BOOKS

IT STARTED WITH A STRAIGHT HORIZONTAL ROD

SCALES AND WEIGHTS: A HISTORICAL OUTLINE. By Bruno Kisch. 297 pp. Yale University Press, New Haven, 1965. $15.00.

by W. James King

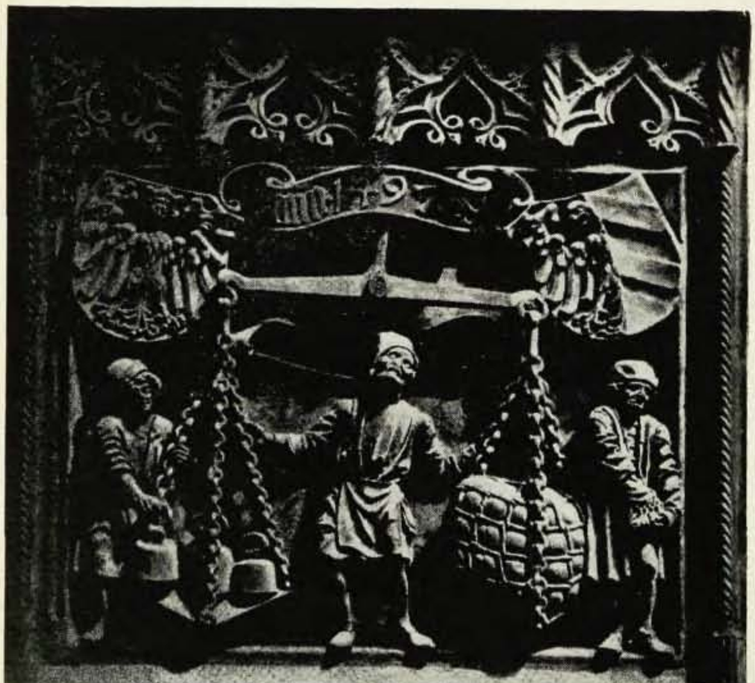
Just as the longest journey can begin with the shortest step, so the most complicated of the arts can begin with the most naïve of techniques. The validity of this assertion can certainly be recognized in the history of the art of experimentation in the physical sciences. The first phase began in the earliest civilizations with the use of a straight rod, either placed vertically in the ground or suspended at its midpoint on a horizontal axis. The former was the gnomon used to mark what day it was in the year and, as the first form of the sundial, used to tell the hour in the day. The latter was the beam of the balance, used by all primitive civilizations to carry out the exchanges so necessary in their trade and commerce.

As is inevitable with man, the creator and manipulator of ideas, the users of these simple instruments came to envision the rod in a wider context and in one beyond its immediate application to daily life. Almost from the beginning, an increasingly sophisticated use of the vertical rod led to observational astronomy and applied mathematics. The lists of *omina* (unusual celestial phenomena) of the second millennium BC, when joined to the mathematical techniques of the Babylonians, became in the first millennium BC predictions of the positions of the moon, Venus and the other planets. The heavens themselves acquired a gridwork of degrees and minutes. In the hands of the Greek astronomers, the gnomon was elaborated into armillary spheres and even into mechanical planetaria. To apply the instruments of observation more accurately some of the simpler trigonometric functions were developed, and the techniques of spherical trigonometry and of stereographic projection were formulated.

The speculations of philosophers on the reasons for the balance of the horizontal rod were not confined to the purely phenomenological approach, as were those on the vertical one by the ancient astronomers who were primarily concerned with describing the phenomena of the heavens. When the Greek philosophers of nature began to speculate on the reasons for the behavior of the balance and lever, their approach was a physical one, of cause and effect, instead of the kinematical one of the astronomers.

It was one of the immediate followers of Aristotle, the author of the pseudo-Aristotelian *Mechanica*, who recognized the unequal-arm balance as a lever and who sought to explain the physical properties of the lever in terms of the geometrical properties of the circle. According to the author of the *Mechanica*, the greater mechanical advantage of the shorter arm expressed the greater force necessary to move that end of the lever in a curve with a smaller radius of curvature. Another approach was that of Archimedes, who set forth his explanation in a strictly Euclidean form, and thereby created the classical expression of one of the oldest laws of statics.

In spite of the early theoretical formulation of the properties of the balance, the great utility of the balance in the physical sciences was not recognized in the West until the Renaissance. Even then it was not adequately exploited until the 17th



MEDIEVAL SCALE FOR HEAVY GOODS. Sculpture on a public weighing house in Nuernberg. From SCALES AND WEIGHTS.

* * *

W. James King, former director of AIP's Project on the Recent History of Physics in the United States, is now a member of the Department of History at the University of Vermont.

STEELYARDS FROM POMPEII. Unequal-arm balances were favorites of the ancient Romans. From SCALES AND WEIGHTS.

and 18th centuries, when investigators like Galileo and Newton, and Black and Lavoisier, showed what might be achieved with it. Unlike the gnomon, which led almost immediately from the calendar to astronomy, the major field of application of the balance was to continue for centuries what it initially was—that of determining the weights of goods and in fixing monetary equivalents.

It is of such applications that the oldest representations were made. The earliest illustration is from the culture of the Hittites, showing what is probably the payment of tribute to a sovereign. In addition to many such transactions, the Egyptians frequently depicted the balance in their wall paintings and in their manuscript scrolls. Its use was prominent in the *Book of the Dead*, that guide to the new citizen of the land of the afterlife. In the book the newcomer is instructed what he is to do at each step of the way, including the moment when his heart is being weighed against the feather of truth and before the assembled gods. The crocodile god sits nearby, ready to swallow his soul if it proves unworthy. Unfortunately, as in the case of the coffin-lid paintings of the constellations, the drawings of the Egyptian artists are not too trustworthy and the details of the Egyptian balance are uncertain.

For several millennia the balance was an instrument with arms of equal length. Then, presumably in the commercial practices of the ancient Greeks and Romans, the balance with unequal arms appeared. One form was called the bismar, and the other, the steelyard or Roman balance. The former had a fixed weight on the end of the beam itself and equilibrium was obtained by moving the point of suspension; the latter had a fixed point of suspension and equilibrium was obtained by moving a known weight along the beam. While no material evidence for the existence of the bismar remains from ancient times—the only evidence being an account in the already cited pseudo-Aristotelian *Mechanica*—there are many relics of Roman steelyards, especially from Pompeii.

The balances of both equal and unequal arms played a vital part in the commerce and embryonic capitalism of the Middle Ages and Renaissance. The efficient Romans had imposed a uniform system of weights and measures throughout their empire but this economic advantage was lost in the chaos of the Dark Ages. Simultaneously with the appearance of medieval civilization in the West, medieval merchants began exchanging commodities and buying goods from areas other than their own, and they turned to the balance as an essential instrument of trade.

Because of the widespread use of the metric system with its decimal divisions, we have forgotten just how difficult it once was to determine monetary and weight equivalents. During the Middle Ages and up until the last century or so, depending on the power and authority of the central government, each community coined its own money. The weight of that money varied not only with the reign of the sovereign, but, if times were bad, within his reign. In addition, coins were apt to be clipped in the many exchanges of commerce.

Moreover each community had its own system of weights, which not only varied through the years, but varied with the kind of merchandise. For example, the unit of gold, silver and jewel weights was the carat. In Bologna it was 0.11 g; in Turin, 10.25 g; in Florence, 14.15 g; in Genoa,

Does this look like an answer to global problems of ignorance, disease and physical deprivation?

Not yet. But we're getting closer.

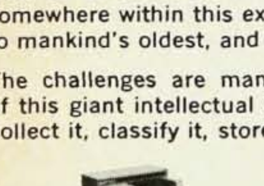
Behind this movement is a simple statistic with startling implications for all of us—*If you count all the scientists and engineers since the beginning of recorded history, ninety percent are alive today!*

We are now in the midst of the result—an incredible explosion of information from every corner of the globe. And somewhere within this explosion will be the ultimate answers to mankind's oldest, and newest problems.

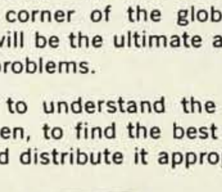
The challenges are many. First, to understand the nature of this giant intellectual force. Then, to find the best way to collect it, classify it, store it... and distribute it appropriately and instantly to the people who need it.

In this light, you might consider today's Xerox products early and primitive steps along a difficult but fascinating path. You'd be right. Yet, has anyone taken these steps before us?

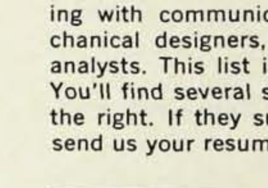
Your degree and background may be more appropriate to our advanced work than you imagined. We're as interested in talking with communication systems specialists as electromechanical designers, organic chemists as much as program analysts. This list is as broad as it is long. Maybe broader. You'll find several specific (and urgent) openings outlined at the right. If they suggest a possible community of interest, send us your resume. An equal opportunity employer (M&F).



The Xerox 914 Copier revolutionized the office copying industry when it was introduced in 1959... and really started us on our way.



Less than 3 years later, the 813 further extended low-cost, quality office copying. One-seventh the volume of the 914, it does just about everything the 914 does except copy solid, 3-dimensional objects.



Another revolution. An electro-mechanical-chemical-optical device called the 2400 because it produces 2,400 copies per hour *directly* from an original document. No stencil or "master" of any kind. You press a button.

XEROX

TOP PHOTO: LDX (Long Distance Xerography) scans, transmits and reproduces images over distances limited only by the transmission medium. Something like it may print the morning paper at your breakfast table some day, or help you manage a global business.

13.22 g; in Milan, 9.8 g; in Venice, 0.20 g. Or consider the market weight called the stone. In Amsterdam it was 3.95 kg; in Berlin the heavy stein was 10.28 kg and the light stein was 5.14 kg; in Sweden it was 13.56 kg; in Vienna it was 11.20 kg. In England the stone for fish or meat was 3.63 kg; the stone for glass was 2.27 kg; the stone for wool was 6.33 kg. There was the pharmaceutical pound of 12 ounces and the market pound of 16 ounces, and so on, for all the various units of weight of different commodities and places.

Vital to the exchange of goods and money were the master weighers and the money changers. Attempts to fix exact weights appear in most of the great lawgiving documents of history. For example, the Bible repeatedly admonished that the merchant should not keep a heavier set of weights for buying and a lighter set for selling; the Magna Carta declared that weights and measures should be uniform and in accordance with the law, as had Charlemagne so decreed. To establish such uniformity standard weights were kept, in ancient times, in the temple, and in medieval times and later, in the town hall. The master weigher of the Middle Ages several times a year would compare the merchant's weights with the standard city weight. Makers of balances and weights also were members of the organic medieval society: they had a guild of their own, with, at least in Paris, St. Michael for their patron.

The money changer, who was just as much money weigher, set up his booth in the marketplace, with his own kind of scales for the rapid evaluation of true weight. In some communities it was forbidden for anyone else to have such scales, with heavy penalties imposed (up to the loss of a hand) for violators of the law. A sharp-eyed changer, besides detecting clipped money, could also detect coins that might be too heavy, which excess would go into his own coffers. Money changers were apt to become embryonic capitalists; money would be deposited with them for temporary keeping, and one account of the de Medici family points to such a beginning of their wealth.

During the 18th century the scientific revolution was bearing its first fruits. New uses for balances were finally discovered by experimenters, and instead of being made by guild members, balances were increasingly made by instrument makers. Physicists more and more were turning their attention to improving the efficiency of the instrument. By that time, the descendants of the gnomon were in turn being replaced by the more efficient telescope. Then in the 19th and early 20th century the balance became the fundamental instrument of the laboratory, and it was exploited as never before. Today it is only one of the many instruments in the arsenal of the experimentalist.

Regrettably, only patches of the rich history of scales and weights appear in the book under review. The subtitle of the work—*A Historical Outline*—is misleading. The author makes few attempts to undertake the historian's task—that of resolving and evaluating conflicting opinions so as to give to the reader a neatly sewn fabric in which the relevant historical facts are matched and integrated into a pattern of causes and effects. Instead, the author has presented only fragments of the whole story, and mostly for the merchant's balance from the period before the 19th century. Although the reference apparatus is excellent—the book is well and profusely illustrated, and there is a 14-page bibliography—the text of the book is incompletely organized and, at times, vaguely written. However, the book can provide entertainment and pleasure for the browsing reader with an antiquarian interest who wishes to learn something of the art of weighing in past times.

CRYSTALS FOR STUDENTS

CRYSTALS PERFECT AND IMPERFECT. By Allan Bennett, et al. 237 pp. Walker, New York, 1965. $5.95.

by H. M. Otte

"Our understanding of crystals will not be complete until we can predict the properties of a crystalline system from first principles, and until we have the technical ability to produce a theoretically possible crystal struc-