Mathematical Treasures of the Smithsonian Institution

Allyn Jackson

Much of the history of science and technology can be told through instruments and devices. A Geiger counter, Samuel Morse's original telegraph, a seventeenth-century telescope, a Bunsen burner from a high school chemistry lab—such a collection of objects would express a great deal about the history and influence of science and technology. But what about mathematics? The field historically has had little need for instruments or experimental apparatus. And while mathematics has been important for many technological feats, its role is often hidden, providing theoretical underpinnings rather than nuts and bolts. Does mathematics leave behind artifacts that tell its story?

Indeed it does, as can be seen in the Mathematics Collection at the Smithsonian Institution in Washington, DC. As a recent visit demonstrated, the collection houses a marvelous array of objects which delight, amuse, and edify—and which express much about mathematics and its impact on the world. Also at the Smithsonian, one can find a more traditional, but no less wonderful, view of mathematics as it is captured on the printed page, through the rare mathematics book collection at the Dibner Library.

Collecting Mathematical History

The Smithsonian Institution was founded in 1846 through a bequest from James Smithson, a British scientist who had never been to the U.S. The first secretary of the Smithsonian was Joseph Henry, codiscoverer with Michael Faraday of electromagnetic induction and a professor at Princeton University. Henry's interests set the stage for an emphasis on science at the Smithsonian, and in fact his original vision was that of a research institution that would facilitate communication among scientists in the U.S. It was only later after receiving a windfall of objects from the U.S. Patent Office and from the 1876 Centennial Exhibition in Philadelphia that the Smithsonian began to orient its activities toward museum collections. Although the 1865 red sandstone building on The Mall in Washington, DC, has come to symbolize the Smithsonian, today that building holds only administrative offices and an information center. The Smithsonian Institution is actually spread over sixteen museums and galleries, the National Zoo, and numerous research facilities in Washington and elsewhere.

At the end of the nineteenth century, there were very few objects relating to mathematics in the Smithsonian collections. It was not until the 1950s, when the Smithsonian's Museum of History and Technology was established, that interest developed in creating collections focused on mathematics and the then-budding discipline of computer science. One of the motivations was the desire to preserve the history of the first relay and electronic computers, which were rapidly becoming obsolete. In 1963 the historian of mathematics, Uta C. Merzbach, was brought to the museum to develop collections in mathematics and computer science by organizing objects already at the Smithsonian and also by obtaining new ob-

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jects for the collections. Merzbach is perhaps best known among mathematicians as the one who revised and expanded Carl B. Boyer's classic book *A History of Mathematics*.

During her twenty-four years at the Smithsonian, Merzbach built a strong collection, with particular emphasis in the areas of digital, analogue, and representational devices spanning the century from the 1850s to the 1950s. Most of the acquisitions were donations from individuals and from educational and business organizations spanning a wide economic range. The intent of the collection is to preserve not only objects that are unique but also ones that represent a particular historical period. The Smithsonian collections are used not only for museum exhibits but also for study by scholars, so efforts are made to obtain patterns, trade literature, and other supplementary materials that can help in the understanding of the objects.

Peggy Kidwell, who watches over the Mathematics Collection.

Today the Museum of History and Technology is called the National Museum of American History, and Peggy Aldrich Kidwell now oversees the Mathematics Collection. Trained in the history of astronomy and mathematical instruments, Kidwell came to the Smithsonian in 1982 as a postdoctoral researcher after receiving her Ph.D. from Yale University. The collection, which comprises perhaps 5,000 objects, is not on permanent display. However, Kidwell is happy to schedule appointments for those who wish to visit the collection. Whether one is working on a specific research project and knows exactly what one wants to see, or whether out of simple curiosity one wants to get a taste of what is in the collection, Kidwell is a knowledgeable guide whose love of history is infectious. In addition to responding to requests for information about the collection or about mathematics history in general, she also answers questions from people who have come across mathematical objects and want to know more about them.

Paper and String, Cardboard and Brass

Recently Kidwell led a visitor down a nondescript corridor and into the room that holds the smaller objects in the Mathematics Collection. Colorful boxes containing computer games and other software stood in piles near an array of chunky computer keyboards and monitors that date from the 1970s and already look surprisingly old-fashioned; these will eventually be added to the ever-growing collection of personal computers. On top of a filing cabinet, the upper half of a mannequin dressed in a uniform lays on its back, arms stretched up toward the ceiling. "We call her Mabel," Kidwell says, explaining that Mabel is a relic from an exhibit past. Kidwell soon dispels the sense of chaos—though not all of the whimsy—with a selection of objects she has assembled on a table. Each is carefully marked with a catalogue number, and some are accompanied by index cards explaining what the objects are. Once hands are clad in white cotton gloves, one can begin to see and touch some bits of history.

Smithsonian Institution photograph no. 97-9588.

Paper models of polyhedra by A. Harold Wheeler. Gift of Helen Wheeler. Photograph by Rick Vargas.

Kidwell has brought out two folded paper models of polyhedra made around 1920 by A. Harold Wheeler, a high school teacher in Worcester, Massachusetts. The collection contains about 1,000 Wheeler models, as well as templates for making them. The models are held together, not with glue, but by ingenious tabs that fit in at just the right places. These two models are certainly not the usual icosahedra or dodecahedra. One of them could perhaps be called a stellation of an icosahedron: each of the twenty triangles making up the faces of an icosahedron is fitted with three triangular pyramids whose bases fill out the face. It looks like a many-pointed star. Even more startling is the other model, which Wheeler called "a combination icosahedron and dodecahedron." That such a patchwork of triangles and irregular quadrilaterals could fit together to form a symmetrical polyhedron is very surprising. The delicacy and precision of the paper folding adds to the impact.

Smithsonian Institution Photograph no. 99-2573.

Adjustable mathematical model, unknown maker. Gift of the University of Michigan. Photograph by Ricardo Blanc.

A famous result of Cauchy says that all convex 3-dimensional polyhedra are rigid; that is, given such a polyhedron, there is no small nontrivial deformation of it that yields a polyhedron with

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Kidwell welcomes groups or individuals to make appointments to visit the collection. There is also a small program for junior or senior college mathematics majors to serve as volunteer interns. For information, go to the Web page http://www.si. edu/cms/, and then look for internships at the National Museum of American History, in the Division of Information, Technology, and Society. There is also a very limited number of fellowships for predoctoral and postdoctoral research in history, particularly as it relates to American culture. For further information, consult the Web page http://www.si.edu/organiza/offices/fellow/start.htm.

Rare Mathematics Book Collection:
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Dibner Library of History of Science & Technology
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Brashear welcomes groups or individuals to make appointments to visit the collection.

Smithsonian Institution Web site:

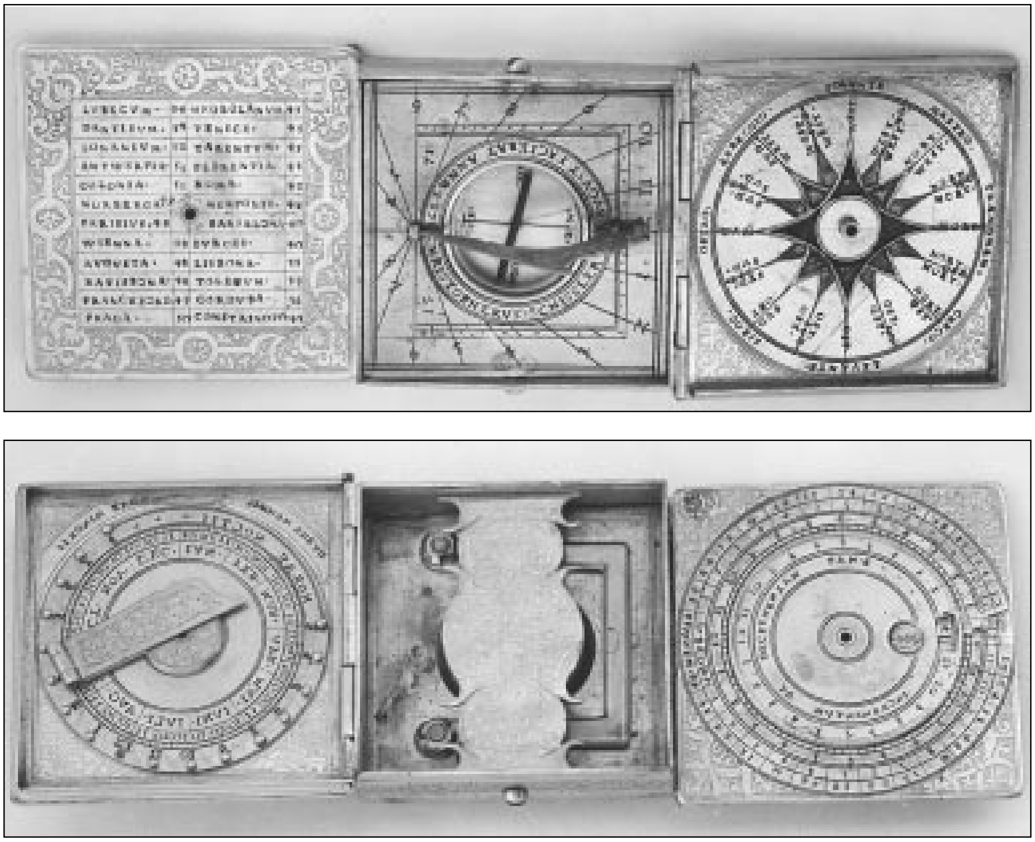
For further information on the Smithsonian Institution, visit the Web site http://www.si.edu/.

faces that are congruent to the corresponding faces of the original polyhedron. For a long time it was thought that no such deformations existed even for nonconvex polyhedra. So it was a surprise when, in 1977, more than 160 years after Cauchy's work, Robert Connelly produced counterexamples: polyhedra that could "flex." What does such a strange beast look like? Kidwell had one example on hand, in the form of a model made by Connelly. Unfortunately, the model, taped together from pieces of cardboard that looked as if they had been cut from an old shoebox, was falling apart, making a demonstration of its flexing properties impossible. A mysterious cut-out window covered over in cellophane provided an interior view.

Models of geometric objects are often found on display in mathematics departments. Kidwell sees it as part of her job to encourage departments to preserve, catalogue, and display such objects. But when they get squeezed out of an overcrowded library and are headed for the dustbin, Kidwell would like to see them before they are tossed. If they are not duplicates of ones the Smithsonian already has, or if they are made of an unusual material or have a special history, they may be added to the collection. One of the most common kinds of models is the string model, used for illustrating ruled surfaces. On this visit Kidwell brought out an especially fine example of a string model that had come from Wesleyan University. After the 1893 World's Fair in Chicago, Wesleyan bought a large number of these models, which were made not by a mathematician but by a German publisher named Ludwig Brill. Kidwell says that often the strings in such models get broken, and it can be very difficult to figure out how to restring them. In the case of this model the restringing, using three colors of thread, was exactly right. Starting with a cone, a cylinder, and a plane, each in its own color, one can rotate the circular metal frame at the top of the model to get a hyperboloid and a paraboloid.

One of Kidwell's interests is collecting keypunch cards. Anyone who ever spent hours in a dreary basement computer lab struggling to program a computer with keypunch cards and tossing great stacks of them into recycling bins might wonder if she isn't a bit daft. But as she pulls down from a shelf what appears to be a book marked "University of California Press, 1940", one understands her interest. It is not a book, but a box of keypunch cards entitled *Stencils for Solving* $x^2 \equiv a \pmod{n}$, and the "author" is the mathematician Raphael M. Robinson, who was on the faculty of the University of California, Berkeley, and who died in 1995. The set of cards, perhaps two inches thick, vividly demonstrates how much more onerous such computations were sixty years ago. In fact, as Kidwell points out, keypunch cards have a long history dating back to 1890, when Herman Hollerith invented them for tabulating U.S. census data that year. Opening a drawer, she pulls out one of Hollerith's cards, now brown with age, and notes that after the census Hollerith tried unsuccessfully to interest railroads in using his invention. He signed a contract to tabulate the Russian census in 1896, the year he started the Tabulating Machine Company. After the company did the U.S. census of 1900, it attracted commercial clients. Later the company merged with three others, and in 1921 it was renamed International Business Machines, or IBM. Pointing out another instance in which past meets present, Kidwell takes out another keypunch card, this one from the 1950s, in which the field for dates has only two spaces for the year. The seeds of the "Year 2000" computer problem were already sown.

The Mathematics Collection has a number of patent models, one-of-a-kind prototypes submitted to the U.S. Patent Office as demonstrations of new inventions. One of these, which was never made into a product that was sold, was created in 1858 by Thomas Hill, president of Harvard University and a Unitarian minister. As Kidwell put it, "He preached on Sundays and did math on Mondays." A student of Benjamin Peirce, Hill once wrote a treatise on mathematics as it revealed divine Providence. But he was also a practical, can-do sort. The first key-driven adding machine was built in Europe in 1851; and when Hill heard about this, he decided he would make his own. The resulting patent model demonstrates his idea. It is a wooden box, about six inches on a side, with an array of keys that are something like typewriter keys but made of wood and marked with numbers. One presses the keys to enter the digits of the numbers to be added, and this causes wheels inside the device to turn and perform the calculation. The wheels stop in a certain position, and small cut-out windows allow one to read off the digits of the result.



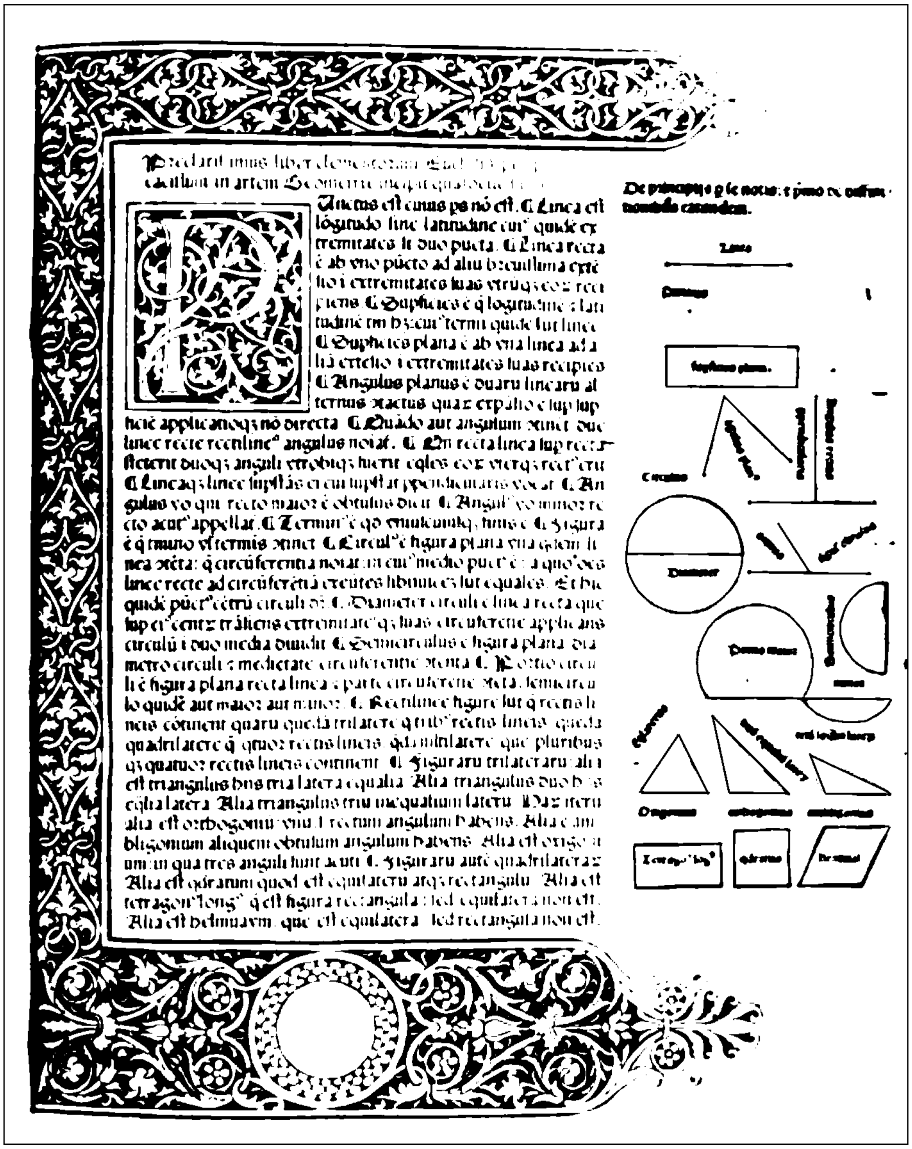
Smithsonian Institution photographs 49,284-H and 49,284-G.

Astronomical compendium by Christopherus Schissler of Augsburg, dated 1571. One side (top) has a list of the latitudes of various cities, a horizontal sundial, and a wind rose. The other side (bottom) of the instrument has a nocturnal (an instrument for telling time at night) and a lunar volvelle.

Most of the objects in the Mathematics Collection are American or were used in the U.S., but there are also many items hailing from other parts of the globe. One example is an "astronomical compendium", made in Augsburg, Germany, in 1571. A great deal of geometry went into the making of this compact timekeeping instrument, which is small enough that it would fit more easily into a pocket than the typical cellular phone. Inside it has a "pop-up" sundial, a compass, and a hole into which one can insert a tiny windvane. Flip it over and there is an instrument that allows one to tell time at night by adjusting a tiny movable arm to align with the position of the Polestar. To top it off, there is a rotating dial that shows the phases of the moon and is designed to convert lunar to solar time.

There are many more treasures in the Mathematics Collection. There are adding machines, cash registers, and calculating devices of all kinds. There are protractors and compasses and T-squares of all sizes, and unending variations on the abacus. There are computers and calculators, including one of the famous HP calculators that had a wrong value for $\sqrt{2}$ (the Smithsonian Electricity Collection has one of the flawed Pentium chips). On display in the museum are parts of the IAS computer, one of the early stored-program computers built in the 1940s at the Institute for Advanced Study under the direction of John von Neumann. The Mathematics Collection also contains eighty paintings done between 1965 and 1973 by the American cartoonist Crockett Johnson, creator of the comic strip "Barnaby". The paintings are the artist's interpretations of mathematical theorems and physical principles. There are also some photographs, including a wide-angle shot of participants in the Semicentennial Meeting of the AMS, held in 1938 in New York City.

Kidwell says that she would like one day to prepare an exhibit on "numbered people in a numbered world," which would explore the ways in which Americans use numbers to describe themselves, other people, and the world around them. Otherwise, no exhibits exclusively about mathematics are in the works, although a few objects from the Mathematics Collection may be found in some exhibits in the Smithsonian. What this means is that one must make an appointment to get a feeling for what is in the Mathematics Collection. But it also means that, rather than peering into a closed display case and reading dry descriptions, one gets to see the objects up close and to discuss them with Kidwell, whose knowledge and insights help to bring the collection to life.



Smithsonian Institution photograph no. 76-15314.

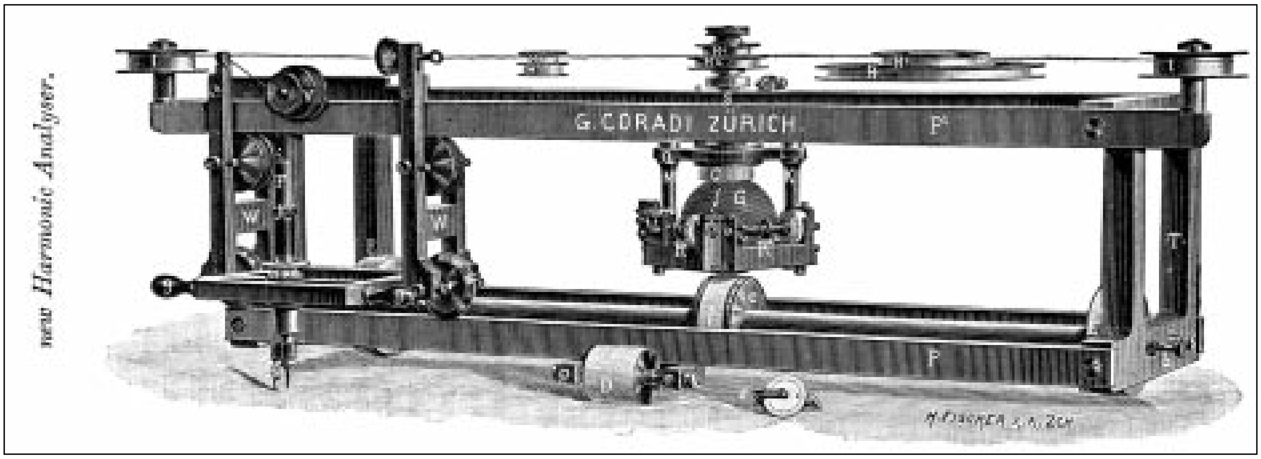
Page one from the first printed edition of Euclid's *Elements*, 1482.

Euclid et Al.

Bern Dibner was an electrical engineer and inventor with a passionate interest in the history of science. Born near Kiev in 1897, he emigrated to the U.S. and in 1924 started the Burndy Engineering Company. The business was sufficiently successful that two years later he took a sabbatical in Europe to study Renaissance art and science. While there he bought a number of rare books in science and technology, which at that time did not command such high prices as they do today. Upon returning to the U.S., Dibner continued to add to the collection, and after his company moved to Norwalk, Connecticut, he built a library there. The Burndy Library opened in 1964 with a collection of about 25,000 rare works in science and technology. In the 1970s Dibner donated a substantial part of the library holdings to the Smithsonian Institution. Later, the remainder of the Burndy Library went to the Massachusetts Institute of Technology, where it became part of the Dibner Institute for the History of Science and Technology. The building that housed the Burndy Library was demolished by the company that bought the building after Dibner's death.

Dibner's gift to the Smithsonian comprised about 10,000 books, 1,600 manuscripts, and 300 *incunabula*—literally, "from the cradle", which means that they were printed before 1501, in the early years of printing. With these holdings the Smithsonian founded the Dibner Library of the History of Science and Technology and added other rare books from its own collection. Dibner's gift included all of the works catalogued in his well-known reference book *Heralds of Science*, which supplies information about two hundred "epochal" works in science and technology, nineteen of them in mathematics. Today the Dibner Library has about six hundred titles that come under Library of Congress headings for mathematics. There are many other works that could be considered mathematics but are not catalogued as such: for example, the 1637 edition of Déscartes's *La Géométrie* is catalogued under philosophy, since it was printed as part of his *Discours de la Méthode*.

The Dibner Library is one of nineteen branches of the Smithsonian Institution Libraries. Like the Smithsonian Mathematics Collection, the Dibner Library is located in the National Museum of American History and is open by appointment only. Rare books curator Ronald Brashear is happy to have visitors come see the books and to help them navigate the collection. Bibliophiles be warned: This collection may cause drooling. On a recent visit, Brashear brought out three of the library's many different editions of Euclid's *Elements*. The oldest one is the first printed edition of the *Elements*, from 1482. The book has weathered its five hundred years astonishingly well. Brashear explained that the impression of newness is partly a result of the binding, which he conjectured dated from the late eighteenth century. The unblemished, supple quality of the pages exemplifies the excellent paper in use at the time. The high quality of the paper, Brashear noted, means that very early books tend to be in good condition. It was not until the nineteenth century that acid



London, Edinburgh, and Dublin *Philosophical Magazine and Journal of Science*, Volume 38, Fifth Series, July 1894.

A Curator's Favorite

During her twenty-four years at the Smithsonian, Uta Merzbach acquired many objects for the Mathematics Collection. Asked if there is one that was especially unusual or valuable, she replies it is difficult to choose only one. But she does confess a special fondness for the multi-integrator Henrici-Coradi analyzer.

First built around the turn of the century by G. Coradi in Zürich according to a design of O. Henrici, the analyzer is a device for computing the Fourier coefficients of a curve. Each integrator consists of a finely tuned arrangement of metal cylinders, spindles, disks and a glass sphere, mounted onto a rectangular frame set upon three wheels. Along the front of the frame is a carriage to which a tracer is attached. Given a curve drawn on a piece of paper, one runs the tracer over the curve, and this causes the various parts of the device to move. The glass sphere rotates, and the angle through which it rotates is communicated to registering wheels. The Fourier coefficient data is then read from these wheels. Varying the size of the disks allows one to compute different Fourier coefficients. Typically six disks were provided.

The Henrici-Coradi analyzer was used by mathematicians: The first one of its kind was made around 1893 for Felix Klein. Henrici continued to make the analyzers for years, and they were custom built according to the needs of the users. The accompanying illustration is taken from the article "On a new Harmonic Analyser," by O. Henrici, *Philosophical Magazine*, July 1894 (pages 110–121). The analyzer in the Smithsonian Mathematics Collection is of post-World War I vintage and has two glass spheres.

Merzbach points out that the Henrici-Coradi analyzer is not only historically significant but also is "beautifully engineered and esthetically pleasing." "It took some effort on my part to find one," she recalls. What's more, "it came as a donation."

—*A.J.*

was used to break down wood fibers to make pulp paper, a practice that today has left many books in far worse shape than incunabula.

The 1482 Euclid has no title page. Where the title page might have been there is instead an introduction, written by the printer, Erhard Ratdolt, who worked in Venice, which discusses the fact that Venetian printers of the time produced very few and rather insignificant mathematics books. He explains that this was due to the difficulty of producing diagrams, a difficulty which he overcame beautifully, as one can see in the many figures placed in the wide margins of the book. After Ratdolt's introduction comes a page decorated with an ornate wood cut that wraps around three sides of the text. Here the title of the book and the name of the author are presented in two lines of modestly sized red type, called a rubrication, and with no further ado the book itself begins. Brashear also brought out a 1543 Euclid, which from the first glance looks very different, as it has its original binding. By this time, title pages were common, and this one announces that the work was edited by Nicolo Tartaglia, and thus it is in Italian. In fact, this is the first translation of Euclid into a modern language. Though it is a later edition, the book is not printed and illustrated as finely as the 1482 Euclid. It also has wide margins, which were a common feature in books from this era and which were used for writing comments.

Finally, Brashear brings out the first English edition of the *Elements*, printed in 1570. The title page, decorated with an elaborate engraving showing muses for various scientific subjects, presents the book:

> The Elements of Geometrie of the most auncient Philsopher Euclide of Megara…With a very fruitfull Praeface made by M. I. Dee specifying the chiefe Mathematicall Sciẽces, what they are, and whereunto commodius: where, also, are disclosed certaine new Secrets

> Mathematicall and Mechanicall, until these our daies, greatly missed.

M. I. Dee is the philosopher and mystic John Dee; the reason for the initial I is that many typefaces at that time did not have the modern letters J and U, so I and V were often substituted. Dee's preface is a strange and fascinating document that discusses with evangelical fervor Euclid's work and relates it to an enormous variety of other disciplines, such as geography, hydrology, music, architecture, astronomy, and astrology. Dee also discusses how mathematics relates to the Almighty and includes a quotation of Plato saying that knowledge of geometry will cause men to turn to God. Reading the closing of the preface, one can almost imagine Dee sitting at his desk, quill in hand, as he set about preparing this book for future generations: "Written at my poore House At Mortlake Anno.1570.February.9."

There are adding machines, cash registers … protractors and compasses …unending variations on the abacus … computers and calculators…

The Dibner Library contains many more wonders of mathematical literature. Brashear opened a 1619 edition of Kepler's *Harmonices Mundi* to find templates for making paper models of 3-dimensional figures. Some of these are quite unusual; is this where, two centuries later, Wheeler got the ideas for the paper models now in the Smithsonian Mathematics Collection? There is a copy of Diophantus' *Arithmetica*, published in 1670—too late to have been a copy of the edition in which Pierre de Fermat wrote his famous marginal comment, as Fermat died in 1665. In fact, this edition has Fermat's marginal comments embedded in the text, a common practice at the time. There is a first edition of Newton's *Principia*, published in 1687, with a poem about Newton written by Edmund Halley, of Halley's comet fame. Brashear pointed out that Halley was instrumental in getting the *Principia* published. There is a 1744 copy of Euler's classic work on the calculus of variations, with elegant plates of engravings depicting various curves. An ingenious design permits the plates to be folded out so that they are visible while one is reading the text in another part of the book. A small notation on the inside cover reveals that this book once sold for 5 pounds 20 pence. In the midst of this wealth of history, Brashear is a patient, knowledgeable guide.

Coming away from a visit to the Smithsonian Mathematics Collection and the rare mathematics books in the Dibner Library, one cannot help but be struck by their significance as well as by their vulnerability. It is so easy for such objects, and all the knowledge and history they contain, to be destroyed or lost. Mathematics depends more heavily on its past than do science and engineering, for in mathematics the oldest ideas continue to provide new inspirations. For this reason, the mathematical treasures at the Smithsonian hold a special resonance.

References

- The article "From connections to collections" by Henry Petroski (*American Scientist*, September–October 1998, pages 416–420) tells the life story of Bern Dibner and how he started his library.
- The book *Heralds of Science, As Represented by Two Hundred Epochal Books and Pamphlets in the Dibner Library, Smithsonian Institution*, is a 1980 edition of Dibner's reference work. Neale Watson Academic Publications, Inc., ISBN 0-88202-191-5, ISBN 0-88202-192-3 (paperback).

About the Cover

The photograph, courtesy of the Smithsonian Institution (photograph no. 99-2582), is of an adjustable string model by Ludwig Brill of Darmstedt, which, in the position shown, shows a plane, a cone, and a cylinder. When twisted, it shows a hyperboloid of one sheet and a hyberbolic paraboloid. The string model was a gift of Wesleyan University to the Smithsonian. Photograph by Ricardo Blanc.