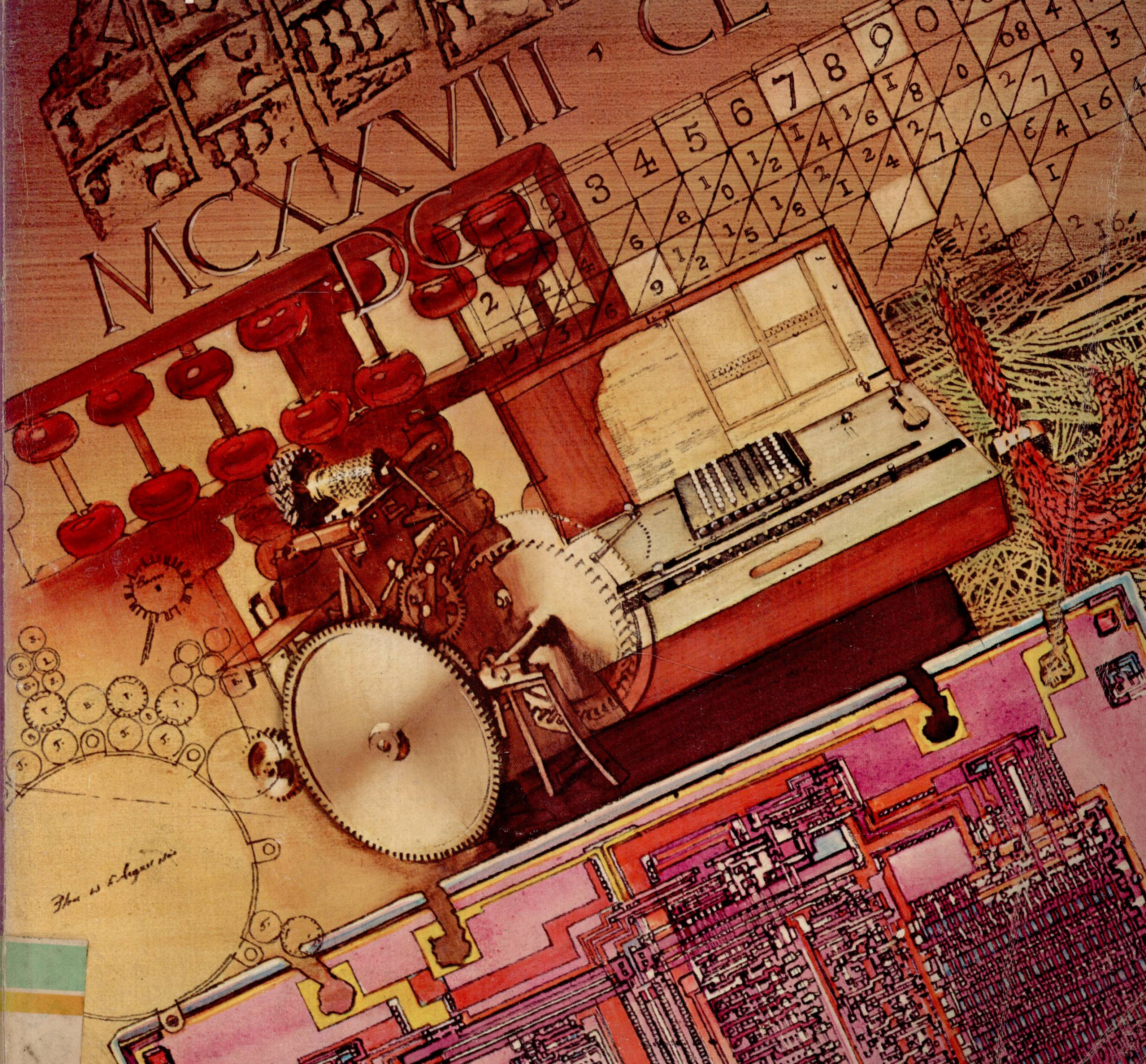
21814

FOUNDATIONS OF COMPUTER TECHNOLOGY

Joseph C. Giarratano



TO THE READER

Sams Computer books cover Fundamentals — Programming — Interfacing — Technology written to meet the needs of computer engineers, professionals, scientists, technicians, students, educators, business owners, personal computerists and home hobbyists.

Our Tradition is to meet your needs and in so doing we invite you to tell us what your needs and interests are by completing the following:

1. I need books on the following topics:

____

2. I have the following Sams titles:

____

3. My occupation is:

_____ Scientist, Engineer
_____ Personal computerist
_____ Technician, Serviceman
_____ Educator
_____ Student
_____ D P Professional
_____ Business owner
_____ Computer store owner
_____ Home hobbyist
Other ____________________

Name (print)______________________________
Address______________________________
City ____________________ State __________ Zip __________

Mail to: **Howard W. Sams & Co., Inc.**
Marketing Dept. #CBS1/80
4300 W. 62nd St., P.O. Box 7092
Indianapolis, Indiana 46206

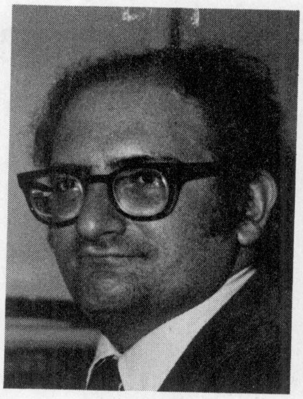
21814

Foundations of Computer Technology

Joseph C. Giarratano received his B.S. and M.S. degrees in physics from California State University at Los Angeles. In 1974 he earned his Ph.D. degree in physics at the University of Texas at Austin.

Dr. Giarratano has worked in the field of medical physics with interests in the applications of computers to medicine. He was also appointed an adjunct clinical professor of radiology at the Medical College of Wisconsin, certified as a radiological physicist by the American Board of Radiology, and elected a Member in Physics by the American College of Radiology. During this period he wrote this four-volume series on computer technology.

Dr. Giarratano now works in the area of software development for microprocessor-based products at Bell Laboratories. He is also on the faculty of Martin Center College in Indianapolis and teaches computer technology there.



Foundations of Computer Technology

by

Joseph C. Giarratano, Ph.D

Howard W. Sams & Co., Inc.
4300 WEST 62ND ST. INDIANAPOLIS, INDIANA 46268 USA

FIRST EDITION
FIRST PRINTING—1982

International Standard Book Number: 0-672-21814-3
Library of Congress Catalog Card Number: 82-50011

Edited by: *Charlie Buffington*
Illustrated by: *Christine Lixon* and *Wm. D. Basham*

Printed in the United States of America.

PREFACE

This is the first book of a 4-volume work about computers. The first two volumes are designed to provide an introduction to computer history and technology. The third and fourth volumes cover elementary and advanced programming in the BASIC programming language. Together, these four volumes describe and explain the fundamental hardware and software concepts of computers.

Computers are being used today for applications extending from science and medicine to moviemaking. More people are using computers than ever before and the number of users keeps increasing all the time. Either directly or indirectly, computers now affect all of us.

In the early years, computers were very hard to program, expensive, and few. Only the government, large businesses, and universities could afford them. The advent of integrated circuit chips a few years ago profoundly changed this situation. Now, low-cost—yet sophisticated—computers are within the reach of high schools, vocational schools, small businesses, and individuals.

When people ask, "What use is a computer?" my response is, "What use is a camera or a typewriter or even a paintbrush?" The intrinsic value of any tool is very little, but in the hands of a knowledgeable person that paintbrush can create a Mona Lisa. The creative potential of the computer is just as great, whether it is used for business, science, or art. It is just a matter of learning how to use this great new tool.

With this series you can learn how to communicate with the computer through the BASIC programming language. BASIC is a popular and powerful language with many built-in functions for numerical and character work. In addition, it is my belief that people work better if they have some idea of their tool's technology and history. For this reason, the first two volumes contain an introduction to computer history and technology. This demonstrates that the computer is not a mysterious oracle producing miraculous answers. Rather, evolution of the computer to its modern form is a product of the hard work of many people for many centuries. The computer technology portion is written to illustrate concepts, rather than design. Many illustrations are used to show how computer components are used in real systems.

The material in the two volumes on technology is independent of Volumes 3 and 4, which cover programming in BASIC. Depending on your interests, you can start with either Volume 1 or 2. However, the technology material will be very useful if you plan to select a computer system. A knowledge of computer technology and history will enable you to better select a computer.

The programming material in Volumes 3 and 4 is actually written for two versions of BASIC. One version is produced by Microsoft, Inc., and is utilized on many microcomputers. Another BASIC described in the last two volumes is produced by Digital Equipment Corporation (DEC). It is used with minicomputers including several models of the DEC PDP-11®* computer. By comparing programs written in Microsoft BASIC with DEC BASIC, you will see examples of the problems encountered in converting a program written in one BASIC to another.

---

* A registered trademark of Digital Equipment Corp.

This first volume discusses the foundations of computer technology. It includes material on:

- The history of computer technology and associated discoveries in electricity, magnetism, and electronics.
- Elements of a computer system.
- Software, the means of controlling the computer.
- Terminals, through which the user communicates with the computer.
- Semiconductor technology, the foundation of computer hardware technology.

JOSEPH C. GIARRATANO

ACKNOWLEDGMENTS

In writing a book covering so many diverse topics, it was my privilege to receive very valuable reviews from a number of people. I greatly appreciate the time and effort they gave in making this a better book. My thanks to: Pierre Gaujard, Chris Horrocks, Bill Gates, James Jarrett, John Hoeppner, Harold Davis, Robert E. Jones, Jr., Vernon McKenny, Milt Gosney, Don Rose, Robert A. Abbott, Ken Barr, Peter Knight, Barbara Nelson, Bruce Christensen, Jerry Mar, Gene Hill, Jim McKevitt, Russ Desserich, Tim Bucholtz, Dev Gupta, Bill Halas, Arlan Andrews, Joyce Andrews, Steven Browning, Walter Pavlicek, Robert Johnston, Philo Foote, Angelo Orlondoni, James Mosher, Richard Turpin, Hans Hagel, Nyles Priest, James Sprandel, Jose Ingojoe, Louis Romould, Bob Probesting, Bruce Euzent, Ryan Wood, J. A. Steir, David Savidge, Marty Friedman, Mike Faulkner, Louis Meharg, Greg Wolynes, David Maksymczak, Lester White, Greg Pickle, and Stan Hitzeman.

I also appreciate the typing assistance of Jan Kocher and Jane Giarratano. Special thanks are due to Pat Baus for numerous and uncomplaining retypings of major portions of the book.

J.C.G.

This book is dedicated to my parents.

CONTENTS

1 ORIGIN OF COMPUTERS

People have always needed better and faster ways to deal with numbers and information. Since the dawn of time, there have been many attempts to devise better ways of calculating and processing information. Modern computers are the heirs of centuries of struggle by people to perform work better. As Leibnitz wrote in the 17th century:

> ***"It is unworthy of excellent men to lose hours like slaves in the labor of calculation which could safely be relegated to anyone else if machines were used."***

DEVELOPMENT OF WRITING AND COUNTING

Fig. 1-1 shows what is generally believed to be the evolutionary course of writing, from the Egyptian hieroglyphics to the alphabet. Notice that the hieroglyphics were a system of picture writing, in which symbols were used to represent words. Writing skills were restricted to special classes of people such as scribes (writers) and priests. In fact, the word *hieroglyphics* comes from the Greek for "sacred carvings," since words were commonly carved into stone or clay. The Phoenicians developed the concept of combining symbols into words and spread their alphabet around the Mediterranean area in the course of their trading. The alphabet evolved more in Greece and then Rome, from which our modern alphabet letters are derived.

The first attempt to keep track of data was the invention of counting. However, efficient number systems, such as the Hindu-Arabic system we use, are a comparatively recent development within the last thousand years. Some of the early numbering systems and the general evolutionary steps of modern numerals from the Hindu-Arabic are shown in Fig. 1-2. The American magnetic numerals are of a special shape that can be recognized by computers, and are most commonly seen on checks and other banking documents. A machine called a *magnetic ink character reader* (MICR) can read these numbers when they are printed with a magnetic ink. The MICR can input numbers and also a corresponding alphabetic set of characters into a computer. *Optical character readers* (OCR) are also available that can read numerals and letters printed with ordinary ink. A computer assisted optical character reader is also available that can read any type of printed material and translate the words into speech as an aid to the handicapped.

Before number systems evolved, it was necessary to use counting aids such as notches in a stick, knots tied in a rope, or stones. It was actually the use of stones or pebbles that paved the way for more efficient aids to calculations. People learned to associate sticks or stones with cattle or members of their tribe; one stone stood for one cow, two stones for two cows, and so forth. Addition and subtraction could be performed using sticks or stones, while multiplication and division were processes of repeated addition and subtraction. Thus, people were

Fig. 1-1.
The generally accepted stages of writing evolution. (*Courtesy NCR Corp.*)

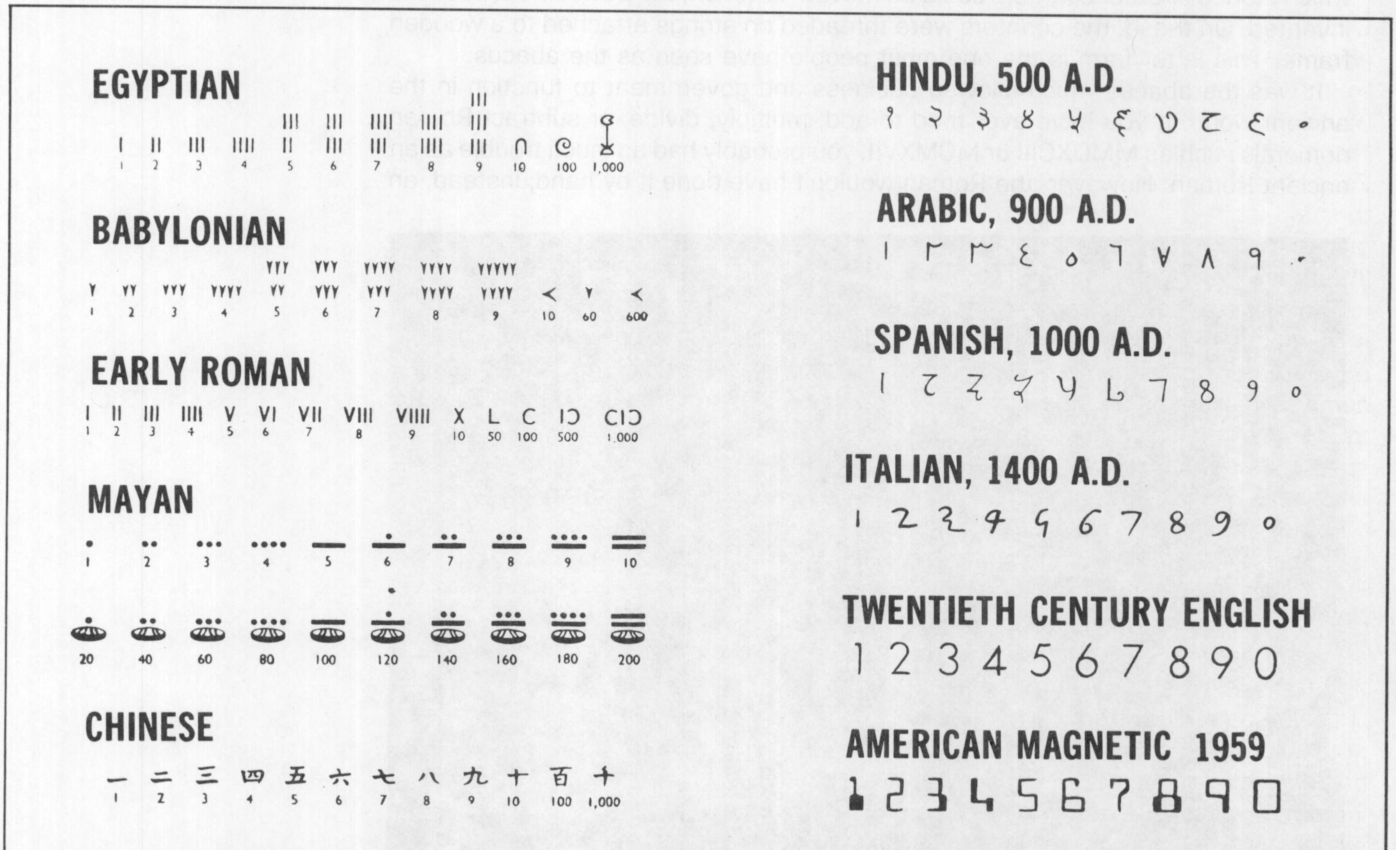


Fig. 1-2.
Evolution of numbers and counting. (*Courtesy NCR Corp.*)

calculating even before the development of efficient number systems. In fact, the word *calculate* comes from the Latin word *calculus,* which means stone. The things that could be done with stones were amazing. About 4000 years ago, at Stonehenge in Britain, giant stones weighing many tons were moved into a circle to form an astronomical observatory. The stones were arranged in a pattern so accurate that they can predict eclipses and other lunar phenomena perfectly until 2100 A.D., and to continue beyond this date only one minor change needs to be made. The jet contrail over the Stonehenge observatory in Fig. 1-3 is a sharp contrast in the "tools" of technology.

THE ABACUS

The moving of stones to calculate led to the development of the *abacus* (see Fig. 1-4), which was known as early as 500 B.C. in Egypt. Early Romans moved the stones along grooves in a board and thus derived the term *calculate.* The Phoenician word *abak,* which means a flat surface covered by sand for the drawing of figures, is considered to be the origin of the word *abacus.* However, a form of the words *counting* or *calculate* appears in many other languages such as the Semitic *abg,* meaning dust, or the Greek *abakion* for a marked counting board. The earliest abacus from Greek and Roman times was a table marked with parallel lines along which stones or other counters could be moved. Later on, the portable abacus was invented. On these, the counters were threaded on strings attached to a wooden frame. This latter form is the one most people have seen as the abacus.

It was the abacus which allowed business and government to function in the ancient world. If you have ever tried to add, multiply, divide, or subtract Roman numerals such as MMDXCIII or MCMXVII, you probably had as much trouble as an ancient Roman. However, the Roman wouldn't have done it by hand; instead, an

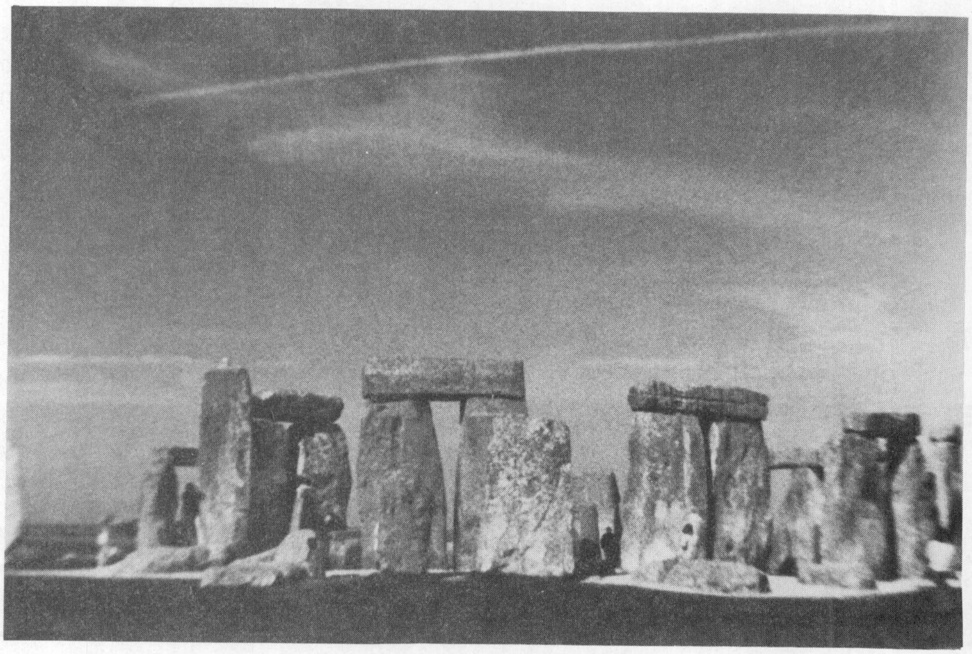


Fig. 1-3.
The Stonehenge observatory. (*Courtesy J. G. Parrish*)

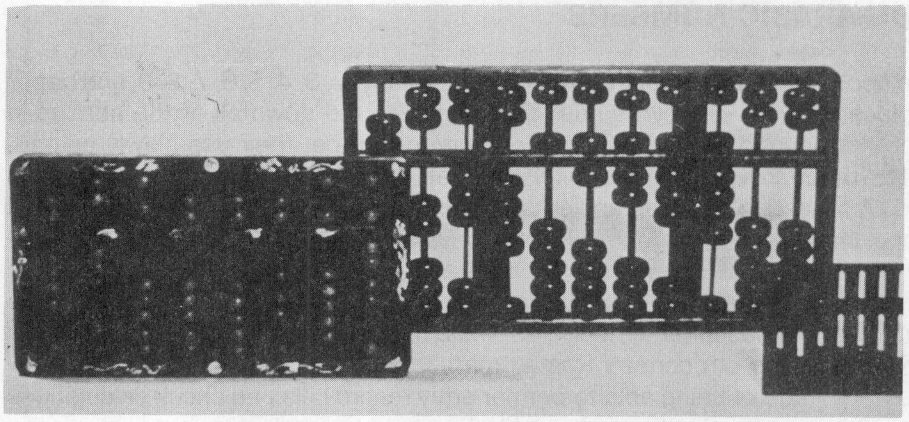


Fig. 1-4.
The abacus. (*Courtesy IBM Corp.*)

abacus would have been used. Even the game of backgammon was derived from this ancient counting board.

THE COUNTING BOARD

The use of the abacus persisted until the Middle Ages in Europe, where noble houses had their own special counting boards and counters for them. These counters were not the simple beads of today's abacus, but were highly carved or cast from metal in a symbol characteristic of the house.

The word *counter* persists even to this day as in the counter of a store. In ancient days, customers would pay for their purchases at the counting board, because that is where the calculations were done. Today there is an electronic calculator on most store counters, but the term counter still applies since that is where the total is counted. Even Shakespeare mentions counters in *A Winters Tale*, when the clown is having trouble shearing a sheep and exclaims, "I cannot do't without counters," and Troilus asks:

> *"Weight you the worth and honor of a king,*
> *So great as our dread father, in a scale*
> *Of common ounces? Will you with counter sum*
> *The past-proportion of his infinite?"*

For portable use, the counting table was too bulky, so the counting lines were marked on a cloth which could be easily transported. The French word for woolen cloth, *bure,* indicates the type of cloth used to cover a table for counting. This term was later extended to call the table a *bureau* and finally the people working at the counting table were called *bureaucrats.*

After the introduction of Hindu-Arabic numerals into Europe, the abacus or counting board started to disappear about the 15th century. However, with an experienced operator, it is still a powerful device. In 1946, a contest was held in Japan between an American using a calculator and a Japanese using an abacus. The abacus won. The main problem with the abacus is that while addition and subtraction are fast, it is much more difficult to perform multiplication and division. Also, the intermediate results of calculations cannot be recorded on the abacus, so there is no way to easily check the stages of a calculation.

HINDU-ARABIC NUMBERS

The appearance of the Hindu-Arabic numbers 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, and paper to replace expensive papyrus both contributed to the downfall of the abacus in Europe. Introduced around the 12th century in Europe, their use slowly spread. The illustration in Fig. 1-5 was taken from an encyclopedia printed in 1504 and shows "Arithmetica between ancient counter reckoning and modern algorism." In this encyclopedia *The Margarita Philosophica* by Gregorius Reisch, the replacement of counters or abacus' by Hindu-Arabic numbers and pen and paper is described. The figure on the right (in Fig. 1-5) using a counting table represents the ancient Greek philosopher, Pythagoras, while the person on the left using pen and ink represents the 6th century Roman mathematician Boethius.

The advantage of being able to permanently record bills and check calculations at all steps was very significant. It enabled customers purchasing items in a store, tax collectors, or mathematicians to easily spot errors.

Better machines were needed to cope with the increasing trade and business of the 17th century. In addition, new discoveries in mathematics, navigation, and science required many more calculations. For example, in order to calculate a ship's position, accurate and precise tables of trigonometric functions such as sines and cosines were needed. However, many calculations had to be done to compute a single sine or cosine. It was also very easy to make one mistake that would ruin many other calculations. There were recorded instances of ships being lost due to faulty navigation tables.

LOGARITHMS AND ANALOG CALCULATORS

The Scot, John Napier, wrote that nothing was worse than "the multiplications, divisions, square, and cubical expansions of great numbers, which, besides the tedious expense of time, are subject to many slippery errors." In order to simplify and speed up calculations, he invented *logarithms* and published the first table of them in 1614. Logs greatly helped calculations because:

1. To multiply, the logs of the numbers to be multiplied are added.

Fig. 1-5.
Counters vs. pen and paper. (*Courtesy IBM Corp.*)

2. To divide, the logs of the numbers to be divided are subtracted.
3. To calculate powers, the logs of the numbers are multiplied.

After the calculations above, the number which corresponds to the log (antilog) is then determined from the log tables as the answer. However, it was still necessary to calculate the logs of numbers for tables, and this involved many calculations.

A simpler, though less exact, method of using logs than from tables was soon invented by Edmund Gunther in 1620 who plotted the logs on a straight line. Multiplication and division were performed with the Gunther method by adding and subtracting lengths using a pair of drafting dividers. The next improvement was by William Oughtred, who used two sliding log scales as the slide rule. This eliminated the need for dividers and made calculations faster. Specialized log scales can be made for any function such as sine, cosine, tangent, hyperbolic sine, and cubes, and used to make a slide rule.

A modern analog calculator or slide rule is shown in Fig. 1-6. Also shown is a closeup of the arrangement of the scales for multiplying 2 × 2. The slide rule scales are graduated according to the logarithms of the quantities to be calculated. Note that the slide rule can only be used for calculations, not computations, since the slide rule has no decision-making capabilities. That is, the person using it must make the decisions as to what calculations are to be performed next, depending on the results of the previous calculations. The slide rule was a very popular and successful analog calculator which was superseded by all-electronic calculators in the early 1970s.

The 17th century also marks an early division of calculators into analog or digital machines. The slide rule is an example of an analog device in that its results were only approximately correct. That is, the precision or number of digits of the answer depends on how big the slide rule is and how fine the rulings are. A small slide rule might only give an answer as 1.33, but on a longer one the answer might be read

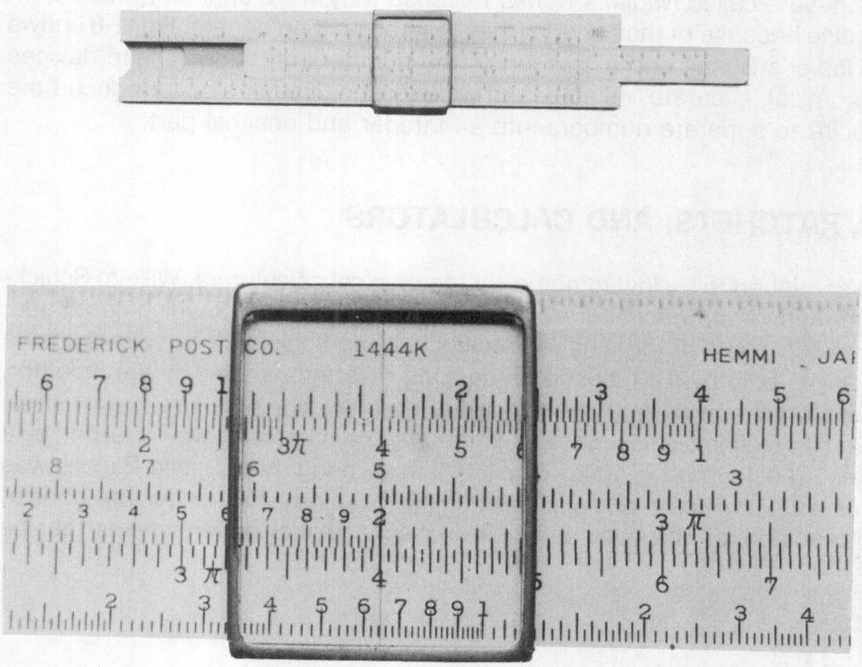


Fig. 1-6.
The slide rule.