The Unicode Standard / the Unicode Consortium ; edited by Julie D. Allen ... [et al.]. — Version 5.2.
Includes bibliographical references and index.
ISBN 978-1-936213-00-9 (http://www.unicode.org/versions/Unicode5.2.0/)
1. Unicode (Computer character set) I. Allen, Julie D.
II. Unicode Consortium.
QA268.U545 2009

ISBN 978-1-936213-00-9
Published in Mountain View, CA
December 2009

Chapter 15

Symbols

The universe of symbols is rich and open-ended. The collection of encoded symbols in the Unicode Standard encompasses the following:

- *Currency symbols*
- *Letterlike symbols*
- *Mathematical alphabets*
- *Number forms*
- *Mathematical symbols*
- *Invisible mathematical operators*
- *Technical symbols*
- *Geometrical symbols*
- *Miscellaneous symbols and dingbats*
- *Enclosed and square symbols*
- *Braille patterns*
- *Western and Byzantine musical symbols*
- *Ancient Greek musical notation*

There are other notational systems not covered by the Unicode Standard. Some symbols mark the transition between pictorial items and text elements; because they do not have a well-defined place in plain text, they are not encoded here.

Combining marks may be used with symbols, particularly the set encoded at U+20D0.. U+20FF (see *Section 7.9, Combining Marks*).

Letterlike and currency symbols, as well as number forms including superscripts and subscripts, are typically subject to the same font and style changes as the surrounding text. Where square and enclosed symbols occur in East Asian contexts, they generally follow the prevailing type styles.

Other symbols have an appearance that is independent of type style, or a more limited or altogether different range of type style variation than the regular text surrounding them. For example, mathematical alphanumeric symbols are typically used for mathematical variables; those letterlike symbols that are part of this set carry semantic information in their type style. This fact restricts—but does not completely eliminate—possible style variations. However, symbols such as mathematical operators can be used with any script or independent of any script.

Special invisible operator characters can be used to explicitly encode some mathematical operations, such as multiplication, which are normally implied by juxtaposition. This aids in automatic interpretation of mathematical notation.

In a bidirectional context (see Unicode Standard Annex #9, "Unicode Bidirectional Algorithm"), most symbol characters have no inherent directionality but resolve their directionality for display according to the Unicode Bidirectional Algorithm. For some symbols, such as brackets and mathematical operators whose image is not bilaterally symmetric, the mirror image is used when the character is part of the right-to-left text stream (see *Section 4.7, Bidi Mirrored—Normative*).

Dingbats and optical character recognition characters are different from all other characters in the standard, in that they are encoded based primarily on their precise appearance.

Braille patterns are a special case, because they can be used to write text. They are included as symbols, as the Unicode Standard encodes only their shapes; the association of letters to patterns is left to other standards. When a character stream is intended primarily to convey text information, it should be coded using one of the scripts. Only when it is intended to convey a particular binding of text to Braille pattern sequence should it be coded using the Braille patterns.

Musical notation—particularly Western musical notation—is different from ordinary text in the way it is laid out, especially the representation of pitch and duration in Western musical notation. However, ordinary text commonly refers to the basic graphical elements that are used in musical notation, and it is primarily those symbols that are encoded in the Unicode Standard. Additional sets of symbols are encoded to support historical systems of musical notation.

Many symbols encoded in the Unicode Standard are intended to support legacy implementations and obsolescent practices, such as terminal emulation or other character mode user interfaces. Examples include box drawing components and control pictures.

Many of the symbols encoded in Unicode can be used as operators or given some other syntactical function in a formal language syntax. For more information, see Unicode Standard Annex #31, "Unicode Identifier and Pattern Syntax."

15.1 Currency Symbols

Currency symbols are intended to encode the customary symbolic signs used to indicate certain currencies in general text. These signs vary in shape and are often used for more than one currency. Not all currencies are represented by a special currency symbol; some use multiple-letter strings instead, such as "Sfr" for Swiss franc. Moreover, the abbreviations for currencies can vary by language. The Unicode Common Locale Data Repository (CLDR) provides further information; see *Section B.6, Other Unicode Online Resources*. Therefore, implementations that are concerned with the *exact* identity of a currency should not depend on an encoded currency sign character. Instead, they should follow standards such as the ISO 4217 three-letter currency codes, which are *specific* to currencies—for example, USD for U.S. dollar, CAD for Canadian dollar.

Unification. The Unicode Standard does not duplicate encodings where more than one currency is expressed with the same symbol. Many currency symbols are overstruck letters. There are therefore many minor variants, such as the U+0024 DOLLAR SIGN $, with one or two vertical bars, or other graphical variation, as shown in *Figure 15-1*.

Figure 15-1. Alternative Glyphs for Dollar Sign

Claims that glyph variants of a certain currency symbol are used consistently to indicate a particular currency could not be substantiated upon further research. Therefore, the Unicode Standard considers these variants to be typographical and provides a single encoding for them. See ISO/IEC 10367, Annex B (informative), for an example of multiple renderings for U+00A3 POUND SIGN.

Fonts. Currency symbols are commonly designed to display at the same width as a digit (most often a European digit, U+0030..U+0039) to assist in alignment of monetary values in tabular displays. Like letters, they tend to follow the stylistic design features of particular fonts because they are used often and need to harmonize with body text. In particular, even

though there may be more or less normative designs for the currency sign per se, as for the euro sign, type designers freely adapt such designs to make them fit the logic of the rest of their fonts. This partly explains why currency signs show more glyph variation than other types of symbols.

Currency Symbols: U+20A0–U+20CF

This block contains currency symbols that are not encoded in other blocks. Contemporary and historic currency symbols encoded in other blocks are listed in *Table 15-1*.

Table 15-1. Currency Symbols Encoded in Other Blocks

Currency	Unicode Code Point	
Dollar, milreis, escudo, peso	U+0024	DOLLAR SIGN
Cent	U+00A2	CENT SIGN
Pound and lira	U+00A3	POUND SIGN
General currency	U+00A4	CURRENCY SIGN
Yen or yuan	U+00A5	YEN SIGN
Dutch florin	U+0192	LATIN SMALL LETTER F WITH HOOK
Afghani	U+060B	AFGHANI SIGN
Rupee	U+09F2	BENGALI RUPEE MARK
Rupee	U+09F3	BENGALI RUPEE SIGN
Ana (historic)	U+09F9	BENGALI CURRENCY DENOMINATOR SIXTEEN
Ganda (historic)	U+09FB	BENGALI GANDA MARK
Rupee	U+0AF1	GUJARATI RUPEE SIGN
Rupee	U+0BF9	TAMIL RUPEE SIGN
Baht	U+0E3F	THAI CURRENCY SYMBOL BAHT
Riel	U+17DB	KHMER CURRENCY SYMBOL RIEL
German mark (historic)	U+2133	SCRIPT CAPITAL M
Yuan, yen, won, HKD	U+5143	CJK UNIFIED IDEOGRAPH-5143
Yen	U+5186	CJK UNIFIED IDEOGRAPH-5186
Yuan	U+5706	CJK UNIFIED IDEOGRAPH-5706
Yuan, yen, won, HKD, NTD	U+5713	CJK UNIFIED IDEOGRAPH-5713
Rupee	U+A838	NORTH INDIC RUPEE MARK
Rial	U+FDFC	RIAL SIGN

Lira Sign. A separate currency sign U+20A4 LIRA SIGN is encoded for compatibility with the HP Roman-8 character set, which is still widely implemented in printers. In general, U+00A3 POUND SIGN should be used for both the various currencies known as pound (or punt) and the various currencies known as lira—for example, the former currency of Italy and the lira still in use in Turkey. Widespread implementation practice in Italian and Turkish systems has long made use of U+00A3 as the currency sign for the lira. As in the case of the dollar sign, the glyphic distinction between single- and double-bar versions of the sign is not indicative of a systematic difference in the currency.

Yen and Yuan. Like the dollar sign and the pound sign, U+00A5 YEN SIGN has been used as the currency sign for more than one currency. While there may be some preferences to use a double-bar glyph for the yen currency of Japan (JPY) and a single-bar glyph for the yuan (renminbi) currency of China (CNY), this distinction is not systematic in all font designs, and there is considerable overlap in usage. As listed in *Table 15-1*, there are also a number of CJK ideographs to represent the words *yen* (or *en*) and *yuan*, as well as the Korean word *won,* and these also tend to overlap in use as currency symbols. In the Unicode Standard, U+00A5 YEN SIGN is intended to be the character for the currency sign for both the yen and the yuan, with details of glyphic presentation left to font choice and local preferences.

Euro Sign. The single currency for member countries of the European Economic and Monetary Union is the euro (EUR). The euro character is encoded in the Unicode Standard as U+20AC EURO SIGN.

For additional forms of currency symbols, see Fullwidth Forms (U+FFE0..U+FFE6). Ancient Roman coin symbols, for such coins and values as the *denarius* and *as*, are encoded in the Ancient Symbols block (U+10190..U+101CF).

15.2 Letterlike Symbols

Letterlike Symbols: U+2100–U+214F

Letterlike symbols are symbols derived in some way from ordinary letters of an alphabetic script. This block includes symbols based on Latin, Greek, and Hebrew letters. Stylistic variations of single letters are used for semantics in mathematical notation. See "Mathematical Alphanumeric Symbols" in this section for the use of letterlike symbols in mathematical formulas. Some letterforms have given rise to specialized symbols, such as U+211E PRESCRIPTION TAKE.

Numero Sign. U+2116 NUMERO SIGN is provided both for Cyrillic use, where it looks like №, and for compatibility with Asian standards, where it looks like №. *Figure 15-2* illustrates a number of alternative glyphs for this sign. Instead of using a special symbol, French practice is to use an "N" or an "n", according to context, followed by a superscript small letter "o" (N^{o} or n^{o}; plural N^{os} or n^{os}). Legacy data encoded in ISO/IEC 8859-1 (Latin-1) or other 8-bit character sets may also have represented the *numero sign* by a sequence of "N" followed by the *degree sign* (U+00B0 DEGREE SIGN). Implementations interworking with legacy data should be aware of such alternative representations for the *numero sign* when converting data.

Figure 15-2. Alternative Glyphs for Numero Sign

№ Nº No. №

Unit Symbols. Several letterlike symbols are used to indicate units. In most cases, however, such as for SI units (Système International), the use of regular letters or other symbols is preferred. U+2113 SCRIPT SMALL L is commonly used as a non-SI symbol for the *liter*. Official SI usage prefers the regular *lowercase letter l*.

Three letterlike symbols have been given canonical equivalence to regular letters: U+2126 OHM SIGN, U+212A KELVIN SIGN, and U+212B ANGSTROM SIGN. In all three instances, the regular letter should be used. If text is normalized according to Unicode Standard Annex #15, "Unicode Normalization Forms," these three characters will be replaced by their regular equivalents.

In normal use, it is better to represent degrees Celsius "°C" with a sequence of U+00B0 DEGREE SIGN + U+0043 LATIN CAPITAL LETTER C, rather than U+2103 DEGREE CELSIUS. For searching, treat these two sequences as identical. Similarly, the sequence U+00B0 DEGREE SIGN + U+0046 LATIN CAPITAL LETTER F is preferred over U+2109 DEGREE FAHRENHEIT, and those two sequences should be treated as identical for searching.

Compatibility. Some symbols are composites of several letters. Many of these composite symbols are encoded for compatibility with Asian and other legacy encodings. (See also "CJK Compatibility Ideographs" in *Section 12.1, Han*.) The use of these composite symbols is discouraged where their presence is not required by compatibility. For example, in normal use, the symbols U+2121 TEL TELEPHONE SIGN and U+213B FAX FACSIMILE SIGN are simply spelled out.

In the context of East Asian typography, many letterlike symbols, and in particular composites, form part of a collection of compatibility symbols, the larger part of which is located in the CJK Compatibility block (see *Section 15.9, Enclosed and Square*). When used in this way, these symbols are rendered as "wide" characters occupying a full cell. They remain upright in vertical layout, contrary to the rotated rendering of their regular letter equivalents. See Unicode Standard Annex #11, "East Asian Width," for more information.

Where the letterlike symbols have alphabetic equivalents, they collate in alphabetic sequence; otherwise, they should be treated as neutral symbols. The letterlike symbols may have different directional properties than normal letters. For example, the four transfinite cardinal symbols (U+2135..U+2138) are used in ordinary mathematical text and do not share the strong right-to-left directionality of the Hebrew letters from which they are derived.

Styles. The letterlike symbols include some of the few instances in which the Unicode Standard encodes stylistic variants of letters as distinct characters. For example, there are instances of blackletter (*Fraktur*), double-struck, italic, and script styles for certain Latin letters used as mathematical symbols. The choice of these stylistic variants for encoding reflects their common use as distinct symbols. They form part of the larger set of mathematical alphanumeric symbols. For the complete set and more information on its use, see "Mathematical Alphanumeric Symbols" in this section. These symbols should not be used in ordinary, nonscientific texts.

Despite its name, U+2118 SCRIPT CAPITAL P is neither script nor capital—it is uniquely the Weierstrass elliptic function symbol derived from a calligraphic *lowercase* p. U+2113 SCRIPT SMALL L is derived from a special *italic* form of the *lowercase letter l* and, when it occurs in mathematical notation, is known as the symbol *ell*. Use U+1D4C1 MATHEMATICAL SCRIPT SMALL L as the *lowercase script l* for mathematical notation.

Standards. The Unicode Standard encodes letterlike symbols from many different national standards and corporate collections.

Mathematical Alphanumeric Symbols: U+1D400–U+1D7FF

The Mathematical Alphanumeric Symbols block contains a large extension of letterlike symbols used in mathematical notation, typically for variables. The characters in this block are intended for use only in mathematical or technical notation; they are not intended for use in nontechnical text. When used with markup languages—for example, with Mathematical Markup Language (MathML)—the characters are expected to be used directly, instead of indirectly via entity references or by composing them from base letters and style markup.

Words Used as Variables. In some specialties, whole words are used as variables, not just single letters. For these cases, style markup is preferred because in ordinary mathematical notation the juxtaposition of variables generally implies multiplication, not word formation as in ordinary text. Markup not only provides the necessary scoping in these cases, but also allows the use of a more extended alphabet.

Mathematical Alphabets

Basic Set of Alphanumeric Characters. Mathematical notation uses a basic set of mathematical alphanumeric characters, which consists of the following:

- The set of basic Latin digits (0–9) (U+0030..U+0039)
- The set of basic uppercase and lowercase Latin letters (a– z, A–Z)

- The uppercase Greek letters A–Ω (U+0391..U+03A9), plus the nabla ∇ (U+2207) and the variant of theta ϴ given by U+03F4
- The lowercase Greek letters α–ω (U+03B1..U+03C9), plus the partial differential sign ∂ (U+2202), and the six glyph variants ϵ, ϑ, ϰ, ϕ, ϱ, and ϖ, given by U+03F5, U+03D1, U+03F0, U+03D5, U+03F1, and U+03D6, respectively

Only unaccented forms of the letters are used for mathematical notation, because general accents such as the acute accent would interfere with common mathematical diacritics. Examples of common mathematical diacritics that can interfere with general accents are the circumflex, macron, or the single or double dot above, the latter two of which are used in physics to denote derivatives with respect to the time variable. Mathematical symbols with diacritics are always represented by combining character sequences.

For some characters in the basic set of Greek characters, two variants of the same character are included. This is because they can appear in the same mathematical document with different meanings, even though they would have the same meaning in Greek text. (See "Variant Letterforms" in *Section 7.2, Greek*.)

Additional Characters. In addition to this basic set, mathematical notation uses the uppercase and lowercase digamma, in regular (U+03DC and U+03DD) and bold (U+1D7CA and U+1D7CB), and the four Hebrew-derived characters (U+2135..U+2138). Occasional uses of other alphabetic and numeric characters are known. Examples include U+0428 CYRILLIC CAPITAL LETTER SHA, U+306E HIRAGANA LETTER NO, and Eastern Arabic-Indic digits (U+06F0..U+06F9). However, these characters are used only in their basic forms, rather than in multiple mathematical styles.

Dotless Characters. In the Unicode Standard, the characters "i" and "j", including their variations in the mathematical alphabets, have the Soft_Dotted property. Any conformant renderer will remove the dot when the character is followed by a nonspacing combining mark above. Therefore, using an individual mathematical italic *i* or *j* with math accents would result in the intended display. However, in mathematical equations an entire subexpression can be placed underneath a math accent—for example, when a "wide hat" is placed on top of *i+j*, as shown in *Figure 15-3*.

Figure 15-3. Wide Mathematical Accents

$$\widehat{\imath+\jmath} = \hat{\imath} + \hat{\jmath}$$

In such a situation, a renderer can no longer rely simply on the presence of an adjacent combining character to substitute for the un-dotted glyph, and whether the dots should be removed in such a situation is no longer predictable. Authors differ in whether they expect the dotted or dotless forms in that case.

In some documents *mathematical italic dotless i* or *j* is used explicitly without any combining marks, or even in contrast to the dotted versions. Therefore, the Unicode Standard provides the explicitly dotless characters U+1D6A4 MATHEMATICAL ITALIC SMALL DOTLESS I and U+1D6A5 MATHEMATICAL ITALIC SMALL DOTLESS J. These two characters map to the ISOAMSO entities *imath* and *jmath* or the TEX macros *\imath* and *\jmath*. These entities are, by default, always italic. The appearance of these two characters in the code charts is similar to the shapes of the entities documented in the ISO 9573-13 entity sets and used by TEX. The mathematical dotless characters do not have case mappings.

Semantic Distinctions. Mathematical notation requires a number of Latin and Greek alphabets that initially appear to be mere font variations of one another. The letter H can appear as plain or upright (H), bold (**H**), italic (*H*), as well as script, Fraktur, and other

styles. However, in any given document, these characters have distinct, and usually unrelated, mathematical semantics. For example, a normal H represents a different variable from a bold **H**, and so on. If these attributes are dropped in plain text, the distinctions are lost and the meaning of the text is altered. Without the distinctions, the well-known Hamiltonian formula turns into the *integral* equation in the variable H as shown in *Figure 15-4*.

Figure 15-4. Style Variants and Semantic Distinctions in Mathematics

Hamiltonian formula: $\mathcal{H} = \int d\tau(\epsilon E^2 + \mu H^2)$

Integral equation: $\mathrm{H} = \int d\tau(\varepsilon \mathrm{E}^2 + \mu \mathrm{H}^2)$

Mathematicians will object that a properly formatted integral equation requires all the letters in this example (except for the "d") to be in italics. However, because the distinction between $\mathcal{H}$ and H has been lost, they would recognize it as a fallback representation of an integral equation, and not as a fallback representation of the Hamiltonian. By encoding a separate set of alphabets, it is possible to preserve such distinctions in plain text.

Mathematical Alphabets. The alphanumeric symbols encountered in mathematics and encoded in the Unicode Standard are given in *Table 15-2*.

Table 15-2. Mathematical Alphanumeric Symbols

Math Style	Characters from Basic Set	Location
plain (upright, serifed)	Latin, Greek, and digits	BMP
bold	Latin, Greek, and digits	Plane 1
italic	Latin and Greek	Plane 1
bold italic	Latin and Greek	Plane 1
script (calligraphic)	Latin	Plane 1
bold script (calligraphic)	Latin	Plane 1
Fraktur	Latin	Plane 1
bold Fraktur	Latin	Plane 1
double-struck	Latin and digits	Plane 1
sans-serif	Latin and digits	Plane 1
sans-serif bold	Latin, Greek, and digits	Plane 1
sans-serif italic	Latin	Plane 1
sans-serif bold italic	Latin and Greek	Plane 1
monospace	Latin and digits	Plane 1

The plain letters have been unified with the existing characters in the Basic Latin and Greek blocks. There are 24 double-struck, italic, Fraktur, and script characters that already exist in the Letterlike Symbols block (U+2100..U+214F). These are explicitly unified with the characters in this block, and corresponding holes have been left in the mathematical alphabets.

The alphabets in this block encode only semantic distinction, but not which specific font will be used to supply the actual plain, script, Fraktur, double-struck, sans-serif, or monospace glyphs. Especially the script and double-struck styles can show considerable variation across fonts. Characters from the Mathematical Alphanumeric Symbols block are not to be used for nonmathematical styled text.

Compatibility Decompositions. All mathematical alphanumeric symbols have compatibility decompositions to the base Latin and Greek letters. This does not imply that the use of these characters is discouraged for mathematical use. Folding away such distinctions by applying the compatibility mappings is usually not desirable, as it loses the semantic distinctions for which these characters were encoded. See Unicode Standard Annex #15, "Unicode Normalization Forms."

Fonts Used for Mathematical Alphabets

Mathematicians place strict requirements on the *specific* fonts used to represent mathematical variables. Readers of a mathematical text need to be able to distinguish single-letter variables from each other, even when they do not appear in close proximity. They must be able to recognize the letter itself, whether it is part of the text or is a mathematical variable, and lastly which mathematical alphabet it is from.

Fraktur. The blackletter style is often referred to as *Fraktur* or *Gothic* in various sources. Technically, Fraktur and Gothic typefaces are distinct designs from blackletter, but any of several font styles similar in appearance to the forms shown in the charts can be used. Note that in East Asian typography, the term *Gothic* is commonly used to indicate a sans-serif type style.

Math Italics. Mathematical variables are most commonly set in a form of italics, but not all italic fonts can be used successfully. For example, a math italic font should avoid a "tail" on the lowercase *italic letter z* because it clashes with subscripts. In common text fonts, the *italic letter v* and *Greek letter nu* are not very distinct. A rounded *italic letter v* is therefore preferred in a mathematical font. There are other characters that sometimes have similar shapes and require special attention to avoid ambiguity. Examples are shown in *Figure 15-5*.

Figure 15-5. Easily Confused Shapes for Mathematical Glyphs

italic a	a	α	alpha
italic v (pointed)	v	ν	nu
italic v (rounded)	υ	υ	upsilon
script X	$\mathcal{X}$	χ	chi
plain Y	Y	Υ	Upsilon

Hard-to-Distinguish Letters. Not all sans-serif fonts allow an easy distinction between *lowercase l* and *uppercase I*, and not all monospaced (monowidth) fonts allow a distinction between the *letter l* and the *digit one*. Such fonts are not usable for mathematics. In Fraktur, the letters $\mathfrak{I}$ and $\mathfrak{J}$, in particular, must be made distinguishable. Overburdened blackletter forms are inappropriate for mathematical notation. Similarly, the *digit zero* must be distinct from the *uppercase letter O* for all mathematical alphanumeric sets. Some characters are so similar that even mathematical fonts do not attempt to provide distinct glyphs for them. Their use is normally avoided in mathematical notation unless no confusion is possible in a given context—for example, *uppercase A* and *uppercase Alpha*.

Font Support for Combining Diacritics. Mathematical equations require that characters be combined with diacritics (dots, tilde, circumflex, or arrows above are common), as well as followed or preceded by superscripted or subscripted letters or numbers. This requirement leads to designs for *italic* styles that are less inclined and *script* styles that have smaller

overhangs and less slant than equivalent styles commonly used for text such as wedding invitations.

Type Style for Script Characters. In some instances, a deliberate unification with a non-mathematical symbol has been undertaken; for example, U+2133 is unified with the pre-1949 symbol for the German currency unit *Mark*. This unification restricts the range of glyphs that can be used for this character in the charts. Therefore the font used for the representative glyphs in the code charts is based on a simplified "English Script" style, as per recommendation by the American Mathematical Society. For consistency, other script characters in the Letterlike Symbols block are now shown in the same type style.

Double-Struck Characters. The double-struck glyphs shown in earlier editions of the standard attempted to match the design used for all the other Latin characters in the standard, which is based on Times. The current set of fonts was prepared in consultation with the American Mathematical Society and leading mathematical publishers; it shows much simpler forms that are derived from the forms written on a blackboard. However, both serifed and non-serifed forms can be used in mathematical texts, and inline fonts are found in works published by certain publishers.

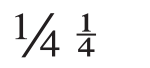
15.3 Number Forms

Number Forms: U+2150–U+218F

Many number form characters are composite or duplicate forms encoded solely for compatibility with existing standards. The use of these composite symbols is discouraged where their presence is not required by compatibility.

Fractions. The Number Forms block contains a series of vulgar fraction characters, encoded for compatibility with legacy character encoding standards. These characters are intended to represent both of the common forms of vulgar fractions: forms with a right-slanted division slash, such as ¼, as shown in the code charts, and forms with a horizontal division line, such as $\frac{1}{4}$, which are considered to be alternative glyphs for the same fractions, as shown in *Figure 15-6*. A few other vulgar fraction characters are located in the Latin-1 block in the range U+00BC..U+00BE.

Figure 15-6. Alternate Forms of Vulgar Fractions



The unusual fraction character, U+2189 VULGAR FRACTION ZERO THIRDS, is in origin a baseball scoring symbol from the Japanese television standard, ARIB STD B24.For baseball scoring, this character and the related fractions, U+2153 VULGAR FRACTION ONE THIRD and U+2154 VULGAR FRACTION TWO THIRDS, use the glyph form with the slanted division slash, and do not use the alternate stacked glyph form.

The vulgar fraction characters are given compatibility decompositions using U+2044 "/" FRACTION SLASH. Use of the *fraction slash* is the more generic way to represent fractions in text; it can be used to construct fractional number forms that are not included in the collections of vulgar fraction characters. For more information on the *fraction slash*, see "Other Punctuation" in *Section 6.2, General Punctuation*.

Roman Numerals. For most purposes, it is preferable to compose the Roman numerals from sequences of the appropriate Latin letters. However, the uppercase and lowercase variants of the Roman numerals through 12, plus L, C, D, and M, have been encoded for

compatibility with East Asian standards. Unlike sequences of Latin letters, these symbols remain upright in vertical layout. Additionally, in certain locales, compact date formats use Roman numerals for the month, but may expect the use of a single character.

In identifiers, the use of Roman numeral symbols—particularly those based on a single letter of the Latin alphabet—can lead to spoofing. For more information, see Unicode Technical Report #36, "Unicode Security Considerations."

U+2180 ROMAN NUMERAL ONE THOUSAND C D and U+216F ROMAN NUMERAL ONE THOUSAND can be considered to be glyphic variants of the same Roman numeral, but are distinguished because they are not generally interchangeable and because U+2180 cannot be considered to be a compatibility equivalent to the Latin letter M. U+2181 ROMAN NUMERAL FIVE THOUSAND and U+2182 ROMAN NUMERAL TEN THOUSAND are distinct characters used in Roman numerals; they do not have compatibility decompositions in the Unicode Standard. U+2183 ROMAN NUMERAL REVERSED ONE HUNDRED is a form used in combinations with C and/or I to form large numbers—some of which vary with single character number forms such as D, M, U+2181, or others. U+2183 is also used for the Claudian letter *antisigma*.

Common Indic Number Forms: U+A830–U+A83F

The Common Indic Number Forms block contains characters widely used in traditional representations of fractional values in numerous scripts of North India, Pakistan and in some areas of Nepal. The fraction signs were used to write currency, weight, measure, time, and other units. Their use in written documents is attested from at least the 16th century CE and in texts printed as late as 1970. They are occasionally still used in a limited capacity.

The North Indic fraction signs represent fraction values of a base-16 notation system. There are atomic symbols for 1/16, 2/16, 3/16 and for 1/4, 2/4, and 3/4. Intermediate values such as 5/16 are written additively by using two of the atomic symbols: 5/16 = 1/4 + 1/16, and so on.

The signs for the fractions 1/4, 1/2, and 3/4 sometimes take different forms when they are written independently, without a currency or quantity mark. These independent forms were used more generally in Maharashtra and Gujarat, and they appear in materials written and printed in the Devanagari and Gujarati scripts. The independent fraction signs are represented by using middle dots to the left and right of the regular fraction signs.

U+A836 NORTH INDIC QUARTER MARK is used in some regional orthographies to explicitly indicate fraction signs for 1/4, 1/2, and 3/4 in cases where sequences of other marks could be ambiguous in reading.

This block also contains several other symbols that are not strictly number forms. They are used in traditional representation of numeric amounts for currency, weights, and other measures in the North Indic orthographies which use the fraction signs. U+A837 NORTH INDIC PLACEHOLDER MARK is a symbol used in currency representations to indicate the absence of an intermediate value. U+A839 NORTH INDIC QUANTITY MARK is a unit mark for various weights and measures.

The North Indic fraction signs are related to fraction signs that have specific forms and are separately encoded in some North Indic scripts. See, for example, U+09F4 BENGALI CURRENCY NUMERATOR ONE. Similar forms are attested for the Oriya script.

Rumi Numeral Forms: U+10E60–U+10E7E

Rumi, also known today as Fasi, is an numeric system used from the 10th to 17th centuries CE in a wide area, spanning from Egypt, across the Maghreb, to al-Andalus on the Iberian

Peninsula. The Rumi numerals originate from the Coptic or Greek-Coptic tradition, but are not a positionally-based numbering system.

The numbers appear in foliation, chapter, and quire notations in manuscripts of religious, scientific, accounting and mathematical works. They also were used on astronomical instruments.

There is considerable variety in the Rumi glyph shapes over time: the digit "nine," for example, appears in a theta shape in the early period. The glyphs in the code charts derive from a copy of a manuscript by Ibn Al-Banna (1256-1321), with glyphs that are similar to those found in 16th century manuscripts from the Maghreb.

CJK Number Forms

Chinese Counting-Rod Numerals. Counting-rod numerals were used in pre-modern East Asian mathematical texts in conjunction with counting rods used to represent and manipulate numbers. The counting rods were a set of small sticks, several centimeters long that were arranged in patterns on a gridded counting board. Counting rods and the counting board provided a flexible system for mathematicians to manipulate numbers, allowing for considerable sophistication in mathematics.

The specifics of the patterns used to represent various numbers using counting rods varied, but there are two main constants: Two sets of numbers were used for alternate columns; one set was used for the ones, hundreds, and ten-thousands columns in the grid, while the other set was used for the tens and thousands. The shapes used for the counting-rod numerals in the Unicode Standard follow conventions from the Song dynasty in China, when traditional Chinese mathematics had reached its peak. Fragmentary material from many early Han dynasty texts shows different orientation conventions for the numerals, with horizontal and vertical marks swapped for the digits and tens places.

Zero was indicated by a blank square on the counting board and was either avoided in written texts or was represented with U+3007 IDEOGRAPHIC NUMBER ZERO. (Historically, U+3007 IDEOGRAPHIC NUMBER ZERO originated as a dot; as time passed, it increased in size until it became the same size as an ideograph. The actual size of U+3007 IDEOGRAPHIC NUMBER ZERO in mathematical texts varies, but this variation should be considered a font difference.) Written texts could also take advantage of the alternating shapes for the numerals to avoid having to explicitly represent zero. Thus 6,708 can be distinguished from 678, because the former would be 𝍠𝍩𝍡, whereas the latter would be 𝍩𝍠𝍡.

Negative numbers were originally indicated on the counting board by using rods of a different color. In written texts, a diagonal slash from lower right to upper left is overlaid upon the rightmost digit. On occasion, the slash might not be actually overlaid. U+20E5 COMBINING REVERSE SOLIDUS OVERLAY should be used for this negative sign.

The predominant use of counting-rod numerals in texts was as part of diagrams of counting boards. They are, however, occasionally used in other contexts, and they may even occur within the body of modern texts.

Suzhou-Style Numerals. The Suzhou-style numerals (Mandarin *su1zhou1ma3zi*) are CJK ideographic number forms encoded in the CJK Symbols and Punctuation block in the ranges U+3021..U+3029 and U+3038..U+303A.

The Suzhou-style numerals are modified forms of CJK ideographic numerals that are used by shopkeepers in China to mark prices. They are also known as "commercial forms," "shop units," or "grass numbers." They are encoded for compatibility with the CNS 11643-1992 and Big Five standards. The forms for ten, twenty, and thirty, encoded at U+3038..U+303A, are also encoded as CJK unified ideographs: U+5341, U+5344, and U+5345, respectively. (For twenty, see also U+5EFE and U+5EFF.)

These commercial forms of Chinese numerals should be distinguished from the use of other CJK unified ideographs as accounting numbers to deter fraud. See *Table 4-11* in *Section 4.6, Numeric Value—Normative*, for a list of ideographs used as accounting numbers.

Why are the Suzhou numbers called Hangzhou numerals in the Unicode names? No one has been able to trace this back. Hangzhou is a district in China that is near the Suzhou district, but the name "Hangzhou" does not occur in other sources that discuss these number forms.

Superscripts and Subscripts: U+2070–U+209F

In general, the Unicode Standard does not attempt to describe the positioning of a character above or below the baseline in typographical layout. Therefore, the preferred means to encode superscripted letters or digits, such as "1^{st}" or "$DC00_{16}$", is by style or markup in rich text. However, in some instances superscript or subscript letters are used as part of the plain text content of specialized phonetic alphabets, such as the Uralic Phonetic Alphabet. These superscript and subscript letters are mostly from the Latin or Greek scripts. These characters are encoded in other character blocks, along with other modifier letters or phonetic letters. In addition, superscript digits are used to indicate tone in transliteration of many languages. The use of *superscript two* and *superscript three* is common legacy practice when referring to units of area and volume in general texts.

A certain number of additional superscript and subscript characters are needed for round-trip conversions to other standards and legacy code pages. Most such characters are encoded in this block and are considered compatibility characters.

Parsing of Superscript and Subscript Digits. In the Unicode Character Database, superscript and subscript digits have not been given the General_Category property value Decimal_Number (gc=Nd), so as to prevent expressions like 2^3 from being interpreted like 23 by simplistic parsers. This should not be construed as preventing more sophisticated numeric parsers, such as general mathematical expression parsers, from correctly identifying these compatibility superscript and subscript characters as digits and interpreting them appropriately.

Standards. Many of the characters in the Superscripts and Subscripts block are from character sets registered in the ISO International Register of Coded Character Sets to be Used With Escape Sequences, under the registration standard ISO/IEC 2375, for use with ISO/IEC 2022. Two MARC 21 character sets used by libraries include the digits, plus signs, minus signs, and parentheses.

Superscripts and Subscripts in Other Blocks. The superscript digits one, two, and three are coded in the Latin-1 Supplement block to provide code point compatibility with ISO/IEC 8859-1. For a discussion of U+00AA FEMININE ORDINAL INDICATOR and U+00BA MASCULINE ORDINAL INDICATOR, see "Letters of the Latin-1 Supplement" in *Section 7.1, Latin*. U+2120 SERVICE MARK and U+2122 TRADE MARK SIGN are commonly used symbols that are encoded in the Letterlike Symbols block (U+2100..U+214F); they consist of sequences of two superscripted letters each.

For phonetic usage, there are a small number of superscript letters located in the Spacing Modifier Letters block (U+02B0..U+02FF) and a large number of superscript and subscript letters in the Phonetic Extensions block (U+1D00..U+1D7F) and in the Phonetic Extensions Supplement block (U+1D80..U+1DBF). The superscripted letters do not contain the word "superscript" in their character names, but are simply called modifier letters. Finally, a small set of superscripted CJK ideographs, used for the Japanese system of syntactic markup of Classical Chinese text for reading, is located in the Kanbun block (U+3190..U+319F).

15.4 Mathematical Symbols

The Unicode Standard provides a large set of standard mathematical characters to support publications of scientific, technical, and mathematical texts on and off the Web. In addition to the mathematical symbols and arrows contained in the blocks described in this section, mathematical operators are found in the Basic Latin (ASCII) and Latin-1 Supplement blocks. A few of the symbols from the Miscellaneous Technical, Miscellaneous Symbols, and Dingbats blocks, as well as characters from General Punctuation, are also used in mathematical notation. For Latin and Greek letters in special font styles that are used as mathematical variables, such as U+210B $\mathscr{H}$ SCRIPT CAPITAL H, as well as the Hebrew letter *alef* used as the first transfinite cardinal symbol encoded by U+2135 $\aleph$ ALEF SYMBOL, see "Letterlike Symbols" and "Mathematical Alphanumeric Symbols" in *Section 15.2, Letterlike Symbols*.

The repertoire of mathematical symbols in Unicode enables the display of virtually all standard mathematical symbols. Nevertheless, no collection of mathematical symbols can ever be considered complete; mathematicians and other scientists are continually inventing new mathematical symbols. More symbols will be added as they become widely accepted in the scientific communities.

Semantics. The same mathematical symbol may have different meanings in different subdisciplines or different contexts. The Unicode Standard encodes only a single character for a single symbolic form. For example, the "+" symbol normally denotes addition in a mathematical context, but it might refer to concatenation in a computer science context dealing with strings, indicate incrementation, or have any number of other functions in given contexts. It is up to the application to distinguish such meanings according to the appropriate context. Where information is available about the usage (or usages) of particular symbols, it has been indicated in the character annotations in the code charts.

Mathematical Property. The mathematical (*math*) property is an informative property of characters that are used as operators in mathematical formulas. The mathematical property may be useful in identifying characters commonly used in mathematical text and formulas. However, a number of these characters have multiple usages and may occur with nonmathematical semantics. For example, U+002D HYPHEN-MINUS may also be used as a hyphen—and not as a mathematical minus sign. Other characters, including some alphabetic, numeric, punctuation, spaces, arrows, and geometric shapes, are used in mathematical expressions as well, but are even more dependent on the context for their identification. A list of characters with the mathematical property is provided in the Unicode Character Database.

For a classification of mathematical characters by typographical behavior and mapping to ISO 9573-13 entity sets, see Unicode Technical Report #25, "Unicode Support for Mathematics."

Mathematical Operators: U+2200–U+22FF

The Mathematical Operators block includes character encodings for operators, relations, geometric symbols, and a few other symbols with special usages confined largely to mathematical contexts.

Standards. Many national standards' mathematical operators are covered by the characters encoded in this block. These standards include such special collections as ANSI Y10.20, ISO 6862, ISO 8879, and portions of the collection of the American Mathematical Society, as well as the original repertoire of TEX.

Encoding Principles. Mathematical operators often have more than one meaning. Therefore the encoding of this block is intentionally rather shape-based, with numerous instances in which several semantic values can be attributed to the same Unicode code point. For example, U+2218 ∘ RING OPERATOR may be the equivalent of *white small circle* or *composite function* or *apl jot*. The Unicode Standard does not attempt to distinguish all possible semantic values that may be applied to mathematical operators or relation symbols.

The Unicode Standard does include many characters that appear to be quite similar to one another, but that may well convey different meanings in a given context. Conversely, mathematical operators, and especially relation symbols, may appear in various standards, handbooks, and fonts with a large number of purely graphical variants. Where variants were recognizable as such from the sources, they were not encoded separately. For relation symbols, the choice of a vertical or forward-slanting stroke typically seems to be an aesthetic one, but both slants might appear in a given context. However, a back-slanted stroke almost always has a distinct meaning compared to the forward-slanted stroke. See *Section 16.4, Variation Selectors*, for more information on some particular variants.

Unifications. Mathematical operators such as *implies* ⇒ and *if and only if* ↔ have been unified with the corresponding arrows (U+21D2 RIGHTWARDS DOUBLE ARROW and U+2194 LEFT RIGHT ARROW, respectively) in the Arrows block.

The operator U+2208 ELEMENT OF is occasionally rendered with a taller shape than shown in the code charts. Mathematical handbooks and standards consulted treat these characters as variants of the same glyph. U+220A SMALL ELEMENT OF is a distinctively small version of the *element of* that originates in mathematical pi fonts.

The operators U+226B MUCH GREATER-THAN and U+226A MUCH LESS-THAN are sometimes rendered in a nested shape. The nested shapes are encoded separately as U+2AA2 DOUBLE NESTED GREATER-THAN and U+2AA1 DOUBLE NESTED LESS-THAN.

A large class of unifications applies to variants of relation symbols involving negation. Variants involving vertical or slanted *negation slashes* and *negation slashes* of different lengths are not separately encoded. For example, U+2288 NEITHER A SUBSET OF NOR EQUAL TO is the archetype for several different glyph variants noted in various collections.

In two instances in this block, essentially stylistic variants are separately encoded: U+2265 GREATER-THAN OR EQUAL TO is distinguished from U+2267 GREATER-THAN OVER EQUAL TO; the same distinction applies to U+2264 LESS-THAN OR EQUAL TO and U+2266 LESS-THAN OVER EQUAL TO. Further instances of the encoding of such stylistic variants can be found in the supplemental blocks of mathematical operators. The primary reason for such duplication is for compatibility with existing standards.

Greek-Derived Symbols. Several mathematical operators derived from Greek characters have been given separate encodings because they are used differently from the corresponding letters. These operators may occasionally occur in context with Greek-letter variables. They include U+2206 Δ INCREMENT, U+220F ∏ N-ARY PRODUCT, and U+2211 ∑ N-ARY SUMMATION. The latter two are large operators that take limits.

Other duplicated Greek characters are those for U+00B5 µ MICRO SIGN in the Latin-1 Supplement block, U+2126 Ω OHM SIGN in Letterlike Symbols, and several characters among the APL functional symbols in the Miscellaneous Technical block. Most other Greek characters with special mathematical semantics are found in the Greek block because duplicates were not required for compatibility. Additional sets of mathematical-style Greek alphabets are found in the Mathematical Alphanumeric Symbols block.

N-ary Operators. N-ary operators are distinguished from binary operators by their larger size and by the fact that in mathematical layout, they take limit expressions.

Invisible Operators. In mathematics, some operators or punctuation are often implied but not displayed. For a set of invisible operators that can be used to mark these implied operators in the text, see *Section 15.5, Invisible Mathematical Operators*.

Minus Sign. U+2212 "−" MINUS SIGN is a mathematical operator, to be distinguished from the ASCII-derived U+002D "-" HYPHEN-MINUS, which may look the same as a minus sign or be shorter in length. (For a complete list of dashes in the Unicode Standard, see *Table 6-3*.) U+22EE..U+22F1 are a set of ellipses used in matrix notation. U+2052 "⁒" COMMERCIAL MINUS SIGN is a specialized form of the minus sign. Its use is described in *Section 6.2, General Punctuation*.

Delimiters. Many mathematical delimiters are unified with punctuation characters. See *Section 6.2, General Punctuation*, for more information. Some of the set of ornamental Brackets in the range U+2768..U+2775 are also used as mathematical delimiters. See *Section 15.8, Miscellaneous Symbols and Dingbats*. See also *Section 15.6, Technical Symbols*, for specialized characters used for large vertical or horizontal delimiters.

Bidirectional Layout. In a bidirectional context, with the exception of arrows, the glyphs for mathematical operators and delimiters are adjusted as described in Unicode Standard Annex #9, "Unicode Bidirectional Algorithm." See *Section 4.7, Bidi Mirrored—Normative*, and "Semantics of Paired Punctuation" in *Section 6.2, General Punctuation*.

Other Elements of Mathematical Notation. In addition to the symbols in these blocks, mathematical and scientific notation makes frequent use of arrows, punctuation characters, letterlike symbols, geometrical shapes, and miscellaneous and technical symbols.

For an extensive discussion of mathematical alphanumeric symbols, see *Section 15.2, Letterlike Symbols*. For additional information on all the mathematical operators and other symbols, see Unicode Technical Report #25, "Unicode Support for Mathematics."

Supplements to Mathematical Symbols and Arrows

The Unicode Standard defines a number of additional blocks to supplement the repertoire of mathematical operators and arrows. These additions are intended to extend the Unicode repertoire sufficiently to cover the needs of such applications as MathML, modern mathematical formula editing and presentation software, and symbolic algebra systems.

Standards. MathML, an XML application, is intended to support the full legacy collection of the ISO mathematical entity sets. Accordingly, the repertoire of mathematical symbols for the Unicode Standard has been supplemented by the full list of mathematical entity sets in ISO TR 9573-13, *Public entity sets for mathematics and science*. An additional repertoire was provided from the amalgamated collection of the STIX Project (Scientific and Technical Information Exchange). That collection includes, but is not limited to, symbols gleaned from mathematical publications by experts of the American Mathematical Society and symbol sets provided by Elsevier Publishing and by the American Physical Society.

Supplemental Mathematical Operators: U+2A00–U+2AFF

The Supplemental Mathematical Operators block contains many additional symbols to supplement the collection of mathematical operators.

Miscellaneous Mathematical Symbols-A: U+27C0–U+27EF

The Miscellaneous Mathematical Symbols-A block contains symbols that are used mostly as operators or delimiters in mathematical notation.

Mathematical Brackets. The mathematical white square brackets, angle brackets, double angle brackets, and tortoise shell brackets encoded at U+27E6..U+27ED are intended for

ordinary mathematical use of these particular bracket types. They are unambiguously narrow, for use in mathematical and scientific notation, and should be distinguished from the corresponding wide forms of white square brackets, angle brackets, and double angle brackets used in CJK typography. (See the discussion of the CJK Symbols and Punctuation block in *Section 6.2, General Punctuation*.) Note especially that the "bra" and "ket" angle brackets (U+2329 LEFT-POINTING ANGLE BRACKET and U+232A RIGHT-POINTING ANGLE BRACKET, respectively) are deprecated. Their use is strongly discouraged, because of their canonical equivalence to CJK angle brackets. This canonical equivalence is likely to result in unintended spacing problems if these characters are used in mathematical formulae.

The flattened parentheses encoded at U+27EE..U+27EF are additional, specifically-styled mathematical parentheses. Unlike the mathematical and CJK brackets just discussed, the flattened parentheses do not have corresponding wide CJK versions which they would need to be contrasted with.

Long Division. U+27CC LONG DIVISION is an operator intended for the representation of long division expressions, as may be seen in elementary and secondary school mathematical textbooks, for example. In use and rendering it shares some characteristics with U+221A SQUARE ROOT; in rendering, the top bar may be stretched to extend over the top of the denominator of the division expression. Full support of such rendering may, however, require specialized mathematical software.

Miscellaneous Mathematical Symbols-B: U+2980–U+29FF

The Miscellaneous Mathematical Symbols-B block contains miscellaneous symbols used for mathematical notation, including fences and other delimiters. Some of the symbols in this block may also be used as operators in some contexts.

Wiggly Fence. U+29D8 LEFT WIGGLY FENCE has a superficial similarity to U+FE34 PRESENTATION FORM FOR VERTICAL WAVY LOW LINE. The latter is a wiggly sidebar character, intended for legacy support as a style of underlining character in a vertical text layout context; it has a compatibility mapping to U+005F LOW LINE. This represents a very different usage from the standard use of fence characters in mathematical notation.

Miscellaneous Symbols and Arrows: U+2B00–U+2B7F

The Miscellaneous Symbols and Arrows block contains more mathematical symbols and arrows. The arrows in this block extend and complete sets of arrows in other blocks. The other mathematical symbols complement various sets of geometric shapes. For a discussion of the use of such shape symbols in mathematical contexts, see "Geometric Shapes: U+25A0–U+25FF" in *Section 15.7, Geometrical Symbols*.

This block also contains various types of generic symbols. These complement the set of symbols in the Miscellaneous Symbols block, U+2600..U+26FF.

Arrows: U+2190–U+21FF

Arrows are used for a variety of purposes: to imply directional relation, to show logical derivation or implication, and to represent the cursor control keys.

Accordingly, the Unicode Standard includes a fairly extensive set of generic arrow shapes, especially those for which there are established usages with well-defined semantics. It does not attempt to encode every possible stylistic variant of arrows separately, especially where their use is mainly decorative. For most arrow variants, the Unicode Standard provides encodings in the two horizontal directions, often in the four cardinal directions. For the single and double arrows, the Unicode Standard provides encodings in eight directions.

Bidirectional Layout. In bidirectional layout, arrows are not automatically mirrored, because the direction of the arrow could be relative to the text direction or relative to an absolute direction. Therefore, if text is copied from a left-to-right to a right-to-left context, or vice versa, the character code for the desired arrow direction in the new context must be used. For example, it might be necessary to change U+21D2 RIGHTWARDS DOUBLE ARROW to U+21D0 LEFTWARDS DOUBLE ARROW to maintain the semantics of "implies" in a right-to-left context. For more information on bidirectional layout, see Unicode Standard Annex #9, "Unicode Bidirectional Algorithm."

Standards. The Unicode Standard encodes arrows from many different international and national standards as well as corporate collections.

Unifications. Arrows expressing mathematical relations have been encoded in the Arrows block as well as in the supplemental arrows blocks. An example is U+21D2 ⇒ RIGHTWARDS DOUBLE ARROW, which may be used to denote *implies*. Where available, such usage information is indicated in the annotations to individual characters in the code charts. However, because the arrows have such a wide variety of applications, there may be several semantic values for the same Unicode character value.

Supplemental Arrows

The Supplemental Arrows-A (U+27F0..U+27FF), Supplemental Arrows-B (U+2900..U+297F), and Miscellaneous Symbols and Arrows (U+2B00..U+2BFF) blocks contain a large repertoire of arrows to supplement the main set in the Arrows block. Many of the supplemental arrows in the Miscellaneous Symbols and Arrows block, particularly in the range U+2B30..U+2B4C, are encoded to ensure the availability of left-right symmetric pairs of less common arrows, for use in bidirectional layout of mathematical text.

Long Arrows. The long arrows encoded in the range U+27F5..U+27FF map to standard SGML entity sets supported by MathML. Long arrows represent distinct semantics from their short counterparts, rather than mere stylistic glyph differences. For example, the shorter forms of arrows are often used in connection with limits, whereas the longer ones are associated with mappings. The use of the long arrows is so common that they were assigned entity names in the ISOAMSA entity set, one of the suite of mathematical symbol entity sets covered by the Unicode Standard.

Standardized Variants of Mathematical Symbols

These mathematical variants are all produced with the addition of U+FE00 VARIATION SELECTOR-1 (VS1) to mathematical operator base characters. The valid combinations are listed in the file StandardizedVariants.txt in the Unicode Character Database. All combinations not listed there are unspecified and are reserved for future standardization; no conformant process may interpret them as standardized variants.

Change in Representative Glyphs for U+2278 and U+2279. In Version 3.2 of the Unicode Standard, the representative glyphs for U+2278 NEITHER LESS-THAN NOR GREATER-THAN and U+2279 NEITHER GREATER-THAN NOR LESS-THAN were changed from using a vertical cancellation to using a slanted cancellation. This change was made to match the long-standing canonical decompositions for these characters, which use U+0338 COMBINING LONG SOLIDUS OVERLAY. The symmetric forms using the vertical stroke continue to be acceptable glyph variants. Using U+2276 LESS-THAN OR GREATER-THAN or U+2277 GREATER-THAN OR LESS-THAN with U+20D2 COMBINING LONG VERTICAL LINE OVERLAY will display these variants explicitly. Unless fonts are created with the intention to add support for both forms, there is no need to revise the glyphs in existing fonts; the glyphic range implied by using the base character code alone encompasses both shapes. For more information, see *Section 16.4, Variation Selectors*.

15.5 Invisible Mathematical Operators

In mathematics, some operators and punctuation are often implied but not displayed. The General Punctuation block contains several special format control characters known as *invisible operators*, which can be used to make such operators explicit for use in machine interpretation of mathematical expressions. Use of invisible operators is optional and is intended for interchange with math-aware programs.

A more complete discussion of mathematical notation can be found in Unicode Technical Report #25, "Unicode Support for Mathematics."

Invisible Separator. U+2063 INVISIBLE SEPARATOR (also known as *invisible comma*) is intended for use in index expressions and other mathematical notation where two adjacent variables form a list and are not implicitly multiplied. In mathematical notation, commas are not always explicitly present, but they need to be indicated for symbolic calculation software to help it disambiguate a sequence from a multiplication. For example, the double $_{ij}$ subscript in the variable a_{ij} means $a_{i,\,j}$ —that is, the *i* and *j* are separate indices and not a single variable with the name *ij* or even the product of *i* and *j*. To represent the implied list separation in the subscript $_{ij}$, one can insert a nondisplaying *invisible separator* between the *i* and the *j*. In addition, use of the invisible comma would hint to a math layout program that it should typeset a small space between the variables.

Invisible Multiplication. Similarly, an expression like mc^2 implies that the mass *m* multiplies the square of the speed *c*. To represent the implied multiplication in mc^2, one inserts a nondisplaying U+2062 INVISIBLE TIMES between the *m* and the *c*. Another example can be seen in the expression $f^{ij}(\cos(ab))$, which has the same meaning as $f^{ij}(\cos(a{\times}b))$, where × represents *multiplication*, not the *cross product*. Note that the spacing between characters may also depend on whether the adjacent variables are part of a list or are to be concatenated (that is, multiplied).

Invisible Plus. The invisible plus operator, U+2064 INVISIBLE PLUS, is used to unambiguously represent expressions like 3¼ which occur frequently in school and engineering texts. To ensure that 3¼ means 3 plus ¼—in uses where it is not possible to rely on a human reader to disambiguate the implied intent of juxtaposition—the invisible plus operator is used. In such uses, not having an operator at all would imply multiplication.

Invisible Function Application. U+2061 FUNCTION APPLICATION is used for an implied function dependence, as in $f(x + y)$. To indicate that this is the function *f* of the quantity $x + y$ and not the expression $fx + fy$, one can insert the nondisplaying *function application symbol* between the *f* and the left parenthesis.

15.6 Technical Symbols

Control Pictures: U+2400–U+243F

The need to show the presence of the C0 control codes unequivocally when data are displayed has led to conventional representations for these nongraphic characters.

Code Points for Pictures for Control Codes. By definition, control codes themselves are manifested only by their action. However, it is sometimes necessary to show the position of a control code within a data stream. Conventional illustrations for the ASCII C0 control codes have been developed—but the characters U+2400..U+241F and U+2424 are intended for use as unspecified graphics for the corresponding control codes. This choice allows a particular application to use *any* desired pictorial representation of the given con-

trol code. It assumes that the particular pictures used to represent control codes are often specific to different systems and are rarely the subject of text interchange between systems.

Pictures for ASCII Space. By definition, the SPACE is a blank graphic. Conventions have also been established for the visible representation of the space. Three specific characters are provided that may be used to visually represent the ASCII space character, U+2420 SYMBOL FOR SPACE, U+2422 BLANK SYMBOL, and U+2423 OPEN BOX.

Standards. The CNS 11643 standard encodes characters for pictures of control codes. Standard representations for control characters have been defined—for example, in ANSI X3.32 and ISO 2047. If desired, the characters U+2400..U+241F may be used for these representations.

Miscellaneous Technical: U+2300–U+23FF

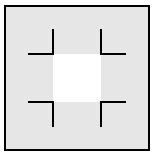
This block encodes technical symbols, including keytop labels such as U+232B ERASE TO THE LEFT. Excluded from consideration were symbols that are not normally used in one-dimensional text but are intended for two-dimensional diagrammatic use, such as most symbols for electronic circuits.

Keytop Labels. Where possible, keytop labels have been unified with other symbols of like appearance—for example, U+21E7 UPWARDS WHITE ARROW to indicate the Shift key. While symbols such as U+2318 PLACE OF INTEREST SIGN and U+2388 HELM SYMBOL are generic symbols that have been adapted to use on keytops, other symbols specifically follow ISO/IEC 9995-7.

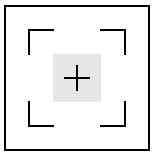
Floor and Ceiling. The floor and ceiling symbols encoded at U+2308..U+230B are tall, narrow mathematical delimiters. These symbols should not be confused with the CJK corner brackets at U+300C and U+300D, which are wide characters used as quotation marks in East Asian text. They should also be distinguished from the half brackets at U+2E22..U+2E25, which are the most generally used editorial marks shaped like corner brackets. Additional types of editorial marks, including further corner bracket forms, can be found in the Supplemental Punctuation block (U+2E00..U+2E7F).

Crops and Quine Corners. Crops and quine corners are most properly used in two-dimensional layout but may be referred to in plain text. This usage of crops and quine corners is as indicated in *Figure 15-7*.

Figure 15-7. Usage of Crops and Quine Corners



Crops



Quine corners

Angle Brackets. U+2329 LEFT-POINTING ANGLE BRACKET and U+232A RIGHT-POINTING ANGLE BRACKET have long been canonically equivalent to the CJK punctuation characters U+3008 LEFT ANGLE BRACKET and U+3009 RIGHT ANGLE BRACKET, respectively. This canonical equivalence implies that the use of the latter (CJK) code points is preferred and that U+2329 and U+232A are also "wide" characters. (See Unicode Standard Annex #11, "East Asian Width," for the definition of the East Asian wide property.) For this reason, the use of U+2329 and U+232A is deprecated for mathematics and for technical publication, where the wide property of the characters has the potential to interfere with the proper formatting of mathematical formulae. The angle brackets specifically provided for mathemat-

ics, U+27E8 MATHEMATICAL LEFT ANGLE BRACKET and U+27E9 MATHEMATICAL RIGHT ANGLE BRACKET, should be used instead. See *Section 15.4, Mathematical Symbols*.

APL Functional Symbols. APL (A Programming Language) makes extensive use of functional symbols constructed by composition with other, more primitive functional symbols. It used backspace and overstrike mechanisms in early computer implementations. In principle, functional composition is productive in APL; in practice, a relatively small number of composed functional symbols have become standard operators in APL. This relatively small set is encoded in its entirety in this block. All other APL extensions can be encoded by composition of other Unicode characters. For example, the APL symbol *a underbar* can be represented by U+0061 LATIN SMALL LETTER A + U+0332 COMBINING LOW LINE.

Symbol Pieces. The characters in the range U+239B..U+23B3, plus U+23B7, constitute a set of bracket and other symbol fragments for use in mathematical typesetting. These pieces originated in older font standards but have been used in past mathematical processing as characters in their own right to make up extra-tall glyphs for enclosing multiline mathematical formulae. Mathematical fences are ordinarily sized to the content that they enclose. However, in creating a large fence, the glyph is not scaled proportionally; in particular, the displayed stem weights must remain compatible with the accompanying smaller characters. Thus simple scaling of font outlines cannot be used to create tall brackets. Instead, a common technique is to build up the symbol from pieces. In particular, the characters U+239B LEFT PARENTHESIS UPPER HOOK through U+23B3 SUMMATION BOTTOM represent a set of glyph pieces for building up large versions of the fences (,), [,], {, and }, and of the large operators ∑ and ∫. These brace and operator pieces are compatibility characters. They should not be used in stored mathematical text, although they are often used in the data stream created by display and print drivers.

Table 15-3 shows which pieces are intended to be used together to create specific symbols.

Table 15-3. Use of Mathematical Symbol Pieces

	Two-Row	Three-Row	Five-Row
Summation	23B2, 23B3		
Integral	2320, 2321	2320, 23AE, 2321	2320, 3×23AE, 2321
Left parenthesis	239B, 239D	239B, 239C, 239D	239B, 3×239C, 239D
Right parenthesis	239E, 23A0	239E, 239F, 23A0	239E, 3×239F, 23A0
Left bracket	23A1, 23A3	23A1, 23A2, 23A3	23A1, 3×23A2, 23A3
Right bracket	23A4, 23A6	23A4, 23A5, 23A6	23A4, 3×23A5, 23A6
Left brace	23B0, 23B1	23A7, 23A8, 23A9	23A7, 23AA, 23A8, 23AA, 23A9
Right brace	23B1, 23B0	23AB, 23AC, 23AD	23AB, 23AA, 23AC, 23AA, 23AD

For example, an instance of U+239B can be positioned relative to instances of U+239C and U+239D to form an extra-tall (three or more line) left parenthesis. The center sections encoded here are meant to be used only with the top and bottom pieces encoded adjacent to them because the segments are usually graphically constructed within the fonts so that they match perfectly when positioned at the same *x* coordinates.

Horizontal Brackets. In mathematical equations, delimiters are often used horizontally, where they expand to the width of the expression they encompass. The six bracket characters in the range U+23DC..U+23E1 can be used for this purpose. In the context of mathematical layout, U+23B4 TOP SQUARE BRACKET and U+23B5 BOTTOM SQUARE BRACKET are also used that way. For more information, see Unicode Technical Report #25, "Unicode Support for Mathematics."

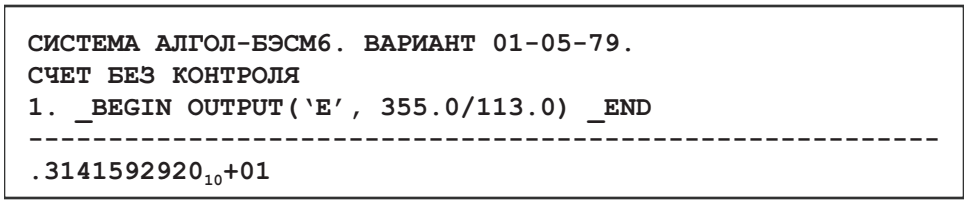
The set of horizontal square brackets, U+23B4 TOP SQUARE BRACKET and U+23B5 BOTTOM SQUARE BRACKET, together with U+23B6 BOTTOM SQUARE BRACKET OVER TOP SQUARE

BRACKET, are used by certain legacy applications to delimit vertical runs of text in non-CJK terminal emulation. U+23B6 BOTTOM SQUARE BRACKET OVER TOP SQUARE BRACKET is used where a single character cell is both the end of one such run and the start of another. The use of these characters in terminal emulation should not be confused with the use of rotated forms of brackets for vertically rendered CJK text. See the further discussion of this issue in *Section 6.2, General Punctuation*.

Terminal Graphics Characters. In addition to the box drawing characters in the Box Drawing block, a small number of vertical or horizontal line characters are encoded in the Miscellaneous Technical symbols block to complete the set of compatibility characters needed for applications that need to emulate various old terminals. The horizontal scan line characters, U+23BA HORIZONTAL SCAN LINE-1 through U+23BD HORIZONTAL SCAN LINE-9, in particular, represent characters that were encoded in character ROM for use with nine-line character graphic cells. Horizontal scan line characters are encoded for scan lines 1, 3, 7, and 9. The horizontal scan line character for scan line 5 is unified with U+2500 BOX DRAWINGS LIGHT HORIZONTAL.

Decimal Exponent Symbol. U+23E8 DECIMAL EXPONENT SYMBOL is a symbol added for compatibility with the Russian standard GOST 10859-64, as well as the paper tape and punch card standard, Alcor (DIN 66006). It represents a fixed token introducing the exponent of a real number in scientific notation, comparable to the more common usage of "e" in similar notations: 1.621e5. It was used in the early computer language ALGOL-60, and appeared in some Soviet-manufactured computers, such as the BESM-6 and its emulators. In the Unicode Standard it is treated simply as an atomic symbol; it is not considered to be equivalent to a generic subscripted form of the numeral "10" and is not given a compatibility decomposition. The vertical alignment of this symbol is slightly lower than the baseline, as shown in *Figure 15-8*.

Figure 15-8. Usage of the Decimal Exponent Symbol



Dental Symbols. The set of symbols from U+23BE to U+23CC form a set of symbols from JIS X 0213 for use in dental notation.

Metrical Symbols. The symbols in the range U+23D1..U+23D9 are a set of spacing symbols used in the metrical analysis of poetry and lyrics.

Electrotechnical Symbols. The Miscellaneous Technical block also contains a smattering of electrotechnical symbols. These characters are not intended to constitute a complete encoding of all symbols used in electrical diagrams, but rather are compatibility characters encoded primarily for mapping to other standards. The symbols in the range U+238D..U+2394 are from the character set with the International Registry number 181. U+23DA EARTH GROUND and U+23DB FUSE are from HKSCS-2001.

Standards. This block contains a large number of symbols from ISO/IEC 9995-7:1994, *Information technology—Keyboard layouts for text and office systems—Part 7: Symbols used to represent functions*.

ISO/IEC 9995-7 contains many symbols that have been unified with existing and closely related symbols in Unicode. These symbols are shown with their ordinary shapes in the

code charts, not with the particular glyph variation required by conformance to ISO/IEC 9995-7. Implementations wishing to be conformant to ISO/IEC 9995-7 in the depiction of these symbols should make use of a suitable font.

Optical Character Recognition: U+2440–U+245F

This block includes those symbolic characters of the OCR-A character set that do not correspond to ASCII characters as well as magnetic ink character recognition (MICR) symbols used in check processing.

Standards. Both sets of symbols are specified in ISO 2033.

15.7 Geometrical Symbols

Geometrical symbols are a collection of geometric shapes and their derivatives plus block elements and characters used for box drawing in legacy environments. In addition to the blocks described in this section, the Miscellaneous Technical (U+2300..U+23FF), Miscellaneous Symbols (U+2600..U+26FF), and Miscellaneous Symbols and Arrows (U+2B00..U+2BFF) blocks contain geometrical symbols that complete the set of shapes in the Geometric Shapes block.

Box Drawing and Box Elements

Box drawing and block element characters are graphic compatibility characters in the Unicode Standard. A number of existing national and vendor standards, including IBM PC Code Page 437, contain sets of characters intended to enable a simple kind of display cell graphics, assuming terminal-type screen displays of fixed-pitch character cells. The Unicode Standard does not encourage this kind of character-cell-based graphics model, but does include sets of such characters for backward compatibility with the existing standards.

Box Drawing. The Box Drawing block (U+2500..U+257F) contains a collection of graphic compatibility characters that originate in legacy standards and that are intended for drawing boxes of various shapes and line widths for user interface components in character-cell-based graphic systems.

The "light," "heavy," and "double" attributes for some of these characters reflect the fact that the original sets often had a two-way distinction, between a light versus heavy line or a single versus double line, and included sufficient pieces to enable construction of graphic boxes with distinct styles that abutted each other in display.

The lines in the box drawing characters typically extend to the middle of the top, bottom, left, and/or right of the bounding box for the character cell. They are designed to connect together into continuous lines, with no gaps between them. When emulating terminal applications, fonts that implement the box drawing characters should do likewise.

Block Elements. The Block Elements block (U+2580..U+259F) contains another collection of graphic compatibility characters. Unlike the box drawing characters, the legacy block elements are designed to fill some defined fraction of each display cell or to fill each display cell with some defined degree of shading. These elements were used to create crude graphic displays in terminals or in terminal modes on displays where bit-mapped graphics were unavailable.

Half-block fill characters are included for each half of a display cell, plus a graduated series of vertical and horizontal fractional fills based on one-eighth parts. The fractional fills do not form a logically complete set but are intended only for backward compatibility. There is also a set of quadrant fill characters, U+2596..U+259F, which are designed to complement

the half-block fill characters and U+2588 FULL BLOCK. When emulating terminal applications, fonts that implement the block element characters should be designed so that adjacent glyphs for characters such as U+2588 FULL BLOCK create solid patterns with no gaps between them.

Standards. The box drawing and block element characters were derived from GB 2312, KS X 1001, a variety of industry standards, and several terminal graphics sets. The Videotex Mosaic characters, which have similar appearances and functions, are unified against these sets.

Geometric Shapes: U+25A0–U+25FF

The Geometric Shapes are a collection of characters intended to encode prototypes for various commonly used geometrical shapes—mostly squares, triangles, and circles. The collection is somewhat arbitrary in scope; it is a compendium of shapes from various character and glyph standards. The typical distinctions more systematically encoded include black versus white, large versus small, basic shape (square versus triangle versus circle), orientation, and top versus bottom or left versus right part.

Hatched Squares. The hatched and cross-hatched squares at U+25A4..U+25A9 are derived from the Korean national standard (KS X 1001), in which they were probably intended as representations of fill patterns. Because the semantics of those characters are insufficiently defined in that standard, the Unicode character encoding simply carries the glyphs themselves as geometric shapes to provide a mapping for the Korean standard.

Lozenge. U+25CA ◊ LOZENGE is a typographical symbol seen in PostScript and in the Macintosh character set. It should be distinguished from both the generic U+25C7 WHITE DIAMOND and the U+2662 WHITE DIAMOND SUIT, as well as from another character sometimes called a lozenge, U+2311 SQUARE LOZENGE.

Use in Mathematics. Many geometric shapes are used in mathematics. When used for this purpose, the center points of the glyphs representing geometrical shapes should line up at the center line of the mathematical font. This differs from the alignment used for some of the representative glyphs in the code charts.

For several simple geometrical shapes—circle, square, triangle, diamond, and lozenge—differences in size carry semantic distinctions in mathematical notation, such as the difference between use of the symbol as a variable or as one of a variety of operator types. The Miscellaneous Symbols and Arrows block contains numerous characters representing other sizes of these geometrical symbols. Several other blocks, such as General Punctuation, Mathematical Operators, Block Elements, and Miscellaneous Symbols contain a few other characters which are members of the size-graded sets of such symbols.

For more details on the use of geometrical shapes in mathematics, see Unicode Technical Report #25, "Unicode Support for Mathematics."

Standards. The Geometric Shapes are derived from a large range of national and vendor character standards. The squares and triangles at U+25E7..U+25EE are derived from the Linotype font collection. U+25EF LARGE CIRCLE is included for compatibility with the JIS X 0208-1990 Japanese standard.

15.8 Miscellaneous Symbols and Dingbats

Miscellaneous Symbols: U+2600–U+26FF

The Miscellaneous Symbols block consists of a very heterogeneous collection of symbols that do not fit in any other Unicode character block and that tend to be rather pictographic in nature. These symbols are typically used for text decorations, but they may also be treated as normal text characters in applications such as typesetting chess books, card game manuals, and horoscopes.

Characters in the Miscellaneous Symbols block may be rendered in more than one way, unlike characters in the Dingbats block, in which characters generally correspond to an explicit glyph.

The order of the Miscellaneous Symbols is completely arbitrary, but an attempt has been made to keep like symbols together and to group subsets of them into meaningful orders. Some of these subsets include weather and astronomical symbols, pointing hands, religious and ideological symbols, the Yijing (I Ching) trigrams, planet and zodiacal symbols, game symbols, musical dingbats, and recycling symbols. (For other moon phases, see the circle-based shapes in the Geometric Shapes block.)

Corporate logos and collections of graphical elements or pictures are not included, because they tend either to be very specific in usage (logos, political party symbols, and so on) or are nonconventional in appearance and semantic interpretation (clip art collections), and hence are inappropriate for encoding as characters. The Unicode Standard recommends that such items be incorporated in text via higher protocols that allow intermixing of graphic images with text, rather than by indefinite extension of the number of miscellaneous symbols encoded as characters.

Standards. The Miscellaneous Symbols are derived from a large range of national and vendor character standards. Among them, characters from the Japanese Association of Radio Industries and Business (ARIB) standard STD-B24 are widely represented in this block. The symbols from ARIB were initially used in the context of digital broadcasting, but in many cases their usage has evolved to more generic purposes.

Weather Symbols. The characters in the ranges U+2600..U+2603 and U+26C4..U+26CB, as well as U+2614 UMBRELLA WITH RAIN DROPS are weather symbols. These commonly occur as map symbols or in other contexts related to weather forecasting in digital broadcasting or on web sites.

Traffic Signs. In general, traffic signs are quite diverse, tend to be elaborate in form and differ significantly between countries and locales. For the most part they are inappropriate for encoding as characters. However, there are a small number of conventional symbols which have been used as characters in contexts such as digital broadcasting or mobile phones. The characters in the ranges U+26CC..U+26CD and U+26CF..U+26E1 are traffic sign symbols of this sort, encoded for use in digital broadcasting.

Dictionary and Map Symbols. The characters in the range U+26E8..U+26FF are dictionary and map symbols used in the context of digital broadcasting. Numerous other symbols in this block and scattered in other blocks also have conventional uses as dictionary or map symbols. For example, these may indicate special uses for words, or indicate types of buildings, points of interest, particular activities or sports, and so on.

Plastic Bottle Material Code System. The seven numbered logos encoded from U+2673 to U+2679, ♳♴♵♶♷♸♹, are from "The Plastic Bottle Material Code System," which was introduced in 1988 by the Society of the Plastics Industry (SPI). This set consistently uses

thin, two-dimensional curved arrows suitable for use in plastics molding. In actual use, the symbols often are combined with an abbreviation of the material class below the triangle. Such abbreviations are not universal; therefore, they are not present in the representative glyphs in the code charts.

Recycling Symbol for Generic Materials. An unnumbered plastic resin code symbol U+267A ♺ RECYCLING SYMBOL FOR GENERIC MATERIALS is not formally part of the SPI system but is found in many fonts. Occasional use of this symbol as a generic materials code symbol can be found in the field, usually with a text legend below, but sometimes also surrounding or overlaid by other text or symbols. Sometimes the UNIVERSAL RECYCLING SYMBOL is substituted for the generic symbol in this context.

Universal Recycling Symbol. Unicode encodes two common glyph variants of this symbol: U+2672 ♲ UNIVERSAL RECYCLING SYMBOL and U+267B ♻ BLACK UNIVERSAL RECYCLING SYMBOL. Both are used to indicate that the material is recyclable. The white form is the traditional version of the symbol, but the black form is sometimes substituted, presumably because the thin outlines of the white form do not always reproduce well.

Paper Recycling Symbols. The two paper recycling symbols, U+267C ♼ RECYCLED PAPER SYMBOL and U+267D ♽ PARTIALLY-RECYCLED PAPER SYMBOL, can be used to distinguish between fully and partially recycled fiber content in paper products or packaging. They are usually accompanied by additional text.

Gender Symbols. The characters in the range U+26A2..U+26A9 are gender symbols. These are part of a set with U+2640 FEMALE SIGN, U+2642 MALE SIGN, U+26AA MEDIUM WHITE CIRCLE, and U+26B2 NEUTER. They are used in sexual studies and biology, for example. Some of these symbols have other uses as well, as astrological or alchemical symbols.

Genealogical Symbols. The characters in the range U+26AD..U+26B1 are sometimes seen in genealogical tables, where they indicate marriage and burial status. They may be augmented by other symbols, including the small circle indicating betrothal.

Game Symbols. This block also contains a variety of small symbol sets intended for the representation of common game symbols or tokens in text. These include symbols for playing card suits, often seen in manuals for bridge and other card games, as well as a set of dice symbols. The chess symbols are often seen in old-style chess notation. In addition, there are symbols for game pieces or notation markers for go, shogi (Japanese chess), and draughts (checkers).

Larger sets of game symbols are encoded in their own blocks. See the discussion of mahjong tile symbols and domino tile symbols later in this section.

Miscellaneous Symbols in Other Blocks. In addition to the blocks described in this section, which are devoted entirely to sets of miscellaneous symbols, there are many other blocks which contain small numbers of otherwise uncategorized symbols. See, for example, the Miscellaneous Symbols and Arrows block U+2B00..U+2B7F and the Enclosed Alphanumeric Supplement block U+1F100..U+1F1FF. Some of these blocks contain symbols which extend or complement sets of symbols contained in the Miscellaneous Symbols block.

Dingbats: U+2700–U+27BF

The Dingbats are derived from a well-established set of glyphs, the ITC Zapf Dingbats series 100, which constitutes the industry standard "Zapf Dingbat" font currently available in most laser printers. Other series of dingbat glyphs also exist, but are not encoded in the Unicode Standard because they are not widely implemented in existing hardware and software as character-encoded fonts. The order of the Dingbats block basically follows the PostScript encoding.

Unifications. Where a dingbat from the ITC Zapf Dingbats series 100 could be unified with a generic symbol widely used in other contexts, only the generic symbol was encoded. This accounts for the encoding gaps in the Dingbats block. Examples of such unifications include card suits, BLACK STAR, BLACK TELEPHONE, and BLACK RIGHT-POINTING INDEX (see the Miscellaneous Symbols block); BLACK CIRCLE and BLACK SQUARE (see the Geometric Shapes block); white encircled numbers 1 to 10 (see the Enclosed Alphanumerics block); and several generic arrows (see the Arrows block). Those four entries appear elsewhere in this chapter.

In other instances, other glyphs from the ITC Zapf Dingbats series 100 glyphs have come to be recognized as having applicability as generic symbols, despite having originally been encoded in the Dingbats block. For example, the series of negative (black) circled numbers 1 to 10 are now treated as generic symbols for this sequence, the continuation of which can be found in the Enclosed Alphanumerics block. Other examples include U+2708 AIRPLANE and U+2709 ENVELOPE, which have definite semantics independent of the specific glyph shape, and which therefore should be considered generic symbols rather than symbols representing only the Zapf Dingbats glyph shapes.

For many of the remaining characters in the Dingbats block, their semantic value is primarily their shape; unlike characters that represent letters from a script, there is no well-established range of typeface variations for a dingbat that will retain its identity and therefore its semantics. It would be incorrect to arbitrarily replace U+279D TRIANGLE-HEADED RIGHTWARDS ARROW with any other right arrow dingbat or with any of the generic arrows from the Arrows block (U+2190..U+21FF). However, exact shape retention for the glyphs is not always required to maintain the relevant distinctions. For example, ornamental characters such as U+2741 EIGHT PETALLED OUTLINED BLACK FLORETTE have been successfully implemented in font faces other than Zapf Dingbats with glyph shapes that are similar, but not identical to the ITC Zapf Dingbats series 100.

The following guidelines are provided for font developers wishing to support this block of characters. Characters showing large sets of contrastive glyph shapes in the Dingbats block, and in particular the various arrow shapes at U+2794..U+27BE, should have glyphs that are closely modeled on the ITC Zapf Dingbats series 100, which are shown as representative glyphs in the code charts. The same applies to the various stars, asterisks, snowflakes, dropshadowed squares, check marks, and x's, many of which are ornamental and have elaborate names describing their glyphs.

Where the preceding guidelines do not apply, or where dingbats have more generic applicability as symbols, their glyphs do not need to match the representative glyphs in the code charts in every detail.

Ornamental Brackets. The 14 ornamental brackets encoded at U+2768..U+2775 are part of the set of Zapf Dingbats. Although they have always been included in Zapf Dingbats fonts, they were unencoded in PostScript versions of the fonts on some platforms. The Unicode Standard treats these brackets as punctuation characters.

Mahjong Tiles: U+1F000–U+1F02F

The characters in this block are game symbols representing the set of tiles used to play the popular Chinese game of mahjong. The exact origin of mahjong is unknown, but it has been around since at least the mid-nineteenth century, and its popularity spread to Japan, Britain, and the United States during the early twentieth century.

Like other game symbols in the Unicode Standard, the mahjong tile symbols are intended as abstractions of graphical symbols for game pieces used in text. Simplified, iconic representation of mahjong pieces are printed in game manuals and appear in discussion about the game. There is some variation in the exact set of tiles used in different countries, so the

Unicode Standard encodes a superset of the graphical symbols for the tiles used in the various local traditions. The main set of tiles consists of three suits with nine numerical tiles each: the Bamboos, the Circles, and the Characters.

Additional tiles include the Dragons, the Winds, the Flowers, and the Seasons. The blank tile symbol is the so-called *white dragon*. Also included is a black tile symbol, which does not represent an actual game tile, but rather indicates a facedown tile, occasionally seen as a symbol in text about playing mahjong.

Domino Tiles: U+1F030–U+1F09F

This block contains a set of graphical symbols for domino tiles. Dominoes is a game which derives from Chinese tile games dating back to the twelfth century.

Domino tile symbols are used for the "double-six" set of tiles, which is the most common set of dominoes and the only one widely attested in manuals and textual discussion using graphical tile symbols.

The domino tile symbols do not represent the domino pieces per se, but instead constitute graphical symbols for particular orientations of the dominoes, because orientation of the tiles is significant in discussion of dominoes play. Each visually distinct rotation of a domino tile is separately encoded. Thus, for example, both U+1F081 DOMINO TILE VERTICAL-04-02 and U+1F04F DOMINO TILE HORIZONTAL-04-02 are encoded, as well as U+1F075 DOMINO TILE VERTICAL- 02-04 and U+1F043 DOMINO TILE HORIZONTAL-02-04. All four of those symbols represent the same game tile, but each orientation of the tile is visually distinct and requires its own symbol for text. The digits in the character names for the domino tile symbols reflect the dot patterns on the tiles.

Two symbols do not represent particular tiles of the double-six set of dominoes, but instead are graphical symbols for a domino tile turned facedown.

Yijing Hexagram Symbols: U+4DC0–U+4DFF

Usage of the Yijing Hexagram Symbols in China begins with a text called《周易》*Zhou Yi,* ("the Zhou Dynasty classic of change"), said to have originated circa 1000 BCE. This text is now popularly known as the *Yijing*, *I Ching*, or *Book of Changes*. These symbols represent a primary level of notation in this ancient philosophical text, which is traditionally considered the first and most important of the Chinese classics. Today, these symbols appear in many print and electronic publications, produced in Asia and all over the world. The important Chinese character lexicon *Hanyu Da Zidian*, for example, makes use of these symbols in running text. These symbols are semantically distinct written signs associated with specific words. Each of the 64 hexagrams has a unique one- or two-syllable name. Each hexagram name is intimately connected with interpretation of the six lines. Related characters are Monogram and Digram Symbols (U+268A..U+268F), Yijing Trigram Symbols (U+2630..U+2637), and Tai Xuan Jing Symbols (U+1D300..U+1D356).

Tai Xuan Jing Symbols: U+1D300–U+1D356

Usage of these symbols in China begins with a text called《太玄經》*Tai Xuan Jing* (literally, "the exceedingly arcane classic"). Composed by a man named 楊雄 Yang Xiong (53 BCE–18 CE), the first draft of this work was completed in 2 BCE, in the decade before the fall of the Western Han Dynasty. This text is popularly known in the West under several titles, including *The Alternative I Ching* and *The Elemental Changes*. A number of annotated editions of *Tai Xuan Jing* have been published and reprinted in the 2,000 years since the original work appeared.

These symbols represent a primary level of notation in the original ancient text, following and expanding upon the traditions of the Chinese classic *Yijing*. The tetragram signs are less well known and less widely used than the hexagram signs. For this reason they were encoded on Plane 1 rather than the BMP.

Monograms. U+1D300 MONOGRAM FOR EARTH is an extension of the traditional Yijing monogram symbols, U+268A MONOGRAM FOR YANG and U+268B MONOGRAM FOR YIN. Because *yang* is typically associated with heaven (Chinese *tian*) and *yin* is typically associated with earth (Chinese *di*), the character U+1D300 has an unfortunate name. Tai Xuan Jing studies typically associate it with human (Chinese *ren*), as midway between heaven and earth.

Digrams. The range of characters U+1D301..U+1D302 constitutes an extension of the Yijing digram symbols encoded in the range U+268C..U+268F. They consist of the combinations of the human (*ren*) monogram with either the *yang* or the *yin* monogram. Because of the naming problem for U+1D300, these digrams also have infelicitous character names. Users are advised to identify the digram symbols by their representative glyphs or by the Chinese aliases provided for them in the code charts.

Tetragrams. The bulk of the symbols in the Tai Xuan Jing Symbols block are the tetragram signs. These tetragram symbols are semantically distinct written signs associated with specific words. Each of the 81 tetragrams has a unique monosyllabic name, and each tetragram name is intimately connected with interpretation of the four lines.

The 81 tetragram symbols (U+1D306..U+1D356) encoded on Plane 1 constitute a complete set. Within this set of 81 signs, a subset of 16 signs known as the Yijing tetragrams is of importance to Yijing scholarship. These are used in the study of the "nuclear trigrams." Related characters are the Yijing Trigram symbols (U+2630..U+2637) and the Yijing Hexagram symbols (U+4DC0..U+4DFF).

Ancient Symbols: U+10190–U+101CF

This block contains ancient symbols, none of which are in modern use. Typically, they derive from ancient epigraphic, papyrological, or manuscript traditions, and represent miscellaneous symbols not specifically included in blocks dedicated to particular ancient scripts. The first set of these consists of ancient Roman symbols for weights and measures, and symbols used in Roman coinage.

Similar symbols can be found in the Ancient Greek Numbers block, U+10140..U+1018F

Phaistos Disc Symbols: U+101D0–U+101FF

The Phaistos disc was found during an archaeological dig in Phaistos, Crete about a century ago. The small fired clay disc is imprinted on both sides with a series of symbols, arranged in a spiral pattern. The disc probably dates from the mid-18th to the mid-14th century BCE.

The symbols have not been deciphered, and the disc remains the only known example of these symbols. Because there is nothing to compare them to, and the corpus is so limited, it is not even clear whether the symbols constitute a writing system for a language or are something else entirely. Nonetheless, the disc has engendered great interest, and numerous scholars and amateurs spend time discussing the symbols.

The repertoire of symbols is noncontroversial, as they were incised in the disc by stamping preformed seals into the clay. Most of the symbols are clearly pictographic in form. The entire set is encoded in the Phaistos Disc Symbols block as a set of symbols, with no assumptions about their possible meaning and functions. One combining mark is

encoded. It represents a hand-carved mark on the disc, which occurs attached to the final sign of groups of other symbols.

15.9 Enclosed and Square

There are a large number of compatibility symbols in the Unicode Standard which consist either of letters or numbers enclosed in some graphic element, or which consist of letters or numbers in a square arrangement. Many of these symbols are derived from legacy East Asian character sets, in which such symbols are commonly encoded as elements.

Enclosed Symbols. Enclosed symbols typically consist of a letter, digit, Katakana syllable, Hangul jamo, or CJK ideograph enclosed in a circle or a square. In some cases the enclosure may consist of a pair of parentheses or tortoise-shell brackets, and the enclosed element may also consist of more than a single letter or digit, as for circled numbers 10 through 50. Occasionally the symbol is shown as white on a black encircling background, in which case the character name typically includes the word NEGATIVE.

Many of the enclosed symbols that come in small, ordered sets—the Latin alphabet, kana, jamo, digits, and Han ideographs one through ten—were originally intended for use in text as numbered bullets for lists. Parenthetical enclosures were in turn developed to mimic typewriter conventions for representing circled letters and digits used as list bullets. This functionality has now largely been supplanted by styles and other markup in rich text contexts, but the enclosed symbols in the Unicode Standard are encoded for interoperability with the legacy East Asian character sets and for the occasional text context where such symbols otherwise occur.

A few of the enclosed symbols have conventional meanings unrelated to the usage of encircled letters and digits as list bullets. In some instances these are distinguished in the standard—often because legacy standards separately encoded them. Thus, for example, U+24B8 Ⓒ CIRCLED LATIN CAPITAL LETTER C is distinct from U+00A9 © COPYRIGHT SIGN, even though the two symbols are obviously similar in appearance. In cases where otherwise generic enclosed symbols have specific conventional meanings, those meanings are called out in the code charts with aliases or other annotations. For example, U+1F157 🅗 NEGATIVE CIRCLED LATIN CAPITAL LETTER H is also a commonly occurring map symbol for "hotel."

Square Symbols. Another convention commonly seen in East Asian character sets is the creation of compound symbols by stacking two, three, four, or even more small-sized letters or syllables into a square shape consistent with the typical rendering footprint of a CJK ideograph. One subset of these consists of square symbols for Latin abbreviations, often for SI and other technical units, such as "km" or "km/h"; these square symbols are mostly derived from Korean legacy standards. Another subset consists of Katakana words for units of measurement, classified ad symbols, and many other similar word elements stacked into a square array; these symbols are derived from Japanese legacy standards. A third major subset consists of Chinese telegraphic symbols for hours, days, and months, consisting of a digit or sequence of digits next to the CJK ideograph for "hour," "day" or "month."

Source Standards. Major sources for the repertoire of enclosed and square symbols in the Unicode Standard include the Korean national standard, KS X 1001:1998; the Chinese national standard, GB 2312:1980; the Japanese national standards JIS X 0208-1997 and JIS X 0213:2000; and CNS 11643. Others derive from the Japanese television standard, ARIB STD B24, and from various East Asian industry standards or corporate glyph registries.

Allocation. The Unicode Standard includes five blocks allocated for the encoding of various enclosed and square symbols. Each of those blocks is described briefly in the text that

follows, to indicate which subsets of these symbols it contains and to highlight any other special considerations that may apply to each block. In addition, there are a number of circled digit and number symbols encoded in the Dingbats block (U+2700..U+27BF). Those circled symbols occur in the ITC Zapf dingbats series 100, and most of them were encoded with other Zapf dingbat symbols, rather than being allocated in the separate blocks for enclosed and square symbols. Finally, a small number of circled symbols from ISO/IEC 8859-1 or other sources can be found in the Latin-1 Supplement block (U+0080..U+00FF) or the Letterlike Symbols block (U+2100..U+214F).

Decomposition. Nearly all of the enclosed and square symbols in the Unicode Standard are considered compatibility characters, encoded for interoperability with other character sets. A significant majority of those are also compatibility decomposable characters, given explicit compatibility decompositions in the Unicode Character Database. The general patterns for these decompositions are described here. For full details for any particular one of these symbols, see the code charts or consult the data files in the UCD.

Parenthesized symbols are decomposed to sequences of opening and closing parentheses surrounding the letter or digit(s) of the symbol. Square symbols consisting of digit(s) followed by a full stop or a comma are decomposed into the digit sequence and the full stop or comma. Square symbols consisting of stacks of Katakana syllables are decomposed into the corresponding sequence of Katakana characters and are given the decomposition tag "<square>". Similar principles apply to square symbols consisting of sequences of Latin letters and symbols. Chinese telegraphic symbols, consisting of sequences of digits and CJK ideographs, are given compatibility decompositions, but do not have the decomposition tag "<square>".

Circled symbols consisting of a single letter or digit surrounded by a simple circular graphic element are given compatibility decompositions with the decomposition tag "<circle>". Circled symbols with more complex graphic styles, including double circled and negative circled symbols, are simply treated as atomic symbols, and are not decomposed. The same decompositional pattern is applied to enclosed symbols where the enclosure is a square graphic element instead of a circle, except that the decomposition tag in those cases is "<square>". Occasionally a "circled" symbol that involves a sequence of Latin letters is preferentially represented with an ellipse surrounding the letters, as for U+1F12E 🄮 CIRCLED WZ, the German *Warenzeichen*. Such elliptic shape is considered to be a typographical adaptation of the circle, and does not constitute a distinct decomposition type in the Unicode Standard.

It is important to realize that the decomposition of enclosed symbols in the Unicode Standard does not make them canonical equivalents to letters or digits in sequence with combining enclosing marks such as U+20DD ◌⃝ COMBINING ENCLOSING CIRCLE. The combining enclosing marks are provided in the Unicode Standard to enable the representation of occasional enclosed symbols not otherwise encoded as characters. There is also no defined way of indicating the application of a combining enclosing mark to more than a single base character. Furthermore, full rendering support of the application of enclosing combining marks, even to single base characters, is not widely available. Hence, in most instances, if an enclosed symbol is available in the Unicode Standard as a single encoded character, it is recommended to simply make use of that composed symbol.

Casing. There are special considerations for the casing relationships of enclosed or square symbols involving letters of the Latin alphabet. The *circled* letters of the Latin alphabet come in an uppercase set (U+24B6..U+24CF) and a lowercase set (U+24D0..U+24EA). Largely because the compatibility decompositions for those symbols are to a single letter each, these two sets are given the derived properties, Uppercase and Lowercase, respectively, and case map to each other. The superficially similar *parenthesized* letters of the Latin alphabet also come in an uppercase set (U+1F110..U+1F129) and a lowercase set

(U+24BC..U+24B5), but are not case mapped to each other and are not given derived casing properties. This difference is in part because the compatibility decompositions for these parenthesized symbols are to sequences involving parentheses, instead of single letters, and in part because the uppercase set was encoded many years later than the lowercase set.

Square symbols consisting of arbitrary sequences of Latin letters, which themselves may be of mixed case, are simply treated as caseless symbols in the Unicode Standard.

Enclosed Alphanumerics: U+2460–U+24FF

The enclosed symbols in this block consist of single Latin letters, digits, or numbers—most enclosed by a circle. The block also contains letters, digits, or numbers enclosed in parentheses, and a series of numbers followed by full stop. All of these symbols are intended to function as numbered (or lettered) bullets in ordered lists, and most are encoded for compatibility with major East Asian character sets.

The circled numbers one through ten (U+2461..U+2469) are also considered to be unified with the comparable set of circled black numbers with serifs on a white background from the ITC Zapf Dingbats series 100. Those ten symbols are encoded in this block, instead of in the Dingbats block.

The negative circled numbers eleven through twenty (U+24EB..U+24F4) are a continuation of the set of circled white numbers with serifs on a black background, encoded at U+2776..U+277F in the Dingbats block.

Enclosed CJK Letters and Months: U+3200–U+32FF

This block contains large sets of circled or parenthesized Japanese Katakana, Hangul jamo, or CJK ideographs, from East Asian character sets. It also contains circled numbers twenty-one through fifty, which constitute a continuation of the series of circled numbers from the Enclosed Alphanumerics block. There are also a small number of Chinese telegraph symbols and square Latin abbreviations, which are continuations of the larger sets primarily encoded in the CJK Compatibility block.

The enclosed symbols in the range U+3248..U+324F, which consist of circled numbers ten through eighty on white circles centered on black squares, are encoded for compatibility with the Japanese television standard, ARIB STD B24. In that standard, they are intended to represent symbols for speed limit signs, expressed in kilometers per hour.

CJK Compatibility: U+3300–U+33FF

The CJK Compatibility block consists entirely of square symbols encoded for compatibility with various East Asian character sets. These come in four sets: square Latin abbreviations, Chinese telegraph symbols for hours and days, squared Katakana words, and a small set of Japanese era names.

Squared Katakana words are Katakana-spelled words that fill a single display cell (em-square) when intermixed with CJK ideographs. Likewise, the square Latin abbreviation symbols are designed to fill a single character position when mixed with CJK ideographs. Note that modern software for the East Asian market can often support the comparable functionality via styles that allow typesetting of arbitrary Katakana words or Latin abbreviations in an em-square. Such solutions are preferred when available, as they are not limited to specific lists of encoded symbols such as those in this block.

Japanese Era Names. The Japanese era name symbols refer to the dates given in *Table 15-4*.

Table 15-4. Japanese Era Names

Code Point	Name	Dates
U+337B	SQUARE ERA NAME HEISEI	1989-01-07 to present day
U+337C	SQUARE ERA NAME SYOUWA	1926-12-24 to 1989-01-06
U+337D	SQUARE ERA NAME TAISYOU	1912-07-29 to 1926-12-23
U+337E	SQUARE ERA NAME MEIZI	1867 to 1912-07-28

Enclosed Alphanumeric Supplement: U+1F100–U+1F1FF

This block contains more enclosed and square symbols based on Latin letters or digits. Most are encoded for compatibility with the Japanese television standard, ARIB STD B24.

Enclosed Ideographic Supplement: U+1F200–U+1F2FF

This block consists mostly of enclosed ideographic symbols. It also contains some additional squared Katakana word symbols. As of Version 5.2, all of the symbols in this block are encoded for compatibility with the Japanese television standard, ARIB STD B24, intended primarily for use in closed captioning.

The enclosed ideographic symbols in the range U+1F210..U+1F231 are enclosed in a square, instead of a circle. One subset of these are symbols referring to broadcast terminology, and the other subset are symbols used in baseball in Japan.

The enclosed ideographic symbols in the range U+1F240..U+1F248 are enclosed in tortoise shell brackets, and are also used in baseball scoring in Japan.

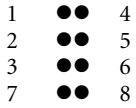
15.10 Braille

Braille Patterns: U+2800–U+28FF

Braille is a writing system used by blind people worldwide. It uses a system of six or eight raised dots, arranged in two vertical rows of three or four dots, respectively. Eight-dot systems build on six-dot systems by adding two extra dots above or below the core matrix. Six-dot Braille allows 64 possible combinations, and eight-dot Braille allows 256 possible patterns of dot combinations. There is no fixed correspondence between a dot pattern and a character or symbol of any given script. Dot pattern assignments are dependent on context and user community. A single pattern can represent an abbreviation or a frequently occurring short word. For a number of contexts and user communities, the series of ISO technical reports starting with ISO/TR 11548-1 provide standardized correspondence tables as well as invocation sequences to indicate a context switch.

The Unicode Standard encodes a single complete set of 256 eight-dot patterns. This set includes the 64 dot patterns needed for six-dot Braille.

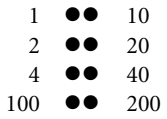
The character names for Braille patterns are based on the assignments of the dots of the Braille pattern to digits 1 to 8 as follows:



The designation of dots 1 to 6 corresponds to that of six-dot Braille. The additional dots 7 and 8 are added beneath. The character name for a Braille pattern consists of BRAILLE PAT-

TERN DOTS-12345678, where only those digits corresponding to dots in the pattern are included. The name for the empty pattern is BRAILLE PATTERN BLANK.

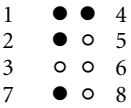
The 256 Braille patterns are arranged in the same sequence as in ISO/TR 11548-1, which is based on an octal number generated from the pattern arrangement. Octal numbers are associated with each dot of a Braille pattern in the following way:



The octal number is obtained by adding the values corresponding to the dots present in the pattern. Octal numbers smaller than 100 are expanded to three digits by inserting leading zeroes. For example, the dots of BRAILLE PATTERN DOTS-1247 are assigned to the octal values of 1_8, 2_8, 10_8, and 100_8. The octal number representing the sum of these values is 113_8.

The assignment of meanings to Braille patterns is outside the scope of this standard.

Example. According to ISO/TR 11548-2, the character LATIN CAPITAL LETTER F can be represented in eight-dot Braille by the combination of the dots 1, 2, 4, and 7 (BRAILLE PATTERN DOTS-1247). A full circle corresponds to a tangible (set) dot, and empty circles serve as position indicators for dots not set within the dot matrix:



Usage Model. The eight-dot Braille patterns in the Unicode Standard are intended to be used with either style of eight-dot Braille system, whether the additional two dots are considered to be in the top row or in the bottom row. These two systems are never intermixed in the same context, so their distinction is a matter of convention. The intent of encoding the 256 Braille patterns in the Unicode Standard is to allow input and output devices to be implemented that can interchange Braille data without having to go through a context-dependent conversion from semantic values to patterns, or vice versa. In this manner, final-form documents can be exchanged and faithfully rendered. At the same time, processing of textual data that require semantic support is intended to take place using the regular character assignments in the Unicode Standard.

Imaging. When output on a Braille device, dots shown as black are intended to be rendered as tangible. Dots shown in the standard as open circles are blank (not rendered as tangible). The Unicode Standard does not specify any physical dimension of Braille characters.

In the absence of a higher-level protocol, Braille patterns are output from left to right. When used to render final form (tangible) documents, Braille patterns are normally not intermixed with any other Unicode characters except control codes.

Script. Unlike other sets of symbols, the Braille Patterns are given their own, unique value of the Script property in the Unicode Standard. This follows both from the behavior of Braille in forming a consistent writing system on its own terms, as well as from the independent bibliographic status of books and other documents printed in Braille. For more information on the Script property, see Unicode Standard Annex #24, "Unicode Script Property."

15.11 Western Musical Symbols

Musical Symbols: U+1D100–U+1D1FF

The musical symbols encoded in the Musical Symbols block are intended to cover basic Western musical notation and its antecedents: mensural notation and plainsong (or Gregorian) notation. The most comprehensive coded language in regular use for representing sound is the common musical notation (CMN) of the Western world. Western musical notation is a system of symbols that is relatively, but not completely, self-consistent and relatively stable but still, like music itself, evolving. This open-ended system has survived over time partly because of its flexibility and extensibility. In the Unicode Standard, musical symbols have been drawn primarily from CMN. Commonly recognized additions to the CMN repertoire, such as quarter-tone accidentals, cluster noteheads, and shape-note noteheads, have also been included.

Graphical score elements are not included in the Musical Symbols block. These pictographs are usually created for a specific repertoire or sometimes even a single piece. Characters that have some specialized meaning in music but that are found in other character blocks are not included. They include numbers for time signatures and figured basses, letters for section labels and Roman numeral harmonic analysis, and so on.

Musical symbols are used worldwide in a more or less standard manner by a very large group of users. The symbols frequently occur in running text and may be treated as simple spacing characters with no special properties, with a few exceptions. Musical symbols are used in contexts such as theoretical works, pedagogical texts, terminological dictionaries, bibliographic databases, thematic catalogs, and databases of musical data. The musical symbol characters are also intended to be used within higher-level protocols, such as music description languages and file formats for the representation of musical data and musical scores.

Because of the complexities of layout and of pitch representation in general, the encoding of musical pitch is intentionally outside the scope of the Unicode Standard. The Musical Symbols block provides a common set of elements for interchange and processing. Encoding of pitch, and layout of the resulting musical structure, involves specifications not only for the vertical relationship between multiple notes simultaneously, but also in multiple staves, between instrumental parts, and so forth. These musical features are expected to be handled entirely in higher-level protocols making use of the graphical elements provided. Lack of pitch encoding is not a shortcoming, but rather is a necessary feature of the encoding.

Glyphs. The glyphs for musical symbols shown in the code charts, are representative of typical cases; however, note in particular that the stem direction is not specified by the Unicode Standard and can be determined only in context. For a font that is intended to provide musical symbols in running text, either stem direction is acceptable. In some contexts—particularly for applications in early music—note heads, stems, flags, and other associated symbols may need to be rendered in different colors—for example, red.

Symbols in Other Blocks. U+266D MUSIC FLAT SIGN, U+266E MUSIC NATURAL SIGN, and U+266F MUSIC SHARP SIGN—three characters that occur frequently in musical notation—are encoded in the Miscellaneous Symbols block (U+2600..U+267F). However, four characters also encoded in that block are to be interpreted merely as dingbats or miscellaneous symbols, not as representing actual musical notes:

U+2669 QUARTER NOTE

U+266A EIGHTH NOTE

U+266B BEAMED EIGHTH NOTES

U+266C BEAMED SIXTEENTH NOTES

Gregorian. The *punctum*, or Gregorian *brevis*, a square shape, is unified with U+1D147 MUSICAL SYMBOL SQUARE NOTEHEAD BLACK. The Gregorian *semibrevis*, a diamond or lozenge shape, is unified with U+1D1BA MUSICAL SYMBOL SEMIBREVIS BLACK. Thus Gregorian notation, medieval notation, and modern notation either require separate fonts in practice or need font features to make subtle differentiations between shapes where required.

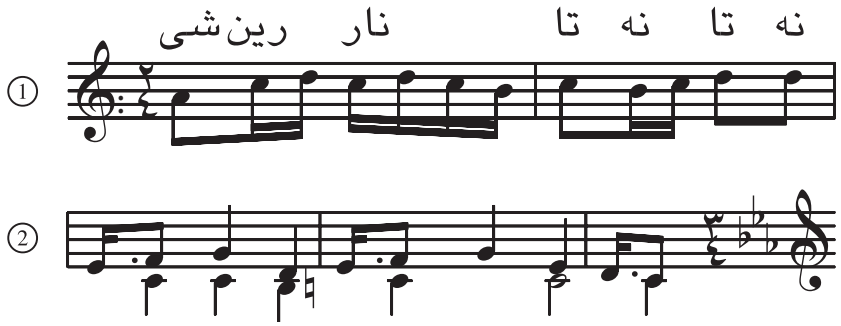
Processing. Most musical symbols can be thought of as simple spacing characters when used inline within texts and examples, even though they behave in a more complex manner in full musical layout. Some characters are meant only to be combined with others to produce combined character sequences, representing musical notes and their particular articulations. Musical symbols can be input, processed, and displayed in a manner similar to mathematical symbols. When embedded in text, most of the symbols are simple spacing characters with no special properties. A few characters have format control functions, as described later in this section.

Input Methods. Musical symbols can be entered via standard alphanumeric keyboard, via piano keyboard or other device, or by a graphical method. Keyboard input of the musical symbols may make use of techniques similar to those used for Chinese, Japanese, and Korean. In addition, input methods utilizing pointing devices or piano keyboards could be developed similar to those in existing musical layout systems. For example, within a graphical user interface, the user could choose symbols from a palette-style menu.

Directionality. When combined with right-to-left texts—in Hebrew or Arabic, for example—the musical notation is usually written from left to right in the normal manner. The words are divided into syllables and placed under or above the notes in the same fashion as for Latin and other left-to-right scripts. The individual words or syllables corresponding to each note, however, are written in the dominant direction of the script.

The opposite approach is also known: in some traditions, the musical notation is actually written from right to left. In that case, some of the symbols, such as clef signs, are mirrored; other symbols, such as notes, flags, and accidentals, are *not* mirrored. All responsibility for such details of bidirectional layout lies with higher-level protocols and is not reflected in any character properties. *Figure 15-9* exemplifies this principle with two musical passages. The first example shows Turkish lyrics in Arabic script with ordinary left-to-right musical notation; the second shows right-to-left musical notation. Note the partial mirroring.

Figure 15-9. Examples of Specialized Music Layout



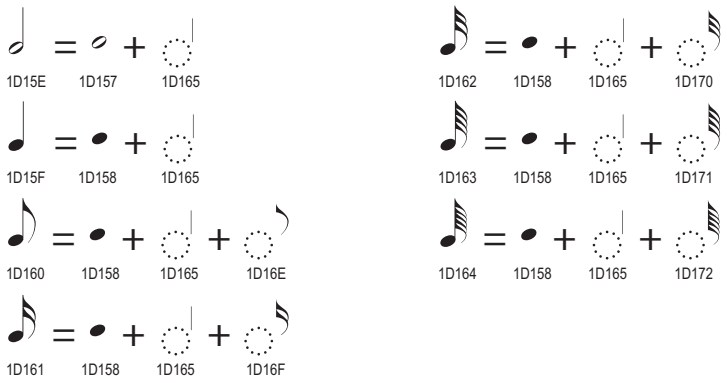
Format Characters. Extensive ligature-like beams are used frequently in musical notation between groups of notes having short values. The practice is widespread and very predictable, so it is therefore amenable to algorithmic handling. The format characters U+1D173 MUSICAL SYMBOL BEGIN BEAM and U+1D174 MUSICAL SYMBOL END BEAM can be used to indicate the extents of beam groupings. In some exceptional cases, beams are left unclosed on one end. This status can be indicated with a U+1D159 MUSICAL SYMBOL NULL NOTEHEAD character if no stem is to appear at the end of the beam.

Similarly, format characters have been provided for other connecting structures. The characters U+1D175 MUSICAL SYMBOL BEGIN TIE, U+1D176 MUSICAL SYMBOL END TIE, U+1D177 MUSICAL SYMBOL BEGIN SLUR, U+1D178 MUSICAL SYMBOL END SLUR, U+1D179 MUSICAL SYMBOL BEGIN PHRASE, and U+1D17A MUSICAL SYMBOL END PHRASE indicate the extent of these features. Like beaming, these features are easily handled in an algorithmic fashion.

These pairs of characters modify the layout and grouping of notes and phrases in full musical notation. When musical examples are written or rendered in plain text without special software, the start/end format characters may be rendered as brackets or left uninterpreted. To the extent possible, more sophisticated software that renders musical examples inline with natural-language text might interpret them in their actual format control capacity, rendering slurs, beams, and so forth, as appropriate.

Precomposed Note Characters. For maximum flexibility, the character set includes both precomposed note values and primitives from which complete notes may be constructed. The precomposed versions are provided mainly for convenience. However, if any normalization form is applied, including NFC, the characters will be decomposed. For further information, see *Section 3.11, Normalization Forms*. The canonical equivalents for these characters are given in the Unicode Character Database and are illustrated in *Figure 15-10*.

Figure 15-10. Precomposed Note Characters

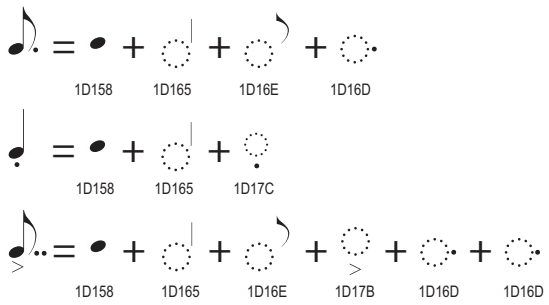


Alternative Noteheads. More complex notes built up from alternative noteheads, stems, flags, and articulation symbols are necessary for complete implementations and complex scores. Examples of their use include American shape-note and modern percussion notations, as shown in *Figure 15-11*.

Figure 15-11. Alternative Noteheads

Augmentation Dots and Articulation Symbols. Augmentation dots and articulation symbols may be appended to either the precomposed or built-up notes. In addition, augmentation dots and articulation symbols may be repeated as necessary to build a complete note symbol. Examples of the use of augmentation dots are shown in *Figure 15-12*.

Figure 15-12. Augmentation Dots and Articulation Symbols



Ornamentation. *Table 15-5* lists common eighteenth-century ornaments and the sequences of characters from which they can be generated.

Table 15-5. Examples of Ornamentation

	1D19C STROKE-2 + 1D19D STROKE-3
	1D19C STROKE-2 + 1D1A0 STROKE-6 + 1D19D STROKE-3
	1D1A0 STROKE-6 + 1D19C STROKE-2 + 1D19C STROKE-2 + 1D19D STROKE-3
	1D19C STROKE-2 + 1D19C STROKE-2 + 1D1A0 STROKE-6 + 1D19D STROKE-3
	1D19C STROKE-2 + 1D19C STROKE-2 + 1D1A3 STROKE-9
	1D1A1 STROKE-7 + 1D19C STROKE-2 + 1D19C STROKE-2 + 1D19D STROKE-3
	1D1A2 STROKE-8 + 1D19C STROKE-2 + 1D19C STROKE-2 + 1D19D STROKE-3
	1D19C STROKE-2 + 1D19C STROKE-2 + 1D19D STROKE-3 + 1D19F STROKE-5
	1D1A1 STROKE-7 + 1D19C STROKE-2 + 1D19C STROKE-2 + 1D1A0 STROKE-6 + 1D19D STROKE-3
	1D1A1 STROKE-7 + 1D19C STROKE-2 + 1D19C STROKE-2 + 1D19D STROKE-3 + 1D19F STROKE-5
	1D1A2 STROKE-8 + 1D19C STROKE-2 + 1D19C STROKE-2 + 1D1A0 STROKE-6 + 1D19D STROKE-3
	1D19B STROKE-1 + 1D19C STROKE-2 + 1D19C STROKE-2 + 1D19D STROKE-3
	1D19B STROKE-1 + 1D19C STROKE-2 + 1D19C STROKE-2 + 1D19D STROKE-3 + 1D19E STROKE-4
	1D19C STROKE-2 + 1D19D STROKE-3 + 1D19E STROKE-4

15.12 Byzantine Musical Symbols

Byzantine Musical Symbols: U+1D000–U+1D0FF

Byzantine musical notation first appeared in the seventh or eighth century CE, developing more fully by the tenth century. These musical symbols are chiefly used to write the religious music and hymns of the Christian Orthodox Church, although folk music manuscripts are also known. In 1881, the Orthodox Patriarchy Musical Committee redefined some of the signs and established the New Analytical Byzantine Musical Notation System, which is in use today. About 95 percent of the more than 7,000 musical manuscripts using this system are in Greek. Other manuscripts are in Russian, Bulgarian, Romanian, and Arabic.

Processing. Computer representation of Byzantine musical symbols is quite recent, although typographic publication of religious music books began in 1820. Two kinds of applications have been developed: applications to enable musicians to write the books they use, and applications that compare or convert this musical notation system to the standard Western system. (See *Section 15.11, Western Musical Symbols*.)

Byzantine musical symbols are divided into 15 classes according to function. Characters interact with one another in the horizontal and vertical dimension. There are three horizontal "stripes" in which various classes generally appear and rules as to how other characters interact within them. These rules, which are still being specified, are the responsibilities of higher-level protocols.

15.13 Ancient Greek Musical Notation

Ancient Greek Musical Notation: U+1D200–U+1D24F

Ancient Greeks developed their own distinct system of musical notation, which is found in a large number of ancient texts ranging from a fragment of Euripides' *Orestes* to Christian hymns. It is also used in the modern publication of these texts as well as in modern studies of ancient music.

The system covers about three octaves, and symbols can be grouped by threes: one symbol corresponds to a "natural" note on a diatonic scale, and the two others to successive sharpenings of that first note. There is no distinction between enharmonic and chromatic scales. The system uses two series of symbols: one for vocal melody and one for instrumental melody.

The symbols are based on Greek letters, comparable to the modern usage of the Latin letters A through G to refer to notes of the Western musical scale. However, rather than using a sharp and flat notation to indicate semitones, or casing and other diacritics to indicate distinct octaves, the Ancient Greek system extended the basic Greek alphabet by rotating and flipping letterforms in various ways and by adding a few more symbols not directly based on letters.

Unification. In the Unicode Standard, the vocal and instrumental systems are unified with each other and with the basic Greek alphabet, based on shape. *Table 15-6* gives the correspondence between modern notes, the numbering used by modern scholars, and the Unicode characters or sequences of characters to use to represent them.

Naming Conventions. The character names are based on the standard names widely used by modern scholars. There is no standardized ancient system for naming these characters.

Table 15-6. Representation of Ancient Greek Vocal and Instrumental Notation

Modern Note	Modern Number	Vocal Notation	Instrumental Notation
g”	70	2127, 0374	1D23C, 0374
	69	0391, 0374	1D23B, 0374
	68	0392, 0374	1D23A, 0374
f”	67	0393, 0374	039D, 0374
	66	0394, 0374	1D239, 0374
	65	0395, 0374	1D208, 0374
e”	64	0396, 0374	1D238, 0374
	63	0397, 0374	1D237, 0374
	62	0398, 0374	1D20D, 0374
d”	61	0399, 0374	1D236, 0374
	60	039A, 0374	1D235, 0374
	59	039B, 0374	1D234, 0374
c”	58	039C, 0374	1D233, 0374
	57	039D, 0374	1D232, 0374
	56	039E, 0374	1D20E, 0374
b’	55	039F, 0374	039A, 0374
	54	1D21C	1D241
	53	1D21B	1D240
a’	52	1D21A	1D23F
	51	1D219	1D23E
	50	1D218	1D23D
g’	49	2127	1D23C
	48	0391	1D23B
	47	0392	1D23A
f’	46	0393	039D
	45	0394	1D239
	44	0395	1D208
e’	43	0396	1D238
	42	0397	1D237
	41	0398	1D20D
d’	40	0399	1D236
	39	039A	1D235
	38	039B	1D234
c’	37	039C	1D233
	36	039D	1D232
	35	039E	1D20E
b	34	039F	039A
	33	03A0	03FD
	32	03A1	1D231
a	31	03F9	03F9
	30	03A4	1D230
	29	03A5	1D22F
g	28	03A6	1D213
	27	03A7	1D22E
	26	03A8	1D22D
f	25	03A9	1D22C
	24	1D217	1D22B
	23	1D216	1D22A
e	22	1D215	0393
	21	1D214	1D205
	20	1D213	1D21C
d	19	1D212	1D229
	18	1D211	1D228

Table 15-6. Representation of Ancient Greek Vocal and Instrumental Notation (Continued)

Modern Note	Modern Number	Vocal Notation	Instrumental Notation
	17	1D210	1D227
c	16	1D20F	0395
	15	1D20E	1D211
	14	1D20D	1D226
B	13	1D20C	1D225
	12	1D20B	1D224
	11	1D20A	1D223
A	10	1D209	0397
	9	1D208	1D206
	8	1D207	1D222
G	7	1D206	1D221
	6	1D205	03A4
	5	1D204	1D220
F	4	1D203	1D21F
	3	1D202	1D202
	2	1D201	1D21E
E	1	1D200	1D21D

Apparent gaps in the numbering sequence are due to the unification with standard letters and between vocal and instrumental notations.

If a symbol is used in both the vocal notation system and the instrumental notation system, its Unicode character name is based on the vocal notation system catalog number. Thus U+1D20D GREEK VOCAL NOTATION SYMBOL-14 has a glyph based on an inverted capital lambda. In the vocal notation system, it represents the first sharp of B; in the instrumental notation system, it represents the first sharp of d'. Because it is used in both systems, its name is based on its sequence in the vocal notation system, rather than its sequence in the instrumental notation system. The character names list in the Unicode Character Database is fully annotated with the functions of the symbols for each system.

Font. Scholars usually typeset musical characters in sans-serif fonts to distinguish them from standard letters, which are usually represented with a serifed font. However, this is not required. The code charts use a font without serifs for reasons of clarity.

Combining Marks. The combining marks encoded in the range U+1D242..U+1D244 are placed over the vocal or instrumental notation symbols. They are used to indicate metrical qualities.

