
Unicode
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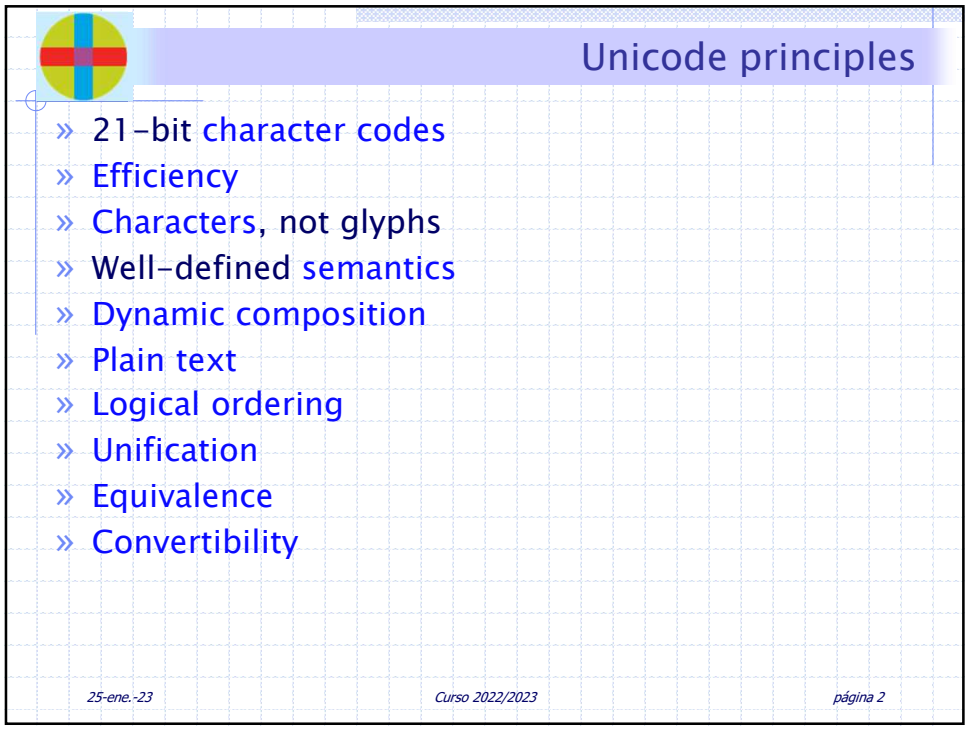
Unicode principles
» 21-bit character codes
» Efficiency
» Characters, not glyphs
» Well-defined semantics
» Dynamic composition
» Plain text
» Logical ordering
» Unification
» Equivalence
» Convertibility
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Character Codes & Efficiency

» Character Codes
- Unicode 4.0 had 57,129 16-bit characters out of a total maximum of 63,470
- A further 45,718 rare or archaic characters are encoded with two consecutive 16-bit code units from reserved ranges (called "surrogates")

» Efficiency
- No special escape or shift characters required
- All representations of Unicode are self-synchronizing and can be randomly accessed
- Formatting characters are kept to a minimum

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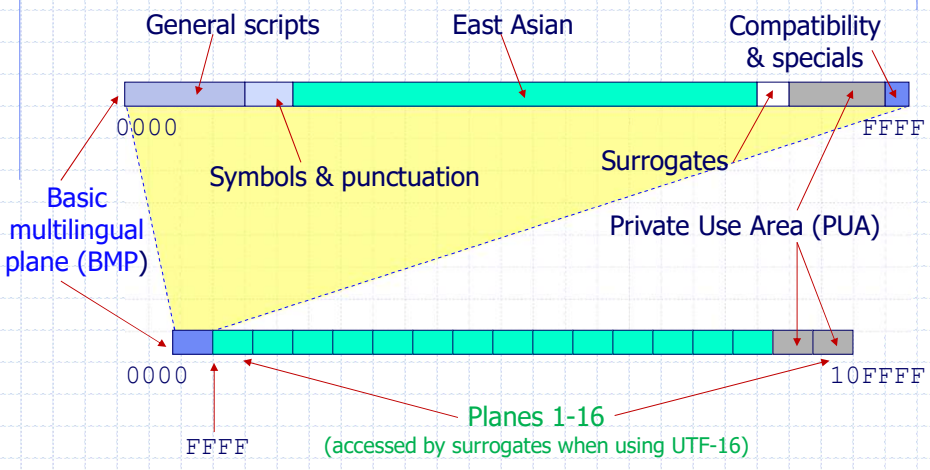
Unicode code space



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Characters vs. Glyphs

- **Character**: the smallest component of written language that has semantic value.
- **Glyph**: represents the shape of a character when rendered or displayed.

- Fonts contain **glyphs**, not characters
- Latin A and Greek A (alpha) are distinct characters with the same glyph
- Arabic letters need up to four glyphs (initial, medial, final, isolated)
- "f" plus "i" is rendered with a single merged glyph in fine typesetting

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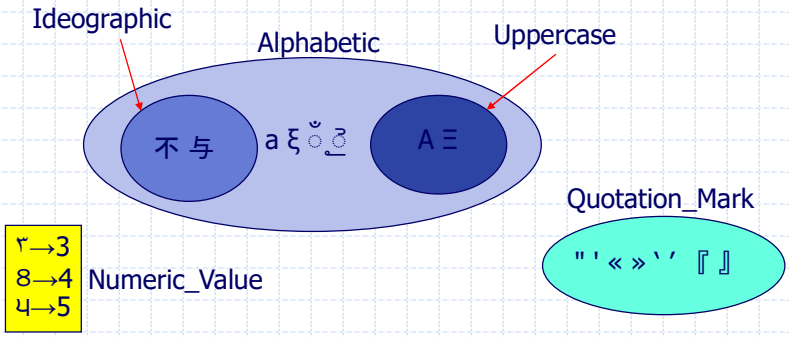
Well-defined Semantics

- Tables generated by the Unicode Consortium give the properties of characters
  - Letter, number, punctuation mark, symbol, diacritic, whitespace …



- Case mapping, Arabic shaping, normalization …

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Unicode General Categories

- **Letters**: upper, lower, title, modifier, other (syllables, ideographs, etc.)
- **Numbers**: digit, letter, other
- **Punctuation**: connector, dash, open, close, initial-quote, final-quote, other
- **Marks**: non-spacing, enclosing, other
- **Symbols**: math, currency, modifier, other
- **Separators**: space, line, paragraph
- **Other**: control, format, surrogate, private-use

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Case Mapping & Normalization

- **Case Mapping**

  dz ↔ Dz ↔ DZ

  Heiß → HEISS → heiss

  ὀσος ↔ ΌΣΟΣ

  topkapı istanbul ↔$_{tr}$ TOPKAPI İSTANBUL

- **Normalization**

  ä U+00E4

  = a + ¨ U+0061 + U+0308

  - Equivalent text – equivalent behavior
  - Same display (for supported repertoire)
  - Normalization generates unique forms

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Dynamic Composition & Plain Text

» Dynamic Composition
- There is no character LATIN CAPITAL LETTER Q WITH CIRCUMFLEX
  - › It can be represented as LATIN CAPITAL LETTER Q followed by U+0302 COMBINING CIRCUMFLEX
  - › COMBINING CIRCUMFLEX isn't the same character as ASCII "^"
- Fonts can have a precomposed glyph for LATIN CAPITAL LETTER Q WITH CIRCUMFLEX

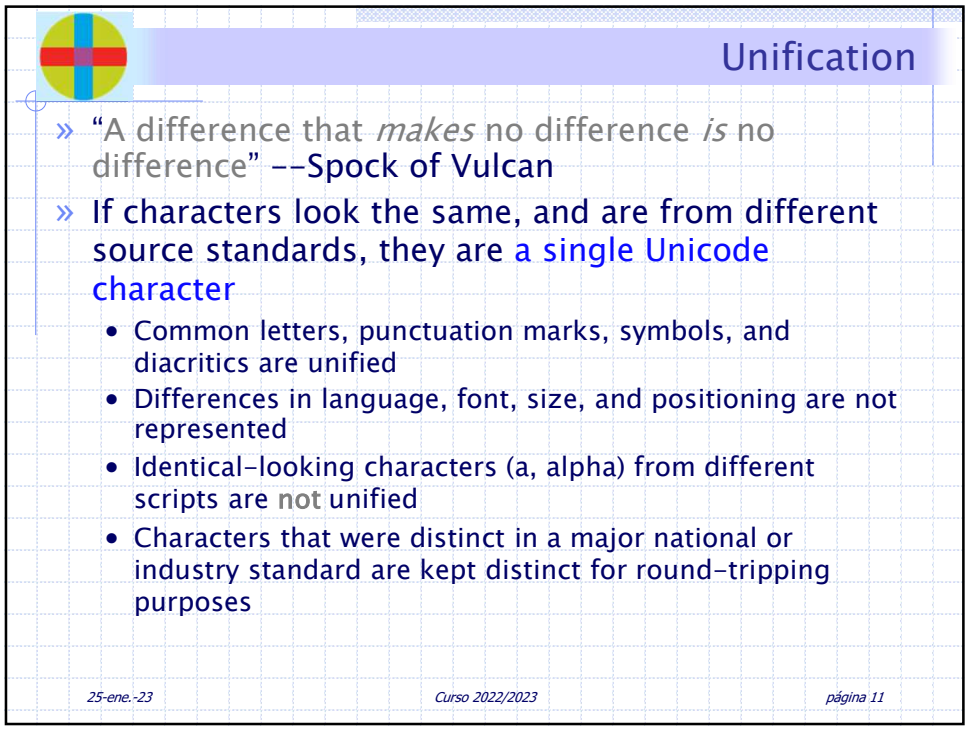
» Plain Text
- Unicode encodes just enough information for *bare legibility*
- Plain text is public, standardized, and universally readable
- SGML, HTML, XML are suitable "fancy text" standards to supply structure and formatting to Unicode plain text

Logical Ordering

» With one minor exception, characters are represented in Unicode in logical order (the order they are typed or spoken).
- Unicode provides a table-driven algorithm for reordering text into proper reading order, including mixed directions

آي.بي.إم. (IBM)، أبل (APPLE)، هيوليت باكرد (Hewlett-Packard)، مايكروسوفت (Microsoft)، أوراكل (Oracle)، صن (Sun)
...
إيزو ١٠٦٤٦ (ISO 10646)

» Text stored in logical order: No special consideration for processing, only for UI and for legacy encoding conversion
» RTL text (mostly Arabic and Hebrew) flows from right to left
» Embedded numbers and LTR text flow right to left
» Line break preserves reading order
» Selection: Contiguous text ≠ contiguous display


Unification
» "A difference that *makes* no difference *is* no difference" --Spock of Vulcan
» If characters look the same, and are from different source standards, they are a single Unicode character
• Common letters, punctuation marks, symbols, and diacritics are unified
• Differences in language, font, size, and positioning are not represented
• Identical-looking characters (a, alpha) from different scripts are not unified
• Characters that were distinct in a major national or industry standard are kept distinct for round-tripping purposes
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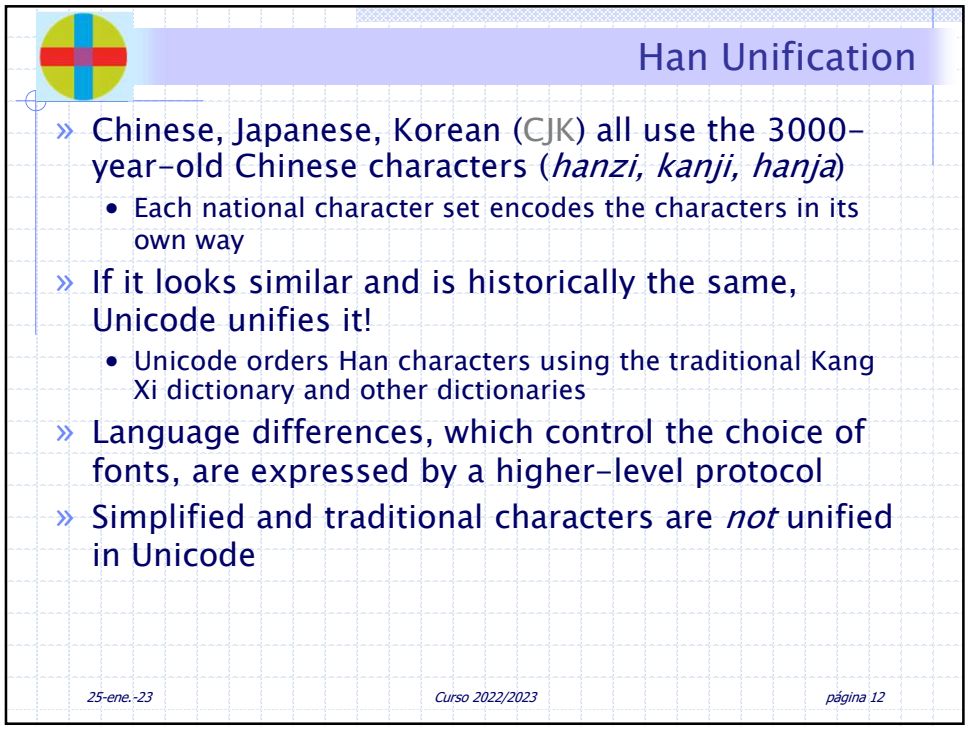
Han Unification
» Chinese, Japanese, Korean (CJK) all use the 3000-year-old Chinese characters (*hanzi, kanji, hanja*)
• Each national character set encodes the characters in its own way
» If it looks similar and is historically the same, Unicode unifies it!
• Unicode orders Han characters using the traditional Kang Xi dictionary and other dictionaries
» Language differences, which control the choice of fonts, are expressed by a higher-level protocol
» Simplified and traditional characters are *not* unified in Unicode
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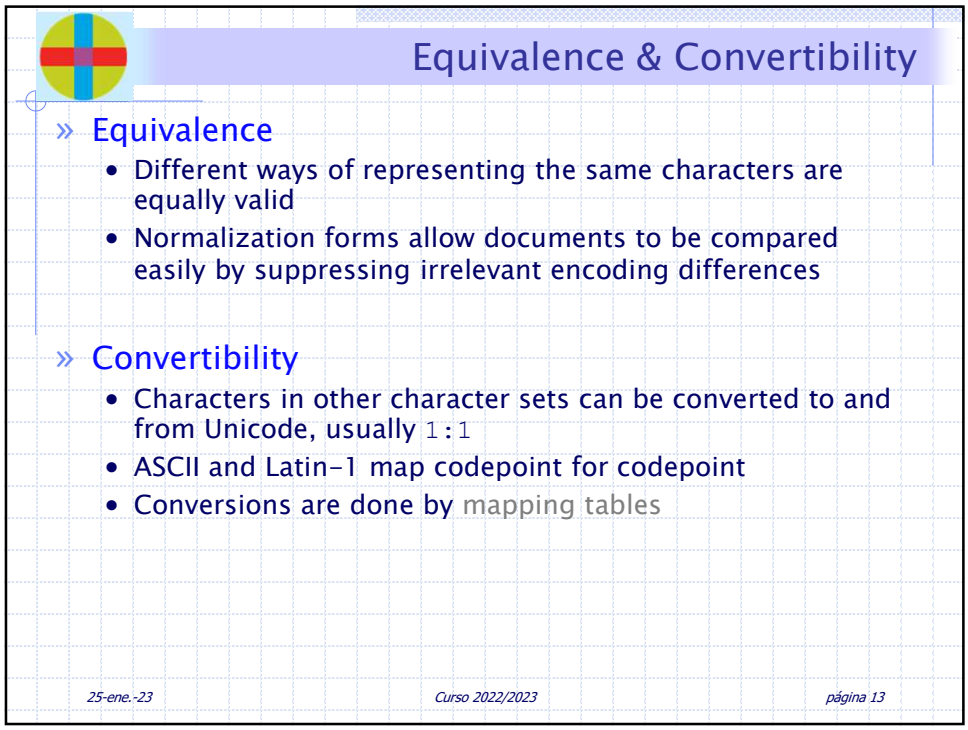
Equivalence & Convertibility
» Equivalence
• Different ways of representing the same characters are equally valid
• Normalization forms allow documents to be compared easily by suppressing irrelevant encoding differences
» Convertibility
• Characters in other character sets can be converted to and from Unicode, usually 1:1
• ASCII and Latin-1 map codepoint for codepoint
• Conversions are done by mapping tables
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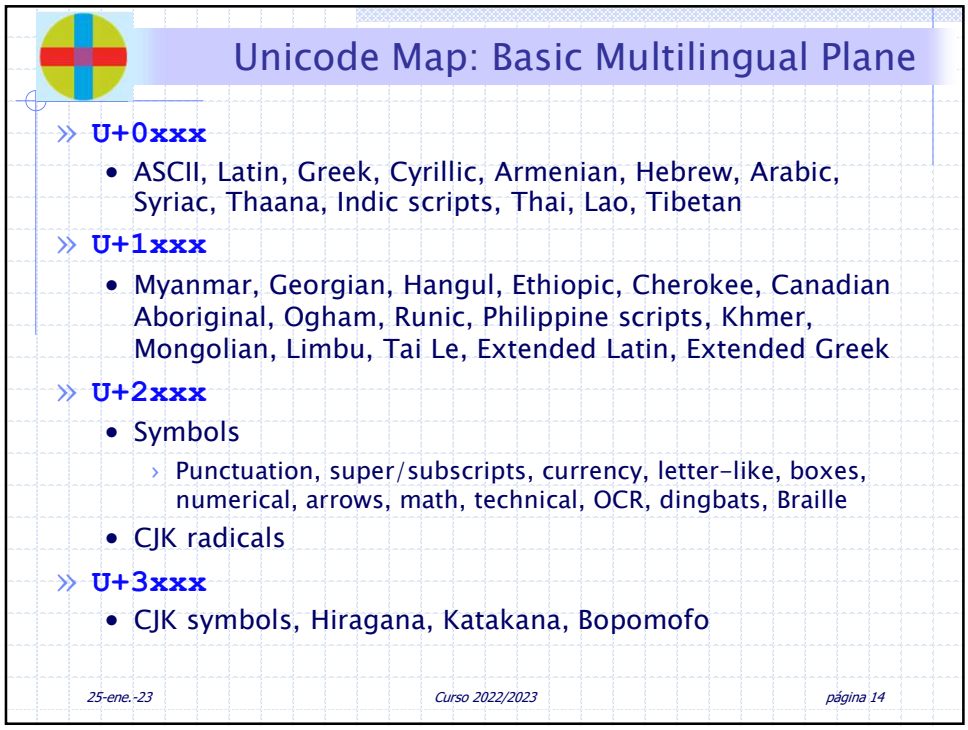
Unicode Map: Basic Multilingual Plane
» U+0xxx
• ASCII, Latin, Greek, Cyrillic, Armenian, Hebrew, Arabic, Syriac, Thaana, Indic scripts, Thai, Lao, Tibetan
» U+1xxx
• Myanmar, Georgian, Hangul, Ethiopic, Cherokee, Canadian Aboriginal, Ogham, Runic, Philippine scripts, Khmer, Mongolian, Limbu, Tai Le, Extended Latin, Extended Greek
» U+2xxx
• Symbols
› Punctuation, super/subscripts, currency, letter-like, boxes, numerical, arrows, math, technical, OCR, dingbats, Braille
• CJK radicals
» U+3xxx
• CJK symbols, Hiragana, Katakana, Bopomofo
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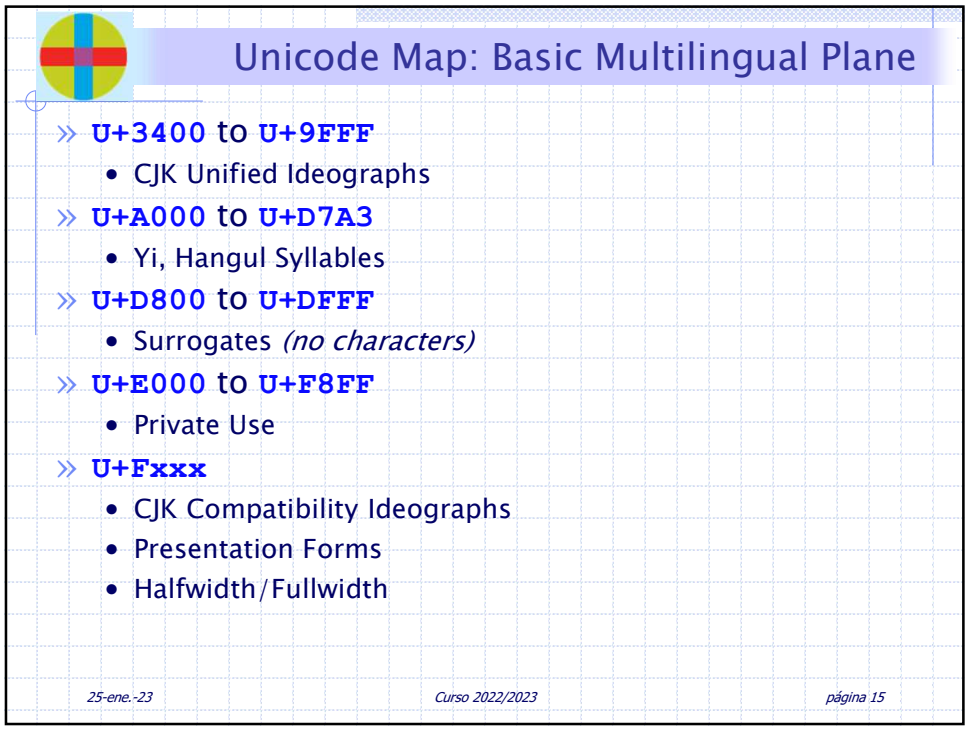
Unicode Map: Basic Multilingual Plane
U+3400 to U+9FFF
CJK Unified Ideographs
U+A000 to U+D7A3
Yi, Hangul Syllables
U+D800 to U+DFFF
Surrogates (no characters)
U+E000 to U+F8FF
Private Use
U+Fxxx
CJK Compatibility Ideographs
Presentation Forms
Halfwidth/Fullwidth
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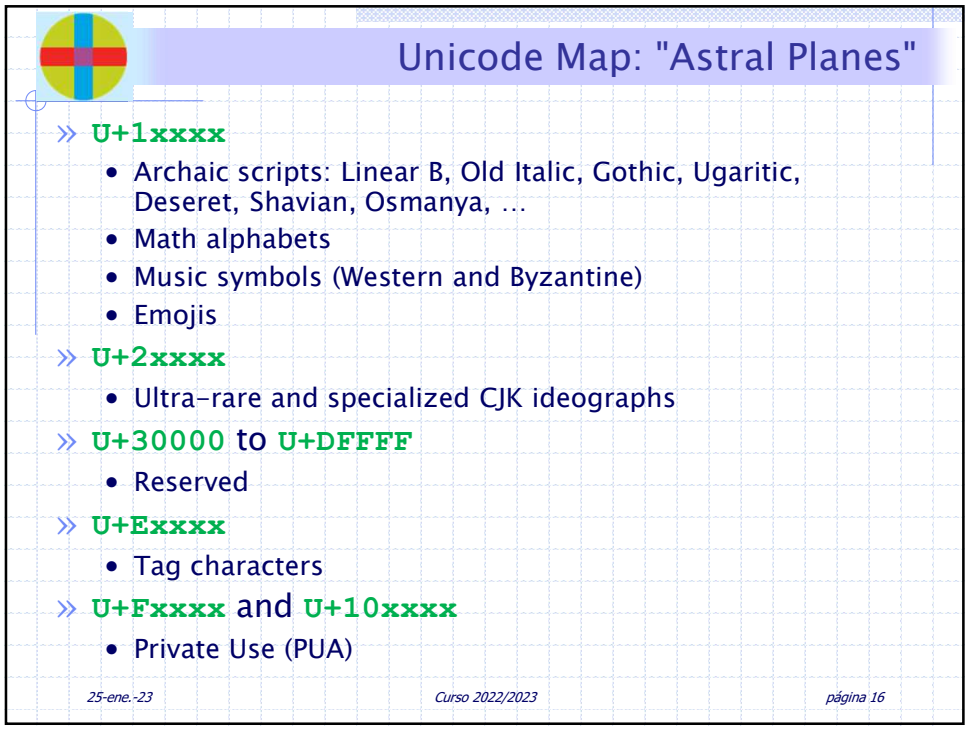
Unicode Map: "Astral Planes"
U+1xxxx
Archaic scripts: Linear B, Old Italic, Gothic, Ugaritic, Deseret, Shavian, Osmanya, …
Math alphabets
Music symbols (Western and Byzantine)
Emojis
U+2xxxx
Ultra-rare and specialized CJK ideographs
U+30000 to U+DFFFF
Reserved
U+Exxxx
Tag characters
U+Fxxxx and U+10xxxx
Private Use (PUA)
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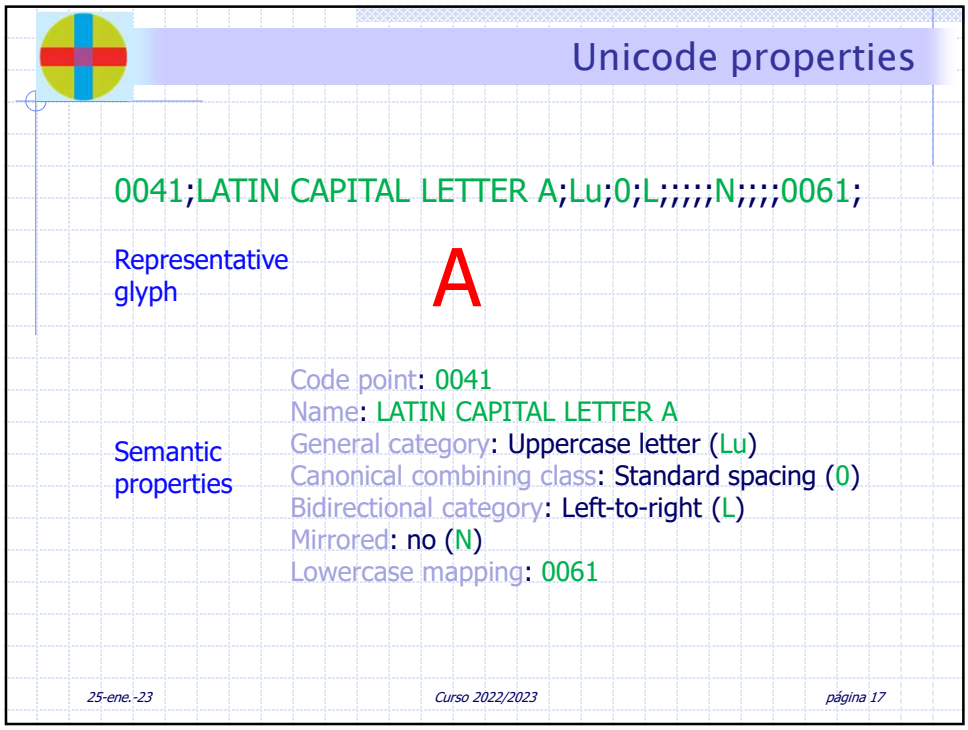
Unicode properties
0041;LATIN CAPITAL LETTER A;Lu;0;L;;;;;N;;;;0061;
Representative glyph
A
Semantic properties
Code point: 0041
Name: LATIN CAPITAL LETTER A
General category: Uppercase letter (Lu)
Canonical combining class: Standard spacing (0)
Bidirectional category: Left-to-right (L)
Mirrored: no (N)
Lowercase mapping: 0061
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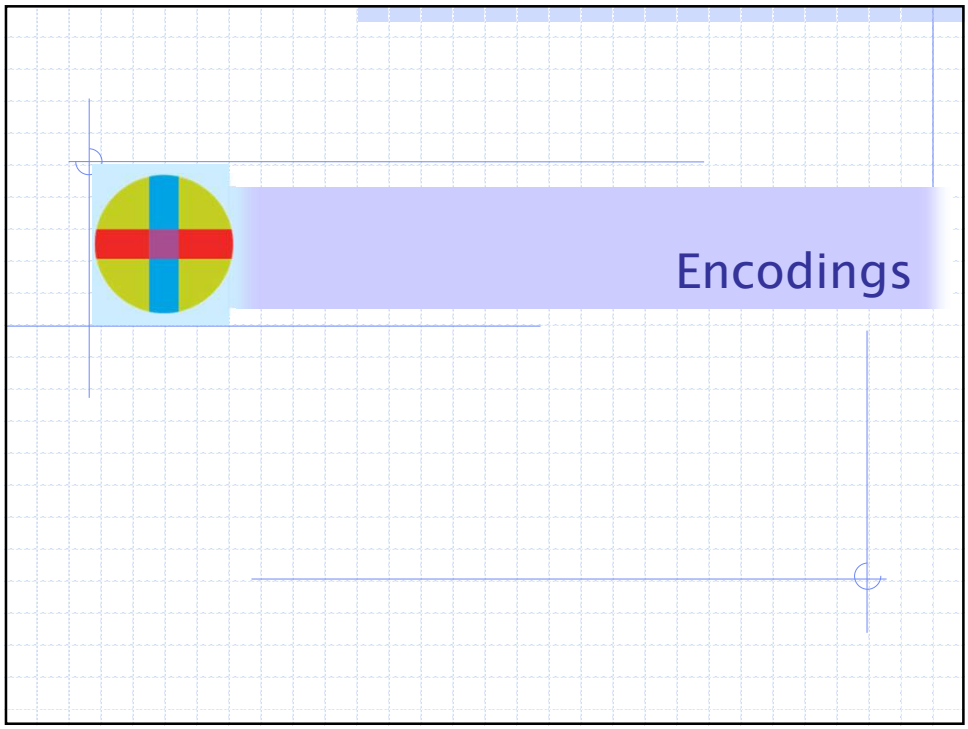
Encodings

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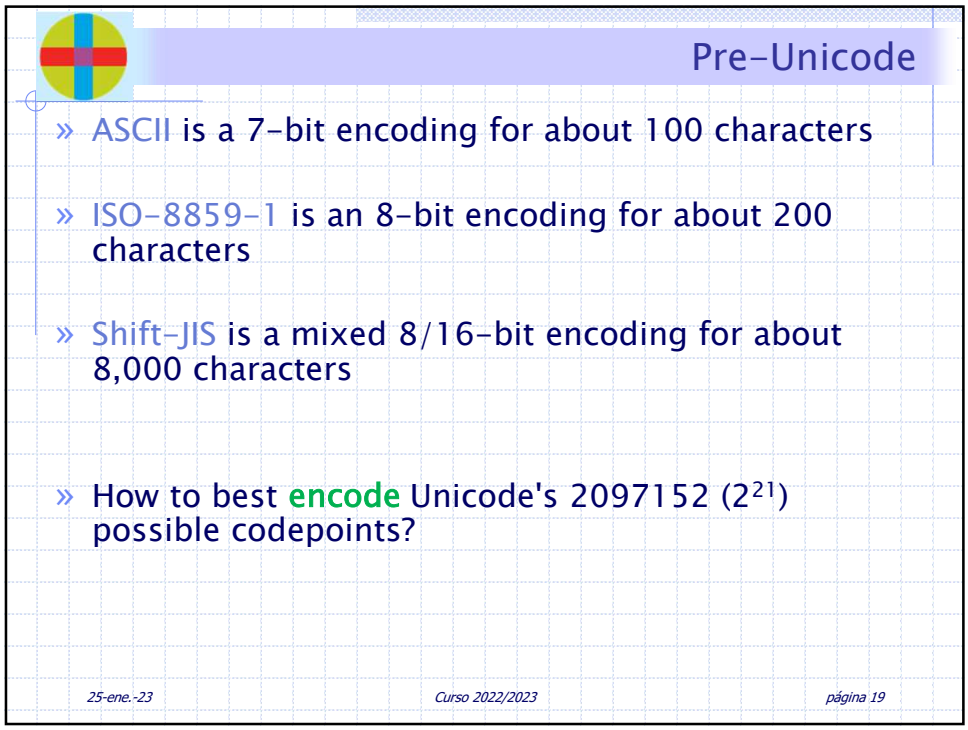
Pre-Unicode
» ASCII is a 7-bit encoding for about 100 characters
» ISO-8859-1 is an 8-bit encoding for about 200 characters
» Shift-JIS is a mixed 8/16-bit encoding for about 8,000 characters
» How to best encode Unicode's 2097152 (2^{21}) possible codepoints?
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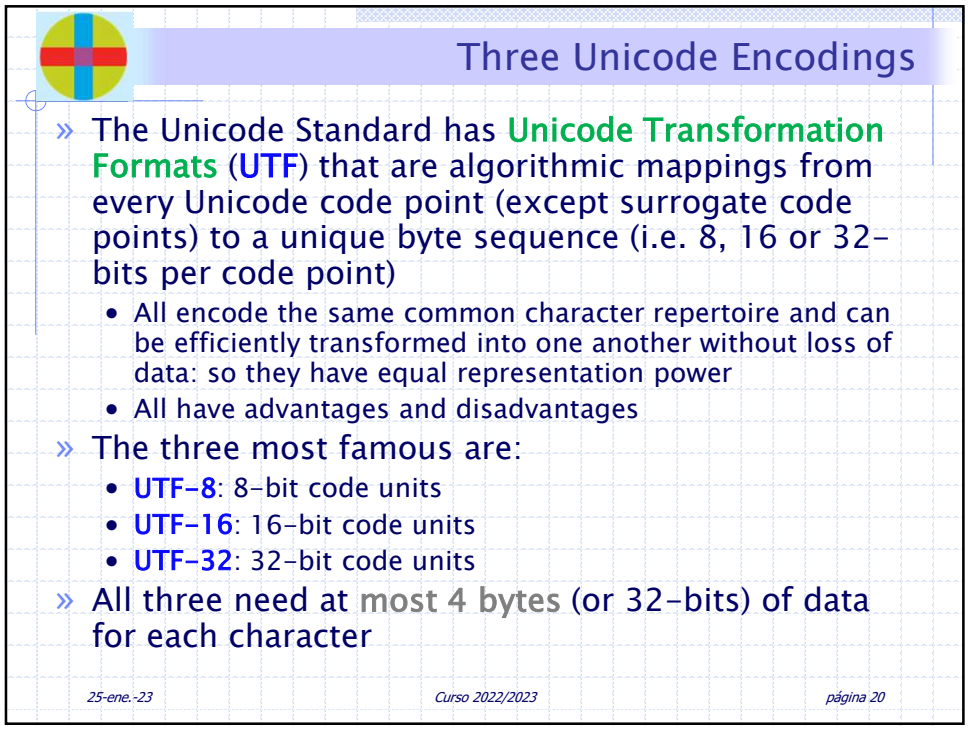
Three Unicode Encodings
» The Unicode Standard has Unicode Transformation Formats (UTF) that are algorithmic mappings from every Unicode code point (except surrogate code points) to a unique byte sequence (i.e. 8, 16 or 32-bits per code point)
• All encode the same common character repertoire and can be efficiently transformed into one another without loss of data: so they have equal representation power
• All have advantages and disadvantages
» The three most famous are:
• UTF-8: 8-bit code units
• UTF-16: 16-bit code units
• UTF-32: 32-bit code units
» All three need at most 4 bytes (or 32-bits) of data for each character
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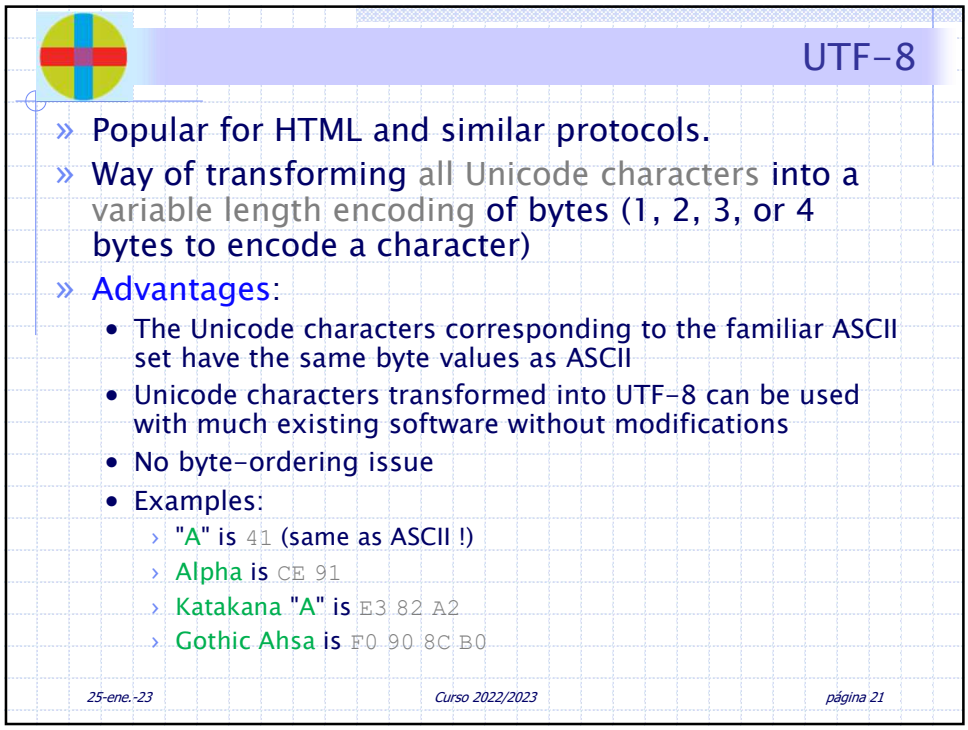
UTF-8
» Popular for HTML and similar protocols.
» Way of transforming all Unicode characters into a variable length encoding of bytes (1, 2, 3, or 4 bytes to encode a character)
» Advantages:
• The Unicode characters corresponding to the familiar ASCII set have the same byte values as ASCII
• Unicode characters transformed into UTF-8 can be used with much existing software without modifications
• No byte-ordering issue
• Examples:
› "A" is 41 (same as ASCII !)
› Alpha is CE 91
› Katakana "A" is E3 82 A2
› Gothic Ahsa is F0 90 8C B0
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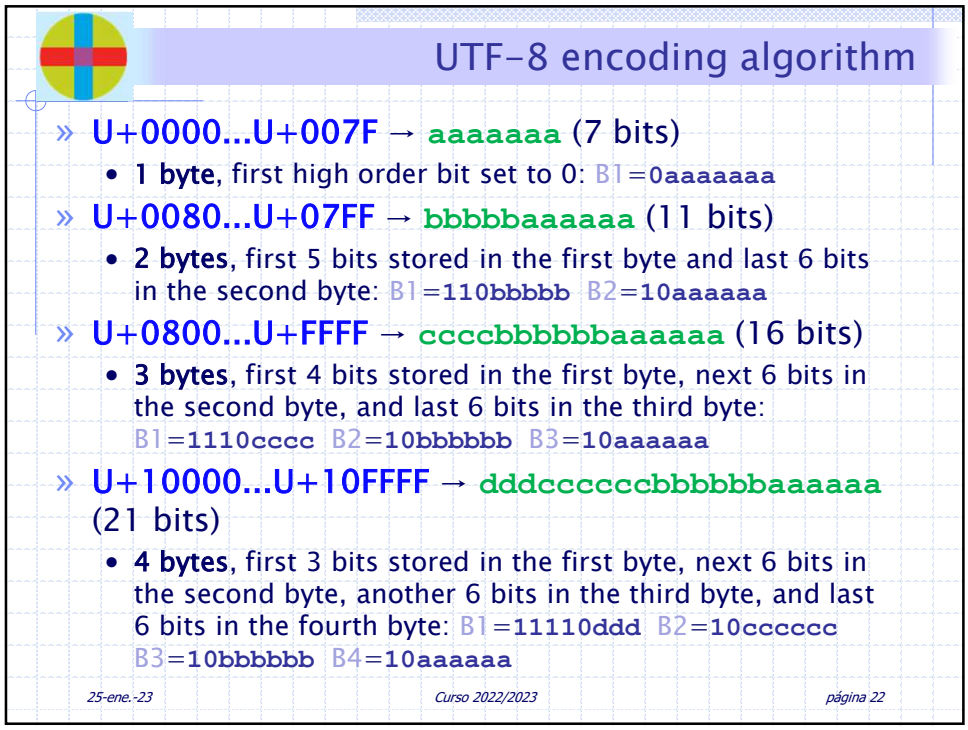
UTF-8 encoding algorithm
» U+0000...U+007F → aaaaaaa (7 bits)
• 1 byte, first high order bit set to 0: B1=0aaaaaaa
» U+0080...U+07FF → bbbbbaaaaaa (11 bits)
• 2 bytes, first 5 bits stored in the first byte and last 6 bits in the second byte: B1=110bbbbb B2=10aaaaaa
» U+0800...U+FFFF → ccccbbbbbbaaaaaa (16 bits)
• 3 bytes, first 4 bits stored in the first byte, next 6 bits in the second byte, and last 6 bits in the third byte: B1=1110cccc B2=10bbbbbb B3=10aaaaaa
» U+10000...U+10FFFF → dddccccccbbbbbbaaaaaa (21 bits)
• 4 bytes, first 3 bits stored in the first byte, next 6 bits in the second byte, another 6 bits in the third byte, and last 6 bits in the fourth byte: B1=11110ddd B2=10cccccc B3=10bbbbbb B4=10aaaaaa
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UTF-8 encoding algorithm

Code Point Range	Binary Format and Split Bytes			
	Byte 1	Byte 2	Byte 3	Byte 4
U+000000... U+00007F	aaaaaaa			
	0aaaaaaa			
U+000080... U+0007FF	bbbbbaaaaaa			
	110bbbbb	10aaaaaa		
U+000800... U+00FFFF	ccccbbbbbbaaaaaa			
	1110cccc	10bbbbbb	10aaaaaa	
U+010000... U+10FFFF	dddccccccbbbbbbaaaaaa			
	11110ddd	10cccccc	10bbbbbb	10aaaaaa

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UTF-16

- Popular in many environments that need to balance efficient access to characters with economical use of storage
  - It is reasonably compact
  - Each BMP character is represented by the obvious 16-bit code unit
  - Other characters are represented by two consecutive 16-bit code units using **surrogates**
  - Examples:
    - "A" is 0041
    - Alpha is 0391
    - Gothic Ahsa (U+10330) is D800 DB30

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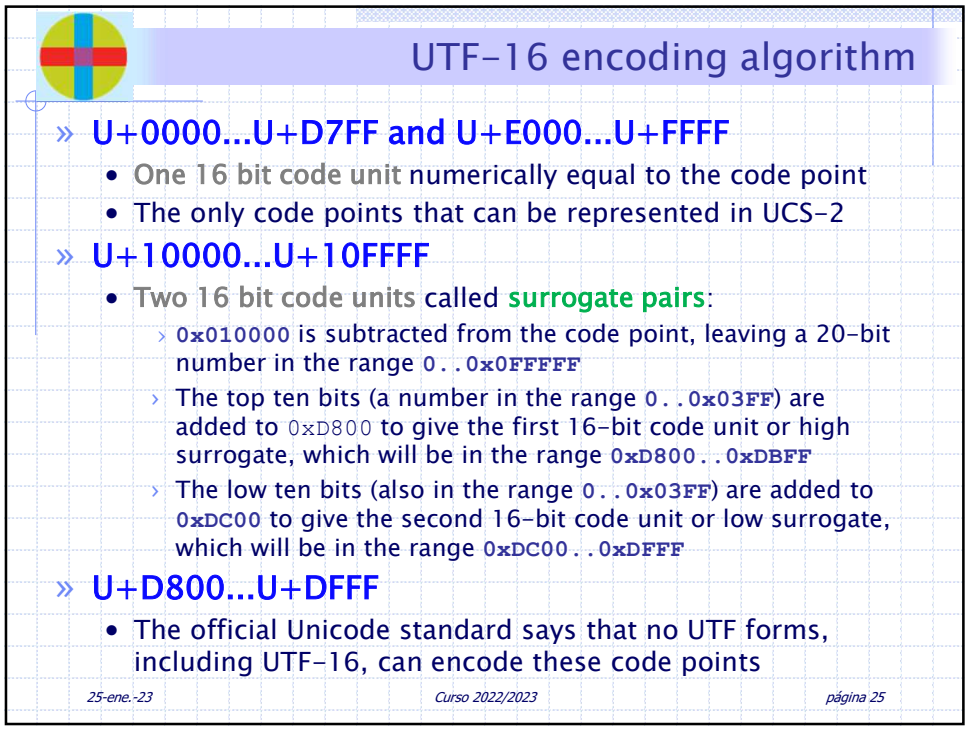
UTF-16 encoding algorithm
» U+0000...U+D7FF and U+E000...U+FFFF
• One 16 bit code unit numerically equal to the code point
• The only code points that can be represented in UCS-2
» U+10000...U+10FFFF
• Two 16 bit code units called surrogate pairs:
› 0x010000 is subtracted from the code point, leaving a 20-bit number in the range 0..0x0FFFFF
› The top ten bits (a number in the range 0..0x03FF) are added to 0xD800 to give the first 16-bit code unit or high surrogate, which will be in the range 0xD800..0xDBFF
› The low ten bits (also in the range 0..0x03FF) are added to 0xDC00 to give the second 16-bit code unit or low surrogate, which will be in the range 0xDC00..0xDFFF
» U+D800...U+DFFF
• The official Unicode standard says that no UTF forms, including UTF-16, can encode these code points
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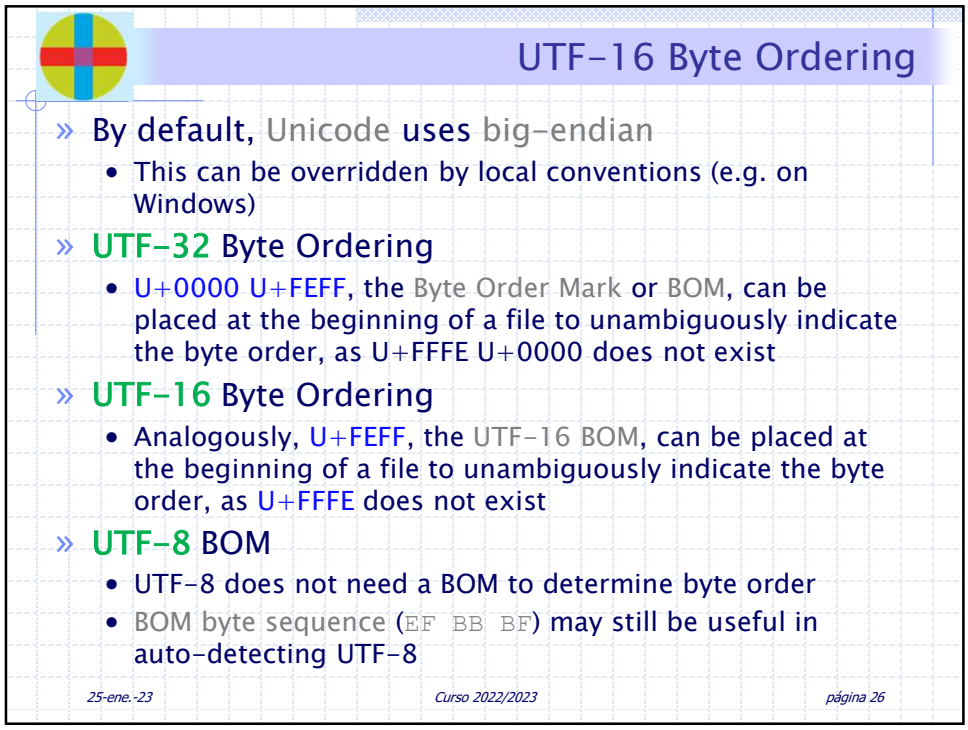
UTF-16 Byte Ordering
» By default, Unicode uses big-endian
• This can be overridden by local conventions (e.g. on Windows)
» UTF-32 Byte Ordering
• U+0000 U+FEFF, the Byte Order Mark or BOM, can be placed at the beginning of a file to unambiguously indicate the byte order, as U+FFFE U+0000 does not exist
» UTF-16 Byte Ordering
• Analogously, U+FEFF, the UTF-16 BOM, can be placed at the beginning of a file to unambiguously indicate the byte order, as U+FFFE does not exist
» UTF-8 BOM
• UTF-8 does not need a BOM to determine byte order
• BOM byte sequence (EF BB BF) may still be useful in auto-detecting UTF-8
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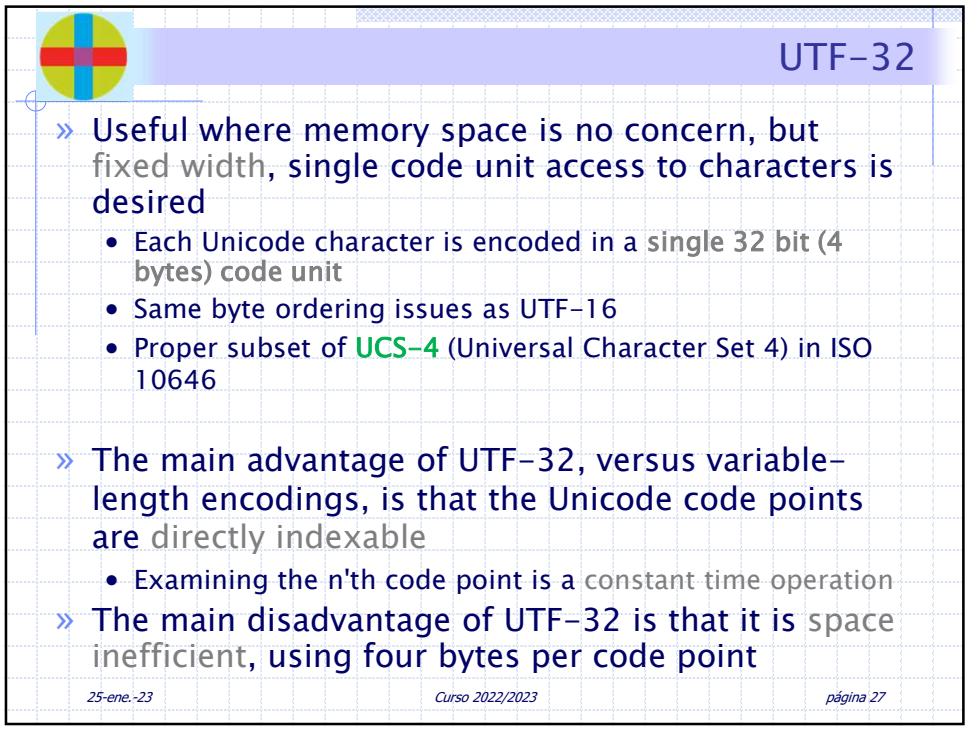
UTF-32
» Useful where memory space is no concern, but fixed width, single code unit access to characters is desired
• Each Unicode character is encoded in a single 32 bit (4 bytes) code unit
• Same byte ordering issues as UTF-16
• Proper subset of UCS-4 (Universal Character Set 4) in ISO 10646
» The main advantage of UTF-32, versus variable-length encodings, is that the Unicode code points are directly indexable
• Examining the n'th code point is a constant time operation
» The main disadvantage of UTF-32 is that it is space inefficient, using four bytes per code point
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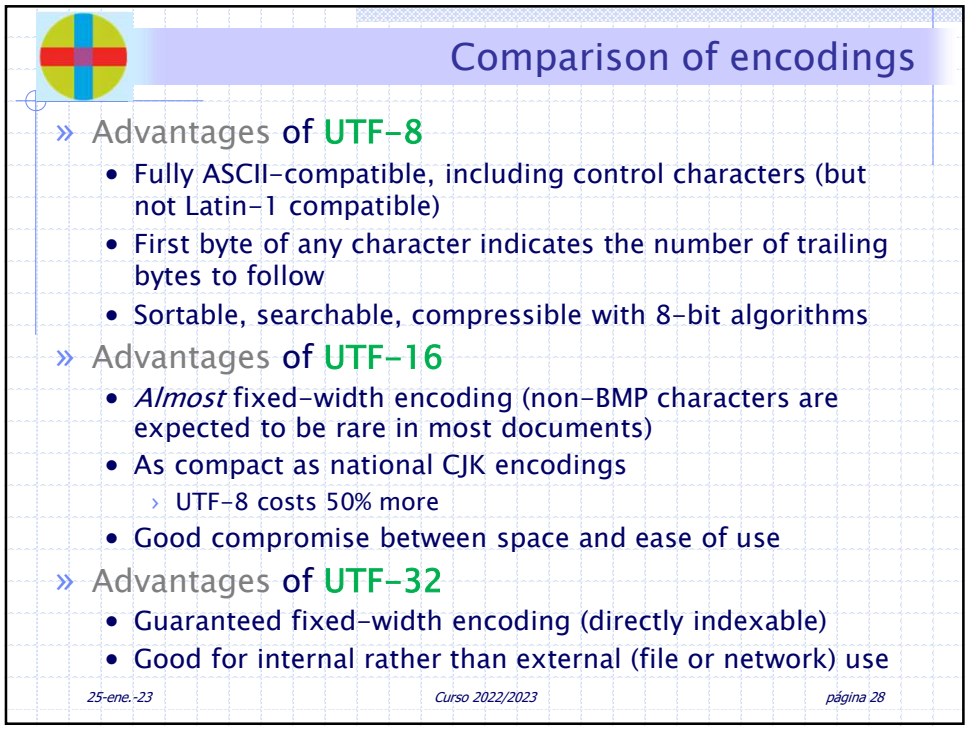
Comparison of encodings
» Advantages of UTF-8
• Fully ASCII-compatible, including control characters (but not Latin-1 compatible)
• First byte of any character indicates the number of trailing bytes to follow
• Sortable, searchable, compressible with 8-bit algorithms
» Advantages of UTF-16
• Almost fixed-width encoding (non-BMP characters are expected to be rare in most documents)
• As compact as national CJK encodings
› UTF-8 costs 50% more
• Good compromise between space and ease of use
» Advantages of UTF-32
• Guaranteed fixed-width encoding (directly indexable)
• Good for internal rather than external (file or network) use
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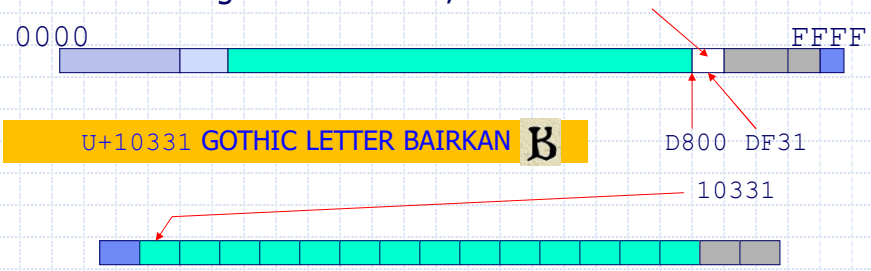
Encoding Unicode

UTF-32 = `10331` (one 32-bit value / code point)
UTF-16 = `D800 DF31` (one or two 16-bit values / code point)
UTF-8 = `F0 90 8C B1` (one to four 8-bit values / code point)

UTF-16 Surrogates: `D800-DFFF`
High: `D800-DBFF`, Low: `DC00-DFFF`



Surrogates used to access `10000-10FFFF` in UTF-16

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¿Preguntas?

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