

What are bases in math

Unveiling the Power of Bases in Mathematics

We encounter numbers daily, from calculating grocery bills to tracking stock prices. But have you ever considered the underlying system that governs how we represent these numbers? This system is deeply rooted in the concept of "bases." Understanding bases isn't just an academic exercise; it unlocks a powerful tool for comprehending how numbers function and even opens doors to other mathematical fields. This delves into the fascinating world of bases, exploring their significance, applications, and nuances.

What are Bases? A Foundation in Number Representation

At its core, a base in mathematics represents the number of unique digits used to represent a number in a positional number system. The most common base we use every day is base-10, also known as the decimal system. In base-10, we have ten unique digits (0-9), and the position of a digit determines its value. For instance, in the number 235, the '2' represents 200, the '3' represents 30, and the '5' represents 5. This positional value is crucial; a '2' in the hundreds place has a vastly different value than a '2' in the ones place.

Exploring Different Bases: Beyond Base-10

Beyond base-10, other bases are used extensively in various fields,

particularly in computer science. Base-2 (binary), base-8 (octal), and base-16 (hexadecimal) are examples.

- **Base-2 (Binary):** This system uses only two digits, 0 and 1. Each digit represents a power of 2. In binary, 1011 represents $(1 \times 2^3) + (0 \times 2^2) + (1 \times 2^1) + (1 \times 2^0) = 8 + 0 + 2 + 1 = 11$ in base-10.
- **Base-8 (Octal):** Utilizing digits 0-7, octal represents numbers as powers of 8. For instance, 35 in octal is $(3 \times 8^1) + (5 \times 8^0) = 24 + 5 = 29$ in base-10.
- **Base-16 (Hexadecimal):** Using digits 0-9 and letters A-F (representing 10-15), hexadecimal is commonly used in computer science for representing memory addresses and color codes. For example, the hexadecimal value "FF" represents $(15 \times 16^1) + (15 \times 16^0) = 240 + 15 = 255$ in base-10.

(Visual Representation): Consider a table to illustrate the conversion:

Base	Digits	Example (Base)	Example (Decimal)
2	0-1	1011	11
8	0-7	35	29
16	0-9, A-F	FF	255

Conversion Between Bases: A Practical Application

Converting numbers between different bases is a crucial skill. Let's look at converting a decimal number to binary: **Example:** Convert 25 to binary. 1. Divide 25 by 2 successively and record the remainders. - $25 / 2 = 12$ R 1 - $12 / 2 = 6$ R 0 - $6 / 2 = 3$ R 0 - $3 / 2 = 1$ R 1 - $1 / 2 = 0$ R 1 2. Read the remainders from bottom to top: 11001. This illustrates a powerful practical application: computer hardware operates primarily in binary, and conversions are essential for translating data between the hardware and user-accessible decimal representation.

Advantages of Using Different Bases

- **Efficiency in computer representation:** Binary simplifies complex computations in computer hardware.
- **Conciseness in representation:** Hexadecimal provides a compact way to represent large binary numbers,

reducing data storage space. • **Enhanced readability for specific contexts:** Octal is easier for humans to read and interpret than the corresponding binary representation, which can be very long for large values.

Disadvantages/Related Topics

While bases offer advantages, several limitations exist:

Calculating in Other Bases

Understanding the arithmetic operations (addition, subtraction, multiplication, division) in different bases is crucial for their practical use.

Case Study: Base-2 Computations

Consider the task of adding two binary numbers: $1011 + 110 = 10001$. This example illustrates that while converting to decimal simplifies understanding the outcome, the actual computational mechanisms rely on base-2 rules.

The Power of Positional Notation

Positional notation is a fundamental feature of base systems. Understanding this system unlocks the ability to represent and manipulate large numbers efficiently.

Beyond Integer Representation

Real numbers can also be represented in different bases, and the principles remain largely the same. This extension allows for a comprehensive understanding of numerical systems.

Actionable Insights

- **Start with the fundamentals:** Master the conversion between bases

and the underlying principles of positional notation. • Explore diverse applications: Understand how different bases are used in computer science, digital electronics, and other relevant fields. • *Develop problem-solving skills*: Practice converting numbers between bases to develop problem-solving skills and gain a deeper understanding of how different number systems function.

Advanced FAQs

1. How are bases used in cryptography? Bases, particularly binary and hexadecimal, are fundamental to the representation of data in cryptographic algorithms, including encryption and decryption processes. 2. What are the limitations of using different bases? The challenges associated with representing fractional or irrational numbers in different bases and potential issues with overflow. 3. *How does the choice of base impact computational complexity?* Specific base choices can significantly impact the efficiency of calculations and algorithm design. 4. **Are there bases beyond 16 commonly used?** Bases greater than 16 have less widespread use but can emerge in theoretical or specialized contexts. 5. **How does the concept of bases relate to abstract algebra?** The concept of a base forms a basis for developing more advanced algebraic structures. This exploration into the fascinating world of bases provides a foundational understanding that stretches far beyond basic number representation. By grasping the core concepts, we gain a deeper appreciation for the elegance and power of mathematics and its practical applications.

What Are Bases in Math?

Unlocking the Secrets of Number Systems

Ever wondered how numbers actually *work*? We use them every single day, from counting our change to calculating our deepest fears (or maybe just our grocery bill). But have you ever stopped to think about the system we use to represent all those quantities? That system, my friends, is all about **bases in math**. It's a concept that might sound a little intimidating at first, but once you crack it, a whole new world of mathematical understanding opens up. So, what exactly are bases in math? At its core, a base is simply the **radix** of a **positional numeral system**. Don't let those fancy words scare you! We'll break them down. Think of it as the number of unique digits (or symbols) used in that particular number system. This, in turn, dictates how we represent quantities. ## The Familiar Friend: Base-10 (The Decimal System) We're all intimately familiar with the base we use every day: **base-10**, also known as the **decimal system**. Why is it called base-10? Because it uses ten unique digits: 0, 1, 2, 3, 4, 5, 6, 7, 8, and 9. Let's take a number like 345. In base-10, this number isn't just three, four, and five crammed together. It's a carefully constructed representation of a quantity based on powers of 10. Here's how it breaks down: * The rightmost digit (5) is in the "ones" place, which is 10^0 . * The next digit to the left (4) is in the "tens" place, which is 10^1 . * The leftmost digit (3) is in the "hundreds" place, which is 10^2 . So, 345 in base-10 is actually $(3 * 10^2) + (4 * 10^1) + (5 * 10^0) = (3 * 100) + (4 * 10) + (5 * 1) = 300 + 40 + 5 = 345$. See? It all adds up! This concept of **place value** is absolutely crucial to understanding bases. Each position a digit occupies has a specific weight, determined by the base raised to a power corresponding to that position. ### Why Base-10? A Historical Perspective You might be wondering, "Why ten?" The most widely accepted theory points to our ten fingers. For millennia, humans have used their fingers for

counting, making a base-10 system a natural and intuitive choice. This has led to the widespread adoption of the decimal system across the globe. ## Beyond Ten: Exploring Other Number Systems While base-10 is our daily driver, math isn't confined to just ten digits. In fact, other bases are incredibly important in various fields, especially in computer science and advanced mathematics. Let's dive into some of these: ### Base-2: The Language of Computers (Binary) Perhaps the most significant base outside of our everyday experience is **base-2**, known as the **binary system**. This system uses only two unique digits: 0 and 1. This is the fundamental language of all digital computers. Why is binary so important for computers? Electronic circuits are built using switches that can be either on or off. These two states perfectly correspond to the digits 0 and 1. A "low voltage" can represent a 0, and a "high voltage" can represent a 1. By combining these simple on/off states, computers can represent and process incredibly complex information. Let's look at a binary number, say 1011. To convert this to base-10, we use the same principle of place value, but this time, the base is 2: * The rightmost digit (1) is in the 2^0 place (ones). * The next digit (1) is in the 2^1 place (twos). * The next digit (0) is in the 2^2 place (fours). * The leftmost digit (1) is in the 2^3 place (eights). So, 1011 in base-2 is $(1 * 2^3) + (0 * 2^2) + (1 * 2^1) + (1 * 2^0) = (1 * 8) + (0 * 4) + (1 * 2) + (1 * 1) = 8 + 0 + 2 + 1 = 11$ in base-10. This ability to convert between different bases is a cornerstone of computational thinking. Understanding **binary representation** is key to grasping how computers operate. ### Base-16: Hexadecimal - A Bridge Between Binary and Human Readability Another crucial base, especially in computing, is **base-16**, or **hexadecimal**. This system uses 16 unique symbols. For the numbers 0 through 9, we use the familiar digits. But what about the remaining six values? We use letters! So, the digits in hexadecimal are 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, B, C, D, E, and F. Here's how the letters correspond to decimal values: * A = 10 * B = 11 * C = 12 * D = 13 * E = 14 * F = 15 Hexadecimal is often used as a more human-readable way to represent long strings of binary numbers. Since 16 is 2^4 , each hexadecimal digit can represent exactly four binary digits (bits). This makes it much easier to work with and remember than long sequences

of 0s and 1s. Let's convert a hexadecimal number, say 3A5, to base-10: * The rightmost digit (5) is in the 16^0 place. * The next digit (A, which is 10 in base-10) is in the 16^1 place. * The leftmost digit (3) is in the 16^2 place. So, 3A5 in hexadecimal is $(3 * 16^2) + (10 * 16^1) + (5 * 16^0) = (3 * 256) + (10 * 16) + (5 * 1) = 768 + 160 + 5 = 933$ in base-10. ### Base-8: Octal - Another Computing Companion You might also encounter **base-8**, known as **octal**. This system uses eight digits: 0, 1, 2, 3, 4, 5, 6, and 7. Like hexadecimal, octal is related to binary, as 8 is 2^3 . This means each octal digit can represent exactly three binary digits. While less common than hexadecimal today, it was historically significant in early computing. Let's convert an octal number, say 723, to base-10: * The rightmost digit (3) is in the 8^0 place. * The next digit (2) is in the 8^1 place. * The leftmost digit (7) is in the 8^2 place. So, 723 in octal is $(7 * 8^2) + (2 * 8^1) + (3 * 8^0) = (7 * 64) + (2 * 8) + (3 * 1) = 448 + 16 + 3 = 467$ in base-10. ## Understanding the "Why": Practical Applications of Bases So, why do we bother with all these different number bases? ### 1. Computer Science and Digital Systems As we've seen, binary, octal, and hexadecimal are fundamental to how computers store and process information. Understanding these bases allows programmers and computer scientists to: * **Represent data efficiently:** Binary is the most basic form, but hexadecimal and octal offer more compact representations for certain data types. * **Debug code:** Understanding memory addresses and data formats, often displayed in hexadecimal, is crucial for debugging. * **Design hardware:** Logic gates and circuits operate on binary principles. ### 2. Advanced Mathematics and Cryptography In higher-level mathematics, different bases can simplify certain calculations or provide alternative perspectives on mathematical concepts. In **cryptography**, the science of secure communication, number systems and their properties are absolutely essential. Complex algorithms rely on number theory and operations within specific bases to encrypt and decrypt messages. ### 3. Historical and Cultural Significance The choice of base can also reflect historical and cultural influences. The Babylonian civilization, for instance, used a base-60 system (sexagesimal), which is why we still have 60 seconds in a minute and 60 minutes in an

hour. This demonstrates how different number systems have shaped our understanding of time and measurement.

Converting Between Bases: A Skill to Master

The ability to convert numbers from one base to another is a vital skill for anyone delving deeper into mathematics or computer science. There are systematic methods for performing these conversions:

Converting from Any Base to Base-10

We've already demonstrated this extensively. The process involves using the place value of each digit and summing the products of the digit and the base raised to the power of its position.

Converting from Base-10 to Any Base

To convert a base-10 number to another base, you repeatedly divide the base-10 number by the target base and record the remainders. The remainders, read from bottom to top, form the representation in the new base. Let's convert 42 (base-10) to binary (base-2):

1. $42 \div 2 = 21$ remainder **0**
2. $21 \div 2 = 10$ remainder **1**
3. $10 \div 2 = 5$ remainder **0**
4. $5 \div 2 = 2$ remainder **1**
5. $2 \div 2 = 1$ remainder **0**
6. $1 \div 2 = 0$ remainder **1**

Reading the remainders from bottom to top, we get 101010. So, 42 in base-10 is 101010 in base-2.

The Foundation of Numbers

In essence, **bases in math** are the fundamental building blocks of how we represent and understand numerical quantities. The base defines the "vocabulary" of a numeral system – the unique symbols it uses and the rules for combining them based on place value. While base-10 is our everyday standard, exploring other bases like binary, hexadecimal, and octal unlocks crucial understanding in computer science, mathematics, and beyond. Mastering the concept of bases empowers you to not only work with numbers more effectively but also to appreciate the underlying elegance and universality of mathematical principles. So, the next time you see a string of 0s and 1s or a hexadecimal code, you'll know you're looking at a different, but equally valid, way of expressing the vast world of numbers.

Understanding Bases in Mathematics: A Foundational Concept

Mathematics is built on a web of foundational ideas, and among the most essential is the concept of a base. At its core, a base refers to the number system's fundamental building block—the value upon which a given numerical representation is constructed. While many students first encounter bases in the context of base-10 arithmetic—the familiar decimal system used daily—this concept extends far beyond simple counting and permeates diverse areas of mathematics, science, and technology.

The Role of Base in Number Systems

A base determines the number of unique digits, or symbols, required to represent numbers within a given numerical system. For example, the base-10 system relies on ten distinct digits—0 through 9—each representing a power of ten in positional notation. This means any number in base-10 can be decomposed into sums of multiples of 10 raised to varying exponents, such as $345 = 3 \times 10^2 + 4 \times 10^1 + 5 \times 10^0$. Similarly, base-2, or binary, uses only two digits—0 and 1—forming the backbone of digital computing, where each digit represents an increasing power of two. Other bases, such as base-8 (octal) and base-16 (hexadecimal), serve specialized roles in simplifying complex binary data into more human-readable forms.

Understanding bases allows mathematicians and computer scientists to translate between representations seamlessly, enabling efficient data storage, error detection, and processing in modern technology. It also reveals deep patterns in how numbers scale and organize, offering insight into the structure of mathematical systems across disciplines.

Applications Across Science and Technology

Beyond number representation, the concept of base plays a crucial role in various scientific and engineering domains. In computer science, binary bases underpin all digital logic and programming, while hexadecimal bases simplify the expression of binary-coded instructions and memory addresses. In physics and engineering, different bases help model periodic phenomena, signal processing, and complex numerical computations through Fourier transforms and modular arithmetic—both deeply rooted in base-related concepts.

Even in everyday life, bases appear implicitly. Timekeeping, for instance, uses base-60 in degrees and minutes, a legacy from ancient Mesopotamian mathematics, demonstrating how historical bases continue to influence modern measurement systems. By recognizing and leveraging these foundational bases, professionals across fields enhance accuracy, optimize performance, and innovate new solutions.

Benefits of Mastering Bases

Grasping the concept of bases cultivates a deeper numerical intuition and flexibility. It empowers learners to switch effortlessly between representations, decode encrypted data, and solve complex equations by breaking them into simpler, base-specific components. In education, this foundational knowledge strengthens problem-solving skills and supports advanced topics like algebra, calculus, and discrete mathematics.

Moreover, understanding bases fosters computational thinking—essential in algorithm design and data science—by clarifying how numbers scale and interact in different contexts. This awareness supports innovation in fields ranging from cryptography to machine learning, where base transformations enable efficient encoding, compression, and analysis of

vast datasets.

The Future of Bases in Mathematics and Beyond

As technology evolves, the significance of bases continues to grow. Quantum computing, for instance, explores higher-dimensional and non-integer bases to represent qubits in superposition, expanding the classical framework of positional notation. Meanwhile, advances in artificial intelligence rely on base-efficient algorithms to process and interpret data with unprecedented speed and precision.

Educational approaches are also adapting, emphasizing conceptual understanding over rote memorization to prepare future generations for a world where mathematical fluency in diverse bases drives innovation. By embracing the rich, dynamic nature of bases, we unlock new pathways in science, engineering, and beyond—proving that even the most fundamental concepts remain vital in shaping tomorrow's discoveries.

Demystifying Mathematical Bases: The Unseen Language of Numbers

In the realm of mathematics, numbers are our fundamental building blocks. We interact with them daily, from counting our change to understanding complex scientific data. But have you ever stopped to consider *how* we represent these numbers? The familiar decimal system, with its ten digits (0-9), is so deeply ingrained in our thinking that we often take it for granted. Yet, this is just one of many ways to express numerical values. This article delves into the fascinating concept of mathematical bases, exploring what they are, how they work, and their profound implications

across various fields.

Understanding the Concept of a Base

At its core, a **base** in mathematics refers to the radix or the number of unique digits (or symbols) used to represent numbers in a positional numeral system. Think of it as the engine that drives our counting system. In a positional system, the value of a digit depends not only on the digit itself but also on its position within the number. This is a crucial distinction from non-positional systems, like Roman numerals, where the value of a symbol remains constant regardless of its placement.

The most common base we encounter is **base-10**, also known as the decimal system. This system utilizes ten distinct digits: 0, 1, 2, 3, 4, 5, 6, 7, 8, and 9. Each position in a base-10 number represents a power of 10. For instance, in the number 345:

1. The '5' is in the units place (10^0), representing $5 * 1 = 5$.
2. The '4' is in the tens place (10^1), representing $4 * 10 = 40$.
3. The '3' is in the hundreds place (10^2), representing $3 * 100 = 300$.

Summing these values ($300 + 40 + 5$) gives us the total value of the number, 345.

Exploring Different Number Systems

While base-10 is ubiquitous in everyday life, other bases are fundamental to computing and various scientific disciplines. Let's explore some of the most prominent ones:

Base-2: The Binary System

Perhaps the most important base in modern technology is **base-2**, or the binary system. This system uses only two digits: 0 and 1. These digits are often referred to as "bits" (binary digits). In binary, each position represents

a power of 2. Consider the binary number 1011:

1. The rightmost '1' is in the 2^0 place (1), representing $1 * 1 = 1$.
2. The next '1' is in the 2^1 place (2), representing $1 * 2 = 2$.
3. The '0' is in the 2^2 place (4), representing $0 * 4 = 0$.
4. The leftmost '1' is in the 2^3 place (8), representing $1 * 8 = 8$.

Adding these values ($1 + 2 + 0 + 8$) gives us the decimal equivalent of 11. The simplicity of binary, with its two states (on/off, true/false), makes it perfectly suited for electronic circuits and the underlying logic of computers. Every piece of information processed by a computer, from text and images to software instructions, is ultimately represented in binary.

Base-8: The Octal System

The **octal system**, or **base-8**, uses eight digits: 0, 1, 2, 3, 4, 5, 6, and 7. Similar to other positional systems, each position represents a power of 8. While less common today than binary or hexadecimal, octal was historically used in some computing applications, particularly with older mainframe computers. It offers a more compact representation of binary numbers, as three binary digits can be represented by a single octal digit (e.g., 111 in binary is 7 in octal, 010 in binary is 2 in octal).

Base-16: The Hexadecimal System

The **hexadecimal system**, or **base-16**, is widely used in computer science and programming. It employs sixteen unique symbols: 0-9 and the letters A-F, where A represents 10, B represents 11, C represents 12, D represents 13, E represents 14, and F represents 15. Each position in a hexadecimal number represents a power of 16. Hexadecimal is highly favored because it provides an even more concise representation of binary data than octal. For example, four binary digits can be represented by a single hexadecimal digit (e.g., 1111 in binary is F in hexadecimal, 0100 in binary is 4 in hexadecimal). This makes it easier for programmers to read and write memory addresses, color codes (like in web design, e.g., #FFFFFF for

white), and data dumps.

The Mechanics of Conversion Between Bases

The ability to convert numbers between different bases is a fundamental skill when working with them. The process relies on understanding the place values associated with each base.

Converting from Any Base to Base-10

To convert a number from any base (let's call it base 'b') to base-10, you multiply each digit by the base raised to the power of its position (starting from 0 on the rightmost digit) and then sum the results.

Example: Convert 1101_2 (binary) to base-10:

$$(1 * 2^3) + (1 * 2^2) + (0 * 2^1) + (1 * 2^0) = (1 * 8) + (1 * 4) + (0 * 2) + (1 * 1) = 8 + 4 + 0 + 1 = 13_{10}$$

Example: Convert $3A5_{16}$ (hexadecimal) to base-10:

$$(3 * 16^2) + (10 * 16^1) + (5 * 16^0) = (3 * 256) + (10 * 16) + (5 * 1) = 768 + 160 + 5 = 933_{10}$$

Converting from Base-10 to Any Base

To convert a number from base-10 to another base, you repeatedly divide the base-10 number by the target base and record the remainders. The remainders, read from bottom to top, form the number in the new base.

Example: Convert 25_{10} to base-2 (binary):

1. $25 \div 2 = 12$ remainder 1
2. $12 \div 2 = 6$ remainder 0
3. $6 \div 2 = 3$ remainder 0
4. $3 \div 2 = 1$ remainder 1

5. $1 \div 2 = 0$ remainder 1

Reading the remainders from bottom to top: 11001_2 .

Example: Convert 150_{10} to base-16 (hexadecimal):

1. $150 \div 16 = 9$ remainder 6

2. $9 \div 16 = 0$ remainder 9

Reading the remainders from bottom to top: 96_{16} .

Why Are Mathematical Bases Important?

The concept of bases extends far beyond theoretical mathematical exercises. Its practical applications are vast and indispensable:

Computer Science and Digital Systems

As highlighted, binary (base-2) is the foundational language of computers. Understanding binary is crucial for comprehending how data is stored, processed, and transmitted. Hexadecimal (base-16) serves as a human-readable shorthand for binary, simplifying tasks like debugging and memory management. Octal (base-8) also plays a role, though its prominence has diminished.

Data Representation and Encoding

Different bases are used to represent various types of data efficiently. For instance, in web development, hexadecimal is used to define colors. In older communication systems, octal was sometimes used for data transmission.

Cryptography and Security

Advanced mathematical concepts, including number theory and modular arithmetic (which inherently involve bases), are critical in modern encryption algorithms. Understanding how numbers are represented and

manipulated in different bases can be a component of secure systems.

Scientific and Engineering Applications

While base-10 remains dominant in general scientific notation, specific scientific and engineering fields might utilize other bases for specialized calculations or data representation. For example, in some signal processing applications, the underlying mathematical principles might implicitly involve bases other than ten.

Understanding Number Theory

Exploring different bases provides a deeper understanding of the fundamental properties of numbers themselves. It reveals how our familiar decimal system is just one arbitrary choice among many possibilities, highlighting the elegance and flexibility of mathematical structures.

Conclusion: The Ubiquitous Nature of Bases

Mathematical bases are the silent architects of our numerical world. From the intricate workings of a computer to the fundamental understanding of how we quantify information, the concept of a base is pervasive. While the decimal system serves our daily needs, recognizing and understanding other bases like binary and hexadecimal unlocks a deeper appreciation for the logic that underpins modern technology and scientific advancement. By demystifying these numerical systems, we gain a more profound insight into the language of mathematics and its indispensable role in shaping our understanding of the universe.

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Questions & Answers About what are

bases in math

No	Question	Answer
1	What's the simplest way to think about 'bases' in math?	Think of a base as the number of unique digits you have available to count with in a number system. For example, our everyday system (base-10) uses digits 0 through 9 (10 unique digits).
2	Why is base-10 so common? Is there a reason it's called 'decimal'?	Base-10 is common because humans have ten fingers! 'Decimal' comes from the Latin word 'decem,' meaning ten.
3	Are there other number systems besides base-10? What are some examples?	Absolutely! Binary (base-2) is crucial for computers, using only 0s and 1s. Octal (base-8) uses digits 0-7, and hexadecimal (base-16) uses digits 0-9 and letters A-F.
4	How do you actually *read* or understand a number in a different base, like binary?	You read it by understanding place value. In base-2, each position represents a power of 2 (... , 8, 4, 2, 1). So, 101 in binary means $(1 * 4) + (0 * 2) + (1 * 1) = 5$ in base-10.
5	Where do we encounter bases other than base-10 in everyday life or technology?	Binary (base-2) is fundamental to all digital technology. Hexadecimal (base-16) is often used in computer programming for representing memory addresses and colors (like #FFFFFF for white).
6	What's the main benefit of using different bases in math and computer science?	Different bases offer efficiency and specific functionalities. Binary is simple for computers to process electronically, while hexadecimal is more compact for humans to read than long binary strings.

7	How do you convert a number from base-10 to another base?	You typically use repeated division. Divide the base-10 number by your target base, record the remainder, and then divide the quotient by the target base. Repeat until the quotient is zero. The remainders, read from bottom to top, form the new number in the target base.
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