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Internationalization

Arabic alphabet

Arabic Alphabet	
العربية	
Type	Abjad
Languages	Arabic
Time period	356 AD to the present
Parent systems	Egyptian • Proto-Sinaitic ◦ Phoenician ▪ Aramaic ▪ Syriac ▪ Nabataean ▪ Arabic Alphabet

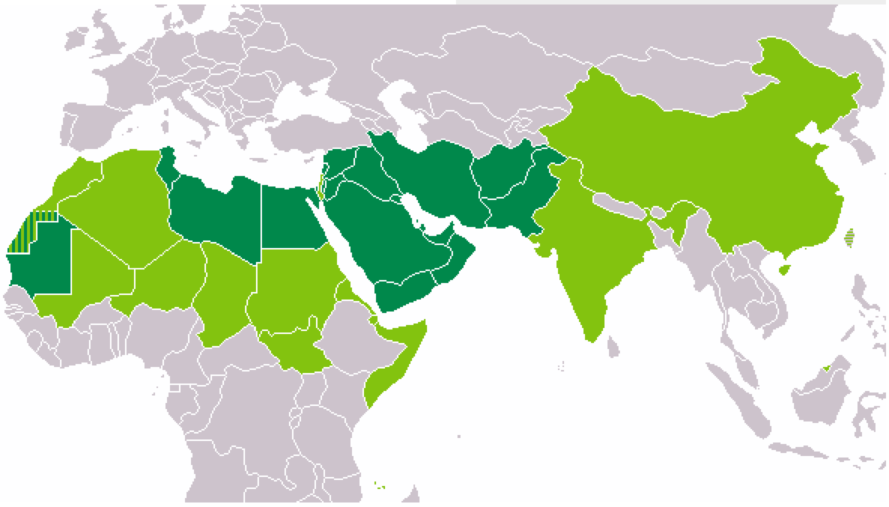
Direction	Right-to-left
ISO 15924	`Arab, 160`
Unicode alias	Arabic
Unicode range	• U+0600–U+06FF Arabic • U+0750–U+077F Arabic Supplement • U+08A0–U+08FF Arabic Extended-A • U+FB50–U+FDFF Arabic Presentation Forms-A • U+FE70–U+FEFF Arabic Presentation Forms-B • U+1EE00–U+1EEFF Arabic Mathematical Alphabetic Symbols

The **Arabic alphabet** (Arabic: الْأَبْجَدِيَّة الْعَرَبِيَّة *al-ʾabjadīyah al-ʿarabīyah*, or الْحُرُوف الْعَرَبِيَّة *al-ḥurūf al-ʿarabīyah*) or **Arabic abjad** is the Arabic script as it is codified for writing Arabic. It is written from right to left in a cursive style and includes 28 letters. Most letters have contextual letterforms.

Originally, the alphabet was an abjad, with only consonants, but it is now considered an "impure abjad". As with other *abjads*, such as the Hebrew alphabet, scribes later devised means of indicating vowel sounds by separate vowel diacritics.

Consonants

The basic Arabic alphabet contains 28 letters. Adaptations of the Arabic script for other languages added and removed some letters, as for Persian, Ottoman Turkish, Kurdish, Urdu, Sindhi, Malay, Pashto, Arwi and Malayalam (Arabi Malayalam), all of which have additional letters as shown below. There are no distinct upper and lower case letter forms.



Countries that utilise the Arabic script:
as the sole official script
as a co-official script.

Many letters look similar but are distinguished from one another by dots (*ʾiʿjām*) above or below their central part (*rasm*). These dots are an integral part of a letter, since they distinguish between letters that represent different sounds. For example, the Arabic letters ب (b), ت (t), and ث (th) have the same basic shape, but have one dot below, two dots above, and three dots above; the letter ن (n) also has the same form in initial and medial forms, with one dot above, though it is somewhat different in isolated and final form.

Both printed and written Arabic are cursive, with most of the letters within a word directly connected to the adjacent letters.

Alphabetical order

There are two main collating sequences for the Arabic alphabet: abjad and hija.

The original *ʾabjadīy* order (أَبْجَدِيّ), used for lettering, derives from the order of the Phoenician alphabet, and is therefore similar to the order of other Phoenician-derived alphabets, such as the Hebrew alphabet. In this order, letters are also used as numbers, Abjad numerals, and possess the same alphanumeric code/cipher as Hebrew gematria and Greek isopsephy.

The *hijāʾī* (هِجَائِي) or *alifbāʾī* (أَلِفْبَائِي) order, used where lists of names and words are sorted, as in phonebooks, classroom lists, and dictionaries, groups letters by similarity of shape.

Abjadī

The *ʾabjadī* order is not a simple historical continuation of the earlier north Semitic alphabetic order, since it has a position corresponding to the Aramaic letter *samekh/semkat* ס, yet no letter of the Arabic alphabet historically derives from that letter. Loss of *sameḵ* was compensated for by the split of *shin* ש into two independent Arabic letters, ش (*shīn*) and س (*sīn*) which moved up to take the place of *sameḵ*. The six other letters that do not correspond to any north Semitic letter are placed at the end.

Common *abjadī* sequence

غ	ظ	ض	ذ	خ	ث	ت	ش	ر	ق	ص	ف	ع	س	ن	م	ل	ك	ي	ط	ح
gh	*ẓ*	*ḍ*	*dh*	*kh*	*th*	*t*	*sh*	*r*	*q*	*ṣ*	*f*	*ʻ*	*s*	*n*	*m*	*l*	*k*	*y*	*ṭ*	*ḥ*
28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	09	08

This is commonly vocalized as follows:

ʾabjad hawwaz ḥuṭṭī kalaman saʿfaṣ qarashat thakhadh ḍaẓagh.

Another vocalization is:

ʾabujadin hawazin ḥuṭiya kalman saʿfaṣ qurishat thakhudh ḍaẓugh

Maghrebian *abjadī* sequence (probably older)[1]

ش	غ	ظ	ذ	خ	ث	ت	س	ر	ق	ض	ف	ع	ص	ن	م	ل	ك	ي	ط	ح
sh	*gh*	*ẓ*	*dh*	*kh*	*th*	*t*	*s*	*r*	*q*	*ḍ*	*f*	*ʻ*	*ṣ*	*n*	*m*	*l*	*k*	*y*	*ṭ*	*ḥ*
28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	09	08

This can be vocalized as:

ʾabujadin hawazin ḥuṭiya kalman ṣaʿfaḍ qurisat thakhudh ẓaghush

Hijāʾī

Modern dictionaries and other reference books do not use the *abjadī* order to sort alphabetically; instead, the newer *hijāʾī* order is used wherein letters are partially grouped together by similarity of shape. The *hijāʾī* order is never used as numerals.

Common *hijāʾī* order

ي	و	ه	ن	م	ل	ك	ق	ف	غ	ع	ظ	ط	ض	ص	ش	س	ز	ر	ذ	د	خ	ح	ج	ث
y	*w*	*h*	*n*	*m*	*l*	*k*	*q*	*f*	*gh*	ʿ	*ẓ*	*ṭ*	*ḍ*	*ṣ*	*sh*	*s*	*z*	*r*	*dh*	*d*	*kh*	*ḥ*	*j*	*th*

Another kind of *hijāʾī* order was used widely in the Maghreb until recently when it was replaced by the Mashriqi order.[1]

Maghrebian *hijāʾī* order

ي	و	ه	ش	س	ق	ف	غ	ع	ض	ص	ن	م	ل	ك	ظ	ط	ز	ر	ذ	د	خ	ح	ج	ث
y	*w*	*h*	*sh*	*s*	*q*	*f*	*gh*	ʿ	*ḍ*	*ṣ*	*n*	*m*	*l*	*k*	*ẓ*	*ṭ*	*z*	*r*	*dh*	*d*	*kh*	*ḥ*	*j*	*th*

Letter forms

The Arabic alphabet is always cursive and letters vary in shape depending on their position within a word. Letters can exhibit up to four distinct forms corresponding to an initial, medial (middle), final, or isolated position (IMFI). While some letters show considerable variations, others remain almost identical across all four positions. Generally, letters in the same word are linked together on both sides by short horizontal lines, but six letters (ا, د, ذ, ر, ز, و) can only be linked to their preceding letter. For example, أرارات (Ararat) has only isolated forms because each letter cannot be connected to its following one. In addition, some letter combinations are written as ligatures (special shapes), notably *lām-alif* لا,[2] which is the only mandatory ligature (the un-ligated combination لـا is considered difficult to read).

Table of basic letters

Arabic letters usage in Literary Arabic

Common		Maghrebian		Letter name	Letter name in Arabic script	Transliteration	Value in Literary Arabic (IPA)	Closest English equivalent in pronunciation	Contextual forms			Isolated form
ʾAbjadī	Hijāʾī	ʾAbjadī	Hijāʾī						Final	Medial	Initial	
1.	1.	1.	1.	*ʾalif*	أَلِف	*ā / ʾ* (also *ʾâ*)	various, including /aː/[a]	c**a**r, f**a**ther	ـا		ا	
2.	2.	2.	2.	*bāʾ*	بَاء	*b*	/b/[b]	**b**arn	ـب	ـبـ	بـ	ب
22.	3.	22.	3.	*tāʾ*	تَاء	*t*	/t/	s**t**ick	ـت	ـتـ	تـ	ت
23.	4.	23.	4.	*thāʾ*	ثَاء	*th* (also *ṯ*)	/θ/	**th**ink, **th**umb	ـث	ـثـ	ثـ	ث
3.	5.	3.	5.	*jīm*	جِيمْ	*j* (also *ǧ*)	/d͡ʒ/[b][c]	**J**im, **g**ym	ـج	ـجـ	جـ	ج
8.	6.	8.	6.	*ḥāʾ*	حَاء	*ḥ* (also *ḩ*)	/ħ/	no equivalent ("guttural" *h*, may be approximated as **h**eart)	ـح	ـحـ	حـ	ح
24.	7.	24.	7.	*khāʾ*	خَاء	*kh* (also *ḫ*, *ḵ*, *ẖ*)	/x/	lo**ch**; German Ba**ch**	ـخ	ـخـ	خـ	خ
4.	8.	4.	8.	*dāl*	دَالْ	*d*	/d/	**d**ear	ـد		د	
25.	9.	25.	9.	*dhāl*	ذَالْ	*dh* (also *ḏ*)	/ð/	**th**at, **th**em, **th**ough	ـذ		ذ	
20.	10.	20.	10.	*rāʾ*	رَاء	*r*	/r/	**r**ap	ـر		ر	
7.	11.	7.	11.	*zāy / zayn*	زَاي	*z*	/z/	**z**ebra	ـز		ز	
15.	12.	21.	24.	*sīn*	سِينْ	*s*	/s/	**s**in	ـس	ـسـ	سـ	س
21.	13.	28.	25.	*shīn*	شِينْ	*sh* (also *š*)	/ʃ/	**sh**in	ـش	ـشـ	شـ	ش
18.	14.	15.	18.	*ṣād*	صَادْ	*ṣ* (also *ş*)	/sˤ/	**s**warm, ba**ss**	ـص	ـصـ	صـ	ص
26.	15.	18.	19.	*ḍād*	ضَادْ	*ḍ* (also *ḑ*)	/dˤ/	**d**warf	ـض	ـضـ	ضـ	ض

9.	16.	9.	12.	*ṭāʾ*	طَاء	*ṭ* (also *ţ*)	/tˤ/	s***t***ar	ـط	ـطـ	طـ	ط
27.	17.	26.	13.	*ẓāʾ*	ظَاء	*ẓ* (also *z̧*)	/ðˤ/	bu***zz***word	ـظ	ـظـ	ظـ	ظ
16.	18.	16.	20.	*ʿayn*	عَين	*ʿ*	/ʕ/	no equivalent ("guttural" voiced *h*; similar to *ḥāʾ* above)	ـع	ـعـ	عـ	ع
28.	19.	27.	21.	*ghayn*	غَين	*gh* (also *ġ, ḡ*)	/ɣ/[b]	Spanish hi***g***o	ـغ	ـغـ	غـ	غ
17.	20.	17.	22.	*fāʾ*	فَاء	*f*	/f/[b]	***f***ar	ـف	ـفـ	فـ	ف[d]
19.	21.	19.	23.	*qāf*	قَاف	*q* (also *q*)	/q/[b]	s***c***ar	ـق	ـقـ	قـ	ق[d]
11.	22.	11.	14.	*kāf*	كَاف	*k*	/k/[b]	***k***ey, ***c***ap	ـك	ـكـ	كـ	ك
12.	23.	12.	15.	*lām*	لاَمْ	*l*	/l/	***l***amp	ـل	ـلـ	لـ	ل
13.	24.	13.	16.	*mīm*	مِيمْ	*m*	/m/	***m***e	ـم	ـمـ	مـ	م
14.	25.	14.	17.	*nūn*	نُون	*n*	/n/	***n***un	ـن	ـنـ	نـ	ن
5.	26.	5.	26.	*hāʾ*	هَاء	*h*	/h/	***h***at	ـه	ـهـ	هـ	ه
6.	27.	6.	27.	*wāw*	وَاو	*w* / *ū*	/w/, /uː/[b]	***w***e	ـو		و	
10.	28.	10.	28.	*yāʾ*	يَاء	*y* / *ī*	/j/, /iː/[b]	***y***acht	ـي	ـيـ	يـ	ي[d]
(not counted as alphabet but plays an important role in Arabic grammar and lexicon, including indication [denoting most irregular female nouns] and spelling)				*hamzah*	هَمْزة	*ʾ*	/ʔ/	uh–oh (aka "glottal stop")	ء (used mainly in medial and final position, which is an unlinked letter)			
				ʾalif hamzah	أَلِف هَمْزة				ـأ		أ	
									ـإ		إ	
				wāw hamzah	وَاو هَمْزة				ـؤ		ؤ	
				yāʾ hamzah	يَاء هَمْزة				ـئ	ـئـ	ئـ	ئ
				ʾalif maddah	أَلِف مَدَّة	*ʾā*	/ʔaː/		ـآ		آ	

Notes

1. **^** *Alif* can represent many phonemes. See the section on ʾalif.
2. ^ ***a b c d e f g h*** See the section on non-native letters and sounds; the letters ?ج?, ?غ?, ?ق?, ?ك? are sometimes used to transcribe the phoneme /g/ in loanwords, ?ب? to transcribe /p/ and ?ف? to transcribe /v/. Likewise the letters ?و? and ?ي? are used to transcribe the vowels /oː/ and /eː/ respectively in loanwords and dialects.

3. **^** ج is pronounced differently depending on the region. See Arabic phonology#Consonants.
4. ^ ***a b c*** See the section on regional variations in letter form.

- See the article *Romanization of Arabic* for details on various transliteration schemes; however, Arabic language speakers may usually not follow a standardized scheme when transcribing names. Also names are regularly transcribed as pronounced locally, not as pronounced in Literary Arabic (if they were of Arabic origin).
- Regarding pronunciation, the phonemic values given are those of Modern Standard Arabic, which is taught in schools and universities. In practice, pronunciation may vary considerably from region to region. For more details concerning the pronunciation of Arabic, consult the articles *Arabic phonology* and *varieties of Arabic*.
- The names of the Arabic letters can be thought of as abstractions of an older version where they were meaningful words in the Proto-Semitic language. Names of Arabic letters may have quite different names popularly.
- Six letters (و ز ر ذ د ا) do not have a distinct medial form and have to be written with their final form without being connected to the next letter. Their initial form matches the isolated form. The following letter is written in its initial form, or isolated form if it is the final letter in the word.
- The letter *alif* originated in the Phoenician alphabet as a consonant-sign indicating a glottal stop. Today it has lost its function as a consonant, and, together with *ya'* and *wāw*, is a *mater lectionis*, a consonant sign standing in for a long vowel (see below), or as support for certain diacritics (*maddah* and *hamzah*).
- Arabic currently uses a diacritic sign, ء, called *hamzah*, to denote the glottal stop [ʔ], written alone or with a carrier:
    - alone: ء
    - with a carrier: إ أ (above or under a *alif*), ؤ (above a *wāw*), ئ (above a dotless *yā'* or *yā' hamzah*).

In academic work, the *hamzah* (ء) is transliterated with the modifier letter right half ring (ʾ), while the modifier letter left half ring (ʿ) transliterates the letter *'ayn* (ع), which represents a different sound, not found in English.

The *hamzah* has a single form, since it is never linked to a preceding or following letter. However, it is sometimes combined with a *wāw*, *yā'*, or *alif*, and in that case the carrier behaves like an ordinary *wāw*, *yā'*, or *alif*.

Alif

Context	Form	Value	Closest English Equivalent
Without diacritics	ا	• initially: *a, i* /a, i/ or sometimes silent in the definite article ال *(a)l-* • medially or finally: *ā* /aː/	Initial position: a - ***u***p; i - h***i***p Medial/ Final position: a - ***u***p
With *hamzah* over	أ	• Initial/ medial/ final: followed by *fatḥah* - *ʾa*, or *ḍammah* - *ʾu* • Isolated or on its own without a vowel (usually followed by a *sukūn*): /ʾ/, pronounced as a glottal stop like "***uh***" in "***uh***-oh"	Initial/ Medial/ Final position: ʾa - h***ea***rt; ʾu - p***ou***r Isolated or on its own without a vowel usually appearing in this case, the medial and final position (usually followed by a *sukūn*): /ʾ/, pronounced as a glottal stop like "***uh***" in "***uh***-oh"
With *hamzah* under	إ	• initially: *ʾi* /ʔi/ • does not appear medially or finally (see hamza)	Initial position: ʾi - ***i***nn
With *maddah*	آ	• *ʾā* /ʔaː/	Initial/ Medial/ Final position: ***aa***rdvark
With *waslah*	ٱ	• ʾ or *silent* /∅/	Initial/ Medial/ Final position: (silent)

Modified letters

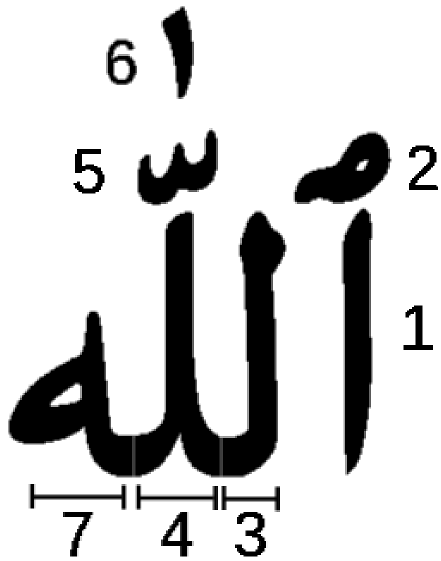
The following are not individual letters, but rather different contextual variants of some of the Arabic letters.

Conditional forms				Name	Translit.	Phonemic Value (IPA)
Isolated	Final	Medial	Initial			
آ	ـآ		آ	*ʾalif mad-dah*	*ʾā*	/ʔaː/
ة	ـة			*tāʾ mar-būṭah*	*h* or t / ẗ / ^{h}	used in final position only and for denoting the feminine *noun/word* or to make the *noun/word* feminine; however, in rare *irregular noun/word* cases, it appears to denote the "masculine"; singular nouns: 1. /ah/ plural nouns: /āt/ (a preceding letter followed by a *fatḥah alif* + *tāʾ* = ـَات)
ى	ـى			*ʾalif maqṣūrah*	*ā / á / y*	used in the final position only and in some special cases, denoting the feminine aspect of the noun/word which acts similar to *tāʾ marbūṭah*; /aː/ (aka "*shortened ʾalif*" - thus the Arabic name, its purpose is for writing purposes mostly used in classical texts and in some dialects like Egyptian Arabic

Ligatures

The use of ligature in Arabic is common. There is one compulsory ligature, that for *lām* + *alif*, which exists in two forms. All other ligatures (*yāʾ* + *mīm*, etc.) are optional.

Contextual forms				Name	Trans.	Value
Final	**Medial**	**Initial**	**Isolated**			
ﻼ		ﻻ		lām + alif	*laa*	/lāː/



Components of a ligature for "Allah":
1. alif
2. hamzat waṣl (همزة وصل)
3. lām
4. lām
5. shadda (شدة)
6. dagger alif (ألف خنجرية)
7. hāʾ

A more complex ligature that combines as many as seven distinct components is commonly used to represent the word *Allāh*.

The only ligature within the primary range of Arabic script in Unicode (U+06xx) is *lām* + *alif*. This is the only one compulsory for fonts and word-processing. Other ranges are for compatibility to older standards and contain other ligatures, which are optional.

- *lām + alif*

  لا

Note: Unicode also has in its Presentation Form B FExx range a code for this ligature. If your browser and font are configured correctly for Arabic, the ligature displayed above should be identical to this one, `U+FEFB` ARABIC LIGATURE LAM WITH ALEF ISOLATED FORM:

ﻻ

- `U+0640` ARABIC TATWEEL + *lām* + *alif*

  ـلا

Note: Unicode also has in its Presentation Form B U+FExx range a code for this ligature. If your browser and font are configured correctly for Arabic, the ligature displayed above should be identical to this one:

- `U+FEFC` ARABIC LIGATURE LAM WITH ALEF FINAL FORM

  ﻼ

Another ligature in the Unicode Presentation Form A range U+FB50 to U+FDxx is the special code for glyph for the ligature *Allāh* ("God"), `U+FDF2` ARABIC LIGATURE ALLAH ISOLATED FORM:

ﷲ

This is a work-around for the shortcomings of most text processors, which are incapable of displaying the correct vowel marks for the word *Allāh* in Koran. Because Arabic script is used to write other texts rather than Koran only, rendering *lām* + *lām* + *hāʾ* as the previous ligature is considered faulty:[3] If one of a number of fonts (Noto Naskh Arabic, mry_KacstQurn, KacstOne, DejaVu Sans, Harmattan, Scheherazade, Lateef, Iranian Sans) is installed on a computer (Iranian Sans is supported by Wikimedia web-fonts), the word will appear without diacritics.

- *lām* + *lām* + *hā'* = LILLĀH (meaning *"to Allāh [only to Allah])*

  ﷲ or لله

- *alif* + *lām* + *lām* + *hā'* = ALLĀH (the Islamic name for "God")

  ﷲ or الله

- *alif* + *lām* + *lām* + `U+0651` ARABIC SHADDA + `U+0670` ARABIC LETTER SUPERSCRIPT ALEF + *hā'*

) اللّٰه *DejaVu Sans* and *KacstOne* don't show the added superscript Alef)

An attempt to show them on the faulty fonts without automatically adding the gemination mark and the superscript alif, although may not display as desired on all browsers, is by adding the `U+200d` (Zero width joiner) after the first or second *lām*

- (*alif* +) *lām* + *lām* + `U+200d` ZERO WIDTH JOINER + *hā'*

  لل‍ه الل‍ه

Gemination

Gemination is the doubling of a consonant. Instead of writing the letter twice, Arabic places a *W*-shaped sign called *shaddah*, above it. Note that if a vowel occurs between the two consonants the letter will simply be written twice. The diacritic only appears where the consonant at the end of one syllable is identical to the initial consonant of the following syllable. (The generic term for such diacritical signs is *ḥarakāt*).

General Unicode	Name	Name in Arabic script	Transliteration
0651 ـّ	*shaddah*	شَدَّة	(consonant doubled)

Nunation

Nunation (Arabic: تنوين *tanwīn*) is the addition of a final *-n* to a noun or adjective. The vowel before it indicates grammatical case. In written Arabic nunation is indicated by doubling the vowel diacritic at the end of the word.

Vowels

Users of Arabic usually write long vowels but omit short ones, so readers must utilize their knowledge of the language in order to supply the missing vowels. However, in the education system and particularly in classes on Arabic grammar these vowels are used since they are crucial to the grammar. An Arabic sentence can have a completely different meaning by a subtle change of the vowels. This is why in an important text such as the *Qur'ān* the three basic vowel signs (see below) are mandated, like the *ḥarakāt* and all the other diacritics or other types of marks, for example the cantillation signs.

Short vowels

In the Arabic handwriting of everyday use, in general publications, and on street signs, short vowels are typically not written. On the other hand, copies of the *Qur'ān* cannot be endorsed by the religious institutes that review them unless the diacritics are included. Children's books, elementary school texts, and Arabic-language grammars in general will include diacritics to some degree. These are known as "vocalized" texts.

Short vowels may be written with diacritics placed above or below the consonant that precedes them in the syllable, called *ḥarakāt*. All Arabic vowels, long and short, follow a consonant; in Arabic, words like "Ali" or "alif", for example, start with a consonant: *'Aliyy*, *alif*.

Short vowels (fully vocalized text)	Code	Name	Name in Arabic script	Trans.	Value
ـَ	064E	fat·ḥah	فَتْحَة	*a*	/a/
ـُ	064F	*ḍammah*	ضَمَّة	*u*	/u/
ـِ	0650	*kasrah*	كَسْرَة	*i*	/i/

Long vowels

In the fully vocalized Arabic text found in texts such as Quran, a long *ā* following a consonant other than a *hamzah* is written with a short *a* sign (*fatḥah*) on the consonant plus an *ʾalif* after it; long *ī* is written as a sign for short *i* (*kasrah*) plus a *yāʾ*; and long *ū* as a sign for short *u* (*ḍammah*) plus a *wāw*. Briefly, ^{a}*a* = *ā*; ^{i}*y* = *ī*; and ^{u}*w* = *ū*. Long *ā* following a *hamzah* may be represented by an *ʾalif maddah* or by a free *hamzah* followed by an *ʾalif* (two consecutive *ʾalif*s are never allowed in Arabic).

The table below shows vowels placed above or below a dotted circle replacing a primary consonant letter or a *shaddah* sign. For clarity in the table, the primary letters on the left used to mark these long vowels are shown only in their isolated form. Please note that most consonants do connect to the left with *ʾalif*, *wāw* and *yāʾ* written then with their medial or final form. Additionally, the letter *yāʾ* in the last row may connect to the letter on its left, and then will use a medial or initial form. Use the table of primary letters to look at their actual glyph and joining types.

Long vowels (fully vocalized text)	Name	Trans.	Value
064E 0627 ـَا	*fatḥah ʾalif*	*ā*	/aː/
064E 0649 ـَىٰ	*fatḥah ʾalif maqṣūrah*	*ā / y*	
064F 0648 ـُو	*ḍammah wāw*	*ū*	/uː/
0650 064A ـِي	*kasrah yāʾ*	*ī*	/iː/

In unvocalized text (one in which the short vowels are not marked), the long vowels are represented by the vowel in question: *ʾalif ṭawīlah/maqṣūrah*, *wāw*, or *yāʾ*. Long vowels written in the middle of a word of unvocalized text are treated like consonants with a *sukūn* (see below) in a text that has full diacritics. Here also, the table shows long vowel letters only in isolated form for clarity.

Combinations وا and يا are always pronounced *wā* and *yāʾ* respectively. The exception is the suffix ـوا in verb endings where *ʾalif* is silent, resulting in *ū* or *aw*.

Long vowels (unvocalized text)	Name	Trans.	Value
0627 ا	(implied *fatḥah*) *ʾalif*	*ā*	/aː/
0649 ى	(implied *fatḥah*) *ʾalif maqṣūrah*	*ā / y*	
0648 و	(implied *ḍammah*) *wāw*	*ū*	/uː/
064A ي	(implied *kasrah*) *yāʾ*	*ī*	/iː/

In addition, when transliterating names and loanwords, Arabic language speakers write out most or all the vowels as long (*ā* with ا *'alif*, *ē* and *ī* with ي *ya'*, and *ō* and *ū* with و *wāw*), meaning it approaches a true alphabet.

Diphthongs

The diphthongs /aj/ and /aw/ are represented in vocalized text as follows:

Diphthongs (fully vocalized text)	Name	Trans.	Value
064A 064E ـَي	*fatḥah yā'*	*ay*	/aj/
0648 064E ـَو	*fatḥah wāw*	*aw*	/aw/

Vowel omission

An Arabic syllable can be open (ending with a vowel) or closed (ending with a consonant):

- open: CV [consonant-vowel] (long or short vowel)
- closed: CVC (short vowel only)

A normal text is composed only of a series of consonants plus vowel-lengthening letters; thus, the word *qalb*, "heart", is written *qlb*, and the word *qalab* "he turned around", is also written *qlb*.

To write *qalab* without this ambiguity, we could indicate that the *l* is followed by a short *a* by writing a *fatḥah* above it.

To write *qalb*, we would instead indicate that the *l* is followed by no vowel by marking it with a diacritic called *sukūn* (ْ), like this: قلْب.

This is one step down from full vocalization, where the vowel after the *q* would also be indicated by a *fatḥah*: قَلْب.

The *Qur'ān* is traditionally written in full vocalization.

The long *i* sound in some editions of the *Qur'ān* is written with a *kasrah* followed by a diacritic-less *y*, and long *u* by a *ḍammah* followed by a bare *w*. In others, these *y* and *w* carry a *sukūn*. Outside of the *Qur'ān*, the latter convention is extremely rare, to the point that *y* with *sukūn* will be unambiguously read as the diphthong /aj/, and *w* with *sukūn* will be read /aw/.

For example, the letters *m-y-l* can be read like English *meel* or *mail*, or (theoretically) also like *mayyal* or *mayil*. But if a *sukūn* is added on the *y* then the *m* cannot have a *sukūn* (because two letters in a row cannot be *sukūn*ated), cannot have a *ḍammah* (because there is never an *uy* sound in Arabic unless there is another vowel after the *y*), and cannot have a *kasrah* (because *kasrah* before *sukūn*ated *y* is never found outside the *Qur'ān*), so it *must* have a *fatḥah* and the only possible pronunciation is /majl/ (meaning mile, or even e-mail). By the same token, m-y-t with a *sukūn* over the *y* can be *mayt* but not *mayyit* or *meet*, and m-w-t with a *sukūn* on the *w* can only be *mawt*, not *moot* (*iw* is impossible when the *w* closes the syllable).

Vowel marks are always written as if the *i'rāb* vowels were in fact pronounced, even when they must be skipped in actual pronunciation. So, when writing the name *Aḥmad*, it is optional to place a *sukūn* on the *ḥ*, but a *sukūn* is forbidden on the *d*, because it would carry a *ḍammah* if any other word followed, as in *Aḥmadu zawjī* "Ahmad is my husband".

Another example: the sentence that in correct literary Arabic must be pronounced *Aḥmadu zawjun sharrīr* "Ahmad is a wicked husband", is usually mispronounced (due to influence from vernacular Arabic varieties) as *Aḥmad zawj sharrīr*. Yet, for the purposes of Arabic grammar and orthography, is treated as if it were not mispronounced and as if yet another word followed it, i.e., if adding any vowel marks, they must be added as if the pronunciation were *Aḥmadu zawjun sharrīrun* with a *tanwīn* 'un' at the end. So, it is correct to add an *un tanwīn* sign on the final *r*, but actually pronouncing it would be a hypercorrection. Also, it is never correct to write a *sukūn* on that *r*, even though in actual pronunciation it is (and in correct Arabic MUST be) *sukūn*ed.

Of course, if the correct *i'rāb* is a *sukūn*, it may be optionally written.

General Unicode	Name	Name in Arabic script	Translit.	Phonemic Value (IPA)
0652 ْ	sukūn	سُكُون	(no vowel with this consonant letter or diphthong with this long vowel letter)	∅
0670 ٰ	alif khanjariyyah [dagger 'alif - smaller 'alif written above consonant]	أَلِف خَنْجَرِيَّة	*ā*	/aː/

The *sukūn* is also used for transliterating words into the Arabic script. The Persian word ماسک (*mâsk*, from the English word "mask"), for example, might be written with a *sukūn* above the س to signify that there is no vowel sound between that letter and the ک.

Additional letters

Regional variations

Some letters take a traditionally different form in specific regions:

Letter				Explanation
Isolated	Final	Medial	Initial	
ڛ	ـڛ	ـڛـ	ڛـ	A traditional form to denotate the *sīn* س letter, rarely used in areas influenced by Persian script and former Ottoman script.[4]
ڢ	ـڢ	ـڢـ	ڢـ	A traditional Maghrebi variant (except for Libya and Algeria) of *fā’* ف.
ڧ/ٯ	ـڧ/ـٯ	ـڧـ	ڧـ	A traditional Maghrebi variant (except for Libya and Algeria) of *qāf* ق. Generally dotless in isolated and final positions and dotted in the initial and medial forms.
ک	ـک	ـکـ	کـ	An alternative version of *kāf* ك used especially in Maghrebi under the influence of the Ottoman script or in Gulf script under the influence of the Persian script.
ى	ى-	-ى-	-ى	Notably in Egypt, Sudan (Nile Valley) and sometimes Maghreb, *yā’* ي is dotless in the isolated and final position. Visually identical to *alif maqṣūrah* ى. The use in handwriting resembles the Perso-Arabic letter ی ـی ـیـ یـ which was also used in Ottoman Turkish.

Non-native letters to Standard Arabic

See also Arabic script#Special letters for languages other than Arabic.

Some modified letters are used to represent non-native sounds of Modern Standard Arabic. These letters are used in transliterated names, loanwords and dialectal words.

Letter	Value	Note
Foreign letters		
ڤ	/v/	Used in loanwords and dialectal words instead of *fā'* ف.[5] Not to be confused with ڨ.
ڥ		Used in Tunisia, Algeria and Morocco.
پ	/p/	Sometimes used when transliterating foreign names and loanwords. Can be substituted with *bā'* ب and pronounced as such.
Dialectal / Foreign letters		
ڜ	/tʃ/[1]	Used in Morocco.
چ		Sometimes used when transliterating foreign names and loanwords and in the Gulf and Arabic dialects. The sequence تش *tā'-shīn* is usually preferred (e.g. تشاد for "Chad").
	/ʒ/[2]	Used in Egypt and can be a reduction of /dʒ/, where ج is pronounced /g/.
	/g/[3]	Used in Israel, for example on road signs.
گ		Used in northwest Africa and west Asia.
ڨ		Used in Tunisia and in Algeria for loanwords and for the dialectal pronunciation of *qāf* ق in some words. Not to be confused with ڤ.
ڭ		Used in Morocco.
ۼ		Rarely used in Persian Gulf.

1. /tʃ/ is considered a native phoneme/allophone in some dialects, e.g. Kuwaiti and Iraqi dialects.
2. /ʒ/ is considered a native phoneme in Levantine and North African dialects and as an allophone in others.
3. /g/ is considered a native phoneme/allophone in most modern Arabic dialects.

Used in languages other than Arabic

Most common non-Classical Arabic consonant phonemes/graphemes

<table>
<tr><th>Language family</th><th>Austron.</th><th>Dravid.</th><th>Turkic</th><th colspan="3">Indic (Indo-European)</th><th colspan="4">Iranian (Indo-European)</th><th colspan="2">Arabic (Semitic)</th></tr>
<tr><th>Language/ Script</th><th>Jawi</th><th>Arwi</th><th>Uyghur</th><th>Sindhi</th><th>Punjabi</th><th>Urdu</th><th>Persian</th><th>Balochi</th><th>Kurdish</th><th>Pashto</th><th>Iraqi</th><th>Hejazi</th></tr>
<tr><td>/p/</td><td>ڤ</td><td>ڣ</td><td colspan="8">پ</td><td colspan="2"></td></tr>
<tr><td>/g/</td><td>ݢ</td><td>?</td><td colspan="7">گ</td><td>ګ</td><td>گ</td><td>ق</td></tr>
<tr><td>/tʃ/</td><td colspan="10">چ</td><td>چ</td><td></td></tr>
<tr><td>/ʒ/</td><td colspan="2">∅</td><td>ژ</td><td colspan="2">∅</td><td colspan="5">ژ</td><td colspan="2">∅</td></tr>
<tr><td>/v/</td><td>ۏ</td><td>و</td><td>ۋ</td><td colspan="4">و</td><td>∅</td><td>ڤ</td><td>∅</td><td colspan="2">ڤ</td></tr>
<tr><td>/ŋ/</td><td>ڠ</td><td>?</td><td>ڭ</td><td>ڱ</td><td rowspan="3">ں</td><td rowspan="3">ن</td><td colspan="4">∅</td><td colspan="2"></td></tr>
<tr><td>/ɳ/</td><td>∅</td><td>ڹ</td><td>∅</td><td>ڻ</td><td colspan="3">∅</td><td>ڼ</td><td colspan="2"></td></tr>
<tr><td>/ɲ/</td><td>ڽ</td><td>ۑ</td><td>∅</td><td>ڃ</td><td colspan="4">∅</td><td colspan="2"></td></tr>
</table>

Numerals

There are two main kinds of numerals used along with Arabic text; Western Arabic numerals and Eastern Arabic numerals. In most of present-day North Africa, the usual Western Arabic numerals are used. Like Western Arabic numerals, in Eastern Arabic numerals, the units are always right-most, and the highest value left-most.

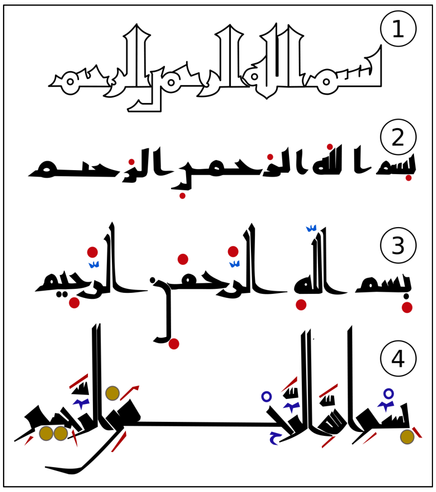
Western (Maghreb, Europe)	Central (Mideast)	Eastern (Persian, Urdu)	
0	٠	۰	۰
1	١	۱	۱
2	٢	۲	۲
3	٣	۳	۳
4	٤	۴	۴
5	٥	۵	۵
6	٦	۶	۶
7	٧	۷	۷
8	٨	۸	۸
9	٩	۹	۹
10	١٠	۱۰	۱۰

Letters as numerals

In addition, the Arabic alphabet can be used to represent numbers (Abjad numerals). This usage is based on the *ʼabjadī* order of the alphabet. أ *ʼalif* is 1, ب *bāʼ* is 2, ج *jīm* is 3, and so on until ي *yāʼ* = 10, ك *kāf* = 20, ل *lām* = 30, ..., ر *rāʼ* = 200, ..., غ *ghayn* = 1000. This is sometimes used to produce chronograms.

History

The Arabic alphabet can be traced back to the Nabataean alphabet used to write the Nabataean. The first known text in the Arabic alphabet is a late 4th-century inscription from *Jabal Ramm* (50 km east of *'Aqabah*) in Jordan, but the first dated one is a trilingual inscription at Zebed in Syria from 512. However, the epigraphic record is extremely sparse, with only five certainly pre-Islamic Arabic inscriptions surviving, though some others may be pre-Islamic. Later, dots were added above and below the letters to differentiate them. (The Aramaic language had fewer phonemes than the Arabic, and some originally distinct Aramaic letters had become indistinguishable in shape, so that in the early writings 15 distinct letter-shapes had to do duty for 28 sounds; cf. the similarly ambiguous Pahlavi alphabet.) The first surviving document that definitely uses these dots is also the first surviving Arabic papyrus (PERF 558), dated April 643, although they did not become obligatory until much later. Important texts were and still are frequently memorized, especially in Qur'an memorization, a practice which probably arose partially from a desire to avoid the great ambiguity of the script.


Evolution of early Arabic calligraphy (9th–11th century). The Basmala is taken as an example, from Kufic Qur'ān manuscripts. (1) Early 9th century script used no dots or diacritic marks;[6] (2) and (3) in the 9th–10th century during the Abbasid dynasty, Abu al-Aswad's system used red dots with each arrangement or position indicating a different short vowel. Later, a second system of black dots was used to differentiate between letters like fā' and qāf;[7][7] (4) in the 11th century (al-Farāhīdī's system) dots were changed into shapes resembling the letters to transcribe the corresponding long vowels. This system is the one used today.[8]

Later still, vowel marks and the *hamzah* were introduced, beginning some time in the latter half of the 7th century, preceding the first invention of Syriac and Hebrew vocalization. Initially, this was done by a system of red dots, said to have been commissioned in the Umayyad era by Abu al-Aswad al-Du'ali a dot above = *a*, a dot below = *i*, a dot on the line = *u*, and doubled dots indicated nunation. However, this was cumbersome and easily confusable with the letter-distinguishing dots, so about 100 years later, the modern system was adopted. The system was finalized around 786 by *al-Farāhīdī*.

Arabic printing presses

Although Napoleon Bonaparte generally receives credit for introducing the printing press to Egypt during his invasion of that country in 1798, and though he did indeed bring printing presses and Arabic script presses to print the French occupation's official newspaper *Al-Tanbiyyah* ("The Courier"), printing in the Arabic language started several centuries earlier.

In 1514, following Gutenberg's invention of the printing press in 1450, Gregorio de Gregorii, a Venetian, published an entire prayer-book in Arabic script; it was entitled *Kitab Salat al-Sawa'i* and was intended for eastern Christian communities.[9]

Between 1580 and 1586, type designer Robert Granjon designed Arabic typefaces for Cardinal Ferdinando de' Medici, and the Medici press published many Christian prayer and scholarly Arabic texts in the late 16th century.

Maronite monks at the Maar Quzhayy Monastery in Mount Lebanon published the first Arabic books to use movable type in the Middle East. The monks transliterated the Arabic language using Syriac script.

A goldsmith (like Gutenberg) designed and implemented an Arabic-script movable-type printing-press in the Middle East. The Greek Orthodox monk Abd Allah Zakhir set up an Arabic printing press using movable type at the monastery of Saint John at the town of Dhour El Shuwayr in Mount Lebanon, the first homemade press in Lebanon using Arabic script. He personally cut the type molds and did the founding of the typeface. The first book came off his press in 1734; this press continued in use until 1899.[10]

Computers

The Arabic alphabet can be encoded using several character sets, including ISO-8859-6, Windows-1256 and Unicode (see links in Infobox above), latter thanks to the "Arabic segment", entries U+0600 to U+06FF. However, none of the sets indicates the form that each character should take in context. It is left to the rendering engine to select the proper glyph to display for each character.

Each letter has a position-independent encoding in Unicode, and the rendering software can infer the correct glyph form (initial, medial, final or isolated) from its joining context. That is the current recommendation. However, for compatibility with previous standards, the initial, medial, final and isolated forms can also be encoded separately.

Unicode

As of Unicode 11.0, the Arabic script is contained in the following blocks:[11]

- Arabic (0600–06FF, 255 characters)
- Arabic Supplement (0750–077F, 48 characters)
- Arabic Extended-A (08A0–08FF, 74 characters)
- Arabic Presentation Forms-A (FB50–FDFF, 611 characters)
- Arabic Presentation Forms-B (FE70–FEFF, 141 characters)
- Rumi Numeral Symbols (10E60–10E7F, 31 characters)
- Indic Siyaq Numbers (1EC70–1ECBF, 68 characters)
- Arabic Mathematical Alphabetic Symbols (1EE00—1EEFF, 143 characters)

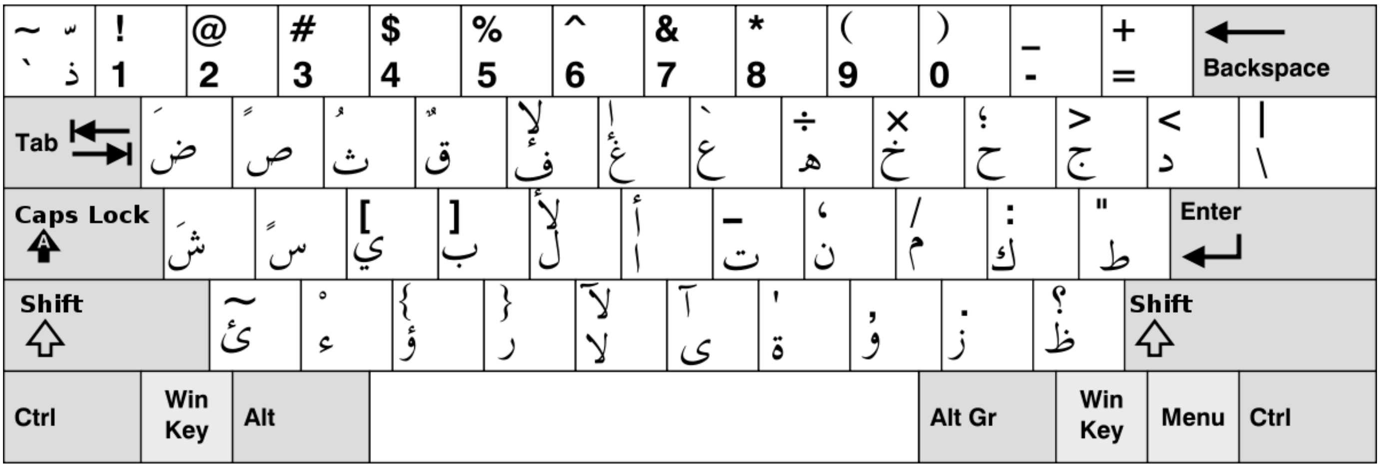
The basic Arabic range encodes the standard letters and diacritics but does not encode contextual forms (U+0621-U+0652 being directly based on ISO 8859-6). It also includes the most common diacritics and Arabic-Indic digits. U+06D6 to U+06ED encode Qur'anic annotation signs such as "end of *ayah*" ۝ and "start of *rub el hizb*" ۞. The Arabic supplement range encodes letter variants mostly used for writing African (non-Arabic) languages. The Arabic Extended-A range encodes additional Qur'anic annotations and letter variants used for various non-Arabic languages.

The Arabic Presentation Forms-A range encodes contextual forms and ligatures of letter variants needed for Persian, Urdu, Sindhi and Central Asian languages. The Arabic Presentation Forms-B range encodes spacing forms of Arabic diacritics, and more contextual letter forms. The Arabic Mathematical Alphabetical Symbols block encodes characters used in Arabic mathematical expressions.

See also the notes of the section on modified letters.

Keyboards

Arabic Mac keyboard layout



Arabic PC keyboard layout

Intellark imposed on a QWERTY keyboard layout.

Keyboards designed for different nations have different layouts so proficiency in one style of keyboard, such as Iraq's, does not transfer to proficiency in another, such as Saudi Arabia's. Differences can include the location of non-alphabetic characters.

All Arabic keyboards allow typing Roman characters, e.g., for the URL in a web browser. Thus, each Arabic keyboard has both Arabic and Roman characters marked on the keys. Usually the Roman characters of an Arabic keyboard conform to the QWERTY layout, but in North Africa, where French is the most common language typed using the Roman characters, the Arabic keyboards are AZERTY.

To encode a particular written form of a character, there are extra code points provided in Unicode which can be used to express the exact written form desired. The range *Arabic presentation forms A* (U+FB50 to U+FDFF) contain ligatures while the range *Arabic presentation forms B* (U+FE70 to U+FEFF) contains the positional variants. These effects are better achieved in Unicode by using the *zero-width joiner* and *non-joiner*, as these presentation forms are deprecated in Unicode, and should generally only be used within the internals of text-rendering software, when using Unicode as an intermediate form for conversion between character encodings, or for backwards compatibility with implementations that rely on the hard-coding of glyph forms.

Finally, the Unicode encoding of Arabic is in *logical order*, that is, the characters are entered, and stored in computer memory, in the order that they are written and pronounced without worrying about the direction in which they will be displayed on paper or on the screen. Again, it is left to the rendering engine to present the characters in the correct direction, using Unicode's bi-directional text features. In this regard, if the Arabic words on this page are written left to right, it is an indication that the Unicode rendering engine used to display them is out of date.[12][13]

There are competing online tools, e.g. Yamli editor, which allow entry of Arabic letters without having Arabic support installed on a PC, and without knowledge of the layout of the Arabic keyboard.[14]

Handwriting recognition

The first software program of its kind in the world that identifies Arabic handwriting in real time was developed by researchers at Ben-Gurion University (BGU).

The prototype enables the user to write Arabic words by hand on an electronic screen, which then analyzes the text and translates it into printed Arabic letters in a thousandth of a second. The error rate is less than three percent, according to Dr. Jihad El-Sana, from BGU's department of computer sciences, who developed the system along with master's degree student Fadi Biadsy.[15]

See also

Wikimedia Commons has media related to ***Arabic alphabet***.

- Kufic
- Rasm

- Arabic diacritics
- Arabic numerals
- Abjad numerals
- Modern Arabic mathematical notation
- Arabic Mathematical Alphabetic Symbols
- Arabic braille
- Ancient South Arabian script
- Arabic calligraphy
- Perso-Arabic script
- Arabic script – about other languages written in Arabic script
- Arabic Unicode
- Arabic Chat Alphabet
- ArabTeX – provides Arabic support for TeX and LaTeX
- Romanization of Arabic
- Algerian braille

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1. ^ ***a b*** (in Arabic) Alyaseer.net ترتيب المداخل والبطاقات في القوائم والفهارس الموضوعية Ordering entries and cards in subject indexes Discussion thread *(Accessed 2009-October–06)*
2. **^** *Rogers, Henry (2005). Writing Systems: A Linguistic Approach. Blackwell Publishing. p. 135.*
3. **^** SIL International: This simplified style is often preferred for clarity, especially in non-Arabic languages
4. **^** *"Notice sur les divers genres d'écriture ancienne et moderne des arabes, des persans et des turcs / par A.-P. Pihan".*
5. **^** *"Arabic Dialect Tutorial" (PDF). Archived from the original (PDF) on 17 December 2008. Retrieved 2 December 2008.*
6. **^** File:Basmala kufi.svg - Wikimedia Commons
7. ^ ***a b*** File:Kufi.jpg - Wikimedia Commons
8. **^** File:Qur'an folio 11th century kufic.jpg - Wikimedia Commons
9. **^** *"294° anniversario della Biblioteca Federiciana: ricerche e curiosità sul Kitab Salat al-Sawai". Retrieved 2017-01-31.*

0. **^** Arabic and the Art of Printing – A Special Section, by Paul Lunde
1. **^** *"UAX #24: Script data file". Unicode Character Database. The Unicode Consortium.*
2. **^** For more information about encoding Arabic, consult the Unicode manual available at The Unicode website
3. **^** See also Multilingual Computing with Arabic and Arabic Transliteration: Arabicizing Windows Applications to Read and Write Arabic & Solutions for the Transliteration Quagmire Faced by Arabic-Script Languages and A PowerPoint Tutorial (with screen shots and an English voice-over) on how to add Arabic to the Windows Operating System. Archived 11 September 2011 at the Wayback Machine.
4. **^** Yamli in the News
5. **^** Israel 21c

External links

- *Shaalan, Khaled; Raza, Hafsa (August 2009). "NERA: Named entity recognition for Arabic". Journal of the American Society for Information Science and Technology.* ***60*** *(8). doi:10.1002/asi.21090.*
- Arabic at Curlie (based on DMOZ)

This article contains major sections of text from the very detailed article Arabic alphabet from the French Wikipedia, which has been partially translated into English. Further translation of that page, and its incorporation into the text here, are welcomed.

Bengali alphabet

The **Bengali alphabet** or **Bangla alphabet** (Bengali: বাংলা ব্ণরমালা, *bangla bôrnômala*) or **Bengali script** (Bengali: বাংলা লিপি, *bangla lipi*) is the writing system for the Bengali language and, together with the Assamese alphabet, is the fifth most widely used writing system in the world. The script is used for other languages like Maithili, Meithei and Bishnupriya Manipuri, and has historically been used to write Sanskrit within Bengal.

Bengali abugida Bangla abugida	
অ আ ই ঈ উ ঊ ঋ এ ঐ ও ঔ ক খ গ ঘ ঙ চ ছ জ ঝ ঞ ট ঠ ড ঢ ণ ত থ দ ধ ন প ফ ব ভ ম য র ল শ ষ স হ	
Type	Abugida
Languages	Sanskrit, Bengali, Meithei, Bishnupriya Manipuri, Kokborok (official), Sylheti, Chakma, Santali
Time period	11th century to the present[1]

From a classificatory point of view, the Bengali script is an abugida, i.e. its vowel graphemes are mainly realised not as independent letters, but as diacritics modifying the vowel inherent in the base letter they are added to. Bengali script is written from left to right and lacks distinct letter cases. It is recognisable, as are other Brahmic scripts, by a distinctive horizontal line running along the tops of the letters that links them together which is known as মাত্রা *matra*. The Bengali script is however less blocky and presents a more sinuous shape.[2]

History

The Bengali script evolved from the Siddham script, which belongs to the Brahmic family of scripts. In addition to differences in how the letters are pronounced in the different languages, there are some typographical differences between the version of the script used for Assamese language and that used for Bengali language:

- *rô* is represented as র in Bengali, and as ৰ in Assamese.
- Assamese script has a character, *wô*, represented as ৱ; in Bengali it was represented as ব, same as *bô*, and was called অন্তঃস্থ ব *ôntôsthô bô*, to differentiate it from the other bô called ব্গরীয় ব *bôrgiyô bô* but it lost its distinctive sound over the course of time (and was pronounced just like ব্গরীয় ব) and recently, it was merged with ব্গরীয় ব (though difference is still found in form of বফলা *bôfôla*, which is the diacritic form of অন্তঃস্থ ব) especially due to both being represented by the same letter.

The version of the script used for Manipuri is also a different variation; it uses the *rô*, represented as র in Bengali script without the different representation as in Assamese script. It also uses the Assamese script character sounding *wô*, represented as ৱ.

The Bengali script was originally not associated with any particular language but was often used in the eastern regions of the Middle kingdoms of India and then in the Pala Empire. It later continued to be specifically used in the Bengal region. It was later standardised into the modern Bengali script by Ishwar Chandra Vidyasagar under the reign of the East India Company. Today, the script holds official script status in Bangladesh and India, and it is associated with the daily life of Bengalis.

Characters

The Bengali script can be divided into vowels and vowel diacritics/marks, consonants and consonant conjuncts, diacritical and other symbols, digits, and punctuation marks.

Vowels

The Bengali script has a total of 11 vowel graphemes, each of which is called a স্বরবর্ণ *swôrôbôrnô* "vowel letter". The *swôrôbôrnôs* represent six of the seven main vowel sounds of Bengali, along with two vowel diphthongs. All of them are used in both Bengali and Assamese languages.

- "অ" *ô* (স্বর অ *shôrô ô*, "vocalic ô") /ɔ/ sounds as the default Inherent vowel for the entire Bengali script.
- Even though the open-mid front unrounded vowel /ɛ/ is one of the seven main vowel sounds in the standard Bengali language, no distinct vowel symbol has been allotted for it in the script since there is no /ɛ/ sound in Sanskrit, the primary written language when the script was conceived. As a result, the sound is orthographically realised by multiple means in modern Bengali orthography, usually using some combination of "এ" *e* (স্বর এ *shôrô e*, "vocalic e") /e/, "অ", "আ" *a* (স্বর আ *shôrô a*) /a/ and the যফলা *jôfôla* (diacritic form of the consonant grapheme য *jô*).
- There are two graphemes for the vowel sound [i] and two graphemes for the vowel sound [u]. The redundancy stems from the time when this script was used to write Sanskrit, a language that had short and long vowels: "ই" *i* (হ্রস্ব ই *rôshshô i*, "short i") /i/ and "ঈ" *ī* (দীর্ঘ ঈ *dirghô ī*, "long ī") /iː/, and "উ" *u* (হ্রস্ব উ *rôshshô u*) /u/ and "ঊ" *ū* (দীর্ঘ ঊ *dirghô ū*) /uː/. The letters are preserved in the Bengali script with their traditional names despite the fact that they are no longer pronounced differently in ordinary speech. These graphemes serve an etymological function, however, in preserving the original Sanskrit spelling in *tôtsômô* Bengali words (words borrowed from Sanskrit).
- The grapheme called "ঋ" *ṛ* (or হ্রস্ব ঋ *rôshshô ri*, "short ri", as it used to be) does not really represent a vowel phoneme in Bengali but the consonant-vowel combination রি /ri/. Nevertheless, it is included in the vowel section of the inventory of the Bengali script. This inconsistency is also a remnant from Sanskrit, where the grapheme represents the vocalic equivalent of a retroflex approximant (possibly an r-colored vowel). Another grapheme called "ঌ" *ḷ* (or হ্রস্ব ঌ *rôshshô li* as it used to be) representing the vocalic equivalent of a dental approximant in Sanskrit but actually representing the constant-vowel combination লি /li/ in Bengali instead of a vowel phoneme, was also included in the vowel section but unlike "ঋ", it was recently discarded from the inventory since its usage was extremely limited even in Sanskrit.
- When a vowel sound occurs syllable-initially or when it follows another vowel, it is written using a distinct letter. When a vowel sound follows a consonant (or a consonant cluster), it is written with a diacritic which, depending on the vowel, can appear above, below, before or after the consonant. These vowel marks cannot appear without a consonant and are called কার *kar*.

Parent systems	Proto-Sinaitic script[a] • Phoenician alphabet[a] ◦ Aramaic alphabet[a] ▪ Brahmi script ▪ Gupta script ▪ Siddham ▪ Eastern Nagari ▪ Bengali abugida
Sister systems	Assamese, Tibetan, Tirhuta, Anga Lipi
Direction	Left-to-right
ISO 15924	`Beng, 325`
Unicode alias	Bengali
Unicode range	U+0980–U+09FF

[a] The Semitic origin of the Brahmic scripts is not universally agreed upon.

- An exception to the above system is the vowel /ɔ/, which has no vowel mark but is considered inherent in every consonant letter. To denote the absence of the inherent vowel [ɔ] following a consonant, a diacritic called the **হসন্ত** *hôsôntô* (◌্) may be written underneath the consonant.
- Although there are only two diphthongs in the inventory of the script: "ঐ" *oi* (*স্বর ঐ shôrô oi*, "vocalic oi") /oi/ and "ঔ" *ou* (*স্বর ঔ shôrô ou*) /ou/, the Bengali phonetic system has, in fact, many diphthongs.[nb 1] Most diphthongs are represented by juxtaposing the graphemes of their forming vowels, as in কেউ *keu* /keu/.
- There also used to be two long vowels: "ৠ" *r̥̄* (*দীর্ঘ ৠ dirghô rri*, "long rri") and "ৡ" *l̥̄* (*দীর্ঘ ৡ dirghô lli*), which were removed from the inventory during the Vidyasagarian reform of the script due to peculiarity to Sanskrit.

The table below shows the vowels present in the modern (since the late nineteenth century) inventory of the Bengali alphabet:

Bengali vowels
(স্বরবর্ণ *sbôrôbôrnô*)

	হ্রস্ব (short)			দীর্ঘ (long)		
	স্বর (vowel phoneme)		কার (vowel mark)	স্বর (vowel phoneme)		কার (vowel mark)
কণ্ঠ্য (Guttural)	অ	*ô* /ɔ~o/[nc 1]	-	আ	*a* /a/	◌া
তালব্য (Palatal)	ই	*i* /i/	ি◌	ঈ	*ī/ee* /i/	◌ী
ওষ্ঠ্য (Labial)	উ	*u* /u/	◌ু	ঊ	*ū/oo* /u/	◌ূ
মূর্ধন্য (Retroflex)	ঋ	*r̥/ri* /ri/	◌ৃ	ৠ	*r̥̄/rri*	◌ৄ
দন্ত্য (Dental)	ঌ	*l̥/li* /li/	◌ৢ	ৡ	*l̥̄/lli*	◌ৣ
যুক্তস্বর (complex vowels)						
কণ্ঠ্যতালব্য (Palatoguttural)	এ	*e* /e~ɛ/[nc 2]	ে◌	ঐ	*oi* /oi/	ৈ◌
কণ্ঠৌষ্ঠ্য (Labioguttural)	ও	*o* /o~ʊ/[nc 3]	ে◌া	ঔ	*ou* /ou/	ে◌ৗ

ক কা কি কী কু কূ কৃ কে কৈ কো কৌ

The consonant ক (kô) along with the diacritic form of the vowels অ, আ, ই, ঈ, উ, ঊ, ঋ, এ, ঐ, ও and ঔ.

Notes

1. **^** The natural pronunciation of the grapheme অ, whether in its independent (visible) form or in its "inherent" (invisible) form in a consonant grapheme, is /ɔ/. But its pronunciation changes to /o/ in the following contexts:
   - অ is in the first syllable and there is a ই /i/ or উ /u/ in the next syllable, as in অতি *ôti* "much" /ɔt̪i/, বলছি *bôlchhi* "(I am) speaking" /ˈboltʃʰi/
   - if the অ is the inherent vowel in a word-initial consonant cluster ending in *rôfôla* "rô ending" /r/, as in পর্থম *prôthôm* "first" /prɔt̪ʰɔm/
   - if the next consonant cluster contains a *jôfôla* "jô ending", as in অনয্ *ônyô* "other" /onːo/, জনয্ *jônyô* "for" /dʒɔnːɔ/
2. **^** Even though the open-mid front unrounded vowel /ɛ/ is one of the seven main vowel sounds in the standard Bengali language, no distinct vowel symbol has been allotted for it in the script, though এ is used.
3. **^** /ʊ/ is the original pronunciation of the vowel ও, though a secondary pronunciation /o/ entered the Bengali phonology by Sanskrit influence. In modern Bengali, both the ancient and adopted pronunciation of ও can be heard in spoken. Example: The word নোংরা (meaning "foul") is pronounced as /nʊŋra/ and /noŋra/ (Romanized as both *nungra* and *nongra*), both.

Consonants

Consonant letters are called বয্ঞ্জনব্ণর *bænjônbôrnô* "consonant letter" in Bengali. The names of the letters are typically just the consonant sound plus the inherent vowel অ *ô*. Since the inherent vowel is assumed and not written, most letters' names look identical to the letter itself (the name of the letter ঘ is itself *ghô*, not *gh*).

- Some letters that have lost their distinctive pronunciation in modern Bengali are called by more elaborate names. For example, since the consonant phoneme /n/ is written as both ন and ণ, the letters are not called simply *nô*; instead, they are called দন্তয্ ন *dôntyô nô* ("dental nô") and মূধরনয্ ণ *murdhônyô nô* ("retroflex nô"). What was once pronounced and written as a retroflex nasal ণ [ɳ] is now pronounced as an alveolar [n] (unless conjoined with another retroflex consonant such as ট, ঠ, ড and ঢ) although the spelling does not reflect the change.
- Although still named *Murdhônyô* when they are being taught, retroflex consonants do not exist in Bengali and are instead fronted to their postalveolar and alveolar equivalents.[3]
- The voiceless palato-alveolar sibilant phoneme /ʃ/ can be written as শ, (*তালবয্ শ talôbyô shô*, "palatal shô"), ষ (*মূধরনয্ ষ murdhônyô shô*, "retroflex shô"), or স (*দন্তয্ স dôntyô sô*, "dental sô" voiceless alveolar fricative), depending on the word.
- The voiced palato-alveolar affricate phoneme /dʒ/ can be written in two ways, as য (*অন্তঃস্থ য ôntôsthô jô*) or জ (ব্গরীয় জ *bôrgiyô jô*). In many varieties of Bengali, [z, dz] are not distinct from this phoneme, but speakers who distinguish them may use the letters য and জ with contrast.
- Since the nasals ঞ *ñô* /ẽɔ/ and ঙ *ngô* /ŋɔ/ cannot occur at the beginning of a word in Bengali, their names are not *ñô* and *ngô* respectively but উঙ *ungô* (pronounced by some as উম *umô* or উঁঅ *ũô*) and ইঞ *iñô* (pronounced by some as নীয় *niyô* or ইঙ *ingô*) respectively.
- Similarly, since the semivowel য় yô / êɔ/ cannot occur at the beginning of a Bengali word (unlike Sanskrit and other Indic languages, Bengali words cannot begin with any semi-vocalic phoneme), its name is not *ôntôsthô yô* but অন্তঃস্থ অ *ôntôsthô ô*.

- There is a difference in the pronunciation of ড় ṛô (ড-এ শূনয্ ড় ḍô-e shunyô ṛô, "ṛô (as) ḍô with a zero (the figure is used analogous to the ring below diacritic as the Bengali equivalent of the Devanagari nuqta, which is again analogous to the underdot)") and ঢ় ṛhô (ঢ-এ শূনয্ ঢ় ḍhô-e shunyô ṛhô) with that of র rô (sometimes called ব-এ শূনয্ র bô-e shunyô rô for distinguishing purpose) - similar to other Indic languages. This is especially true in the parlance of western and southern part of Bengal but lesser on the dialects of the eastern side of the Padma River. ড় and ঢ় were introduced to the inventory during the Vidyasagarian reform to indicate the retroflex flap in the pronunciation of ড ḍô and ঢ ḍhô in the middle or end of a word. It is an allophonic development in some Indic languages not present in Sanskrit. Yet in ordinary speech these letters are pronounced the same as র in modern Bengali.

Bengali consonants
(বয্ঞ্জনব্ণর *bænjônbôrnô*)

	স্প্শর **(Stop)**								অনুনাসিক **(Nasal)**		অন্তঃস্থ **(Approxim**	
	ব্গরীয় ব্ণর (Generic sounds)											
Voicing →	অঘোষ (Voiceless)				ঘোষ (Voiced)							
Aspiration →	অল্পপরাণ (Unaspirated)		মহাপরাণ (Aspirated)		অল্পপরাণ (Unaspirated)		মহাপরাণ (Aspirated)				অল্পপরা	
কন্ঠয্ **(Guttural)**[nc 1]	ক	*kô* /kɔ/	খ	*khô* /kʰɔ/	গ	*gô* /gɔ/	ঘ	*ghô* /gʱɔ/	ঙ	*ngô* /ŋɔ/		
তালবয্ **(Palatal)**[nc 3]	চ	*chô/sô* /tʃɔ~tsɔ~sɔ/	ছ	*chhô/ssô* /tʃʰɔ~tsʰɔ~sɔ/	জ	*ǰô* /dʒɔ~dzɔ~zɔ/	ঝ	*ǰhô* /dʒʱɔ~dzʱɔ/	ঞ	*ñô* /nɔ~ẽɔ/[nc 4]	য	/
মূধরনয্ **(Retroflex)**[nc 7]	ট	*ṭô* /ʈɔ/	ঠ	*ṭhô* /ʈʰɔ/	ড	*ḍô* /ɖɔ/	ঢ	*ḍhô* /ɖʱɔ/	ণ	*ṇô* /nɔ~ɳɔ/[nc 8]	র	
দন্তয্ **(Dental)**	ত	*tô* /t̪ɔ/	থ	*thô* /t̪ʰɔ/	দ	*dô* /d̪ɔ/	ধ	*dhô* /d̪ʱɔ/	ন	*nô* /nɔ/	ল	
ওষ্ঠয্ **(Labial)**	প	*pô* /pɔ/	ফ	*phô/fô* /pʰɔ~ɸɔ~fɔ/[nc 9]	ব	*bô* /bɔ/	ভ	*bhô* /bʱɔ~β/	ম	*mô* /mɔ/	ব	

Post-reform letters	ড়	*ṛô* /ɽɔ/	ঢ়	*ṛhô* /ɽʰɔ~ɽ/	য়	*yô* /ẽɔ~jɔ/

Notes

1. **^** Though in modern Bengali the letters ক, খ, গ, ঘ, ঙ are actually velar consonants and the letter হ is actually a glottal consonant, texts still use the Sanskrit name "কন্ঠ্য" ("guttural").
2. **^** When used at the beginning or end of a word, হ is pronounced voiceless /hɔ/ but when used in the middle, it is sounded voiced as /ɦɔ/.
3. **^** Palatal letters phonetically represent palato-alveolar sounds but in Eastern dialects they mostly are depalatalised or de-palatalised and deaffricated.
4. **^** Original sound for ঞ was /ɲɔ/ but in modern Bengali, it represents /ẽɔ/ and in consonant conjuncts is pronounced /nɔ/ same as ন.
5. **^** In Sanskrit, য represented voiced palatal approximant /j/. In Bengali, it developed two allophones: voiced palato-alveolar affricate /dʒɔ/ same as জ when used at the beginning of a word and the palatal approximant in other cases. When reforming the script, Ishwar Chandra Vidyasagar introduced য়, representing /êɔ/, to indicate the palatal approximant in the pronunciation of য in the middle or end of a word. In modern Bengali, য represents /dʒɔ/ and the open-mid front unrounded vowel /ɛ/ as the diacritic *jôfôla*. It falls into voiced alveolar sibilant affricate /dzɔ/ in Eastern dialects and is also used to represent voiced alveolar sibilant /zɔ/ for Perso-Arabic loanwords.
6. ^ ***a b c*** In Bengali, there are three letters for sibilants: শ, ষ, স. Originally all three had distinctive sounds. In modern Bengali, the most common sibilant varies between /ʃ~ɕ/ – originally represented by শ, but today, স and ষ in words are often pronounced as /ɕ~ʃ/. The other sibilant in Bengali is /s/, originally represented by স, but today, শ and ষ, in words, can sometimes be pronounced as /s/. Another, now extinct, sibilant was /ʂ/, originally represented by ষ. ষ is mostly pronounced as /ɕ~ʃ/, but in conjunction with apical alveolar consonants, the /ʂ/ sound can sometimes be found.
7. **^** In modern text often the name দন্তমূলীয় ("alveolar") or পশ্চাদ্দন্তমূলীয় ("postalveolar") is used to describe letters previously described as retroflex more precisely.
8. **^** The original sound for ণ was /ɳɔ/ but in modern Bengali it is almost always pronounced /nɔ/ same as ন; except for in conjuncts with other retroflex letters, original sound for ণ can occasionally be found.
9. **^** Although ফ represents the aspirated form of the voiceless bilabial stop /pʰɔ/ it is pronounced either voiceless labial fricative /ɸɔ/ (in Eastern dialects) or voiceless labiodental fricative /fɔ/ in ordinary speech.

Consonant conjuncts

Up to four consonant clusters can be orthographically represented as a typographic ligature called a consonant conjunct (Bengali: যুক্তাক্ষর/যুক্তবর্ণ *juktakkhôr/juktôbôrnô* or more specifically যুক্তব্যঞ্জন). Typically, the first consonant in the conjunct is shown above and/or to the left of the following consonants. Many consonants appear in an abbreviated or compressed form when serving as part of a conjunct. Others simply take exceptional forms in conjuncts, bearing little or no resemblance to the base character.

The consonant ligature ndrô (ন্দ্র) : ন (nô) in green, দ (dô) in blue and র (rô) in maroon.

Often, consonant conjuncts are not actually pronounced as would be implied by the pronunciation of the individual components. For example, adding ল *lô* underneath শ *shô* in Bengali creates the conjunct শ্ল, which is not pronounced *shlô* but *slô* in Bengali. Many conjuncts represent Sanskrit sounds that were lost centuries before modern Bengali was ever spoken as in জ্ঞ. It is a combination of জ ǰô and ঞ ñô but it is not pronounced "ǰñô" or "jnô". Instead, it is pronounced *ggô* in modern Bengali. Thus, as conjuncts often represent (combinations of) sounds that cannot be easily understood from the components, the following descriptions are concerned only with the construction of the conjunct, and not the resulting pronunciation.

(Some graphemes may appear in a form other than the mentioned form due to the font used)

Fused forms

Some consonants fuse in such a way that one stroke of the first consonant also serves as a stroke of the next.

- The consonants can be placed on top of one another, sharing their vertical line: ক্ক kkô গ্ন gnô গ্ল glô ন্ন nnô প্ন pnô প্প ppô ল্ল llô etc.
- As the last member of a conjunct, ব bô can hang on the vertical line under the preceding consonants, taking the shape of ব bô (includes বফলা *bôfôla*): গ্ব gbô ণ্ব "ṇbô" দ্ব "dbô" ল্ব lbô শ্ব "shbô".
- The consonants can also be placed side-by-side, sharing their vertical line: দ্দ ddô ন্দ ndô ব্দ bdô ব্জ bǰô প্ট pṭô শ্চ shchô শ্ছ shchhô, etc.

Approximated forms

Some consonants are written closer to one another simply to indicate that they are in a conjunct together.

- The consonants can be placed side-by-side, appearing unaltered: দ্গ dgô দ্ঘ dghô ড্ড ḍḍô.
- As the last member of a conjunct, ব bô can appear immediately to the right of the preceding consonant, taking the shape of ব bô (includes বফলা *bôfôla*): ধ্ব "dhbô" ব্ব bbô হ্ব "hbô".

Compressed forms

Some consonants are compressed (and often simplified) when appearing as the first member of a conjunct.

- As the first member of a conjunct, the consonants ঙ ngô চ chô ড ḍô and ব bô are often compressed and placed at the top-left of the following consonant, with little or no change to the basic shape: ঙ্ক্ষ "ngkṣô" ঙ্খ ngkhô ঙ্ঘ ngghô ঙ্ম ngmô চ্চ chchô চ্ছ chchhô চ্ঞ "chnô" ড্ঢ ḍḍhô ব্ব bbô.
- As the first member of a conjunct, ত tô is compressed and placed above the following consonant, with little or no change to the basic shape: ত্ন tnô ত্ম "tmô" ত্ব "tbô".
- As the first member of a conjunct, ম mô is compressed and simplified to a curved shape. It is placed above or to the top-left of the following consonant: ম্ন mnô ম্প mpô ম্ফ mfô ম্ব mbô ম্ভ mbhô ম্ম mmô ম্ল mlô.
- As the first member of a conjunct, ষ ṣô is compressed and simplified to an oval shape with a diagonal stroke through it. It is placed to the top-left of the following consonants: ষ্ক ṣkô ষ্ট ṣṭô ষ্ঠ ṣṭhô ষ্প ṣpô ষ্ফ ṣfô ষ্ম ṣmô.
- As the first member of a conjunct, স sô is compressed and simplified to a ribbon

shape. It is placed above or to the top-left of the following consonant: স্ক skô স্খ skhô স্ট sṭô স্ত stô স্থ sthô স্ন snô স্প spô স্ফ sfô সব্ "sbô" স্ম "smô" স্ল slô.

Abbreviated forms

Some consonants are abbreviated when appearing in conjuncts and lose part of their basic shape.

- As the first member of a conjunct, জ ǰô can lose its final down-stroke: জ্জ ǰǰô জ্ঞ "ǰñô" জব্ "jbô".
- As the first member of a conjunct, ঞ ñô can lose its bottom half: ঞ্চ ñchô ঞ্ছ ñch-hô ঞ্জ ñǰô ঞ্ঝ ñǰhô.
- As the last member of a conjunct, ঞ ñô can lose its left half (the এ part): জ্ঞ "ǰñô".
- As the first member of a conjunct, ণ ṇô and প pô can lose their down-stroke: ণ্ঠ ṇṭhô ণ্ড ṇḍô প্ত ptô প্স psô.
- As the first member of a conjunct, ত tô and ভ bhô can lose their final upward tail: ত্ত ttô ত্থ tthô তর্ trô ভর্ bhrô.
- As the last member of a conjunct, থ thô can lose its final upstroke, taking the form of হ hô instead: ন্থ nthô স্থ sthô ম্থ mthô
- As the last member of a conjunct, ম mô can lose its initial down-stroke: ক্ম "kmô" গ্ম "gmô" ঙ্ম ngmô ট্ম "ṭmô" ণ্ম "ṇmô" ত্ম "tmô" দ্ম "dmô" ন্ম nmô ম্ম mmô শ্ম "shmô" ষ্ম ṣmô স্ম "smô".
- As the last member of a conjunct, স sô can lose its top half: ক্স ksô.
- As the last member of a conjunct ট ṭô, ড ḍô and ঢ ḍhô can lose their matra: প্ট pṭô ণ্ড ṇḍô ণ্ট ṇṭô ণ্ঢ ṇḍhô.
- As the last member of a conjunct ড ḍô can change its shape: ণ্ড ṇḍô

Variant forms

Some consonants have forms that are used regularly but only within conjuncts.

- As the first member of a conjunct, ঙ ngô can appear as a loop and curl: ঙ্ক ngkô ঙ্গ nggô.
- As the last member of a conjunct, the curled top of ধ dhô is replaced by a straight downstroke to the right, taking the form of ঝ ǰhô instead: গ্ধ gdhô দ্ধ ddhô ন্ধ nd-hô ব্ধ bdhô.
- As the first member of a conjunct, র rô appears as a diagonal stroke (called রেফ *ref*) above the following member: র্ক rkô র্খ rkhô র্গ rgô র্ঘ rghô, etc.
- As the last member of a conjunct, র rô appears as a wavy horizontal line (called রফলা *rôfôla*) under the previous member: খর্ khrô গর্ grô ঘর্ ghrô বর্ brô, etc.
  - In some fonts, certain conjuncts with রফলা *rôfôla* appear using the compressed (and often simplified) form of the previous consonant: জর্ ǰrô টর্ ṭrô ঠর্ ṭhrô ডর্ ḍrô মর্ mrô সর্ srô.
  - In some fonts, certain conjuncts with রফলা *rôfôla* appear using the abbreviated form of the previous consonant: কর্ krô তর্ trô ভর্ bhrô.
- As the last member of a conjunct, য jô appears as a wavy vertical line (called যফলা *jôfôla*) to the right of the previous member: কয্ "kyô" খয্ "khyô" গয্ "gyô" ঘয্ "ghyô"

etc.

  - In some fonts, certain conjuncts with যফলা *jôfôla* appear using special fused forms: দয্ "dyô" নয্ "nyô" শয্ "shyô" ষয্ "ṣyô" সয্ "syô" হয্ "hyô".

Exceptions

- When followed by র rô or ত tô, ক kô takes on the same form as ত tô would with the addition of a curl to the right: কর্ krô, ক্ত ktô.
- When preceded by the abbreviated form of ঞ ñô, চ chô takes the shape of ব bô: ঞ্চ ñchô
- When preceded by another ট ṭô, ট is reduced to a leftward curl: ট্ট ṭṭô.
- When preceded by ষ ṣô, ণ ṇô appears as two loops to the right: ষ্ণ ṣṇô.
- As the first member of a conjunct, or when at the end of a word and followed by no vowel, ত tô can appear as ?: ?স "tsô" ?প tpô ?ক tkô etc.
- When preceded by হ hô, ন nô appears as a curl to the right: হ্ন "hnô".
- Certain combinations must be memorised: ক্ষ "kṣô" হ্ম "hmô".

Certain compounds

When serving as a vowel mark, উ u, ঊ u, and ঋ ri take on many exceptional forms.

- উ u
  - When following গ gô or শ shô, it takes on a variant form resembling the final tail of ও o: গু gu শু shu.
  - When following a ত tô that is already part of a conjunct with প pô, ন nô or স sô, it is fused with the ত to resemble ও o: ন্তু ntu স্তু stu প্তু ptu.
  - When following র rô, and in many fonts also following the variant রফলা *rôfôla*, it appears as an upward curl to the right of the preceding consonant as opposed to a downward loop below: রু ru গ্রু gru ত্রু tru থ্রু thru দ্রু dru ধ্রু dhru ব্রু bru ভ্রু bhru শ্রু shru.
  - When following হ hô, it appears as an extra curl: হু hu.
- ঊ u
  - When following র rô, and in many fonts also following the variant রফলা *rôfôla*, it appears as a downstroke to the right of the preceding consonant as opposed to a downward hook below: রূ rū গ্রূ grū থ্রূ thrū দ্রূ drū ধ্রূ dhrū ভ্রূ bhrū শ্রূ shrū.
- ঋ ri
  - When following হ hô, it takes the variant shape of উ u: হৃ hri.
- Conjuncts of three consonants also exist, and follow the same rules as above: স sô + ত tô +র rô = স্তর্ strô, ম mô + প pô + র rô = ম্পর্ mprô, জ ǰô + জ ǰô + ব bô = জ্জব্ "ǰǰbô", ক্ষ "kṣô" + ম mô = ক্ষ্ম "kṣmô".
- Theoretically, four-consonant conjuncts can also be created, as in র rô + স sô + ট ṭô + র rô = ্স্টর্র rsṭrô, but they are not found in native words.

Diacritics and other symbols

These are mainly the Brahmi-Sanskrit diacritics, phones and punctuation marks present in languages with Sanskrit influence or Brahmi-derived scripts.

সংশোধক ব্ণর *sôngshodhôk bôrnô*

Symbol/ Graphemes	Name	Function	Romanization	IPA transcription
?[nc 1]	খণ্ড ত *khôndô tô*	Special character. Final unaspirated dental [t̪]	t	/t̪/
◌ং[nc 2]	অনুসব্ার *ônushshar*	Diacritic. Final velar nasal [ŋ]	ng	/ŋ/
◌ঃ[nc 2]	বিস্গর *bishôrgô*	Diacritic. 1. Doubles the next consonant sound without the vowel (spelling feature) in **দুঃখ** *dukkhô*, the *k* of **খ** *khô* was repeated before the whole **খ** *khô* 2. "h" sound at end, examples: **এঃ** *eh!*, **উঃ** *uh!* 3. Silent in spellings like **অন্তঃনগর** *ôntônôgôr* meaning "Inter-city" 4. Also used as abbreviation, like **কিঃমিঃ**, for the word ***কিলোমিটার*** "kilometer" (similar to "km" in English), another example can be **ডাঃ** for **ডাক্তার** *dāktār* "doctor"	h	/ḥ/
◌ঁ	চন্দ্রবিন্দু *chôndrôbindu*	Diacritic. Vowel nasalization	ñ	/ñ/
◌্	হসন্ত *hôshôntô*	Diacritic. Suppresses the inherent vowel [ɔ] *(ô)*	–	–
?	অবগ্রহ *ôbôgrôhô*	Special character or sign. Used for prolonging vowel sounds Example1: **শুন**??? *shunôôôô* meaning "listennnn..." (listen), this is where the default inherited vowel sound *ô* in **ন** *nô* is prolonged. Example2: **কি**???? *kiiii?* meaning "Whatttt...?" (What?), this is where the vowel sound *i* which is attached with the consonant **ক** *kô* is prolonged.	-	–

্য	যফলা *jôfôla*	Diacritic. Used with two types of pronunciation in modern Bengali depending on the location of the consonant it is used with within a syllable Example 1 - When the consonant it is used with is syllable-initial, it acts as the vowel /ɛ/: ত্যাগ is pronounced /tɛg/ Example 2 - When the consonant it is used with is syllable-final, it doubles the consonant: মুখ্য is pronounced /mukʰ:ɔ/ Notably used in transliterating English words with /ɛ/ sounding vowels, e.g. ব্ল্যাক "black" and sometimes as a diacritic to indicate non-Bengali vowels of various kinds in transliterated foreign words, e.g. the schwa indicated by a *jôfôla*, the French u, and the German umlaut ü as উ্য uyô, the German umlaut ö as ও্য oyô or এ্য eyô	ê / yô	/ɛ/ or /:/
্র	রফলা *rôfôla*	Diacritic. [r] pronounced following a consonant phoneme.	r	/r/

র্ক	রেফ *ref/reph*	Diacritic. [r] pronounced preceding a consonant phoneme.	r	/r/
◌্ব	বফলা *bôfôla*	Diacritic. Used in spellings only if they were adopted from Sanskrit and has two different pronunciations depending on the location of the consonant it is used with Example 1 - When the consonant it is used with is syllable-initial, it remains silent: **স্বাধীন** is pronounced as /ʃad̪ʱin/ rather than /ʃbad̪ʱin/ Example 2 - When the consonant it is used with is syllable-final, it doubles the consonant: **বিদ্বান** is pronounced /bidːan/ and **বিশ্ব** is pronounced /biʃːɔ/ However, certain Sanskrit sandhis (phonetic fusions) such as '**ঋগ্বেদ**', '**দিগ্বিজয়**', '**উদ্বেগ**', '**উদ্বৃত্ত**' are pronounced /rigbed/, /di̯gbidʒɔê/, /udb̯eg/, /udb̯rittɔ/ respectively while usage with the consonant **হ** defies phonological rules: '**আহ্বান**' and '**জিহ্বা**' are properly pronounced /aobɦan/ and /dʒiobɦa/ rather than /aɦban/ and /dʒiɦba/, respectively. Also used in transliterating Islam-related Arabic words **Note**: Not all instances of **ব** bô used as the last member of a conjunct are *bôfôla*, for example, in the words **অম্বর** *ôm**b**ôr*, **লম্বা** *lôm**b**a*, **তিব্বত** *tib**b**ôt*, **বাল্ব** *bal**b***, etc.	-	/ː/
৺	ঈশ্বার *ishshar*	Sign. Represents the name of a deity or also written before the name of a deceased person	–	–
?	আঞ্জী/ সিদ্ধিরস্তু *anji /siddhirôstu*	Sign. Used at the beginning of texts as an invocation	–	–

Notes

1. **^** ? (*khôndô tô* "part-*tô*") is always used syllable-finally and always pronounced as /t̪/. It is predominantly found in loan words from Sanskrit such as ভবিষয্? *bhôbishyôt* "future", সতয্জি? *sôtyôjit* (a proper name), etc. It is also found in some onomatopoeic words (such as থপা? *thôpat* "sound of something heavy that fell", মড়া? *môrat* "sound of something breaking", etc.), as the first member of some consonant conjuncts (such as ?স tsô, ?প tpô, ?ক tkô, etc.), and in some foreign loanwords (e.g. না?সি *natsi* "Nazi", জুজু?সু *ju-jutsu* "Jujutsu", ?সুনামি *tsunami* "Tsunami", etc.) which contain the same conjuncts. It is an overproduction inconsistency, as the sound /t̪/ is realised by both ত and ?. This creates confusion among inexperienced writers of Bengali. There is no simple way of telling which symbol should be used. Usually, the contexts where ? is used need to be memorised, as they are less frequent. In the native Bengali words, syllable-final ত *tô* /t̪ɔ/ is pronounced /t̪/, as in নাতনি /nat̪ni/ "grand-daughter", করাত /kɔrat̪/ "saw", etc.
2. ^ ***a b*** ঃ *-h* and ং *-ng* are also often used as abbreviation marks in Bengali, with ং *-ng* used when the next sound following the abbreviation would be a nasal sound, and ঃ *-h* otherwise. For example, ডঃ *dôh* stands for ডক্টর *dôktôr* "doctor" and নং *nông* stands for নমব্র *nômbôr* "number". Some abbreviations have no marking at all, as in ঢাবি *dhabi* for ঢাকা বিশব্বিদয্ালয় *Dhaka Bish-bôbidyalôy* "University of Dhaka". The full stop can also be used when writing out English letters as initials, such as ই.ইউ. *i.iu* "EU".

Digits and numerals

The Bengali script has ten numerical digits (graphemes or symbols indicating the numbers from 0 to 9). Bengali numerals have no horizontal headstroke or মাতরা্ "matra".

Bengali numerals

Hindu-Arabic numerals	0	1	2	3	4	5	6	7	8	9
Bengali numerals	০	১	২	৩	৪	৫	৬	৭	৮	৯

Numbers larger than 9 are written in Bengali using a positional base 10 numeral system (the decimal system). A period or dot is used to denote the decimal separator, which separates the integral and the fractional parts of a decimal number. When writing large numbers with many digits, commas are used as delimiters to group digits, indicating the thousand (হাজার *hazar*), the hundred thousand or lakh (লাখ *lakh* or লক্ষ *lôkkhô*), and the ten million or hundred lakh or crore (কোটি *koti*) units. In other words, leftwards from the decimal separator, the first grouping consists of three digits, and the subsequent groupings always consist of two digits.

For example, the English number 17,557,345 will be written in traditional Bengali as ১,৭৫,৫৭,৩৪৫.

Punctuation marks

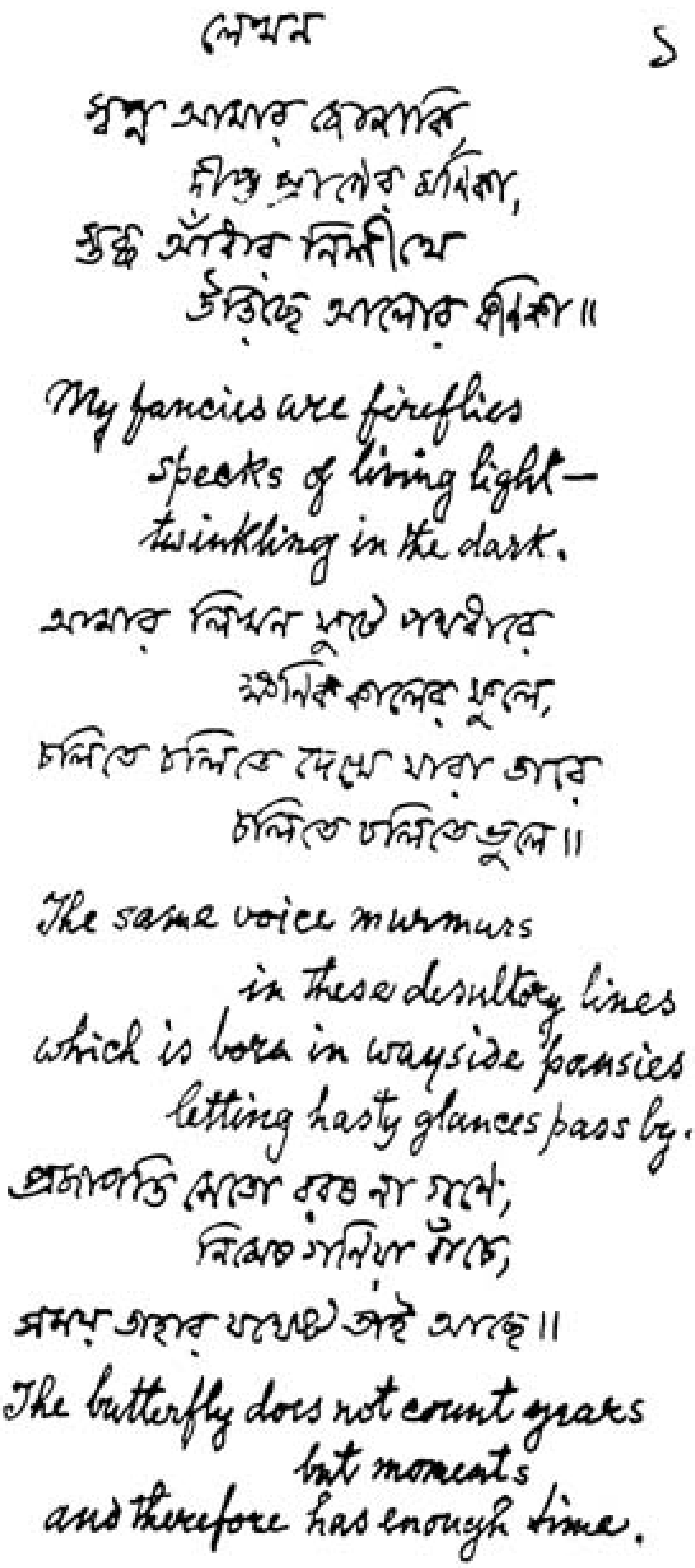
Bengali punctuation marks, apart from the downstroke দাড়ি *dari* (।), the Bengali equivalent of a full stop, have been adopted from western scripts and their usage is similar: Commas, semicolons, colons, quotation marks, etc. are the same as in English. Capital letters are absent in the Bengali script so proper names are unmarked.

An apostrophe, known in Bengali as ঊ্ধব্রকমা *urdhbôkôma* "upper comma", is sometimes used to distinguish between homographs, as in পাটা *pata* "plank" and পা'টা *pa'ta* "the leg". Sometimes, a hyphen is used for the same purpose (as in পা-টা, an alternative of পা'টা).

Characteristics of the Bengali text

Bengali text is written and read horizontally, from left to right. The consonant graphemes and the full form of vowel graphemes fit into an imaginary rectangle of uniform size (uniform width and height). The size of a consonant conjunct, regardless of its complexity, is deliberately maintained the same as that of a single consonant grapheme, so that diacritic vowel forms can be attached to it without any distortion. In a typical Bengali text, orthographic words, words as they are written, can be seen as being separated from each other by an even spacing. Graphemes within a word are also evenly spaced, but that spacing is much narrower than the spacing between words.

Unlike in western scripts (Latin, Cyrillic, etc.) for which the letter-forms stand on an invisible baseline, the Bengali letter-forms instead hang from a visible horizontal left-to-right headstroke called মাতরা *matra*. The presence and absence of this matra can be important. For example, the letter ত *tô* and the numeral ৩ "3" are distinguishable only by the presence or absence of the *matra*, as is the case between the consonant cluster ত্র *trô* and the independent vowel এ *e*. The letter-forms also employ the concepts of letter-width and letter-height (the vertical space between the visible matra and an invisible baseline).



An example of handwritten Bengali script. Part of a poem written by Nobel Laureate Rabindranath Tagore in 1926 in Hungary.

According to Bengali linguist Munier Chowdhury, there are about nine graphemes that are the most frequent in Bengali texts, shown with its percentage of appearance in the table on the right.[4]

Grapheme	Percentage
আ	11.32
এ	8.96
র	7.01
অ	6.63
ব	4.44
ক	4.15
ল	4.14
ত	3.83
ম	2.78

Standardization

In the script, clusters of consonants are represented by different and sometimes quite irregular forms; thus, learning to read is complicated by the sheer size of the full set of letters and letter combinations, numbering about 350. While efforts at standardising the alphabet for the Bengali language continue in such notable centres as the Bangla Academy at Dhaka (Bangladesh) and the Pôshchimbônggô Bangla Akademi at Kolkata (West Bengal, India), it is still not quite uniform yet, as many people continue to use various archaic forms of letters, resulting in concurrent forms for the same sounds. Among the various regional variations within this script, only the Assamese and Bengali variations exist today in the formalised system.

It seems likely that standardisation of the alphabet will be greatly influenced by the need to typeset it on computers. The large alphabet can be represented, with a great deal of ingenuity, within the ASCII character set, omitting certain irregular conjuncts. Work has been underway since around 2001 to develop Unicode fonts, and it seems likely that it will split into two variants, traditional and modern. In this and other articles on Wikipedia dealing with the Bengali language, a Romanization scheme used by linguists specialising in Bengali phonology is included along with IPA transcription. A recent effort by the Government of West Bengal focused on simplifying the Bengali orthography in primary school texts.

There is yet to be a uniform standard collating sequence (sorting order of graphemes to be used in dictionaries, indices, computer sorting programs, etc.) of Bengali graphemes. Experts in both Bangladesh and India are currently working towards a common solution for the problem.

Romanization

Romanization of Bengali is the representation of the Bengali language in the Latin script. There are various ways of Romanization systems of Bengali, created in recent years but failed to represent the true Bengali phonetic sound. While different standards for romanisation have been proposed for Bengali, they have not been adopted with the degree of uniformity seen in languages such as Japanese or Sanskrit.[nb 2] The Bengali alphabet has often been included with the group of Brahmic scripts for romanisation in which the true phonetic value of Bengali is never represented. Some of them are the International Alphabet of Sanskrit Transliteration or "IAST system"[5] "Indian languages Transliteration" or ITRANS (uses upper case alphabets suited for ASCII keyboards),[6] and the extension of IAST intended for non-Sanskrit languages of the Indian region called the National Library at Kolkata romanisation.[7]

Sample texts

Article 1 of the Universal Declaration of Human Rights

Bengali in Bengali alphabet

ধারা ১: সমস্ত মানুষ সব্াধীনভাবে সমান ম্যরাদা এবং অধিকার নিয়ে জন্মগর্হণ করে। তাঁদের বিবেক এবং বুদ্ধি আছে; সুতরাং সকলেরই একে অপরের পর্তি ভর্াতৃতব্সুলভ মনোভাব নিয়ে আচরণ করা উচিত।

Bengali in phonetic Romanization

Dhara æk: Šomosto manush šadhinbhabe šoman morjada æbong odhikar niye jonmogrohon kore. Tãder bibek æbong buddhi achhe; šutôrang sokoleri æke oporer proti bhratrittošulobh monôbhab niye achoron kora uchit.

Bengali in IPA

d̪ʱara ɛk ʃɔmost̪o̪ manuʃ ʃad̪ʱinbʱabe ʃɔman mɔrdʒad̪a̪ eboŋ od̪ʱikar niêe dʒɔnmogrohon kɔre. t̪ãd̪e̪r bibek eboŋ budd̪ʱːi atʃʰe; sut̪o̪raŋ sɔkoleri ɛke ɔporer prot̪i̪ bʱrat̪r̪it̪ːosulɔbʱ monobʱab niêe atʃoron kɔra utʃit̪

Gloss

Clause 1: All human free-manner-in equal dignity and right taken birth-take do. Their reason and intelligence exist; therefore everyone-indeed one another's towards brotherhood-ly attitude taken conduct do should.

Translation

Article 1: All human beings are born free and equal in dignity and rights. They are endowed with reason and conscience. Therefore, they should act towards one another in a spirit of brotherhood.

Unicode

Bengali script was added to the Unicode Standard in October 1991 with the release of version 1.0.

The Unicode block for Bengali is U+0980–U+09FF:

Bengali[1][2] Official Unicode Consortium code chart (PDF)																
	0	1	2	3	4	5	6	7	8	9	A	B	C	D	E	F
U+098x	?	◌ঁ	◌ং	◌ঃ		অ	আ	ই	ঈ	উ	ঊ	ঋ	ঌ			এ
U+099x	ঐ			ও	ঔ	ক	খ	গ	ঘ	ঙ	চ	ছ	জ	ঝ	ঞ	ট
U+09Ax	ঠ	ড	ঢ	ণ	ত	থ	দ	ধ	ন		প	ফ	ব	ভ	ম	য
U+09Bx	র		ল				শ	ষ	স	হ			◌়	?	◌া	◌ি
U+09Cx	◌ী	◌ু	◌ূ	◌ৃ	◌ৄ			◌ে	◌ৈ			◌ো	◌ৌ	◌্	?	
U+09Dx								◌ৗ					ড়	ঢ়		য়
U+09Ex	ৠ	ৡ	◌ৢ	◌ৣ			০	১	২	৩	৪	৫	৬	৭	৮	৯
U+09Fx	ৰ	ৱ	৲	৳	৴	৵	৶	৷	৸	৹	৺	?	?	?	?	

Notes

1.^ As of Unicode version 11.0
2.^ Grey areas indicate non-assigned code points

See also

- Bengali Braille
- Robert B. Wray movable type for Bengali (1778)

Notes

1. **^** Different Bengali linguists give different numbers of Bengali diphthongs in their works depending on methodology, e.g. 25 (Chatterji 1939: 40), 31 (Hai 1964), 45 (Ashraf and Ashraf 1966: 49), 28 (Kostic and Das 1972:6–7) and 17 (Sarkar 1987).
2. **^** In Japanese, there is some debate as to whether to accent certain distinctions, such as Tōhoku vs Tohoku. Sanskrit is well-standardized because the speaking community is relatively small, and sound change is not a large concern.

References

1. **^** Ancient Scripts
2. **^** George Cardona and Danesh Jain (2003), The Indo-Aryan Languages, Routledge, ISBN 978-0415772945
3. **^** *Mazumdar, Bijaychandra (2000). The history of the Bengali language (Repr. [d. Ausg.] Calcutta, 1920. ed.). New Delhi: Asian Educational Services. p. 57. ISBN 8120614526. "yet it is to be noted as a fact, that the cerebral letters are not so much cerebral as they are dental in our speech. If we carefully notice our pronunciation of the letters of the 'ট' class we will see that we articulate 'ট' and 'ড,' for example, almost like English T and D without turning up the tip of the tongue much away from the region of the teeth."*
4. **^** See Chowdhury 1963
5. **^** *"Learning International Alphabet of Sanskrit Transliteration". Sanskrit 3 – Learning transliteration. Gabriel Pradiipaka & Andrés Muni. Archived from the original on 12 February 2007. Retrieved 20 November 2006.*
6. **^** *"ITRANS – Indian Language Transliteration Package". Avinash Chopde. Retrieved 20 November 2006.*
7. **^** *"Annex-F: Roman Script Transliteration" (PDF). Indian Standard: Indian Script Code for Information Interchange — ISCII. Bureau of Indian Standards. 1 April 1999. p. 32. Retrieved 20 November 2006.*

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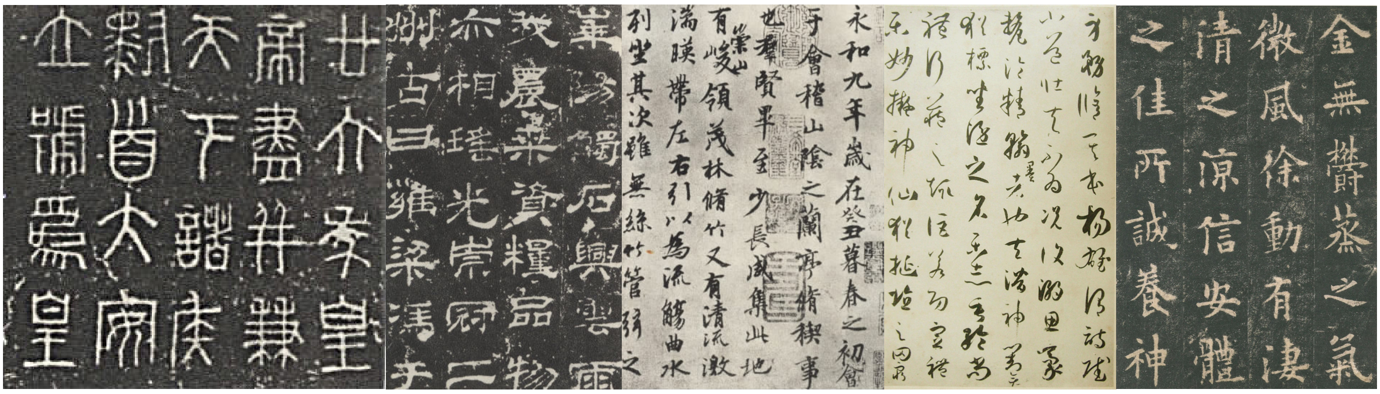
Chinese script styles

In Chinese calligraphy, Chinese characters can be written according to five major styles. These styles are intrinsically linked to the history of Chinese script.

Styles

Main styles of Chinese character calligraphy

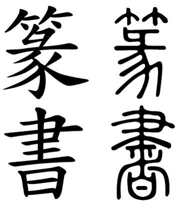
English name	**Chinese** (trad. Hanzi) **Japanese** (Kanji) **Korean** (Hanja) **Vietnamese** (Hán tự)	**Chinese** (Hanzi - simplified)	**Chinese, Mandarin** (Pinyin)	**Japanese** (Hepburn Romaji)	**Korean** (Hangul)	**Korean** (Revised Romanization)	**Vietnamese** (chữ Quốc ngữ)
Seal script (Small seal)	篆書	篆书	*Zhuànshū*	*Tensho*	전서	*Jeonseo*	*Triện thư*
Clerical script (Official script)	隸書 (Jpn: 隷書)	隶书	*Lìshū*	*Reisho*	예서	*Yeseo*	*Lệ thư*
Semi-cursive script (Running script)	行書	行书	*Xíngshū*	*Gyōsho*	행서	*Haengseo*	*Hành thư*
Cursive script (Sloppy script)	草書	草书	*Cǎoshū*	*Sōsho*	초서	*Choseo*	*Thảo thư*
Regular script (Standard script)	楷書	楷书	*Kǎishū*	*Kaisho*	해서	*Haeseo*	*Khải thư*



When used in decorative ornamentation, such as book covers, movie posters, and wall hangings, characters are often written in ancient variations or simplifications that deviate from the modern standards used in Chinese, Japanese, Vietnamese or Korean. Modern variations or simplifications of characters, akin to Chinese Simplified characters or Japanese *shinjitai*, are occasionally used, especially since some simplified forms derive from cursive script shapes in the first place.

The Japanese syllabaries of katakana and hiragana are used in calligraphy; the katakana were derived from the shapes of regular script characters and hiragana from those of cursive script. In Korea, the post-Korean War period saw the increased use of hangul, the Korean alphabet, in calligraphy.

Seal script



The seal script (often called "small seal" script) is the formal script of the Qín system of writing, which evolved during the Eastern Zhōu dynasty in the state of Qín and was imposed as the standard in areas Qín gradually conquered. Although some modern calligraphers practice the most ancient oracle bone script as well as various other scripts older than seal script found on Zhōu dynasty bronze inscriptions, seal script is the oldest style that continues to be *widely* practiced.

Today, this style of Chinese writing is used predominantly in seals, hence the English name. Although seals (name chops), which make a signature-like impression, are carved in wood, jade and other materials, the script itself was originally written with brush and ink on bamboo books and other media, just like all other ancient scripts.

Most people today cannot read the seal script, so it is considered an ‘ancient’ script, generally not used outside the fields of calligraphy and carved seals. However, because seals act like legal signatures in the cultures of China, Japan, Korea, and Vietnam, and because vermillion seal impressions are a fundamental part of the presentation of works of art such as calligraphy and painting, seals and therefore seal script remain ubiquitous.

Clerical script

The clerical script (often simply termed lìshū; and sometimes called "official", "draft", or "scribal" script) is popularly thought to have developed in the Hàn dynasty and to have come directly from seal script, but recent archaeological discoveries and scholarship indicate that it instead developed from a roughly executed and rectilinear popular or 'vulgar' variant of the seal script as well as from seal script itself, resulting first in a 'proto-clerical' version in the Warring States period to Qin dynasty,[1] which then developed into clerical script in the early Western Hàn dynasty, and matured stylistically thereafter.

Clerical script characters are often "flat" in appearance, being wider than the preceding seal script and the modern standard script, both of which tend to be taller than they are wide; some versions of clerical are square, and others are wider. Compared with the preceding seal script, forms are strikingly rectilinear; however, some curvature and some seal script influence often remains. Seal script tended towards uniformity of stroke width, but clerical script gave the brush freer rein, returning to the variations in width seen in early Zhōu brushwork. Most noticeable is the dramatically flared tail of one dominant horizontal or downward-diagonal stroke, especially that to the lower right. This characteristic stroke has famously been called 'silkworm head and wild goose tail' (蠶頭雁尾 cántóu yànwěi) in Chinese) due to its distinctive shape.

The archaic clerical script or 'proto-clerical' of the Chinese Warring States period to Qín Dynasty and early Hàn Dynasty can often be difficult to read for a modern East Asian person, but the mature clerical script of the middle to late Hàn dynasty is generally legible. Modern calligraphic works and practical applications (e.g., advertisements) in the clerical script tend to use the mature, late Hàn style, and may also use modernized character structures, resulting in a form as transparent and legible as regular (or standard) script. The clerical script remains common as a typeface used for decorative purposes (for example, in displays), but other than in artistic calligraphy, adverts and signage, it is not commonly written.

Semi-cursive script

行書 

The semi-cursive script (also called "running" script, 行書) approximates normal handwriting in which strokes and, more rarely, characters are allowed to run into one another. In writing in the semi-cursive script, the brush leaves the paper less often than in the regular script. Characters appear less angular and rounder.

In general, an educated person in China or Japan can read characters written in the semi-cursive script with relative ease, but may have occasional difficulties with certain idiosyncratic shapes.

Cursive script

草書 

The cursive script (sometimes called "sloppy script", 草書) is a fully cursive script, with drastic simplifications requiring specialized knowledge; hence it is difficult to read for those unfamiliar with it.

Entire characters may be written without lifting the brush from the paper at all, and characters frequently flow into one another. Strokes are modified or eliminated completely to facilitate smooth writing and to create a beautiful, abstract appearance. Characters are highly rounded and soft in appearance, with a noticeable lack of angular lines. Due to the drastic simplification and ligature involved, this script is not considered particularly legible to the average person, and thus has never achieved widespread use beyond the realm of literati calligraphers.

The cursive script is the source of Japanese *hiragana*, as well as many modern simplified forms in Simplified Chinese characters and Japanese *shinjitai*.

Regular script

楷書 楷书

The regular script (often called "standard" script or simply 'kǎishū' 楷书) is one of the last major calligraphic styles to develop, emerging between the Chinese Hàn dynasty and Three Kingdoms period, gaining dominance in the Southern and Northern Dynasties, and maturing in the Táng Dynasty. It emerged from a neatly written, early period semi-cursive form of clerical script. As the name suggests, the regular script is "regular", with each of the strokes placed slowly and carefully, the brush lifted from the paper and all the strokes distinct from each other.

The regular script is also the most easily and widely recognized style, as it is the script to which children in East Asian countries and beginners of East Asian languages are first introduced. For learners of calligraphy, the regular script is usually studied first to give students a feel for correct placement and balance, as well as to provide a proper base for the other, more flowing styles.

In the regular script samples to the right, the characters in the left column are in Traditional Chinese while those to the right are in Simplified Chinese.

Edomoji

There is also a large family of native Japanese calligraphic styles known as *edomoji*, characters created in the Edo period of Japanese history, such as *sumōmoji* (sumo letters) used to write sumō wrestling posters, *kanteiryū*, used for kabuki, *higemoji*, and so on. These styles are typically not taught in Japanese calligraphy schools.

Chinese and Korean people can read *edomoji*, but the style has a distinct Japanese feel to it. It is therefore commonly used in China and Korea to advertise Japanese restaurants.

Munjado

Munjado is a Korean decorative style of rendering Chinese characters in which brush strokes are replaced with representational paintings that provide commentary on the meaning.[1] The characters thus rendered are traditionally those for the eight Confucian virtues of humility, honor, duty, propriety, trust, loyalty, brotherly love, and filial piety.

Kaō

The *kaō* is a stylized calligraphic signature. Many Japanese emperors, shogun, and even modern politicians develop their own *kaō*.

See also

- Eight Principles of Yong
- Stroke order
- List of languages by writing system § Chinese characters and derivatives

- Horizontal and vertical writing in East Asian scripts
    - Hanzi
    - Kanji
    - Hanja
    - Chữ Nôm
- Simplified Chinese characters
- Traditional Chinese characters
- Sino-Xenic pronunciations
- Wonton font
- Written Chinese

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External links

Wikimedia Commons has media related to ***Chinese Characters***.

- Chinese Calligraphy Script in the book (1997) "Chinese Calligraphy, Abstract Art, Mind Painting" by Ngan Siu-Mui
- History of Chinese writing
- Evolution of Chinese Characters
- Zhongwen.com : a searchable dictionary with information about character formation

- Chinese character etymologies
- Chinese Characters: Explanation of the forms of Chinese Characters; of their ideographic nature. Based on the Shuo Wen, other traditional sources and modern archeological finds.

Hebrew language

Hebrew (/ˈhiːbruː/; עִבְרִית, *Ivrit* [ivˈʁit] or [ʕivˈɾit]) is a Northwest Semitic language native to Israel, spoken by over 9 million people worldwide.[8] Historically, it is regarded as the language of the Israelites and their ancestors, although the language was not referred to by the name Hebrew in the Tanakh.[note 1] The earliest examples of written Paleo-Hebrew date from the 10th century BCE.[9] Hebrew belongs to the West Semitic branch of the Afroasiatic language family. Hebrew is the only living Canaanite language left, and the only truly successful example of a revived dead language.[10][11]

Hebrew had ceased to be an everyday spoken language somewhere between 200 and 400 CE, declining since the aftermath of the Bar Kokhba revolt.[2][12][note 2] Aramaic and to a lesser extent Greek were already in use as international languages, especially among elites and immigrants.[14] It survived into the medieval period as the language of Jewish liturgy, rabbinic literature, intra-Jewish commerce, and poetry. Then, in the 19th century, it was revived as a spoken and literary language. It became the *lingua franca* of Palestine's Jews, and subsequently of the State of Israel. According to *Ethnologue*, in 1998, it was the language of 5 million people worldwide.[5] After Israel, the United States has the second largest Hebrew-speaking population, with 220,000 fluent speakers,[15] mostly from Israel.

Modern Hebrew is the official language of the State of Israel, while premodern Hebrew is used for prayer or study in Jewish communities around the world today. The Samaritan dialect is also the liturgical tongue of the Samaritans, while modern Hebrew or Arabic is their vernacular. As a foreign language, it is studied mostly by Jews and students of Judaism and Israel, and by archaeologists and linguists specializing in the Middle East and its civilizations, as well as by theologians in Christian seminaries.

The Torah (the first five books), and most of the rest of the Hebrew Bible, is written in Biblical Hebrew, with much of its present form specifically in the dialect that scholars believe flourished around the 6th century BCE, around the time of the Babylonian captivity. For this reason, Hebrew has been referred to by Jews as *Lashon Hakodesh* (לשון הקדש), "the Holy Language", since ancient times.

Hebrew

עברית, *Ivrit*

Portion of the Temple Scroll, one o longest of the Dead Sea Scrolls dis ered at Qumran

Pronunciation	Modern: [ivˈʁit] – Anc [ʕibˈrit][1]
Native to	Israel
Region	Land of Israel
Ethnicity	Israelites; Jews and S
Extinct	Mishnaic Hebrew ext spoken language by t century CE, surviving gical language along cal Hebrew for Judais
Revival	Revived in the late 1 ry CE. 9 million speak Modern Hebrew of w million are native spe (2017)[5]

Etymology

The modern English word "Hebrew" is derived from Old French *Ebrau*, via Latin from the Greek Ἑβραῖος (*Hebraîos*) and Aramaic *'ibrāy*: all ultimately derived from Biblical Hebrew *Ibri* (עברי), one of several names for the Israelite (Jewish and Samaritan) people. It is traditionally understood to be an adjective based on the name of Abraham's ancestor, Eber, mentioned in Genesis 10:21. The name is believed to be based on the Semitic root *ʕ-b-r* (עבר) meaning "beyond", "other side", "across";[16] interpretations of the term "Hebrew" generally render its meaning as roughly "from the other side [of the river/desert]"—i.e., an exonym for the inhabitants of the land of Israel/Judah, perhaps from the perspective of Mesopotamia, Phoenicia, or the Transjordan (with the river referenced perhaps the Euphrates, Jordan, or Litani; or maybe the northern Arabian Desert between Babylonia and Canaan).[17] Compare cognate Assyrian *ebru*, of identical meaning.[18]

One of the earliest references to the language's name as 'Hebrew' is found in the prologue to the Book of Ben Sira,[a] from the 2nd century BCE.[19] The Bible does not use the term 'Hebrew' in reference to the language of the Hebrew people;[20] the ancient Israelites referred to their tongue as "Canaanite language" (שפת כנען), (Isaiah 19:18)—and later *Yəhudit* (יהודית; meaning literally "Judean/Jewish language"), when Judah (*Yəhuda*) became the surviving Hebraic kingdom after the destruction of the northern Kingdom of Israel in the late 8th century BCE (Isa. 36; 2 Kings 18).

History

Hebrew belongs to the Canaanite group of languages. In turn, the Canaanite languages are a branch of the Northwest Semitic family of languages.[21]

According to Avraham Ben-Yosef, Hebrew flourished as a spoken language in the Kingdoms of Israel and Judah during about 1200 to 586 BCE.[22] Scholars debate the degree to which Hebrew was a spoken vernacular in ancient times following the Babylonian exile, when the predominant international language in the region was Old Aramaic.

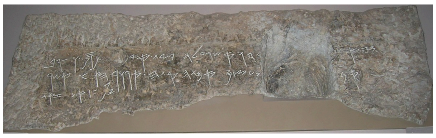
Hebrew was extinct as a colloquial language by Late Antiquity, but it continued to be used as a literary language and as the liturgical language of Judaism, evolving various dialects of literary Medieval Hebrew, until its revival as a spoken language in the late 19th century.[23][24]

Oldest Hebrew inscriptions

In July 2008 Israeli archaeologist Yossi Garfinkel discovered a ceramic shard at Khirbet Qeiyafa which he claimed may be the earliest Hebrew writing yet discovered, dating around 3,000 years ago.[25] Hebrew University archaeologist Amihai Mazar said that the inscription was "proto-Canaanite" but cautioned that, "The differentiation between the scripts, and between the languages themselves in that period, remains unclear," and suggested that calling the text Hebrew might be going too far.[26]

The Gezer calendar also dates back to the 10th century BCE at the beginning of the Monarchic Period, the traditional time of the reign of David and Solomon. Classified as Archaic Biblical Hebrew, the calendar presents a list of seasons and related agricultural activities. The Gezer calendar (named after the city in whose proximity it was found) is written in an old Semitic script, akin to the Phoenician one that through the Greeks and Etruscans later became the Roman script. The Gezer calendar is written without any vowels, and it does not use consonants to imply vowels even in the places where later Hebrew spelling requires it.

Language family	Afro-Asiatic • Semitic ◦ Central Semitic ▪ Northwest Sem ▪ Canaanite ▪ **Hebrew**
Early forms	Biblical Hebrew • Mishnaic Hebrew ◦ Medieval Hebrev
Standard forms	Modern Hebrew
Writing system	Hebrew alphabet Hebrew Braille Paleo-Hebrew alphab ic Biblical Hebrew) Imperial Aramaic scri Biblical Hebrew)
Signed forms	Signed Hebrew (oral accompanied by sign
Official status	
Official language in	Israel (as Moderr
Regulated by	Academy of the Heb guage האקדמיה ללשון העברית (*HaAkademia LaLasho*
Language codes	
ISO 639-1	`he`
ISO 639-2	`heb`
ISO 639-3	Variously: `heb` – Modern Hebre `hbo` – Classical Hebr cal) `smp` – Samaritan Heb gical) `obm` – Moabite (extin `xdm` – Edomite (extin
Glottolog	`hebr1246`[7]
Linguasphere	`12-AAB-a`



The Shebna Inscription, from the tomb of a royal steward found in Siloam, dates to the 7th century BCE.

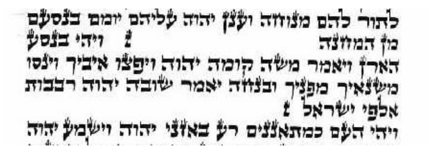
Numerous older tablets have been found in the region with similar scripts written in other Semitic languages, for example Protosinaitic. It is believed that the original shapes of the script go back to Egyptian hieroglyphs, though the phonetic values are instead inspired by the acrophonic principle. The common ancestor of Hebrew and Phoenician is called Canaanite, and was the first to use a Semitic alphabet distinct from Egyptian. One ancient document is the famous Moabite Stone written in the Moabite dialect; the Siloam Inscription, found near Jerusalem, is an early example of Hebrew. Less ancient samples of Archaic Hebrew include the ostraca found near Lachish which describe events preceding the final capture of Jerusalem by Nebuchadnezzar and the Babylonian captivity of 586 BCE.

Classical Hebrew

Biblical Hebrew

In its widest sense, Biblical Hebrew means the spoken language of ancient Israel flourishing between the 10th century BCE and the turn of the 4th century CE.[27] It comprises several evolving and overlapping dialects. The phases of Classical Hebrew are often named after important literary works associated with them.

- Archaic Biblical Hebrew from the 10th to the 6th century BCE, corresponding to the Monarchic Period until the Babylonian Exile and represented by certain texts in the Hebrew Bible (Tanakh), notably the Song of Moses (Exodus 15) and the Song of Deborah (Judges 5). Also called Old Hebrew or Paleo-Hebrew. It was written in the Paleo-Hebrew alphabet. A script descended from this, the Samaritan alphabet, is still used by the Samaritans.



Hebrew script used in writing a Torah scroll. Note ornamental "crowns" on tops of certain letters.

- Standard Biblical Hebrew around the 8th to 6th centuries BCE, corresponding to the late Monarchic period and the Babylonian Exile. It is represented by the bulk of the Hebrew Bible that attains much of its present form around this time. Also called Biblical Hebrew, Early Biblical Hebrew, Classical Biblical Hebrew (or Classical Hebrew in the narrowest sense).
- Late Biblical Hebrew, from the 5th to the 3rd centuries BCE, that corresponds to the Persian Period and is represented by certain texts in the Hebrew Bible, notably the books of Ezra and Nehemiah. Basically similar to Classical Biblical Hebrew, apart from a few foreign words adopted for mainly governmental terms, and some syntactical innovations such as the use of the particle *she-* (alternative of ''asher' "that, which, who"). It adopted the Imperial Aramaic script (from which the modern Hebrew script descends).
- Israelian Hebrew is a proposed northern dialect of biblical Hebrew, attested in all eras of the language, in some cases competing with late biblical Hebrew as an explanation for non-standard linguistic features of biblical texts.

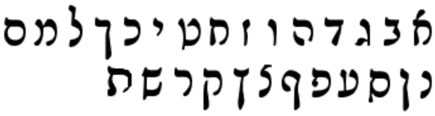
Early post-Biblical Hebrew

- Dead Sea Scroll Hebrew from the 3rd century BCE to the 1st century CE, corresponding to the Hellenistic and Roman Periods before the destruction of the Temple in Jerusalem and represented by the Qumran Scrolls that form most (but not all) of the Dead Sea Scrolls. Commonly abbreviated as DSS Hebrew, also called Qumran Hebrew. The Imperial Aramaic script of the earlier scrolls in the 3rd century BCE evolved into the Hebrew square script of the later scrolls in the 1st century CE, also known as *ketav Ashuri* (Assyrian script), still in use today.

- Mishnaic Hebrew from the 1st to the 3rd or 4th century CE, corresponding to the Roman Period after the destruction of the Temple in Jerusalem and represented by the bulk of the Mishnah and Tosefta within the Talmud and by the Dead Sea Scrolls, notably the Bar Kokhba letters and the Copper Scroll. Also called Tannaitic Hebrew or Early Rabbinic Hebrew.

Sometimes the above phases of spoken Classical Hebrew are simplified into "Biblical Hebrew" (including several dialects from the 10th century BCE to 2nd century BCE and extant in certain Dead Sea Scrolls) and "Mishnaic Hebrew" (including several dialects from the 3rd century BCE to the 3rd century CE and extant in certain other Dead Sea Scrolls).[28] However, today, most Hebrew linguists classify Dead Sea Scroll Hebrew as a set of dialects evolving out of Late Biblical Hebrew and into Mishnaic Hebrew, thus including elements from both but remaining distinct from either.[29] By the start of the Byzantine Period in the 4th century CE, Classical Hebrew ceases as a regularly spoken language, roughly a century after the publication of the Mishnah, apparently declining since the aftermath of the catastrophic Bar Kokhba War around 135 CE.

Displacement by Aramaic



Rashi script

A silver matchbox holder with inscription in Hebrew

Around the 6th century BCE, the Neo-Babylonian Empire conquered the ancient Kingdom of Judah, destroying much of Jerusalem and exiling its population far to the East in Babylon. During the Babylonian captivity, many Israelites learned Aramaic, the closely related Semitic language of their captors. Thus for a significant period, the Jewish elite became influenced by Aramaic.[30]

After Cyrus the Great conquered Babylon, he allowed the Jewish people to return from captivity. As a result, a local version of Aramaic came to be spoken in Israel alongside Hebrew. By the beginning of the Common Era, Aramaic was the primary colloquial language of Samarian, Babylonian and Galileean Jews, and western and intellectual Jews spoke Greek, but a form of so-called Rabbinic Hebrew continued to be used as a vernacular in Judea until it was displaced by Aramaic, probably in the 3rd century CE. Certain Sadducee, Pharisee, Scribe, Hermit, Zealot and Priest classes maintained an insistence on Hebrew, and all Jews maintained their identity with Hebrew songs and simple quotations from Hebrew texts.[13][31][32]

While there is no doubt that at a certain point, Hebrew was displaced as the everyday spoken language of most Jews, and that its chief successor in the Middle East was the closely related Aramaic language, then Greek,[31][note 2] scholarly opinions on the exact dating of that shift have changed very much.[12] In the first half of the 20th century, most scholars followed Geiger and Dalman in thinking that Aramaic became a spoken language in the land of Israel as early as the beginning of Israel's Hellenistic Period in the 4th century BCE, and that as a corollary Hebrew ceased to function as a spoken language around the same time. Segal, Klausner, and Ben Yehuda are notable exceptions to this view. During the latter half of the 20th century, accumulating archaeological evidence and especially linguistic analysis of the Dead Sea Scrolls has disproven that view. The Dead Sea Scrolls, uncovered in 1946–1948 near Qumran revealed ancient Jewish texts overwhelmingly in Hebrew, not Aramaic.

The Qumran scrolls indicate that Hebrew texts were readily understandable to the average Israelite, and that the language had evolved since Biblical times as spoken languages do.[note 3] Recent scholarship recognizes that reports of Jews speaking in Aramaic indicates a multilingual society, not necessarily the primary language spoken. Alongside Aramaic, Hebrew co-existed within Israel as a spoken language.[34] Most scholars now date the demise of Hebrew as a spoken language to the end of the Roman Period, or about 200 CE.[35] It continued on as a literary language down through the Byzantine Period from the 4th century CE.

The exact roles of Aramaic and Hebrew remain hotly debated. A trilingual scenario has been proposed for the land of Israel. Hebrew functioned as the local mother tongue with powerful ties to Israel's history, origins, and golden age and as the language of Israel's religion; Aramaic functioned as the international language with the rest of the Middle East; and eventually Greek functioned as another international language with the eastern areas of the Roman Empire. According to another summary, Greek was the language of government, Hebrew the language of prayer, study and religious texts, and Aramaic was the language of legal contracts and trade.[36] There was also a geographic pattern: according to Spolsky, by the beginning of the Common Era, "Judeo-Aramaic was mainly used in Galilee in the north, Greek was concentrated in the former colonies and around governmental centers, and Hebrew monolingualism continued mainly in the southern villages of Judea."[31] In other words, "in terms of dialect geography, at the time of the tannaim Palestine could be divided into the Aramaic-speaking regions of Galilee and Samaria and a smaller area, Judaea, in which Rabbinic Hebrew was used among the descendants of returning exiles."[13][32] In addition, it has been surmised that Koine Greek was the primary vehicle of communication in coastal cities and among the upper class of Jerusalem, while Aramaic was prevalent in the lower class of Jerusalem, but not in the surrounding countryside.[36] After the suppression of the Bar Kokhba revolt in the 2nd century CE, Judaeans were forced to disperse. Many relocated to Galilee, so most remaining native speakers of Hebrew at that last stage would have been found in the north.[37]

The Christian New Testament contains some Semitic place names and quotes.[38] The language of such Semitic glosses (and in general the language spoken by Jews in scenes from the New Testament) is often referred to as "Hebrew" in the text,[39] although this term is often re-interpreted as referring to Aramaic instead[note 4][note 5] and is rendered accordingly in recent translations.[41] Nonetheless, these glosses can be interpreted as Hebrew as well.[42] It has been argued that Hebrew, rather than Aramaic or Koine Greek, lay behind the composition of the Gospel of Matthew.[43] (See the Hebrew Gospel hypothesis or Language of Jesus for more details on Hebrew and Aramaic in the gospels.)

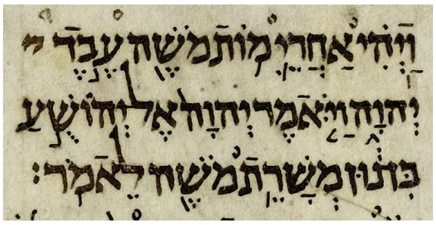
Mishnah and Talmud

The term "Mishnaic Hebrew" generally refers to the Hebrew dialects found in the Talmud, excepting quotations from the Hebrew Bible. The dialects organize into Mishnaic Hebrew (also called Tannaitic Hebrew, Early Rabbinic Hebrew, or Mishnaic Hebrew I), which was a spoken language, and Amoraic Hebrew (also called Late Rabbinic Hebrew or Mishnaic Hebrew II), which was a literary language. The earlier section of the Talmud is the Mishnah that was published around 200 CE, although many of the stories take place much earlier, and was written in the earlier Mishnaic dialect. The dialect is also found in certain Dead Sea Scrolls. Mishnaic Hebrew is considered to be one of the dialects of Classical Hebrew that functioned as a living language in the land of Israel. A transitional form of the language occurs in the other works of Tannaitic literature dating from the century beginning with the completion of the Mishnah. These include the halachic Midrashim (Sifra, Sifre, Mechilta etc.) and the expanded collection of Mishnah-related material known as the Tosefta. The Talmud contains excerpts from these works, as well as further Tannaitic material not attested elsewhere; the generic term for these passages is *Baraitot*. The dialect of all these works is very similar to Mishnaic Hebrew.

About a century after the publication of the Mishnah, Mishnaic Hebrew fell into disuse as a spoken language. The later section of the Talmud, the Gemara, generally comments on the Mishnah and Baraitot in two forms of Aramaic. Nevertheless, Hebrew survived as a liturgical and literary language in the form of later Amoraic Hebrew, which sometimes occurs in the text of the Gemara.

Because as early as the Torah's transcription the Scribe has been the highest position in Judaism, Hebrew was always regarded as the language of Israel's religion, history and national pride, and after it faded as a spoken language, it continued to be used as a *lingua franca* among scholars and Jews traveling in foreign countries.[44] After the 2nd century CE when the Roman Empire exiled most of the Jewish population of Jerusalem following the Bar Kokhba revolt, they adapted to the societies in which they found themselves, yet letters, contracts, commerce, science, philosophy, medicine, poetry, and laws continued to be written mostly in Hebrew, which adapted by borrowing and inventing terms.

Medieval Hebrew



Aleppo Codex: 10th century Hebrew Bible with Masoretic pointing (Joshua 1:1).

After the Talmud, various regional literary dialects of Medieval Hebrew evolved. The most important is Tiberian Hebrew or Masoretic Hebrew, a local dialect of Tiberias in Galilee that became the standard for vocalizing the Hebrew Bible and thus still influences all other regional dialects of Hebrew. This Tiberian Hebrew from the 7th to 10th century CE is sometimes called "Biblical Hebrew" because it is used to pronounce the Hebrew Bible; however, properly it should be distinguished from the historical Biblical Hebrew of the 6th century BCE, whose original pronunciation must be reconstructed. Tiberian Hebrew incorporates the remarkable scholarship of the Masoretes (from *masoret* meaning "tradition"), who added vowel points and grammar points to the Hebrew letters to preserve much earlier features of Hebrew, for use in chanting the Hebrew Bible. The Masoretes inherited a biblical text whose letters were considered too sacred to be altered, so their markings were in the form of pointing in and around the letters. The Syriac alphabet, precursor to the Arabic alphabet, also developed vowel pointing systems around this time. The Aleppo Codex, a Hebrew Bible with the Masoretic pointing, was written in the 10th century, likely in Tiberias, and survives to this day. It is perhaps the most important Hebrew manuscript in existence.

Kochangadi Synagogue in Kochi, India dated to 1344.

During the Golden age of Jewish culture in Spain, important work was done by grammarians in explaining the grammar and vocabulary of Biblical Hebrew; much of this was based on the work of the grammarians of Classical Arabic. Important Hebrew grammarians were Judah ben David Hayyuj, Jonah ibn Janah, Abraham ibn Ezra[45] and later (in Provence) David Kimhi. A great deal of poetry was written, by poets such as Dunash ben Labrat, Solomon ibn Gabirol, Judah ha-Levi, Moses ibn Ezra and Abraham ibn Ezra, in a "purified" Hebrew based on the work of these grammarians, and in Arabic quantitative or strophic meters. This literary Hebrew was later used by Italian Jewish poets.[46]

The need to express scientific and philosophical concepts from Classical Greek and Medieval Arabic motivated Medieval Hebrew to borrow terminology and grammar from these other languages, or to coin equivalent terms from existing Hebrew roots, giving rise to a distinct style of philosophical Hebrew. This is used in the translations made by the Ibn Tibbon family. (Original Jewish philosophical works were usually written in Arabic.) Another important influence was Maimonides, who developed a simple style based on Mishnaic Hebrew for use in his law code, the Mishneh Torah. Subsequent rabbinic literature is written in a blend between this style and the Aramaized Rabbinic Hebrew of the Talmud.

Hebrew persevered through the ages as the main language for written purposes by all Jewish communities around the world for a large range of uses—not only liturgy, but also poetry, philosophy, science and medicine, commerce, daily correspondence and contracts. There have been many deviations from this generalization such as Bar Kokhba's letters to his lieutenants, which were mostly in Aramaic,[47] and Maimonides' writings, which were mostly in Arabic;[48] but overall, Hebrew did not cease to be used for such purposes. For example, the first Middle East printing press, in Safed (modern Israel,) produced a small number of books in Hebrew in 1577, which were then sold to the nearby Jewish world. [49] This meant not only that well-educated Jews in all parts of the world could correspond in a mutually intelligible language, and that books and legal documents published or written in any part of the world could be read by Jews in all other parts, but that an educated Jew could travel and converse with Jews in distant places, just as priests and other educated Christians could converse in Latin. For example, Rabbi Avraham Danzig wrote the *Chayei Adam* in Hebrew, as opposed to Yiddish, as a guide to *Halacha* for the "*average* 17-year-old" (Ibid. Introduction 1). Similarly, the Chofetz Chaim, Rabbi Yisrael Meir Kagan's purpose in writing the *Mishna Berurah* was to "produce a work that could be studied daily so that Jews might know the proper procedures to follow minute by minute". The work was nevertheless written in Talmudic Hebrew and Aramaic, since, "the ordinary Jew [of Eastern Europe] of a century ago, was fluent enough in this idiom to be able to follow the Mishna Berurah without any trouble."[50]

Revival

Hebrew has been revived several times as a literary language, most significantly by the Haskalah (Enlightenment) movement of early and mid-19th-century Germany. In the early 19th century, a form of spoken Hebrew had emerged in the markets of Jerusalem between Jews of different linguistic backgrounds to communicate for commercial purposes. This Hebrew dialect was to a certain extent a pidgin.[51] Near the end of that century the Jewish activist Eliezer Ben-Yehuda, owing to the ideology of the national revival (שיבת ציון, *Shivat Tziyon,* later Zionism), began reviving Hebrew as a modern spoken language. Eventually, as a result of the local movement he created, but more significantly as a result of the new groups of immigrants known under the name of the Second Aliyah, it replaced a score of languages spoken by Jews at that time. Those languages were Jewish dialects of local languages, including Judaeo-Spanish (also called "Judezmo" and "Ladino"), Yiddish, Judeo-Arabic, and Bukhori (Tajiki), or local languages spoken in the Jewish diaspora such as Russian, Persian, and Arabic.

The major result of the literary work of the Hebrew intellectuals along the 19th century was a lexical modernization of Hebrew. New words and expressions were adapted as neologisms from the large corpus of Hebrew writings since the Hebrew Bible, or borrowed from Arabic (mainly by Eliezer Ben-Yehuda) and older Aramaic and Latin. Many new words were either borrowed from or coined after European languages, especially English, Russian, German, and French. Modern Hebrew became an official language in British-ruled Palestine in 1921 (along with English and Arabic), and then in 1948 became an official language of the newly declared State of Israel. Hebrew is the most widely spoken language in Israel today.

In the Modern Period, from the 19th century onward, the literary Hebrew tradition revived as the spoken language of modern Israel, called variously *Israeli Hebrew*, *Modern Israeli Hebrew*, *Modern Hebrew*, *New Hebrew*, *Israeli Standard Hebrew*, *Standard Hebrew*, and so on. Israeli Hebrew exhibits some features of Sephardic Hebrew from its local Jerusalemite tradition but adapts it with numerous neologisms, borrowed terms (often technical) from European languages and adopted terms (often colloquial) from Arabic.

The literary and narrative use of Hebrew was revived beginning with the Haskalah movement. The first secular periodical in Hebrew, *HaMe'assef* (The Gatherer), was published by maskilim in Königsberg (today's Kaliningrad) from 1783 onwards.[52] In the mid-19th century, publications of several Eastern European Hebrew-language newspapers (e.g. *Hamagid*, founded in Ełk in 1856) multiplied. Prominent poets were Hayim Nahman Bialik and Shaul Tchernichovsky; there were also novels written in the language.

Eliezer Ben-Yehuda

The revival of the Hebrew language as a mother tongue was initiated in the late 19th century by the efforts of Eliezer Ben-Yehuda. He joined the Jewish national movement and in 1881 immigrated to Palestine, then a part of the Ottoman Empire. Motivated by the surrounding ideals of renovation and rejection of the diaspora "shtetl" lifestyle, Ben-Yehuda set out to develop tools for making the literary and liturgical language into everyday spoken language. However, his brand of Hebrew followed norms that had been replaced in Eastern Europe by different grammar and style, in the writings of people like Ahad Ha'am and others. His organizational efforts and involvement with the establishment of schools and the writing of textbooks pushed the vernacularization activity into a gradually accepted movement. It was not, however, until the 1904–1914 Second Aliyah that Hebrew had caught real momentum in Ottoman Palestine with the more highly organized enterprises set forth by the new group of immigrants. When the British Mandate of Palestine recognized Hebrew as one of the country's three official languages (English, Arabic, and Hebrew, in 1922), its new formal status contributed to its diffusion. A constructed modern language with a truly Semitic vocabulary and written appearance, although often European in phonology, was to take its place among the current languages of the nations.

While many saw his work as fanciful or even blasphemous[53] (because Hebrew was the holy language of the Torah and therefore some thought that it should not be used to discuss everyday matters), many soon understood the need for a common language amongst Jews of the British Mandate who at the turn of the 20th century were arriving in large numbers from diverse countries and speaking different languages. A Committee of the Hebrew Language was established. After the establishment of Israel, it became the Academy of the Hebrew Language. The results of Ben-Yehuda's lexicographical work were published in a dictionary (*The Complete Dictionary of Ancient and Modern Hebrew*). The seeds of Ben-Yehuda's work fell on fertile ground, and by the beginning of the 20th century, Hebrew was well on its way to becoming the main language of the Jewish population of both Ottoman and British Palestine. At the time, members of the Old Yishuv and a very few Hasidic sects, most notably those under the auspices of Satmar, refused to speak Hebrew and spoke only Yiddish.

In the Soviet Union, the use of Hebrew, along with other Jewish cultural and religious activities, was suppressed. Soviet authorities considered the use of Hebrew "reactionary" since it was associated with Zionism, and the teaching of Hebrew at primary and secondary schools was officially banned by the People's Commissariat for Education as early as 1919, as part of an overall agenda aiming to secularize education (the language itself did not cease to be studied at universities for historical and linguistic purposes[54]). The official ordinance stated that Yiddish, being the spoken language of the Russian Jews, should be treated as their only national language, while Hebrew was to be treated as a foreign language.[55] Hebrew books and periodicals ceased to be published and were seized from the libraries, although liturgical texts were still published until the 1930s. Despite numerous protests,[56] a policy of suppression of the teaching of Hebrew operated from the 1930s on. Later in the 1980s in the USSR, Hebrew studies reappeared due to people struggling for permission to go to Israel (refuseniks). Several of the teachers were imprisoned, e.g. Yosef Begun, Ephraim Kholmyansky, Yevgeny Korostyshevsky and others responsible for a Hebrew learning network connecting many cities of the USSR.

Modern Hebrew

Hebrew, Arabic and English multilingual signs on an Israeli highway

Standard Hebrew, as developed by Eliezer Ben-Yehuda, was based on Mishnaic spelling and Sephardi Hebrew pronunciation. However, the earliest speakers of Modern Hebrew had Yiddish as their native language and often introduced calques from Yiddish and phono-semantic matchings of international words.


Dual language Hebrew and English keyboard

The pronunciation of modern Israeli Hebrew is based mostly on the Sephardic Hebrew pronunciation. However, the language has adapted to Ashkenazi Hebrew phonology in some respects, mainly the following:

- the elimination of pharyngeal articulation in the letters *chet* (ח) and *ayin* (ע) by many speakers.
- the conversion of (ר) /r/ from an alveolar flap [ɾ] to a voiced uvular fricative [ʁ] or uvular trill [ʀ], by most of the speakers, like in most varieties of standard German or Yiddish. *see Guttural R*
- the pronunciation (by many speakers) of *tzere* ֵ as [eɪ] in some contexts (*sifréj* and *téjša* instead of Sephardic *sifré* and *tésha*)
- the partial elimination of vocal *Shva* ְ (*zmán* instead of Sephardic *zěman*)[57]
- in popular speech, penultimate stress in proper names (*Dvóra* instead of *Děvorá*; *Yehúda* instead of *Yěhudá*) and some other words[58]
- similarly in popular speech, penultimate stress in verb forms with a second person plural suffix (*katávtem* "you wrote" instead of *kětavtém*).[note 6]

The vocabulary of Israeli Hebrew is much larger than that of earlier periods. According to Ghil'ad Zuckermann:

> The number of attested Biblical Hebrew words is 8198, of which some 2000 are hapax legomena (the number of Biblical Hebrew roots, on which many of these words are based, is 2099). The number of attested Rabbinic Hebrew words is less than 20,000, of which (i) 7879 are Rabbinic par excellence, i.e. they did not appear in the Old Testament (the number of new Rabbinic Hebrew roots is 805); (ii) around 6000 are a subset of Biblical Hebrew; and (iii) several thousand are Aramaic words which can have a Hebrew form. Medieval Hebrew

> added 6421 words to (Modern) Hebrew. The approximate number of new lexical items in Israeli is 17,000 (cf. 14,762 in Even-Shoshan 1970 [...]). With the inclusion of foreign and technical terms [...], the total number of Israeli words, including words of biblical, rabbinic and medieval descent, is more than 60,000.[59]:64-65

In Israel, Modern Hebrew is currently taught in institutions called Ulpanim (singular: Ulpan). There are government-owned, as well as private, Ulpanim offering online courses and face-to-face programs.

Current status

Academy of the Hebrew Language

Modern Hebrew is the primary official language of the State of Israel. As of 2013, there are about 9 million Hebrew speakers worldwide,[60] of whom 7 million speak it fluently.[61][62][63]

Currently, 90% of Israeli Jews are proficient in Hebrew, and 70% are highly proficient.[64] Some 60% of Israeli Arabs are also proficient in Hebrew,[64] and 30% report having a higher proficiency in Hebrew than in Arabic.[8] In total, about 53% of the Israeli population speaks Hebrew as a native language,[65] while most of the rest speak it fluently. However, in 2013 Hebrew was the native language of only 49% of Israelis over the age of 20, with Russian, Arabic, French, English, Yiddish and Ladino being the native tongues of most of the rest. Some 26% of immigrants from the former Soviet Union and 12% of Arabs reported speaking Hebrew poorly or not at all.[64][66]

Due to the current climate of globalization and Americanization, steps have been taken to keep Hebrew the primary language of use, and to prevent large-scale incorporation of English words into Hebrew vocabulary. The Academy of the Hebrew Language of the Hebrew University of Jerusalem currently invents about 2,000 new Hebrew words each year for modern words by finding an original Hebrew word that captures the meaning, as an alternative to incorporating more English words into Hebrew vocabulary. The Haifa municipality has banned officials from using English words in official documents, and is fighting to stop businesses from using only English signs to market their services.[67] In 2012, a Knesset bill for the preservation of the Hebrew language was proposed, which includes the stipulation that all signage in Israel must first and foremost be in Hebrew, as with all speeches by Israeli officials abroad. The bill's author, MK Akram Hasson, stated that the bill was proposed as a response to Hebrew "losing its prestige", and children incorporating more English words into their vocabulary.[68]

Hebrew is also an official national minority language in Poland, since 6 January 2005.[69]

Phonology

Biblical Hebrew had a typical Semitic consonant inventory, with pharyngeal /ʕ ħ/, a series of "emphatic" consonants (possibly ejective, but this is debated), lateral fricative /ɬ/, and in its older stages also uvular /χ ʁ/. /χ ʁ/ merged into /ħ ʕ/ in later Biblical Hebrew, and /b ɡ d k p t/ underwent allophonic spirantization to [v ɣ ð x f θ] (known as begadkefat). The earliest Biblical Hebrew vowel system contained the Proto-Semitic vowels /a aː i iː u uː/ as well as /oː/, but this system changed dramatically over time.

By the time of the Dead Sea Scrolls, /ɬ/ had shifted to /s/ in the Jewish traditions, though for the Samaritans it merged with /ʃ/ instead. (Elisha Qimron 1986. *Hebrew of the Dead Sea Scrolls*, 29). The Tiberian reading tradition of the Middle Ages had the vowel system /a ɛ e i ɔ o u ă ɔ̆ ɛ̆/, though other Medieval reading traditions had fewer vowels.

A number of reading traditions have been preserved in liturgical use. In Oriental (Sephardi and Mizrahi) Jewish reading traditions, the emphatic consonants are realized as pharyngealized, while the Ashkenazi (northern and eastern European) traditions have lost emphatics and pharyngeals (although according to Ashkenazi law, pharyngeal articulation is preferred over uvular or glottal articulation when representing the community in religious service such as prayer and Torah reading), and show the shift of /w/ to /v/. The Samaritan tradition has a complex vowel system which does not correspond closely to the Tiberian systems.

Modern Hebrew pronunciation developed from a mixture of the different Jewish reading traditions, generally tending towards simplification. In line with Sephardi Hebrew pronunciation, emphatic consonants have shifted to their ordinary counterparts, /w/ to /v/, and [ɣ ð θ] are not present. Most Israelis today also merge /ʕ ħ/ with /ʔ χ/, do not have contrastive gemination, and pronounce /r/ as a uvular fricative [ʁ] or a voiced velar fricative [ɣ] rather than an alveolar trill, because of Ashkenazi Hebrew influences. The consonants /tʃ/ and /dʒ/ have become phonemic due to loan words, and /w/ has similarly been re-introduced.

Consonants

Proto Semitic	IPA	Hebrew written		Biblical	Tiberian	Modern	Example Word	Meaning
b	**[b]**	ב[3]	*ḇ/b*	/b/	/v/, /b/	/v/, /b/	**בית**	house
d	**[d]**	ד[3]	*ḏ/d*	/d/	/ð/, /d/	/d/	**דב**	bear
g	**[g]**	ג[3]	*ḡ/g*	/g/	/ɣ/, /g/	/g/	**גמל**	camel
p	**[p]**	פ[3]	*p̄/p*	/p/	/f/, /p/	/f/, /p/	**פחם**	coal
t	**[t]**	ת[3]	*ṯ/t*	/t/	/θ/, /t/	/t/	**תמר**	palm
k	**[k]**	כ[3]	*ḵ/k*	/k/	/x/, /k/	/χ/, /k/	**כוכב**	star
ṭ	**[t’]**	ט	*ṭ*	*ṭ*	/tˤ/	/t/	**טבח**	cook
q	**[k’]**	ק	*q*	*q*	/q/	/k/	**קבר**	tomb
ḏ	**[ð] / [d͡ð]**	ז[2]	*z*	/ð/	/z/	/z/	**זכר**	male
z	**[z] / [d͡z]**			/z/			**זרק**	threw

*s	[s] / [t͡s]	ס	s	/s/	/s/	/s/	סוכר	sugar
*š	[ʃ] / [t͡ʃ]	שׁ[2]	š	/ʃ/	/ʃ/	/ʃ/	שׁמים	sky
*ṯ	[θ] / [t͡θ]			/θ/			שׁמונה	eight
*ś	[ɬ] / [t͡ɬ]	שׂ[1]	ś	/ɬ/	/s/	/s/	שׂמאל	left
*ṯ̣	[θʼ] / [t͡θʼ]	צ	ṣ	ṱ	/sˤ/	/ts/	צל	shadow
*ṣ	[sʼ] / [t͡sʼ]						צרח	screamed
*ṣ́	[ɬʼ] / [t͡ɬʼ]						צחק	laughed
*ġ	[ɣ]~[ʁ]	ע	ʻ	/ʁ/	/ʕ/	/ʔ/, -	עורב	raven
*ʻ	[ʕ]			/ʕ/			עשׂר	ten
*ʼ	[ʔ]	א	ʼ	/ʔ/	/ʔ/	/ʔ/, -	אב	father
*ḫ	[x]~[χ]	ח[2]	ḥ	/χ/	/ħ/	/χ/	חמשׁ	five
*ḥ	[ħ]			/ħ/			חבל	rope
*h	[h]	ה	h	/h/	/h/	/h/, -	הגר	emigrated
*m	[m]	מ	m	/m/	/m/	/m/	מים	water
*n	[n]	נ	n	/n/	/n/	/n/	נביא	prophet
*r	[ɾ]	ר	r	/ɾ/	/ɾ/	/ʁ/	רגל	leg
*l	[l]	ל	l	/l/	/l/	/l/	לשון	tongue
*y	[j]	י	y	/j/	/j/	/j/	יד	hand
*w	[w]	ו	w	/w/	/w/	/v/	ורד	rose
Proto-Semitic	**IPA**	**Hebrew**		**Biblical**	**Tiberian**	**Modern**	**Example**	

Notes:

1. Proto-Semitic *ś was still pronounced as [ɬ] in Biblical Hebrew, but no letter was available in the Phoenician alphabet, so the letter ש did double duty, representing both /ʃ/ and /ɬ/. Later on, however, /ɬ/ merged with /s/, but the old spelling was largely retained, and the two pronunciations of ש were distinguished graphically in Tiberian Hebrew as שׁ /ʃ/ vs. שׂ /s/ < /ɬ/.
2. Biblical Hebrew as of the 3rd century BCE apparently still distinguished the phonemes ġ /ʁ/, ḫ /χ/, ḏ /ð/ and ṯ /θ/, based on transcriptions in the Septuagint. As in the case of /ɬ/, no letters were available to represent these sounds, and existing letters did double duty: ח /χ/ /ħ/, ע /ʁ/ /ʕ/, שׁ /θ/ /ʃ/ and ז /ð/ /z/. In all of these cases, however, the sounds represented by the same letter eventually merged, leaving no evidence (other than early transcriptions) of the former distinctions.

3. Hebrew and Aramaic underwent begadkefat spirantization at a certain point, whereby the stop sounds /b ɡ d k p t/ were softened to the corresponding fricatives [v ɣ ð x f θ] (written ḇ ḡ ḏ ḵ p̄ ṯ) when occurring after a vowel and not geminated. This change probably happened after the original Old Aramaic phonemes /θ, ð/ disappeared in the 7th century BCE,[70] and most likely occurred after the loss of Hebrew /χ, ʁ/ c. 200 BCE.[note 7] It is known to have occurred in Hebrew by the 2nd century.[71] After a certain point this alternation became contrastive in word-medial and final position (though bearing low functional load), but in word-initial position they remained allophonic.[72] In Modern Hebrew, the distinction has a higher functional load due to the loss of gemination, although only the three fricatives /v χ f/ are still preserved (the fricative /x/ is pronounced /χ/ in modern Hebrew). (The others are pronounced like the corresponding stops, apparently under the influence of later non-native speakers whose native European tongues lacked the sounds /ɣ ð θ/ as phonemes.)

Hebrew grammar

Hebrew grammar is partly analytic, expressing such forms as dative, ablative, and accusative using prepositional particles rather than grammatical cases. However, inflection plays a decisive role in the formation of the verbs and nouns. For example, nouns have a construct state, called "smikhut", to denote the relationship of "belonging to": this is the converse of the genitive case of more inflected languages. Words in smikhut are often combined with hyphens. In modern speech, the use of the construct is sometimes interchangeable with the preposition "shel", meaning "of". There are many cases, however, where older declined forms are retained (especially in idiomatic expressions and the like), and "person"-enclitics are widely used to "decline" prepositions.

Morphology

Like all Semitic languages, the Hebrew language exhibits a pattern of stems consisting typically of "triliteral", or 3-consonant consonantal roots (4-consonant roots also exist), from which nouns, adjectives, and verbs are formed in various ways: e.g. by inserting vowels, doubling consonants, lengthening vowels, and/or adding prefixes, suffixes, or infixes.

Hebrew uses a number of one-letter prefixes that are added to words for various purposes. These are called inseparable prepositions or "Letters of Use" (Hebrew: **אותיות השימוש**, translit. *Otiyot HaShimush*). Such items include: the definite article *ha-* (/ha/) (="the"); prepositions *be-* (/bə/) (="in"), *le-* (/lə/) (="to"; a shortened version of the preposition *el*), *mi-* (/mi/) (="from"; a shortened version of the preposition *min*); conjunctions *ve-* (/və/) (="and"), *she-* (/ʃe/) (="that"; a shortened version of the Biblical conjunction *asher*), *ke-* (/kə/) (="as", "like"; a shortened version of the conjunction *kmo*).

The vowel accompanying each of these letters may differ from those listed above, depending on the first letter or vowel following it. The rules governing these changes, hardly observed in colloquial speech as most speakers tend to employ the regular form, may be heard in more formal circumstances. For example, if a preposition is put before a word which begins with a moving Shva, then the preposition takes the vowel /i/ (and the initial consonant may be weakened): colloquial *be-kfar* (="in a village") corresponds to the more formal *bi-khfar*.

The definite article may be inserted between a preposition or a conjunction and the word it refers to, creating composite words like *mé-ha-kfar* (="from the village"). The latter also demonstrates the change in the vowel of *mi-*. With *be*, *le* and *ke*, the definite article is assimilated into the prefix, which then becomes *ba*, *la* or *ka*. Thus **be-ha-matos* becomes *ba-matos* (="in the plane"). Note that this does not happen to *mé* (the form of "min" or "mi-" used before the letter "he"), therefore *mé-ha-matos* is a valid form, which means "from the airplane".

** indicates that the given example is grammatically non-standard.*

Syntax

Like most other languages, the vocabulary of the Hebrew language is divided into verbs, nouns, adjectives, and so on, and its sentence structure can be analyzed by terms like object, subject, and so on.

- Many Hebrew sentences have several correct orders of words. One can change the order of the words in the sentence and keep the same meaning. For example, the sentence "Dad went to work", in Hebrew, includes a word for *Dad* (**אבא** *aba*), for *went* (**הלך** *halaḵ*), and for *to work* (to the working place = **לעבודה** *la-ʿavoda*). However, unlike in English, those three words can be put in almost any combination (**אבא הלך לעבודה/ לעבודה אבא הלך/ לעבודה הלך אבא/ הלך אבא לעבודה** and so on).
- In Hebrew, there is no word that is supposed to come before every singular noun (i.e. an article).
- Hebrew sentences do not have to include verbs; the copula in the present tense is omitted. For example, the sentence "I am here" (**אני פה** *ani po*) has only two words; one for I (**אני**) and one for here (**פה**). In the sentence "I am that person" (**אני הוא האדם הזה** *ani hu ha'adam ha'ze*), the word for "am" corresponds to the word for "he" (**הוא**). However, this may also be omitted. Thus, the sentence (**אני האדם הזה**) is identical in meaning.
- Though early Biblical Hebrew had a verb-subject-object ordering, this gradually transitioned to a subject-verb-object ordering.[73]
- In Hebrew there is a specific preposition (**את** *et*) for direct objects that would not have a preposition marker in English. The English phrase "he ate the cake" would in Hebrew be **הוא אכל את העוגה** *hu akhal et ha'ugah* (literally, "He ate **את** the cake"). The word **את**, however, can be omitted, making **הוא אכל העוגה** *hu akhal ha'ugah* ("He ate the cake"). Former Israeli Prime Minister David Ben-Gurion was convinced that **את** should never be used as it elongates the sentence without adding meaning.
- In spoken Hebrew **את ה-** *et ha-* is also often replaced by **ת'-** *ta-*, e.g. **ת'אנשים** *ta-anashim* instead of **את האנשים** *et ha-anashim*. This phenomenon has also been found by researchers in the Bar Kokhba documents: **מעיד אני עלי תשמים... שאני נותן תכבלים ברגליכם**, writing **תללו** instead of **את הללו**, as well as **תדקל** and so on.

Writing system

Modern Hebrew is written from right to left using the Hebrew alphabet, which is an abjad, or consonant-only script of 22 letters. The ancient paleo-Hebrew alphabet is similar to those used for Canaanite and Phoenician. Modern scripts are based on the "square" letter form, known as *Ashurit* (Assyrian), which was developed from the Aramaic script. A cursive Hebrew script is used in handwriting: the letters tend to be more circular in form when written in cursive, and sometimes vary markedly from their printed equivalents. The medieval version of the cursive script forms the basis of another style, known as Rashi script. When necessary, vowels are indicated by diacritic marks above or below the letter representing the syllabic onset, or by use of *matres lectionis*, which are consonantal letters used as vowels. Further diacritics are used to indicate variations in the pronunciation of the consonants (e.g. *bet*/*vet*, *shin*/*sin*); and, in some contexts, to indicate the punctuation, accentuation, and musical rendition of Biblical texts (see Cantillation).

Hebrew alphabet

Liturgical use in Judaism

Audio example of liturgical Hebrew

This is a portion of the blessing that is traditionally chanted before the Aliyah La-Torah (reading of the Torah).

Problems playing this file? See media help.

Hebrew has always been used as the language of prayer and study, and the following pronunciation systems are found.

Ashkenazi Hebrew, originating in Central and Eastern Europe, is still widely used in Ashkenazi Jewish religious services and studies in Israel and abroad, particularly in the Haredi and other Orthodox communities. It was influenced by the Yiddish language.

Sephardi Hebrew is the traditional pronunciation of the Spanish and Portuguese Jews and Sephardi Jews in the countries of the former Ottoman Empire, with the exception of Yemenite Hebrew. This pronunciation, in the form used by the Jerusalem Sephardic community, is the basis of the Hebrew phonology of Israeli native speakers. It was influenced by the Judezmo language.

Mizrahi (Oriental) Hebrew is actually a collection of dialects spoken liturgically by Jews in various parts of the Arab and Islamic world. It was possibly influenced by the Aramaic and Arabic languages, and in some cases by Sephardi Hebrew, although some linguists maintain that it is the direct heir of Biblical Hebrew and thus represents the true dialect of Hebrew. The same claim is sometimes made for Yemenite Hebrew or *Temanit*, which differs from other Mizrahi dialects by having a radically different vowel system, and distinguishing between different diacritically marked consonants that are pronounced identically in other dialects (for example gimel and "ghimel".)

These pronunciations are still used in synagogue ritual and religious study, in Israel and elsewhere, mostly by people who are not native speakers of Hebrew, though some traditionalist Israelis use liturgical pronunciations in prayer.

Many synagogues in the diaspora, even though Ashkenazi by rite and by ethnic composition, have adopted the "Sephardic" pronunciation in deference to Israeli Hebrew. However, in many British and American schools and synagogues, this pronunciation retains several elements of its Ashkenazi substrate, especially the distinction between tsere and segol.

See also

- Paleo-Hebrew alphabet
- List of Hebrew dictionaries
- Hebraism
- Hebraization of English
- Hebrew abbreviations
- Hebrew literature
- Hebrew numerals
- Jewish languages
- List of English words of Hebrew origin
- Romanization of Hebrew
- Study of the Hebrew language

Notes

1. **^** See original text
1. **^** In the Tanakh (Jewish Bible), the language was referred to as *Yehudit* "the language of Judah" or *səpaṯ Kəna'an* "the language of Canaan".[2] Later Hellenistic writers such as Josephus and the Gospel of John used the term *Hebraisti* to refer to both Hebrew and Aramaic.[2]
2. ^ ***a b*** Sáenz-Badillos, Ángel and John Elwolde: "There is general agreement that two main periods of RH (Rabbinical Hebrew) can be distinguished. The first, which lasted until the close of the Tannaitic era (around 200 CE), is characterized by RH as a spoken language gradually developing into a literary medium in which the Mishnah, Tosefta, *baraitot* and Tannaitic *midrashim* would be composed. The second stage begins with the *Amoraim* and sees RH being replaced by Aramaic as the spoken vernacular, surviving only as a literary language. Then it continued to be used in later rabbinic writings until the tenth century in, for example, the Hebrew portions of the two Talmuds and in midrashic and haggadic literature."[13]
3. **^** Fernández & Elwolde: "It is generally believed that the Dead Sea Scrolls, specifically the Copper Scroll and also the Bar Kokhba letters, have furnished clear evidence of the popular character of MH [Mishnaic Hebrew]."[33]
4. **^** The Cambridge History of Judaism: "Thus in certain sources Aramaic words are termed 'Hebrew,' ... For example: η επιλεγομενη εβραιστι βηθεσδα 'which is called in the Hebrew tongue Bethesda' (John 5.2). This is not a Hebrew name but rather an Aramaic one: בית חסדא, 'the house of Hisda'."[34]
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maic. Thus in John 19:13, Ἑβραιστὶ δὲ Γαββαθᾶ is given as an explanation of the Lithostrotos, and Γαββαθᾶ is a Grecized form of the Aramaic word gabbĕtā, 'raised place.'"[40]

6. **^** These pronunciations may have originated in learners' mistakes formed on the analogy of other suffixed forms (*katávta*, *alénu*), rather than being examples of residual Ashkenazi influence.
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External links

For a list of words relating to Hebrew language, see the ***Hebrew language*** category of words in Wiktionary, the free dictionary.

Hebrew edition of Wikipedia, the free encyclopedia

Hebrew edition of Wikisource, the free library

Government

- Official website of the Academy of the Hebrew Language
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General information

- Hebrew language at the Jewish Virtual Library
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- Hebrew language at the University of Texas at Austin College of Liberal Arts
- Hebrew Basic Course by the Foreign Service Institute
- Hebrew for the 21st century, online ulpan

- Morfix, online dictionary
- Hebrew verbs conjugation – Hebrew verb conjugation tool

Iotation

In Slavic languages, **iotation** (/joʊˈteɪ.ʃən/, /ˌaɪ.oʊˈteɪ.ʃən/) is a form of palatalization that occurs when a consonant comes into contact with a palatal approximant /j/ from the succeeding phoneme. The /j/ is represented by iota (ι) in the Cyrillic alphabet and the Greek alphabet on which it is based. For example, ***ni*** in English ***onion*** has the sound of iotated ***n***. Iotation is a distinct phenomenon from Slavic first palatalization in which only the front vowels are involved, but the final result is similar.

Sound change

Iotation occurs when a labial (/m/, /b/), dental (/n/, /s/, /l/) or velar (/k/, /g/, /x/) consonant comes into contact with a *iotified vowel*, i.e. one preceded by a palatal glide /j/. As result, the consonant becomes partially or completely palatalized.[1] In many Slavic languages, iotated consonants are called "soft" and the process of iotation is called "softening".

Iotation can result in a partial palatalization so the centre of the tongue is raised during and after the articulation of the consonant. There can also be a complete sound change to a palatal or alveolo-palatal consonant. This table summarizes the typical outcomes in the modern Slavic languages:

Labial			Dental/alveolar			Velar		
origin	**partial**	**complete**	**origin**	**partial**	**complete**	**origin**	**partial**	**complete**
m	m^j	mj, mʎ	n	n^j	ɲ	k	k^j	c, t͡ɕ, t͡ʃ
b	b^j	bj, bʎ	d	d^j	ɟ, d͡ʑ	g	g^j	ɟ, d͡ʑ, d͡ʒ
p	p^j	pj, pʎ	t	t^j	c, t͡ɕ	x	x^j	ç, ɕ, ʃ
v	v^j	vj, vʎ	s	s^j	ɕ, ʃ			
f	f^j	fj, fʎ	z	z^j	ʑ, ʒ			
			l	l^j	ʎ			

According to most scholars, the period of iotation started approximately in the 5th century, in the era of Proto-Slavic, and it lasted for several centuries, probably into the late Common Slavic dialect differentiation. Here are examples from the early stage:[1]

- Proto-Slavic **kĭasĭa* > Russian, Ukrainian, Bulgarian чаша, Czech *číše*, Serbo-Croatian *čaša*

Orthography

Iotified vowels

In Slavic languages, iotified vowels are preceded by a palatal approximant /j/ before a vowel, at the beginning of a word, or between two vowels in the middle of a word, creating a diphthongoid, a partial diphthong.[2] In the Greek alphabet, the consonant is represented by iota (ι). For example, the English *apple* is cognate to Russian *яблоко (jabloko)*: both come from Proto-Indo-European stem *ābol-. As a result of the phenomenon, no native Slavic root starts with an [e] or an [a] but only with a [je] and [ja]; although other vowels are possible.

As it was invented for the writing of Slavic languages, the original Cyrillic alphabet has relatively complex ways for representing iotation by devoting an entire class of letters to deal with the issue. There are letters which represent iotified vowels; the same letters also palatalize preceding consonants (with or without self-iotation), which is why iotation and palatalization are often mixed up. There are also two special letters (*soft sign* Ь and *hard sign* Ъ) that also induce iotation; in addition, Ь palatalizes preceding consonant, allowing combinations of both palatalized (soft) and plain (hard) consonants with [j]. Originally, these letters produced short vowels [i] and [u]. The exact use depends on the language.

The adjective for a phone which undergoes iotation is *iotated*. The adjective for a letter formed as a ligature of the Early Cyrillic I (I) and another letter, used to represent iotation, is iotified.. The use of a iotified letter does not necessarily denote iotation. Even a iotified letter following a consonant letter is not iotated in most orthographies, but iotified letters imply iotated pronunciation after vowels, soft and hard signs as well as in isolation

In the Cyrillic alphabet, some letter forms are iotified, formed as a ligature of Early Cyrillic I (I) and a vowel.

Normal			Iotified			Comment
Name	**Shape**	**Sound**	**Name**	**Shape**	**Sound**	
A	A	/a/	Iotified A	Ꙗ	/ja/	Now supplanted by Ya (Я)
E	E	/e/	Iotified E	Ѥ	/je/	No longer used
Uk	ОУ	/u/	Iotified Uk	Ю	/ju/	Uk is an archaic form of U (У)
Little Yus	Ѧ	/ẽ/	Iotified Little Yus	Ѩ	/jẽ/	No longer used
Big Yus	Ѫ	/õ/	Iotified Big Yus	Ѭ	/jõ/	No longer used

In old inscriptions, other iotified letters, even consonants, could be found, but they are not in the regular alphabet.

There are more letters that serve the same function, but their glyphs are not made in the same way.

Normal			Iotified			Comment
Name	Shape	Sound	Name	Shape	Sound	
A	Aa	/a/	Ya	Яя	/ja/	Common for East Slavic alphabets
E	Ээ	/e/	Ye	Ee	/je/	Used in Belarusian and Russian
E	Ee		Ye	Єє		Used in Ukrainian
I	Ii	/i/	Yi	Її	/ji/	Used in Ukrainian
O	Oo	/o/	Yo	Ёё	/jo/	The latter is used in Belarusian and Russian, in Ukrainian the digraph "Йо" is used instead
U	Уу	/u/	Yu	Юю	/ju/	Common for East Slavic alphabets

Iotated consonants

Iotated consonants occur as result of iotation. They are represented in IPA with superscript *j* after it and in X-SAMPA with apostrophe after it so the pronunciation of iotated *n* could be represented as [n^j] or [`n'`].

When Vuk Karadžić reformed the Serbian language, the system still largely influential in Macedonian, he created new letters to represent iotated consonants:

Name	Shape	Sound
Dje	Ђ ђ	/d^j/
Gje	Ѓ ѓ	/g^j/
Lje	Љ љ	/l^j/
Nje	Њ њ	/n^j/
Tje	Ћ ћ	/t^j/
Kje	Ќ ќ	/k^j/

See also

- Cyrillic alphabet
- Cyrillic ligatures
- Palatalization (disambiguation)
- Soft sign

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Malayalam

Malayalam (/mæləˈjɑːləm/;[4] മലയാളം, *Malayāḷam* ? [maləja:ɭəm]) is a Dravidian language spoken across the Indian state of Kerala by the Malayali people and it is one of 22 scheduled languages of India. Designated a "Classical Language in India" in 2013,[5] it was developed into the current form mainly by the influence of the poet Thunchaththu Ezhuthachan in the 16th century. Malayalam has official language status in the state of Kerala and in the union territories of Lakshadweep and Puducherry.[6][7][8] It belongs to the Dravidian family of languages and is spoken by 38 million people. Malayalam is also spoken by linguistic minorities in the neighbouring states; with significant number of speakers in the Nilgiris, Kanyakumari and Coimbatore districts of Tamil Nadu, and Dakshina Kannada district of Karnataka. Malayalam serves as a link language on certain islands, including the Mahl-dominated Minicoy Island.[9][10][11]

The origin of Malayalam remains a matter of dispute among scholars. One view holds that Malayalam and modern Tamil are offshoots of Middle Tamil and separated from it sometime after c. 7th century CE. A second view argues for the development of the two languages out of "Proto-Dravidian" or "Proto-Tamil-Malayalam" in the prehistoric era.[12][13]

The earliest script used to write Malayalam was the Vatteluttu alphabet, and later the Kolezhuttu, which derived from it.[14] The current Malayalam script is based on the Vatteluttu script, which was extended with Grantha script letters to adopt Indo-Aryan loanwords from Sanskrit.[15] With a total of 52 letters, the Malayalam script has the largest number of letters among Indian language orthographies.[16] The oldest literary work in Malayalam, distinct from the Tamil tradition, is dated from between the 9th and 11th centuries.[12] The first travelogue in any Indian language is the Malayalam *Varthamanappusthakam*, written by Paremmakkal Thoma Kathanar in 1785.[17][18]

Malayalam	
മലയാളം	
മലയാളം	
Malayalam in Malayalam script	
Pronunciation	[maləja:ɭəm]
Native to	India
Ethnicity	Malayali
Native speakers	39 million (2011)
Language family	Dravidian • Southern Dravidia [1] ◦ Tamil–Kannada ▪ Tamil–Kodagu ▪ Tamil–Malayala ▪ Malayalam lan guages ▪ **Malayalam**
Dialects	• Jeseri (Lakshadweep)
Writing system	Malayalam script (Brahmic) Malayalam Braille Vatteluttu alphabet (historical) Kolezhuthu (historica Malayanma (historica Grantha (historical) Arabi Malayalam (historical/rarely used now) Syriac script (historica
Official status	

Etymology

The word *Malayalam* originated from the Tamil words *malai*, meaning "mountain", and *alam*, meaning "region" or "-ship" (as in "township"); *Malayalam* thus translates directly as "the mountain region." The term originally referred to the land of the Chera dynasty, and only later became the name of its language.[19] The language Malayalam is alternatively called *Alealum*, *Malayalani*, *Malayali*, *Malean*, *Maliyad*, and *Mallealle*.[20]

The earliest extant literary works in the regional language of present-day Kerala probably date back to as early as the 12th century. However, the named identity of this language appears to have come into existence only around the 16th century, when it was known as "Malayayma" or "Malayanma"; the words were also used to refer to the script and the region. The word "Malayalam" was coined in the later period, and the local people referred to their language as both "Tamil" and "Malayalam" until the colonial period.[21]

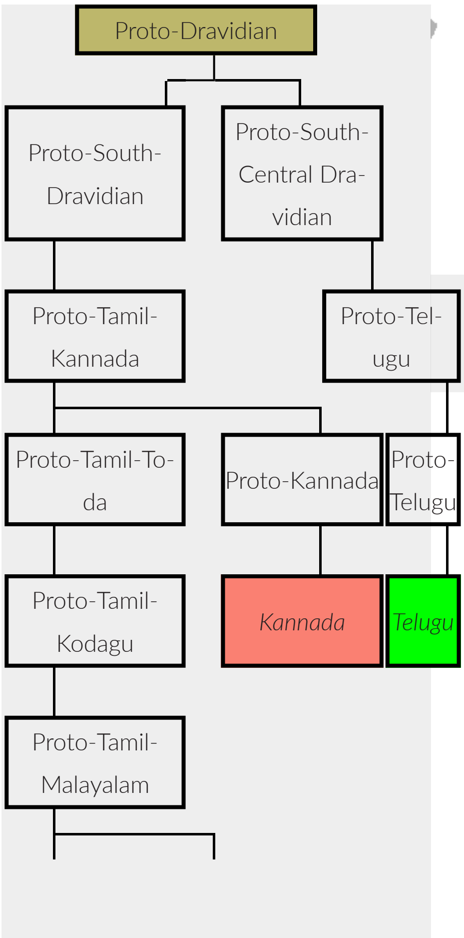
Evolution

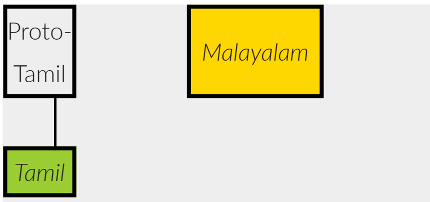
The generally held view is that Malayalam was the western coastal dialect of Tamil[22] and separated from Tamil sometime between the 9th and 13th centuries.[23] Some scholars however believe that both Tamil and Malayalam developed during the prehistoric period from a common ancestor, 'Proto-Tamil-Dravidian', and that the notion of Malayalam being a 'daughter' of Tamil is misplaced.[12] This is based on the fact that Malayalam and several Dravidian languages on the western coast have common features which are not found even in the oldest historical forms of Tamil.[24]

Robert Caldwell, in his 1856 book "*A Comparative Grammar of the Dravidian or South-Indian Family of Languages*", opined that Malayalam branched from *Classical Tamil* and over time gained a large amount of Sanskrit vocabulary and lost the personal terminations of verbs.[19] As the language of scholarship and administration, Old-Tamil, which was written in Tamil-Brahmi and the Vatteluttu alphabet later, greatly influenced the early development of Malayalam. The Malayalam script began to diverge from the Tamil-Brahmi script in the 8th and 9th centuries CE. And by the end of the 13th century a written form of the language emerged which was unique from the Tamil-Brahmi script that was used to write Tamil.[25]

Official language in	India: • Kerala (State),[2] • Lakshadweep (Te[rri]tory) • Mahé, Puducherr (Territory)
Regulated by	Kerala Sahitya Akademi, Government of Kerala
Language codes	
ISO 639-1	`ml`
ISO 639-2	`mal`
ISO 639-3	`mal`
Glottolog	`mala1464`[3]
Linguasphere	`49-EBE-ba`

Malayalam-speaking area





This tree diagram depicts the genealogy of the primary Dravidian languages spoken in South India.

Malayalam is similar to some Sri Lankan Tamil dialects, and the two are often mistaken by native Indian Tamil speakers.[26][27]

Dialects

Variations in intonation patterns, vocabulary, and distribution of grammatical and phonological elements are observable along the parameters of region, religion, community, occupation, social stratum, style and register.

Dialects of Malayalam are distinguishable at regional and social levels,[28] including occupational and also communal differences. The salient features of many varieties of tribal speech (e.g., the speech of Muthuvans, Malayarayas, Malai Ulladas, Kanikkars, Kadars, Paliyars, Kurumas, and Vedas) and those of the various dialects Namboothiris, Nairs, Ezhavas, Syrian Christians (Nasrani), Latin Christians, Muslims, fishermen and many of the occupational terms common to different sections of Malayalees have been identified.[29]

According to the Dravidian Encyclopedia, the regional dialects of Malayalam can be divided into thirteen dialect areas.[30] They are as follows:

South Travancore	Central Travancore	West Vempanad
North Travancore	Kochi-Thrissur	South Malabar
South Eastern Palghat	North Western Palghat	Central Malabar
Wayanad	North Malabar	Kasaragod
Lakshadweep		

According to Ethnologue, the dialects are:[20] Malabar, Nagari-Malayalam, South Kerala, Central Kerala, North Kerala, Kayavar, Namboodiri, Nair, Moplah (Mapilla), Pulaya, Nasrani, and Kasargod. The community dialects are: Namboodiri, Nair, Moplah (Mapilla), Pulaya, and Nasrani.[20] Whereas both the Namboothiri and Nair dialects have a common nature, the Mapilla dialect is among the most divergent of dialects, differing considerably from literary Malayalam.[20]

As regards the geographical dialects of Malayalam, surveys conducted so far by the Department of Linguistics, University of Kerala restricted the focus of attention during a given study on one specific caste so as to avoid mixing up of more than one variable such as communal and geographical factors. Thus for examples, the survey of the Ezhava dialect of Malayalam, results of which have been published by the Department in 1974, has brought to light the existence of twelve major dialect areas for Malayalam, although the isoglosses are found to crisscross in many instances. Sub-dialect regions, which could be marked off, were found to be thirty. This number is reported to tally approximately with the number of principalities that existed during the pre-British period in Kerala. In a few instances at least, as in the case of Venad, Karappuram, Nileswaram and Kumbala, the known boundaries of old principalities are found to coincide with those of certain dialects or sub-dialects that retain their individuality even today. This seems to reveal the significance of political divisions in Kerala in bringing about dialect difference.

Divergence among dialects of Malayalam embrace almost all aspects of language such as phonetics, phonology, grammar and vocabulary. Differences between any two given dialects can be quantified in terms of the presence or absence of specific units at each level of the language. To cite a single example of language variation along the geographical parameter, it may be noted that there are as many as seventy seven different expressions employed by the Ezhavas and spread over various geographical points just to refer to a single item, namely, the flower bunch of coconut. 'Kola' is the expression attested in most of the panchayats in the Palakkad, Ernakulam and Thiruvananthapuram districts of Kerala, whereas 'kolachil' occurs most predominantly in Kannur and Kochi and 'klannil' in Alappuzha and Kollam. 'Kozhinnul' and 'kulannilu' are the forms most common in Trissur Idukki and Kottayam respectively. In addition to these forms most widely spread among the areas specified above, there are dozens of other forms such as 'kotumpu' (Kollam and Thiruvananthapuram), 'katirpu' (Kottayam), krali (Pathanamthitta), pattachi, gnannil (Kollam), 'pochata' (Palakkad) etc. referring to the same item.

It may be noted at this point that labels such as "Brahmin Dialect" and "Syrian Caste Dialect" refer to overall patterns constituted by the sub-dialects spoken by the subcastes or sub-groups of each such caste. The most outstanding features of the major communal dialects of Malayalam are summarized below:

- Lexical items with phonological features reminiscent of Sanskrit (e.g., *viddhi*, meaning "fool"), *bhosku* ("lie"), *musku* ("impudence"), *dustu* ("impurity"), and *eebhyan* and *sumbhan* (both meaning "good-for-nothing fellow") abound in this dialect.
- The dialect of the educated stratum among the Nairs resembles the Brahmin dialect in many respects. The amount of Sanskrit influence, however, is found to be steadily decreasing as one descends along the parameter of education.
- One of the striking features differentiating the Nair dialect from the Ezhava dialect is the phonetic quality of the word-final: an enunciative vowel unusually transcribed as "U". In the Nair dialect it is a mid-central unrounded vowel whereas in the Ezhava dialect it is often heard as a lower high back unrounded vowel.
- The Syrian Christian dialect of Malayalam is quite close to the Nair dialect, especially in phonology. The speech of the educated section among Syrian Christians

and that of those who are close to the church are peculiar in having a number of assimilated as well as unassimilated loan words from English and Syriac. The few loan words which have found their way into the Christian dialect are assimilated in many cases through the process of de-aspiration.

- The Latin Christian dialect of Malayalam is close to the fishermen dialect. It is also influenced by Latin, Portuguese and English.
- The Muslim dialect shows maximum divergence from the literary Standard Dialect of Malayalam. It is very much influenced by Arabic and Urdu rather than by Sanskrit or by English. The retroflex continuant *zha* of the literary dialect is realised in the Muslim dialect as the palatal *ya*.
- Tamil spoken in the Kanyakumari district has many Malayalam words.

External influences and loanwoards

Malayalam has incorporated many elements from other languages over the years, the most notable of these being Sanskrit and later, English.[31] According to Sooranad Kunjan Pillai who compiled the authoritative Malayalam lexicon, the other principal languages whose vocabulary was incorporated over the ages were Pali, Prakrit, Urdu, Hindi, Chinese, Arabic, Syriac, Dutch and Portuguese.[32]

Many medieval liturgical texts were written in an admixture of Sanskrit and early Malayalam, called Manipravalam.[33] The influence of Sanskrit was very prominent in formal Malayalam used in literature. Malayalam has a substantially high amount of Sanskrit loan words but are seldom used.[34] Loan words and influences also from Hebrew, Syriac and Ladino abound in the Jewish Malayalam dialects, as well as English, Portuguese, Syriac and Greek in the Christian dialects, while Arabic and Persian elements predominate in the Muslim dialects. The Muslim dialect known as Mappila Malayalam is used in the Malabar region of Kerala. Another Muslim dialect called Beary bashe is used in the extreme northern part of Kerala and the southern part of Karnataka.

For a comprehensive list of loan words, see Loan words in Malayalam.

Geographic distribution and population

Malayalam is a language spoken by the native people of southwestern India (from Talapady to Kanyakumari).According to the Indian census of 2011, there were 32,299,239 speakers of Malayalam in Kerala, making up 93.2% of the total number of Malayalam speakers in India, and 96.74% of the total population of the state. There were a further 701,673 (2.1% of the total number) in Karnataka, 957,705 (2.7%) in Tamil Nadu, and 406,358 (1.2%) in Maharashtra. The number of Malayalam speakers in Lakshadweep is 51,100, which is only 0.15% of the total number, but is as much as about 84% of the population of Lakshadweep. In all, Malayalis made up 3.22% of the total Indian population in 2011. Of the total 34,713,130 Malayalam speakers in India in 2011, 33,015,420 spoke the standard dialects, 19,643 spoke the *Yerava* dialect and 31,329 spoke non-standard regional variations like *Eranadan*.[35] As per the 1991 census data, 28.85% of all Malayalam speakers in India spoke a second language and 19.64% of the total knew three or more languages.

Large numbers of Malayalis have settled in Chennai (Madras), Bangalore, Hyderabad, Mumbai (Bombay), Pune and Delhi. A large number of Malayalis have also emigrated to the Middle East, the United States, and Europe. There were 179,860 speakers of Malayalam in the United States, according to the 2000 census, with the highest concentrations in Bergen County, New Jersey and Rockland County, New York.[36] There are 172,000 of Malayalam speakers in Malaysia. There were 7,093 Malayalam speakers in Australia in 2006.[37] The 2001 Canadian census reported 7,070 people who listed Malayalam as their mother tongue, mainly in Toronto, Ontario. The 2006 New Zealand census reported 2,139 speakers.[38] 134 Malayalam speaking households were reported in 1956 in Fiji. There is also a considerable Malayali population in the Persian Gulf regions, especially in Dubai and Doha.

Phonology

For the consonants and vowels, the International Phonetic Alphabet (IPA) symbol is given, followed by the Malayalam character and the ISO 15919 transliteration.[39]

Vowels

	Short			Long		
	Front	**Central**	**Back**	**Front**	**Central**	**Back**
Close	/i/ ഇ i	/ɨ̆/ * ŭ	/u/ ഉ u	/iː/ ഈ ī		/uː/ ഊ ū
Mid	/e/ എ e	/ə/ * a	/o/ ഒ o	/eː/ ഏ ē		/oː/ ഓ ō
Open		/a/ അ a			/aː/ ആ ā	

The first letter in Malayalam

- */ɨ̆/ is the *saṁvr̥tōkāram*, an epenthentic vowel in Malayalam. Therefore, it has no independent vowel letter (because it never occurs at the beginning of words) but, when it comes after a consonant, there are various ways of representing it. In medieval times, it was just represented with the symbol for /u/, but later on it was just completely omitted (that is, written as an inherent vowel). In modern times, it is written in two different ways – the Northern style, in which a chandrakkala is used, and the Southern or Travancore style, in which the diacritic for a /u/ is attached to the preceding consonant and a chandrakkala is written above.
- */a/ (phonetically central: [ä]) and /ə/ are both represented as basic or "default" vowels in the Abugida script (although /ə/ never occurs word-initially and therefore does not make use of the letter അ), but they are distinct vowels.

Malayalam has also borrowed the Sanskrit diphthongs of /äu/ (represented in Malayalam as ഔ, au) and /ai/ (represented in Malayalam as ഐ, ai), although these mostly occur only in Sanskrit loanwords. Traditionally (as in Sanskrit), four vocalic consonants (usually pronounced in Malayalam as consonants followed by the *saṁvr̥tōkāram*, which is not officially a vowel, and not as actual vocalic consonants) have been classified as vowels: vocalic r (ഋ, /rɨ̆/, r̥), long vocalic r (ൠ, /rɨː/, r̥̄), vocalic l (ഌ, /lɨ̆/, l̥) and long vocalic l (ൡ, /lɨː/, l̥̄). Except for the first, the other three have been omitted from the current script used in Kerala as there are no words in current Malayalam that use them.

Consonants

		Labial		Dental		Alveolar		Retroflex		Palatal		Velar		Glottal
Nasal		m മ ?m?		n̪ ന ?n?		n ന ?ṉ?		ɳ ണ ?ṇ?		ɲ ഞ ?ñ?		ŋ ങ ?ṅ?		
Stop	**plain**	p പ ?p?	b ബ ?b?	t̪ ത ?t?	d̪ ദ ?d?	t * ?ṯ?		ʈ ട ?ṭ?	ɖ ഡ ?ḍ?	t͡ʃ ച ?c?	d͡ʒ ജ ?j?	k ക ?k?	ɡ ഗ ?g?	
	aspirated	pʰ ഫ ?ph?	bʱ ഭ ?bh?	t̪ʰ ഥ ?th?	d̪ʱ ധ ?dh?			ʈʰ ഠ ?ṭh?	ɖʱ ഢ ?ḍh?	t͡ʃʰ ഛ ?ch?	d͡ʒʱ ഝ ?jh?	kʰ ഖ ?kh?	ɡʱ ഘ ?gh?	
Fricative		f ഫ* ?f?		s̪ സ ?s?				ʂ ഷ ?ṣ?		ɕ ശ ?ś?				h ഹ ?h?
Approximant	**central**	ʋ വ ?v?						ɻ ഴ ?ḻ?		j യ ?y?				
	lateral					l ല ?l?		ɭ ള ?ḷ?						
Rhotic						ɾ ര ?r?		r റ ?ṟ?						

- The unaspirated alveolar plosive stop once had a separate character but it has become obsolete, as the sound only occurs in geminate form (when geminated it is written with a റ below another റ) or immediately following other consonants (in these cases, റ or ററ are usually written in small size underneath the first consonant). The archaic letter can be found in the ?ṯ? row here [2].
- The alveolar nasal also had a separate character that is now obsolete (it can be seen in the ?ṉ? row here [3]) and the sound is now almost always represented by the symbol that was originally used only for the dental nasal. However, both sounds are extensively used in current colloquial and official Malayalam, and although they were allophones in Old Malayalam, they now occasionally contrast in gemination – for example, *eṉṉāl* ("by me", first person singular pronoun in the instrumental case) and *ennāl* ("if that is so", elided from the original *entāl*), which are both written *ennāl*.
- The letter ഫ represents both /pʰ/, a phoneme occurring in Sanskrit loanwords, and /f/, which is mostly found in comparatively recent borrowings from European languages.
- The voiceless unaspirated plosives, the nasals and the laterals can be geminated.[39]
- The retroflex lateral is clearly retroflex, but may be more of a flap [?] (= [ɭ̆]) than an approximant [ɭ]. The approximant /ɻ/ has both rhotic and lateral qualities, and is in-

determinate between an approximant and a fricative, but is laminal post-alveolar rather than a true retroflex. The articulation changes part-way through, perhaps explaining why it behaves as both a rhotic and a lateral, both an approximant and a fricative, but the nature of the change is not understood.[40]

Number system and other symbols

Praslesham	?	Corresponds to Devanagari avagraha, used when a Sanskrit phrase containing an *avagraha* is written in Malayalam script. The symbol indicates the elision of the word-initial vowel *a* after a word that ends in *ā*, *ē*, or *ō*, and is transliterated as an apostrophe ('), or sometimes as a colon + and apostrophe (:'). (Malayalam: പ്രശ്ലേഷം, *praślēṣam* ?)
Malayalam date mark	?	Used in an abbreviation of a date.
Danda	।	Archaic punctuation marks.
Double danda	॥	

Malayalam numbers and fractions are written as follows. These are archaic and no longer commonly used. Note that there is a confusion about the glyph of Malayalam digit zero. The correct form is oval-shaped, but occasionally the glyph for ¼ (?) is erroneously shown as the glyph for 0.

0	1	2	3	4	5	6	7	8	9	10	100	1000	¼	½	¾
	൧	൨	൩	൪	൫	൬	൭	൮	൯	?	?	?	?	?	?

Grammar

Malayalam has a canonical word order of SOV (subject–object–verb) as do other Dravidian languages.[41] A rare OSV word order occurs in interrogative clauses when the interrogative word is the subject.[42] Both adjectives and possessive adjectives precede the nouns they modify. Malayalam has 6[43] or 7[44] grammatical cases. Verbs are conjugated for tense, mood and aspect, but not for person, gender or number except in archaic or poetic language.

Nouns

The declensional paradigms for some common nouns and pronouns are given below. As Malayalam is an agglutinative language, it is difficult to delineate the cases strictly and determine how many there are, although seven or eight is the generally accepted number. Alveolar plosives and nasals (although the modern Malayalam script does not distinguish the latter from the dental nasal) are underlined for clarity, following the convention of the National Library at Kolkata romanization.

Personal pronouns

Vocative forms are given in parentheses after the nominative, as the only pronominal vocatives that are used are the third person ones, which only occur in compounds.

	Singular				*Plural*			
Case	**First person**	**Second person**	**Third person (masculine)**	**Third person (feminine)**	**First person (exclusive)**	**First person (inclusive)**	**Second person**	**Third Person**
Nominative	ñāṉ	nī	avaṉ (voc. avaṉē)	avaḷ (voc. avaḷē)	ñaṅṅaḷ	nām/ nammaḷ	niṅṅaḷ	avar (voc. avarē)
Accusative	eṉṉe	niṉṉe	avaṉe	avaḷe	ñaṅṅaḷe	namme	niṅṅaḷe	avare
Genitive	eṉṯe (also eṉ, eṉṉuṭe)	niṉṯe (also niṉ, niṉṉuṭe)	avaṉṯe (also avaṉuṭe)	avaḷuṭe	ñaṅṅaḷuṭe (also ñaṅṅuṭe)	nammuṭe	niṅṅaḷuṭe	avaruṭe
Dative	eṉikku	niṉakku	avaṉu	avaḷkku	ñaṅṅaḷkku	namukku	niṅṅaḷkku	avaṟkku
Instrumental	eṉṉāl	niṉṉāl	avaṉāl	avaḷāl	ñaṅṅaḷāl (also ñaṅṅāl)	nammāl	niṅṅaḷāl (also niṅṅāl)	avarāl
Locative	eṉṉil (also eṅkal)	niṉṉil (also niṅkal)	avaṉil (also avaṅkal)	avaḷil (also avaḷkal)	ñaṅṅaḷil	nammil	niṅṅaḷil	avaril (also avaṟkal)
Sociative	eṉṉōṭu	niṉṉōṭu	avaṉōṭu	avaḷōṭu	ñaṅṅaḷōṭu	nammōṭu	niṅṅaḷōṭu	avarōṭu

Other nouns

The following are examples of some of the most common declension patterns.

Word	*Tree*		*Elephant*		*Human*		*Dog*	
Case	**Singular**	**Plural**	**Singular**	**Plural**	**Singular**	**Plural**	**Singular**	**Plural**
Nominative	maram	maraṅgaḷ	āṉa	āṉakaḷ	maṉuṣyaṉ	maṉuṣyar	paṭṭi	paṭṭikaḷ
Vocative	maramē	maraṅgaḷē	āṉē	āṉakaḷē	maṉuṣyā	maṉuṣyarē	paṭṭī	paṭṭikaḷē
Accusative	maratte	maraṅgaḷe	āṉaye	āṉakaḷe	maṉuṣyaṉe	maṉuṣyare	paṭṭiye	paṭṭikaḷe
Genitive	marathiṉṯe	maraṅgaḷuṭe	āṉayuṭe	āṉakaḷuṭe	maṉuṣyaṉṯe	maṉuṣyaruṭe	paṭṭiyuṭe	paṭṭikaḷuṭe
Dative	marathinu	maraṅgaḷkku	āṉaykku	āṉakaḷkku	maṉuṣyaṉu	maṉuṣyaṟkku	paṭṭiykku	paṭṭikaḷkku
Instrumental	marathāl	maraṅgaḷāl	āaṉayāl	āaṉakaḷāl	maṉuṣyaṉāl	maṉuṣyarāl	paṭṭiyāl	paṭṭikaḷāl
Locative	marathil	maraṅgaḷil	āṉayil	āṉakaḷil	maṉuṣyaṉil	maṉuṣyaril	paṭṭiyil	paṭṭikaḷil
Sociative	marathōṭu	maraṅgaḷōṭu	āṉayōṭu	āṉakaḷōṭu	maṉuṣyaṉōṭu	maṉuṣyarōṭu	paṭṭiyōṭu	paṭṭikaḷōṭu

Words adopted from Sanskrit

When words are adopted from Sanskrit, their endings are usually changed to conform to Malayalam norms:

Nouns

- Masculine Sanskrit nouns with a word stem ending in a short /a/ take the ending /an/ in the nominative singular. For example, Kr̥ṣṇa → Kr̥ṣṇan. The final /n/ is dropped before masculine surnames, honorifics, or titles ending in /an/ and beginning with a consonant other than /n/ – e.g., "Krishna Menon", "Krishna Kaniyaan" etc., but "Krishnan Ezhutthachan". Surnames ending with /ar/ or /aḷ/ (where these are plural forms of "an" denoting respect) are treated similarly – "Krishna Pothuval", "Krishna Chakyar", but "Krishnan Nair", "Krishnan Nambiar", as are Sanskrit surnames such "Varma(n)", "Sharma(n)", or "Gupta(n)" (rare) – e.g., "Krishna Varma", "Krishna Sharman". If a name is a compound, only the last element undergoes this transformation – e.g., "Kr̥ṣṇa" + "dēva" = "Kr̥ṣṇadēvan", not "Kr̥ṣṇandēvan".
- Feminine words ending in a long /ā/ or /ī/ are changed to end in a short /a/ or /i/, for example "Sītā" → "Sīta" and "Lakṣmī" → "Lakṣmi". However, the long vowel still appears in compound words, such as "Sītādēvi" or" Lakṣmīdēvi". The long ī is generally reserved for the vocative forms of these names, although in Sanskrit the vocative actually takes a short /i/. There are also a small number of nominative /ī/ endings that have not been shortened – a prominent example being the word "strī" for "woman".
- Nouns that have a stem in /-an/ and which end with a long /ā/ in the masculine nominative singular have /vŭ/ added to them, for example "Brahmā" (stem "Brahman") → "Brahmāvŭ". When the same nouns are declined in the neuter and take a short /a/ ending in Sanskrit, Malayalam adds an additional /m/, e.g. "Brahma" (neuter nominative singular of "Brahman") becomes "Brahmam". This is again omitted when forming compounds.
- Words whose roots end in /-an/ but whose nominative singular ending is /-a-/ (for example, the Sanskrit root of "karma" is actually "karman") are also changed. The original root is ignored and "karma" (the form in Malayalam being "karmam" be-

cause it ends in a short /a/) is taken as the basic form of the noun when declining.[45] However, this does not apply to all consonant stems, as "unchangeable" stems such as "manas" ("mind") and "suhrt̥" ("friend") are identical to the Malayalam nominative singular forms (although the regularly derived "manam" sometimes occurs as an alternative to "manas").

- Sanskrit words describing things or animals rather than people with a stem in short /a/ end with an /m/ in Malayalam. For example,"Rāmāyaṇa" → "Rāmāyaṇam". In most cases, this is actually the same as the Sanskrit accusative case ending, which is also /m/ (or, allophonically, anusvara due to the requirements of the sandhi word-combining rules) in the neuter nominative. However, "things and animals" and "people" are not always differentiated based on whether or not they are sentient beings; for example, "Narasimha" becomes "Narasiṃham" and not "Narasiṃhan", whereas "Ananta" becomes "Anantan" even though both are sentient. This does not strictly correspond to the Sanskrit neuter gender, as both "Narasiṃha" and "Ananta" are masculine nouns in the original Sanskrit.
- Nouns with short vowel stems other than /a/, such as "Viṣṇu", "Prajāpati" etc. are declined with the Sanskrit stem acting as the Malayalam nominative singular (the Sanskrit nominative singular is formed by adding a visarga, e.g., as in "Viṣṇuḥ")
- The original Sanskrit vocative is often used in formal or poetic Malayalam, e.g. "Harē" (for "Hari") or "Prabhō" (for "Prabhu" – "Lord"). This is restricted to certain contexts – mainly when addressing deities or other exalted individuals, so a normal man named Hari would usually be addressed using a Malayalam vocative such as "Harī". The Sanskrit genitive is also occasionally found in Malayalam poetry, especially the personal pronouns "mama" ("my" or "mine") and "tava" ("thy" or "thine"). Other cases are less common and generally restricted to the realm of Maṇipravāḷam.
- Along with these tatsama borrowings, there are also many tadbhava words in common use. These were incorporated via borrowing before the separation of Malayalam and Tamil. As the language did not then accommodate Sanskrit phonology as it now does, words were changed to conform to the Old Tamil phonological system, for example "Kr̥ṣṇa" → "Kaṇṇan".[46] Most of his works are oriented on the basic Malayalam family and cultures and many of them were path-breaking in the history of Malayalam literature.

Writing system

Malayalam Script (Aksharamala) letters

Historically, several scripts were used to write Malayalam. Among these were the Vatteluttu, Kolezhuthu and Malayanma scripts. But it was the Grantha script, another Southern Brahmi variation, which gave rise to the modern Malayalam script. It is syllabic in the sense that the sequence of graphic elements means that syllables have to be read as units, though in this system the elements representing individual vowels and consonants are for the most part readily identifiable. In the 1960s Malayalam dispensed with many special letters representing less frequent conjunct consonants and combinations of the vowel /u/ with different consonants.

A public notice board written using Malayalam script. The Malayalam language possesses official recognition in the state of Kerala, and the union territories of Lakshadweep and Puducherry

Malayalam script consists of a total of 578 characters. The script contains 52 letters including 16 vowels and 36 consonants, which forms 576 syllabic characters, and contains two additional diacritic characters named anusvāra and visarga.[47][48] The earlier style of writing has been superseded by a new style as of 1981. This new script reduces the different letters for typesetting from 900 to fewer than 90. This was mainly done to include Malayalam in the keyboards of typewriters and computers.

In 1999 a group named "Rachana Akshara Vedi" produced a set of free fonts containing the entire character repertoire of more than 900 glyphs. This was announced and released along with a text editor in the same year at Thiruvananthapuram, the capital of Kerala. In 2004, the fonts were released under the GNU GPL license by Richard Stallman of the Free Software Foundation at the Cochin University of Science and Technology in Kochi, Kerala.

Malayalam has been written in other scripts like Roman, Syriac[49][50][51] and Arabic. Suriyani Malayalam was used by Saint Thomas Christians (also known as Nasranis) until the 19th century.[49][50][51] Arabic scripts particularly were taught in madrasahs in Kerala and the Lakshadweep Islands.[52][53]

Literature

Kerala Sahitya Akademy at Thrissur

The earliest written record resembling Malayalam is the Vazhappalli inscription (ca. 830 CE).[54] The early literature of Malayalam comprised three types of composition: Malayalam Nada, Tamil Nada and Sanskrit Nada.

- Classical songs known as Nadan Pattu
- Manipravalam of the Sanskrit tradition, which permitted a generous interspersing of Sanskrit with Malayalam. Niranam poets[55] Manipravalam Madhava Panikkar, Sankara Panikkar and Rama Panikkar wrote Manipravalam poetry in the 14th century.
- The folk song rich in native elements

Malayalam poetry to the late 20th century betrays varying degrees of the fusion of the three different strands. The oldest examples of Pattu and Manipravalam, respectively, are *Ramacharitam* and *Vaishikatantram*, both from the 12th century.[56]

The earliest extant prose work in the language is a commentary in simple Malayalam, *Bhashakautalyam* (12th century) on Chanakya's *Arthashastra*. Adhyatmaramayanam by Thunchaththu Ramanujan Ezhuthachan (known as the father of the Malayalam language) who was born in Tirur, one of the most important works in Malayalam literature. Unnunili Sandesam written in the 14th century is amongst the oldest literary works in Malayalam language.[57]

By the end of the 18th century some of the Christian missionaries from Kerala started writing in Malayalam but mostly travelogues, dictionaries and religious books. Varthamanappusthakam (1778), written by Paremmakkal Thoma Kathanar[58] is considered to be the first travelogue in an Indian language.

Early period

Malayalam letters on old Travancore Rupee coin

The earliest known poem in Malayalam, *Ramacharitam*, dated to the 12th to 14th century CE, was completed before the introduction of the Sanskrit alphabet. It shows the same phase of the language as in Jewish and Nasrani *Sasanas* (dated to mid-8th century A.D.).[19] But the period of the earliest available literary document cannot be the sole criterion used to determine the antiquity of a language. In its early literature, Malayalam has songs, *Pattu*, for various subjects and occasions, such as harvesting, love songs, heroes, gods, etc. A form of writing called *Campu* emerged from the 14th century onwards. It mixed poetry with prose and used a vocabulary strongly influenced by Sanskrit, with themes from epics and *Puranas*.[25]

Rama-charitam, which was composed in the 14th century A.D., may be said to have inaugurated Malayalam literature just as Naniah's Mahabharatam did for Telugu. The fact is that dialectical and local peculiarities had already developed and stamped themselves in local songs and ballads. But these linguistic variations were at last gathered together and made to give a coloring to a sustained literary work, the *Rama-charitam*, thereby giving the new language a justification and a new lease on life.

The Malayalam language, with the introduction of a new type of devotional literature, underwent a metamorphosis, both in form and content, and it is generally held that modernity in Malayalam language and literature commenced at this period. This change was brought about by Thunchathu Ezhuthachan (16th century) who is known as the father of modern Malayalam. Till this time Malayalam indicated two different courses of development depending on its relationship with either Sanskrit or Tamil.

The earliest literary work in Malayalam now available is a prose commentary on Chanakya's Arthashastra, ascribed to the 13th century. The poetical works called *Vaisikatantram* are also believed to belong to the early 14th century. These works come under a special category known as Manipravalam, literally the combination of two languages, the language of Kerala and Sanskrit. A grammar and rhetoric in this hybrid style was written sometime in the 14th century in Sanskrit and the work, called the *Lilatikalam*, is the main source of information for a student of literary and linguistic history.

According to this book, the Manipravalam and Pattu styles of literary compositions were in vogue during this period. "Pattu" means "song" and more or less represents the pure Malayalam school of poetry. From the definition of the Pattu style given in the *Lilatikalam*, it can be surmised that the language of Kerala during this period was more or less in line with Tamil, but this has misled many people to believe incorrectly that Malayalam was itself Tamil during this period and before.

The latest research shows that Malayalam as a separate spoken language in Kerala began showing independent lines of development from its parental tongue Proto-Tamil-Malayalam (which is not modern Tamil), preserving the features of the earliest Dravidian tongue, which only in due course gave birth to the literary form of Tamil, namely Sen Tamil and Malayalam, the spoken form of which is prevalent in Kerala. However, till the 13th century there is no hard evidence to show that the language of Kerala had a literary tradition except in folk songs.

The literary tradition consisted of three early Manipravalam Champus, a few Sandesa Kavyas and innumerable amorous compositions on the courtesans of Kerala, which throb with literary beauty and poetical fancies, combined with a relishing touch of realism about them with regard to the then social conditions. Many prose works in the form of commentaries upon Puranic episodes form the bulk of the classical works in Malayalam.

The Pattu (a sutra devoted to define this pattern is termed a *pattu*) school also has major works like the Ramacharitam (12th century), and the Bhagavad Gita (14th century) by a set of poets belonging to one family called the Kannassas. Some of them like Ramacharitam have a close resemblance to the Tamil language during this period. This is to be attributed to the influence of Tamil works on native poets belonging to areas that lie close to the Tamil country.

It was during the 16th and 17th centuries that later Champu kavyas were written. Their specialty was that they contained both Sanskritic and indigenous elements of poetry to an equal degree, and in that manner were unique.

Unnayi Varyar, whose Nalacharitan Attakkatha is popular even today, was the most prominent poet of the 18th century among not only the Kathakali writers, but also among the classical poets of Kerala. He is often referred to as the Kalidasa of Kerala. Although Kathakali is a dance drama and its literary form should more or less be modeled after the drama, there is nothing more in common between an Attakkatha and Sanskrit drama.

That is to say, the principles of dramaturgy to be observed in writing a particular type of Sanskrit drama are completely ignored by an author of Attakkatha. Delineation of a particular *rasa* is an inevitable feature with Sanskrit drama, whereas in an Attakkatha all the predominant *rasas* are given full treatment, and consequently the theme of an Attakkatha often loses its integrity and artistic unity when viewed as a literary work.

Any Attakkatha fulfills its objective if it affords a variety of scenes depicting different types of characters, and each scene would have its own hero with the *rasa* associated with that character. When that hero is portrayed he is given utmost importance, to the utter neglect of the main sentiment (*rasa*) of the theme in general. However, the purpose of Attakkatha is not to present a theme with a well-knit emotional plot as its central point, but to present all approved types of characters already set to suit the technique of the art of Kathakali.

The major literary output of the century was in the form of local plays composed for the art of kathakali, the dance dramas of Kerala also known as Attakkatha. It seems the *Gitagovinda* of Jayadeva provided a model for this type of literary composition. The verses in Sanskrit narrate the story and the dialogue is composed in imitation of songs in the *Gitagovinda*, set to music in appropriate *ragas* in the classical Karnataka style.

Besides the Raja of Kottarakkara and Unnayi Varyar referred to above, nearly a hundred plays were composed during this century by poets belonging to all categories and subscribing to all standards, such as Irayimman Tampi and Ashvati Raja, to mention just two.

Devotional literature in Malayalam found its heyday during the early phase of this period. Ezhuthachan referred to above gave emphasis to the *Bhakti* cult. The *Jnanappana* by Puntanam Nambudiri is a unique work in the branch of philosophical poetry. Written in simple language, it is a sincere approach to the advaita philosophy of Vedanta.

It took nearly two centuries for a salutary blending of the scholarly Sanskrit and popular styles to bring Malayalam prose to its present form, enriched in its vocabulary by Sanskrit but at the same time flexible, pliable and effective as to popular parlance.

As regards literature, the leading figures were Irayimman Thampi and Vidwan Koithampuran, both poets of the royal court. Their works abound in a beautiful and happy blending of music and poetry. The former is surely the most musical poet of Kerala and his beautiful lullaby commencing with the line *Omana Thinkalkidavo* has earned him an everlasting name. But the prime reason why he is held in such high esteem in Malayalam is the contribution he has made to Kathakali literature by his three works, namely the *Dakshayagam*, the *Kichakavadham* and the *Uttara-svayamvaram*. The latter's Kathakali work *Ravana Vijayam* has made him immortal in literature.

Impact of European scholars

The first printed book in Kerala was *Doctrina Christam*, written by Henrique Henriques in Lingua Malabar Tamul. It was transliterated and translated into Malayalam, and printed by the Portuguese in 1578.[59][60] In the 16th and 17th centuries, Thunchaththu Ramanujan Ezhuthachan was the first to substitute Grantha-Malayalam script for the Tamil Vatteluttu alphabet. Ezhuthachan, regarded as the father of the modern Malayalam language, undertook an elaborate translation of the ancient Indian epics *Ramayana* and *Mahabharata* into Malayalam. His *Adhyatma Ramayana* and *Mahabharata* are still read with religious reverence by the Malayalam-speaking Hindu community. Kunchan Nambiar, the founder of *Tullal*, was a prolific literary figure of the 18th century.

The British printed Malabar English Dictionary by Graham Shaw in 1779 was still in the form of a Tamil-English Dictionary.[61] The Syrian Christians of Kerala started to learn the Tulu-Grantha Bhasha of Nambudiris under the British Tutelage. Paremmakkal Thoma Kathanar wrote the first Malayalam travelogue called *Varthamanappusthakam* in 1789.

The educational activities of the missionaries belonging to the Basel Mission deserve special mention. Hermann Gundert, (1814 – 1893), a German missionary and scholar of exceptional linguistic talents, played a distinguishable role in the development of Malayalam literature. His major works are Keralolpathi (1843), Pazhancholmala (1845), Malayalabhaasha Vyakaranam (1851), *Paathamala (1860) the first Malayalam school text book*, Kerala pazhama (1868), *the first Malayalam dictionary (1872)*, Malayalarajyam (1879) - Geography of Kerala, *Rajya Samacharam (1847 June) the first Malayalam news paper*, Paschimodayam (1879) - Magazine.[62] He lived in Thalassery for around 20 years. He learned the language from well established local teachers Ooracheri Gurukkanmar from Chokli, a village near Thalassery and consulted them in works. He also translated the Bible into Malayalam.[63][64]

In 1821, the Church Mission Society (CMS) at Kottayam in association with the Syriac Orthodox Church started a seminary at Kottayam in 1819 and started printing books in Malayalam when Benjamin Bailey, an Anglican priest, made the first Malayalam types. In addition, he contributed to standardizing the prose.[65] Hermann Gundert from Stuttgart, Germany, started the first Malayalam newspaper, *Rajya Samacaram* in 1847 at Talasseri. It was printed at Basel Mission.[66] Malayalam and Sanskrit were increasingly studied by Christians of Kottayam and Pathanamthitta. By the end of the 19th century Malayalam replaced Syriac as language of Liturgy in the Syrian Christian churches.

Thanks to the efforts of kings like Swathi Thirunal and to the assistance given by him to the Church Mission and London Mission Societies, a number of schools were started.

1850–1904

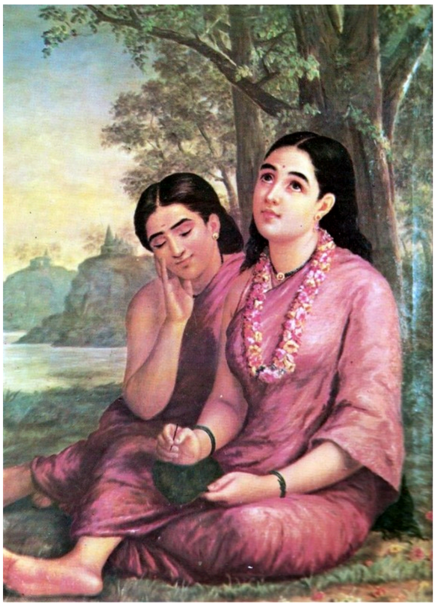
The establishment of the Madras University in 1857 marks an important event in the cultural history of Kerala. It is from here that a generation of scholars well versed in Western literature and with the capacity to enrich their own language by adopting Western literary trends came into being. Prose was the first branch to receive an impetus by its contact with English. Though there was no shortage of prose in Malayalam, it was not along Western lines. It was left to the farsighted policy of the Maharaja of Travancore (1861 to 1880) to start a scheme for the preparation of textbooks for use by schools in the state. Kerala Varma V, a scholar in Sanskrit, Malayalam and English was appointed Chairman of the Committee formed to prepare textbooks. He wrote several books suited for various standards.

The growth of journalism, too, helped in the development of prose. Initiated by missionaries for the purpose of religious propaganda, journalism was taken up by local scholars who started newspapers and journals for literary and political activities.

Vengayil Kunhiraman Nayanar, (1861-1914) from Thalassery was the author of first Malayalam short story, Vasanavikriti. After him innumerable world class literature works by was born in Malayalam.

With his work *Kundalatha* in 1887, Appu Nedungadi marks the origin of prose fiction in Malayalam. Other talented writers were Chandu Menon, the author of *Indulekha*, a great social novel, in 1889 and another called *Sarada*. Also there was C V Raman Pillai, who wrote the historical novel *Marthandavarma* in 1890 as well as works like Dharmaraja, and Ramaraja Bahadur.

In poetry there were two main trends, one represented by Venmani Nampoodiris(venmani Poets) and the other by Kerala Varma. The latter's poetry was modeled on the old Manipravalam style abounding in Sanskrit words and terms, but it had a charm of its own when adapted to express new ideas in that masterly way characteristic of himself. His translation of Kalidasa's *Abhijnanasakuntalam* in 1882 marks an important event in the history of Malayalam drama and poetry. Also Kerala Varma's *Mayura-sandesam* is a *Sandesakavya* (messenger poem) written after the manner of Kalidasa's *Meghadutam*. Though it cannot be compared with the original, it was still one of the most popularly acclaimed poems in Malayalam.



Shakuntala writes to Dushyanta. Painting by Raja Ravi Varma. The poetry was translated by Kerala Varma as Abhijnanasakuntalam

One of the notable features of the early decades of the 20th century was the great interest taken by writers in translating works from Sanskrit and English into Malayalam. Kalidasa's *Meghaduta* and *Kumarasambhava* by A. R. Raja Raja Varma and the *Raghuvamsa* by K. N. Menon must be mentioned. One of the most successful of the later translators was C. S. Subramaniam Potti who set a good model by his translation of the *Durgesanandini* of Bankim Chandra from an English version of it.

Twentieth century

The early decades of the 20th century saw the beginning of a period of rapid development of all branches of Malayalam literature. A good number of authors familiar with the latest trends in English literature came forward to contribute to the enrichment of their mother tongue. Their efforts were directed more to the development of prose than poetry.

Prose

Several Bengali novels were translated during this period. C. S. S. Potti, mentioned above, also brought out the *Lake of Palms* of R. C. Dutt under the title *Thala Pushkarani*, *Kapalakundala* by V. K. Thampi and *Visha Vruksham* by T. C. Kalyani Amma were also translations of novels by Bankimochandra Chatterji.

Among the original novels written at that time only a few are worth mentioning, such as *Bhootha Rayar* by Appan Thampuran, *Keraleswaran* by Raman Nambeesan and *Cheraman Perumal* by K. K. Menon. Although a large number of social novels were produced during this period, only a few are remembered, such as *Snehalatha* by Kannan Menon, *Hemalatha* by T. K. Velu Pillai and *Kambola-balika* by N. K. Krishna Pillai. But by far the most inspiring work of that time was *Aphante Makal* by M. B. Namboodiri, who directed his literary talents towards the abolition of old worn-out customs and manners which had for years been the bane of the community.

Short stories came into being. With the advent of E. V. Krishna Pillai, certain marks of novelty became noticeable in the short story. His *Keleesoudham* proved his capacity to write with considerable emotional appeal.

C. V. Raman Pillai was a pioneer in prose dramas. He had a particular knack for writing dramas in a lighter vein. His *Kurupillakalari* of 1909 marks the appearance of the first original Malayalam prose drama. It is a satirical drama intended to ridicule the Malayali official classes who started imitating Western fashion and etiquette. There were other authors, less well-known, who wrote in this vein.

Under the guidance of A. Balakrishna Pillai, a progressive school of authors appeared in almost all branches of literature, such as the novel, the short story, the drama, and criticism.

Malayalam language in mobile phone

Poetry

Kumaran Asan's celebrated poem, *Veena Poovu* (*The Fallen Flower*) depicts in a symbolic manner the tragedy of human life in a moving and thought-provoking manner. Vallathol's *Bandhanasthanaya Aniruddhan*, which demonstrates an exceptionally brilliant power of imagination and deep emotional faculties, depicts a situation from the Puranic story of Usha and Aniruddha. Ulloor S. P. Iyer was another veteran who joined the new school. He wrote a series of poems like *Oru Mazhathulli* in which he excelled as a romantic poet.

The three more or less contemporary poets Kumaran Asan, Vallathol Narayana Menon and Ulloor S. Parameswara Iyer considerably enriched Malayalam poetry. Some of their works reflect social and political movements of that time. Asan wrote about untouchability in Kerala; Ullor's writings reflect his deep devotion and admiration for the great moral and spiritual values, which he believed were the real assets of ancient social life of India. They were known as the trio of Malayalam poetry. After them there were others like K. K. Nair and K. M. Panikkar who contributed to the growth of poetry.

See also

- Beary bashe
- Bible translations into Malayalam
- Malayali
    - Arabi Malayalam
- Judeo-Malayalam
- Lingua Malabar Tamul
- Malayalam calendar
- Malayalam literature
- Malayalam poetry
- Manipravalam
- Suriyani Malayalam
- Tulu script

Notes

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Malayalam edition of Wikipedia, the free encyclopedia

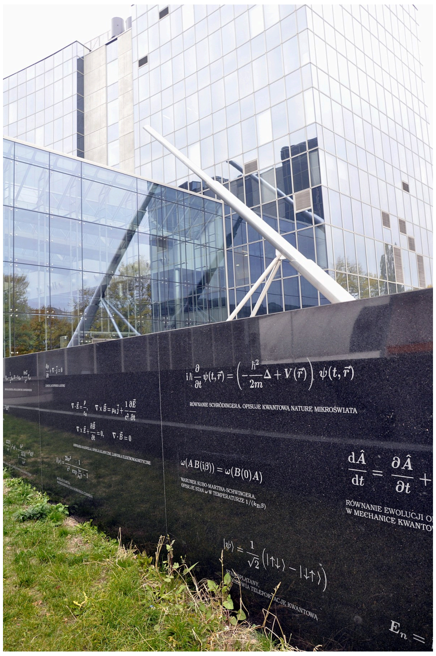
Wikimedia Commons has media related to ***Malayalam language***.

- Unicode Code Chart for Malayalam (PDF Format)
- Malayalam Grammar
- Malayali Podcasts in RaydioActive
- Malayalam Typing

Math Formulas

Maxwell's equations

Maxwell's equations are a set of partial differential equations that, together with the Lorentz force law, form the foundation of classical electromagnetism, classical optics, and electric circuits. The equations provide a mathematical model for electric, optical and radio technologies, such as power generation, electric motors, wireless communication, lenses, radar etc. Maxwell's equations describe how electric and magnetic fields are generated by charges, currents, and changes of the fields. One important consequence of the equations is that they demonstrate how fluctuating electric and magnetic fields propagate at the speed of light. Known as electromagnetic radiation, these waves may occur at various wavelengths to produce a spectrum from radio waves to γ-rays. The equations are named after the physicist and mathematician James Clerk Maxwell, who between 1861 and 1862 published an early form of the equations that included the Lorentz force law. He also first used the equations to propose that light is an electromagnetic phenomenon.



Maxwell's equations (mid-left) as featured on a monument in front of Warsaw University's Center of New Technologies

The equations have two major variants. The microscopic Maxwell equations have universal applicability, but are unwieldy for common calculations. They relate the electric and magnetic fields to total charge and total current, including the complicated charges and currents in materials at the atomic scale. The "macroscopic" Maxwell equations define two new auxiliary fields that describe the large-scale behaviour of matter without having to consider atomic scale charges and quantum phenomena like spins. However, their use requires experimentally determining parameters for a phenomenological description of the electromagnetic response of materials.

The term "Maxwell's equations" is often also used for equivalent alternative formulations. Versions of Maxwell's equations based on the electric and magnetic potentials are preferred for explicitly solving the equations as a boundary value problem, analytical mechanics, or for use in quantum mechanics. The spacetime formulations (i.e., on spacetime rather than space and time separately), are commonly used in high energy and gravitational physics because they make the compatibility of the equations with special and general relativity manifest.[note 1] In fact, Einstein developed special and general relativity to accommodate the absolute speed of light that drops out of the Maxwell equations with the principle that only relative movement has physical consequences.

Since the mid-20th century, it has been understood that Maxwell's equations are not exact, but a classical limit of the fundamental theory of quantum electrodynamics.

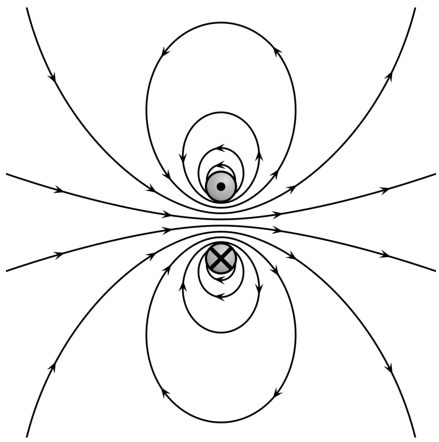
Conceptual descriptions

Gauss's law

Gauss's law describes the relationship between a static electric field and the electric charges that cause it: The static electric field points away from positive charges and towards negative charges, and the net outflow of the electric field through any closed surface is proportional to the charge enclosed by the surface. Picturing the electric field by its field lines, this means the field lines begin at positive electric charges and end at negative electric charges. 'Counting' the number of field lines passing through a closed surface yields the total charge (including bound charge due to polarization of material) enclosed by that surface, divided by dielectricity of free space (the vacuum permittivity).

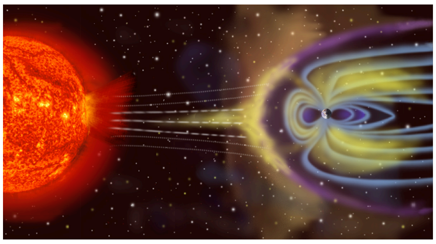
Gauss's law for magnetism

Gauss's law for magnetism states that there are no "magnetic charges" (also called magnetic monopoles), analogous to electric charges.[1] Instead, the magnetic field due to materials is generated by a configuration called a dipole, and the net outflow of the magnetic field through any closed surface is zero. Magnetic dipoles are best represented as loops of current but resemble positive and negative 'magnetic charges', inseparably bound together, having no net 'magnetic charge'. In terms of field lines, this equation states that magnetic field lines neither begin nor end but make loops or extend to infinity and back. In other words, any magnetic field line that enters a given volume must somewhere exit that volume. Equivalent technical statements are that the sum total magnetic flux through any Gaussian surface is zero, or that the magnetic field is a solenoidal vector field.



Gauss's law for magnetism: magnetic field lines never begin nor end but form loops or extend to infinity as shown here with the magnetic field due to a ring of current.

Faraday's law

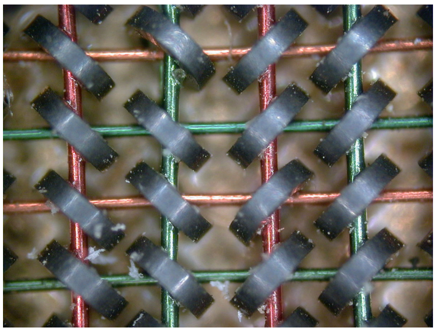


In a geomagnetic storm, a surge in the flux of charged particles temporarily alters Earth's magnetic field, which induces electric fields in Earth's atmosphere, thus causing surges in electrical power grids. (Not to scale.)

The **Maxwell–Faraday** version of Faraday's law of induction describes how a time varying magnetic field creates ("induces") an electric field.[1] In integral form, it states that the work per unit charge required to move a charge around a closed loop equals the rate of decrease of the magnetic flux through the enclosed surface.

The dynamically induced electric field has closed field lines similar to a magnetic field, unless superposed by a static (charge induced) electric field. This aspect of electromagnetic induction is the operating principle behind many electric generators: for example, a rotating bar magnet creates a changing magnetic field, which in turn generates an electric field in a nearby wire.

Ampère's law with Maxwell's addition



Magnetic core memory (1954) is an application of Ampère's law. Each core stores one bit of data.

Ampère's law with Maxwell's addition states that magnetic fields can be generated in two ways: by electric current (this was the original "Ampère's law") and by changing electric fields (this was "Maxwell's addition", which he called displacement current). In integral form, the magnetic field induced around any closed loop is proportional to the electric current plus displacement current (proportional to the rate of change of electric flux) through the enclosed surface.

Maxwell's addition to Ampère's law is particularly important: it makes the set of equations mathematically consistent for non static fields, without changing the laws of Ampere and Gauss for static fields.[2] However, as a consequence, it predicts that a changing magnetic field induces an electric field and vice versa.[1][3] Therefore, these equations allow self-sustaining "electromagnetic waves" to travel through empty space (see electromagnetic wave equation).

The speed calculated for electromagnetic waves, which could be predicted from experiments on charges and currents,[note 2] exactly matches the speed of light; indeed, light *is* one form of electromagnetic radiation (as are X-rays, radio waves, and others). Maxwell understood the connection between electromagnetic waves and light in 1861, thereby unifying the theories of electromagnetism and optics.

Formulation in terms of electric and magnetic fields (microscopic or in vacuum version)

In the electric and magnetic field formulation there are four equations that determine the fields for given charge and current distribution. A separate law of nature, the Lorentz force law, describes how, conversely, the electric and magnetic field act on charged particles and currents. A version of this law was included in the original equations by Maxwell but, by convention, is included no longer. The vector calculus formalism below, due to Oliver Heaviside,[4][5] has become standard. It is manifestly rotation invariant, and therefore mathematically much more transparent than Maxwell's original 20 equations in x,y,z components. The relativistic formulations are even more symmetric and manifestly Lorentz invariant. For the same equations expressed using tensor calculus or differential forms, see alternative formulations.

The differential and integral equations formulations are mathematically equivalent and are both useful. The integral formulation relates fields within a region of space to fields on the boundary and can often be used to simplify and directly calculate fields from symmetric distributions of charges and currents. On the other hand, the differential equations are purely *local* and are a more natural starting point for calculating the fields in more complicated (less symmetric) situations, for example using finite element analysis.[6]

Formulation in SI units convention

Name	Integral equations	Differential equations
Gauss's law	$\oiint_{\partial\Omega} \mathbf{E} \cdot \mathrm{d}\mathbf{S} = \frac{1}{\varepsilon_0} \iiint_\Omega \rho \, \mathrm{d}V$	$\nabla \cdot \mathbf{E} = \frac{\rho}{\varepsilon_0}$
Gauss's law for magnetism	$\oiint_{\partial\Omega} \mathbf{B} \cdot \mathrm{d}\mathbf{S} = 0$	$\nabla \cdot \mathbf{B} = 0$
Maxwell–Faraday equation (Faraday's law of induction)	$\oint_{\partial\Sigma} \mathbf{E} \cdot \mathrm{d}\boldsymbol{l} = -\frac{\mathrm{d}}{\mathrm{d}t} \iint_\Sigma \mathbf{B} \cdot \mathrm{d}\mathbf{S}$	$\nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t}$
Ampère's circuital law (with Maxwell's addition)		

Formulation in Gaussian units convention

The definitions of charge, electric field, and magnetic field can be altered to simplify theoretical calculation, by absorbing dimensioned factors of ε_0 and c into the units of calculation, by convention. With a corresponding change in convention for the Lorentz force law this yields the same physics, i.e. trajectories of charged particles, or work done by an electric motor. These definitions are often preferred in theoretical and high energy physics where it is natural to take the electric and magnetic field with the same units, to simplify the appearance of the electromagnetic tensor: the Lorentz covariant object unifying electric and magnetic field would then contain components with uniform unit and dimension.[7]:vii Such modified definitions are conventionally used with the Gaussian (CGS) units. Using these definitions and conventions, colloquially "in Gaussian units",[8] the Maxwell equations become:[9]

Name	Integral equations	Differential equations
Gauss's law	$\oiint$	
Gauss's law for magnetism	$\oiint$	
Maxwell–Faraday equation (Faraday's law of induction)		
Ampère's circuital law (with Maxwell's addition)		

Note that the equations are particularly readable when length and time are measured in compatible units like seconds and lightseconds i.e. in units such that c = 1 unit of length/unit of time. Ever since 1983, metres and seconds are compatible except for historical legacy since *by definition* c = 299 792 458 m/s (≈ 1.0 feet/nanosecond).

Further cosmetic changes, called rationalisations, are possible by absorbing factors of 4π depending on whether we want Coulomb's law or Gauss law to come out nicely, see Lorentz-Heaviside units (used mainly in particle physics). In theoretical physics it is often useful to choose units such that Plancks constant, the elementary charge, and even Newton's constant are 1. See Planck units.

Key to the notation

Symbols in **bold** represent vector quantities, and symbols in *italics* represent scalar quantities, unless otherwise indicated.

The equations introduce the electric field, **E**, a vector field, and the magnetic field, **B**, a pseudovector field, each generally having a time and location dependence. The sources are

- the total electric charge density (total charge per unit volume), ρ, and
- the total electric current density (total current per unit area), **J**.

The universal constants appearing in the equations are

- the permittivity of free space, ε_0, and
- the permeability of free space, μ_0, and
- the speed of light,

Differential equations

In the differential equations,

- the nabla symbol, **∇**, denotes the three-dimensional gradient operator, del,
- the **∇**· symbol (pronounced "del dot") denotes the divergence operator,
- the **∇**× symbol (pronounced "del cross") denotes the curl operator.

Integral equations

In the integral equations,

- Ω is any fixed volume with closed boundary surface $\partial\Omega$, and
- Σ is any fixed surface with closed boundary curve $\partial\Sigma$,

Here a *fixed* volume or surface means that it does not change over time. The equations are correct, complete and a little easier to interpret with time-independent surfaces. For example, since the surface is time-independent, we can bring the differentiation under the integral sign in Faraday's law:

Maxwell's equations can be formulated with possibly time-dependent surfaces and volumes by using the differential version and using Gauss and Stokes formula appropriately.

- $\oiint$ is a surface integral over the boundary surface $\partial\Omega$, with the loop indicating the surface is closed
- is a volume integral over the volume Ω,
- is a line integral around the boundary curve $\partial\Sigma$, with the loop indicating the curve is closed.
- is a surface integral over the surface Σ,
- The *total* electric charge Q enclosed in Ω is the volume integral over Ω of the charge density ρ (see the "macroscopic formulation" section below):

  where dV is the volume element.

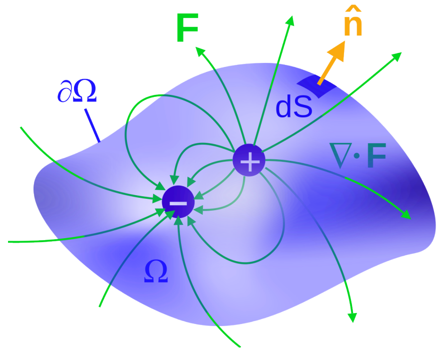
- The *net* electric current I is the surface integral of the electric current density **J** passing through a fixed surface, Σ:

  where d**S** denotes the vector element of surface area S, normal to surface Σ. (Vector area is sometimes denoted by **A** rather than **S**, but this conflicts with the notation for magnetic potential).

Relationship between differential and integral formulations

The equivalence of the differential and integral formulations are a consequence of the Gauss divergence theorem and the Kelvin–Stokes theorem.

Flux and divergence



*Volume Ω and its closed boundary ∂Ω, containing (respectively enclosing) a source (+) and sink (−) of a vector field **F**. Here, **F** could be the **E** field with source electric charges, but not the **B** field, which has no magnetic charges as shown. The outward unit normal is **n**.*

According to the (purely mathematical) Gauss divergence theorem the electric flux through the boundary surface ∂Ω can be rewritten as

$$\oiint$$

The integral version of Gauss's equation can thus be rewritten as

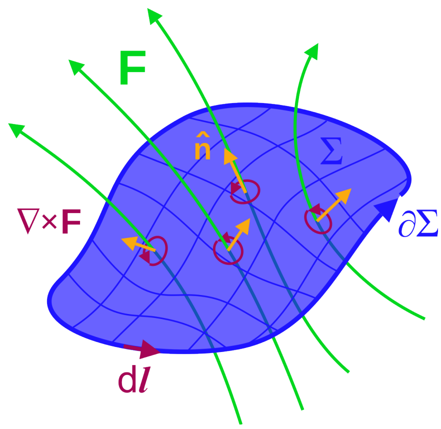
Since Ω is arbitrary (e.g. an arbitrary small ball with arbitrary center), this is satisfied iff the integrand is zero. This is the differential equations formulation of Gauss equation up to a trivial rearrangement.

Similarly rewriting the magnetic flux in Gauss's law for magnetism in integral form gives

$$\oiint .$$

which is satisfied for all Ω iff .

Circulation and curl



*Surface Σ with closed boundary ∂Σ. **F** could be the **E** or **B** fields. Again, **n** is the unit normal. (The curl of a vector field doesn't literally look like the "circulations", this is a heuristic depiction.)*

By the Kelvin–Stokes theorem we can rewrite the line integrals of the fields around the closed boundary curve ∂Σ to an integral of the "circulation of the fields" (i.e. their curls) over a surface it bounds, i.e.

,

Hence the modified Ampere law in integral form can be rewritten as

.

Since Σ can be chosen arbitrarily, e.g. as an arbitrary small, arbitrary oriented, and arbitrary centered disk, we conclude that the integrand is zero iff Ampere's modified law in differential equations form is satisfied. The equivalence of Faraday's law in differential and integral form follows likewise.

The line integrals and curls are analogous to quantities in classical fluid dynamics: the circulation of a fluid is the line integral of the fluid's flow velocity field around a closed loop, and the vorticity of the fluid is the curl of the velocity field.

Charge conservation

The invariance of charge can be derived as a corollary of Maxwell's equations. The left hand side of the modified Ampere's Law has zero divergence by the div–curl identity. Combining the right hand side, Gauss's law, and interchange of derivatives gives:

i.e.

.

By the Gauss Divergence Theorem, this means the rate of change of charge in a fixed volume equals the net current flowing through the boundary:

$$\oiint$$

In particular, in an isolated system the total charge is conserved.

Vacuum equations, electromagnetic waves and speed of light

In a region with no charges ($\rho = 0$) and no currents (**J** = **0**), such as in a vacuum, Maxwell's equations reduce to:

Taking the curl (∇×) of the curl equations, and using the curl of the curl identity we obtain

The quantity has the dimension of (time/length)^2. Defining , the equations above have the form of the standard wave equations

Already during Maxwell's lifetime, it was found that the known values for and give , then already known to be the speed of light in free space. This let him to propose that light and radio waves were propagating electromagnetic waves, since amply confirmed. In the old SI system of units, the values of and are defined constants, (which means that by definition) that define the ampere and the metre. In the new SI system, only *c* keeps its defined value, and the electron charge gets a defined value.

In materials with relative permittivity, ε_r, and relative permeability, μ_r, the phase velocity of light becomes

which is usually[note 3] less than *c*.

In addition, **E** and **B** are perpendicular to each other and to the direction of wave propagation, and are in phase with each other. A sinusoidal plane wave is one special solution of these equations. Maxwell's equations explain how these waves can physically propagate through space. The changing magnetic field creates a changing electric field through Faraday's law. In turn, that electric field creates a changing magnetic field through Maxwell's addition to Ampère's law. This perpetual cycle allows these waves, now known as electromagnetic radiation, to move through space at velocity *c*.

Macroscopic formulation

The above equations are the "microscopic" version of Maxwell's equations, expressing the electric and the magnetic fields in terms of the (possibly atomic-level) charges and currents present. This is sometimes called the "general" form, but the macroscopic version below is equally general, the difference being one of bookkeeping.

The microscopic version is sometimes called "Maxwell's equations in a vacuum": this refers to the fact that the material medium is not built into the structure of the equations, but appears only in the charge and current terms. The microscopic version was introduced by Lorentz, who tried to use it to derive the macroscopic properties of bulk matter from its microscopic constituents.[10]:5

"Maxwell's macroscopic equations", also known as **Maxwell's equations in matter**, are more similar to those that Maxwell introduced himself.

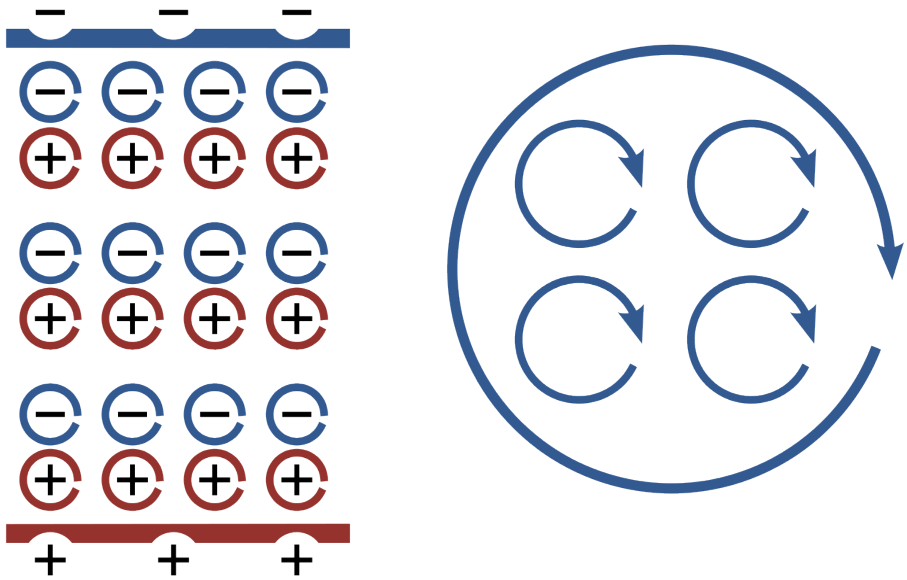
Name	Integral equations (SI convention)	Differential equations (SI convention)	Differential equations (Gaussian convention)
Gauss's law	$\oiint$		
Gauss's law for magnetism	$\oiint$		
Maxwell–Faraday equation (Faraday's law of induction)			
Ampère's circuital law (with Maxwell's addition)			

In the "macroscopic" equations, the influence of bound charge Q_b and bound current I_b is incorporated into the displacement field **D** and the magnetizing field **H**, while the equations depend only on the free charges Q_f and free currents I_f. This reflects a splitting of the total electric charge Q and current I (and their densities ρ and **J**) into free and bound parts:

The cost of this splitting is that the additional fields **D** and **H** need to be determined through phenomenological constituent equations relating these fields to the electric field **E** and the magnetic field **B**, together with the bound charge and current.

See below for a detailed description of the differences between the microscopic equations, dealing with *total* charge and current including material contributions, useful in air/vacuum;[note 4] and the macroscopic equations, dealing with *free* charge and current, practical to use within materials.

Bound charge and current



Left: A schematic view of how an assembly of microscopic dipoles produces opposite surface charges as shown at top and bottom. Right: How an assembly of microscopic current loops add together to produce a macroscopically circulating current loop. Inside the boundaries, the individual contributions tend to cancel, but at the boundaries no cancelation occurs.

When an electric field is applied to a dielectric material its molecules respond by forming microscopic electric dipoles – their atomic nuclei move a tiny distance in the direction of the field, while their electrons move a tiny distance in the opposite direction. This produces a *macroscopic bound charge* in the material even though all of the charges involved are bound to individual molecules. For example, if every molecule responds the same, similar to that shown in the figure, these tiny movements of charge combine to produce a layer of positive bound charge on one side of the material and a layer of negative charge on the other side. The bound charge is most conveniently described in terms of the polarization **P** of the material, its dipole moment per unit volume. If **P** is uniform, a macroscopic separation of charge is produced only at the surfaces where **P** enters and leaves the material. For non-uniform **P**, a charge is also produced in the bulk.[11]

Somewhat similarly, in all materials the constituent atoms exhibit magnetic moments that are intrinsically linked to the angular momentum of the components of the atoms, most notably their electrons. The connection to angular momentum suggests the picture of an assembly of microscopic current loops. Outside the material, an assembly of such microscopic current loops is not different from a macroscopic current circulating around the material's surface, despite the fact that no individual charge is traveling a large distance. These *bound currents* can be described using the magnetization **M**.[12]

The very complicated and granular bound charges and bound currents, therefore, can be represented on the macroscopic scale in terms of **P** and **M**, which average these charges and currents on a sufficiently large scale so as not to see the granularity of individual atoms, but also sufficiently small that they vary with location in the material. As such, *Maxwell's macroscopic equations* ignore many details on a fine scale that can be unimportant to understanding matters on a gross scale by calculating fields that are averaged over some suitable volume.

Auxiliary fields, polarization and magnetization

The *definitions* (not constitutive relations) of the auxiliary fields are:

where **P** is the polarization field and **M** is the magnetization field, which are defined in terms of microscopic bound charges and bound currents respectively. The macroscopic bound charge density ρ_b and bound current density $\mathbf{J}_b$ in terms of polarization **P** and magnetization **M** are then defined as

If we define the total, bound, and free charge and current density by

and use the defining relations above to eliminate **D**, and **H**, the "macroscopic" Maxwell's equations reproduce the "microscopic" equations.

Constitutive relations

In order to apply 'Maxwell's macroscopic equations', it is necessary to specify the relations between displacement field **D** and the electric field **E**, as well as the magnetizing field **H** and the magnetic field **B**. Equivalently, we have to specify the dependence of the polarisation **P** (hence the bound charge) and the magnetisation **M** (hence the bound current) on the applied electric and magnetic field. The equations specifying this response are called constitutive relations. For real-world materials, the constitutive relations are rarely simple, except approximately, and usually determined by experiment. See the main article on constitutive relations for a fuller description.[13]:44–45

For materials without polarization and magnetisation, the constitutive relations are (by definition)[7]:2

where ε_0 is the permittivity of free space and μ_0 the permeability of free space. Since there is no bound charge, the total and the free charge and current are equal.

An alternative viewpoint on the microscopic equations is that they are the macroscopic equations *together* with the statement that vacuum behaves like a perfect linear "material" without additional polarisation and magnetisation. More generally, for linear materials the constitutive relations are[13]:44–45

where ε is the permittivity and μ the permeability of the material. For the displacement field **D** the linear approximation is usually excellent because for all but the most extreme electric fields or temperatures obtainable in the laboratory (high power pulsed lasers) the interatomic electric fields of materials of the order of 10^{11} V/m are much higher than the external field. For the magnetizing field , however, the linear approximation can break down in common materials like iron leading to phenomena like hysteresis. Even the linear case can have various complications, however.

- For homogeneous materials, ε and μ are constant throughout the material, while for inhomogeneous materials they depend on location within the material (and perhaps time).[14]:463
- For isotropic materials, ε and μ are scalars, while for anisotropic materials (e.g. due to crystal structure) they are tensors.[13]:421[14]:463
- Materials are generally dispersive, so ε and μ depend on the frequency of any incident EM waves.[13]:625[14]:397

Even more generally, in the case of non-linear materials (see for example nonlinear optics), **D** and **P** are not necessarily proportional to **E**, similarly **H** or **M** is not necessarily proportional to **B**. In general **D** and **H** depend on both **E** and **B**, on location and time, and possibly other physical quantities.

In applications one also has to describe how the free currents and charge density behave in terms of **E** and **B** possibly coupled to other physical quantities like pressure, and the mass, number density, and velocity of charge-carrying particles. E.g., the original equations given by Maxwell (see History of Maxwell's equations) included Ohms law in the form

Alternative formulations

Following is a summary of some of the numerous other mathematical formalisms to write the microscopic Maxwell's equations, with the columns separating the two homogeneous Maxwell equations from the two inhomogeneous ones involving charge and current. Each formulation has versions directly in terms of the electric and magnetic fields, and indirectly in terms of the electrical potential φ and the vector potential **A**. Potentials were introduced as a convenient way to solve the homogeneous equations, but it was thought that all observable physics was contained in the electric and magnetic fields (or relativistically, the Faraday tensor). The potentials play a central role in quantum mechanics, however, and act quantum mechanically with observable consequences even when the electric and magnetic fields vanish (Aharonov–Bohm effect).

Each table describes one formalism. See the main article for details of each formulation. SI units are used throughout.

Vector calculus

Formulation	Homogeneous equations	Inhomogeneous equations
Fields 3D Euclidean space + time		
Potentials (any gauge) 3D Euclidean space + time		
Potentials (Lorenz gauge) 3D Euclidean space + time		

Tensor calculus

Formulation	Homogeneous equations	Inhomogeneous equations
Fields space + time **spatial metric independent of time**		
Potentials space (with topological restrictions) + time **spatial metric independent of time**		
Potentials (Lorenz gauge) space (with topological restrictions) + time **spatial metric independent of time**		

Differential forms

Formulation	Homogeneous equations	Inhomogeneous equations
Fields Any space + time		
Potentials (any gauge) Any space (with topological restrictions) + time		
Potential (Lorenz Gauge) Any space (with topological restrictions) + time **spatial metric independent of time**		

Relativistic formulations

The Maxwell equations can also be formulated on a spacetime-like Minkowski space where space and time are treated on equal footing. The direct spacetime formulations make manifest that the Maxwell equations are relativistically invariant. Because of this symmetry electric and magnetic field are treated on equal footing and are recognised as components of the Faraday tensor. This reduces the four Maxwell equations to two, which simplifies the equations, although we can no longer use the familiar vector formulation. In fact the Maxwell equations in the space + time formulation are not Galileo invariant and have Lorentz invariance as a hidden symmetry. This was a major source of inspiration for the development of relativity theory. To repeat: the space + time formulation is not a non-relativistic approximation and it describes the same physics by simply renaming variables. For this reason the relativistic invariant equations are usually called the Maxwell equations as well.

Each table describes one formalism.

Tensor calculus

Formulation	Homogeneous equations	Inhomogeneous equations
Fields Minkowski space		
Potentials (any gauge) Minkowski space		
Potentials (Lorenz gauge) Minkowski space		
Fields Any spacetime		
Potentials (any gauge) Any spacetime (with topological restrictions)		
Potentials (Lorenz gauge) Any spacetime (with topological restrictions)		

Differential forms

Formulation	Homogeneous equations	Inhomogeneous equations
Fields Any spacetime		
Potentials (any gauge) Any spacetime (with topological restrictions)		
Potentials (Lorenz gauge) Any spacetime (with topological restrictions)		

- In the tensor calculus formulation, the electromagnetic tensor $F_{\alpha\beta}$ is an antisymmetric covariant rank 2 tensor; the four-potential, A_α, is a covariant vector; the current, J^α, is a vector; the square brackets, [ ], denote antisymmetrization of indices; ∂_α is the derivative with respect to the coordinate, x^α. In Minkowski space coordinates are chosen with respect to an inertial frame; $(x^\alpha) = (ct,x,y,z)$, so that the metric tensor used to raise and lower indices is $\eta_{\alpha\beta} = \mathrm{diag}(1,-1,-1,-1)$. The d'Alembert operator on Minkowski space is $\Box = \partial_\alpha \partial^\alpha$ as in the vector formulation. In general spacetimes, the coordinate system x^α is arbitrary, the covariant derivative ∇_α, the Ricci tensor, $R_{\alpha\beta}$ and raising and lowering of indices are defined by the Lorentzian metric, $g_{\alpha\beta}$ and the d'Alembert operator is defined as $\Box = \nabla_\alpha \nabla^\alpha$. The topological restriction is that the second real cohomology group of the space vanishes (see the differential form formulation for an explanation). Note that this is violated for Minkowski space with a line removed, which can model a (flat) spacetime with a point-like monopole on the complement of the line.

- In the differential form formulation on arbitrary space times, $F = F_{\alpha\beta} \mathrm{d}x^\alpha \wedge \mathrm{d}x^\beta$ is the electromagnetic tensor considered as a 2-form, $A = A_\alpha \mathrm{d}x^\alpha$ is the potential 1-form, J is the current 3-form, d is the exterior derivative, and is the Hodge star on forms defined (up to its an orientation, i.e. its sign) by the Lorentzian metric of spacetime. Note that in the special case of 2-forms such as F, the Hodge star depends on the metric tensor only for its local scale. This means that, as formulated, the differential form field equations are conformally invariant, but the Lorenz gauge condition breaks conformal invariance. The operator is the d'Alembert–Laplace–Beltrami operator on 1-forms on an arbitrary Lorentzian spacetime. The topological condition is again that the second real cohomology group is trivial. By the isomorphism with the second de Rham cohomology this condition means that every closed 2-form is exact.

Other formalisms include the geometric algebra formulation and a matrix representation of Maxwell's equations. Historically, a quaternionic formulation[15][16] was used.

Solutions

Maxwell's equations are partial differential equations that relate the electric and magnetic fields to each other and to the electric charges and currents. Often, the charges and currents are themselves dependent on the electric and magnetic fields via the Lorentz force equation and the constitutive relations. These all form a set of coupled partial differential equations which are often very difficult to solve: the solutions encompass all the diverse phenomena of classical electromagnetism. Some general remarks follow.

As for any differential equation, boundary conditions[17][18][19] and initial conditions[20] are necessary for a unique solution. For example, even with no charges and no currents anywhere in spacetime, there are the obvious solutions for which **E** and **B** are zero or constant, but there are also non-trivial solutions corresponding to electromagnetic waves. In some cases, Maxwell's equations are solved over the whole of space, and boundary conditions are given as asymptotic limits at infinity.[21] In other cases, Maxwell's equations are solved in a finite region of space, with appropriate conditions on the boundary of that region, for example an artificial absorbing boundary representing the rest of the universe,[22][23] or periodic boundary conditions, or walls that isolate a small region from the outside world (as with a waveguide or cavity resonator).[24]

Jefimenko's equations (or the closely related Liénard–Wiechert potentials) are the explicit solution to Maxwell's equations for the electric and magnetic fields created by any given distribution of charges and currents. It assumes specific initial conditions to obtain the so-called "retarded solution", where the only fields present are the ones created by the charges. However, Jefimenko's equations are unhelpful in situations when the charges and currents are themselves affected by the fields they create.

Numerical methods for differential equations can be used to compute approximate solutions of Maxwell's equations when exact solutions are impossible. These include the finite element method and finite-difference time-domain method.[17][19][25][26][27] For more details, see Computational electromagnetics.

Overdetermination of Maxwell's equations

Maxwell's equations *seem* overdetermined, in that they involve six unknowns (the three components of **E** and **B**) but eight equations (one for each of the two Gauss's laws, three vector components each for Faraday's and Ampere's laws). (The currents and charges are not unknowns, being freely specifiable subject to charge conservation.) This is related to a certain limited kind of redundancy in Maxwell's equations: It can be proven that any system satisfying Faraday's law and Ampere's law *automatically* also satisfies the two Gauss's laws, as long as the system's initial condition does.[28][29] This explanation was first introduced by Julius Adams Stratton in 1941.[30] Although it is possible to simply ignore the two Gauss's laws in a numerical algorithm (apart from the initial conditions), the imperfect precision of the calculations can lead to ever-increasing violations of those laws. By introducing dummy variables characterizing these violations, the four equations become not overdetermined after all. The resulting formulation can lead to more accurate algorithms that take all four laws into account.[31]

Both identities , which reduce eight equations to six independent ones, are the true reason of overdetermination.[32]:161–162[33]

Maxwell equations as the classical limit of QED

Maxwell's equations and the Lorentz force law (along with the rest of classical electromagnetism) are extraordinarily successful at explaining and predicting a variety of phenomena; however they are not exact, but a classical limit of quantum electrodynamics (QED).

Some observed electromagnetic phenomena are incompatible with Maxwell's equations. These include photon–photon scattering and many other phenomena related to photons or virtual photons, "nonclassical light" and quantum entanglement of electromagnetic fields (see quantum optics). E.g. quantum cryptography cannot be described by Maxwell theory, not even approximately. The approximate nature of Maxwell's equations becomes more and more apparent when going into the extremely strong field regime (see Euler–Heisenberg Lagrangian) or to extremely small distances.

Finally, Maxwell's equations cannot explain any phenomenon involving individual photons interacting with quantum matter, such as the photoelectric effect, Planck's law, the Duane–Hunt law, and single-photon light detectors. However, many such phenomena may be approximated using a halfway theory of quantum matter coupled to a classical electromagnetic field, either as external field or with the expected value of the charge current and density on the right hand side of Maxwell's equations.

Variations

Popular variations on the Maxwell equations as a classical theory of electromagnetic fields are relatively scarce because the standard equations have stood the test of time remarkably well.

Magnetic monopoles

Maxwell's equations posit that there is electric charge, but no magnetic charge (also called magnetic monopoles), in the universe. Indeed, magnetic charge has never been observed (despite extensive searches)[note 5] and may not exist. If they did exist, both Gauss's law for magnetism and Faraday's law would need to be modified, and the resulting four equations would be fully symmetric under the interchange of electric and magnetic fields.[7]:273–275

See also

- Algebra of physical space
- Fresnel equations
- Gravitoelectromagnetism
- Interface conditions for electromagnetic fields
- Moving magnet and conductor problem
- Riemann–Silberstein vector
- Spacetime algebra
- Wheeler–Feynman absorber theory

Notes

1. **^** Maxwell's equations in any form are compatible with relativity. These spacetime formulations, though, make that compatibility more readily apparent by revealing that the electric and magnetic fields blend into a single tensor, and that their distinction depends on the movement of the observer and the corresponding observer dependent notion of time.
2. **^** The quantity we would now call $1/\sqrt{\varepsilon_0\mu_0}$, with units of velocity, was directly measured before Maxwell's equations, in an 1855 experiment by Wilhelm Eduard Weber and Rudolf Kohlrausch. They charged a leyden jar (a kind of capacitor), and measured the electrostatic force associated with the potential; then, they discharged it while measuring the magnetic force from the current in the discharge wire. Their result was 3.107×10^8 m/s, remarkably close to the speed of light. See Joseph F. Keithley, *The story of electrical and magnetic measurements: from 500 B.C. to the 1940s*, p. 115
3. **^** There are cases (anomalous dispersion) where the phase velocity can exceed c, but the "signal velocity" will still be $< c$
4. **^** In some books—e.g., in U. Krey and A. Owen's Basic Theoretical Physics (Springer 2007)—the term *effective charge* is used in-

stead of *total charge*, while *free charge* is simply called *charge*.

5. **^** See magnetic monopole for a discussion of monopole searches. Recently, scientists have discovered that some types of condensed matter, including spin ice and topological insulators, which display *emergent* behavior resembling magnetic monopoles. (See sciencemag.org and nature.com.) Although these were described in the popular press as the long-awaited discovery of magnetic monopoles, they are only superficially related. A "true" magnetic monopole is something where $\nabla \cdot \mathbf{B} \neq 0$, whereas in these condensed-matter systems, $\nabla \cdot \mathbf{B} = 0$ while only $\nabla \cdot \mathbf{H} \neq 0$.

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Further reading can be found in list of textbooks in electromagnetism

Historical publications

- On Faraday's Lines of Force – 1855/56 Maxwell's first paper (Part 1 & 2) – Compiled by Blaze Labs Research (PDF)
- On Physical Lines of Force – 1861 Maxwell's 1861 paper describing magnetic lines of Force – Predecessor to 1873 Treatise
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- J. Clerk Maxwell (1873) A Treatise on Electricity and Magnetism
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External links

- *Hazewinkel, Michiel, ed. (2001) [1994], "Maxwell equations", Encyclopedia of Mathematics, Springer Science+Business Media B.V. / Kluwer Academic Publishers, ISBN 978-1-55608-010-4*
- maxwells-equations.com — An intuitive tutorial of Maxwell's equations.
- Mathematical aspects of Maxwell's equation are discussed on the Dispersive PDE Wiki.

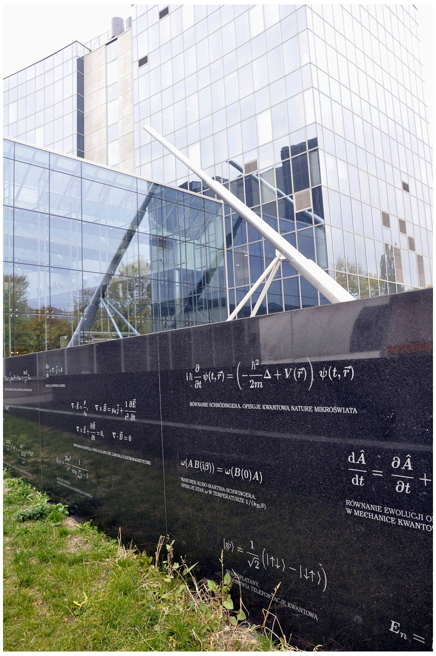
Modern treatments

- Electromagnetism (ch. 11), B. Crowell, Fullerton College
- Lecture series: Relativity and electromagnetism, R. Fitzpatrick, University of Texas at Austin
- *Electromagnetic waves from Maxwell's equations* on Project PHYSNET.
- MIT Video Lecture Series (36 × 50 minute lectures) (in .mp4 format) – Electricity and Magnetism Taught by Professor Walter Lewin.

Other

- Feynman's derivation of Maxwell equations and extra dimensions
- *Nature Milestones: Photons – Milestone 2 (1861) Maxwell's equations*

Schrödinger equation



Schrödinger equation as part of a monument in front of Warsaw University's Centre of New Technologies

In quantum mechanics, the **Schrödinger equation** is a mathematical equation that describes the changes over time of a physical system in which quantum effects, such as wave–particle duality, are significant. These systems are referred to as quantum (mechanical) systems. The equation is considered a central result in the study of quantum systems, and its derivation was a significant landmark in the development of the theory of quantum mechanics. It was named after Erwin Schrödinger, who derived the equation in 1925, and published it in 1926, forming the basis for his work that resulted in his being awarded the Nobel Prize in Physics in 1933.[1][2]

In classical mechanics, Newton's second law ($\mathbf{F} = m\mathbf{a}$) is used to make a mathematical prediction as to what path a given physical system will take over time following a set of known initial conditions. Solving this equation gives the position, and the momentum of the physical system as a function of the external force F on the system. Those two parameters are sufficient to describe its state at each time instant. In quantum mechanics, the analogue of Newton's law is Schrödinger's equation for a quantum system (usually atoms, molecules, and subatomic particles whether free, bound, or localized). The equation is mathematically described as a linear partial differential equation, which describes the time-evolution of the system's wave function (also called a "state function").[3]:1–2

The concept of a wavefunction is a fundamental postulate of quantum mechanics, that defines the state of the system at each spatial position, and time. Using these postulates, Schrödinger's equation can be derived from the fact that the time-evolution operator must be unitary, and must therefore be generated by the exponential of a self-adjoint operator, which is the quantum Hamiltonian. This derivation is explained below.

In the Copenhagen interpretation of quantum mechanics, the wave function is the most complete description that can be given of a physical system. Solutions to Schrödinger's equation describe not only molecular, atomic, and subatomic systems, but also macroscopic systems, possibly even the whole universe.[4]:292ff Schrödinger's equation is central to all applications of quantum mechanics including quantum field theory which combines special relativity with quantum mechanics. Theories of quantum gravity, such as string theory, also do not modify Schrödinger's equation.

The Schrödinger equation is not the only way to study quantum mechanical systems and make predictions, as there are other quantum mechanical formulations such as matrix mechanics, introduced by Werner Heisenberg, and path integral formulation, developed chiefly by Richard Feynman. Paul Dirac incorporated matrix mechanics and the Schrödinger equation into a single formulation.

Equation

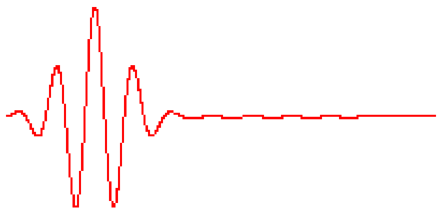
Time-dependent equation

The form of the Schrödinger equation depends on the physical situation (see below for special cases). The most general form is the time-dependent Schrödinger equation (TDSE), which gives a description of a system evolving with time:[5]:143

Time-dependent Schrödinger equation *(general)*

$$i\hbar\frac{\partial}{\partial t}|\Psi(\mathbf{r},t)\rangle = \hat{H}|\Psi(\mathbf{r},t)\rangle$$

where i is the imaginary unit, $\hbar$ is the reduced Planck constant which is : $\hbar = \frac{h}{2\pi}$, the symbol $\frac{\partial}{\partial t}$ indicates a partial derivative with respect to time t, Ψ (the Greek letter psi) is the wave function of the quantum system, **r** and t are the position vector and time respectively, and $\hat{H}$ is the Hamiltonian operator (which characterises the total energy of the system under consideration).



A wave function that satisfies the nonrelativistic Schrödinger equation with V = 0. In other words, this corresponds to a particle traveling freely through empty space. The real part of the wave function is plotted here.

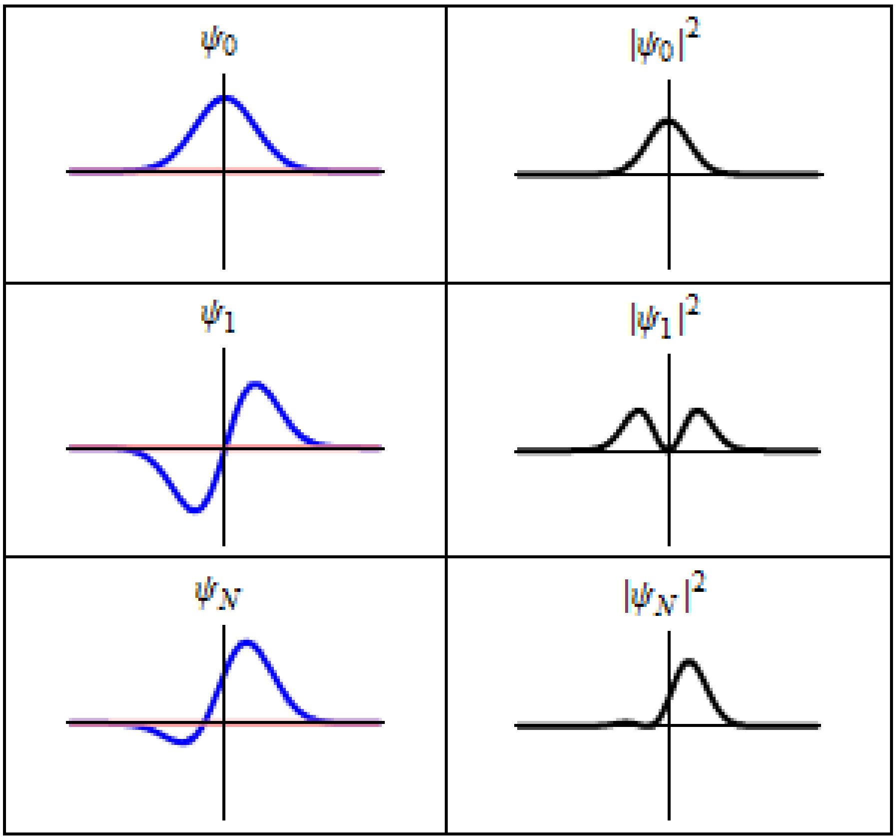
The most famous example is the nonrelativistic Schrödinger equation for the relative coordinate **r** of a single particle moving in the electric field of a second, usually much heavier, particle (but not a magnetic field; see the Pauli equation):[6]

Time-dependent Schrödinger equation in position basis

(single nonrelativistic particle)

$$i\hbar\frac{\partial}{\partial t}\Psi(\mathbf{r},t) = \left[\frac{-\hbar^2}{2\mu}\nabla^2 + V(\mathbf{r},t)\right]\Psi(\mathbf{r},t)$$

where μ is the particle's "reduced mass", V is its potential energy, ∇^2 is the Laplacian (a differential operator), and Ψ is the wave function (more precisely, in this context, it is called the "position-space wave function"). In plain language, it means "total energy equals kinetic energy plus potential energy", but the terms take unfamiliar forms for reasons explained below.



*Each of these three rows is a wave function which satisfies the time-dependent Schrödinger equation for a harmonic oscillator. Left: The real part (blue) and imaginary part (red) of the wave function. Right: The probability distribution of finding the particle with this wave function at a given position. The top two rows are examples of **stationary states**, which correspond to standing waves. The bottom row is an example of a state which is not a stationary state. The right column illustrates why stationary states are called "stationary".*

Given the particular differential operators involved, this is a linear partial differential equation. It is also a diffusion equation, but unlike the heat equation, this one is also a wave equation given the imaginary unit present in the transient term.

The term *"Schrödinger equation"* can refer to both the general equation, or the specific nonrelativistic version. The general equation is indeed quite general, used throughout quantum mechanics, for everything from the Dirac equation to quantum field theory, by plugging in diverse expressions for the Hamiltonian. The specific nonrelativistic version is a strictly classical approximation to reality and yields accurate results in many situations, but only to a certain extent (see relativistic quantum mechanics and relativistic quantum field theory).

To apply the Schrödinger equation, the Hamiltonian operator is set up for the system, accounting for the kinetic and potential energy of the particles constituting the system, then inserted into the Schrödinger equation. The resulting partial differential equation is solved for the wave function, which contains information about the system.

Time-independent equation

The time-dependent Schrödinger equation described above predicts that wave functions can form standing waves, called stationary states (also called "orbitals", as in atomic orbitals or molecular orbitals). These states are particularly important as their individual study later simplifies the task of solving the time-dependent Schrödinger equation for *any* state. Stationary states can also be described by a simpler form of the Schrödinger equation, the *time-independent Schrödinger equation* (TISE).

Time-independent Schrödinger equation (*general*)

$$\hat{\mathrm{H}}\,|\Psi\rangle = E|\Psi\rangle$$

where *E* is a constant equal to the total energy of the system. This is only used when the Hamiltonian itself is not dependent on time explicitly. However, even in this case the total wave function still has a time dependency.

In words, the equation states:

> *When the Hamiltonian operator acts on a certain wave function Ψ, and the result is proportional to the same wave function Ψ, then Ψ is a stationary state, and the proportionality constant, E, is the energy of the state Ψ.*

In linear algebra terminology, this equation is an eigenvalue equation and in this sense the wave function is an eigenfunction of the Hamiltonian operator.

As before, the most common manifestation is the nonrelativistic Schrödinger equation for a single particle moving in an electric field (but not a magnetic field):

Time-independent Schrödinger equation (*single nonrelativistic particle*)

$$\left[\frac{-\hbar^2}{2\mu}\nabla^2 + V(\mathbf{r})\right]\Psi(\mathbf{r}) = E\Psi(\mathbf{r})$$

with definitions as above.

The time-independent Schrödinger equation is discussed further below.

Derivation

In the modern understanding of quantum mechanics, Schrödinger's equation may be derived as follows.[7] If the wave-function at time t is given by $\Psi(t)$, then by the linearity of quantum mechanics the wave-function at time t' must be given by $\Psi(t') = U(t', t)\Psi(t)$, where $U(t', t)$ is a linear operator. Since time-evolution must preserve the norm of the wave-function, it follows that $U(t', t)$ must be a member of the unitary group of operators acting on wave-functions. We also know that when $t' = t$, we must have $U(t, t) = 1$. Therefore, expanding the operator $U(t', t)$ for t' close to t, we can write $U(t', t) = 1 - iH(t' - t)$ where H is a Hermitian operator. This follows from the fact that the Lie algebra corresponding to the unitary group comprises Hermitian operators. Taking the limit as the time-difference $t' - t$ becomes very small, we obtain Schrödinger's equation.

So far, H is only an abstract Hermitian operator. However using the correspondence principle it is possible to show that, in the classical limit, the expectation value of H is indeed the classical energy. The correspondence principle does not completely fix the form of the quantum Hamiltonian due to the uncertainty principle and therefore the precise form of the quantum Hamiltonian must be fixed empirically.

Implications

The Schrödinger equation and its solutions introduced a breakthrough in thinking about physics. Schrödinger's equation was the first of its type, and solutions led to consequences that were very unusual and unexpected for the time.

Total, kinetic, and potential energy

The *overall* form of the equation is *not* unusual or unexpected, as it uses the principle of the conservation of energy. The terms of the nonrelativistic Schrödinger equation can be interpreted as total energy of the system, equal to the system kinetic energy plus the system potential energy. In this respect, it is just the same as in classical physics.

Quantization

The Schrödinger equation predicts that if certain properties of a system are measured, the result may be *quantized*, meaning that only specific discrete values can occur. One example is *energy quantization*: the energy of an electron in an atom is always one of the quantized energy levels, a fact discovered via atomic spectroscopy. (Energy quantization is discussed below.) Another example is quantization of angular momentum. This was an *assumption* in the earlier Bohr model of the atom, but it is a *prediction* of the Schrödinger equation.

Another result of the Schrödinger equation is that not every measurement gives a quantized result in quantum mechanics. For example, position, momentum, time, and (in some situations) energy can have any value across a continuous range.[8]:165–167

Measurement and uncertainty

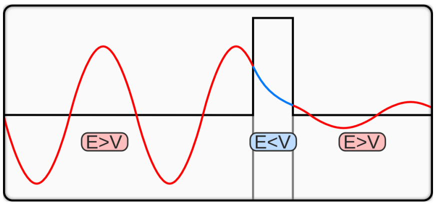
In classical mechanics, a particle has, at every moment, an exact position and an exact momentum. These values change deterministically as the particle moves according to Newton's laws. Under the Copenhagen interpretation of quantum mechanics, particles do not have exactly determined properties, and when they are measured, the result is randomly drawn from a probability distribution. The Schrödinger equation predicts what the probability distributions are, but fundamentally cannot predict the exact result of each measurement.

The Heisenberg uncertainty principle is the statement of the inherent measurement uncertainty in quantum mechanics. It states that the more precisely a particle's position is known, the less precisely its momentum is known, and vice versa.

The Schrödinger equation describes the (deterministic) evolution of the wave function of a particle. However, even if the wave function is known exactly, the result of a specific measurement on the wave function is uncertain.

Quantum tunneling

In classical physics, when a ball is rolled slowly up a large hill, it will come to a stop and roll back, because it doesn't have enough energy to get over the top of the hill to the other side. However, the Schrödinger equation predicts that there is a small probability that the ball will get to the other side of the hill, even if it has too little energy to reach the top. This is called quantum tunneling. It is related to the distribution of energy: although the ball's assumed position seems to be on one side of the hill, there is a chance of finding it on the other side.

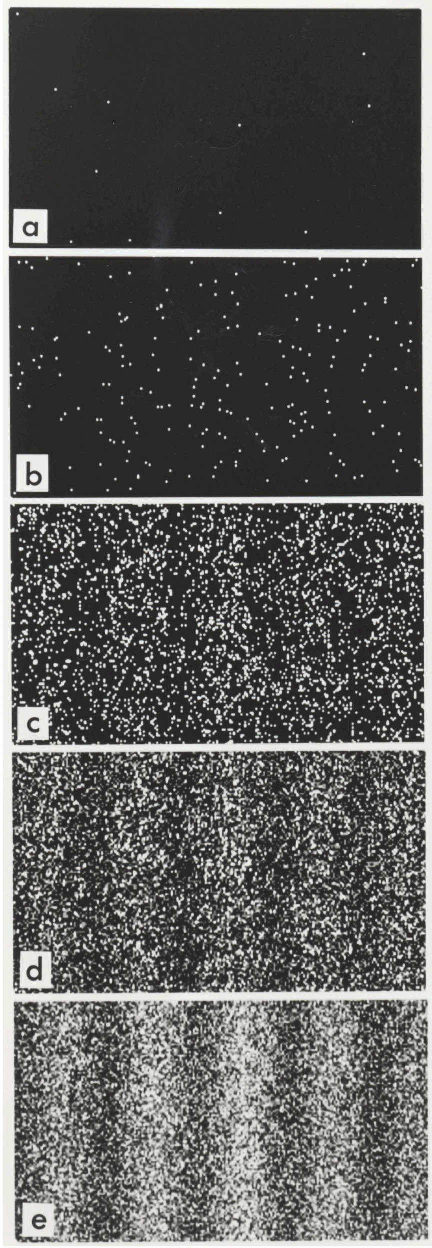


Quantum tunneling through a barrier. A particle coming from the left does not have enough energy to climb the barrier. However, it can sometimes "tunnel" to the other side.

Particles as waves

The nonrelativistic Schrödinger equation is a type of partial differential equation called a wave equation. Therefore, it is often said particles can exhibit behavior usually attributed to waves. In some modern interpretations this description is reversed – the quantum state, i.e. wave, is the only genuine physical reality, and under the appropriate conditions it can show features of particle-like behavior. However, Ballentine[9]:Chapter 4, p.99 shows that such an interpretation has problems. Ballentine points out that whilst it is arguable to associate a physical wave with a single particle, there is still only *one* Schrödinger wave equation for many particles. He points out:

> *"If a physical wave field were associated with a particle, or if a particle were identified with a wave packet, then corresponding to N interacting particles there should be N interacting waves in ordinary three-dimensional space. But according to (4.6) that is not the case; instead there is one "wave" function in an abstract 3N-dimensional configuration space. The misinterpretation of psi as a physical wave in ordinary space is possible only because the most common applications of quantum mechanics are to one-particle states, for which configuration space and ordinary space are isomorphic."*



A double slit experiment showing the accumulation of electrons on a screen as time passes.

Two-slit diffraction is a famous example of the strange behaviors that waves regularly display, that are not intuitively associated with particles. The overlapping waves from the two slits cancel each other out in some locations, and reinforce each other in other locations, causing a complex pattern to emerge. Intuitively, one would not expect this pattern from firing a single particle at the slits, because the particle should pass through one slit or the other, not a complex overlap of both.

However, since the Schrödinger equation is a wave equation, a single particle fired through a double-slit *does* show this same pattern (figure on right). Note: The experiment must be repeated many times for the complex pattern to emerge. Although this is counterintuitive, the prediction is correct; in particular, electron diffraction and neutron diffraction are well understood and widely used in science and engineering.

Related to diffraction, particles also display superposition and interference.

The superposition property allows the particle to be in a quantum superposition of two or more quantum states at the same time. However, it is noted that a "quantum state" in quantum mechanics means the *probability* that a system will be, for example at a position x, not that the system will actually be at position x. It does not imply that the particle itself may be in two classical states at once. Indeed, quantum mechanics is generally unable to assign values for properties prior to measurement at all.

Many-Worlds interpretation

In Dublin in 1952 Erwin Schrödinger gave a lecture in which at one point he jocularly warned his audience that what he was about to say might "seem lunatic". It was that, when his equations seem to be describing several different histories, they are "not alternatives but all really happen simultaneously". This is the earliest known reference to the Many-worlds interpretation of quantum mechanics.[10]

Interpretation of the wave function

The Schrödinger equation provides a way to calculate the wave function of a system and how it changes dynamically in time. However, the Schrödinger equation does not directly say *what*, exactly, the wave function is. Interpretations of quantum mechanics address questions such as what the relation is between the wave function, the underlying reality, and the results of experimental measurements.

An important aspect is the relationship between the Schrödinger equation and wavefunction collapse. In the oldest Copenhagen interpretation, particles follow the Schrödinger equation *except* during wavefunction collapse, during which they behave entirely differently. The advent of quantum decoherence theory allowed alternative approaches (such as the Everett many-worlds interpretation and consistent histories), wherein the Schrödinger equation is *always* satisfied, and wavefunction collapse should be explained as a consequence of the Schrödinger equation.

Historical background and development

Erwin Schrödinger

Following Max Planck's quantization of light (see black body radiation), Albert Einstein interpreted Planck's quanta to be photons, particles of light, and proposed that the energy of a photon is proportional to its frequency, one of the first signs of wave–particle duality. Since energy and momentum are related in the same way as frequency and wavenumber in special relativity, it followed that the momentum p of a photon is inversely proportional to its wavelength λ, or proportional to its wavenumber k:

$$p = \frac{h}{\lambda} = \hbar k,$$

where h is Planck's constant and $\hbar$ is the reduced Planck constant, $h/2\pi$. Louis de Broglie hypothesized that this is true for all particles, even particles which have mass such as electrons. He showed that, assuming that the matter waves propagate along with their particle counterparts, electrons form standing waves, meaning that only certain discrete rotational frequencies about the nucleus of an atom are allowed.[11] These quantized orbits correspond to discrete energy levels, and de Broglie reproduced the Bohr model formula for the energy levels. The Bohr model was based on the assumed quantization of angular momentum L according to:

$$L = n\frac{h}{2\pi} = n\hbar.$$

According to de Broglie the electron is described by a wave and a whole number of wavelengths must fit along the circumference of the electron's orbit:

$$n\lambda = 2\pi r.$$

This approach essentially confined the electron wave in one dimension, along a circular orbit of radius r.

In 1921, prior to de Broglie, Arthur C. Lunn at the University of Chicago had used the same argument based on the completion of the relativistic energy–momentum 4-vector to derive what we now call the de Broglie relation.[12] Unlike de Broglie, Lunn went on to formulate the differential equation now known as the Schrödinger equation, and solve for its energy eigenvalues for the hydrogen atom. Unfortunately the paper was rejected by the Physical Review, as recounted by Kamen.[13]

Following up on de Broglie's ideas, physicist Peter Debye made an offhand comment that if particles behaved as waves, they should satisfy some sort of wave equation. Inspired by Debye's remark, Schrödinger decided to find a proper 3-dimensional wave equation for the electron. He was guided by William R. Hamilton's analogy between mechanics and optics, encoded in the observation that the zero-wavelength limit of optics resembles a mechanical system—the trajectories of light rays become sharp tracks that obey Fermat's principle, an analog of the principle of least action.[14] A modern version of his reasoning is reproduced below. The equation he found is:[15]

$$i\hbar\frac{\partial}{\partial t}\Psi(\mathbf{r},\,t)=-\frac{\hbar^2}{2m}\nabla^2\Psi(\mathbf{r},\,t)+V(\mathbf{r})\Psi(\mathbf{r},\,t).$$

However, by that time, Arnold Sommerfeld had refined the Bohr model with relativistic corrections.[16][17] Schrödinger used the relativistic energy momentum relation to find what is now known as the Klein–Gordon equation in a Coulomb potential (in natural units):

$$\left(E+\frac{e^2}{r}\right)^2\psi(x)=-\nabla^2\psi(x)+m^2\psi(x).$$

He found the standing waves of this relativistic equation, but the relativistic corrections disagreed with Sommerfeld's formula. Discouraged, he put away his calculations and secluded himself in an isolated mountain cabin in December 1925.[18]

While at the cabin, Schrödinger decided that his earlier nonrelativistic calculations were novel enough to publish, and decided to leave off the problem of relativistic corrections for the future. Despite the difficulties in solving the differential equation for hydrogen (he had sought help from his friend the mathematician Hermann Weyl[19]:3) Schrödinger showed that his nonrelativistic version of the wave equation produced the correct spectral energies of hydrogen in a paper published in 1926.[19]:1[20] In the equation, Schrödinger computed the hydrogen spectral series by treating a hydrogen atom's electron as a wave $\Psi(x,\,t)$, moving in a potential well V, created by the proton. This computation accurately reproduced the energy levels of the Bohr model. In a paper, Schrödinger himself explained this equation as follows:

> The already ... mentioned psi-function.... is now the means for predicting probability of measurement results. In it is embodied the momentarily attained sum of theoretically based future expectation, somewhat as laid down in a catalog.
>
> — *Erwin Schrödinger*[21]

This 1926 paper was enthusiastically endorsed by Einstein, who saw the matter-waves as an intuitive depiction of nature, as opposed to Heisenberg's matrix mechanics, which he considered overly formal.[22]

The Schrödinger equation details the behavior of Ψ but says nothing of its *nature*. Schrödinger tried to interpret it as a charge density in his fourth paper, but he was unsuccessful.[23]:219 In 1926, just a few days after Schrödinger's fourth and final paper was published, Max Born successfully interpreted Ψ as the probability amplitude, whose absolute square is equal to probability density.[23]:220 Schrödinger, though, always opposed a statistical or probabilistic approach, with its associated discontinuities—much like Einstein, who believed that quantum mechanics was a statistical approximation to an underlying deterministic theory—and never reconciled with the Copenhagen interpretation.[24]

Louis de Broglie in his later years proposed a real valued wave function connected to the complex wave function by a proportionality constant and developed the De Broglie–Bohm theory.

The wave equation for particles

The Schrödinger equation is a diffusion equation, the *solutions* are functions which describe wave-like motions. Wave equations in physics can normally be derived from other physical laws – the wave equation for mechanical vibrations on strings and in matter can be derived from Newton's laws, where the wave function represents the displacement of matter, and electromagnetic waves from Maxwell's equations, where the wave functions are electric and magnetic fields. The basis for Schrödinger's equation, on the other hand, is the energy of the system and a separate postulate of quantum mechanics: the wave function is a description of the system.[25] The Schrödinger equation is therefore a new concept in itself; as Feynman put it:

> Where did we get that (equation) from? Nowhere. It is not possible to derive it from anything you know. It came out of the mind of Schrödinger.
>
> — *Richard Feynman*[26]

The foundation of the equation is structured to be a linear differential equation based on classical energy conservation, and consistent with the De Broglie relations. The solution is the wave function ψ, which contains all the information that can be known about the system. In the Copenhagen interpretation, the modulus of ψ is related to the probability the particles are in some spatial configuration at some instant of time. Solving the equation for ψ can be used to predict how the particles will behave under the influence of the specified potential and with each other.

The Schrödinger equation was developed principally from the De Broglie hypothesis, a wave equation that would describe particles,[27] and can be constructed as shown informally in the following sections.[28] For a more rigorous description of Schrödinger's equation, see also Resnick *et al*.[29]

Consistency with energy conservation

The total energy E of a particle is the sum of kinetic energy T and potential energy V, this sum is also the frequent expression for the Hamiltonian H in classical mechanics:

$$E = T + V = H$$

Explicitly, for a particle in one dimension with position x, mass m and momentum p, and potential energy V which generally varies with position and time t:

$$E = \frac{p^2}{2m} + V(x,t) = H.$$

For three dimensions, the position vector **r** and momentum vector **p** must be used:

$$E = \frac{\mathbf{p}\cdot\mathbf{p}}{2m} + V(\mathbf{r},t) = H$$

This formalism can be extended to any fixed number of particles: the total energy of the system is then the total kinetic energies of the particles, plus the total potential energy, again the Hamiltonian. However, there can be interactions between the particles (an *N*-body problem), so the potential energy *V* can change as the spatial configuration of particles changes, and possibly with time. The potential energy, in general, is *not* the sum of the separate potential energies for each particle, it is a function of all the spatial positions of the particles. Explicitly:

$$E = \sum_{n=1}^{N} \frac{\mathbf{p}_n\cdot\mathbf{p}_n}{2m_n} + V(\mathbf{r}_1, \mathbf{r}_2 \cdots \mathbf{r}_N, t) = H$$

Linearity

The simplest wavefunction is a plane wave of the form:

$$\Psi(\mathbf{r},t) = Ae^{i(\mathbf{k}\cdot\mathbf{r}-\omega t)}$$

where the A is the amplitude, **k** the wavevector, and ω the angular frequency, of the plane wave. In general, physical situations are not purely described by plane waves, so for generality the superposition principle is required; any wave can be made by superposition of sinusoidal plane waves. So if the equation is linear, a linear combination of plane waves is also an allowed solution. Hence a necessary and separate requirement is that the Schrödinger equation is a linear differential equation.

For discrete **k** the sum is a superposition of plane waves:

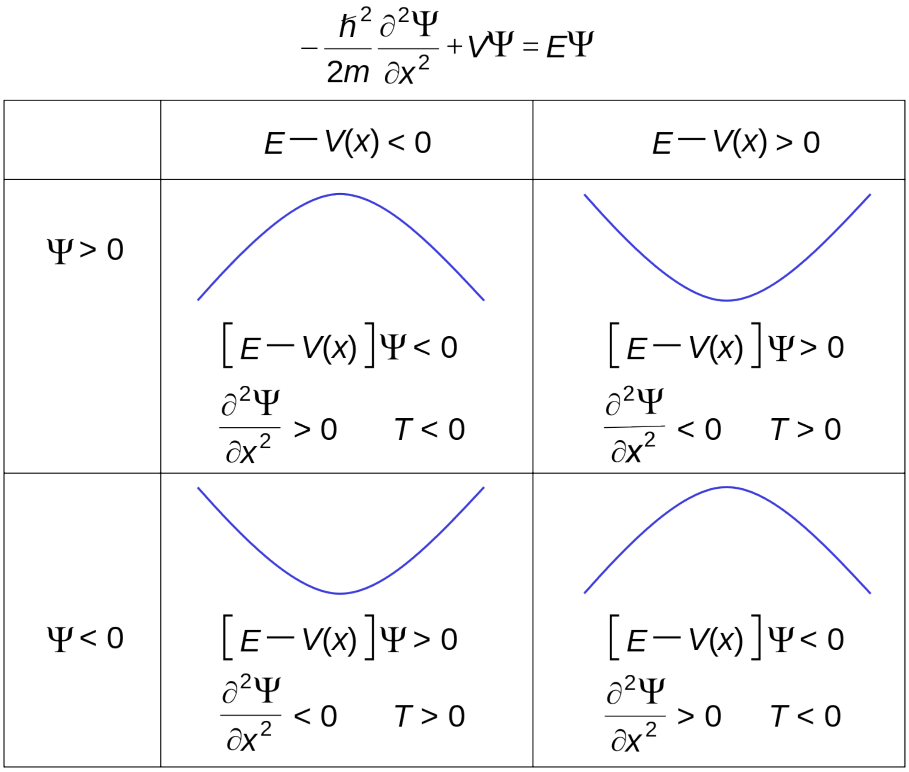
$$\Psi(\mathbf{r},t) = \sum_{n=1}^{\infty} A_n e^{i(\mathbf{k}_n\cdot\mathbf{r}-\omega_n t)}$$

for some real amplitude coefficients A_n, and for continuous **k** the sum becomes an integral, the Fourier transform of a momentum space wavefunction:[30]

$$\Psi(\mathbf{r},t) = \frac{1}{(\sqrt{2\pi})^3}\int \Phi(\mathbf{k}) e^{i(\mathbf{k}\cdot\mathbf{r}-\omega t)} d^3\mathbf{k}$$

where $d^3\mathbf{k} = dk_x dk_y dk_z$ is the differential volume element in **k**-space, and the integrals are taken over all **k**-space. The momentum wavefunction $\Phi(\mathbf{k})$ arises in the integrand since the position and momentum space wavefunctions are Fourier transforms of each other.

Consistency with the De Broglie relations



Diagrammatic summary of the quantities related to the wavefunction, as used in De broglie's hypothesis and development of the Schrödinger equation.[27]

Einstein's light quanta hypothesis (1905) states that the energy E of a photon is proportional to the frequency ν (or angular frequency, $\omega = 2\pi\nu$) of the corresponding quantum wavepacket of light:

$$E = h\nu = \hbar\omega$$

Likewise De Broglie's hypothesis (1924) states that any particle can be associated with a wave, and that the momentum p of the particle is inversely proportional to the wavelength λ of such a wave (or proportional to the wavenumber, $k = \frac{2\pi}{\lambda}$), in one dimension, by:

$$p = \frac{h}{\lambda} = \hbar k\,,$$

while in three dimensions, wavelength λ is related to the magnitude of the wavevector **k**:

$$\mathbf{p} = \hbar\mathbf{k}\,, \quad |\mathbf{k}| = \frac{2\pi}{\lambda}\,.$$

The Planck–Einstein and de Broglie relations illuminate the deep connections between energy with time, and space with momentum, and express wave–particle duality. In practice, natural units comprising $\hbar = 1$ are used, as the De Broglie *equations* reduce to *identities*: allowing momentum, wavenumber, energy and frequency to be used interchangeably, to prevent duplication of quantities, and reduce the number of dimensions of related quantities. For familiarity SI units are still used in this article.

Schrödinger's insight, late in 1925, was to express the phase of a plane wave as a complex phase factor using these relations:

$$\Psi = Ae^{i(\mathbf{k}\cdot\mathbf{r}-\omega t)} = Ae^{i(\mathbf{p}\cdot\mathbf{r}-Et)/\hbar}$$

and to realize that the first order partial derivatives were:

with respect to space:

with respect to time:

Another postulate of quantum mechanics is that all observables are represented by linear Hermitian operators which act on the wavefunction, and the eigenvalues of the operator are the values the observable takes. The previous derivatives are consistent with the energy operator, corresponding to the time derivative,

where E are the energy eigenvalues, and the momentum operator, corresponding to the spatial derivatives (the gradient ∇),

where **p** is a vector of the momentum eigenvalues. In the above, the "hats" (ˆ) indicate these observables are operators, not simply ordinary numbers or vectors. The energy and momentum operators are *differential operators*, while the potential energy function V is just a multiplicative factor.

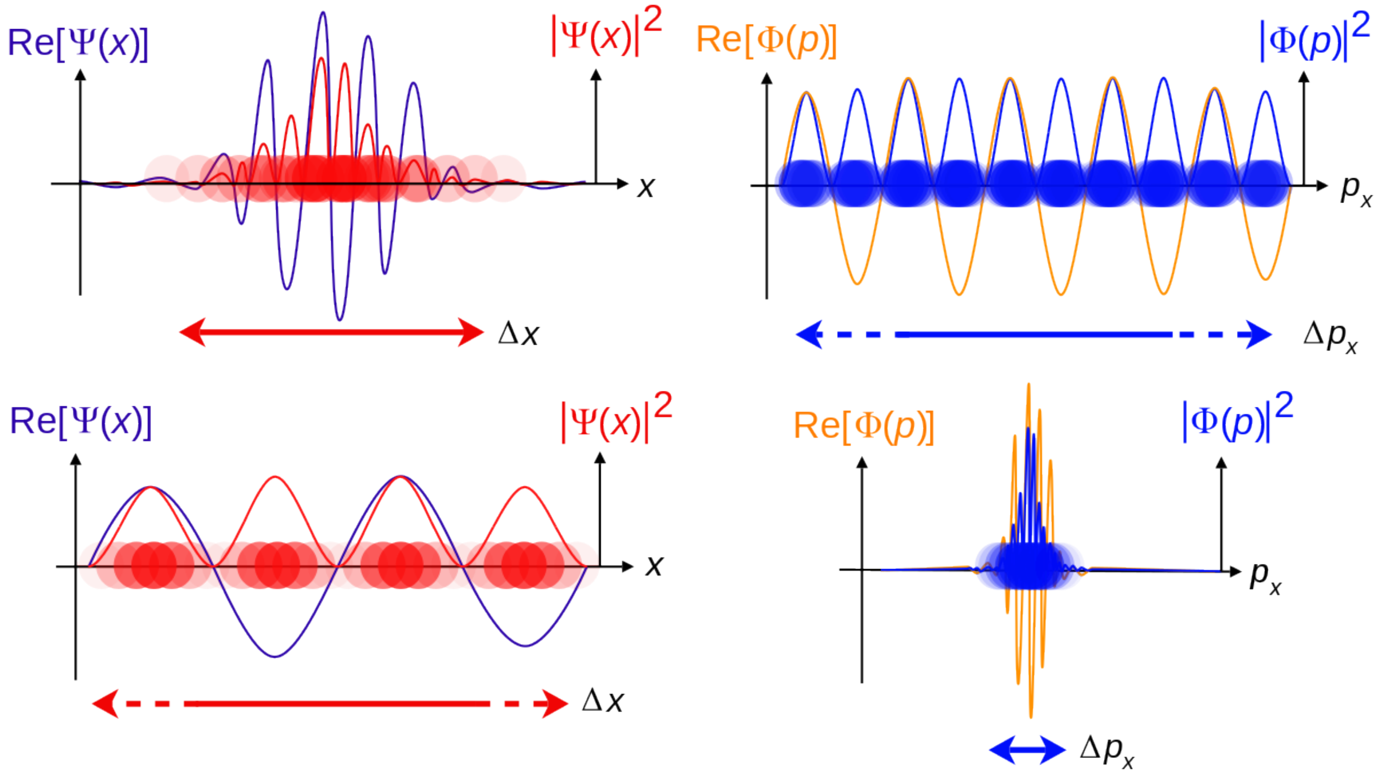
Substituting the energy and momentum operators into the classical energy conservation equation obtains the operator:

so in terms of derivatives with respect to time and space, acting this operator on the wavefunction Ψ immediately led Schrödinger to his equation:

Wave–particle duality can be assessed from these equations as follows. The kinetic energy T is related to the square of momentum $\mathbf{p}$. As the particle's momentum increases, the kinetic energy increases more rapidly, but since the wavenumber $|\mathbf{k}|$ increases the wavelength λ decreases. In terms of ordinary scalar and vector quantities (not operators):

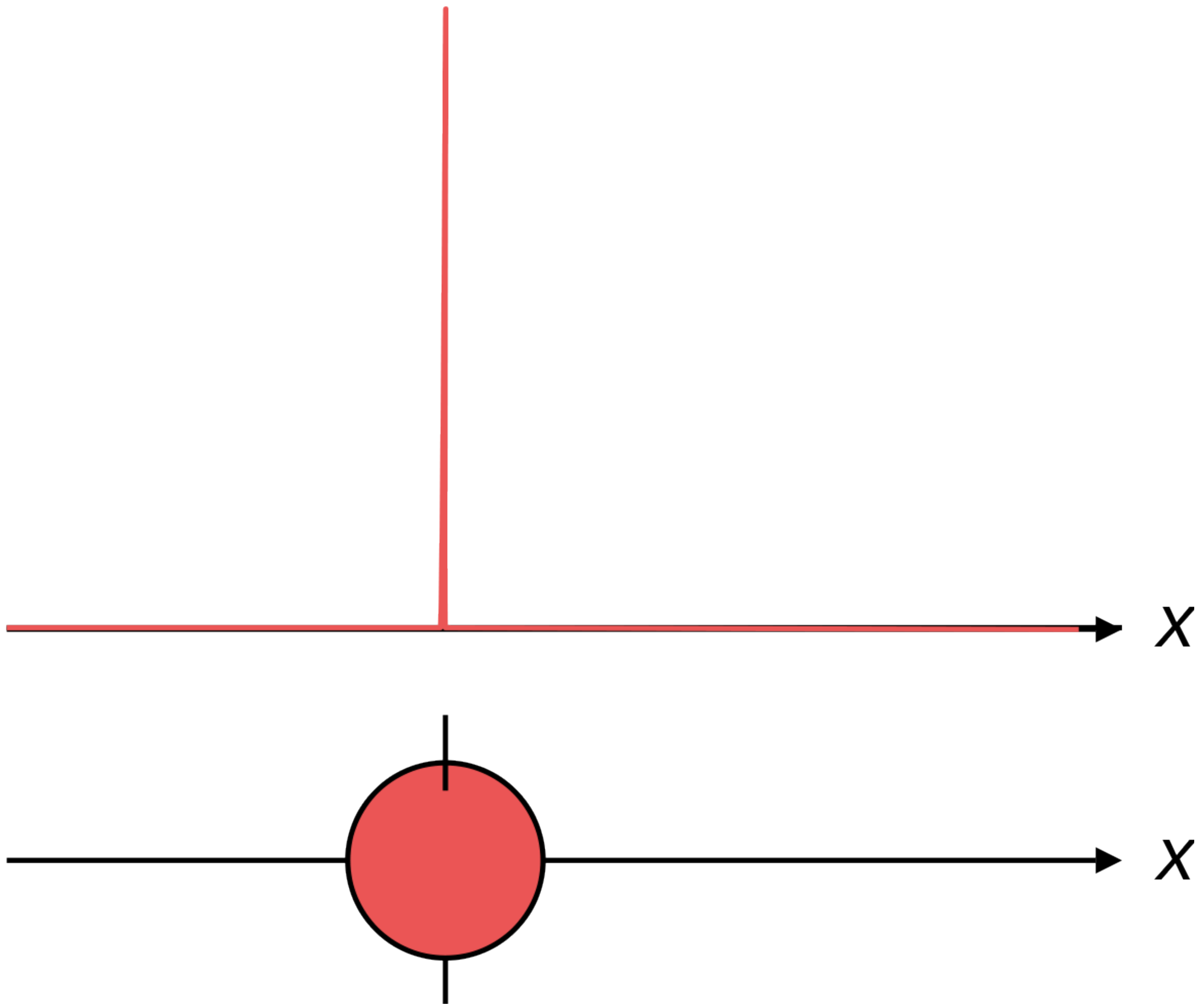
The kinetic energy is also proportional to the second spatial derivatives, so it is also proportional to the magnitude of the *curvature* of the wave, in terms of operators:

As the curvature increases, the amplitude of the wave alternates between positive and negative more rapidly, and also shortens the wavelength. So the inverse relation between momentum and wavelength is consistent with the energy the particle has, and so the energy of the particle has a connection to a wave, all in the same mathematical formulation.[27]



Increasing levels of wavepacket localization, meaning the particle has a more localized position.

Perfect localization



In the limit $\hbar \to 0$, the particle's position and momentum become known exactly. This is equivalent to the classical particle.

Schrödinger required that a wave packet solution near position **r** with wavevector near **k** will move along the trajectory determined by classical mechanics for times short enough for the spread in **k** (and hence in velocity) not to substantially increase the spread in **r**. Since, for a given spread in **k**, the spread in velocity is proportional to Planck's constant $\hbar$, it is sometimes said that in the limit as $\hbar$ approaches zero, the equations of classical mechanics are restored from quantum mechanics.[31] Great care is required in how that limit is taken, and in what cases.

The limiting short-wavelength is equivalent to $\hbar$ tending to zero because this is limiting case of increasing the wave packet localization to the definite position of the particle (see images right). Using the Heisenberg uncertainty principle for position and momentum, the products of uncertainty in position and momentum become zero as $\hbar \to 0$:

where σ denotes the (root mean square) measurement uncertainty in x and p_x (and similarly for the y and z directions) which implies the position and momentum can only be known to arbitrary precision in this limit.

One simple way to compare classical to quantum mechanics is to consider the time-evolution of the *expected* position and *expected* momentum, which can then be compared to the time-evolution of the ordinary position and momentum in classical mechanics. The quantum expectation values satisfy the Ehrenfest theorem. For a one-dimensional quantum particle moving in a potential , the Ehrenfest theorem says[32]

Although the first of these equations is consistent with the classical behavior, the second is not: If the pair were to satisfy Newton's second law, the right-hand side of the second equation would have to be

,

which is typically not the same as . In the case of the quantum harmonic oscillator, however, is linear and this distinction disappears, so that in this very special case, the expected position and expected momentum do exactly follow the classical trajectories.

For general systems, the best we can hope for is that the expected position and momentum will *approximately* follow the classical trajectories. If the wave function is highly concentrated around a point , then and will be *almost* the same, since both will be approximately equal to . In that case, the expected position and expected momentum will remain very close to the classical trajectories, at least for as long as the wave function remains highly localized in position.[33] When Planck's constant is small, it is possible to have a state that is well localized in *both* position and momentum. The small uncertainty in momentum ensures that the particle *remains* well localized in position for a long time, so that expected position and momentum continue to closely track the classical trajectories.

The Schrödinger equation in its general form

is closely related to the Hamilton–Jacobi equation (HJE)

where S is action and H is the Hamiltonian function (not operator). Here the generalized coordinates q_i for i = 1, 2, 3 (used in the context of the HJE) can be set to the position in Cartesian coordinates as $\mathbf{r} = (q_1, q_2, q_3) = (x, y, z)$.[31]

Substituting

where ρ is the probability density, into the Schrödinger equation and then taking the limit $\hbar \to 0$ in the resulting equation, yields the Hamilton–Jacobi equation.

The implications are as follows:

- The motion of a particle, described by a (short-wavelength) wave packet solution to the Schrödinger equation, is also described by the Hamilton–Jacobi equation of motion.
- The Schrödinger equation includes the wavefunction, so its wave packet solution implies the position of a (quantum) particle is fuzzily spread out in wave fronts. On

the contrary, the Hamilton–Jacobi equation applies to a (classical) particle of definite position and momentum, instead the position and momentum at all times (the trajectory) are deterministic and can be simultaneously known.

Nonrelativistic quantum mechanics

The quantum mechanics of particles without accounting for the effects of special relativity, for example particles propagating at speeds much less than light, is known as **nonrelativistic quantum mechanics**. Following are several forms of Schrödinger's equation in this context for different situations: time independence and dependence, one and three spatial dimensions, and one and N particles.

In actuality, the particles constituting the system do not have the numerical labels used in theory. The language of mathematics forces us to label the positions of particles one way or another, otherwise there would be confusion between symbols representing which variables are for which particle.[29]

Time independent

If the Hamiltonian is not an explicit function of time, the equation is separable into a product of spatial and temporal parts. In general, the wavefunction takes the form:

where ψ(space coords) is a function of all the spatial coordinate(s) of the particle(s) constituting the system only, and $\tau(t)$ is a function of time only.

Substituting for ψ into the Schrödinger equation for the relevant number of particles in the relevant number of dimensions, solving by separation of variables implies the general solution of the time-dependent equation has the form:[15]

Since the time dependent phase factor is always the same, only the spatial part needs to be solved for in time independent problems. Additionally, the energy operator $\hat{E} = i\hbar \frac{\partial}{\partial t}$ can always be replaced by the energy eigenvalue E, thus the time independent Schrödinger equation is an eigenvalue equation for the Hamiltonian operator:[5]:143ff

This is true for any number of particles in any number of dimensions (in a time independent potential). This case describes the standing wave solutions of the time-dependent equation, which are the states with definite energy (instead of a probability distribution of different energies). In physics, these standing waves are called "stationary states" or "energy eigenstates"; in chemistry they are called "atomic orbitals" or "molecular orbitals". Superpositions of energy eigenstates change their properties according to the relative phases between the energy levels.

The energy eigenvalues from this equation form a discrete spectrum of values, so mathematically energy must be quantized. More specifically, the energy eigenstates form a basis – any wavefunction may be written as a sum over the discrete energy states or an integral over continuous energy states, or more generally as an integral over a measure. This is the spectral theorem in mathematics, and in a finite state space it is just a statement of the completeness of the eigenvectors of a Hermitian matrix.

One-dimensional examples

For a particle in one dimension, the Hamiltonian is:

and substituting this into the general Schrödinger equation gives:

This is the only case the Schrödinger equation is an ordinary differential equation, rather than a partial differential equation. The general solutions are always of the form:

For *N* particles in one dimension, the Hamiltonian is:

where the position of particle *n* is x_n. The corresponding Schrödinger equation is:

so the general solutions have the form:

For non-interacting distinguishable particles,[34] the potential of the system only influences each particle separately, so the total potential energy is the sum of potential energies for each particle:

and the wavefunction can be written as a product of the wavefunctions for each particle:

For non-interacting identical particles, the potential is still a sum, but wavefunction is a bit more complicated – it is a sum over the permutations of products of the separate wavefunctions to account for particle exchange. In general for interacting particles, the above decompositions are *not* possible.

Free particle

For no potential, $V = 0$, so the particle is free and the equation reads:[5]:151ff

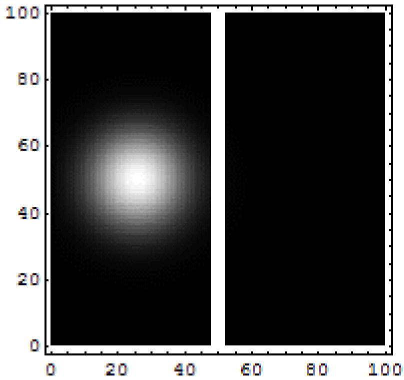
which has oscillatory solutions for $E > 0$ (the C_n are arbitrary constants):

and exponential solutions for $E < 0$

The exponentially growing solutions have an infinite norm, and are not physical. They are not allowed in a finite volume with periodic or fixed boundary conditions.

See also free particle and wavepacket for more discussion on the free particle.

Constant potential



For a constant potential, $V = V_0$, the solution is oscillatory for $E > V_0$ and exponential for $E < V_0$, corresponding to energies that are allowed or disallowed in classical mechanics. Oscillatory solutions have a classically allowed energy and correspond to actual classical motions, while the exponential solutions have a disallowed energy and describe a small amount of quantum bleeding into the classically disallowed region, due to quantum tunneling. If the potential V_0 grows to infinity, the motion is classically confined to a finite region. Viewed far enough away, every solution is reduced to an exponential; the condition that the exponential is decreasing restricts the energy levels to a discrete set, called the allowed energies.[30]

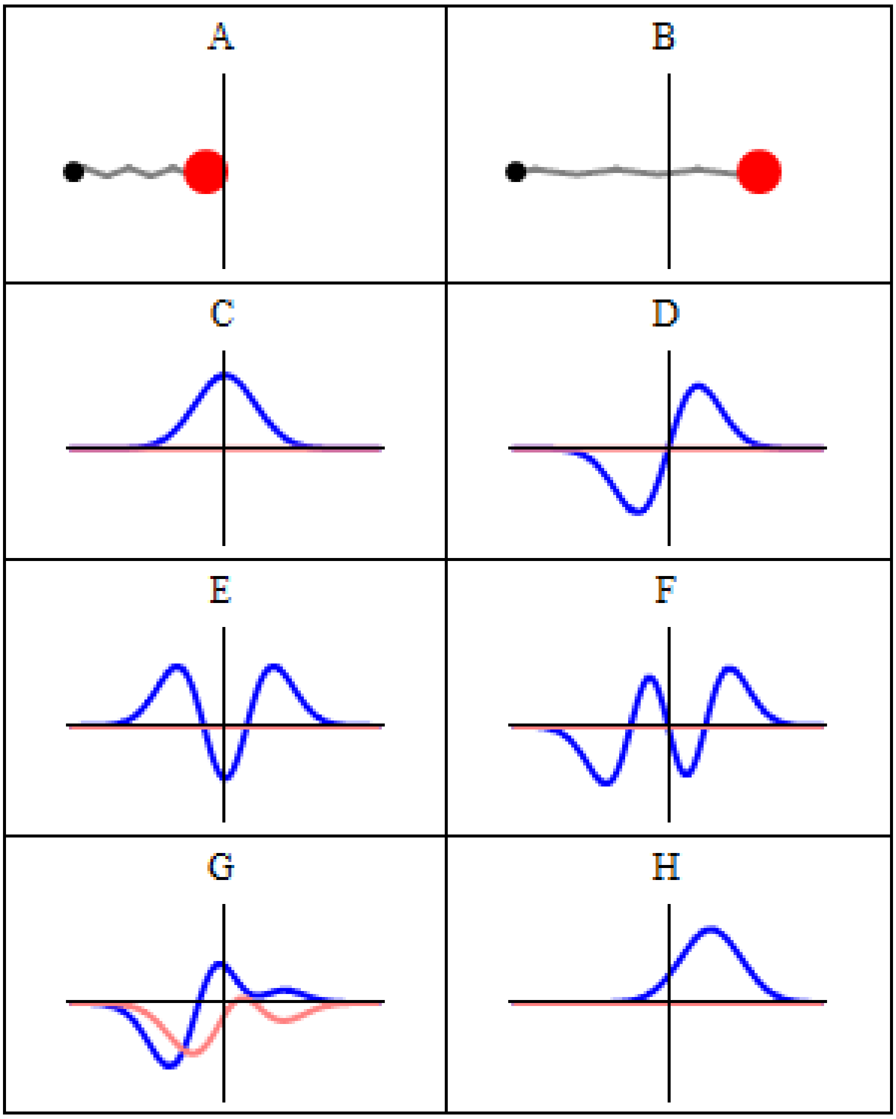
Harmonic oscillator

The Schrödinger equation for this situation is

It is a notable quantum system to solve for; since the solutions are exact (but complicated – in terms of Hermite polynomials), and it can describe or at least approximate a wide variety of other systems, including vibrating atoms, molecules,[35] and atoms or ions in lattices,[36] and approximating other potentials near equilibrium points. It is also the basis of perturbation methods in quantum mechanics.

There is a family of solutions – in the position basis they are

where n = 0,1,2,..., and the functions H_n are the Hermite polynomials.



A harmonic oscillator in classical mechanics (A–B) and quantum mechanics (C–H). In (A–B), a ball, attached to a spring, oscillates back and forth. (C–H) are six solutions to the Schrödinger Equation for this situation. The horizontal axis is position, the vertical axis is the real part (blue) or imaginary part (red) of the wavefunction. Stationary states, or energy eigenstates, which are solutions to the time-independent Schrödinger equation, are shown in C, D, E, F, but not G or H.

Three-dimensional examples

The extension from one dimension to three dimensions is straightforward, all position and momentum operators are replaced by their three-dimensional expressions and the partial derivative with respect to space is replaced by the gradient operator.

The Hamiltonian for one particle in three dimensions is:

generating the equation:

with stationary state solutions of the form:

where the position of the particle is **r**. Two useful coordinate systems for solving the Schrödinger equation are Cartesian coordinates so that **r** = (x, y, z) and spherical polar coordinates so that **r** = (r, θ, φ), although other orthogonal coordinates are useful for solving the equation for systems with certain geometric symmetries.

For N particles in three dimensions, the Hamiltonian is:

where the position of particle n is $\mathbf{r}_n$ and the gradient operators are partial derivatives with respect to the particle's position coordinates. In Cartesian coordinates, for particle n, the position vector is $\mathbf{r}_n = (x_n, y_n, z_n)$ while the gradient and Laplacian operator are respectively:

The Schrödinger equation is:

with stationary state solutions:

Again, for non-interacting distinguishable particles the potential is the sum of particle potentials

and the wavefunction is a product of the particle wavefunctions

For non-interacting identical particles, the potential is a sum but the wavefunction is a sum over permutations of products. The previous two equations do not apply to interacting particles.

Following are examples where exact solutions are known. See the main articles for further details.

Hydrogen atom

This form of the Schrödinger equation can be applied to the hydrogen atom:[25][27]

where e is the electron charge, **r** is the position of the electron relative to the nucleus ($r = |\mathbf{r}|$ is the magnitude of the relative position), the potential term is due to the Coulomb interaction, wherein ε_0 is the electric constant (permittivity of free space) and

is the 2-body reduced mass of the hydrogen nucleus (just a proton) of mass m_p and the electron of mass m_e. The negative sign arises in the potential term since the proton and electron are oppositely charged. The reduced mass in place of the electron mass is used since the electron and proton together orbit each other about a common centre of mass, and constitute a two-body problem to solve. The motion of the electron is of principle interest here, so the equivalent one-body problem is the motion of the electron using the reduced mass.

The wavefunction for hydrogen is a function of the electron's coordinates, and in fact can be separated into functions of each coordinate.[37] Usually this is done in spherical polar coordinates:

where R are radial functions and $Y_\ell^m(\theta, \varphi)$ are spherical harmonics of degree ℓ and order m. This is the only atom for which the Schrödinger equation has been solved for exactly. Multi-electron atoms require approximative methods. The family of solutions are:[38]

where:

- is the Bohr radius,
- are the generalized Laguerre polynomials of degree $n - \ell - 1$.
- n, ℓ, m are the principal, azimuthal, and magnetic quantum numbers respectively: which take the values:

NB: generalized Laguerre polynomials are defined differently by different authors—see main article on them and the hydrogen atom.

Two-electron atoms or ions

The equation for any two-electron system, such as the neutral helium atom (He, $Z = 2$), the negative hydrogen ion (H^-, $Z = 1$), or the positive lithium ion (Li^+, $Z = 3$) is:[28]

where $\mathbf{r}_1$ is the relative position of one electron ($r_1 = |\mathbf{r}_1|$ is its relative magnitude), $\mathbf{r}_2$ is the relative position of the other electron ($r_2 = |\mathbf{r}_2|$ is the magnitude), $r_{12} = |\mathbf{r}_{12}|$ is the magnitude of the separation between them given by

μ is again the two-body reduced mass of an electron with respect to the nucleus of mass M, so this time

and Z is the atomic number for the element (not a quantum number).

The cross-term of two laplacians

is known as the *mass polarization term*, which arises due to the motion of atomic nuclei. The wavefunction is a function of the two electron's positions:

There is no closed form solution for this equation.

Time dependent

This is the equation of motion for the quantum state. In the most general form, it is written:[5]:143ff

and the solution, the wavefunction, is a function of all the particle coordinates of the system and time. Following are specific cases.

For one particle in one dimension, the Hamiltonian

generates the equation:

For N particles in one dimension, the Hamiltonian is:

where the position of particle n is x_n, generating the equation:

For one particle in three dimensions, the Hamiltonian is:

generating the equation:

For N particles in three dimensions, the Hamiltonian is:

where the position of particle n is $\mathbf{r}_n$, generating the equation:[5]:141

This last equation is in a very high dimension, so the solutions are not easy to visualize.

Solution methods

List of quantum-mechanical systems with analytical solutions
Hartree–Fock method and post Hartree–Fock methods
Perturbation theory
The variational method

Quantum Monte Carlo methods

Density functional theory

The WKB approximation and semi-classical expansion

Properties

The Schrödinger equation has the following properties: some are useful, but there are shortcomings. Ultimately, these properties arise from the Hamiltonian used, and the solutions to the equation.

Linearity

In the development above, the Schrödinger equation was made to be linear for generality, though this has other implications. If two wave functions ψ_1 and ψ_2 are solutions, then so is any linear combination of the two:

where a and b are any complex numbers (the sum can be extended for any number of wavefunctions). This property allows superpositions of quantum states to be solutions of the Schrödinger equation. Even more generally, it holds that a general solution to the Schrödinger equation can be found by taking a weighted sum over all single state solutions achievable. For example, consider a wave function $\Psi(x, t)$ such that the wave function is a product of two functions: one time independent, and one time dependent. If states of definite energy found using the time independent Schrödinger equation are given by $\psi_E(x)$ with amplitude A_n and time dependent phase factor is given by

then a valid general solution is

Additionally, the ability to scale solutions allows one to solve for a wave function without normalizing it first. If one has a set of normalized solutions ψ_n, then

can be normalized by ensuring that

This is much more convenient than having to verify that

Momentum space Schrödinger equation

The Schrödinger equation is often presented in the position basis form (with). But as a vector operator equation it has a valid representation in any arbitrary complete basis of kets in Hilbert space. For example, in the momentum space basis the equation reads

where is the plane wave state of definite momentum , , is the Fourier transform of , and denotes Fourier convolution.

In the 1D example with absence of a potential, (or similarly in the case of a background potential constant throughout space), each stationary state of energy is of the form

for arbitrary complex coefficients . Such a wave function, as expected in free space, is a superposition of plane waves moving right and left with momenta ; upon momentum measurement the state would collapse to one of definite momentum with probability .

A version of the momentum space Schrödinger equation is often used in solid-state physics, as Bloch's theorem ensures the periodic crystal lattice potential couples with for only discrete reciprocal lattice vectors . This makes it convenient to solve the momentum space Schrödinger equation at each point in the Brillouin zone independently of the other points in the Brillouin zone.

Real energy eigenstates

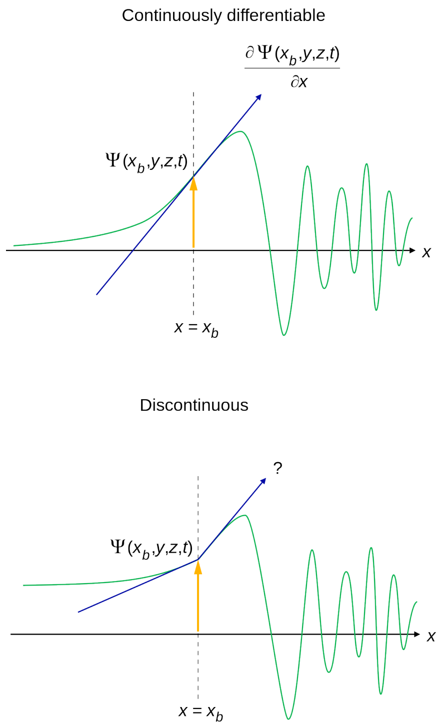
For the time-independent equation, an additional feature of linearity follows: if two wave functions ψ_1 and ψ_2 are solutions to the time-independent equation with the same energy E, then so is any linear combination:

Two different solutions with the same energy are called *degenerate*.[30]

In an arbitrary potential, if a wave function ψ solves the time-independent equation, so does its complex conjugate, denoted ψ^*. By taking linear combinations, the real and imaginary parts of ψ are each solutions. If there is no degeneracy they can only differ by a factor.

In the time-dependent equation, complex conjugate waves move in opposite directions. If $\Psi(x, t)$ is one solution, then so is $\Psi^*(x, -t)$. The symmetry of complex conjugation is called time-reversal symmetry.

Space and time derivatives



Continuity of the wavefunction and its first spatial derivative (in the x direction, y and z coordinates not shown), at some time t.

The Schrödinger equation is first order in time and second in space, which describes the time evolution of a quantum state (meaning it determines the future amplitude from the present).

Explicitly for one particle in 3-dimensional Cartesian coordinates – the equation is

The first time partial derivative implies the initial value (at $t = 0$) of the wavefunction

is an arbitrary constant. Likewise – the second order derivatives with respect to space implies the wavefunction *and* its first order spatial derivatives

are all arbitrary constants at a given set of points, where x_b, y_b, z_b are a set of points describing boundary b (derivatives are evaluated at the boundaries). Typically there are one or two boundaries, such as the step potential and particle in a box respectively.

As the first order derivatives are arbitrary, the wavefunction can be a continuously differentiable function of space, since at any boundary the gradient of the wavefunction can be matched.

On the contrary, wave equations in physics are usually *second order in time*, notable are the family of classical wave equations and the quantum Klein–Gordon equation.

Local conservation of probability

The Schrödinger equation is consistent with probability conservation. Multiplying the

Schrödinger equation on the right by the complex conjugate wavefunction, and multiplying the wavefunction to the left of the complex conjugate of the Schrödinger equation, and subtracting, gives the continuity equation for probability:[39]

where

is the probability density (probability per unit volume, * denotes complex conjugate), and

is the probability current (flow per unit area).

Hence predictions from the Schrödinger equation do not violate probability conservation.

Positive energy

If the potential is bounded from below, meaning there is a minimum value of potential energy, the eigenfunctions of the Schrödinger equation have energy which is also bounded from below. This can be seen most easily by using the variational principle, as follows. (See also below).

For any linear operator $\hat{A}$ bounded from below, the eigenvector with the smallest eigenvalue is the vector ψ that minimizes the quantity

over all ψ which are normalized.[39] In this way, the smallest eigenvalue is expressed through the variational principle. For the Schrödinger Hamiltonian $\hat{H}$ bounded from below, the smallest eigenvalue is called the ground state energy. That energy is the minimum value of

(using integration by parts). Due to the complex modulus of ψ^2 (which is positive definite), the right hand side is always greater than the lowest value of $V(x)$. In particular, the ground state energy is positive when $V(x)$ is everywhere positive.

For potentials which are bounded below and are not infinite over a region, there is a ground state which minimizes the integral above. This lowest energy wavefunction is real and positive definite – meaning the wavefunction can increase and decrease, but is positive for all positions. It physically cannot be negative: if it were, smoothing out the bends at the sign change (to minimize the wavefunction) rapidly reduces the gradient contribution to the integral and hence the kinetic energy, while the potential energy changes linearly and less quickly. The kinetic and potential energy are both changing at different rates, so the total energy is not constant, which can't happen (conservation). The solutions are consistent with Schrödinger equation if this wavefunction is positive definite.

The lack of sign changes also shows that the ground state is nondegenerate, since if there were two ground states with common energy E, not proportional to each other, there would be a linear combination of the two that would also be a ground state resulting in a zero solution.

Analytic continuation to diffusion

The above properties (positive definiteness of energy) allow the analytic continuation of the Schrödinger equation to be identified as a stochastic process. This can be interpreted as the Huygens–Fresnel principle applied to De Broglie waves; the spreading wavefronts are diffusive probability amplitudes.[39] For a free particle (not subject to a potential) in a random walk, substituting $\tau = it$ into the time-dependent Schrödinger equation gives:[40]

which has the same form as the diffusion equation, with diffusion coefficient $\frac{\hbar}{2m}$. It is also revealed that the diffusion equation yields the Schrödinger equation in accordance with the Markov process.[41] In that case, the relation of De Broglie is reasonably derived from the correlation between diffusivities, regardless of the photon energy.[42] Thus, the relation is now not a hypothesis but an actual one expressing the nature of micro particle.

Regularity

On the space of square-integrable densities, the Schrödinger semigroup is a unitary evolution, and therefore surjective. The flows satisfy the Schrödinger equation , where the derivative is taken in the distribution sense. However, since for most physically reasonable Hamiltonians (e.g., the Laplace operator, possibly modified by a potential) is unbounded in , this shows that the semigroup flows lack Sobolev regularity in general. Instead, solutions of the Schrödinger equation satisfy a Strichartz estimate.

Relativistic quantum mechanics

Relativistic quantum mechanics is obtained where quantum mechanics and special relativity simultaneously apply. In general, one wishes to build relativistic wave equations from the relativistic energy–momentum relation

instead of classical energy equations. The Klein–Gordon equation and the Dirac equation are two such equations. The Klein–Gordon equation,

,

was the first such equation to be obtained, even before the nonrelativistic one, and applies to massive spinless particles. The Dirac equation arose from taking the "square root" of the Klein–Gordon equation by factorizing the entire relativistic wave operator into a product of two operators – one of these is the operator for the entire Dirac equation. Entire Dirac equation:

The general form of the Schrödinger equation remains true in relativity, but the Hamiltonian is less obvious. For example, the Dirac Hamiltonian for a particle of mass m and electric charge q in an electromagnetic field (described by the electromagnetic potentials φ and $\mathbf{A}$) is:

in which the $\boldsymbol{\gamma} = (\gamma^1, \gamma^2, \gamma^3)$ and γ^0 are the Dirac gamma matrices related to the spin of the particle. The Dirac equation is true for all spin-$\frac{1}{2}$ particles, and the solutions to the equation are 4-component spinor fields with two components corresponding to the particle and the other two for the antiparticle.

For the Klein–Gordon equation, the general form of the Schrödinger equation is inconvenient to use, and in practice the Hamiltonian is not expressed in an analogous way to the Dirac Hamiltonian. The equations for relativistic quantum fields can be obtained in other ways, such as starting from a Lagrangian density and using the Euler–Lagrange equations for fields, or use the representation theory of the Lorentz group in which certain representations can be used to fix the equation for a free particle of given spin (and mass).

In general, the Hamiltonian to be substituted in the general Schrödinger equation is not just a function of the position and momentum operators (and possibly time), but also of spin matrices. Also, the solutions to a relativistic wave equation, for a massive particle of spin s, are complex-valued $2(2s + 1)$-component spinor fields.

Quantum field theory

The general equation is also valid and used in quantum field theory, both in relativistic and nonrelativistic situations. However, the solution ψ is no longer interpreted as a "wave", but should be interpreted as an operator acting on states existing in a Fock space.

First order form

The Schrödinger equation can also be derived from a first order form[43][44][45] similar to the manner in which the Klein-Gordon equation can be derived from the Dirac equation. In 1D the first order equation is given by

This equation allows for the inclusion of spin in nonrelativistic quantum mechanics. Squaring the above equation yields the Schrödinger equation in 1D. The matrices obey the following properties

The 3 dimensional version of the equation is given by

Here is a nilpotent matrix and are the Dirac gamma matrices (). The Schrödinger equation in 3D can be obtained by squaring the above equation. In the nonrelativistic limit and , the above equation can be derived from the Dirac equation.[44]

See also

- Eckhaus equation
- Fractional Schrödinger equation
- List of quantum-mechanical systems with analytical solutions
- Logarithmic Schrödinger equation
- Nonlinear Schrödinger equation

- Quantum carpet
- Quantum revival
- Relation between Schrödinger's equation and the path integral formulation of quantum mechanics
- Schrödinger field
- Schrödinger picture
- Schrödinger's cat
- Theoretical and experimental justification for the Schrödinger equation

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