pacity" ceases to be a synonym for the last—it's an electrical property). Time units quite naturally raise considerations of reform by decimalization; the use of *hertz* for frequencies, radio waves, and musical scales is one of the matters in question. The mechanical units include for energy *joule*, which naturally is the unit for heat also. A whole chapter is required for the electrical and magnetic units. The history of thermometry is well done. Equally thoroughly described are optics, acoustics, and ionizing radiation.

After reviewing the Système International in the final chapter, Danloux-Dumesnils relaxes for a delightful monologue addressed, from his French base, to the British and North Americans, chastising them for their metric neglect. The appendix is 10^1 pages on logarithms—so essential in expressing, for instance, lengths from 10^{-15} meter for an atomic nucleus to 10^{20} meters for a galaxy. The index, footnotes, and reference documentation show reliable editing.

Danloux-Dumesnils does not discuss nonmetric units, conversion tables, machine, automobile, and air technology, or metric standards for dimensions of such goods as paper, lumber, and threads, subjects which are taken up by Frank Donovan in his book.

Prepare Now for a Metric Future is one of the first accounts of metric trends written for general readers in the United States. It is doubtful that any future account, welcome though it will be, will equal the style of Donovan's, which manages to be light and amusing as well as informative.

Donovan begins with a history of the various haphazard systems of weights and measures used throughout the world. Next is described the scientists' quest for a "natural basic unit," eventually leading to the metric system. Our Customary System and the metric system are then compared. The last half of the book describes metrication by various countries, especially modern Japan and Britain, and attempts by the United States. It concludes with a discussion of conversion for our metric future—"When, how, and how much."

Donovan makes his abstruse subject come alive for the nonscientific reader by colorful vignettes. Take, for example, the difficulties the scientists had in converting the suspicious French to the metric system about 1790. First of all, their surveyors were halted and often imprisoned. Did they not carry odd-looking instruments, and did they not dot the countryside with white flags? (White was the royal color.) Therefore they must be Bourbon agents engaged in overthrowing the government. Napoleon—hardly the champion of the metric system he is often pictured as being—did not enforce the system at home but only in the conquered countries, as one more way of Gallicizing them. As for the French at home, well, they were suspicious of those "long, foreign names of the new units, nor did they understand the prefixes, particularly those derived from Greek." It was not the Napoleonic wars that really spread the metric system but the Great Exposition held in London's Crystal Palace in 1851, which allowed European businessmen to compare their goods and ideas and to see the advantages that the scientists and educators had predicted for the universal metric system.

Metric symbol that British converts display on new goods, cartons, advertisements, and business forms. The symbol was designed by the British Standards Institute. Britain expects to complete its conversion to the metric system by 1975.

One last amusing tale Donovan tells is of Ferdinand Hassler, a mathematics instructor employed by the U.S. Treasury Department in 1830. On his own, with no legal sanction, Hassler decided to devise a complete set of standards of weights and measures for the United States. He then made a set of standards for each customhouse. Congress in 1838 asked that a complete set be sent to each state governor. This was not considered a permanent system at the time. Such is the origin of our Customary System, which some antimetrics think too hallowed by tradition to be replaced by the metric system.

Donovan illuminates the background of the great metric controversy in the United States which began early in the 19th century. "But for an unexpected adjournment of the first session (1902) of Congress, a bill would have been passed requiring all government departments to use the system exclusively." Even the *New York Times* admitted that the bill would certainly pass by a large majority. Donovan explains how a motion to adjourn Congress before the metric debate, followed by months of agitation against the bill by certain industries, defeated the attempt to establish limited metric standards at that time.

To convert the United States, at last, to the metric system would, it was estimated by one source in 1962, cost $11 billion. Dedicated to this effort is the Metric Association, whose former president, Fred J. Helgren, calculated that this cost could be covered in 16 years by eliminating the teaching of the Customary System in elementary arithmetic. Donovan claims a child can learn the simple metric units and how to move a decimal point in a few hours, thus gaining a a year or two for more constructive learning.

Donovan honestly includes the arguments against metrication, but maintains that thinking men almost unanimously believe that its adoption by the United States is inevitable. He quotes Edward Teller and Harold Urey in other supportive arguments.

The appendix has tables of the six basic SI units (modernized 1960 metric system), supplementary and derived units, and English-metric conversion factors. The index is useful, but the addition of footnotes and a bibliography would be helpful. For example, one would like to know who it was in the last century who admonished "the children of the Pilgrim Fathers" thus:

> When the gravediggers begin to measure our last resting places by the metric system, then understand that the curse of the Almighty may crush it just as he did the impious attempt to abolish the Sabbath.

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3.14159265358979323846264

A History of π (Pi). PETR BECKMANN. Golem, Boulder, Colo., 1970. 190 pp., illus. $6.30.

Petr Beckmann, an electrical engineer with a penchant for mathematics and history, has written a very readable account of π from the time of ancient Egypt and Babylonia to the present—a period of about 4000 years. Such developments as the Archimedean classical method, the Cusa-Snell refinement, continued fraction expansions, infinite products and infinite series methods, π by probability, and Monte Carlo procedures are clearly explained. The mathematics is not slighted and is generally elementary; a reader can safely skip any passages he may find too taxing. The book ends with the citation of a few cases of *morbus cyclometricus*, the circle-squaring disease.

Claiming that the history of π "is a quaint little mirror of the history of man," Beckmann holds up the mirror to the reader by giving some of the background of the times under discussion. He sees the men who make history forming two opposing classes—the thinkers and the thugs. For example, the Greeks were thinkers and the Romans were thugs. The basic law seems to be that the thugs always win, but the thinkers always live longer. As a Czech (though now living in the United States), Beckmann is very conscious of the existence of thugs.

The book has some shortcomings: It is marred by a couple of dozen careless errors, such as bad hyphenation, the consistent misspelling of Apollonius ("Appolonius"), and incorrect or missing superscripts. There are some historical errors: In his zeal to discredit the Romans (as thugs), Beckmann converts the accidental destruction of the first Alexandrian library into a deliberate act of Roman vandalism. He also reports Archimedes' tomb as still unfound, and, because the Egyptian rope stretchers laid out right angles with a 3-4-5 triangle, he credits them with a knowledge of the Pythagorean theorem. There are some serious errors of omission: Thus, in bringing the computation of π to modern times, Beckmann ends with the 2037-place calculation on the ENIAC in 1949. Omitted are the more recent facts that: (i) in 1959, François Genuys, in Paris, computed π to 16,167 places using an IBM 704; (ii) in 1961, J. W. Wrench, Jr., and D. Shanks, of Washington, D.C., computed π to 100,265 places, using an IBM 7090; (iii) in 1965, Jean Guilloud and his co-workers at the Commissariat à l'Energie Atomique in Paris attained 250,000 places on a STRETCH computer; (iv) exactly one year later, the last group found π to 500,000 places on a CDC 6600. Nor were these extensive machine calculations performed merely because of the challenge or feat involved, but rather to obtain statistical information on the normalcy or nonnormalcy of π. The famous 707-place calculation of π made by W. Shanks in 1873 seemed to indicate that π was not even *simply* normal; this led in 1946 to a check of the computation, revealing errors starting with the 528th place.

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A Wide-Ranging Concept

The Origins of Feedback Control. OTTO MAYR. Translated from the German edition (Munich, 1969). M.I.T. Press, Cambridge, Mass., 1970. viii, 152 pp., illus. $7.95.

The need for closer communication between scholars in different disciplines is made explicit by this valuable excursion into the history of technology undertaken by a mechanical engineer who is now curator of mechanical engineering at the Smithsonian Institution. Mayr may be said to be "flying a kite" by tracing through history examples of devices that meet his definition of a feedback system: namely one that carries out commands and maintains the controlled variable equal to the command signal in spite of external disturbances, that operates as a closed loop with negative feedback, and that includes a sensing element and a comparator, one of which can be distinguished as a separate physical element. The devices that meet these demands in the author's opinion include Ktesibio's water clock, Philon's oil lamp, and the float valve as used by Heron of Alexandria in the Hellenistic world, and a variety of clocks constructed in the Islamic world during the later middle ages similarly employing float valves. Heron's *Pneumatica*, which revealed a delight in the intellectual quality of the feedback system for its own sake, seems to have been known only in the Islamic world in the early middle ages, but after the 12th century many more manuscripts of the work appeared in Western Europe. Nevertheless the float valve was not used between the 12th and the 18th centuries. Why was this feedback system neglected? Is there here involved some basic change in attitude that makes technological development much slower than it need have been?

According to the author, in the 18th century the number of feedback devices greatly increased, including perhaps the most famous of all, Watt's centrifugal governor, but Mayr also shows that in fields other than technology the same intellectual system was being employed—by Adam Smith in his *Wealth of Nations*, in the political philosophy of "checks and balances," and presumably he might have added Ricardo's wage law and Malthus's theory of population growth. It is part of Mayr's claim, which I hope will be more fully set forth in another book, that the burgeoning of feedback devices in 18th-century England represents a fundamental change in human outlook, in that it involves a reappraisal of what may be accomplished by the machine alone. Having heard so much, almost to boredom, of Newton's clockmaker, one is glad to know that the divine mechanic also made water closets.

The book is clearly illustrated with 72 figures, and block diagrams are used in analysis throughout.

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Ingenuity Illustrated

Technology in the Ancient World. HENRY HODGES. With drawings by Judith Newcomer. Knopf, New York, 1970. xviii, 302 pp. $10.

I have found, in teaching courses in history of technology, that engineering students respond with more enthusiasm to the technology of ancient Egypt, Mesopotamia, Greece, and Rome than to the scientific technology of the Industrial Revolution and later. Usually, I think, the excitement follows the discovery of a totally unexpected sophistication, both of equipment and techniques, that is to be found in the early phases of civilized society. Equally intriguing are the advances in masonry construction, metallurgy, glassmaking, woodworking, water raising, and the arts of making textiles, pottery, beer and wine, and a variety of tools of both war and peace.

Yet it is difficult to find text material that will support the notion that our technological heritage is both very broad and extremely deep. Except for Hodges, nobody has yet made a serious attempt to provide, in a work of moderate length, a summary account of tools, techniques, and products of the technologist.

While Hodges's book includes many errors and imperfections, it is a big step in the right direction. It is a