*Ivor Darreg*

# NUMAUDO

## AN INTERNATIONAL PRONOUNCEABLE CODING SYSTEM FOR MATHEMATICS AND SYMBOLIC LOGIC



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# Table of Contents



11 ap 61

# PREFACE

The Numaudo system, and thus the present work, resulted from investigations into the nature of audible communication and coding methods, which the author made while developing new methods for musical composition and new apparatus for producing sound electronically. Hints derived from a background in languages suggested further inquiry concerning the relations between musical forms and rules, on the one hand, and grammar and syntax of languages, on the other.

Recent advances in such fields as information theory have stimulated concomitant advances in other fields now seen to be related, but hitherto thought to be relatively unconnected. Examples of such fields are: written message transmission, teletypewriter and telegraph; facsimile and picture transmission; spoken message transmission, by wire and radio; bandwidth compression methods; quantizing systems and analog-to-digital and digital-to-analog conversion; digital computing systems; information storage and retrieval; machine translation of languages; automatic control of machinery from stored digital data; cryptography; abbreviations and space-saving codes; structural linguistics; spoken-word recognizing equipment; sound recording; redundancy methods for error detection and avoidance; pattern recognition of many kinds; studies of stylistic differences, similarities, and changes in music, literature, and other fields.

An outstanding characteristic possessed in common by the above-enumerated items is *the idea of conveying information in digital form.* Digital representation almost always involves *coding.* Now, most attention has been directed to the art of coding visual communications, such as typewritten messages. Language has been studied mainly in its *written* form, so that even those whose chief interest is in coding methods have largely ignored the important fact that written language *is a code for spoken language,* which preceded writing by thousands of years.

The digitalizing concept has even recently invaded the study of spoken language, in that *phonetics,* the study of the many shades and gradations of speech-sounds, has had to make room for *phonemics,* the study of families or categories of speech-sounds, within which categories in any given dialect of a language, minute variations of timbre do not alter the meaning of an utterance.

Phonemics will be a fundamental consideration in the designing of machines (one is tempted to say robots) that are to respond to spoken instructions and in some cases to purvey spoken information. This much being evident, why not have a speakable code on a phonemic basis to convey digital information? Thus Numaudo was born.

But a code for digital information might be expanded into a code for mathematics. If so, it ought to be tied to the existing international mathematical notation. This proved to be possible: Numaudo expresses, with practically one-to-one correspondence, each written mathematical symbol by a corresponding spoken symbol. More than this, it provides spoken representations for symbolic logic.

Syllables, rather than letters, form the basis for Numaudo coding. If any precedent is needed, surely the success of the syllables devised by Guido d'Arezzo, in the eleventh century—*re, mi, fa, sol,* and *la* having retained their meanings for more than 900 years!—should be sufficient. Indeed, the sol-fa syllables constitute a digital representation themselves: they call for a stepwise progression of pitches, rather than a continuous gliding of the voice.

While thanks are due several mathematicians who offered encouragement by agreeing that a pronounceable code for mathematics was both practical and needed, the author alone is responsible for any errors of omission or commission, which of course should be called to his attention for the benefit of all users of this system.

IVOR DARREG. *Los Angeles, California, April, 1960.*

## *RÉSUMÉ EN FRANÇAIS*

Le système Numaudo est un code à parler qui comprend environ 450 syllabes. Chaque syllabe exprime un symbole mathématique, un chiffre, une lettre algébrique, un symbole de la logique, un mot logique, ou autre chose pareille. Le Numaudo n'est pas une langue, parce qu'il ne traduit point les symboles écrits; il les exprime par des syllabes en manière tout à fait renversable. Vraiment, il s'appèle *Numaudo* car il nous donne des nombres qu'on peut entendre: d'après le latin: numerus, *nombre;* audire, *entendre.*

On préfère la prononciation latine du mot *Numaudo,* c'est-à-dire *"nou-maou-do"*, mais on tolère la prononciation française de ce mot. Néanmoins, tous les syllabes du système Numaudo doivent être prononcés selon l'alphabet phonétique international, parce que le Numaudo est un code complètement international, ainsi comme l'écriture des chiffres et des signes mathématiques est presque partout uniforme.

C'est un phénomène très curieux: les langues ordinaires, comme le français, le russe, l'anglais, l'allemand, le chinois, —ces langues ont été parlées durant une époque bien longue, et sans aucun doute leurs ancêtres survécurent des millénaires avant ou les alphabets ou les hiéroglyphes. Mais au contraire la «langue» mathématique commença par l'écriture seule. Cette écriture est bien internationale, comme nous avons dit; mais quand on lit à haute voix, il n'y a plus d'uniformité!

D'ailleurs, quand on lit, on traduit. Le mot *quinze* n'est pas les deux mots *un, cinq,* mais l'homme qui lit les deux chiffres *15* ne dit qu'un mot. Et voici les chiffres *96*, qui deviennent *quatre-vingt-seize!* Les Anglais traduisent aussi; tout le monde traduit les chiffres de l'arithmétique et les symboles de l'algèbre. Donc l'étude mathématique est trop difficile. Mais avec un code comme le Numaudo, on pourra «parler en langue mathématique», et la pensée mathématique marchera aussi rapidement que la pensée ordinaire.

La téchnologie contemporaine a produit beaucoup de machines automatiques. On aura bientôt des machines qui reprondront aux ordres parlés. Un système aux syllabes régularisées, comme le Numaudo, permettra une construction économique de telles machines. Un code mathématique aussi sera très utile pour les machines à calculer: on pourra dire des syllabes numaudos qui exprimeront un problème, puis un appareil électronique les changera en signaux électriques, par lesquels la machine fera son compte.

Les signes mathématiques (et également les signes nouveaux de la logique)nous offrent un mélange des chiffres, des signes cabalistiques, des lettres latines, des lettres grecques ... qui fait bien difficile les travaux des imprimeurs. Une machine à écrire quelconque manque des signes mathématiques; il faut les écrire à main. Le système Numaudo resout ce problème très facilement: l'alphabet du système contient 21 lettres ordinaires, *abdefghijklmnoprstuvz.* Tout ce qu'on écrit en mathématique est exprimable par des syllabes formées d'après l'alphabet numaudo. Par conséquent, on peut télégraphier l'arithmétique, l'algèbre, le calcul, et la logique symbolique, par ces 21 lettres seules; on n'a aucune besoin de chiffres ni de symboles hors de l'alphabet. Chaque machine à écrire, y compris les machines automatiques et télégraphiques, devient une machine mathématique. Tous les deux, le Numaudo parlé et le Numaudo écrit, seront utiles.

Les sons du Numaudo suivent les sons des symboles de l'Association phonétique internationale, mais on permet des exceptions. Aux Français qui ne peuvent pas prononcer une *h* vraiment aspirée (comme l'*h* allemande) on permet de la prononcer comme *j* en *jour.* On tolère aussi un *e* muet (mais très bref), phonétiquement [ə], après certaines consonnes au fin de syllabe: *met* comme «mette», ne pas comme «mê»; *fin* comme «finne», ne pas comme le mot «fin» en français, parce que les voyelles nasales n'existent pas en Numaudo. Les diphtongues numaudos tiennent les sons des voyelles détachées: *eu* est *è-ou,* ne pas *eu* français [œ]; *ai* est *a-i,* ne pas *ê.* L'*u* numaudo est l'*ou* français; l'*e* est toujours grave ou circonflexe.

Voilà la liste des syllabes numaudos sur les pages 52-53.

## ZUSAMMENFASSUNG IN DEUTSCHER SPRACHE

Der „Numaudo" ist einer Code, etwa 450 *Silben* enthaltend. Er ist nicht eine Sprache, sondern ein sprechbares Ausdrucksmittel, dessen Silben die Zahlen, die mathematischen Zeichen, die Zeichen der symbolischen Logik, usw., darstellen. Der Name *Numaudo* wird aus dem Latein gebildet: *numerus*, „Zahl"; *audire*, „hören". Durch Numaudo kann man Arithmetik und Algebra wirklich sprechen; also sind die Numaudo-Silben „hörbare Zahlen".

Das Lautlesen der mathematischen Zeichen auf Deutsch, Französisch, Englisch, usw. ist nicht ein blosses Lesen, sondern eine Übersetzung! Das einfache Wort *zehn* wird gelesen, wann man die zwei Ziffern 1 und 0 sieht. Ganz gleich geht es beim Lautlesen anderer mathematischer Zeichen. Im Gegenteil ist das Numaudo-Lautlesen nur eine Codierung, die völlig umkehrbar ist.

Die Aussprache des Numaudos wird auf die internationale Lautschrift gegründet, weil jede Numaudo-Buchstabe gehört dem internationalen phonetischen Alphabet an. Der Numaudo benutzt 21 aus den 26 Buchstaben des gewöhnlichen Alphabets, und mit nur kleinen Ausnahmen lauten immer diese Buchstaben wie die entsprechenden Buchstaben der Lautschrift.

Jeder Fernschreiber kann diese 21 Buchstaben schreiben; auch kann jede Schreibmaschine diese Buchstaben schreiben. Sie sind auch telegraphierbar. Nun ist es möglich, allerlei mathematischen Formeln, ohne besonderen Symbole zu senden.

Oft wird die Mathemathik eine „Sprache" genannt. Jedoch begannen alle gewöhnliche Sprachen ohne Schrift, wohingegen begann die Mathematik als internationale Schrift ohne internationale Aussprache. Durch Numaudo-Code wird die Mathematik zum ersten Male eine echte Sprache werden.

Vor kurzem haben die Erfinder uns elektronische Rechenmaschine und andere merkwürdige elektronische Automaten gegeben. Es sind Geräte, die man durch ein gesprochenes Wort in Gang bringen kann. Bald wird die Fabrikation solcher Maschine eine wichtige Industrie werden. Der Gebrauch eines Codes, z.B. des Numaudos, wird die sparsame Fabrikation dieser Automaten erleichtern. In allen Ländern werden die Numaudo-Silben dieselben sein, so werden auch die Maschinenbefehle und die gesprochene Zahleninformation dieselben sein.

*Bemerkungen über die Numaudo-Aussprache:* Das *s* ist immer stimmlos, wie deutsches *ss* (ß) ; das *z* bezeichnet, wie englisches oder französisches *z*, immer ein stimmhaftes *s* (deut. *sausen*). Das *h* wird entweder als deut. *h* im Anlaut oder als *ch* (*ach*) gesprochen. Das Zungenspitzen-*r* ist vorzüglicher als das Zäpfchen-*r*. Das *v* ist dem deutschen *w* gleich; es muss immer stimmhaft sein. Im Auslaut wird die stimmlose Aussprache der stimmhaften Konsonanten, wie auf Deutsch, nur geduldet. Die *Diphthonge* des Numaudos haben Betonung am ersten Vokal, und die Aussprache ihrer Vokale ist dieselbe der einfachen Vokale. Das *e* ist offen (*des*); auch ist das *o* offen (*doch*). Das *i* ist aber geschlossen (*Liebe*). *Eu* ist nicht *oi*, sondern *ĕ–u*. *Ei* ist nicht *ai*, sondern *ē–i* (vgl. die Musik-Note *Eis*).

Weil die Aussprache des Numaudos ganz systematisch ist, und weil die Bedeutungen der Numaudo-Silben folgen die Bedeutungen der mathematischen und logischen Zeichen auf systematischer Art, so werden der mathematische Unterricht und der Verlauf der mathematischen Gedanken leichter und schneller gehen, als ist jetzt der Fall. Die Gleichordnung der gesprochenen und der geschriebenen Mathematik durch den Gebrauch des Numaudo-Codes wird fast überall zuträglich sein.

Um den Numaudo zu benutzen, muss man nur ca. 50 Silben lernen, die sein Fach betreffen. Wenn es in der Zukunft notwendig sei, neue Silben einzuführen, wird es möglich sein, mehr als 2000 Silben zu erfinden, ohne Bruch der Codenregeln.

Ein *alphabetisches Verzeichnis der Silben* wird auf den Seiten 52-53 gegeben. Diese Silben sind mit den gewöhnlichen Sprachen verträglich; üblich bei Mischung gibt es keine Zweideutigkeiten.

## КРАТКИЙ ОБЗОР ДЛЯ РУССКИХ

Новый код *Нумаудо* имеет около 450 слогов. Этот код называется Нумаудом потому, что он выражает цифры, математические знаки, буквы, и логические символы тоже, *слышными образами* т.е., слогами. «*Нум*» из латинского numerus, *число;* «*ауд*» из audire, *слышать*. Нумаудо пишется латинскими буквами, которые же произносятся вполне согласно Международному Фонетическому Алфавиту. Нумаудо не считается языком; оно только дает правила для международного произношения интернационального «математического языка». До сих пор, писание цифр, алгебраических знаков, и пр., почти одинаково во всех странах, но когда лица читают вслух, нет никакой одинаковости.

Чтение арифметических и алгебраических счетов и задач вслух обыкновенно вовлекает перевод. Написанные цифры *10* не читаются двумя словами, а только одним словом: *десять*--а в этом же слове совсем не видны *двух цифр 1 и 0*. Наоборот, когда цифры, буквы, и знаки математики читаются кодом Нумаудом, перевода нет: каждый математический знак заменяется нумаудным слогом, и, в свою очередь, нумаудный слог может заменяться обратно первым математическим знаком. Например, 10 = sagu, 1 = sa, и 0 = gu; 100 = sagugu; 0,1 = gunasa. Не надо иметь в коде отдельных нумаудных слогов, чтобы выражать кодом *десять, сто, тысячу, одну десятую,* и т.д.

В будущем, скорость и свободность математических мыслей будут повышаться Нумаудом, так как не будет перевода этих мыслей на нематематический язык. Будут математические разговоры без всякого колебания. Теперешняя трудность у студентов, когда изучают алгебру и высшие отделения математики, происходит от того, что им невожможно прямо говорить то, которое читают в математических учебниках--им надо его *переводить* на свой родной явык. Главный принцип нумаудного кода вот такой: Каждому математическому знаку свой слог; каждому слогу свой знак. Слог принадлежит знаку, как звук принадлежит букве.

Это взаимное отношение между математикой и Нумаудом значит, что в каком-то переносном смысле Нумаудо станет «голосом математики». Вот замечательный факт: обыкновенные языки, как и русский, французский, английский, немецкий, и т.д., давным давно говорились, прежде изобретения написанных знаков: но с начала и еще теперь, математика—*язык просто письменный,* без истинной высказываемой формы. Поэтому, желательно вырабатывать систему для чтения вслух и разговоров «по-математически»: т.е. Нумаудо.

Есть и другая причина для Нумауда: В последнее время сделали новые электронные счетные машины и разнообразные электронные и электрические автоматы, среди которых есть машины, подчинящие приказы и выдающие информацию устно. Надо только сказать два-три слова в микрофон, чтобы пустить машину в ход, или остановить ее. Дешевлее производить такие машины, употребляющие нумаудные слоги, чем машины, употребляющие слова обыкновенных языков.

*Примечания о произношении нумаудных букв:* Как уже объяснилось, Нумаудо имеет фонетическое основание. Вообще, произношение букв в этом коде следует международный фонетический алфавит, а практические причины делают маленькие исключения, например: Русские, и другие, язык которых не имеет придыхания [h], могут произносить [x] в таких случаях: 1½, sa ha sadaze, (сахасадазэ); *сорок километров в час,* vogu kih, (вогу ких). Гласная *O* произносится везде самым полным ясным звуком, никогда как *A*. Гласная *E* всегда твердая, как русское *Э;* никогда не произносится как *И*. Предпочтительно, буква *I* в Нумауде произносится без мягкости русского *И*. Согласные b, d, g, v, z всегда хранят свою звонкость, даже на концах слогов: произношение d как t, v как f, и т.д., на конце слогов терпится, а не рекомендуется.

Не надо выучить целый код Нумаудо наизусть, чтобы его употреблять в своем деле. В первых порах только нужны 40-50 слогов. Слоги Нумауда не выдумались произвольно, а вполне систематической программой: где возможно, слова были избраны с английского, русского, французского, немецкого, греческого, латинского, и испанского языков, чтобы помогать память. Если надо будет, совершенно возможно добавить новые слоги, как так около 2000 новых слогов возможны по нумаудным правилам.

АЛФАВИТНЫЙ СПИСОК СЛОГОВ В СИСТЕМЕ, С ОБЪЯСНЕНИЯМИ: *СМ. СТР. 52,53.*

## RESUMEN EN ESPAÑOL

El Numaudo es sistema *silábico*, que sirve para expresar en forma audible los símbolos matemáticos y lógicos. Cada sílaba del código Numaudo significa una cifra, una letra del alfabeto latino o del alfabeto griego, un símbolo matemático, o un símbolo lógico. El Numaudo no es idioma por sí mismo. Se llama *Numaudo*, según las dos voces latinas: *numerus*, número, y *audire*, oír, porque las sílabas de este sistema son «números audibles». La pronunciación de las letras del alfabeto del Numaudo es fonética e internacional, y sigue, en principio, la pronunciación de los símbolos de la Asociación Fonética Internacional.

Se dice frecuentemente que las matemáticas son «la lengua de las ciencias». Pero esta lengua no se habla jamás; existe solamente en forma escrita. Cuando se leen en voz alta los símbolos matemáticos, se *traducen* en lengua ordinaria. Por ejemplo, las dos cifras *15* no se leen «*uno, cinco*», sino «*quince*». La palabra *quince* no es representación audible de las cifras *15;* es *traducción* de ellas. Hay sistema matemática escrita de casi perfecta internacionalidad, mientras que en cada país se traducen los símbolos del sistema en palabras del idioma del país. El Numaudo no traduce, porque no es idioma, sino representación audible de los símbolos matemáticos. El que habla Numaudo, habla aritmética, álgebra, cálculo, o lógica.

Después de la adopción del código Numaudo, irá más rápida y fácilmente el pensamiento matemático, porque las sílabas numáudicas conservarán enteramente la exactitud de los símbolos matemáticos escritos. Los discípulos aprenderán las matemáticas más rápidamente también.

El progreso tecnológico, hecho durante los años 1947-1960, nos ha dado máquinas de calcular electrónicas y otras aplicaciones de los principios matemáticos a las ciencias e industrias. Hay máquinas automáticas que se arrancan por mandamientos hablados en el micrófono. Para economizar lo más posible en la fabricación de tales mecanismos, necesita un sistema—como el Numaudo—científico y regular.

Explicación de los sonidos numáudicos: Las vocales se pronuncian como en español. Los diptongos también tienen sonidos semejantes a los españoles. Hay consonantes cuyos sonidos difieren de los sonidos de las consonantes españolas, a saber: la b tiene sonido más fuerte que la b española; la d es más fuerte también; la g siempre se pronuncia como en la palabra gato; h no es muda, sino tiene el sonido de la j española; la j numáudica, al contrario, es símbolo fonético que se pronuncia como y española; la r tiene preferentemente el sonido fuerte de rr; la v debe ser distinta de la b, y los que no pueden pronunciar la v labiodental pueden substituirla por u muy breve, como en la palabra huevo; la z es la z inglesa y francesa, teniendo sonido semejante a la s suave en desde, rasgo. Es muy importante la clarísima y distintísima pronunciación de cada sílaba numáudico.

El Numaudo será útil en su forma escrita, así como en su forma primera de sistema hablado. El escribir del álgebra y del cálculo presenta muchas dificultades: la mezcla de letras latinas y griegas, las pequeñas cifras, difíciles de leer, y los signos cabalísticos que se hallan en pocas tipografías. Hoy día, cuando la tecnología afecta tan profundamente a todo el mundo, es necesario facilitar la aplicación de las matemáticas. Necesita método para telegrafiar expresiones matemáticas; necesita sistema para escribir expresiones matemáticas por máquina. El Numaudo efectua ambos objetos fácilmente. Todo que ahora se escribe por los símbolos, las cifras, y las letras latinas y griegas, para expresar las ideas matemáticas, se puede escribir y hablar también en Numaudo. Las 450 sílabas del sistema Numaudo se escriben por 21 letras ordinarias. No es necesario aprender signos especiales. No hay sonidos difíciles de oír por teléfono.

Para comenzar a aplicar el Numaudo en cualquiera empresa, bastan 40-50 sílabas al principio. No es necesario el aprender de todas las 450 sílabas.

Véase la lista de las sílabas numáudicas en las páginas 52 y 53.

# *Numaudo*

IVOR DARREG

*ABSTRACT:* A novel coding system for mathematical signs, numerals, punctuation marks, binary and octal notations, and symbolic logic has been devised. Called "Numaudo" (i.e., *audible numbers*), the system provides 450 syllables easily pronounceable by persons of most nationalities. Nearly all mathematical and logical expressions, and the common physical unit designations, can be spoken by means of these syllables, which are compatible with words of the major languages. The system can be used for spoken as well as written input and output, in connection with automatic control devices, electronic computers, and information processing equipment. When applied to the discussion and teaching of mathematics and symbolic logic, the system will accelerate learning processes and promote general mathematical literacy. The written form of the system can be transmitted by Morse code or teletypewriter, and is easily printed, since it does not require any characters other than the letters of the ordinary Roman alphabet.

*Name:* The system herein described is called *Numaudo,* from the Latin words *numerus,* number, and *audire,* to hear. While an English pronunciation of the name will be tolerated, it is recommended that *Numaudo* be pronounced in internationally acceptable fashion: viz. with the first *u* as in *rule,* the diphthong *au* as *ou* in *out,* and the final *o* as in *orb,* the stress falling on the second syllable.

*Scope:* Syllables have been provided, in accordance with a logical and phonetic scheme, to cover the ordinary needs of arithmetic, algebra, calculus, theory of numbers, Boolean algebra, symbolic logic, and related fields. In addition, a special code for the powers of ten has been provided, and several codes for binary and related notations used for computer work. There are syllables for the common physical units, and for the so-called "relation words" frequently encountered in mathematical contexts. A spoken punctuation method is also supplied, together with a set of optional syllables. The assigned syllables (which are listed on Pages 52 and 53) total just over 450, yet ample room for expansion of Numaudo in the future is left, since over 2000 additional syllables could be formed in full compliance with the principles of the system.

While a system of this nature is likely to appear arbitrary in some of its features, Numaudo will not present any actual memorizing problems. Most of the syllables have been derived from words in the principal languages, as explained in the text. Nearly all the remaining syllables have been constructed in a thoroughly systematic manner, and as each one is introduced, an explanation or mnemonic aid will be appended. The average person using Numaudo will only have to commit about 40 syllables to memory—those pertaining to some specialized field.

*Convertibility:* As far as was feasible, Numaudo was so designed that its syllables could be read off one-for-one from a page written in *conventional* mathematical and logical notations. Conversely, conventional symbols can be written down from dictation in spoken Numaudo. The written form of Numaudo closely follows the accepted international phonetic transcription, while provision has been made to allow transmission of all present and future Numaudo syllables by teletypewriter, Morse code, and other methods restricted to the ordinary Latin alphabet. Accordingly, through Numaudo every ordinary typewriter becomes a mathematical typewriter, and no special symbols are required to print mathematical or logical expressions—not even numerals or punctuation marks.

*The Need for Numaudo:* Mathematics and symbolic logic are often referred to as "languages"—yet they, unlike the other languages, whether natural or artificial, *began with written forms exclusively,* no attention being paid to the possibility—or desirability—of pronouncing their symbols; whereas *other languages began as purely spoken systems,* surviving for many millennia before writing was invented.

Thus we have a paradoxical situation: Virtually the same mathematical symbols are in use the world over—practically every country has accepted the Arabic numerals, and conventional signs for operations, together with Roman and Greek letters for various algebraic and other purposes. Yet in each country these internationally-uniform written symbols are *spoken differently*. Furthermore, the numeral-names in most languages are irregular, *e.g.*, in English there are special words for *eleven* and *twelve;* in *thirteen, fourteen,* etc., the units digit is read first, whereas in *thirty-five, sixty-seven,* etc., the tens digit is read first. Again, as one goes from arithmetic to algebra and then to other branches of mathematics, it becomes more and more difficult, whatever one's native tongue, to read off formulas and equations. Awkward circumlocutions are required. Ambiguities often result, even if the written form is clear enough.

Thus, if we have a uniform written mathematical notation, it seems only reasonable that there should be an equally international spoken form also. Upon devising the Numaudo system, it was found that it could be made compatible with the principal languages, so that Numaudo words can be used in English, Russian, French, Spanish, German, Italian, and other sentences; and it further became apparent that the written form of Numaudo syllables could be made compatible with existing communication devices, as already mentioned.

Rapidly accelerating technological changes—the introduction of electronic computers, the development of information theory, the emergence of automatic data-processing methods, and recently experimentation with mechanical translation of languages, and with information storage and retrieval systems—have not only demanded corresponding progress in mathematics, but also in symbolic logic and in borderline fields, such as Boolean algebra and the algebra of classes. Wider ranges of magnitude have to be dealt with, so that notations such as $3 \times 10^{-9}$ now are quite common. Machines will be built that can respond to spoken instructions, and/or give out spoken data. The wide availability of telephone circuits and sound-recording devices provides a further reason for Numaudo.

So long as mathematics remained the possession of a scholarly élite, the awkwardness of mathematical expressions in spoken form was not a serious problem. Today, however, nearly every school student will have to become mathematically literate. A few decades ago, it sufficed to know arithmetic and be able to recite the multiplication table to oneself or mumble the sums one was adding. Now this is not sufficient; one will need to "think in algebra"—the spoken or imagined auditory accompaniment to mathematical and logical problem-solving will need to be just as fluent and rapid as the visual phase. Thus a readily-spoken symbol-code will speed up the learning process, as well as facilitating the remembering and using of mathematical and logical procedures after one has left school. Indeed the primarily-written nature of contemporary mathematics, as against the primarily-spoken nature of ordinary language, could well explain the widespread antipathy to mathematics as a school subject, and the difficulties many have acquiring mathematical skills, even when they sincerely want to do so.

Quite possibly, the existence of an auditory form for most mathematical and logical symbols will lead to faster thought-processes among mathematicians, as well as with engineers, scientists, and anyone else who must do mathematical thinking. In addition, it is likely that the existence of Numaudo will permit actual *conversing in mathematics and talking symbolic logic,* in a way that is not possible with the present makeshift expedients.

Another use for Numaudo will be in the teaching of mathematics to the blind, and to schoolchildren whose sight must not be strained with excessive reading. No problems should be encountered in transcribing Numaudo into Braille.

Note that when a given set of mathematical or logical symbols are read in Numaudo instead of being read in an ordinary language, there will be a considerable saving of time. Correspondingly, the written form of Numaudo will take up less space than would the words used to denote mathematical symbols, numbers, etc.

*Alphabet and Pronunciation:* The following letters form the primary alphabet for Numaudo: *a, b, d, e, f, g, h, i, j, k, l, m, n, o, p, r, s, t, u, v, z.* As secondary or supplementary letters the following may be used, as will be explained: c or *ʃ*; *q, ə,* or *ö*; ʔ or *ʔ*; y or *ü*. Because Numaudo is an international code for the already international written mathematical and logical symbols, it has to have an equally international phonetic basis. Work done by experts in linguistics and kindred fields has established certain principles, which have been taken into account in constructing Numaudo.

For example, it is well known that the different languages, and even different dialects of any one language, have widely-varying sound-systems. No French sound, for instance, corresponds *exactly* to any English sound, though most sounds of one language have their rough counterparts in the other. A numaudo-type code based upon English sounds would be useless and unintelligible to most Europeans and Orientals, and the British pronunciation of such an English code might not be intelligible to Americans. While any one of the ordinary languages possesses from 30 to 45 speech-sounds, there will be varieties and sub-varieties of each such sound. A trained phonetician can recognize hundreds of speech-sounds, and the standard International Phonetic Alphabet has over a hundred letters, with diacritical marks and modifying symbols making about a thousand notations possible. Such precision, however, and such fine distinctions are intolerably cumbersome for denoting connected speech. Thus attention has been given in the last two decades to *phonemics,* or the study of broad categories of sounds actually used to distinguish words in any given language.

While a language such as English can have 30 or more *phonemes,* a spoken code such as Numaudo cannot have so many, because it must be intelligible to a German when spoken by a Russian, or intelligible to a Japanese when spoken by a Greek. More important still, a computer-input device, an automatic machine of the voice-controlled type, a voice-actuated typewriter, or other apparatus yet to be invented, must function equally well, whatever the nationality or accent of the person—or the machine!—that speaks Numaudo into it. Furthermore, as already mentioned, it must be possible to insert Numaudo code syllables into sentences spoken in any ordinary language, natural or artificial, without confusion or ambiguity resulting.

Obviously, total compatibility of this sort is unattainable. The twenty most widely-spoken languages just do not have a sufficient number of sounds in common, or even nearly equivalent, to construct an ample code-system. Nevertheless, it is feasible to construct a system which is 90% compatible, and in which ambiguities are rare. In the following pronunciation list, it will be noted that any one sound may be pronounced in several ways. This latitude will take care of such circumstances, for instance, as the absence of a *w*-sound in Russian while several other languages have a *w*-sound but no *v*-sound, and still other languages have neither, but do have a sound intermediate between *w* and *v*.

Voice-operated machines and computer inputs should be designed to respond to any sound within the range indicated—that is, to phonemes rather than to allophones —and speaking machines, such as talking voltmeters, computer outputs, and telemetering apparatus that responds to interrogation, should be designed to utter intermediate qualities of speech-sounds, at the center of the tolerance range, whenever possible.

In Numaudo, the vowels have their Continental values:

*a* as in *father, ah;* (the French sounds of *a* in *là* and *pas* are both acceptable);
*e* as in *let, met* (*ĕ*); *e* in *there* is accepted also;
*i* as in *police, machine* (English long *ē* in *me*); (never *ĭ* as in *bit*);
*o* as in *orb, porch,* or as the *aw* in *lawn;* (but not *ō* or *ŏ* as in *go* or *hot*);
*u* as in *rude, June*—but *u* as in *put* will be tolerated.
The supplementary vowels will be discussed later.

The Consonants are sounded as follows in Numaudo:

*b* as in *bib* ;
*d* as in *did* ;
*f* as in *fluff* ;
*g* as in *gag* (never "soft" as in *ginger*) ;
*h* as in *hit, hold, hot,* or better still as German *ch* or Spanish *j* (always fully sounded, never silent, and never used in any digraphs such as *ph, ch, th;* Italians, Frenchmen, and others who cannot pronounce *h* may substitute the English or French *j*-sound);
*j* as the *y* in *yet, year, young* (This is the value of j as an International Phonetic Symbol, and j must not be given its English sound) ;
*k* as in *kick* ;
*l* as in *lull* ;
*m* as in *minimum* ;
*n* as in *noon* ;
*p* as in *pip* ;
*r* as in *roaring,* or better still as trilled Italian or Spanish *rr* ;
*s* as in *sassafras* (never as in *was, rose, vision,* or *sugar*) ;
*t* as in *take, tot* (never *th,* and never as in *nation*) ;
*v* as in *very* (but any sound between *v* and *w* as in *well* will be tolerated) ;
*z* as in *zero, zeal, fizz* .

*BEFORE READING FURTHER, PLEASE REVIEW CAREFULLY ALL THE VOWEL AND CONSONANT SOUNDS GIVEN ON THIS AND THE PRECEDING PAGES!* Hardly any language but English ever spells the vowel sounds as: *ā* in *late, ă* in *hat, ē* in *me, ĕ* in *her, ī* in *mile, ĭ* in *bit, ŏ* in *dot, ō* in *son, ŏ* in *move, ū* in *music, ŭ* in *but.* Therefore Numaudo syllables would not be understood internationally if pronunciations according to such English spellings as those just given were permitted. To function as the existing written symbols function, and to be their proper audible representation, Numaudo must conform as closely as possible to international phonetic practices.

The *supplementary letters* mentioned above have not been used in any of the 450 syllables assigned within this article. (See Pages 52-53 for an alphabetical list.) They are merely optional, being given only as a hedge against future unexpected developments. Otherwise stated, if anyone insists on adding more sounds to the Numaudo system, the supplementary ones given here are the ones to add first. If they are never added, so much the better. The Supplementary Sounds are pronounced as follows:

*ʃ, š* (may be coded as *c*) either as *sh* in *fish* or as *ch* in *church* ;

*ø, ö, ə,* (may be coded as *q*) as German *ö* or as *ŭ* in *up* ;

*ü, y* as French *u* or German *ü* (this sound does not occur in English) ;

*ʔ* (may be coded as a standard question-mark or as an apostrophe), the glottal stop, best described as a catch in the throat, and heard in American *oh-oh* when it means disappointment or surprise. Most languages have the sound, but no letter for it.

The characters *ʃøyʔ* are official international phonetic symbols. The characters *š, ö, ü, '* are widely accepted by philologists. The character *ə* is almost universally used for the obscure *a* in *sofa,* a sound near enough to *ö* and to *u*-in-*but* that a system such as Numaudo can ignore the differences. The codings *c, q, y, ?'* are mere expedients for typewriter and punched-card use, save that *y* happens to be an official phonetic symbol.

Accordingly, the letters *w* and *x* will never be used in Numaudo syllables (see Page 50 for further information) and *c, q,* and *y* may never actually come into use. Thus five letters of the standard 26 are available for non-speech uses, such as symbolizing bells, buzzers, tone-signals, or the like that may be used by some machines that also utter spoken-Numaudo sounds.

Numaudo may be punctuated like ordinary language, since syllables will be supplied for all uses of dots, commas, colons, etc. Written Numaudo may follow the punctuation rules of the French language.

For the English-speaking Numaudo user, a word about *diphthongs:*

If two vowels are used in forming a Numaudo syllable, the resulting diphthong does not have a value different from what should be expected from the pronunciation of the vowels taken separately, as explained at the bottom of Page 3. That is, these vowels are phonetic symbols, not subject to the vagaries of French or English spelling principles. Thus *ai* will have the sound of *ai* in *aisle; au* will sound like *ou* in *house; ei* will sound like *ei* in *eight; oi* will sound like *oi* in *oil; ou* will sound like *ow* in *mower; ui* will sound like *ooey* in *gooey.* Diphthongs will be used sparingly, although cases will occur where it will be better to use diphthongs rather than the two supplemental vowels. Any two vowels, even two of the same vowel, may be combined to make a diphthong; but only those listed above are congenial to speakers of the principal languages. In all cases the loudest, or stressed, vowel is the first one in the diphthong.

N.B.: As already explained, conventional mathematical symbols are *a written system without a legitimate spoken form.* Thus at this point it is time for a reminder that *spoken Numaudo* is a code for the conventional written mathematical and logical symbols, and *written Numaudo* is a code for a code--a code of the second order--and thereby subsidiary to spoken Numaudo. In actual teaching of this system, *viva voce* instruction by the teacher, or sound recordings, will present spoken Numaudo syllables while the conventional mathematical symbols are shown or pointed to, to establish a firm association between them. The written form of Numaudo will be taught later on, in order not to cause difficulties with languages such as French or English, which are unphonetically spelled, or with languages such as Greek, Russian, Japanese, or Hebrew, which do not use the Roman alphabet.

This reminder has been inserted here because necessary emphasis within this paper upon the written form of Numaudo may cause one to forget that the spoken form of this system is primary to the written, and far more important. However, it remains to be seen whether the ability, by means of written Numaudo, to print mathematics and symbolic logic with only 21 letters, not even needing numerals, will promote mathematico-logical literacy.

*Construction of the Syllables:* The fact that the major languages possess relatively few sounds and sound-combinations in common, severely restricts the number of ways in which sounds can be combined into syllables, as well as the number of elementary sounds that can be used in such syllables. This explains why some of the syllables will appear arbitrary. For example, the Indo-European languages agree surprisingly well in their numeral names, and such forms as *tri* for *3* and *sep* for *7* in the compiled language Esperanto would be understood all over Europe. Numaudo cannot use such international names for the ten digits because Numaudo must meet the needs of present and future machines as well as persons. That is, Numaudo has been designed so as to make it easier to build a machine that can listen to or speak Numaudo than to build one for some other system.

First in order of preference are syllables *beginning with a consonant and ending in a vowel,* such as: *ba, do, ki, mo.*

Next come syllables *beginning with a consonant and ending in a diphthong,* such as: *bau, mai, lei, noi, sau.*

Third come syllables of the pattern *consonant-vowel-consonant,* such as: *lem, nun, sek, mis, fad.*

Fourth in rank would be those patterned *consonant-diphthong-consonant,* such as *laim, feis.*

Last of all are any syllables that would have to contain *supplementary sounds.* These are to be avoided if possible. This includes vowels or diphthongs by themselves: refer back to remarks on *?* (glottal stop), lower part of Page 4.

*Consonant-clusters are not to be used at all:* No syllables like *stu, fand, pleits, tra, miks,* &c., may be added to the system. The reason is that many languages forbid consonant-clusters.

There are not to be any *closed syllables of the type vowel-consonant:* Such syllables as *ap, eb, oist, ost, erd* are never to be introduced into Numaudo.

The ending of syllables with *voiced consonants,* as *moid, reb, sug,* is to be avoided as much as possible by substituting the corresponding voiceless consonant, so that *ref* will be preferred to *rev, lup* to *lub, mas* to *maz*--but in such cases as *log,* where a conventional symbol can be carried over intact into Numaudo, the voiceless-consonant counterpart (in this case, *lok*) will be kept out of use as long as possible, and assigned to something as unrelated to logarithms as possible if it should ever have to be used. This accommodates speech-patterns of speakers of German, Dutch, Russian, Polish, and quite a number of other languages which avoid final voiced consonants.

As far as possible, syllables containing *l* and those containing *r,* but otherwise identical, will not be assigned to similar notions. This is out of deference to Chinese, Japanese, and several other languages which do not possess both *l* and *r.*

Such syllables as *de, vu, tu,* which are words in several languages, are preferably assigned in such a way that they will not occur by themselves in such a way that they could be mistaken for such words when spoken in conjunction with those languages. This has been done where practicable, and this principle should govern the assignment of other syllables as Numaudo grows in vocabulary.

Despite the restrictions enumerated, there is ample "room for expansion" in Numaudo, and as it is tested, used, and improved, ideas for further growth of a kind not clearly visualized at present will occur to its users.

One important reason for restricting the type of syllables allowed, is to make it as easy as possible to analyze a long spoken or written "word" into its constituent syllables, and to preclude ambiguity that otherwise would result from wrong syllable-divisions. Listening machines, especially, will be much more reliable, and less expensive to construct, when it is determined beforehand that they will not have to handle syllables beginning with vowels, and that any succession of two consonants *must* be from the end of one syllable and the beginning of another.

## COMMON SYMBOLS AND THEIR NUMAUDO REPRESENTATIONS:

(NOTE: Pronunciations in English spelling will be given in parentheses after each Numaudo syllable. This is for the aid of English-speaking learners only, and such English-type spellings are not actually to be used in writing Numaudo.)

*THE TEN DECIMAL DIGITS:* These, the fundamental and most frequently-used syllables in the Numaudo system, are constructed according to these principles:

a) Even digits begin with voiced consonants;

b) Odd digits begin with voiceless consonants;

c) The five vowels, *a, e, i, o, u,* in that customary alphabetical order, are used twice in succession to form the ten syllables.

This has been done in order to aid memory, to simplify the design of automatic spoken-digit-recognizing equipment, and to permit simplification of devices incorporating binary-coded decimal representation.

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 0 |
|---|---|---|---|---|---|---|---|---|---|
| *sa* | *ze* | *fi* | *vo* | *pu* | *ba* | *te* | *di* | *ko* | *gu* |
| (sah) | (zeh) | (fee) | (vaw) | (poo) | (bah) | (teh) | (dee) | (kaw) | (goo) |

The customary decimal positional notation is followed, but commas are not used in the written form, since the comma is a decimal point in most countries. Instead, a space may be left between each group of three syllables, and in speaking there will be a slight pause after each such group of three numerals, and a slight stress on the first syllable of each group of three. Optionally, the groups of three syllables forming large numbers may be connected by hyphens.

(*Te* is pronounced *tĕ*, as in *test; Ze* is pronounced *zĕ*, as in *zealous, zest.*)
Examples: 8, *di* ; 18, *sadi* ; 418, *vosadi* ; 3,418, *fivosadi* or *fi-vosadi* ;
(dee) (sah-dee) (vaw-sah-dee) (fee-vaw-sah-dee) (fee, vaw-sah-dee)

249,135,780, *zevoko-safipu-tedigu* ; 400, *vogugu* ; 67,016, *bate-gusaba* ; 98, *kodi* .
(zeh'vaw-kaw, sah'fee-poo, teh'dee-goo) (vaw'goo-goo) (bah'teh, goo'sah-bah) (kaw-dee)

Ordinarily, long numbers will not present a problem. Present-day numerical data, particularly in scientific practice, often is expressed with one or two significant figures, multiplied by a positive or negative *power of ten*. Therefore, a special method for coding powers of ten has been incorporated into Numaudo, thus:

Suffixing *de* to a number will multiply it by a *positive* power of ten. In other words, *de* means: "(--- times) ten to the *n*th power".

Suffixing *do* to a number will multiply it by a *negative* power of ten. In other words, *do* means: "(--- times) ten to the minus-*n*th power".

In Numaudo expressions of this kind, the number to be multiplied will come first, then *de* or *do*, then the number expressing the absolute value of the exponent that ten is to have. All the syllables involved will be written as a single word, as this will prevent ambiguity, rather than causing it. In speaking, *de* or *do* will be slightly prolonged. ⟶ *please note pronunciation carefully:* (deh) (daw)

To lessen the burden on the memory, separate syllables have *not* been provided for such powers of ten as *hundred, thousand, million,* etc. It is really much simpler to say, for instance, *sadeko* for $1\times10^9$, than it would be to invent a word, requiring a separate memorization effort, to mean "1,000,000,000". In many cases, an even shorter form, *deko,* could be allowed. (Admittedly, two other possibilities exist: with the exponent representation described on Page 8, one can say *sagupoko;* and then there is the rather impractical "brute-force" method of "spelling out" as *sa-gugugu-gugugu-gugugu.* )

Examples: $3\times10^7$, *fidete* ; $3\times10^{-7}$, *fidote* ; $10^{29}$, *sadezeko* or *dezeko* ;
(fee-deh-teh) (fee-daw-teh) (sah-deh-zeh-kaw) (deh-zeh-kaw)

$10^{-15}$, (*sa*)*dosapu* ; $3.2\times10^{-11}$, *finaze-dosasa* ; $4.7\times10^{23}$, *vonate-dezefi.*
[(sah-)daw-sah-poo] (fee-nah-zeh, daw-sah-sah) (vaw-nah-teh, deh-zeh-fee)

In speaking, pauses and inflections of the voice will be used as required to assist in making the meaning clear. However, speaking fluently in Numaudo code will not be difficult or complicated: any impressions of difficulty are merely the result of the inability to convey in writing all the pertinent aspects of a *spoken* system.

As the above examples have just illustrated, the *decimal point* is represented by the syllable *na*. Incidentally, this substitutes a uniform syllable for the usual European comma (as in *3,56*) the American period (as in *3.56*) and the usual British raised period (as in $3{\cdot}56$). A pause before the decimal-point syllable is optional. Some digital machines may require a warning that a number is less than unity: in such cases, *gu* should precede *na*. Elsewhere, this *gu* is optional.

The *plus sign* +, when, and only when, it is used as the *addition operator,* is spoken as *pa*. Example: 43+75, *vofi pa tepu* .
(pah) (vaw-fee pah teh-poo)

However, when no addition is performed, and the plus sign merely is prefixed to show that a number is positive as opposed to negative, *ga* is the rendering. (gah)

Similarly, the minus sign as *subtraction operator* is expressed by *mi,* but the minus sign prefixed to *negative numbers* is rendered by *go*. (mee) (gaw)

*TOTALS* may be preceded by the syllable *toit*. Sub-totals or intermediate results may be indicated by prefixing *tois*. (toyce) (toyt)

The main reason for making a distinction between signs and operators is that Numaudo will be used in many cases for giving instructions to machines, or for talking about machines and instructions to them. The instructions "a negative number will follow" and "subtract the following number from the preceding one" may be quite different. Similar reasoning applies to the distinction between a sign to show a number is positive, and instructions to add it to something else.

*Also, there are such cases as the indication of charged ions in chemistry, polarities in electrical engineering, etc., where the use of two kinds each of plus and minus signs may be helpful.*

Multiplication is indicated by the syllable *mu*, but, as in the conventional written symbol-system, the syllables which stand for the letters used in algebra (these syllables will be given later) may be juxtaposed to indicate multiplication without need for *mu*. Whether the conventional multiplication sign be ×, or the · dot (raised above the line in American practice, on the line elsewhere) the Numaudo representation is uniformly *mu*. (moo) (As an aid to memory, this is the first part of the word "multiply".)

*NOTE: certain syllables, such as -de- and -do-, already mentioned, include the notion of multiplication, so need no* mu.

Division, whether expressed by the fraction bar /, by the horizontal line —— separating numerator and denominator, by the division sign ÷, or by words such as "over" or "divided by", is uniformly expressed by *da* in Numaudo. Fractions with several members in numerator or denominator will be expressed with the aid of parentheses, as will be explained below.

Examples: ¾ *fidavo* or *fi da vo* ; 100 ÷ 7 *sagugu da te* . $\frac{34}{1783}$ *fivo da* (feedahvaw) (fee dah vaw) (sahgoogoo dah teh) (feevaw dah *satedifi* . sah-teh-dee-fee)

Exponents are expressed by the syllable *po* (from the word "exponent") preceding them, and, if anything follows the exponent that could cause ambiguity, the syllable *nu* follows the exponent and precedes this other sign. In other words, *po* and *nu* are used as parentheses to enclose the exponent. Furthermore, various kinds of superscripts, as the 2 in the expression for a second derivative, or the expressions placed above Σ, are treated in Numaudo as though they were exponents and enclosed between *po* and *nu*.

Subscripts, in a similar manner, are preceded by the syllable *su* (which, of course, is the first part of the word "subscript"), and, if necessary, just as has been explained in the case of exponents, are followed by *zu*.

In the rare cases where subscripts or exponents have their own subscripts or exponents, the syllables are doubled: *popo, nunu, susu, zuzu*.

Expressions underneath a Σ are treated as subscripts.

The radical sign √ is expressed by two or three syllables: *ra* precedes the radicand and *re* follows the radicand. If the index be other than the (conventionally understood) 2, *ru* precedes the index, these being followed by *ra*, the radicand, and *re*. Examples: √2 *razere* ; ∛2 *rufirazere* ; ∜24 *rusaze razevore* ; (rah-zeh'-reh) (roo-fee'-rah-zeh'-reh) (roo-sah'-zeh--rah-zeh'-vaw-reh)

√94607 *ra-kovobagute-re* . (*R* in these syllables stands for *radical*.) (rah-kaw-vaw--bah-goo-teh-reh)

The equality sign = is expressed by *fe*, pronounced as in *fed, fence*. (This is for the French word *fait*, often used in this meaning.)

EXAMPLES: 2 + 3 = 5 *ze pa fi fe pu* . (zeh pah fee feh poo) 197 - 83 = 114 *sakote mi difi fe sasavo* . (sahkawteh mee deefee feh sahsahvaw)

8 × 7 = 56 *di mu te fe puba* . (dee moo teh feh poobah) 27 ÷ 3 = 9 *zete da fi fe ko* . (zehteh dah fee feh kaw)

*Parentheses* of course take a pair of syllables, *to* for "(" and *tu* for ")". Brackets, similarly, have *ho* for "[" and *hu* for "]". Braces, being less often used, take three-letter syllables: *tot* {, *tut* }.

Examples: (5-2)×(4+3) *to pu mi ze tu mu to vo pa fi tu* . ( taw poo mee zeh too moo taw vaw pah fee too)

$(2+3+5)^2$ *to ze pa fi pa pu tu po ze (nu)* [ taw zeh pah fee pah poo too paw zeh (noo)].

The *vinculum*, ‾‾‾‾, as sign of aggregation, is rarely used, but the syllables *hot* and *hut* may be used, just as though the vinculum were a pair of parenthesis-like signs. The customary radical sign √ is sometimes considered as though it were the element √ followed by a vinculum over the radicand, but in Numaudo, radicals will be dealt with as already has been explained on the lower half of Page 8. Likewise, the fraction-bar is not considered a vinculum in Numaudo, but is expressed as has been set forth in Paragraph 4 of Page 8.

As explained at the bottom of Page 7, the syllable *ga* has been assigned as an optional plus sign + for denoting positive numbers (equivalent to multiplication (gah) by +1), while the syllable *go* is the minus sign for prefixing to negative numbers (equivalent to multiplication (gaw) by −1). The syllable *gi* stands for the so-called (ghee—*gea* as in *gear*) "imaginary unit" $\sqrt{-1}$, and as an aid to memory the *i* in this syllable may be thought of as the *i* commonly used to represent $\sqrt{-1}$. (Naturally, the *j* used instead of *i* in such fields as electrical engineering will also be represented by *gi* in Numaudo.) The syllable *ge* stands for −*i*. Thus all four syllables *ga, ge, gi, go* may be regarded as operators or signs, and are prefixed to other syllables which stand for (hard g as in "get,") numerals or letters, to form *complex numbers* of the type $a \pm ib$. If the representation of an imaginary in conventional notation should happen to have the *i* last, it will be transposed in Numaudo; thus *i*3 or 3*i* will both be expressed as *gifi*. (Hard G again: gheefee) This uniform representation will allow complex numbers to be expressed with fewer syllables without risking ambiguity. The use of *gi* by itself to mean *i*, and *ge* by itself to mean −*i*, will be allowed.

Examples: +4 +*i*7, *gavogite* (gahvawgheeteh) +4−*i*7, *gavogete* (gahvawghehteh) [ge as in get]

−4 +*i*7, *gavogite* (gaw vawgheeteh) −4−*i*7, *govogete* (gawvawghĕteh)

+6.2 +*i*37.9, *gabanaze−gifitenako* (gahbahnahzeh−gheefeetehnahkaw) −2.8−*i*67.0, *gozenadi−gebatenagu* (gawzehnahdee−ghebahtehnahgoo)

It is possible that there will be special machines or storage devices, the input to which will consist mainly or exclusively of complex numbers. In such cases, it may be advisable or necessary to put in real numbers in the form +3 +*i*0 *gafigigu*, and pure imaginaries in the form (+1×0)+*i*2 *gagugize*. Whether the (gahgoogheezeh) "plus sign" *ga* will or will not be necessary before positive real numbers, will (gahleegheegoo) depend on the requirements of the machine. It was assumed in the above examples that machines would usually require its use.

Of course, in the teaching of mathematics and in fields other than engineering, other Numaudo renderings of imaginary and complex numbers than those recommended above, may be employed.

From what has already been said, and what will be explained below, the extension of Numaudo to the representation of hypercomplex numbers, co-ordinates, vectors and the like, will be sufficiently obvious. At this stage—that of an initial, elementary presentation of the Numaudo system—we do not wish to be too specific about those details of the system that are better elaborated by the persons versed in specialized fields, who will extend the system as need will dictate.

Since the conventional mathematical notation has the resource of *blank space* to aid in grouping items for avoiding ambiguity, whereas an interval of silence in spoken Numaudo may not necessarily be unambiguously equivalent to such a blank space—and in the case of tape-recorded speech or punched-or-recorded-tape coding of written Numaudo, blank tape may not necessarily equal blank spaces of the conventional notation, the syllable *ri* (ree) has been assigned as a *separation mark*, to be inserted wherever needed to avoid ambiguity or to group syllables in neater or more comprehensible fashion.

Besides the separation mark *ri*, there is another *special separation mark, ha.* *Ha* is used primarily to separate the integer from the fraction in mixed numbers. That is, *ha* would be used in the Numaudo rendering of 1 1/32 to prevent it being misread as 11/32. Sometimes it might be helpful to use *ha* to mean "the number following is the numerator of a fraction", since many circumstances could arise where the syllable *da* might come too late. *Ri* and *ha* will have uses in symbolic logic and other applications—eventually more separation-marking syllables may have to be assigned.

Examples: *Counting:* 1, 2, 3, 4, 5, ... *sa ri ze ri fi ri vo ri pu* ...
(In those cases where a sequence of numbers might be misinterpreted as a single large number "12,345" or the like)

*Ri* to indicate the end of a line in reading off a table.

3 √2 *fi mu razere* (an example where the separation marks are not used).
(fee moo rahzehreh)

1¼ *sa ha fidavo* (sah hah feedahvaw) 2½ *ze ha sadaze* (zeh hah sahdahzeh) 5-1/3 *pu ha sadafi* (pooh hah sahdahfee)

1, ¼, 1½, ... *sa ri fidavo ri sa ha sadaze* ...
(sah, ree feedahvaw, ree sah hah sahdahzeh ...)

(This last example represents a case where the quantities here separated by commas are successive entries in a list, entries in a line or column of a table, successive instrument readings called off as they are observed, etc.)

It will be understood, of course, that these separation marks are not mandatory. If, through rhythmic grouping, stress, inflection of the voice, etc., it is found possible to avoid ambiguity, then the separation marks may be omitted. Or, they may be used at the beginning of a Numaudo utterance to establish the pattern, and then dropped. *Ri* may be repeated, *riri,* to indicate a greater separation.

*Ordinal numbers* are indicated by suffixing the syllable *ma*. "Ordinal" is here to be taken in a generalized sense, as this use of *ma* will be found helpful even outside mathematics proper, and will extend the usefulness of Numaudo.

1 or one, *sa*. (sah) First, *sama*. (sahmah) 2 or two, *ze*. (zeh) Second, *zema*. (zehmah) 3 or three, *fi*. (fee) Third (ordinal, not fraction), *fima*. (feemah) *N*th, *nima*. (neemah)

The constant *e* (2.71828+), the base of natural logarithms, is represented by the syllable *ke* (pronounced as *kĕ* in *keg*). Note that when the letter *E* or *e* is used for any other purpose than to denote this number, it will then be represented by *ju* (yoo) (see "letters" below).

The constant π (3.14159+) is assigned the syllable *pi* (pronounced *pee*), as this is the pronunciation of the name of that Greek letter in most languages except English.

The large capital Π, denoting a continued product, is represented by the syllable *pir* (pronounced as the word *peer*).

The large capital sigma Σ is assigned the syllable *si*. As already explained (see) in the middle of Page 8, the expressions conventionally printed above the sigma are treated as if they were exponents, and the expressions conventionally printed below the sigma are treated as if they were subscripts. This device is to reduce the burden of remembering additional syllables, as ambiguity could hardly result.

The *continuation sign, three dots* ... , and the abbreviation *etc.* or equivalent words, are represented by the syllable *mo*. This is done whether further expressions follow the continuation sign or not.

Examples: 1, 4, 9, 16, ... *sa ri vo ri ko ri saba mo* .
(sah ree vaw ree kaw ree sahbah maw )

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Examples: 1, 4, 9, 16, ... *sa ri vo ri ko ri saba mo .*
(sah ree vaw ree kaw ree sahbah maw )

(Examples continued from preceding page) 1, 2, 3, ... 10 *sa ri ze ri fi mo sagu*
(sah ree zeh ree fee maw sahgoo)

The *comma* when used for "ordered couples" and similar purposes, and also when used in symbolic logic, is represented by the syllable *ki*. Note that (Page 6, at bottom) the comma used in English-speaking countries to (kee) set off groups of three figures in large numbers, and the comma used as a decimal point in other countries, are *never* represented by *ki*. *Ki* may be used as a separation mark.

Example: ( 3, 4 ) *to fi ki vo tu*
(taw fee kee vaw too)

The *integral sign* $\int$ is represented by *so*. (saw) Remarks about sigma above, as to the treatment of expressions at top and bottom of the sigma, apply also to the integral sign.

*Non-terminating decimals* may be indicated with a variant of the *mo* used as the continuation sign: namely, *mor*, pronounced as the word "more", from which *mo* and *mor* have been taken. No attempt has been made to represent the phenomenon of *indefinitely repeating decimals*, because this would place too much demand upon the listener's memory and attention span.

Examples: 3.14159... *finasavosapuko mor* (fee-nah-sah-vaw-sah-pooh-kaw more) 0.142857... *gunasavozedipute mor* (goonahsahvawzehdeepoohteh more)

## LETTERS IN ALGEBRA ETC.

While all twenty-six letters of the Latin alphabet, in both capital and lower-case forms, and all twenty-four letters of the Greek alphabet as well, may be found in algebraic and other mathematical expressions as conventionally notated, only a few of these letters, viz. *a, b, c, d, n, x, y, z,* account for the vast majority of the letters used.

The different languages using the Latin alphabet do not agree on the *naming* of the letters of the Latin (Roman) alphabet. Indeed, the English names and sounds of those letters differ so radically from the usage of other languages that it was impractical to compile syllables for Numaudo with regard to the English spelling, and thus it has been necessary to assume a more international set of letter-sounds (substantially that agreed upon by phoneticians and philologists) in constructing the system. Furthermore, it has been necessary to give the (often merely approximate) English spelling under every syllable explained in this paper.

It should be repeated here that the *spoken form* of Numaudo is primary to the *written form of Numaudo* used in this paper, even though the spoken form of Numaudo is secondary to the conventional written mathematical notation. Therefore this paper and any subsequent editions of it will eventually be supplemented by a sound recording.

While the ancient Romans named the letters of their alphabet, these will not do as a basis for international letter-names, because modern opinion as to how to pronounce the names differs considerably. Furthermore, the letters *j, u, w* are not part of the original Latin alphabet, being merely derivatives of *I* and *V*. Also, even though there is considerable international agreement on such names as *el, em,* and *en,* these syllables begin with vowels, and thus are not allowable in Numaudo. (See page 5.)

The foregoing and other considerations compel the adoption of a somewhat arbitrary compromise solution to the naming problem.

Since a few letters account for most of the letter-occurrences in ordinary mathematics, syllables from the preferred list will be assigned to them, thus:

"Knowns": *a*, ja (yah); *b*, je (yeh); *c*, ji (yee); *d*, jo (yaw); *e*, ju (you).

(CONTINUED ON NEXT PAGE)

(Continued): "Unknowns": *v*, *la* (lah); *w*, *le* (leh); *x*, *li* (lee); *y*, *lo* (law); *z*, *lu* (loo).

*N* or *n*, in the usual meanings, *ni*. (Pronounced "nee".)

Because *p* and *q* are very frequently used in symbolic logic, they also receive syllables from the preferred list (fortunately, coinciding with their Latin names): *p*, *pe* (pe as in "pet"); *q*, *ku* (pch) (koo).

Note carefully that the syllable *jo* stands for *d* whenever this letter is used as a general number or is used with other letters such as *a*, *b*, *c*, ... for ordinary mathematical and logical purposes, but *jo* *NEVER* means the *d* of calculus in such expressions as *dx* —in fact, in many countries this d is kept in roman type while the other letters go in italics: d*x*, d*y*, etc. The *d* of calculus, then, is expressed by the syllable *du* (doo as in "doom"), and the ordinary *d* is distinguished from it by using the syllable *jo* (yaw).

Similarly, note carefully that the constant *e* (sometimes written with a Greek $\epsilon$), 2.718+, is rendered by the syllable *ke* (ke as in "keg"), but the letter *E* or *e* in ordinary uses is rendered by the syllable *ju* (yoo, as the word "you"), conforming with the series of "knowns", *a*, *b*, *c*, *d*, *e*, given above.

The letter *f*, when used to indicate a function, is expressed by the syllable *fu* (foo), which, of course, comes from the first two letters of the word *function*. Because *fu* does not stand for any ordinary algebraic use of the letter *f*, but only for a function, it will not always be necessary to express the parentheses in such an expression as *f* (*x*). For additional function symbols, see the list at the end of this article. The letter *f*, in any other use than that of indicating functions, is represented by the syllable *fef*.

*Résumé of the Letter-Designations:*

| Letter | Numaudo | (Pronunciation, In English spelling) |
|---|---|---|
| *a* | *ja* | (yah) |
| *b* | *je* | (ye as in "yes") |
| *c* | *ji* | (yee) |
| *d* | *jo* | (yaw) |
| *e* | *ju* | (you) |
| *f* | *fef* | (feff) |
| *g* | *geg* | (ghegg) |
| *h* | *has* | (hahss) |
| *i* | *hik* | (heek) |
| *j* | *jot* | (yawt) |
| *k* | *kak* | (kahk) |
| *l* | *lel* | (lell) |
| *m* | *mem* | (mem) |
| *n* | *ni* | (nee) |
| *o* | *hok* | (hawk) |
| *p* | *pe* | (pe in "pet") |
| *q* | *ku* | (coo) |
| *r* | *rer* | (rare) |
| *s* | *ses* | (sess) |
| *t* | *tit* | (teet) |
| *u* | *huk* | (hoohk) |
| *v* | *la* | (lah) |
| *w* | *le* | (le in "led") |
| *x* | *li* | (lee) |
| *y* | *lo* | (law) |
| *z* | *lu* | (loo) |

If, and only if, a letter must be shown to be a capital, *i.e.*, if a capital has a different value in the conventional mathematical notation in this particular instance from the corresponding small letter, then prefix *kap* to every such capital. Use *kap* as sparingly as possible.

The above résumé does not include the special syllables for constants, functions, etc., for reasons which should be obvious.

On very rare occasions, the above code-syllables for the letters may have to be used to spell words or abbreviations, or proper names. For instance, subscript words occur in engineering formulas; occasional words, abbreviations, and names are used in symbolic logic. The syllable *ver* (as in "very") is to precede any such spellings, and *ri* (ree) or another "separation mark" may follow the spelling if ambiguity needs to be guarded against. The practice of so spelling is to be avoided wherever possible--generally a stipulation in ordinary language can be made, as in conventional notation one will stipulate, "...where *u* is the velocity *as measured*..." or "*P* will denote effective output power in this chapter" or "...where *J* is the relation 'grandparent of *X*' and *K* is the relation 'great-grandparent of *X*' " and the like. Later on in this article we shall deal with the mixture of Numaudo with ordinary languages. The syllable *ver* mentioned above is taken from the Latin *verbum*, "word".

*The letters of the Greek Alphabet* have been assigned syllables as follows:

| Name | Letter | Numaudo | (Pron.) |
|---|---|---|---|
| *alpha* | A α | *laf* | (lahf) |
| *beta* | B β (ϐ) | *bet* | (bett) |
| *gamma* | Γ γ | *gam* | (gahm) |
| *delta* | Δ | *det* | (dett) |
| | δ | *del* | (dell) |
| *epsilon* | E ε ϵ | *pes* | (pess) |
| *zeta* | Z ζ | *zet* | (zett) |
| *eta* | H η | *he* | (heh) |
| *theta* | Θ θ ϑ | *het* | (hett) |
| *iota* | I ι | *jit* | (yeet) |
| *kappa* | K κ ϰ | *ka* | (kah) |
| *lambda* | Λ | *lan* | (lahn) |
| | λ | *lam* | (lahm) |
| *mu* | M μ | *mim* | (meem) |
| *nu* | N ν | *nin* | (neen) |

| Name | Letter | Numaudo | (Pronunc.) |
|---|---|---|---|
| *xi* | Ξ ξ | *kis* | (keess) |
| *omicron* | O o | *moik* | (moik) |
| *pi* | Π | *pir* | (peer) |
| | π (ϖ) | *pi* | (pee) |
| *rho* | P ρ ϱ | *ro* | (raw) |
| *sigma* | Σ | *si* | (see) |
| | σ (ς) | *sig* | (seeg) |
| *tau* | T τ | *tau* | (tou as in "tousle") |
| *upsilon* | Υ υ | *vu* | (vooh) |
| *phi* | Φ φ ϕ | *pif* | (peef) |
| *chi* | X χ | *hi* | (hee) |
| *psi* | Ψ ψ | *pis* | (peace) |
| *omega* | Ω ω | *mog* | (mawg) |

Since long practice has assigned permanent values to some of the Greek letters, e.g., Σ, π, for other purposes, and there is little use of those particular letters, and thus little risk of ambiguity, it has not been felt necessary to assign more than one syllable to a letter, as had to be done with the Roman letters *d, f, e.* However, in the case of delta, lambda, pi, and sigma, the capital form occurs often enough with a different meaning from that of the corresponding small letter that compelling the use of the prefix *kap* in those cases would have been intolerably cumbersome. In other cases, *kap* may be employed to distinguish a capital just as has been recommended for the Roman letters. Also, there are extra forms of several of the Greek letters, but these alternative forms are seldom used for mathematical purposes. If they should ever have to be distinguished from the ordinary forms, syllables can be assigned to them when the need arises. Furthermore, prime marks or subscripts may be employed.

Most users of Numaudo will not have to memorize either the complete Roman alphabet code nor the complete Greek alphabet code--just those few syllables needed for their specialty. This, indeed, is one reason why the syllables assigned to certain letters have been discussed separately from the alphabetical lists.

Those using calculus, for example, will need to know that small delta δ is represented by *del,* while capital delta Δ is represented by *det,* and the special character ∂, which is not a part of the Greek alphabet, is represented by *der.* Other letters of the Greek alphabet will not be of so much importance to them.

Incidentally, three additional Ancient Greek letters, ϝ, ϑ, ϙ, not needed in the Greek language proper, were used by the ancient Greeks as *numerals*. Thus these characters are generally available wherever Greek type is available, so they can be recommended for expanding the conventional mathematical notation in the future. Therefore, Numaudo syllables have been assigned to them: ϝ *vau*, (vow) ϑ *san*, (sahn) ϙ *kop*. (kawp) (These are adapted from the names of these letters.)

The *prime marks* are rendered as follows: ′ (single prime) by *bo*, (baw) ″ (double prime) by *bu*, while the rare triple prime ‴ is represented by the combination *bobu*, (bawboo) and the still rarer quadruple prime ⁗ is represented by *bubu*. (booboo) (boo)

Examples: *A*′ kapjabo, (kahpyahbaw) *a*′ jabo, (yahbaw) *a*″ jabu, (yahboo) *a*‴ jabobu, (yahbawboo) ϕ′ pifbo (peefbaw)

The requirements of *Boolean Algebra* are easily met with Numaudo syllables. For the "not" forms, the prime mark *bo*, just explained, or the syllable pair *hot...hut* (see Page 9) may be used by those who insist on the vinculum notation. If the practice is followed of using only capital letters *A, B, C, ...*, then since there are no capital/lowercase distinctions to be made, the syllable *kap* will not be necessary. Should an "attention signal" be needed, that what follows is Boolean, then the syllable *bul*, pronounced as the name *Boole*, may be employed for this purpose.

*Inequality expressions:* The sign ≠ "not equal to" is rendered by *no*, (naw) The "greater than" sign > is expressed by *fa*, (fah) while the "less than" sign < is rendered by *fo*. (faw) In the event that the signs <, > occur in a text with other meanings than inequality, other syllables may have to be assigned to them for such auxiliary meanings. Numaudo is not likely to be used in those circumstances, however.

*Approximate equality*, often denoted by the signs ≃ and ≅, is assigned the syllable *ti*. (tee)

When the sign ≡ denotes *identity*, it is represented by *sam*, which is taken from the English word "same" and the Russian word *samyĭ* САМЫЙ. (sahm) However, the syllable *sam* is not used for the three-line sign when it means "congruent" in Number Theory, nor is it used when it means "mutual implication" in Symbolic Logic.

We are now ready to give examples of algebraic expressions:

$a - b = c$, ja mi je fe ji (yah mee yeh feh yee) $(a + b)^2$, to ja pa je tu po ze (taw yah pah yeh too paw zeh)

$a^2 + b^2$, (ordinarily) japoze pa jepoze ; (if there is special need to guard against ambiguity) japozenu pa jepozenu (yah-paw-zeh-pah-yah-paw-zeh) (yah-paw-zeh-noo-pah-yah paw-zeh-noo) . $\sqrt{a}$, ra ja re (rah yah reh) . $\sqrt{ab}$, ra jaje re (rah yahyeh reh)

$\sqrt{a+b}$, ra ja pa je re (rah yah pah yeh reh) . $\sqrt[z]{x-y}$, ru lu ra li mi lo re (roo loo rah lee mee law reh) .

$\frac{1}{x}$, sa da lo (sah dah law) $\frac{(x+y)}{2k}$, to li pa lo tu da ze kak (taw lee pah law too dah zeh kahk) . (In the last example, the *to...tu*, i.e., the parentheses around the quantity $x+y$, may be omitted in speaking, provided that the speaker can convey the correct grouping through pauses, intonation of the voice, etc. However, a more liberal use of parentheses and other signs of aggregation will be required in many applications of Numaudo, than is generally needed with conventional mathematical notation. This is inevitable, from the time-dependent nature of audible communication for which Numaudo is primarily intended.

Further examples of algebraic expressions:

$ax^2 + bx + c = 0$ , jalipoze pa jeli pa ji fe gu . $y = f(x)$ , lo fe fu li
(yah-leepaw-zeh pah yeh-ee pah yee feh goo) (law feh foo lee)

(alternative, with parentheses expressed): lo fe futolitu ( since the parentheses
(law feh footawleetoo)

help to separate the other syllables, they may be combined into one "word".)

$\omega = 2\pi f$ , mog fe zepifef. $\pi < \sqrt{10}$ , pi fo rasagure . $x > y$ , li fa lo .
(mawg feh zeh-pee-feff) (pee faw rah-sahgoo-reh) (lee fah law )

$a_1$, $a_2$, $a_3$, $a_4$, ... $a_{n-1}$, $a_n$ ... ja.susa ki jasuze ki jasufi ki jasuvo ki
( yah-soo-sah kee yah-soo-zeh kee yah-soo-fee kee yah-soo-vaw kee
mo jasunimisazu ki jasuni mo
maw yah-soo-nee-mee-sah-zoo kee yah-soo-nee maw )

(The preceding example illustrates the Numaudo rendering of letters bearing subscripts, and the use of the "end-of-subscript" syllable *zu* only where required for clarity, and the rendering of commas and continuation signs.)

Numaudo renders *logarithms* as follows: Common logarithms to base 10 are called for by using the syllable *log,* just as in ordinary notation. Corresponding to the conventional $\log_e$ or ln, for the natural logarithms, there is the Numaudo *lon,* (lawn )
of which the derivation should be obvious. Logarithms to any other bases can be designated with the subscripting syllable *su,* followed by that for the base.

Examples: $\log 3 \cong 0.4771$ , *log fi ti gu na votetesa* . $\log_2 256 = 8$, *logsuzezu*
(lawg fee tee goo nah vawtetesah) (lawg-soo-zeh-zoo

*zepuba fe di* . (*Zu* used here because more numerals follow that do not belong to
zeh-poo-bah feh dee) (zoo)
the subscript.)

In those cases where a characteristic is negative but the mantissa remains positive, the rendering is: $\bar{2}.74183$ , *goze-gana-tevosa-difi* , using the sign
(gawzeh gahnah tehvawsah-deefee)
syllables *go, ga,* as was explained on Pages 7 & 9. The interpretation of the
(gaw gah)
alternative notation, 8.74183-10, is straightforward: *di-na-tevosa-difi-mi-sagu* .
( dee nah tehvawsah-deefee mee sahgoo)

It will be noted that the use of spaces and hyphens in the groups of syllables given as Examples throughout this paper has not been uniform. This is not an oversight; on the contrary, it has been done to show the permissible latitude in the written form of Numaudo. Different speakers may choose to clarify their Numaudo utterances in different ways, according to their needs at the time. Different machine systems will present different problems, and thus considerable latitude has to be allowed the designers of such machines and systems. Much the same situation already obtains in ordinary mathematical and logical notation practice. Symbols are grouped differently by different persons; the same symbols are used with different values in different fields; the same mathematical or logical concept often has a number of different notations. Indeed, the existence of these many accepted conventional alternative notations has prolonged this description of our system by at least one-fourth.

The *plus-or-minus* sign $\pm$ , for specifying tolerances, error limits, etc. is assigned the syllable *pom,* made from the initials of *plus or minus.*

Examples: *a±ib,* ja pom gije . $45.731 \pm .002$ , vopunatefisa pom nagugoze .
(yah pawm gee-yeh) (vawpoonahtehfeesah pawm nahgoogoozeh)

The percent sign, %, is rendered by *sen,* this being like the accented syllable of its name in most languages.

Examples: 40%, *vogusen* . 3½%, *fihasadazesen,* or *fi ha sa da ze sen* .

0.7%, *gunatesen* . ± 5%, *pom pusen.*

(PRONUNCIATIONS OF THE PERCENTAGE EXAMPLES ON PRECEDING PAGE: 40%, vaw-goo-sen; 3½%, fee-ha-sah-dah-zeh-sen ; 0.7%, goo-nah-teh-sen; ± 5%, pawm poo-sen.)

The less-used *per mille* sign (or, "parts per thousand", " instances per thousand"), ‰, is represented by *dof,* (dawf) abbreviated from *dofi* (dawfee) (see Page 7).

The designation "ppm" or the equivalent expressions "parts per million", "instances (occurrences) per million population" and the like, may be rendered by *dob,* (dawb) which is an abbreviation from *doba.* (dawbah) This will be convenient for statisticians, analytical chemists, and others who habitually use such expressions.

Since Numaudo has obvious applications in financial work, for instance in data-processing for business and government purposes, accounting, commercial arithmetic, banking, etc., *monetary units* must be provided for.

For the present, the simplest expedient would seem to be: The principal monetary unit of one's country (franc, dollar, pound, lira, peso, etc.) will be represented by the syllable *mon,* (mawn) while the next unit in order of importance (centime, cent, shilling, centesimo, centavo, etc.) will be represented by the syllable *mun.* (moon) So long as financial data concern one country only, these syllables will suffice. Should the data have to be transmitted from one country to another, each occurrence of *mon* or *mun* will have to be preceded by the name of the country in some ordinary language. Later on, it may be possible to obtain international agreement for new syllables to be added to Numaudo, so that all monetary units of all countries can have syllables unambiguously their own. In the special case of sterling currency, *pen* can be used for pence. (*Mon* and *mun* are derived from Latin words, as they appear in such English forms as *mon*etary, re*mun*eration, etc.)

The Latin preposition *per* is taken into Numaudo without change, for use primarily in its commercial meaning. Also, the term NET.

*Time of day* is expressed by the international 24-hour four-digit system, using the Numaudo equivalents for figures 0000 through 2359, viz. *gugugugu* to *zefipuko,* preceded by the syllable *sai,* (sounding as the word "sigh"). Intentionally, no syllables are provided for *a.m.* or *p.m.* A group of six digits rather than four digits implies time in hours, minutes, and seconds.

*Dates* are expressed by first using the syllable *dat,* then giving the day, the separation mark *ri,* the month (1 for January, 2 for February, etc.), the separation mark *ri* again, and the year, always in that order. The day-month-year order is standard practice in most countries, the USA being a conspicuous exception. The separation marks *ri* can be dispensed with, if the month-number be expressed with the *secondary numerals,* to be explained. If the *day of the week* is also to be given, this, too, can be expressed with the secondary numerals, and precede the day-of-the-month number.

Syllables for mentioning hours, minutes, days, etc. separately, will be given under *Units* later on in this paper.

*The Secondary Numerals.* Sometimes, as in the case of dates just mentioned, and in giving page numbers, paragraph numbers, or in rendering numerals in boldface or italic type, or in parentheses, or Roman numerals, etc., it is convenient to have an auxiliary set of numerals. Numaudo provides for this by duplicating the consonants in each of the basic digit syllables given on Page 6. Accordingly, the secondary numerals will be:

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 0 |
|---|---|---|---|---|---|---|---|---|---|
| *sas* (sahs | *zez* zezz | *fif* feef | *vov* vawv | *pup* poop | *bab* bahb | *tet* tet | *did* deed | *kok* kawk | *gug* goohg ) |

The providing of this extra set of numerals is not intended to hinder anyone from using Numaudo equivalents of 3′ , (7) , and the like. Or the convention may be adopted of calling the large-sized numerals, used in headings or to mark divisions in a long writing, "capitals"—whereupon the meaning of the *kap* prefix for letters can be extended to numerals and other signs when they are to be taken as written or printed in larger size than standard. This will facilitate the numbering of equations and formulas.

Examples of time-of-day:

2000, *sai-zegugugu;* (sigh-zeh-goo-goo-goo) 1245, *sai-sazevopu;* (sigh-sah-zeh-vaw-poo) 0830, *sai-gudifigu .* (sigh-goo-dee-fee-goo)

Examples of dates:

8 February 1960, *dat di ri ze ri sakobagu.* (daht dee ree zeh ree sah-kaw-bah-goo)

24 December 1962, *dat zevo ri saze ri sakobaze .* (daht zehvaw ree sahzeh ree sahkawbahzeh)

31 March 1981, *dat fisa ri fi ri sakodisa .* (daht feesah ree fee ree sahkawdeesah)

Examples of dates, using the secondary numerals:

8 February 1960, *dat di zez sakobagu.* (daht dee zezz sah-kaw-bah-goo)

22 July 1958, *dat zeze tet sakopudi .* (daht zehzeh tet sahkawpoodee)

Friday, 12 October 1492, *dat bab saze sasgug savokoze.* (daht bahb sahzeh sahss-goog sah-vaw-kaw-zeh)

(Note that in these last date examples primary and secondary numerals are alternated. Naturally, time of day would be given before day of the week, so the former would still be expressed in primary numerals if time of day were given as well as the full date. Obviously, there are many other circumstances besides dates where this alternation of the two series of numerals would be convenient, especially since it would do away with separation marks.)

Possible uses for secondary numerals and primed, "marked", or "capitalized" numerals are: (1) Parenthesis-enclosed numerals, as in this paragraph; (2) An alternative method of distinguishing major and minor monetary units, as dollars from cents, shillings from pounds and pence, etc. ; (3) Another alternative of distinguishing amounts of money from other numerals not signifying money; (4) decimals from whole numbers; (5) numbers in non-decimal notation, such as binary, octonary, duodecimal, etc., from decimal numbers ; (6) Numbers to which a machine is to pay attention, from other numbers it is to ignore; (7) Numbers a machine is to print out from those it is not to print out; (8) Numbers a machine is to add (multiply, or otherwise calculate with) from those it is merely to store; (10) Totals, sub-totals, etc. that are often printed in red ink or otherwise marked.

Quite likely, some machines will be so built that they will make no distinction between primary and secondary numerals. Providing secondary numerals and many other special syllables *does not* mean that every kind of machine built to accept Numaudo input has to accept a wide variety of Numaudo syllables—indeed, most such machines will not accept much more than the ten digit-syllables and a few instruction syllables. Much of the system is designed primarily for use in speaking, e.g., the letter-codes for algebra and calculus, and the operation symbols and signs of aggregation. Inventors of future machines may alter this situation radically, however.

## *SCALES OF NOTATION OTHER THAN DECIMAL*

Electronic computers have brought the *binary notation* into prominence, where as recently as two decades ago it was but a mathematical curiosity. Thus it is imperative that Numaudo provide for binary notation.

The syllable *bi* (bee) shall precede every series of binary numbers, unless some other provision for a binary indicator has been made. The effect of *bi* will be cancelled by any of the syllables signalling other scales of notation, which syllables will be given below. As several alternative binary notations will be described here, and as still others may be invented later, other indicators may be needed also. *Bin* (bean) is an obvious choice for the second such indicator.

If one wishes to imitate the conventional notation slavishly, one may use *sa* for 1 and *gu* for 0, as with decimal notation. Published descriptions of binary arithmetic by various authors have amply demonstrated the confusion that can result by unrestricted application of this practice.

As alternatives to *sa* and *gu*, then, the syllables *hen* for binary *"one"* and *zor* for binary *"zero"* are suggested. (*Hen* is from Greek ἕν; *zor* is of course abbreviated from the international word *zero*.)

Examples of "straight binary": 10, *bi sagu* (bee sahgoo) or *bi hen zor* (bee hen zorr) or simply *henzor* (henzorr) if the use of these special syllables makes it clear enough in the particular instance that binary is intended. 111, *bi sasasa* (bee sahsahsah) or *henhenhen*. 1101.01, *bi sasagusa na gusa* (bee sahsahgoosah nah goosah) or *henhenzorhen na zorhen* (henhenzorhen nah zorrhen). (*Na* can be the binary point as well as the decimal point without confusion.)

Since long strings of one's and zero's can be monotonous, and thus confusing, various expedients have been suggested and used to make it easier to deal with binary notation. One method is to provide names for some of the powers of two. Then, wherever a 1 appears, the binary name for its place can be called off, while the 0's remain unexpressed. This might cause some confusion in naming binary fractions. Nevertheless, it would be sufficiently useful in describing holes punched in paper tape, computer coding, etc., that a Numaudo adaptation is given here:

1, *bi sa;* 10 *bi ze;* 100, (decimal 4), *bi vo;* 1000 (decimal 8), *bi di;* 10,000 (decimal 16), *bi sei* (bee say); 100,000 (decimal 32), *bi bau;* (bee bou--bou as in "bounce") 1,000,000 (decimal 64), *bi bou* (bee bo).

Higher powers of two than the sixth (decimal 64) would be expressed by repeating these names, and using a separation mark to block off the long binary numbers into groups of two, three, four, five, or six, as desired. The syllable *sei* is adapted from the French word for sixteen; the syllables *bau* and *bou* are adapted from the name of *Baudot*, who developed the five-unit binary code named for him. According to the names just given, then, binary 11,111 (decimal 31) would be called *bi seidivozesa;* (bee say-dee-vaw-zeh-sah) 100,001 (decimal 33) would be called *bi seisa;* (bee say-sah) while binary 1010 (decimal 10) would be called *bi dize*. (bee deezeh) In any of the above cases, *bi* would not have to be repeated, so long as the series of numbers, however long, continued to be expressed in binary.

IMPORTANT:SEE PAGE 51, par.4

Another method of simplifying binary representation—one which has been used in certain computers and elsewhere as well——consists in rendering binary numbers according to another base which is a power of two. The process of doing so, or of reconverting to binary, is almost automatic, since it involves little more than blocking the binary digits off into groups, and giving each such group a name. It is thus much simpler than binary-to-decimal conversion. Quaternary (base four) numbering would not effect much saving. Too large a base, as 32 or more, would demand the invention of too many additional digits. Thus only bases 8 and 16 need be considered.

The syllable *vos* (vawss) will signify that the following digit-syllables are to be taken as octonary (octal), i.e., base 8. Thus octonary 77 (decimal 63) will be rendered *vos tete;* (vawss tehteh) octonary 24 (decimal 20), *vos zevo;* (vawss zehvaw) octonary 17 (binary 1111, decimal 15), *vos sate*. (vawss sahteh) As already suggested, the secondary numerals could be used wherever they would be an aid in keeping octonary numbers from being confused with decimal. (*Vos* is from the Russian word for *eight*, ВОСЕМЬ *vosem'*.)

For the sexadecimal system (base 16), six new digits are required. Various expedients have been adopted for adding these to the conventional notation. One of these, the use of the letters U,V,W,X,Y,Z, can be adapted to Numaudo as follows: digits zero through nine are expressed by *gu...ko* as for decimal notation; the digit for ten is made up by compounding an international root *dek* with the syllable for U to give *duk;* (dookh) the syllables for V,W,X,Y, and Z (which, along with that for U, are given on Page 12) are modified by suffixing an *r* to give: eleven, *lar;* (lahrr) twelve, *ler,* (lairr) thirteen, *lir;* (leerr) fourteen, *lor;* (lawrr) and fifteen, *lur*. (loorr) Thus the five vowels are made to run in the same sequence as for *sa, ze,* etc., simplifying memorizing.

To indicate that the numbers to follow are expressed in sexadecimal notation, the syllable *sez* has been assigned as indicator. (Like *sei*, mentioned previously, *sez* is derived from the French word *seize*, sixteen. *Sez* renders the pronunciation quite well.) The sexadecimal system (the term *hexadecimal*, sometimes seen, is an etymologically improper Greek-Latin mixture) acquires added importance from being the basis for *binary-coded decimal representation schemes*, of which more in a moment.

Examples of scale-of-16: 12 (decimal 18), *sez saze.* (sez sah-zeh) 4Z (decimal 79) *sez volur.* (sez vawloorr)
UX (decimal 173), *sez duklir.* (sez doohk-leerr) 0.1 (decimal 0.0625), *sez gu na sa.* (sez goo nah sah)

The following is offered as a possible abbreviated scheme of syllables for scale-of-eight, scale-of-sixteen, and binary-coded decimal: For the binary 1 in this sub-system of Numaudo, the three letters *l, a, i,* in that order, are used to form numeral-syllables. (Mnemonic: *l* and *i* look like the figure 1; *a* is the *first* letter of the alphabet.) For the binary 0 in this sub-system, the letters *m, e, u* in that order are used in forming the numeral-syllables. Accordingly, octal numerals will consist of *three letters* forming one syllable of the consonant-diphthong type, as follows:

| *DECIMAL:* | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *OCTAL:* | *meu* | *mei* | *mau* | *mai* | *leu* | *lei* | *lau* | *lai* | *meimeu* | *meimei* | ... |
| *BINARY:* | 000 | 001 | 010 | 011 | 100 | 101 | 110 | 111 | 001000 | 001001 | ... |
| *Pron.:* | (mĕ·o͝o [e in end] | may | mou [as in mouse] | my | lĕ·o͝o [e in end] | lay | lou [as in loud] | lie | may-mĕ·o͝o | maymay | ... |

(NOTE: Unfortunately it is extremely difficult to describe the pronunciation of *eu* in ordinary English spelling. However, anyone can say it easily, once having heard it. The sound of *ĕ* in *let* is quickly followed by that of *u̯* in *rule,* all in one syllable.)

For binary-coded decimal, or plain sexadecimal, another *l* or *m* is appended to make a four-letter consonant-diphthong-consonant syllable, thus:

| *DECIMAL:* | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|---|
| *BCD OR 16:* | *meum* | *meul* | *meim* | *meil* | *maum* | *maul* | *maim* | *mail* | *leum* |
| *BINARY:* | 0000 | 0001 | 0010 | 0011 | 0100 | 0101 | 0110 | 0111 | 1000 |
| *Pronunc.:* | (mĕ-oom | mĕ-ool | maim | mail | moum [like "mound"] | moul [ditto] | mime | mile | lĕ-oom |

| *D:* | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | ... |
|---|---|---|---|---|---|---|---|---|---|---|
| *6:* | *leul* | *leim* | *leil* | *laum* | *laul* | *laim* | *lail* | *meum–meul* | *meum–meim* | ... |
| *B:* | 1001 | 1010 | 1011 | 1100 | 1101 | 1110 | 1111 | 0001 0000 | 0001 0000 | ... |
| *P:* | lĕ-ool | lame | layl | loum [like "loud"] | loul [ditto] | lime | lisle | mĕ·oom-mĕ·ool | mĕ·oom-maim | ... |

*The foregoing is called a sub-system of Numaudo because it is a suggestion, not an essential part of the system. It has the advantage of presenting a series of digits with distinctive sounds, that reveal their binary composition. Use of the three-letter series for octal does not oblige one to use the four-letter series. The three-letter forms may be extended by prefixing* hen *or* zor, *and so may the four-letter forms, to express 'check-bits' or five-unit codes.*

Binary-coded decimal representations may be adapted from any of the binary and power-of-two-scale notations just discussed. There are many possible such systems, and the best-known are the "straight" or 8-4-2-1, for which the indicator syllable is *deb* for *DE*cimal *B*inary, and the "excess-three", for which the indicator is *teb* for *Three-Excess-Binary.* Binary-coded decimal schemes have in common that they choose ten out of the sixteen possible four-place binary or sexadecimal numbers, and arrange to skip over the other six and prevent them from occurring.

Other indicators for other binary-coded-decimal systems can be devised as needed by those in the field, as they have need for them. It is not necessary to give examples here of decimal numbers in binary code, because the systems described on the two preceding pages can be applied readily enough to the binary-decimal coding schemes described in contemporary computer literature.

However, binary-coded decimal had to be mentioned here because this seemingly strange mode of representing numbers offers important advantages in the design and manufacture of electronic digital equipment. It stems from the naturally binary, either-on-or-off nature of electric switches, relays, and the electronic circuits which do switching.

Furthermore, the presence of holes or absence of holes in punched cards and tape also constitute a form of binary representation. This explains the amount of space devoted here to binary, and why several alternative systems have been set forth. Still other alternatives may well be made in the future, yet keeping within the bounds of the Numaudo system.

On rare occasions, base 3, or *ternary,* notation is used. The indicator *ter* is suggested. For base 4, or *quaternary,* the syllable *fir,* from German *vier,* may be employed. Bases 5, 6, 7, and 9 are too seldom used to need indicators—if ever needed, they can be called for in words of ordinary language.

Base twelve, or *duodecimal,* however, does have certain applications. For this, two additional digits are required, for which have been assigned the syllable *dek* for the value *ten,* and the syllable *lef* for the value *eleven*. The indicator is *duz,* (dooz) from *douze,* French for twelve. Twelve-hole punched cards and month-indication may require the use of *doz* (from *dozen*) for the value *twelve,* since there is then a ten, but no zero.

The syllable *dek* (from Greek δέκα) may also be used where a single syllable with the value of *ten* is needed in ordinary decimal arithmetic. However, a different syllable, *des,* from "decimal", is needed as the *decimal-system indicator* or *decimal restorer,* (dess) used after non-decimal numbers to cancel the effect of *bi, bin, vos, sez,* etc.

## *ANGULAR MEASUREMENT*

Degrees of arc are indicated by the syllable *deg* immediately after the numeral syllables. Minutes of arc are followed by *boi,* while seconds of arc are followed by *bui.* These two syllables are made from the prime and double-prime syllables (boy) *bo, bu,* (booey) mentioned on Page 14. Note that *degrees of temperature* have other syllables, (baw, boo) and that *minutes and seconds of time* also have other syllables than those used for angular measurement.

Examples of angular measurement: 270°, *zetegudeg.* (zeh-teh-goo-deg) 10° 40′, *sagudeg voguboi* (sahgoo-deg vawgooboy)

59° 37′ 48″, *pukodeg fiteboi vodibui.* (poo-kaw-deg fee-teh-boy vaw-dee-booey) 69.8°, *bakonadideg.* (bah-kaw-nah-dee-deg)

Radians are expressed by following the numbers with the syllable *rad.* (rahd)

In many European countries the *centesimal* angular measurement is used, and thus Numaudo must provide for it. In this system, a circle is divided into 400 equal parts instead of 360, and these parts are called *grades.* The syllable *gar* has been assigned for grades, and is used just as is *deg* above. However, the syllables given above for sexagesimal minutes and seconds are not to be used for what are sometimes called *centesimal minutes and seconds.* Instead, the decimal-point syllable *na* will be used after *gar* , then the separation mark *ha* may be used between the centesimal minute and second numerals, if felt desirable.

Example; 42ᵍ 35′ 16″, *vozegar na fipu ha saba .* (vawzehgarr nah feepoo hah sahbah)

The common *trigonometric functions* are called for in Numaudo as follows:

sin, *sin* (seen) cos, *kos* (kawss) tan, *tan* (tahn) cot, *kot* (kawt)

sec, *kan* (kahn) cosec, csc, *ken* (ken)

The hyperbolic functions are designated by adding the syllable *hip* (heep) after the regular function syllable; thus for sinh one will use *sin hip* (seen heep), etc.

For the time being, the less-used functions not given in this paper may be spelt out, using the method outlined at top of Page 13. The word *arc* and its equivalents may be rendered by the (necessarily transposed) syllable *kar*.

Obviously, geometry proper lies outside the scope of a primarily spoken system such as Numaudo, but whenever, as in analytical geometry, the conventional notation has a symbolic representation that can be written on one line at a time and can be rendered intelligibly by naming the symbols in succession, as Numaudo does, this system will be applicable.

Vectors, such as those used in electrical engineering, sometimes are expressed by giving the magnitude and then a symbol, and then the angle in the usual angular measurement. For this symbol that is associated with the angular measurement, Numaudo uses the syllable *nag*, metathesized from *angle*. It precedes the angular measurement, and follows the magnitude.

Boldface type is often used in vector representation, as well as for other purposes. To denote that boldface type has been or would have been employed in conventional notation, the syllable *fet* is prefixed to *each* syllable that is to stand for a boldface character. This syllable is derived from the German word *fett*, used to describe bold-(fat-)face type. *Fet*, like *kap* (with which it may be combined, in the order *fetkap*), affects only *one* following syllable, no more.

Superior dots are represented by modifications of the prime syllables *bo, bu*, thus: one superior dot ˙, as in $\dot{x}$, by *bot* (bawt), so that $\dot{x}$ would be *libot* (leebawt). Two superior dots ¨, as in $\ddot{x}$, by *but* (boot), so that $\ddot{x}$ would be *libut* (leeboot). As explained in connection with the prime syllables, the dot syllables may be combined to represent three or more superior dots.

## THEORY OF NUMBERS

The sign $\equiv$ when, and only when, it means "congruent" in the Theory of Numbers, is represented by *kon* (kawn). The abbreviation "mod" for "modulo" is taken over unchanged. Thus $22 \equiv 29 \bmod 7$ becomes *zeze kon zeko mod te* (zehzeh kawn zehkaw mawd teh).

*Factorials* have two conventional symbols, $n!$ and $\lfloor n$. Both of these symbols have just one representation in Numaudo, viz. *fak* (fahk). This syllable follows the number.

## MISCELLANEOUS SIGNS

$\geqslant$ (greater than or equal to), *fai* (fie).

$\leqslant$ (less than or equal to), *foi* (foy)

$\infty$ (infinite, infinity, too great to measure), *nif* (neef)

$\propto$ (varies as, or any other meaning of this sign) *mut* (moot)

$\aleph$ (Hebrew letter aleph) *hal* (hahl)

. (period, dot, *quâ* punctuation mark, "full stop"—does not mean decimal point, multiplication sign, or conjunction in symbolic logic), *zo* (zaw)

$\backsim$ (or any other sign standing for "difference") *dif* (deef)

→ (tends to, approaches; not chemical meaning), *til* (teel) (after English *till* and Scandinavian *til* )

∇ (inverted capital delta) *led* (*del* backwards)

: (colon when expressing a ratio, and only then when it is necessary to make a distinction between a ratio and a fraction; not the colon as a punctuation mark) *dau* (dow as in "dower")

:: (if it should ever be necessary to employ the obsolescent proportion sign, simply use *dau* twice, *daudau*.)

|*Z*| (when two vertical lines are used to enclose an expression, as just shown, with any of the usual mathematical meanings, they are treated in Numaudo as a kind of parentheses, and the left-hand one is represented by *tos* (tawss) and the right-hand one by *tus*, (toose) so that the illustrative example would be *toslutus* or *tos lu tus* . (tawss-loo-toose))

lim *lim* (leem) (taken over unchanged, so that the expression

$$\lim_{y \to \infty}$$

would, by the "pseudo-subscript" convention alluded to on Page 8, be represented as *lim su lo til nif zu*, (leem soo law teel neef zoo) the *zu* being used or not, according to the danger of ambiguity in the particular instance.)

∵ (because, since) *ker* (kairr) (after French *car* )

∴ (hence, therefore) *tak* (tahk) (after Latin *itaque* and Slavic *itak*)

Q.E.D. (*Quod Erat Demonstrandum*, "which was to be shown") *ked*

## *PUNCTUATION*

Already given: Period . *zo.* (zaw) Comma , *ki.* (kee) Blank Space *ri.* (ree)

Colon : *kol* (kawl) Semicolon ; *koil* (koil) Question mark ? *kes* (kess) (French *Qu' est-ce?*)

Exclamation Point ! *hei* (hey!) (used after exclamations, commands, unusual items, in connection with signals to start or stop a machine, and as an equivalent of the Latin abbreviation N.B., and for other purposes. Not used for logic and not used for factorials [see *fak* ]. Derived from the international interjection *hey*.)

Dash —— *pau* (pow as in "power") (Latin *pausa*, pause. Besides ordinary punctuation uses, may be used as the line separating a list of figures to be added, from their total or sub-total.)

Quotation Marks:

Beginning " or « *va* (vah) Closing " or » *za* (zah)

Inner or secondary quotation marks, such as:

Beginning ' or other, *vai* (vie) (vi in "violet") ' or other, *zai* (zie) (si in "desire")

Logical uses of quotation marks, such as naming or mentioning an expression without using it in the ordinary sense, are included within the scope of these four quotation-mark codes. French punctuation practice is to be followed wherever practicable, in the use of quotation marks. If more kinds of such marks are needed, add the "prime syllables", *vabo*, etc.

Because quotation-mark usage differs from country to country, some explanation is required here: The pair *va-za* is intended to be used as the outer, or first pair, regardless of the practice in one's country (that is, in the U.S.A., double marks above the writing-line are used; in England, single marks above the line; in France and Spain, double marks on the line; etc.) The pair *vai-zai* is intended for the second or inner pair, also regardless of one's country's printing practice.

¿ If one wishes to follow Spanish practice and use a question mark at the beginning of an expression as well as at its end, the syllable *kas* may be employed for this purpose. (kahss) *Kas-kes* thus becomes an enclosing pair, like parentheses. This will be of especial advantage when one wishes to signify that the enclosed data are doubtful, or to ask for a repeat. (kahss kess)

\- Hyphen, *hif*. This is not used for a dash, nor for a minus sign, nor for a subtraction operator, but rather in a wider, more general interpretation of the *compounding* or *linking* function of the hyphen in ordinary languages. The hyphen syllable *hif* (heef) may be used to block off groups of numerals into threes, fours, etc., (heef) and may be used between a numerical coefficient and the following letter-syllable; *hif* is recommended between ordinary-language words and Numaudo syllables when such a combination forms a logical unit.

( ) When parentheses are to be taken in the ordinary-language sense (so-called parenthetical matter, non-essential additional words, change of tone of voice, etc.) and such parentheses do not imply aggregation, operands, or expressions governed by a function, the pair of modified syllables *tol* (tall) for "(" and *tul* (tool) for ")" will be used instead of *to, tu*.

* Star, asterisk. The syllable *tel* is assigned, (from Latin *stella*.)

† Dagger, obelisk. Arbitrarily considered as "star-prime" *telbo*.

‡ Double dagger. Arbitrarily considered as "star-double-prime" *telbu*.

§ Section mark. *Son*. (sawn)

¶ Paragraph sign. *Par*.

The two preceding signs may be found useful to indicate divisions in lists, tables, etc.

' Apostrophe. Breath-mark. *Pof*. While the apostrophe proper will be extremely rare in the kind of contexts wherein Numaudo might be used, there will be occasional need, especially in instruction manuals, to indicate the best place to break an utterance into breath-groups, and the meaning of the apostrophe in musical notation suggests this use of the sign '.

The division between signs and punctuation marks will have to be somewhat arbitrarily made in this paper. Especially in symbolic logic, some of the signs could well be called punctuation marks, but will be treated under the *Symbolic Logic* heading nevertheless.

## *PUNCTUATION: EXPRESSED AND IMPLIED, SPOKEN AND WRITTEN*

The provision of spoken equivalents for ordinary punctuation marks in Numaudo, as just summarized above, does not conflict with the remarks made near the bottoms of Pages 4, 14, and 15, regarding use of ordinary, silent punctuation signs with written Numaudo. Circumstances will differ widely, and thus need for written and/or spoken indication of punctuation will differ also. Sometimes Numaudo will be spoken slowly, sometimes (especially when machines utter it) rapidly. When Numaudo is mixed with ordinary language (which will be a very frequent occurrence) additional punctuation will be needed---spoken, written, or both.

To set down detailed prescriptive rules for punctuation, at this early stage of the system, might needlessly and severely hamper a fruitful growth of Numaudo in the future. Therefore only recommendations will be made.

Work done by phoneticians and experts in the field of structural linguistics, particularly in the last two decades, has established not only the overall principles underlying the phonetic and phonemic structure of languages in general (see Page 3), but has further established the great importance of *stress* (relative loudness of successive syllables) and *intonation* (rise and fall of voice-pitch) in the patterning of speech, in any language. That is to say, stress and intonation have semantic importance: they help to make one's meaning clear, even in those languages, such as English, which are popularly not supposed to be "tone-languages". And, in a rough sense, stress and intonation in spoken language correspond to such devices of written language as punctuation, white space, size of type, italic and boldface letters, capitalization, and style of handwriting. However, this correspondence is far from exact, and varies from language to language, and even from person to person and from situation to situation.

As recently as 1930, one might have feared that mechanical apparatus for producing speech would only be capable of doing so in an unvarying monotone. The eerie, "inhuman" effect of such speech—even though merely imagined—may well have deterred many persons from developing or planning to use such equipment. However, the development since that time of devices which can utter speech with normal-sounding stress and intonation has completely removed this objection.

Indeed, monotony would be far more objectionable in Numaudo than it would in ordinary languages. The mathematical and logical notations, for which Numaudo provides a spoken code, are of very low redundancy, *i.e.,* they hardly ever repeat any item of information they once have stated. Thus if one symbol is lost from a mathematical context, it will be next to impossible to resupply it without asking that the message be repeated. Yet in an average language, such as English, almost 40 % of a message may be illegible or garbled or inaudible, yet the meaning can be inferred fairly safely from what remains.

Monotonous delivery breeds inattention, and mistakes in Numaudo could be very serious. This explains our recommendation on Page 7 that pauses and inflections of the voice be used to make the meaning clear. It is recommended that where digits or symbols are grouped, as *sazeko-fidipu* or *jalilo,* that a stress-pattern be used such as *sázekofídipu* or *sazekófidipú,* and also that where there are different kinds of symbols, such as syllables standing for letters, those standing for numerals, and those representing operators, that these different kinds of symbols be distinguished by appropriate variation of voice-pitch. If the utterance is entirely, or almost entirely, in Numaudo, the patterns of one's own language can be followed; but in the case of mixed ordinary language and Numaudo, it is recommended that the Numaudo portions be spoken in a deliberately unusual stress-and-intonation pattern. While everything was done that could be done in the compilation of the Numaudo syllables to avoid ambiguities resulting from collision of Numaudo syllables with common words in various languages that might be mistaken for them, some degree of ambiguity is inevitable. As will be evident to anyone who has read thus far, even the conventional mathematical notation contains glaring ambiguities. As Numaudo is used by more and more persons in more and more different kinds of situations, means for overcoming ambiguities will be evolved, and can be incorporated into instruction manuals.

The problems resulting from the low redundancy of mathematical symbolizing have already been encountered in the electronic computer field, where often in the storage and computing facilities of the machines themselves, deliberate redundancy has been introduced to aid in spotting errors. Sometimes an entire problem will be done over, or certain equipment will actually be duplicated. Even in hand computation there have always been checking systems, such as "casting out 9's" or multiplying back to check a division problem.

Thus attention must be given to methods of introducing redundancy into Numaudo, since a spoken code will usually have to contend with a noisy environment or channel. Attention is called to the restriction of types of syllables, so that certain types of syllables cannot possibly occur within the system, so that, if they should appear to occur, there must be an error somewhere.

Because of the importance of the digit-syllables, a certain measure of redundancy was incorporated into them. Even if the consonants are not clearly heard, the use in succession of five different vowels reduces ambiguity. The series begins with *sa* for 1, rather than 0, for mnemonic reasons: *A* being the first letter of the alphabet and the first vowel, *E* being the second vowel, and so on. The secondary numerals provide a still further insurance against ambiguity. With regard to other syllables of the system, workers in various fields can assist in further development of counter-ambiguity measures.

The question-mark syllables may be used in asking for repeats, if desired. In giving repeats, whether requested or not, the repetition is preceded by *rep* and, if necessary to avoid ambiguity, is followed by *ret*. The syllable *ror* may be used to (rett) (rawrr)
indicate that one has made an error. This corresponds to a series of dots in telegraph code.

Referring again to the topic of punctuation, spoken Numaudo does not have to follow the punctuation associated with conventional mathematical or logical notation, though it may; and, in turn, written Numaudo does not have to follow the punctuation of either.

It is recommended that the punctuation mark immediately preceding and introducing a conventional mathematical expression, such as a colon, be expressed by the appropriate Numaudo syllable. This will provide a more comfortable transition from ordinary language to Numaudo, and also avoid overuse of the signal syllable *num*, (noom)
which has the meaning, "What follows is in Numaudo".

It is recommended that *ki* and *zo*, the comma and period equivalents, be inserted after mathematical expressions when reading them aloud in Numaudo, whenever this would help the listener to know that more was to follow or the portion of utterance corresponding to a phrase or a sentence of ordinary language was finished.

If spoken Numaudo is dictated, full punctuation should be spoken.

If Numaudo is to be sent in telegraph code or punched into cards or is to be sent by teletypewriter—or is in any other way to be re-encoded, full syllable-style punctuation should be spoken or written.

In conversation, punctuation may be held to a minimum. In informal correspondence using Numaudo, syllable punctuation may be omitted and white space may take the place of much written silent punctuation.

Over the telephone, punctuation, pauses, and repetitions are recommended.

Consonants must always be pronounced clearly, and when certain consonants are difficult for persons of certain nationalities, substitutes will be allowed according to a table for each mother-tongue where such difficulties obtain.

In the case of English, British and certain other speakers of English who do not sound the *r*'s after vowels in such syllables as *for, lar, mer,* etc. should make a special effort to sound all *r*'s in Numaudo. General American speakers who use a vowel-like *r*-sound should try to use a tongue-trilled *r* in all Numaudo syllables, if they possibly can.

The precision of Numaudo pronunciation requirements will be governed almost entirely by the tolerances that can be built into future listening machines. The wider that the design engineers can make such phonetic/phonemic tolerances, the more latitude can be allowed speakers of Numaudo.

To preclude false operation of listening machines, special signal-syllables will be provided. Naturally, only a few of these will be given here. Just as certain equipment is locked to prevent its operation by unauthorized persons, or its accidental turn-on, much Numaudo-using apparatus will be designed to respond only to specific *key-syllables,* or to function differently according to special codes spoken to it. The restriction to 21 phonemes, within which this paper will set out the system, does not apply to such key syllables.

Whatever may be chosen for the key syllables, they will have to be so chosen that by no conceivable chance will a similar sequence of syllables occur in the ordinary language spoken in the vicinity of the machine. Even with such a restriction, the possible number of two- or three-syllable combinations is enormous.

For general use where a private "key" is not required, *jui* (yooey) may be used as an attention signal before each Numaudo utterance to be acted upon by a machine. (It should be possible to utter Numaudo syllables in the presence of a machine that is turned on, without actuating it. Yet in such cases it still is desirable to notify any persons present, by means of the attention syllable *num*, that a series of Numaudo syllables will be uttered, and then utter them, but not actually start the machine until *jui* has been said.) In cases where no machine is involved, *jui*, or some variation of it, may be a very convenient abbreviation of a request to start calculating, or of "Only the following syllables, not the preceding, are part of the problem".

Corresponding to *num* as a beginning signal, the end of a Numaudo utterance and notification that what follows is not Numaudo may be made by *fin*, taken from the Spanish, French, and Latin words for "end". Corresponding to *jui* (feen), the signal to a machine to stop paying attention to what is being said (that is, until the next *jui* or the next private key syllables) is *tas* (tahss). That is, it has to be possible to deactivate a listening machine without having to go and turn it off, and thus be able to keep on speaking Numaudo without causing false machine responses.

The foregoing is not intended to limit the use of any other unassigned syllables for such purposes.

Receipt of a Numaudo utterance (or transmission) is acknowledged by *res* (ress). Where a listening machine is not equipped to transmit or utter Numaudo, or where it is not feasible to provide such facilities, tones on the order of the dial telephone signals may be used to asknowledge receipt, to show that it is ready to receive, to show that it failed to receive, to show that it is not available, and so on. After telephone engineers have devised suitable signals, and reasonable international agreement on their meanings and uses has been secured, they can be given Numaudo "names".

The English words *yes* and *no* are taken over into Numaudo with their usual meanings and pronunciations, but of course are spelt *jes* and *nou*, respectively. (The English "long o" diphthong in *nou* distinguishes it from the syllable *no* (naw), which means "not equal to".)

## *CHEMICAL CODE*

It might be desirable to extend Numaudo to the expression of chemical formulas and equations, at least, so far as this is feasible. In favor of this step it may be pointed out that mathematical computations are frequently involved in chemical work, so that a common terminology would be expedient. Furthermore, conventional chemical notation is in much the same state as conventional mathematical notation: both have international written forms, but not international uniform spoken codes.

The following is put forth as a tentative proposal:

All chemical coding is to be preceded by the syllable *kem*.

The usual symbols for the elements are rendered according to the names of the Latin letters, as given on Page 12, and all capital letters must always be preceded by *kap*, since ambiguity would otherwise result.

Parentheses and brackets are used in the customary manner, with the syllables *to, tu, ho, hu,* already given.

Subscripts are called for as usual by the syllable *su*, but *zu* will hardly ever be needed.

(Chemical Code, cont'd.) The single arrow $\longrightarrow$ for an irreversible reaction is rendered by *fei* (fay).

The double arrow for a reversible reaction $\rightleftharpoons$ is rendered by *fek*.

Hydrates and similar addition compounds are expressed with *kai*, (kai "kite") the "and" syllable (see Symbolic Logic section below).

Ions, as $Ca^{++}$, are expressed with the exponent syllable *po* followed by the proper number of plus signs *ga* (N.B. not *pa*), or minus signs *go* (not *mi*); or by a digit syllable and the sign syllable where the number of signs would be inconvenient.

The operator plus sign *pa* is used between the items taking part in a reaction, in the conventional manner.

Atomic-weight superscripts for isotopes are treated as if they were exponents.

Atomic-number prefixed subscripts are treated as subscripts, but *subo* is used, i.e., "subscript-primed".

The effect of the syllable *kem* (kem) is cancelled by the syllable *mat* (maht). It may be necessary in certain instances to go into and out of this chemical sub-system to make one's meaning clearer.

No attempt is made to render structural formulas, or to provide a complete chemical code, as this would be better done outside the limits of Numaudo. However, this sub-system may well serve as a preliminary to a "Chemaudo" of the future, and certainly this sub-system will be helpful in applying Numaudo to analytical and physical chemistry, where so much mathematics is involved.

Examples of chemical coding: $C_{12}H_{22}O_{11}$ *kem kapjisusaze kaphassuzeze kaphoksusasa ri*. (kem kahp-yee-soo-sah-zeh kahp-hahss-soo-zehzeh kahp-hawk-soo-sah-sah ree.)

HCl *kaphas kapjilel ri*. (kahp hahss kahp yee-lell ree)

$CaCl_2$ *kapjija kapjilelsuze ri*. (kahp-yee-yah kahp-yee-lell-soo-zeh ree)

$3\,O_2 \rightleftharpoons 2\,O_3$ *fikaphoksuze fek zekaphoksufi ri*. (fee-kahp-hawk-soo-zeh fek zeh-kahp-hawk-soo-fee ree)

$Fe_2(SO_4)_3 \rightleftharpoons 2\,Fe^{+++} + 3\,SO_4^{--}$ *kapfefjusuzetokapseskaphoksuvotusufi fek zekapfefjupogagaga(nu) pa fikapseskaphoksuvozupogogo ri*. (kahp-feff-yoo-soo-zeh-taw-kahp-sess-kahp-hawk-soo-vaw-too-soo-fee [fek zeh-kahp-feff-yoo-paw-gah-gah-gah-[noo] pah fee-kahp-sess-kap-hawk-soo-vaw-zoo-paw-gaw-gaw ree)

$NH_4NO_3 \longrightarrow N_2O + 2\,H_2O$ *kapnikaphassuvokapnikaphoksufi fei kapnisuzekaphok pa kaphassuzekaphok zo mat* (kahp-nee-kahp-hahss-soo-vaw-kahp-nee-kahp-hawk-soo-fee [fay kahp-nee-soo-zeh-kahp-hawk pah kahp-hahss-soo-zeh-kahp-hawk) (zaw maht)

Spaces, hyphens, etc. may be added at will in the above examples, and pauses are optional. One pair *kem...mat* was used to enclose all the examples because they followed one another immediately. In practice, any example, however brief, would be enclosed between *kem* and *mat*.

Any person who would like to try constructing an audible chemical code that would be independent of the Numaudo system, should be encouraged by these considerations: (1) It probably could be done in such a manner as to take up only half the space, expression for expression, as the above sub-system; (2) It would not have to meet the requirements of computing machines, as Numaudo must, though it might have to be compatible with information storage and retrieval equipment, because it would have to be used in searches of chemical literature, etc.

Within the limitations of Numaudo, there should be room in the future for the elaboration of sub-systems besides those presented in this paper. In an era of accelerating progress, such as the present, there will be no trouble finding new applications for Numaudo, which applications, in their turn, will make new demands upon the system.

## *MIXTURE OF NUMAUDO WITH ORDINARY LANGUAGES*

In this paper it has been assumed that if the conventional mathematical notation provided for a concept, and the notation in question was not obsolete, then Numaudo should provide a syllable for it. Actually, Numaudo will have to go beyond this bare minimum. First, due to typographical difficulties and the like, certain symbols have several different meanings, e.g. ≡. Second, special ways had to be found to cope with such notations as the vinculum, the radical sign, exponents, and subscripts, as these typographical devices could not be directly translated into a succession of morphemes in time (the syllables of spoken Numaudo) nor yet into an alphabet restricted to Roman letters only (the written form of Numaudo). Third, as will become quite apparent in the symbolic-logic section, there are frequently-occurring "relation-words" which could be considered just as much a part of mathematics and/or logic as the customary symbols. Furthermore, punctuation marks have already been assigned codes. Fourth, common physical units are so extensively used in science and engineering that syllables will be given for all the important ones.

Nevertheless, at this stage in the development of Numaudo it would be inexpedient to tie up a large portion of the available syllables in a mere duplication of the vocabulary of conventional languages. Nor is it expedient at this early stage to demand that every Numaudo-user acquire a considerable vocabulary before beginning to speak the system. The growth of the Numaudo vocabulary beyond the resources of present mathematical and logical notation has to be orderly and careful — otherwise *rigor*, one of the greatest merits of mathematics and logic, would be lost.

Otherwise stated, in order that a person may begin speaking and listening to Numaudo as soon as possible, the system has to be of some use even when the student has learned but twenty or thirty syllables. This implies alternation and mixture with ordinary language. Such alternation is further implied by the current practice in books which contain both conventional mathematical or logical notation and sentences in an ordinary language.

If the definite meanings associated with the conventional mathematical and logical signs can be preserved in their Numaudo forms, there will never be any exact synonyms of such symbols in any ordinary language—not even in a consciously-constructed language such as Esperanto. There will be approximations, not duplications; and one purpose of Numaudo is to permit the juxtaposition of rigorous mathematical and logical terms with vague and less definite terms of ordinary language, so that the difference between them will become more evident.

Hitherto, there has been a loss in clarity, a blurring of meanings, whenever ordinary words have been used to render mathematical or logical expressions. In fact some harm has been done by such quasi-metaphorical expressions as "square" for the second power of a quantity and "cube" for the third power of a quantity — irregularities in usage that serve no useful purpose, whatever may have been the motive that inspired their introduction in the first place. Much more harm has resulted from the indiscriminate use with vague meanings of such mathematical expressions as "to the *n*th power" in ordinary language: in this case, comparison of the original meaning with the popular, ordinary-language meaning will show how much they have diverged; further confirmation of this may be found in the article on nth in Fowler's *Modern English Usage*.

When reading aloud from a printed page containing both mathematical symbols and ordinary language, a certain amount of translation into ordinary language takes place, even though the average reader is unaware of it. So with symbolic logic: a controversy has been going on over the proper rendering of the sign ⊃; there are at least four sides to the controversy, with proponents of "implies", "If...then...", "entails", and "only if" all arguing for their interpretations. This does not mean that the meaning of the sign ⊃ is vague; it means that ordinary languages are vague, and when someone pronounces this sign in Numaudo as *ta*, that person is thereby avoiding the strains of the controversy.

Numaudo, in other words, is not "just another language"; it is for such reasons as those given above that Numaudo is called a "coding system". To speak symbols in Numaudo is not to translate them; it is merely to encode them, a process rather like transliteration. Indeed, like transliteration, Numaudo-encoded passages can be decoded; the process is reversible. The situation is similar to that of putting ordinary language into Continental Morse Code and recovering it at the other end. With habitual use of Morse code, the radio operator comes to think of .... as *being* the letter H; the encoding and decoding processes become unconscious-automatic, and the code characters are firmly tied to the alphabet. However, the correspondence is not perfectly one-to-one: there is a separation mark .-.-.- used between integers and fractions which has no true counterpart in print; the code characters -...- and .-.-. , although they have conventional transcriptions = and + respectively, are ordinarily used with meanings quite different from the regular meanings of those written signs. Again, no distinction between small and capital letters is made; there is no exclamation point in the contemporary form of Continental Morse code, although there used to be; many common written signs simply cannot be sent in Morse code at all—indeed, this is one reason for evolving written Numaudo.

But the successful back-and-forth conversion relation between ordinary language and telegraph code shows that, even without absolute one-to-one correspondence, Numaudo will be a practical system. It is only necessary that in the teaching and learning process, the conventional written mathematical and logical symbols be firmly associated with and tied to their Numaudo counterparts, so that Numaudo will become and remain "the voice of mathematics and logic" rather than "just another language".

To be useful at all, Numaudo has to be able to say what ordinary language cannot say, or cannot express without awkward circumlocutions. To be valuable, Numaudo has to save time. Now, within this article, this saving of time may not have become very evident during the exposition of the system. The *written* forms of the Numaudo syllables may *look* longer than the written mathematical symbols for which they stand. This is not a fair basis of comparison. Spoken Numaudo is primary to written Numaudo, and the true basis of comparison is the amount of time it takes to say something in Numaudo, compared with the amount of time it takes to read the same (unfortunately, it isn't always quite the same!) expression in ordinary words. Roughly, this corresponds to the number of syllables in a Numaudo expression as compared with the number of syllables in the corresponding English expression.

For instance:

*Ex plus wye, the quantity squared, over double-u to the fourth minus thirty-six.*
*To li pa to tu po ze da lepovo mi fiba.*

English, 21 syllables; Numaudo, 14 syllables.

*Four times nine is thirty-six.*
*Vo mu ko fe fiba.*

English, 7 syllables, Numaudo, 6.

*The square root of one hundred eleven.*
*Pa sasasa re.*

English, 10 syllables, Numaudo, 5.

In connection with the above comparisons, note that they are made on a basis of the number of *syllables*, not *letters*. Some of the apparent length of the English examples is due to unphonetic spelling, so a comparison by number of letters would be unfair to the English. In the first example, the English could have been lengthened by saying "divided by the quantity double-u to the fourth power minus thirty-six" which would have given 8 more syllables. This should make it likely that Numaudo will save time, when the saving in number of syllables is as great as it is, without resorting to such expedients as that just given.

Another factor here is that the *names* of the letters of the alphabet are not their *sounds*. Thus it takes a whole syllable, not a single letter, to spell out the name of a letter, in whatever language, save for the 5 vowels. Those not aware of this fact may have a false impression of the brevity of the spoken forms of mathematical expressions.

This also applies to abbreviations, such as *cm, mm, sec, hr, kg,* etc., since in some cases it may take as many syllables to call off the names of the letters in the abbreviation as it would to speak the word in full. If the Numaudo treatment of some of the unit-designations given below appears arbitrary, remember that very few abbreviations meet the syllable requirements of the system, and those that do not must be rejected.

## *PHYSICAL AND ENGINEERING UNITS*

Obviously, a complete list cannot be given here, only the smallest list that will enable the use of Numaudo in physics and engineering. New syllables can be added after need for them has been demonstrated; for this purpose some form of committee may be set up to pass on proposed new syllables and avoid conflicts in symbolizing. In any case, conventional abbreviations can be spelt out, using the *"ver"* method, top of Page 13. English units, such as *foot, inch, pound, quart, BTU,* and so on, not being international, may either have their abbreviations spelt out, or the English words may be used. (That is, if any communications are to be made internationally, English units will have to be changed to metric, and if communications are to be made to another English-measure country, the presence of English words will not matter.)

The reader is referred to the top of Page 7, where the special Numaudo notation for positive and negative powers of ten is explained. With this device, the need for assigning syllables to *decimeter, dekameter, hectometer, deciliter, dekagram,* etc. is eliminated. Only the most frequent multiples and submultiples of a unit need individual syllables. In some cases below, this device will be used to denote the preferred manner of expressing that unit.

| | | | |
|---|---|---|---|
| second | sec., s | *sek* | (sek) |
| minute | min., m | *min* | (meen) |
| hour | hr., h | *hor* | (hawrr) |
| day | | *dei* | (day) |
| week | | *heb* | (heb) |
| month | | *mes* | (mess) |
| year | | *jar* | (yahrr) |
| (millisecond, *-dofisek;* microsecond, *-dobasek* ) | | | (daw-fee-sek) (daw-bah-sek) |
| meter | m. | *met* | (mett) |
| micron | μ | *mik* | (meek) |
| millimeter | mm. | *mom* | (mawm) |
| centimeter | cm. | *sem* | (sem) |
| kilometer | Km. | *kim* | (keem) |

(All other units of length, such as ångström, millimicron, etc. by *-de-* or *-do-*)

Exception: nautical mile (*not statute mile!*), *naut* (nout, rhyming with "pout")

| | | | |
|---|---|---|---|
| hectare | ha. | *har* | (hahrr) |
| (other square measure by exponent, as square meter, *metpoze*) | | | (mett-paw-zeh) |
| liter | l. | *lit* | (leet) |
| (other cubic or volume measure by exponent, as cubic meter, *metpofi* ) | | | (mett-paw-fee) |
| atmosphere (pressure unit) | | *tam* | (tahm) |
| millibar | | *mib* | (meeb) |
| (other units by *de, do*) | | | |
| dyne | | *din* | (deen) |

*(continued on next page )*

(Physical & Engineering Units, continued)

| | | | |
|---|---|---|---|
| millimeter of mercury (as unit of pressure only) | mm Hg | *hig* | (heeg) |
| kilogram per square centimeter | kg/cm² | *ṗem* | (pemm) |
| newton | | *nut* | (nooht) |
| erg | | *gon* | (gawn) |
| joule | | *daul* | (dowel) |
| calorie (gram) | cal. | *gal* | (gahl) |
| Calorie (kilogram) | Cal. | *kal* | (kahl) |
| phot | | *fot* | (fawt) |
| lux | | *luk* | (loohk) |
| lumen | | *lum* | (loom) |
| candlepower | | *kir* | (keerr) |
| lambert | L. | *lab* | (lahb) |
| diopter | D. | *dip* | (deep) |
| electron-volt | eV | *vel* | (vell) |
| 1,000,000 eV | MeV | *mev* | (mev) |
| roentgen | r. | *ren* | (renn) |
| curie | | *kur* | (koor) |
| bel | B | *bel* | (bell) |
| decibel | dB | *dib* | (deeb) |
| decibel referred to 1 milliwatt | dBm | *dem* | (demm) |
| neper | | *nep* | (nepp) |
| mel | | *mel* | (mell) |
| octave | | *dub* | (doohb) |
| volt | V | *vol* | (vawl) |
| ampere | amp., A | *pam* | (palm) |
| ohm | Ω | *rom* | (rawm) |
| megohm | MΩ | *meg* | (meg) |
| henry | H | *rin* | (reen) |
| farad | F | *faf* | (fahf) |
| microfarad | μF | *muf* | (moohf) |
| picofarad | pF, μμF | *pik* | (peek) |
| coulomb | | *kul* | (koohl) |
| watt | W | *vat* | (vaht) |
| kilowatt | kW | *kat* | (kaht) |
| volt-ampere | VA | *vam* | (vahm) |
| kilovolt-ampere | kVA | *kam* | (kahm) |
| reactive volt-ampere, or var | | *var* | (vahrr) |
| reactive kilovolt-ampere, or kilovar | kVAr | *kav* | (kahv) |
| power factor, % (*lel* or *ji*, i.e. *L* or *C*, may be added to indicate lagging or leading) | | *ṗoit* | (poyt) |
| cycles per second, Hertz - cps, c/s ,~,Hz | | *her* | (hairr) |
| gilbert | | *gil* | (gheel) |
| oersted | | *ted* | (tedd) |
| gauss | | *gau* | (gow) |
| weber | | *veb* | (vebb) |
| maxwell | | *lin* | (leen) |
| magnetic permeability(μ) | | *mui* | (mooey) |
| microgram | γ | *mug* | (moohg) |
| milligram | mg | *mig* | (meeg) |
| gram | g | *gai* | (guy) |
| kilogram | kg | *kig* | (keeg) |
| millier, metric ton | | *ton* | (tawn) |
| specific gravity or density referred to water | | *den* | (denn) |
| mol (chemistry) | | *mol* | (maul) |
| normal(chemistry) *N.* | | *nor* | (nawrr) |
| pH (chemistry) | | *peh* | SEE NOTE |
| meters per second | | *meis* | (mace) |
| kilometers per hour | | *kih* | SEE NOTE |
| g, accel./gravity | | *gag* | (gahg) |
| bit, binit, binary digit as unit of information | | *bit* | (beet) |
| brig(a generalized bel) | | *big* | (beeg) |
| light-year | | *lui* | (looey) |
| degree Centigrade | °C. | *tem* | (temm) |
| degree Kelvin | °K. | *tek* | (tek) |

*NOTE:* Two of the syllables given above, *ṗeh* and *kih*, contain sound-combinations not conforming to the English speech-pattern. In both cases the *h* is to be fully sounded, rather as the syllables *pech, kiech* would be pronounced in German. Persons who cannot pronounce *h* in such a position may either pronounce those syllables (pedge) (keedge) or they may use *pe-has* (peh-hahss) for *ṗeh* and *kim-per-hor* (keem-pairr-hawrr) instead of *kih*. It was felt that the greater ease of remembering *ṗeh, kih* than other syllables that might have been assigned, outweighed the inconvenience that might be caused speakers of two or three of the many languages involved.

Note that when conventional letter-symbols are used instead of names of units, such as *I* for current instead of "amperes", this practice is followed in Numaudo:

*E*=250 would be rendered *ju fe zepugu,* for example, rather than *zepuguvol* or *zepugu verla,* unless the original statement in conventional notation read *E*=250 V., in which latter case either the *ver* signal and the code for the letter V, or the unit name *vol* would be used.

(yoo feh zeh-poo-goo) (zehpoogoovawl) (vairr-lah) (vair) (vawl)

Pay especial attention to the manner in which letter-symbols, as *F* for force, *B* for magnetic flux density, θ for an angle, etc. are coded in Numaudo by the syllables given on Pages 12 and 13, *but—caution here!*— abbreviations such as km., mg., and the like are coded by the *ver* prefix to show "spelling-out" before the letter-symbols are given. Otherwise there would be intolerable confusion between letters (usually italic) for mathematical symbols, and letters (usually roman) for abbreviations. This, indeed, is why syllables have been provided for so many of the units—to avoid resorting to the *ver* system, so far as feasible.

It will be noted that "unit" syllables have been provided even for specific gravity, magnetic permeability, and power factor, not generally considered units. In these cases (and any new ones like them which may later be added to the system) the "unit-like" syllables may precede the numerals instead of following them, as:

sp. gr. 0.997, *den gunakokote ;* μ 250, *mui zepugu,* and so on.

The prefixes *micro-, nano-, pico-, milli-, centi-, deci-, deka-, hecto-, kilo-, myria-, mega-, giga-, tera-,* used with physical units, are not a part of the Numaudo system. To provide syllables for these thirteen prefixes would be as unnecessary a duplication of facilities and burden upon the memory as it would have been to provide syllables for "hundred","thousand","million", "billion" etc.—as has been pointed out, middle of Page 7. Of course, the *abbreviations* for these prefixes may be spelt out with the abbreviations for the units, as *verkakla* for *kV.*, but in all ordinary cases it will be found more convenient and more in keeping with the principles of the system to use the unit names and the Numaudo powers-of--ten notation method, so that 5 mV. will become *pudofivol* and 13 kV. will become *safi-defivol,* etc. It is optional in any given case to express or suppress the period often used with abbreviations. Periods may be supplied if otherwise ambiguity would result; the syllable for *abbreviation* periods is *zop.*

As already mentioned on Page 12, bottom, letters, whether mathematical symbols or used to spell out abbreviations, do not need the prefix *kap* to show that they are capitalized, *unless in the given particular instance* the meaning of a capital letter would differ from that of the corresponding small letter. This is another reason for preferring *doba* to *vermim* for "micro-" and *deba* to *verkapmem* for "mega-", and *dofi* to *vermem* for "milli-", since carelessness in the use of such letters as μ m M is frequent—and understandably so!

Examples: 12 square meters, *saze metpoze ;* (sah-zeh met-paw-zeh) 2 grams, *zegai ;* (zeh-guy)

35 seconds (time), *fipusek ;* (fee-pooh-sek) 9.5 kVA, *konapukam ;* (kaw-nah-poo-kahm) 11 mW , *sasadofivat ;* (sah-sah-daw-fee-vaht)

6′ 3″ or 6 ft. 3 in. or 6 feet 3 inches, *ba verfeftit fi verhikni* or *ba* feet *fi* inches. (Either of the two Numaudo renderings may stand for any of the three original expressions.) ( bah vairr-feff-teet fee vairr-heek-nee or bah feet fee inches)

65 mm , *bapumom ;* (bah-poo-mawm) 4857 Å , *vodipute-dosagumet ;* (vaw-dee-poo-teh-daw-sah-goo-mett) .003 μF, *nagugufi muf ;* (nah-goo-goo-fee moof)

25 Mc/s, *zepudebaher ;* (zeh-poo-deh-bah-hairr) 110 amp.-hr., *sasagu pamhor ;* (sah-sah-goo-pahm-hawrr) 391 kWh, *fikosakathor ;* (fee-kaw-sah-kaht-hawrr)

-32.8° C. , *gofizenaditem ;* (gaw-fee-zeh-nah-dee-tem) 45°K. , *voputek ;* (vaw-poo-tek) $10^{-4}$ mm Hg , *dovohig ;* (daw-vaw-heeg)

(Further Examples of Units) 4 liters/min., *volitpermin* ; 12dB/octave, *saze dib per dub* ; (vaw-leet-pairr-meen) (sah-zeh-deeb-pairr-doob) 4096 bits, *vogukobabit or zeposaze bit* ; (vaw-goo-kaw-bah-beet OR zeh-paw-sah-zeh-beet) 6000 gauss, *badefigau* ; (bahde-fee-gow) $H_c$ = 400 oersteds, *has-su-ji fe voguguted* . (hahss-soo-yee—feh-vaw-goo-goo-tedd)

To facilitate learning and remembering the syllables standing for units, it was necessary to allow a considerable number of them to end in voiced consonants, such as *b, d, g, v, z*. Since several languages, such as German and Polish, do not pronounce voiced consonants in final position, the English-speaking user of Numaudo must not be surprised to hear *dub* pronounced as *dup*, or *mev* sounded as *mef*.

Some mention of this was made on Page 6. Fortunately, the syllables ending in voicdd consonants are not likely to be involved in communications with machines. It is merely that some English-speaking Numaudo users, if they were not aware of this voicing/devoicing problem, might add syllables to the system which could be confused with those already assigned (especially, those assigned to units). Of course, if the units are unrelated, or the subject of the new syllable is unrelated to the subject of the existing counterpart-syllable, no harm would be done at all. For example, it is extremely improbable that *decibel* and *diopter* would occur in the same context, so the assignments *dib/dip* could hardly result in ambiguity.

## *INFORMATION STORAGE AND RETRIEVAL SYSTEMS*

This rapidly-developing field offers applications for Numaudo. While the published work on information storage and retrieval has dealt with the problem almost exclusively in visual terms, even to the point of describing information-coding schemes which cannot be pronounced and machine "language" which is unpronounceable, one important fact remains which the most visile of persons cannot deny: The telephone and voice-radio networks are very highly developed communication systems at the present time; they afford practically instantaneous communication over long distances; and their use is continually expanding.

Requests for information constitute an obvious use of telephone facilities, and undoubtedly a large percentage of telephone calls are requests for information such that the inquiry can be formulated in machine-acceptable terms, and the reply could be made by a machine having a small repertory of Numaudo syllables. Similar considerations hold for a large number of radiotelephone contacts, such as aircraft requesting information from ground stations.

Paralleling this situation, there are extensive teletypewriter and Morse networks, both radio and telegraph, and these are so arranged that the letters of the Roman alphabet are easier to transmit than numerals or punctuation marks, and many other characters cannot be transmitted at all. Since every syllable in Numaudo can be expressed within the Roman alphabet, written Numaudo is a convenient medium for teletyped and Morse-coded requests for information. Furthermore, the conversion from spoken to written Numaudo and vice versa by purely automatic means will be entirely practicable.

Sound-recording and dictating machines of various kinds have become almost ubiquitous. By using the Numaudo system, any such machine becomes a convenient input device for information-storage or data-processing equipment. Also, much of the data now accumulated as voice recordings may be worth storing in information storage and retrieval equipment, where it could be indexed, and later called for, by entirely audio means, and this often from a distance over a telephone line. In this way much tedious, error-introducing transcription would be eliminated.

Closely allied to the development of information storage and retrieval devices, and of electronic computing equipment, is the rapidly growing field of mechanical translation of languages. Since, for the near future at least, the bulk of

material presented for such translating processes will be of a scientific or technical nature, it will inevitably contain much numerical data and a considerable proportion of unit-names and mathematical symbols. To provide for such symbols in the machine output would complicate an already intricate device, and thus the possibility of expressing all such data in Numaudo before putting the texts through the translation process, should be attractive. Numaudo will of course pass through a translating machine unchanged, whether that machine be for spoken- or written-language translation; this should permit a considerable reduction in vocabulary-memory capacity (which is a principal cost factor here).

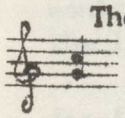
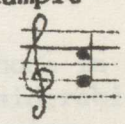
Another reason for mentioning machine translation here is that the conversion from written data to spoken data, and from spoken to written, when such information is expressed in an ordinary language, is a species of translation—at least from the machine-designer's standpoint. While apparatus to perform these tasks is mainly in the developmental stage as yet, it will eventually be perfected, and so must be taken into account in elaborating the Numaudo system. That is to say, the convenience that would result from being able to communicate with information storage and retrieval equipment by telephone should be an inducement for the adoption of an internationally-uniform code for mathematical and logical data, unit-names and instruction signals, such as the one here presented.

We intend to imply that telephonic access to information stored in *written* as well as spoken form is desirable, and conversely, print-out, whether local or at remote points, is equally desirable from either spoken or written stored information. Because of the comparatively early developmental stage of information storage and retrieval equipment, and of conversion devices, it would be unwise to give definitely prescriptive examples here of the application of this system, so our best course will be to present hypothetical examples.

Syllables and uses of syllables presented here to illustrate how Numaudo might be used in this field, are thus not to be considered assigned or pre-empted, since the designing engineer should retain a free hand.

Let us suppose, then, that the Public Library in a certain city has installed special telephone-answering equipment, in turn connected to a portion of the library's information storage.

An inquirer will dial, not the library's regular directory number, but a special number directly connected to the answering equipment, this latter number probably not being listed in the telephone directory, but given in an instruction pamphlet detailing this service and how to use it.

The equipment will answer, first sounding a special tone-signal, for example  , then such words as *"Answering Unit 3, Deepcar Library"*, the signal  again, then some such "go-ahead" signal as the letter-code *kak*.

If the inquirer inadvertently uses some irrelevant phrase in ordinary language, he will be interrupted with a recording, saying *"For any other service, please dial the regular library number, DUgmore 5-9987; for any other service, please dial the regular library number, DUgmore 5-9987; ... "* and so on till the client hangs up and dials the other number.

If the inquirer knows how to use the equipment properly, he will wait a few seconds, then make his inquiry in Numaudo, such as: *"Num kas tein buk kes ? Sui* (noom kahss tain boohk kess ? sooey
(pause) *pusagu-natedi . Tas. Kak . "*
[ pause ] pooh-sah-goo-nah-teh-dee tahss kahk )

Freely translated, this inquiry would mean *"Have you any book(s) on electronic computers in the library? End of question. Go ahead. "* (The Dewey decimal classification number for such books is 510.78, hence "pusagu-natedi".)

The equipment will answer, sounding the tone-signal faintly, then *"Jes"* or
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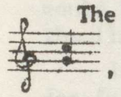
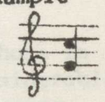
The equipment will answer, first sounding a special tone-signal, for example  , then such words as *"Answering Unit 3, Deepcar Library"*, the signal  again, then some such "go-ahead" signal as the letter-code *kak*.

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It was assumed, for the preceding example, that the request was whether a book or books on the subject were in the library *catalog*, not necessarily on the library *shelves* for circulation at that moment.

If the inquirer wanted to know whether a specific book was in the catalog, he could use the full Call Number, as e.g. 510.78 V947, which the reader may imagine to be substituted into the preceding example, in the form *pusako-natedi ri la kovote.*

Other book-classifying systems, such as the Library of Congress system, or the Universal Decimal Classification, could be accommodated similarly. Requests for an author by name (for example, "Has the library any books by Schnorkelfeder?") might be accommodated by spelling out the name with the code syllables given on Page 12. Requests by title probably could be answered by pattern-recognizing and scanning equipment, at greater expense and complexity, of course, than subject or author's-name requests. Some form of speech-pattern-recognizing equipment might also be needed where classification of subjects was by keywords rather than letters and/or numbers.

If the added cost of perpetual-inventory equipment were warranted, inquirers could put the question, "Is there a copy of 155 A784 available for circulation?", receive an affirmative or negative answer from the machine, and in either case reserve the book. Other machines would locate the book and set it aside, or in case it was out, make sure that it was set aside when returned and send the notice, and in either case, make the proper charges for the service.

Again, provision might be made to read back to the inquirer a one-minute tape-recorded abstract of a book, document, or article, the charges for this service being billed automatically. Even before the facilities we have described would become generally available, librarians in branch and private libraries could obtain information from a central library by means such as described.

Apparatus is already in existence whereby banks, insurance companies, and factories can keep data up-to-the-minute, so that any given account balance, production figure, or the like can be printed out on demand. The use of Numaudo in this form of information retrieval should be very helpful, since a teller at a branch bank could obtain a customer's actual balance without needing any special equipment or special transmission lines--only the regular telephone. Similar considerations apply to an insurance agent out on a call, or engineers making field surveys and needing information from a central point in a hurry. Of course, due to the confidential nature of much of this information, secret key-syllables would be used to unlock the information-retrieval equipment at the other end of the line, much in the manner of a combination lock.

In summary, many cases exist where it is already customary to telephone in for information and where the answer will be very brief, even though considerable time is required by present methods to search for it. Speaking and listening machines, using Numaudo, can take over many routine jobs and do them much faster than information clerks can, thus releasing persons for more interesting and varied tasks.

It should be pointed out, also, that once an incoming Numaudo utterance was recorded, a machine could scan its memory for such purposes as matching syllable-sequences etc. at an extremely high speed, since the speeds and frequencies used for internal operations of the machine are not limited by those of normal human utterance. Thus conversion from Numaudo to other codes would not always be necessary for machine purposes.

A further remark is in order, concerning the following section on Symbolic Logic. As theory and practice advances in the field of information storage and retrieval, more use will be made of logical concepts. Reference has already been made in the Information Retrieval literature to the possibility of making searches involving the *logical sum* or *logical product* of two classes. Again, data to be stored for retrieval will use logical symbols more and more as time goes on, and significant cost reductions and simplicity of equipment design can be achieved if such signs are stored as their Numaudo equivalents.

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Both information storage and retrieval and symbolic logic are rapidly growing fields at the present time. Had we given many examples of the application of Numaudo to information storage and retrieval, such examples might be obsolete before any extensive use of Numaudo for that field had occurred! Already, some of the machines and systems proposed for storage and retrieval have become obsolete before they could be finished or tested. As for symbolic logic, although it is an older field, particularly if considered as including Boolean algebra, the written symbol-system for it is far from settled, there being two, three, or more signs for some of the most elementary concepts. It is hoped that the providing of a systematic set of speakable representations for symbolic logic will ultimately have a desirable reaction upon the present array of written symbols for logic.

## SYMBOLIC LOGIC

### *BOOLEAN ALGEBRA*

Near the middle of Page 14 we have already explained how Numaudo may easily express Boolean algebra, and we gave the attention signal *bul*, (bool) to show that what follows is Boolean.

The syllable *mat* (maht) may be used to cancel the effect of *bul*, (bool) to show a return to ordinary mathematics. *Mat* may also be used when desired to show a return to ordinary mathematics from symbolic logic proper, or from class calculus, if ambiguity has to be guarded against in the particular instance. *Mat* was also introduced as a "cancel" signal when discussing the optional subsystem on Page 27, and it can be used to return from any future subsystem that may be devised. Sometimes *mat* may be desirable when leaving ordinary language, to show that one is going into only the *mathematical part* of Numaudo, not the complete system.

### *CALCULUS OF CLASSES*

*Class membership* is generally expressed by the Greek letter $\in$, first letter of ἐστί. The syllable *be* has been assigned for class membership, but *be* does not stand for other uses of Greek epsilon: for other purposes $\epsilon, \varepsilon$ is represented by *pes*, (pess) as stated on Page 13. Example: $x \in A$, *li be kapja.*
(lee beh kahp-yah) (bĕ as in "bet".)

Non-membership in a class has been represented in the literature by several symbols, such as $\tilde{\epsilon}, \notin, \sim\epsilon$. The syllable *ben*, compounded from *be* and *ne* for "not", has been assigned. Example; $x \notin B$, li ben kapje.
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*Class Inclusion*, generally expressed by the symbol $\subset$, is rendered by *zi*. (zee)
Example: $A \subset B$, kapja zi kapje.
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*Non-inclusion in a class* is expressed by *zin*. (zeen) Usual symbol, $\not\subset$.

*The complement* e.g. of a class, usually denoted by a bar over a letter, as $\bar{x}$, $\bar{y}$, and so on, is expressed in Numaudo by prefixing *goi*, (goy) derived from the minus-sign syllable *go*. (gaw) Thus $\bar{z}$ would become *goilu*. (goy-loo)

*Goi* affects only the syllable immediately following it. When a longer expression is to be considered as having a bar over it, the parenthesis-like pair of syllables *hot, hut* (hawt hoot) assigned to the vinculum, may be used, as detailed on Page 9.

The *logical sum* of two classes, generally symbolized by $\cup$, is expressed by the syllable *sum;* (soom) thus $F \cup G$ would be *kapfef sum kapgeg*. (kahp-fefff-soom-kahp-ghegg) (hard G as in "get")

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*Non-inclusion in a class* is expressed by *zin*. (zeen) Usual symbol, $\not\subset$.

*The complement* e.g. of a class, usually denoted by a bar over a letter, as $\bar{x}$, $\bar{y}$, and so on, is expressed in Numaudo by prefixing *goi*, (goy) derived from the minus-sign syllable *go*. (gaw) Thus $\bar{z}$ would become *goilu*. (goy-loo)

*Goi* affects only the syllable immediately following it. When a longer expression is to be considered as having a bar over it, the parenthesis-like pair of syllables *hot, hut* (hawt hoot) assigned to the vinculum, may be used, as detailed on Page 9.

The *logical sum* of two classes, generally symbolized by $\cup$, is expressed by the syllable *sum;* (soom) thus $F \cup G$ would be *kapfef sum kapgeg*. (kahp-feff-soom-kahp-ghegg) (hard G as in "get")

The *logical product*, usually denoted by ∩, is expressed by the syllable *por*. (pawrr)
Example: $F \cap G$, kapfef por kapgeg . (kahp-feff pawrr kahp-ghegg )

(Note that although all capital letters in the preceding examples have been signalled by *kap*, this might not be necessary very often in actual practice. Only where ambiguity is a real risk at the time, need it be done.)

The *null class*, usually represented by a capital lambda, Λ, has been assigned the syllable *lan* (i.e., "lambda-null"). Since capital lambda is not much used for (lahn)
other meanings, this syllable is allowed for any use of the letter lambda when capitalized.

The *universe* or *universal class*, generally symbolized by U or V, has been assigned the syllable *vun*. (voon)

Since the universal class is sometimes denoted by 1, as it is in Boolean algebra, and the null class is then denoted by 0, it is suggested here that the optional binary-notation syllables given at top of Page 18, *hen* for 1 and *gor* for 0, be used for this form of conventional notation, rather than *sa* and *gu*. This will be in accord with the "T" and "F" of truth-tables, the ON and OFF conditions of switching circuits, the application of "0" and "1" to describing the states and logical operations of certain computer circuits, etc.

Usually the conventional minus sign - of ordinary mathematics is used in Boolean algebra and class calculus without change, so Numaudo follows this practice and uses *mi*, just as is done for the subtraction operator. ( mee )

If symbols are needed for generalized operators, they may be derived by affixing the "prime" syllable *bo* to the syllable for the sign related to the desired operator, as *pabo* for ⊕, *mubo* for ⊗, etc. In cases where one does not relate an operator to an ordinary operator, one may use the Numaudo equivalents of letter-symbols, or one may coin new syllables.

The operator ∘ (small circle) is represented by *zui*. (zooey)

The breve symbol, ˘, used principally to denote the converse of a relation, in the fashion $\breve{R}$ or $R\breve{}$, is represented by the syllable *gou*, before the syllable to be affected by it. (go)

The relative product, sometimes symbolized by a heavy vertical line | and sometimes in other manners, is assigned the syllable *pit*. (peet)

*Powers of a relation* are expressed by the usual exponent representations, *(kap)rerpoze, (kap)rerpofi*, and so on.
[(kahp) rairr-paw-zeh, (kahp) rairr-paw-fee]

## *CALCULUS OF PROPOSITIONS*

The if···· then···· relation, often called "implication" and symbolized ⊃, is represented by the syllable *ta*. Example, $p \supset q$, pe ta kw . (tah) (peh tah koo)

The logical "and" or conjunction relation, variously symbolized by . & · ∧ , is assigned the syllable *kai*, from the Greek word καί. (Caution: when a dot . is used to symbolize "and" and at the same time dots are used for parentheses, take care not to pronounce such parenthetical or punctuation dots as *kai* when they do not really mean "and"; dot punctuation will be taken up later in this section.) *Kai* is pronounced as *kī* in *kite*.

The tilde sign ~ for "not" is rendered by *ne*. This syllable already has the meaning *no, not* in several languages. (neh; ne as in "net" "never" "negative")
As the prime mark ′ is still used sometimes (especially in Boolean-type systems) with the meaning of *not*, those who do so may use *bo*, the prime syllable; but even here, *ne* is preferred when "not" is meant, for the sake of uniformity in Numaudo.

As for the vinculum notation for "not", while a logical-complement syllable has been provided for the bar over a single letter, as $\bar{m}$, and a pair of parenthesis-like syllables have been provided for the longer vinculum over several characters, as $\overline{x \vee y}$, there will be many cases of overlapping bars if this notation is used as a general rendering of "not"—and while, in expounding this system, we are not primarily concerned with typographical difficulties in the *conventional* notation, we need not refrain here from pointing out that the overlapping-bar notation is a troublesome problem to printers. That is, Numaudo renderings of the bar and the prime notations have been provided primarily to permit the reading of existing written and printed logical expressions aloud in Numaudo without having to translate as one reads; this provision for the convenience of readers does not mean that such notations are *recommended,* and furthermore the prime-mark in ordinary mathematics has quite a different signification than negation, and the logical-complement notion in the class calculus is not necessarily the same as the "not" applied to propositions. Thus the tilde notation is recommended for expressions originally in Numaudo dealing with propositions. It should also be remembered that in most languages the words for which *ne* stands are placed before the words governed, just as is done with the tilde ~ in symbolic logic.

The usual disjunction, inclusive *or,* generally symbolized by $\vee$, which stands for Latin *vel*, is rendered in Numaudo by *ve.* (It may be pointed out here that Latin *vel* has an enclitic form *ve.*) (veh; ve as in "vend")

*Examples:* $p \vee q$, pe ve ku ; $p \vee (q \vee r)$, pe ve to ku ve rer tu .
( peh veh koo ) (peh veh taw koo veh rairr too )

The concept "*exclusive*-or", corresponding to Latin *aut*, often has no special symbol provided for it in many of the symbolic-logic systems. Occasionally $\wedge$ has been used, but others have used this symbol for "and", and the symbol $\bar{\wedge}$ is sometimes encountered. Exclusive-or can be conventionally expressed by $(p \vee q)\ \&\sim(p \& q)$. However, recent developments in the application of logic to electronic computers and other devices have resulted in the development of "exclusive-or circuits" and "exclusive-or networks" and have shown the practical utility of apparatus to operate on the basis "Either $p$ or $q$, but not both". Also, in applying logical concepts to business contracts, and in applying logic to information-retrieval systems, exclusive-or may well be useful. The Numaudo syllable for A (exclusive-or) is *maut,* (mout) the *aut* of which is pronounced like the word "out".

Example: $p \mathrel{A} q \equiv (p \vee q) \ \& \sim(p \& q)$

pe maut ku se to pe ve ku tu kai ne to pe kai ku tu
(peh mout koo seh taw peh veh koo too ky neh taw peh ky koo too )

The relation of *co-implication,* symbolized by $\equiv$ and often read "···if and only if ···", is expressed by *se.* (see) (Note that the sign $\equiv$ has two other meanings in mathematics, for which the syllables *sam* and *kon* are provided.)

Example: $p \equiv q \ = \ (p \supset q) \ \& \ (q \supset p)$

pe se ku fe to pe ta ku tu kai to ku ta pe tu .
(peh seh koo feh taw peh tah koo too kie taw koo tah peh too )

The notion "such that" has two principal modes of expression: the symbols $\ni$, $|$, and $\backslash$ (and possibly other signs this writer has not seen yet!)—— these signs being rendered by the syllable *vi;* (vee) and the "capped" or "circumflexed"-letter method, where letters bear the mark $\hat{}$, as $\hat{w}$, $\hat{x}$, $\hat{y}$, $\hat{z}$, $\hat{\mu}$, $\hat{\theta}$, etc., for which the circumflex is rendered by *sir* (sеer) (from French *circonflexe*) and this syllable affects only the letter immediately following it.

Examples: $\hat{x}\ (x \in A)$, sirli to li be kapja tu ;
(seer-lee taw lee beh kahp-yah too )

$x \ni (\varphi x \& \sim \psi x)$, li vi to pifli kai ne pisli tu .
(lee vee taw peef-lee kie neh peace-lee too)

In this case, the two notations are provided separate syllables because: there seems to be a slight distinction between them made by some authors; the circumflex notation is more convenient in cases where several letters, with or without circumflex, are involved, as $\hat{x}\hat{y}$ or $x\hat{y}$ ; occasionally in other branches of mathematics a circumflexed letter is used; the \ or ə notation is more convenient when it is applied to a long expression, say one enclosed in parentheses; the separate-symbol notation is also convenient when one wishes to apply it to ordinary-language words or abbreviations.

The *assertion sign* $\vdash$ is rendered by *heu,* which is taken from the Latin interjection *heu.* (heh-oo, but in one syllable)

The exact meaning of the assertion sign varies from author to author, and some do not use it at all. However, in a spoken system such as Numaudo, it will be very convenient to have an assertion sign, "We assert that ... is so"; "An important expression follows"; "Your attention, please!" ; "This time, we are *using* the following expression, not merely *mentioning* it" ; and so on. In speaking, the assertion sign might well be generalized and used throughout mathematics, since a number of typographical devices are not available in spoken form, but *heu* would take their place fairly efficiently.

Example: $\vdash [p \vee (q \vee r)] \supset [q \vee (p \vee r)]$

heu ho pe ve to ku ve rer tu hu ta ho ku ve to pe ve rer tu hu .
(heh-oo haw peh veh taw koo veh mirr too hoo tah haw koo veh taw peh veh rairr too hoo )

DOTS AS PUNCTUATION. It has become a general practice in symbolic logic to use dots instead of parentheses and brackets, and occasionally in place of other punctuation, for a considerable portion of symbolic-logic writing, and this is especially the case where overlapping parentheses and brackets would confuse by number--and both legibility and ease of writing are improved by eliminating multiple parentheses and brackets. The rules for the use of dots as punctuation have not been settled as yet, and there is the further complication, already mentioned, of the widespread use of a dot to mean "and". As has been done with prime-marks, we shall provide a syllable for a single dot . *bon,* (bawn) and a syllable for two dots : *bun*--these following the pattern set by the prime-mark and superior-dot syllables. To represent three dots, *bonbun* (boon) is used, just as the three dots are written .: , and to represent four dots, *bunbun,* just as :: is written.

For an example, let us restate the formula given above (an axiom from *Principia Mathematica* that many other books have quoted) in its original form:

$\vdash : p \vee (q \vee r) .\supset. q \vee (p \vee r)$

Heu bun pe ve to ku ve rer tu bon ta bon ku ve to pe ve rer tu .
(heh-oo boon peh veh taw koo veh rairr too bawn tah bawn koo veh taw peh veh rairr too )

In connection with both parentheses and dots, it appears entirely practical in speaking to eliminate many of them by proper grouping, rhythm of speech, stress-patterns, and intonation of the voice, especially where groupings have already been established by uttering parenthesis or other punctuating syllables at the start of one's speaking. One will not eliminate punctuation when reading, or when dictating for transcription in conventional notation; but in lecturing, discussions, and conversation, elimination of many extra syllables by relying on tone of voice will be found a valuable timesaver. Denoting pauses by asterisks, and inflections of the voice by accents, the above example might be read:

*Hēu! * pē vè * kù-vẹ-rér * tū * kū' vè * pè-vẹ-rér .*

The hyphens are meant to suggest running the syllables together; acute, grave, and hook accents are meant to suggest primary, secondary, and reduced stress respectively; the macron here means drawling and higher voice-pitch. Use of Numaudo in conversation and discussion will soon establish desirable speech-patterns, and then instruction tapes can be prepared for teaching effective Numaudo diction.

The *neither-nor* situation, occasionally symbolized by ↓ (i.e., a line drawn through the *or* symbol), has been assigned the syllable *nek,* for Latin *nec,* of the same meaning.

The Sheffer stroke operator, usually written |, sometimes /, and usually taken to mean "not both" (the expressions flanking it) has been assigned the syllable *ner.* (nairr)

Frequently, when a logical statement is to be taken as a definition, it is followed by the abbreviation "Df." in roman type. In Numaudo, the first syllable of *definition,* namely *def,* is used for this purpose. Naturally, when "Df", with or without a period, is used as a subscript, the syllable *su* is prefixed to it, so that

$=_{Df}$ and $\supset_{Df}$ become *fesudef* (fessoodeff) and *tasudef* (tahssoodeff), respectively.

The *universal quantifier* has no special symbol, being expressed by the mere enclosure of a letter-symbol or the like in a pair of parentheses. Thus its ordinary Numaudo rendering will be, for instance, (*x*), to li tu. (taw lee too) If a single syllable meaning "all" is wanted, *tout* might be used. (tote)

The *existential quantifier,* (∃), will require the syllable *me* for the reversed E, ∃. (meh—me as in met) In speech, a special tone of voice, such as a longer syllable than usual at a higher pitch, can make parentheses unnecessary (subject, of course, to our previous remark that reading from print and writing to dictation ordinarily require full punctuation to be expressed).

Examples of quantifiers: (*x*) φ*x*, to li tu pif li *OR* toutli pifli ; (taw lee too peef lee OR tote-lee peef-lee)

(∃ *x*) (φ*x* & ψ*x* ) tomelitu to pifli kai pisli tu or meli pifli kai pisli . (taw-meh-lee-too taw peef-lee ky peace-lee too) OR: (meh-lee(PAUSE)peeflee ky peacelee).

As the normal capital E in assertions of existence and the like occurs but seldom, it is not necessary to provide a special syllable for it; and likewise for the exclamation point sometimes used after it. Therefore, E! *k* would be rendered *kapju hei kak* . (kahp-yoo hey kahk)

For the *unit class* the ordinary code for iota is used; thus ι*x* (the class having *x* as its sole member) is expressed by *jitli.* (yeet-lee)

However, the *description operator* (inverted iota) has a special syllable, *toi.* (This is intended to suggest "iota backward".)

Example: ι*x* (*Fx* & *Gx*) , toili to kapfef-li kai kapgeg-li tu . (toy-lee taw kahp-feff-lee kie kahp-ghegg-lee too)

A warning is necessary here to the effect that typographical difficulties at printing offices, and/or typewriter limitations, have caused the production of many examples of symbolic logic where E is used for ∃, ι is used for ɪ, v is used for ∨, letters or abbreviations or actual words are used for symbols, and symbols are appropriated from mathematics proper and given other meanings. The situation has created serious confusion already, and more confusion may be expected in the future. Indeed, this is one of the principal reasons for presenting the Numaudo system at this time.

Owing to the conditions just stated, it should be continually borne in mind that *the proper reading in Numaudo of a written symbol depends on what the symbol* MEANS, *not on how the symbol* LOOKS. If . means *and,* then it should be read *kai;* if . means *decimal point,* it should be read *na;* if . means the period at end of a sentence, it should be read *zo;* if . means *multiplied by,* it should be read *mu;* if . means an abbreviation precedes it, it should be read *zop;* if . means the symbolic-logic substitute for parentheses, it should be read *bon;* and if . does not mean anything in the particular instance, it should not be read at all!

*MODAL LOGIC:* The *necessity sign*, □, is rendered by *nes*. (The syllable *nes* will be used for "necessarily", even though *N* be used for □ (ness).)

The *possibility sign*, ◊, is rendered by *pot*. (This is derived from the Latin root *pot-*, as retained in such modern words (pawt) as *potent, potential,* etc. Even if a letter or other symbol is used instead of ◊, *pot* will still be the Numaudo syllable for the possibility sign.)

*Strict implication*, generally symbolized by $-\!\!\supset$, is rendered by *tap*.

*Strict co-implication*, generally symbolized by ≡, is rendered by *sep*. (tahp) (sepp)

(Both the above syllables are derived, of course, from *ta* and *se*, respectively.)

Examples: $[\Box p \,\&\, \Box \sim (q \,\&\, r)] -\!\!\supset [s -\!\!\supset (p \,\&\, \{\sim q \vee \sim r\})]$

Ho nespe kai nesne to kukairer tuhu tap ho ses tap to pe kai
(haw ness-peh kie ness-neh taw koo-kie-rairr too-hoo tahp haw sess tahp taw peh kie
tot-neku-ve-nerer tut-tu-hu.
tawt-neh-koo-veh-neh-rairr toot-too-hoo )

$\sim(\Diamond p \,\&\, \Diamond q) \supset (\Box \sim p \vee \Box \sim q)$

Ne to pot-pe kai pot-ku tu ta to nesnepe ve nesneku tu .
(neh taw pawt peh kie pawt koo too tah taw ness neh peh veh ness neh koo too )

$(p \equiv r \;\&\; q \equiv s) \supset ([p \supset q] \equiv [r \supset s])$

To pe sep rer kai ku sep ses tu ta to ho pe ta ku hu sep ho rer ta ses hu tu.
(taw peh sepp rairr kie koo sepp sess too tah taw haw peh tah koo hoo sepp haw rairr tah sess hoo too)

$p -\!\!\supset q \;.=.\; \sim\Diamond(p \,\&\, \sim q)$ Df.

Pe tap ku bon fe bon nepot to pe kai neku tu def.
(peh tahp koo bawn feh bawn neh-pawt taw peh kie neh-koo too deff )

Besides modal logic requiring extra symbols, as just shown, there are and will be other systems of logic, such as three-valued logic, and various forms of applied logic, which may require special symbols, or special values to be assigned certain existing conventional symbols. To express these in Numaudo will involve coining new syllables, of which an ample number should be available, even while observing the restrictions mentioned in the earlier part of this paper.

Some of the roman-letter abbreviations used in existing symbolic logic are worthy candidates for Numaudo syllables to represent them. This has already been done with "Df.". (See preceding example.) Which other abbreviations should have their own syllables will have to be decided after frequency statistics have been compiled.

The notion called *functional application* by Quine and others, and denoted by ' as in $\alpha'\beta$, and often equated to the expression *"The ... of ..."* in ordinary language, has been assigned the syllable *van*. Thus $\alpha$ ' $\beta$ , our example, would become *laf van bet*.
(lahf vahn bett)

The symbol ", usually called *projection*, is represented by *vap*.
(vahpp)

Both the above symbols have syllables derived from *va*, the beginning-quotation-mark sign, this being done for mnemonic reasons.

In symbolic logic, and occasionally in other branches of mathematics, *German letters* (*Fraktur*) are sometimes used. Often capitals only are used, in which case the syllable *kap* will not be required; if small and capital German letters are employed, then *kap* may be needed. From the German word *Deutsch* the syllable *doi* has been taken, and as with other code syllables already given, it applies only to the one letter-code immediately following it. Thus $\mathfrak{N}$ will be designated by *doini*, or *kapdoini* (kahp-doy-nee) if it has to be distinguished from lower-case German letters used in the same context.

*Script letters*, printed in imitation of handwriting, are sometimes used, both in mathematics and in logic. The signal for a script letter is *man*, (mahnn) suggestive of *manual, manuscript*.

Examples: $\mathcal{B}$, *man je;* (mahn yeh) $\mathcal{L}_b$, *manlel je;* (mahn-lell yeh) $\mathcal{K}_2$, *man kak suze* . (mahn kahk soo-zeh)

(To our knowledge, none but capital script letters ever occur in this usage.)

Symbolic Logic examples: $x \in \mathfrak{S}$ , li be doises ; (lee beh doy-sess) $\mathfrak{F} \subset \mathfrak{T}$ , doifef zi doitit; (doy-feff zee doy-teet)

$B \neq \Lambda$ , kapje no lan ; (kahp-yeh naw lahn) $x\ R\ y\ .\supset.\ y\ \breve{R}\ x$ , li kaprer lo bon ta bon (lee kahp rairr law bawn tah bawn)

→lo gou-kaprer li ; (→law go- kahp-rairr lee) $x\ R\ y\ \&\ y\ S\ z\ .\supset.\ x\ R|S\ z$ , li kaprer lo kai lo kapses lu (lee kahp-rairr law kie law kahp-sess loo

bon ta bon li kaprer pii kapses lu ; (bawn tah bawn lee kahp-rairr peet kahp-sess loo ) $\hat{z}(z \notin x) = \bar{x}$ , sirlu to lu ben li tu fegoi li (seerr-loo taw loo ben lee too feh goylee)

Enough examples have now been given of symbolic logic and allied studies that it should be evident that the Numaudo system provides a readily speakable code for all ordinary uses of logical, as well as mathematical, symbols. Further it should be evident that symbolic logic proper, class calculus, and ordinary mathematics may be combined, in their Numaudo-coded form, with less risk of confusion and ambiguity than occurs when such combinations are attempted in the conventional notation. With the provision of symbols for ordinary punctuation, it also becomes practical to fit mathematical and logical expressions into sentences in ordinary language without upsetting the grammatical structure of such sentences; and it now becomes practicable to use punctuation with mathematico-logical expressions and yet never run the risk of sentence-ending periods becoming confused with decimal points or multiplication dots, or of grammatical-rhetorical colons becoming confused with ratio signs, or of hyphens and dashes becoming confused with minus signs—this last, unfortunately, being a fairly frequent occurrence.

While examples will not be given here, it should be fairly obvious how one could extend the codes already given to express logical syntax, various offshoots of symbolic logic, and even structural linguistics. Considerable attention has been given in recent years to what might be called the algebra of grammar. Undoubtedly even more attention will be given this field in the near future, since it has important applications in such fields as machine translation of languages.

In the writer's opinion, symbolic logic has not developed as rapidly as it might have done, had there been an easily-pronounceable spoken form of symbolization for it. Time and again, the writer has seen persons discussing mathematics or logic suddenly develop an anxious expression on their faces, and then rush frantically to the blackboard or pencil-and-paper, and their very haste made the written symbols illegible and ambiguous—the more anxious they were to convey their ideas, the less effective the symbols became.

Handwriting is adequate enough for deliberate communication, where there has been time to think through thoroughly what one has to say; but in *discussion* or *conversation* or in instances of sudden insight, handwriting is far too slow. The deaf, faced with this problem, had to evolve a sign-language with freely-made gestures that go much faster than one could write symbols on a blackboard or than one could spell out letter by letter.

Another drawback of a primarily handwritten system is that one's thought-processes in thinking out a problem have only the benefit of visual and kinæsthetic feedback. There is little or none of the auditory feedback that can occur when one is composing a text in ordinary language. Even the rapid kinæsthetic feedback available to the typist writing out ordinary sentences is denied the mathematician or logician, because the number of different symbols required exceeds the number of symbols (84 to 92) available at one time on any typewriter. (Even on such a machine as the Varityper with which this article is written, considerable *time* is required to change from one set of type to another, and back again; and there still are many symbols not available for the machine that must be written in by hand.)

Also, the conventional mathematico-logical notation suffers from the fact that in handwriting, only a comparatively small number of distinctively different symbols are possible. (This has caused much trouble to those who would devise phonetic alphabets.) It takes a really skilled penman to keep such characters as $v$ and $\nu$ apart, for instance. Or, note the notations $x.y$ or $x \cdot y$ that had to be invented because no one could be expected to write legibly $x \times y$, let alone $X \times Y$ !

This limitation of handwriting has caused the already-mentioned assignment of several meanings to one letter or symbol, e.g. $d$, $e$, $f$, $i$, $.$, $\equiv$. In a field which is credited with setting an example of rigor for other fields to follow, such ambiguities (and the converse ambiguity of having several symbols for one meaning, as . & $\wedge$) are scarcely excusable.

It may now be clear why the *syllable,* rather than the phoneme (single speech-sound category) was selected as the unit in Numaudo coding. There are not enough individual speech-sounds to stand for all the currently-used mathematical symbols, letters, and numerals—certainly not enough for future growth; but there are enough syllables, even within the restrictions listed on Pages 3 to 6.

The special artificial languages, Tilp (S.C. Dodd) and Lingua Scientifica (R.M. Biow) which are quite different from one another and from Numaudo, were able to use single letters, standing for phonemes, as they both started from a very small number of fundamental ideas, out of which were built the rest of the systems. Numaudo was not able to do this, because it is only a code for existing written symbols, not containing enough additions to the existing symbol-systems to constitute an independent language: and the Numaudo rendering of each existing mathematico-logical symbol has to be "transparent" and instantly reconvertible; thus Numaudo must have at least as many units as there are original symbols, since a many-to-one relationship cannot be allowed,

This reversible, one-to-one conversion relation between Numaudo code syllables and written symbols is very important because it supplies the basis for auditory feedback. Admittedly, on the level of elementary arithmetic some auditory feedback is possible: consider how much trouble the average person would have doing multiplication or long-division problems if he or she were prevented from saying over "three times seven is twenty-one, carry two" and the like. So long as one remains at the grade-school level of arithmetic, this may be adequate, because the ordinary language version of the multiplication table does not distort the numerical version too drastically. (Yet within the English language we find different renderings of the same symbols: "Thrice seven is twenty-one";"three sevens are twenty-one" ; "Three times seven equals twenty-one" *and other renderings,* so that the auditory multiplication tables of different English-speaking persons are not the same, and the recitation of entries from the multiplication table would actually disturb anyone else brought up under another system.)

Now that more persons will be expected to go far beyond the elementary-arithmetic level, and to become skilled in algebra, calculus, and logic, such crude forms of auditory feedback will no longer suffice. As one progresses toward higher mathematics, the verbal renderings of symbols become actual translations from one language into another--and it is hard enough to learn mathematics without being compelled to become a good interpreter at the same time. When translation, or

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It may now be clear why the *syllable,* rather than the phoneme (single speech-sound category) was selected as the unit in Numaudo coding. There are not enough individual speech-sounds to stand for all the currently-used mathematical symbols, letters, and numerals—certainly not enough for future growth; but there are enough syllables, even within the restrictions listed on Pages 3 to 6.

The special artificial languages, Tilp (S.C. Dodd) and Lingua Scientifica (R.M. Biow) which are quite different from one another and from Numaudo, were able to use single letters, standing for phonemes, as they both started from a very small number of fundamental ideas, out of which were built the rest of the systems. Numaudo was not able to do this, because it is only a code for existing written symbols, not containing enough additions to the existing symbol-systems to constitute an independent language: and the Numaudo rendering of each existing mathematico-logical symbol has to be "transparent" and instantly reconvertible; thus Numaudo must have at least as many units as there are original symbols, since a many-to-one relationship cannot be allowed,

This reversible, one-to-one conversion relation between Numaudo code syllables and written symbols is very important because it supplies the basis for auditory feedback. Admittedly, on the level of elementary arithmetic some auditory feedback is possible: consider how much trouble the average person would have doing multiplication or long-division problems if he or she were prevented from saying over "three times seven is twenty-one, carry two" and the like. So long as one remains at the grade-school level of arithmetic, this may be adequate, because the ordinary language version of the multiplication table does not distort the numerical version too drastically. (Yet within the English language we find different renderings of the same symbols: "Thrice seven is twenty-one";"three sevens are twenty-one" ; "Three times seven equals twenty-one" *and other renderings,* so that the auditory multiplication tables of different English-speaking persons are not the same, and the recitation of entries from the multiplication table would actually disturb anyone else brought up under another system.)

Now that more persons will be expected to go far beyond the elementary-arithmetic level, and to become skilled in algebra, calculus, and logic, such crude forms of auditory feedback will no longer suffice. As one progresses toward higher mathematics, the verbal renderings of symbols become actual translations from one language into another--and it is hard enough to learn mathematics without being compelled to become a good interpreter at the same time. When translation, or

rather, interpreting, becomes involved in the feedback path, in both directions, the benefits of auditory feedback, which the student has enjoyed up to this point, are mostly lost. This inevitably slows down the learning process and interferes with memorizing in the best of persons.

Since the Numaudo user will not have to translate, auditory feedback will be fully effective, and the memory-records of conventional symbols as seen, kinæsthetic memory of how the symbol is written, auditory memory of how the Numaudo syllable for it sounds, kinæsthetic memory of speech-organ movements required to pronounce the Numaudo syllable, and eventually kinæsthetic memories pertaining to the typing of the written-Numaudo syllable and visual memory of how the written syllable looks —all these will become fully integrated and reinforce one another.

Thus it is important in the *teaching and learning* of Numaudo that the student be aware that Numaudo is a *code,* not a language. Otherwise the benefits of doing away with the present translating process (see page 29, at top) will not be realized. Through Numaudo it is possible to read and memorize more readily and efficiently from the vast quantity of books already printed in conventional notation. The gaining of the advantages of auditory feedback, easier memorizing, fluent reading, and fluent discussion of mathematics and logic does not entail reforming the existing notation, nor scrapping present textbooks.

Under the present system, the student or practitioner of mathematics, in doing a problem or reading about one, will accompany his writing or reading of symbols with overt or subvocal speech, or at least imagined speech, and the spoken accompaniment will at least partly be a translation into ordinary language, and thereby a distortion of the meaning of the written symbols: especially, it will often be vague or ambiguous where the symbols are definite. Naturally, a conflict is set up, whether or not one is consciously aware of it.

Besides the frankly artificial languages mentioned above, there are several international auxiliary languages, such as Esperanto and Interlingua. The question has been raised, What relation does Numaudo have to such languages? These languages are intended for everyday discourse rather than for scientific exactness. Whatever success Esperanto has had has been just because it deliberately incorporates a certain amount of vagueness. Interglossa aimed for precision where it did not belong, and did not survive; Interlingua apparently does not seek such extreme precision. Writers on symbolic logic, P. Rosenbloom for instance, group Esperanto and Interlingua with the "natural" languages, for similar reasons. Bertrand Russell has stated several times that mathematics and logic are too rigorous to serve as the sole vehicles of everyday discourse; even though he assiduously promoted an enlarged vocabulary and scope for rigorous mathematico-logical language, he still maintains that ordinary languages are necessary. Now Numaudo is designed to transmit undiminished the rigor and precision of the mathematics and logic which it encodes; and thus to say, to make audible, those combinations of ideas which are imperfectly expressed by ordinary languages. Its relation to a language compiled from other languages, as Zamenhof compiled Esperanto, is then much the same as its relation to French or German. That is, Numaudo is compatible with the international auxiliary languages; it is compatible with artificial languages like Tilp and Lingua Scientifica; it is compatible with ordinary languages like Russian or English. It does not overlap very much on the territory of any other language simply because the already existing languages, mathematics and logic, do not; it is but their microphone and loudspeaker, as it were.

Since mathematics and logic already function as written languages, they will also function as spoken languages in their Numaudo form. The written symbols have been used mainly together with ordinary written languages; so will Numaudo be used mainly in conjunction with ordinary spoken languages. The Numaudo phrases and expressions will take care of the more precise notions; the sentences and phrases of ordinary spoken language will take care of the less precise notions. Animated conversations, discussions, and lectures will take place, and no one will have to slow down for the mathematico-logical parts.

The use of Numaudo in conversation will serve to emphasize the greater importance mathematics is coming to have in this day and age of engineering technology, automatic machines, expanded communication networks, scientific progress, and ever more complicated business enterprises. Mathematical and logical techniques are even invading the humanities: new trends in art frequently have an explicit or implicit mathematico-logical basis.

At the same time, the use of Numaudo in speaking will accustom people to the proper method of speaking to voice-operated machines, which machines will become more and more common in the next two decades. The more precise and regulated the manner in which persons communicate with listening and speaking machines, the less elaborate and expensive the construction of such machines has to be; and the sooner we can have them to use.

If an attempt be made to design a machine to respond to instructions in ordinary language, such as English, immediately one faces the problem of homonyms, such as *here, hear; I, eye, aye;* etc. The numeral-words *one, two, four, eight*, present problems of this kind, even beyond simple homonyms: frequent conversational words and phrases, such as *want to, before, create, too much, tending to,* might set off false responses from a digital machine designed for English numerals and instructions. It is too much to expect everyone in the vicinity of a listening machine to monitor his vocabulary continually—and the changes one would have to make in one's speech habits to accommodate such situations would be far more difficult to keep in mind than the twenty syllables of Numaudo that would be required for accomplishing the same results at less machine-manufacturing expense.

While most machines employing Numaudo will be digital in nature, apparatus for performing at least the simpler logical calculations is already in existence, and thus it is quite likely that in a few years machines accepting symbolic logic in Numaudo form can be built. Logic-machine design is such a new field that the possible uses of such equipment have not even been catalogued yet. However, even at this early stage the possibilities are sufficiently evident that it was felt advisable to include logic as well as ordinary mathematics within the system.

Those using Numaudo logic syllables in conversation, then, should take care to use them in a sufficiently precise manner that no drastic adjustments in speaking habits will be required when spoken-logic machines eventually come into use. In particular, one should watch for cases where mathematico-logical symbols (and thus the syllables alloted to them) are about to take on *additional meanings:* such new meanings should first be expressed in ordinary language, if that be possible at all; and then new syllables can be introduced to accommodate such meanings, rather than extending the meaning of an existing syllable and thus making it more vague. (A useful temporary expedient will be the subscript method via syllables *su ... zu;* another device will be the temporary use of syllables from the *Reserved List,* which will be given later.)

## *THE METALANGUAGE CONCEPT*

In recent years, quite a number of logicians, philosophers, and semanticists, as well as structural linguisticians, have introduced the idea of *metalanguage* into their respective fields. That is to say, it is now being realized that *a system can not be thoroughly proved, adequately criticized, or unambiguously discussed, while one remains entirely within the confines of that system.* For instance, one uses ordinary language to discuss mathematics, in which case ordinary language is the metalanguage and mathematics the *object-language;* conversely, one may analyze syntax of English, in which case English is the object-language and a certain part of mathematical logic is the metalanguage. So long as one tries to discuss the structure of the English language using only English words, one is bound to overlook many important factors; and indeed this has been the case for centuries. (The use of French, German, or Latin as a metalanguage in discussing the structure of English mitigates but does not eliminate the problem, because those languages are related to English, being part of the Indo-European family.)

If any further example of the need for a metalanguage is required, one only has to consider the many famous philosophical problems raised by the Ancient Greeks and the mediæval philosophers who used Latin, and that some of these problems resisted solution for century after century. Only after modern symbolic logic and analytical methods emerged, only after one could go outside the language in which the questions were framed, could anyone solve the problems or prove them to be pseudo-problems generated by the structure of the "natural" language used.

Now, suppose that logical symbols are being used to discuss the structure of English sentences. The strings of symbols *quã* ink-marks on paper constitute a language different from English, adequate to serve as a metalanguage for such a purpose. But, the moment one reads these symbols aloud, or even imagines a spoken accompaniment to the act of reading them, English words appear, albeit unintentionally: the names of letters in English form, the names for symbols (often fanciful or facetious, as "horseshoe" or "cap" ), and—most dangerous of all—English words will appear which are only approximate *translations* of the logical symbols. Thus the *written* symbols do constitute a metalanguage, but the reading of them, whether aloud or allegedly "silently" causes a return to the object-language, so there is no longer a metalanguage proper.

Oddest fact of all is that authors have used the phrase "a metalanguage for *talking* about the object-language" without realizing that they have provided a metalanguage for *writing* about the object language, but certainly none for *talking* about it! There seems to be a blind spot here—or rather a deaf spot. The difficulty is carefully ignored.

Supplying a spoken form of the mathematico-logical metalanguage may turn out to be one of the most important functions of Numaudo. This also applies where the object-language is not an ordinary language such as English, but where mathematico-logical language is used to discuss engineering problems or scientific observations without putting such data into ordinary words.

## *RELATION WORDS*

As an optional supplement to the Numaudo code, and as a bridge between mathematics-and-logic and other languages, natural or artificial, a list is appended of syllables for certain words or phrases frequently occurring in mathematical and logical texts. Since considerable difference of opinion exists, among the best of authorities, regarding the admissibility of any or all these concepts for mathematico-logical purposes, the inclusion of this list is not to be taken as necessarily reflecting the author's opinions. Where words are given opposite syllables, and the words have several meanings, generally only one of the meanings is actually rendered by the syllable. Unfortunately space is not available to give definitions in such cases. The utility of this supplement will only be determined by the way it works out in practice.

First is given a list of syllables already assigned, which are sometimes classed as relation words, connectives, or correlatives. They are presented here in the order of their occurrence in this article:

| *Syllable* | *Relation word* | *Page* |
|---|---|---|
| FE | equals, is | 8 |
| MO | etc. | 10 |
| NO | (is)not equal to | 14 |
| FA | (is)greater (than) | 14 |
| FO | (is)less (than) | 14 |
| TI | (is)nearly | 14 |
| SAM | (is)identical with | 14 |
| PER | per | 16 |
| FAI | (is)greater than or equal to | 21 |
| FOI | (is)less than or equal to | 21 |
| MUT | varies as | 21 |
| TIL | till, approaching | 22 |
| DAU | to (in ratios) | 22 |
| KER | because, since | 22 |
| TAK | therefore | 22 |
| KED | q.e.d. | 22 |
| FIN | end | 26 |
| JES | yes | 26 |
| NOU | no | 26 |
| BE | is a ... | 36 |
| BEN | is not a ... | 36 |
| ZI | belongs in | 36 |

(*Continued on next page*)

(Relation-word Syllables Already Given. Continued from preceding page.)

| Syllable | Relation word | Page | Syllable | Relation word | Page |
|---|---|---|---|---|---|
| FEI | becomes | 27 | HEU | I state: | |
| ZIN | does not belong in | 36 | | I assert that | 39 |
| GOI | non- | 36 | NEK | neither...nor... | 40 |
| TA | entails | 37 | NER | not both | 40 |
| KAI | and | 37 | DEF | by definition | 40 |
| NE | not | 37 | TOUT | all | 40 |
| VE | and/or | 38 | ME | there is | 40 |
| MAUT | or (but not both) | 38 | TOI | the | 40 |
| SE | if and only if | 38 | NES | necessarily | 41 |
| VI | such that | 38 | POT | possibly | 41 |
| SIR | (the...)such that | 38 | VAN | the...of... | 41 |

About 30 more syllables already assigned and not listed above would be considered to be relation words by some people. For instance, *vun* or *nif* might be called translations of *everything*. Conversely, others might consider the above list far too long, and reject such syllables as *ked, goi, heu, pot* on the ground that they do not fit their personal definition of what a relation word should be.

Note, however, that if the words listed above were *exact* translations, there would be no need for mathematico-logical symbols, let alone Numaudo. Similarly, the words to be given in the following list are not to be considered exact determinants of the meanings the corresponding syllables shall have when such syllables are used with the remaining syllables of the Numaudo system. To prescribe beforehand that the syllables in the list following should translate exactly the words opposite them would be ultimately to force the (often vague) meanings of English words upon the mathematical and logical symbols that might be added to the conventional written system in the future. Even the remote possibility of such an eventuality is definitely to be guarded against. The exact meanings of the syllables to be given below will be established when or if they are used with already-established syllables. (*List is arranged in alphabetical order of the syllables.*)

| SYLLABLE | (PRON.) | RELATION WORD | (DERIV.) |
|---|---|---|---|
| *bam* | (bahm) | interact, interacting, interaction (with) | |
| *bat* | (baht) | and/but (Russian *a*) | |
| *bef* | (beff) | before (time) | *E* |
| *bei* | (bay) | how much/how many | |
| *bez* | (bezz) | without | *R* |
| *dai* | (die) | of | *I* |
| *dan* | (dahn) | in, within, inside (of) | *F* |
| *dez* | (dezz) | some (*corresponding to indefinite article*) | *F* |
| *dis* | (deess) | this | *E, G* |
| *don* | (dawn) | where | *S* |
| *dot* | (dawt) | that (yonder) *NOT a conjunction*(demonstrative) | |
| *fil* | (feel) | much, many | *G* |
| *fom* | (fawm) | from | *E, G* |
| *gei* | (gay) | General verb of action (not mere state) | |
| *gif* | (gheef) | if (*Old*) | *E* |
| *jed* | (yedd) | each | *G* |
| *jun* | (yune) | unit (generalized) | *E* |
| *kau* | (cow) | whatever | |
| *kel* | (kell) | which | *F* |
| *kif* | (keef) | who | |
| *kog* | (kawg) | when | *R* |
| *kom* | (kawm) | how, as | *F* |

| SYLLABLE | (PRON.) | RELATION WORD | (DERIV.) |
|---|---|---|---|
| *kui* | (kooey) | that (*conjunction only*) | *F, I, S* |
| *let* | (let) | let (as, let *x* equal) | *E* |
| *lun* | (loon) | a, an (indefinite article) | *F, S* |
| *mak* | (mahk) | maximum | *L* |
| *mas* | (mahs) | but (Spanish *pero*, German *aber*) | *I, S* |
| *mit* | (meet) | with | *G* |
| *mum* | (moom) | minimum | *L* |
| *nai* | (nigh) | near (nigh) | *E* |
| *nan* | (nahn) | other(s) | *G* |
| *nau* | (now) | General conjunction/interjection/particle/primary adverb | *E* |
| *nil* | (neel) | nothing | *L* |
| *nom* | (nawm) | General noun, anything | *L, F* |
| *nui* | (nooey) | Originator of the communication, I, we (first person) | *F* |
| *nun* | (noon) | now (time only) | *G* |
| *nur* | (ncorr) | only | *G* |
| *poi* | (poy) | then | *I* |
| *pos* | (pawss) | after | *L, R* |
| *pur* | (poohrr) | for | *F* |
| *rau* | (rou) | outside (of) | *G* |
| *rei* | (ray) | thing (actual concrete object(s) only) | *L* |

(Continued on Following Page)

(Relation-word Syllables Already Given. Continued from preceding page.)

| Syllable | Relation word | Page | Syllable | Relation word | Page |
|---|---|---|---|---|---|
| FEI | becomes | 27 | HEU | I state: | |
| ZIN | does not belong in | 36 | | I assert that | 39 |
| GOI | non- | 36 | NEK | neither...nor... | 40 |
| TA | entails | 37 | NER | not both | 40 |
| KAI | and | 37 | DEF | by definition | 40 |
| NE | not | 37 | TOUT | all | 40 |
| VE | and/or | 38 | ME | there is | 40 |
| MAUT | or (but not both) | 38 | TOI | the | 40 |
| SE | if and only if | 38 | NES | necessarily | 41 |
| VI | such that | 38 | POT | possibly | 41 |
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|---|---|---|---|
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| *bat* | (baht) | and/but (Russian *a*) | |
| *bef* | (beff) | before (time) | *E* |
| *bei* | (bay) | how much/how many | |
| *bez* | (bezz) | without | *R* |
| *dai* | (die) | of | *I* |
| *dan* | (dahn) | in, within, inside (of) | *F* |
| *dez* | (dezz) | some (*corresponding to indefinite article*) | *F* |
| *dis* | (deess) | this | *E, G* |
| *don* | (dawn) | where | *S* |
| *dot* | (dawt) | that (yonder) *NOT a conjunction*(demonstrative) | |
| *fil* | (feel) | much, many | *G* |
| *fom* | (fawm) | from | *E, G* |
| *gei* | (gay) | General verb of action (not mere state) | |
| *gif* | (gheef) | if (*Old*) | *E* |
| *jed* | (yedd) | each | *G* |
| *jun* | (yune) | unit (generalized) | *E* |
| *kau* | (cow) | whatever | |
| *kel* | (kell) | which | *F* |
| *kif* | (keef) | who | |
| *kog* | (kawg) | when | *R* |
| *kom* | (kawm) | how, as | *F* |

| SYLLABLE | (PRON.) | RELATION WORD | (DERIV.) |
|---|---|---|---|
| *kui* | (kooey) | that (*conjunction only*) | *F, I, S* |
| *let* | (let) | let (as, let *x* equal) | *E* |
| *lun* | (loon) | a, an (indefinite article) | *F, S* |
| *mak* | (mahk) | maximum | *L* |
| *mas* | (mahs) | but (Spanish *pero*, German *aber*) | *I, S* |
| *mit* | (meet) | with | *G* |
| *mum* | (moom) | minimum | *L* |
| *nai* | (nigh) | near (nigh) | *E* |
| *nan* | (nahn) | other(s) | *G* |
| *nau* | (now) | General conjunction/interjection/particle/primary adverb | *E* |
| *nil* | (neel) | nothing | *L* |
| *nom* | (nawm) | General noun, anything | *L, F* |
| *nui* | (nooey) | Originator of the communication, I, we (first person) | *F* |
| *nun* | (noon) | now (time only) | *G* |
| *nur* | (ncorr) | only | *G* |
| *poi* | (poy) | then | *I* |
| *pos* | (pawss) | after | *L, R* |
| *pur* | (poohrr) | for | *F* |
| *rau* | (rou) | outside (of) | *G* |
| *rei* | (ray) | thing (actual concrete object(s) only) | *L* |

(Continued on Following Page)

(RELATION-WORD LIST, CONTINUED)

| SYLLABLE (PR) | | RELATION WORD | DERIV. | SYLLABLE (PR.) | | RELATION WORD | DERIV. |
|---|---|---|---|---|---|---|---|
| *rel* | (rell) | General Relation of any sort | *L* | *sup* | (soup) | General modifier (adjective/adverb) | |
| *roi* | (roy) | General Preposition | | *tad* | (tahd) | to, towards | *L* |
| *rui* | (rooey) | it, he, she, they, one (general 3rd-pers. Pronoun) | | *tai* | (tie) | event in space-time | *E* |
| *rum* | (room) | why | *G* | *tal* | (tahl) | such | *S, L* |
| *sait* | (site) | instant (a time) | *G* | *tis* | (teess) | what | *Gk* |
| *sev* | (sev) | several, a plurality of, more than one | *E* | *vui* | (vooey) | you; anyone or thing addressed | *F* |
| *sof* | (sawff) | except | *F* | *zon* | (zawn) | but (German *sondern*, Spanish *sino*) | *G* |
| *soi* | (soy) | through (across) | | *meit** | (mate) | between | |
| *sui* | (sooey) | -self (reflexive pronoun) | *L* | | | | |

*(*Meit* properly belongs after *mas* in the * position on page 47.)

Fortunately for learning purposes, it was not necessary to assign very many arbitrary syllables to the words in the above list. The *Derivation* column indicates the language(s) from which each syllable was taken, or upon a word of which it was modeled, as follows: *E*, English; *F*, French; *G*, German; *Gk*, Greek; *I*, Italian; *L*, Latin; *R*, Russian; *S*, Spanish. If no derivation letter appears, the syllable is arbitrary. It may be remarked here in passing that while not all the derivations have been given for the syllables assigned throughout this article, the vast majority of them (except the digit-syllables) are derived from or modeled upon some existing language.

Many common relation-words not on the list, and many useful concepts not in ordinary languages may be compounded by juxtaposing Numaudo syllables. For example, "unless" would be "if not", *negif* or *gifne* or *gif ne*, depending on the desired nuance. "You two" would be *vuize*. "Thing *x* such that *x* is a concrete object" or ℓ(*x* ∈ concrete object) could, if desired, be abbreviated to *lisur ei*, or one might say *letliferei* or even *lirei;* in any event, much time would be saved by using syllables from the relation-word list.

In the event that one wishes to combine (compound) Numaudo syllables with ordinary-language words, the hyphen syllable *hif* should be used. Except in the most unusual cases, no regular hyphen will be needed: it is wise not to use a written hyphen - because it could be mistaken for a dash or a minus sign. Thus one may write or say: person*hif*sus*a*, (although it might be safe to use person*a*, person*ze*, etc., later in a discourse), *zinhif*Europe country, *henzorhenhif*input circuit (where one wishes to speak about the number of inputs the circuit has without leaving the binary counting system), output*hif*sul*eu* (where one wishes to keep on "thinking in octal"), (this can be shortened to "output*leu*" if proper inflection of the voice is used), true*hif*bef*nun* statement. Before omitting *hif* in speaking, one must, at least in imagination, try out the effect, to find if ambiguity would result.

Note that in ordinary language—at least in English—a slant-line / has nothing to do with the fraction-bar. Render this and other such marks according to meaning. Generally *ve* will render "and/or", and *kaivemas* would render the "and/but" we have used to explain *bat*. *Plus* signs + in ordinary language may not always correspond to *pa; kai* or even the non-committal *rel* may be more accurate in many instances.

Use, especially in conversation, of Numaudo will bring out unexpected needs that could not possibly be foreseen here. Use of Numaudo with speaking and listening machines will bring out still more unexpected consequences and needs for special syllables and usages. Again there is no point in being presumptuous and trying to forecast their exact nature. Instead, Numaudo has been framed as an *open-ended system*, with some optional, removable features and many provisions for future additions and growth.

The reason for emphasizing the *optional* character of certain sub-systems of Numaudo is that growth of the system is to be by *addition and/or subtraction*, and

not by radical *changes in meaning* of the syllables already assigned in the system. Slight changes through actual usage and practice are inevitable, but sweeping changes would destroy the value of this article as a reference manual, and would jeopardize the financial investments which will result when the Numaudo system or certain parts of it are built into machines and used in information storage. Whatever is not germane to the interests of any given person using Numaudo may simply be left alone—if enough general agreement to reject certain features ensues, then those minor portions will in effect cease to be Numaudo syllables.

Whenever it becomes needful to ensure uniform use and acceptance of new syllables to be added to the system, and to give more exact definitions of the meanings and applications of syllables already assigned, a Numaudo Standardization Committee can be organized with the co-operation of users of the system and of existing bodies that work with the standardization of units, symbols, terminology, etc. in various countries and internationally.

In the meantime, certain syllables, to be given below, will be *reserved*—that is, no meanings will be assigned to them, but they may be used for private meanings (secret or unpublished meanings), for nonce purposes (that is, with a special meaning that lasts only for the duration of a single conversation, lecture, or paragraph), or as mere empty space-time fillers (for instance, to "hold the place" for meaningful words or syllables that one hopes will be inserted later on). If any syllable (there are more than 2000, in fact) conforms to the rules given on Pages 3, 4, 5, and 6, and does not occur in the Alphabetical Index List to be given as the concluding portion of this article, which list naturally includes the Reserved syllables about to be given, it may be assigned a new meaning and provisionally added to the system, subject, of course, to future rulings of a standardization Committee, should such ever be established.

LIST OF RESERVED SYLLABLES

| Syllable | Pronunciation | Syllable | Pronunciation | Syllable | Pronunciation | Syllable | Pronunciation |
|---|---|---|---|---|---|---|---|
| *ban* | (bahn) | *geu* | (gheh-oo) | *loi* | (loy) | *sal* | (sahl) |
| *beu* | (beh-oo) | *hai* | (hi) | *men* | (men) | *tin* | (teen) |
| *dou* | (dough) | *jai* | (yi) | *nei* | (nay) | *vou* | (voh) |
| *fau* | (fou--as in *foul*) | *jei* | (yay) | *pui* | (pooey) | *zau* | (zow) |
| *fui* | (fooey) | *kun* | (koon) | *ran* | (rahn) | *zoi* | (zoy) |

There are several reasons for having as many as 20 reserved syllables: The user can select from different initial letters and different vowels those which sound something like the private words or temporary-meaning words he has in mind at the moment; with this many syllables, articulation tests and machine test routines can be made up that simulate better the handling of normal Numaudo passages; it will never be necessary to resort to the confusing practice of using the same syllable for different meanings at different times: there will be ample time to forget the first temporary meaning before using a second.

A few syllables containing supplementary sounds have also been reserved. Of course, it may never be necessary to employ the supplementary sounds given on pages 3 and 4, in which case the syllables to be given will not function in the Numaudo system; but if anyone ever has to bring the supplementary sounds into use, the following syllables are to be considered already pre-empted: *cq* or *ʃø*, (sheuh); *cqc* or *ʃøʃ*, (shush); *ʔy* or *ʔy*, (not expressible in English); *nq* or *nø*, (neuh); *ly*, (French "lu"); *luʔ* or *luʔ*, (loo'); *kic* or *kiʃ*, (keesh). (In each case, the syllable is first written in typewriter-compatible coding, then in International Phonetic Association transcription, then the nearest English spelling for its pronunciation is given.)

Having now expounded a pronounceable system of coding the symbols and ideas of mathematics, symbolic logic, and certain fields related thereto, and having furnished a sufficient number of examples and a sufficient amount of information to enable the average reader to apply all or part of the system in any manner he or she chooses, there remain only minor points in need of clarification.

Since it was found possible to present a comprehensive system, complete with subsystems, without having to bring in the supplementary sounds, the Numaudo alphabet may now be considered as containing 21 letters, *a, b, d, e, f, g, h, i, j, k, l, m, n, o, p, r, s, t, u, v, z.* The supplementary sounds [ø y ʔ ʃ] may then be considered as primarily represented by their International Phonetic Association symbols, just given, and the coding letters *c, q,* may be assigned to non-speech sounds along with *w, x,* since *c* and *q* as phonetic symbols are very rare and as such denote sounds too much like *k* to be used in a phonemic system like Numaudo. That is, it is now clear that supplementary sounds will be confined mainly to private uses, such as the key-syllables alluded to on Pages 25 and 35, and thus the need to transmit supplementary symbols by teletypewriter and the like may never materialize.

Really secret key-syllables may even contain such sounds as θæŋ (thang) or ðɜ- (thur), since they could be imparted by word-of-mouth and would only be known to a very few persons. The only limitation on key-syllables is the expense of building special machines to respond properly to unusual sounds.

In case it is not clear to the reader why *w* and *x* were excluded from the Numaudo alphabet, an explanation follows: [w] is an international phonetic symbol for the sound of *w* in English *well, away,* but there are many languages, such as German, Russian, Czech, Greek, Japanese, and others, that have either a *v*- or a *w*-sound, but not both. Thus, to be international, Numaudo has to elect one of the letters *v, w,* to stand for both sounds or any intermediate sound, such as [β], which occurs in several languages. This means that speakers of English must expect to hear *vo,* for example, sounded as (vaw) or (waw) or anything between these pronunciations, and if they wish to pronounce some *v*'s as *w*, they are free to do so. Similarly, [x] is the international phonetic symbol for the sound of German *ch* in *ach*. This is close enough to the sound of English *h* in *hot, ahead,* that again a phonemic system such as Numaudo has to make a choice between *h, x;* and whichever letter is chosen will stand for both sounds or anything between. Unfortunately there is an added complication: French and Italian have neither the sound [h] nor the sound [x]. After spending much thought on this problem, it was concluded that Frenchmen and Italians who cannot pronounce either of those sounds will have to be allowed to sound all *h*'s in Numaudo as either [ʒ] or [dʒ]—*i.e.,* the French or the English *j*-sounds. This may seem to be a bizarre solution to the problem, but it is in accord with the principles advocated in several modern works on linguistic science. (This also explains the pronunciations given for *peh, kih,* on Page 31.)

Some phoneticians use non-standard symbols (recall our account of the chaotic situation in symbolic logic, Pages 36-40!) and there are those who would have spelt our *je* as *ye,* our *kai* as *kay,* our *naut* as *nawt,* and there are still others who would have rendered our *kai* as *kaj*. We have to mention this here because if we did not, someone would surely ask the reasons for our choice. Our choice stems from the following considerations: (1) *j* has been established as an international phonetic symbol sounding as it does in Numaudo for at least three times as long as some phoneticians have been using *y* for this sound; (2) if we used *j* or *y*, and *w*, in our diphthongs, *ai, au,* etc., it would cause more confusion and difficulty in learning the system than it would alleviate; that is, our choice respects the reading habits of more nationalities than would the alternatives. Machine designers, however, should note that the actual pronunciation of *i* or *u* in such diphthongs may vary all the way from a full vowel to a full consonant, and design phoneme-recognition circuits accordingly.

One way out of the difficulties mentioned above would have been to have left out *h, j, r, v, z,* and the diphthongs entirely. Had we done this, it would have simplified the phonetic/phonemic structure, but at the same time it would have made the code monotonous in sound, tiresome to listen to, and harder to remember because few if any syllables could be modeled on the words of regular languages. With only ¼ as many possible syllables, there would be no real room for growth, since all the best syllables would be taken —it would then be a closed system. It goes without saying that the rapidly-changing world of today has little need for closed systems.

The day may even come when the rules of syllable-formation (such as prohibition of consonant-clusters) may have to be relaxed—though that is fairly far in the future. The use of diphthongs other than the seven (*ai, au, ei, eu, oi, ou, ui*) to which we have confined ourselves in this article (possibilities are: *eo, ea, iu, ue*) would provide many more syllables.

In connection with the *reserved* syllables on Page 49, and the paragraph on *separation marks* on Page 9, the reserved syllables may be used as separation devices.

The reference to *additioncl symbols for functions* on Page 12 will be taken care of by assigning the syllable *fuf* (foof) as an optional *function indicator*. For instance, when *g* is to be used as a function symbol and it is desired to emphasize this fact, *g(x)* can be said as *gegfufli* instead of *gegtolitu*. Generally, Greek letters such as ψ, φ, ξ will obviously denote functions and an indicator will not be required for them. *Fuf* may be used as a general expression: "any function whatever of..." , or as a relation-word "property of being a function".

In the third and fourth paragraphs on Page 18, where an optional alternative binary notation is given, with *sei* for 16, *bau* for 32, and *bou* for 64, special syllables also should have been given as follows: *nul* for 0, *hap* for 1(Greek derivation), *dos* for 2 (Spanish), *for* for 4, and *vit* for 8. Then binary 11111(decimal 31) called *seidivozesa* (say-dee-vaw-zeh-sah) on Page 18, could be called *seivitfordos-hap*, (say-veet-fawrr-dawss-hahp) making this optional sub-system independent of the others given for binary. The *mul* (nool) for zero would serve to hold the empty places where groups were blocked off by *ri* or other separation mark to express large numbers, as described in Paragraph 4, page 18, and at the same time would permit (by *na*) the expression of binary fractions. *Dos* could be used to mean "two" (binary 10) in such expressions as "twos' complement"; similarly *vit* to mean "eight" (octal 10) where parallel expressions are used in talking about octal numbers.

While very few *instruction syllables* for computers, data-processing equipment, information-retrieval devices, and voice-controlled machines have been given, this does not mean that the application of Numaudo to the giving of instructions is unimportant. Quite the contrary: development of all these devices and possibly of other related inventions is being seriously retarded for want of just such a coding system as Numaudo provides. However, the best selection of instruction syllables will be made by the designers and users of voice-operated equipment, and will vary from machine to machine. To attempt to prophesy at this time what instruction syllables will be needed and how many there will have to be, would be dangerously interfering with research and development work. Those planning such devices will merely be asked to become familiar with the Numaudo system and how its syllables are constructed, then to add new syllables according to the rules laid down here; then when a Numaudo Standardization Committee has been organized, to submit proposed vocabularies of instructions to the committee for approval.

*Supplementary material* will be issued as soon as feasible, to assist interested parties in learning and using the Numaudo coding system. Among the items planned are: (1) a tape recording, and possibly a disk recording, of this text, to elucidate Numaudo pronunciation and diction, and provide practice in listening; (2) a set of examples in written Numaudo, for practice in decoding into conventional notation; (3) a set of spoken examples, for similar decoding practice; (4) supplementary leaflets describing the application of Numaudo in specialized fields.

We will conclude our presentation by giving an index-list of all the syllables so far assigned, in alphabetical order. Meanings, and pronunciations according to English-language spelling habits, will be found on the pages indicated after each syllable.

§ + §

## ALPHABETICAL INDEX OF SYLLABLES

*Only syllables actually assigned are listed here. Those mentioned, but not actually given a rôle in the system, and not in the following list, are available for future assignment, just as all unlisted syllables are available.*

| SYLL. | MEANING | PAGE |
|---|---|---|
| ba | 6 | 6 |
| bab | secondary 6 | 16 |
| bam | interact | 47 |
| ban | reserved | 49 |
| bat | and/but | 47 |
| bau | spec.binary 32 | 18 |
| be | $\in$ (*logic*) | 36 |
| bef | before | 47 |
| bei | how much | 47 |
| bel | bel | 31 |
| ben | $\notin$ (*logic*) | 36 |
| bet | letter beta $\beta$ | 13 |
| beu | reserved | 49 |
| bez | without | 47 |
| bi | binary indic. | 17 |
| big | brig/log | 31 |
| bin | *2nd* bin.indic. | 17 |
| bit | bit (*inform'n*) | 31 |
| bo | prime mark ′ | 14 |
| boi | minute of arc | 20 |
| bon | 1 dot(*logic*) | 39 |
| bot | superior dot ˙ | 21 |
| bou | 64,spec.binary | 18 |
| bu | double prime ″ | 14 |
| bui | second of arc | 20 |
| bul | Boolean indic. | 14 |
| bun | 2 dots(*logic*) | 39 |
| but | super.2 dots ¨ | 21 |
| da | / divided by | 8 |
| dai | of | 47 |
| dan | in | 47 |
| dat | date follows | 16 |
| dau | ratio colon : | 22 |
| daul | joule | 31 |
| de | pos.power 10 | 7 |
| deb | bin.cod.decim. | 19 |
| def | definition | 40 |
| deg | degree of arc | 20 |
| dei | day | 30 |
| dek | duodecimal *ten* | 20 |
| del | small delta $\delta$ | 13 |
| dem | dbm | 31 |
| den | density/water | 31 |
| der | $\partial$ | 13 |
| des | decimal rest. | 20 |
| det | Capital delta $\Delta$ | 13 |
| dez | some | 47 |
| di | 8 | 6 |
| dib | db,decibel | 31 |
| did | secondary 8 | 16 |
| dif | difference | 21 |
| din | dyne | 30 |
| dip | diopter | 31 |
| dis | this | 47 |
| do | neg.power ten | 7 |
| dob | parts/million | 16 |
| dof | per mille ‰ | 16 |
| doi | Fraktur type | 42 |
| don | where | 47 |
| dos | special "two" | 51 |
| dot | that(*relative*) | 47 |
| dou | reserved | 49 |
| doz | special 12 | 20 |
| du | differential | 12 |
| dub | octave | 31 |
| duk | sexad. U,ten | 18 |
| duz | duodec.indic. | 20 |
| fa | > | 14 |
| faf | farad | 31 |
| fai | $\geqslant$ | 21 |
| fak | factorial | 21 |
| fau | reserved | 49 |
| fe | = | 8 |
| fef | letter *F f* | 12 |
| fei | chem. $\rightarrow$ | 27 |
| fek | chem. $\rightleftharpoons$ | 27 |
| fet | boldface type | 21 |
| fi | 3 | 6 |
| fif | secondary 3 | 16 |
| fil | much/many | 47 |
| fin | end of Numaudo | 26 |
| fir | quaternary | 20 |
| fo | < | 14 |
| foi | $\leqslant$ | 21 |
| fom | from | 47 |
| for | special bin.4 | 51 |
| fot | phot | 31 |
| fu | *f*( ) function | 12 |
| fuf | function ind. | 51 |
| fui | reserved | 49 |
| ga | positive sign + | 7 |
| gag | accel.gravity | 31 |
| gai | gram(me) | 31 |
| gal | gram-calorie | 31 |
| gam | letter gamma | 13 |
| gar | grade (angle) | 20 |
| gau | gauss | 31 |
| ge | $-(\sqrt{-1})$ | 9 |
| geg | letter *G g* | 12 |
| gei | verb of action | 47 |
| geu | reserved | 49 |
| gi | $i$ $(\sqrt{-1})$ | 9 |
| gif | if | 47 |
| gil | gilbert | 31 |
| go | minus sign | 7 |
| goi | complement of | 36 |
| gon | erg | 31 |
| gou | converse of | 37 |
| gu | 0 (zero) | 6 |
| gug | secondary 0 | 16 |
| ha | separ. mark | 10 |
| hai | reserved | 49 |
| hal | letter aleph $\aleph$ | 21 |
| hap | spec. bin. 1 | 51 |
| har | hectare | 30 |
| has | letter *H h* | 12 |
| he | letter eta $\eta$ | 13 |
| heb | week | 30 |
| hei | exclamation | 22 |
| hen | binary "*one*" | 18 |
| her | hertz, c/s | 31 |
| het | letter theta $\theta$ | 13 |
| heu | assertion | 39 |
| hi | letter chi $\chi$ | 13 |
| hif | hyphen | 23 |
| hig | mm.Hg. | 31 |
| hik | letter *I i* | 12 |
| hip | hyperbolic | 21 |
| ho | [ | 8 |
| hok | letter *O o* | 12 |
| hor | hour | 30 |
| hot | begin vinculum | 9 |
| hu | ] | 8 |
| huk | letter *U u* | 12 |
| hut | end vinculum | 9 |
| ja | letter *A a* | 11,12 |
| jai | reserved | 49 |
| jar | year | 30 |
| je | letter *B b* | 11,12 |
| jed | each | 47 |
| jei | reserved | 49 |
| jes | yes | 26 |
| ji | letter *C c* | 11,12 |
| jit | letter iota $\iota$ | 13 |
| jo | letter *D d* | 11,12 |
| jot | letter *J j* | 12 |
| ju | letter *E e* | 11,12 |
| jui | machine,begin! | 26 |
| jun | a unit | 47 |
| ka | letter kappa $\varkappa$ | 13 |
| kai | & and . | 37 |
| kak | letter *K k* | 12 |
| kal | kg.-Calorie | 31 |
| kam | kVA | 31 |
| kan | se(can)t | 21 |
| kap | Capital Letter | 12 |
| kar | arc | 21 |
| kas | ¿ begin ques. | 23 |
| kat | kilowatt | 31 |
| kau | whatever | 47 |
| kav | kilovar | 31 |
| ke | $e \cong 2.71828..$ | 10 |
| ked | Q.E.D. | 22 |
| kel | which | 47 |
| kem | chem. signal | 26 |
| ken | csc | 21 |
| ker | $\because$ | 22 |
| kes | ? | 22 |
| ki | , | 11 |
| kif | who | 47 |
| kig | kilogram | 31 |
| kih | km per hour | 31 |
| kim | kilometer | 30 |
| kir | candlepower | 31 |
| kis | letter xi $\xi$ | 13 |
| ko | 9 | 6 |
| kog | when | 47 |
| kok | secondary 9 | 16 |
| koil | semicolon ; | 22 |
| kol | colon : | 22 |
| kom | how, as | 47 |
| kon | congruent | 21 |
| kop | Greek koppa $\varphi$ | 14 |
| kos | cos(ine) | 21 |
| kot | cot(angent) | 21 |
| ku | letter *Q q* | 12 |
| kui | that (*conjunct*) | 47 |
| kul | coulomb | 31 |
| kun | reserved | 49 |
| kur | curie | 31 |
| la | letter *V v* | 12 |
| lab | lambert | 31 |
| laf | letter alpha $\alpha$ | 13 |
| lai | octal 7 | 19 |
| lail | sexad. Z 15 | 19 |
| laim | sexad. Y 14 | 19 |
| lam | small lambda $\lambda$ | 13 |
| lan | null class $\Lambda$ | 37,13 |
| lar | sexad. V 11 | 18 |
| lau | octal 6 | 19 |
| laul | sexad. X 13 | 19 |
| laum | sexad. W 12 | 19 |
| le | letter *W w* | 12 |
| led | $\nabla$ | 22 |
| lef | eleven(duodec.) | 22 |
| lei | octal 5 | 19 |
| leil | sexad. V 11 | 19 |
| leim | sexad. U 10 | 19 |
| lel | letter *L l* | 12 |
| ler | sexad. W 12 | 19 |
| let | let | 47 |
| leu | octal 4 | 19 |
| leul | sexadecimal 9 | 19 |
| leum | sexadecimal 8 | 19 |
| li | letter *X x* | 12 |
| lim | lim,limit | 22 |
| lin | maxwell | 31 |
| lir | sexad. X 13 | 18 |
| lit | liter | 30 |
| lo | letter *Y y* | 12 |

ALPHABETICAL LIST OF ASSIGNED SYLLABLES, continued

| | | | |
|---|---|---|---|
| log log(arithm) 15 | na decimal point 7 | re end radical 8 | tem °C Centigrade 31 |
| loi reserved 49 | nag at angle of ∠ 21 | rei concrete obj. 47 | ter ternary system 20 |
| lon ln, $\log_e$ 15 | nai near 47 | rel relation(any) 48 | tet secondary 7 16 |
| lor sexad. Y 14 18 | nan other 47 | ren roentgen 31 | ti approximately ≅ 14 |
| lu letter *Z z* 12 | nau general part. 47 | rep repeat follows 25 | til arrow ⟶ 22 |
| lui light-year 31 | naut nautic. mile 30 | rer letter *R r* 12 | tin reserved 49 |
| luk lux 31 | ne ~ not(*logic*) 37 | res "Roger" 26 | tis what 48 |
| lum lumen 31 | nei reserved 49 | ret end of repeat 25 | tit letter *T t* 12 |
| lun an(*indef. art.*) 47 | nek neither-nor ↓ 40 | ri blank space 9 | to ( 8 |
| lur sexadec. Z 15 18 | nep neper 31 | rin henry 31 | toi ' (the) 40 |
| ma ordinal 10 | ner Sheffer stroke 40 | ro letter rho ϱ 13 | tois sub-total 7 |
| mai octal 3 19 | nes necessarily □ 41 | roi gen./prepos. 48 | toit total 7 |
| mail sexadec. 7 19 | net net 16 | rom ohm 31 | tol ( *non-mathem.* 23 |
| maim sexadec. 6 19 | ni letter *N, n* 12 | ror error signal 25 | ton metric ton 31 |
| mak maximum 47 | nif ∞ 21 | ru non-square root 8 | tos beg. vert.line 22 |
| man script letter 42 | nil nil, nothing 47 | rui 3rd-pers.pron. 48 | tot begin.brace { 8 |
| mas but (general) 47 | nin letter nu ν 13 | rum why 48 | tout all, univ.qfr. 40 |
| mat to mathematics 36 | no ≠ 14 | sa 1 6 | tu ) 8 |
| mau octal 2 19 | nom General Noun 47 | sai time-of-day 16 | tul )*non-mathemat.* 23 |
| maul sexadec. 5 19 | nor chem. normal 31 | sait a time 48 | tus vert.line end \| 22 |
| maum sexadec. 4 19 | nou (word) no 26 | sal reserved 49 | tut ending brace } 8 |
| maut exclusive or 38 | nu end exponent 8 | sam identical ≡ 14 | va beg.quotes " 22 |
| me ∃ 40 | nui 1st-pers.pron. 47 | san Gk.charact. ϑ 14 | vai beg.quote ' 22 |
| meg megohm 31 | nul bin.spec.zero 51 | sas secondary 1 16 | vam volt-ampere 31 |
| mei octal 1 19 | num Numaudo begin. 25 | se mut.impl. ⩦ 38 | van ' *logic* 41 |
| meil sexadec. 3 19 | nun now 47 | sei spec.bin.16 18 | vap " *logic* 41 |
| meim sexadec. 2 19 | nur only 47 | sek second(time) 30 | var var 31 |
| meis m/sec. 31 | nut newton 31 | sem centimeter 30 | vat watt 31 |
| meit between 48 | pa + addition oper. 7 | sen % 15 | vau Gk. digamma ϝ 14 |
| mel mel(acoust.) 31 | pam ampere 31 | sep *modal logic* ⩧ 41 | ve inclusive or ∨ 38 |
| mem letter *M m* 12 | par paragraph ¶ 23 | ses letter *S s* 12 | veb weber 31 |
| men reserved 49 | pau dash —— 22 | sev several, plural 48 | vel electron-volt 31 |
| mes month 30 | pe letter *P p* 12 | sez sexadec.indic. 19 | ver spelling out 13 |
| met meter(length) 30 | peh pH, chemistry 31 | si Cap.sigma Σ 10,13 | vi such that ∋ 38 |
| meu octal 0 19 | pem kg/cm² 31 | sig small sigma σς 13 | vit special 8 bin. 51 |
| meul sexad. 1 19 | pen penny, pence 16 | sin sin (sine) 21 | vo 4 6 |
| meum sexad. 0 19 | per per 16 | sir circumflex ^ 38 | vol volt 31 |
| mev M e V 31 | pes letter epsilon 13 | so integral ∫ 11 | vos octal system 18 |
| mi subtraction op. 7 | pi small pi π 13 | sof except 48 | vou reserved 49 |
| mib millibar 30 | pif letter phi Φφ 13 | soi through 48 | vov secondary 4 16 |
| mig milligram 31 | pik picofarad 31 | son § section 23 | vu letter upsilon υ 13 |
| mik micron (μ) 30 | pir capital pi Π 13 | su subscript begin 8 | vui you *sing/pl.* 48 |
| mim letter mu μ 13 | pis letter psi Ψψ 13 | sui self(reflexive) 48 | vun V universal cl. 37 |
| min minute of time 30 | pit relative prod. 37 | sum logical sum ∪ 36 | za close quote " 22 |
| mit with 47 | po exponent sign 8 | sup gen/adj/adv. 48 | zai close quote ' 22 |
| mo etc., ... 10 | pof apostrophe ' 23 | ta entails ⊃ 37 | zau reserved 49 |
| mod modulo 21 | poi then 47 | tad to/towards 48 | ze 2 6 |
| mog letter omega Ωω 12 | poit power factor 31 | tai event 48 | zet letter zeta ζ 12 |
| moik omicron ο 12 | pom ± 15 | tak ∴ 22 | zez secondary 2 16 |
| mol mol(chemistry) 31 | por logical prod. ∩ 37 | tal such 48 | zi inclusion ⊂ 36 |
| mom millimeter 30 | pos after 47 | tam atmosphere 30 | zin non-inclusion ⊄ 36 |
| mon money unit 16 | pot possibly ◊ 41 | tan tan(tangent) 21 | zo period . 21 |
| mor ...endless decim. 11 | pu 5 6 | tap *modal logic* ⇉ 41 | zoi reserved 49 |
| mu multiplication 8 | pui reserved 49 | tas machine, quit! 26 | zon but(*sondern*) 48 |
| muf microfarad (μf) 31 | pup secondary 5 16 | tau letter tau τ 13 | zop abbreviation 32 |
| mug microgram (γ) 31 | pur for (prep) 47 | te 7 6 | zor binary zero 18 |
| mui mag.permeabil. 31 | ra begin radical 8 | teb excess-three 19 | zu end subscript 8 |
| mum minimum 47 | rad radian 20 | ted oersted 31 | zui operator ο 37 |
| mun (second) money u. 16 | ran reserved 49 | tek °Kelvin(abs.) 31 | |
| mut varies as ∝ 21 | rau outside of 47 | tel asterisk * 23 | |

*(For supplementary reserved syllables, see Page 49.)*