Decimal Numbers: Base 10

Digits: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9

Example:

\[ 3271 = (3 \times 10^3) + (2 \times 10^2) + (7 \times 10^1) + (1 \times 10^0) \]

Numbers: positional notation

- Number Base B \(\Rightarrow\) B symbols per digit:
  - Base 10 (Decimal): 0, 1, 2, 3, 4, 5, 6, 7, 8, 9
  - Base 2 (Binary): 0, 1

- Number representation:
  - \(d_3d_2d_1d_0\) is a 32 digit number
  - value = \(d_3 \times B^3 + d_2 \times B^2 + d_1 \times B^1 + d_0 \times B^0\)

  \[ \text{Binary: } 01 \] (In binary digits called “bits”)

  \[ \text{often written} = 26 \]

  \[ \text{Here 5 digit binary # turns into a 2 digit decimal #} \]

  \[ \text{Can we find a base that converts to binary easily?} \]

Hexadecimal Numbers: Base 16

- Hexadecimal:
  - 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, B, C, D, E, F
- Normal digits + 6 more from the alphabet
- In C, written as 0x... (e.g., 0xFA5B)

- Conversion: Binary \(\Rightarrow\) Hex
  - 1 hex digit represents 16 decimal values
  - 4 binary digits represent 16 decimal values
  - 1 hex digit replaces 4 binary digits

- One hex digit is a “nibble”. Two is a “byte”

Example:

\[ \text{1011 1000 0011 (binary) = 0xA9} \]

Hexadecimal vs. Hexadecimal vs. Binary

Examples:

- 00 0 0000
- 01 1 0001
- 02 2 0010
- 03 3 0011
- 04 4 0100
- 05 5 0101
- 06 6 0110
- 07 7 0111
- 08 8 1000
- 09 9 1001
- 0A A 1010
- 0B B 1011
- 0C C 1100
- 0D D 1101
- 0E E 1110
- 0F F 1111

How do we convert between hex and Decimal?

**MEMORIZE!**

Kilo, Mega, Giga, Tera, Peta, Exa, Zetta, Yotta

[kilobyte](https://physics.nist.gov/cuu/Units/binary.html)

- Common use prefixes (all SI, except K (= k in SI))

<table>
<thead>
<tr>
<th>Prefix</th>
<th>Symbol</th>
<th>Exponent</th>
<th>Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kilo</td>
<td>k</td>
<td>2^10</td>
<td>1,024</td>
</tr>
<tr>
<td>Mega</td>
<td>M</td>
<td>2^20</td>
<td>1,000,000</td>
</tr>
<tr>
<td>Giga</td>
<td>G</td>
<td>2^30</td>
<td>1,000,000,000</td>
</tr>
<tr>
<td>Tera</td>
<td>T</td>
<td>2^40</td>
<td>1,000,000,000,000</td>
</tr>
<tr>
<td>Peta</td>
<td>P</td>
<td>2^50</td>
<td>1,000,000,000,000,000</td>
</tr>
<tr>
<td>Exa</td>
<td>E</td>
<td>2^60</td>
<td>1,000,000,000,000,000,000</td>
</tr>
<tr>
<td>Zetta</td>
<td>Z</td>
<td>2^70</td>
<td>1,000,000,000,000,000,000,000</td>
</tr>
<tr>
<td>Yotta</td>
<td>Y</td>
<td>2^80</td>
<td>1,000,000,000,000,000,000,000,000</td>
</tr>
</tbody>
</table>

- Confusing! Common usage of “kilobyte” means 1024 bytes, but the “correct” SI value is 1000 bytes

- Hard Disk manufacturers & Telecommunications are the only computing groups that use SI factors, so what is advertised as a 30 GB drive will actually only hold about 28 x 2^30 bytes, and a 1 Mbit/s connection transfers 10^6 bps.

[kibibyte](https://en.wikipedia.org/wiki/Binary_prefix)

- New IEC Standard Prefixes [only to exbi officially]

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</thead>
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<tr>
<td>kibi</td>
<td>Ki</td>
<td>2^10</td>
<td>1,024</td>
</tr>
<tr>
<td>mebi</td>
<td>Mi</td>
<td>2^20</td>
<td>1,000,000</td>
</tr>
<tr>
<td>gibi</td>
<td>Gi</td>
<td>2^30</td>
<td>1,000,000,000</td>
</tr>
<tr>
<td>tebi</td>
<td>Ti</td>
<td>2^40</td>
<td>1,000,000,000,000</td>
</tr>
<tr>
<td>pebi</td>
<td>Pi</td>
<td>2^50</td>
<td>1,000,000,000,000,000</td>
</tr>
<tr>
<td>ebi</td>
<td>Ei</td>
<td>2^60</td>
<td>1,000,000,000,000,000,000</td>
</tr>
<tr>
<td>zebi</td>
<td>Zi</td>
<td>2^70</td>
<td>1,000,000,000,000,000,000,000</td>
</tr>
<tr>
<td>yobi</td>
<td>Yi</td>
<td>2^80</td>
<td>1,000,000,000,000,000,000,000,000</td>
</tr>
</tbody>
</table>

As of this writing, this proposal has yet to gain widespread use...

- International Electrotechnical Commission (IEC) in 1999 introduced these to specify binary quantities.
- Names come from shortened versions of the original SI prefixes (same pronunciation) and bi is short for “binary”, but pronounced “bee” :-(
- Now SI prefixes only have their base-10 meaning and never have a base-2 meaning.
MEMORIZE!

What is \(2^{34}\)? How many bits addresses (i.e., what's \(\log_2\) Tog = Tog of 2.5 TIB?)

The way to remember #s

\[ \begin{align*}
X &= 10_{24} \quad y = 8 \quad \text{yobi} \quad \text{~10^{24}} \\
X &= 10_{21} \quad y = 7 \quad \text{zeti} \quad \text{~10^{21}} \\
X &= 10_{18} \quad y = 6 \quad \text{ebi} \quad \text{~10^{18}} \\
X &= 10_{15} \quad y = 5 \quad \text{pebi} \quad \text{~10^{15}} \\
X &= 10_{12} \quad y = 4 \quad \text{tebi} \quad \text{~10^{12}} \\
X &= 10_{09} \quad y = 3 \quad \text{gibi} \quad \text{~10^{09}} \\
X &= 10_{06} \quad y = 2 \quad \text{mebi} \quad \text{~10^{06}} \\
X &= 10_{03} \quad y = 1 \quad \text{ki} \quad \text{~10^{03}} \\
X &= \_0 \quad y = 0 \quad -- \\
\end{align*} \]