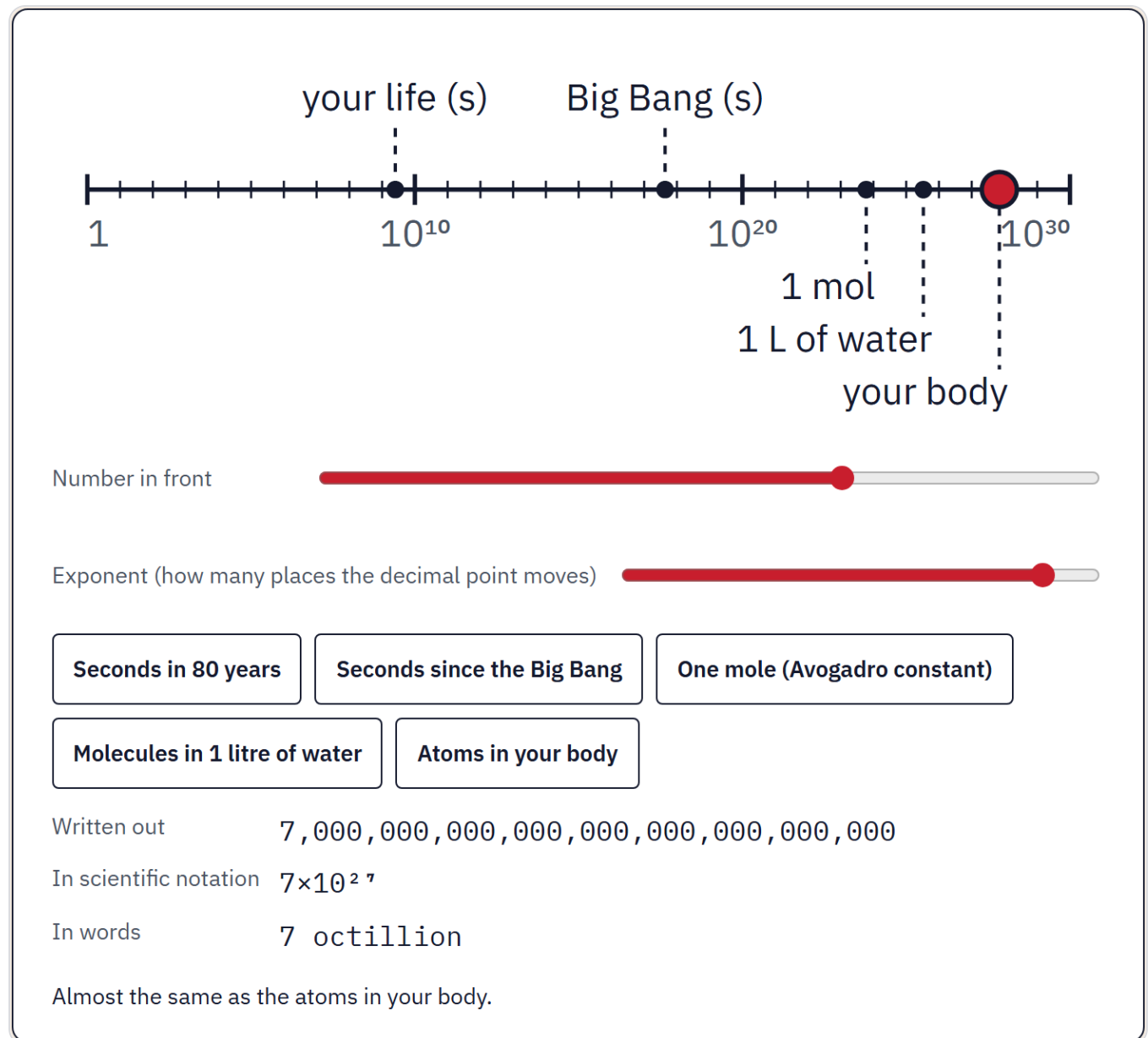
OpenStax defines the order of magnitude as $\text{round}(\log_{10} x)$. Watch the threshold: rounding flips at $\sqrt{10} \approx 3.16$, not at 5. So 9,000 is of order 4 even though its scientific exponent is 3. By that rule, a proton (10^{-15} m) and the observable universe (10^{26} m) are $\log_{10}(10^{26}/10^{-15}) = 41$ orders of magnitude apart.

Landy, Silbert and Goldin (*Cognitive Science*, 2013) found that about half of participants placed numbers from 10^3 to 10^9 linearly and that nearly all the rest followed a **segmented linear heuristic**: linear within each word (“millions”, “billions”) and evenly spaced between words. The segmented group was also more optimistic about ineffective policy strategies. The authors attribute it to the lexical structure of number names, not to poor arithmetic.



Try it: the ladder of zeros

Choose the number in front and the exponent, or jump to a reference. See how it's written out, how it's read and where it lands on the ladder.



Interactive widget. Try it on the web: <https://kingofdumbs.com/en/lessons/huge-numbers>

Estimating without a calculator: the Fermi method

♦ → ♠ From intermediate to technical

In ♦ we said	In ♠ we write
break the problem into factors	$N = \prod f_i \Rightarrow \log N = \sum \log f_i$
errors partly cancel out	independent errors: $\sigma(\log N) \approx \sqrt{n} \cdot \sigma(\log f)$
bound it between a minimum and a maximum	geometric mean $\sqrt[n]{x_{\min} \cdot x_{\max}}$
a bundle of 6×10^{23} things	$N_A = 6.022 \ 140 \ 76 \times 10^{23} \text{ mol}^{-1}$ (exact)
a mole of water weighs about 18 g	$M(\text{H}_2\text{O}) = 2 \cdot 1.008 + 15.999 = 18.015 \text{ g/mol}$

$$N = \prod f_i \Rightarrow \log N = \sum \log f_i$$

$$\sigma(\log N) \approx \sqrt{n} \cdot \sigma(\log f)$$

$$x \approx \sqrt[n]{x_{\min} \cdot x_{\max}}$$

$$70 \text{ kg as water: } 7.0 \times 10^{27}$$

$$\text{real composition: } 6.7 \times 10^{27}$$

A Fermi estimate is a product $N = \prod f_i$, and on a log scale, a sum: $\log N = \sum \log f_i$. If each factor has an independent multiplicative error with standard deviation σ in log, the total grows as $\sqrt{n} \cdot \sigma$, not $n \cdot \sigma$. With five factors known “to within a factor of 2”, the result typically lands within a factor of $2^{\sqrt{5}} \approx 4.7$: inside the order of magnitude.

For an unknown factor bounded between $x_{\min}$ and $x_{\max}$, the geometric mean $\sqrt[n]{x_{\min} \cdot x_{\max}}$ is the midpoint on a log scale. OpenStax uses it for the mass of a moose: between 10^2 and 10^3 kg, $\approx 3 \times 10^2$ kg.

The atoms in a 70 kg body, with two independent models:

- **All water:** $70,000 / 18.015 \times 3 \times N_A = 7.0 \times 10^{27}$.
- **Composition by mass** (O 61%, C 23%, H 10%, N 2.6%, WebElements) with conventional atomic weights: 6.7×10^{27} . The remaining 3.4% are heavy atoms (Ca, P, K...) and add less than 1% to the count.

Both land next to Freitas's $\approx 7 \times 10^{27}$ (*Nanomedicine* I, 3.1). The Avogadro constant has been exact since the 2019 SI redefinition, so all the uncertainty is in the model, not in N_A .



Final challenge

1. How many zeros does 10^6 have when written out?

- a. 10
- b. 6: it's a million
- c. 60

2. A Spanish news story says «3 billones de dólares». In English, that's...

- a. 3 billion dollars
- b. 3 trillion dollars
- c. 3 million dollars

3. On an ordinary ruler from 0 to a billion, where does a million land?

- a. Around the middle
- b. Stuck to zero: a thousandth of the way
- c. Near the end



In three sentences

1. Each zero is $\times 10$, and scientific notation counts them: 7×10^{27} is a 7 with 27 zeros, about seven octillion atoms, the ones in your body.
2. Prefixes name the zeros in threes (kilo, mega, giga... up to quetta), and in Spanish a *billón* is a million millions, not a billion.

3. To compare or estimate, count zeros: use a log scale when ratios matter, break the problem into factors and check you've got the order of magnitude right.



Sources

- SI prefixes: [NIST, metric prefixes](#) and [BIPM, CGPM 2022, Resolution 3](#) (ronna, quetta, ronto and quecto). Usage rules (inseparable symbol, no compound prefixes, kilogram, powers of 2): [BIPM, SI Brochure](#), section 3. Binary prefixes: [NIST](#).
- Billion, octillion and nonillion in US English: [Merriam-Webster](#). The Spanish billón: [DLE](#) and [Diccionario panhispánico de dudas](#).
- Order of magnitude and reference orders: [OpenStax, University Physics vol. 1, 1.1](#). Fermi estimates: [OpenStax, 1.5](#).
- How adults place large numbers: Landy, Silbert and Goldin, *Cognitive Science* 37, 775 (2013), [doi:10.1111/cogs.12028](#).
- Atoms in the human body: Freitas, [Nanomedicine I, 3.1](#), checked against our own calculation from the composition in [WebElements \(U. of Sheffield\)](#) and [CIAAW](#) atomic weights.
- Avogadro constant, exact: [NIST CODATA](#). Limits of a double: [MDN, Number.MAX_VALUE](#).
- Age of the universe (for the widget): Planck 2018, [arXiv:1807.06209](#), 13.787 ± 0.020 billion years, checked against [WMAP \(NASA\)](#), 13.77.

How this lesson was made: researched and written with help from Claude, from the sources above, checked and cross-checked against a second source on 13 October 2026. Numbers without their own link are calculations from them. The drawings are our own.

Answers

1. **b)** 6: it's a million. That's it: the exponent counts the zeros. 1,000,000.
2. **b)** 3 trillion dollars. Right. The Spanish billón is a million millions: your trillion.
3. **b)** Stuck to zero: a thousandth of the way. Exactly. A million is a thousandth of a billion. On a log scale, though, it does land in the middle.

A King of Dumbs lesson, kingofdumbs.com. Offline version; the original, with widgets you can play with, is at: <https://kingofdumbs.com/en/lessons/huge-numbers>

Updated on October 15, 2026.