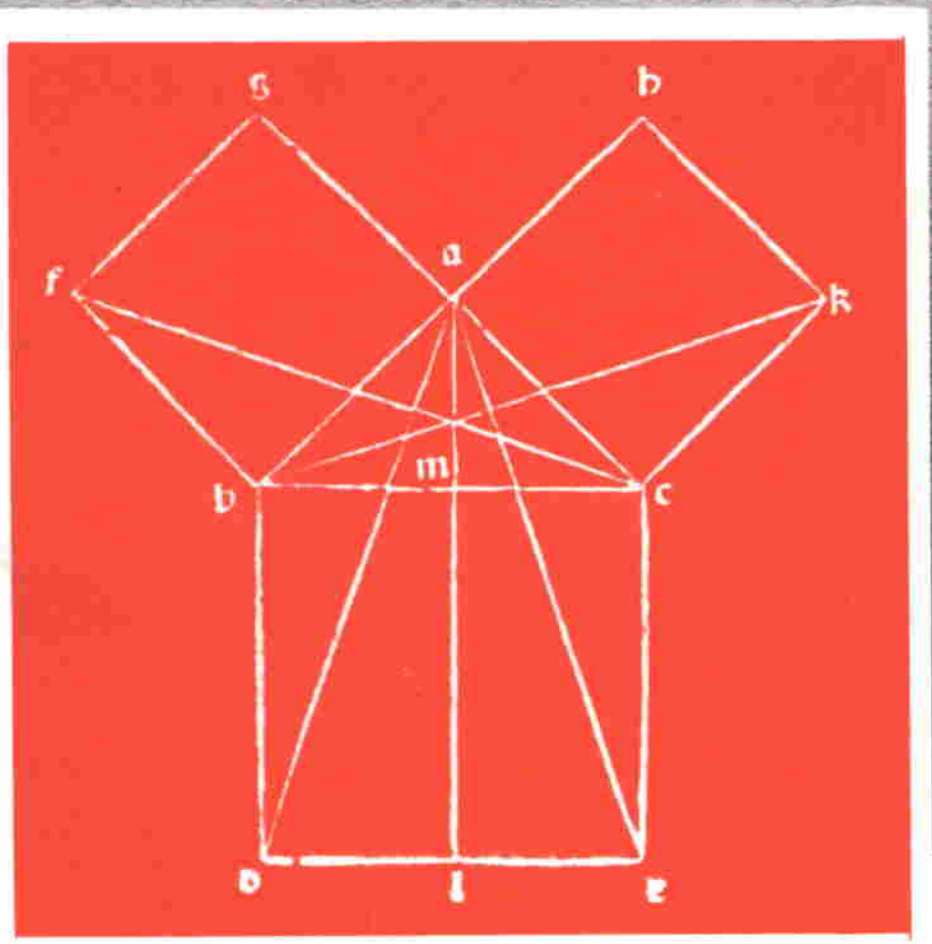
THE HISTORY OF MATHEMATICS

AN EXHIBITION OF RARE BOOKS



RARE BOOK ROOM

The Library

LEHIGH UNIVERSITY October – December 1961

The cover design is a photographic reproduction of the diagram accompanying the Pythagorean Theorem, Proposition 46, in Euclid's *Elementa Geometriae*, Venice, 1482.

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From the Private Collection of

ROBERT BRODHEAD HONEYMAN

Lehigh, Class of 1920

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PREFACE

In 1958 there was held at Lehigh University an exhibition of rare books on the subject of The Size and Shape of the Earth. Again, in 1959 another exhibition in the Library commemorated the anniversary of Darwin's *Origin of Species*. And a year ago we joined other libraries of the world in celebrating the Tercentenary of the Royal Society of London.

Now we present still another exhibition, on the History of Mathematics.

All of this has been made possible only through the friendly benefaction of Mr. and Mrs. Robert B. Honeyman, Jr., to whom Lehigh University is deeply indebted.

On the present occasion I must also express our thanks to Prof. Carl B. Boyer, of Brooklyn College, for his work in writing the Introduction and preparing the short commentaries on the authors. I should add that any blame for errors in describing the physical volumes on exhibit must attach not to Prof. Boyer, but to myself.

15 September 1961

James D. Mack,
Librarian

CLASSICS IN THE HISTORY OF MATHEMATICS

By CARL B. BOYER

"The history of mathematics should really be the kernel of the history of culture." So wrote George Sarton a quarter of a century ago, and the validity of his statement is made clear in 1961 in the exhibit of books, most of them now quite rare, from the collections of Mr. and Mrs. Robert B. Honeyman, and Lehigh University. Each of the works shown is a link in the chain of intellectual development which stretches from antiquity to the twentieth century, clearly indicating the progressive element in the history of mathematics. A glance at Descartes' *Géometrie*, appended to his celebrated *Discours de la méthode* of 1637, will convince one that the author's boast was not an empty one when he held that his geometry was to that of the ancients as the rhetoric of Cicero is to the A B C's of children. Similarly, the lofty analysis of Lagrange's *Théorie des fonctions analytiques* is to the crude elements of the calculus of Leibniz and Newton as a cathedral is to a wood-cutter's hut. And the celebrated problems with which Hilbert in 1900 challenged the twentieth-century mathematicians would have dismayed Cardano and Tartaglia, mathematical duelists of the sixteenth century. The books in this collection make clear the progressive element in the history of mathematics; but they illustrate more than that. The history of science also is characterized by progress, in which each generation builds upon the work of its predecessors. Newton wrote that, if he had seen further than had his predecessors, it was because he had stood upon the shoulders of giants—Huygens, Galileo, Kepler, Copernicus, and others whose works have become classics. However, in science each generation purges the subject of errors and irrelevancies, striving for ever greater economy and consistency in its description of the natural world. Outmoded laws, however ancient, are discarded to make way for new and more accurately descriptive formulations. As T. H. Huxley put it, the tragedy in science is the slaying of a beautiful theory by one ugly fact.

In mathematics, by contrast, one generation does not superciliously discard the work of its predecessors with the appearance of each new creation. Whereas science subtracts as it adds, mathematics adds without subtracting. In the 1820's Lobatchevsky and Bolyai published the first works on non-Euclidean geometry, and about a century later this new type of geometry was found to be more scientifically appropriate in Einstein's relativity theory than was the much older

Euclidean geometry. Yet the new geometries have in no sense displaced the mathematics of Euclid, despite the fact that they are in direct contradiction with the older work.

Science cannot tolerate such inconsistencies. Enough of the old must be discarded to eliminate contradiction within scientific theory, and to conform theory with experience. Mathematics, on the other hand, is quite hospitable to contradictory systems, for it deals not with reality but with validity. That is, it is the subject which draws necessary conclusions. The conclusions which Euclid drew from his premises more than twenty-two hundred years ago are as valid today as they were then; at the same time, the conclusions which Bolyai and Lobatchevsky drew from other premises more than a century ago are also valid today. Both sets of conclusions, both modes of thought, will continue to be valid, in terms of their respective premises, for all centuries to come. In this sense, then, an exhibit of classics in the history of mathematics has significance beyond what would be possible in the history of science: every one of the books is a permanent part of mathematics.

But immortality can have uncomfortable consequences. If each individual in the human species had enjoyed bodily immortality, there would be no room for us on the earth today. So too, if every published volume in mathematics were to survive without physical deterioration, the problems of library storage quickly would become insurmountable. Fortunately, however, mathematics contains within itself several governing devices which are likely to keep the problem from getting out of hand. It has developed a strong preference for economy of thought and language, that is, the art of saying many things in a single way through a symbolic shorthand which over-awes the uninitiated. The volumes in this exhibit well illustrate the evolutionary development of mathematical notation. The first use in print of our familiar plus and minus signs, for example, was made by Johann Widman in 1489, only three years before Columbus discovered America; and the earliest appearance in print of our symbol for equality is found in Robert Recorde's *Whetstone of Witte* of 1557, the year before Elizabeth I became Queen of England. Viète's *Canon mathematicae* (1579) contains virtually the first systematic use of decimal fractions about a thousand years after the Hindu-Arabic system of notation had been introduced for decimal integers. The use of the modern exponential notation originated with Descartes; our symbols in the calculus were devised by Leibniz; and our functional notation is due to Euler. These authors, along with many more, have continued to give mathematics a symbolic language which can compress volumes of words into a single

page. An exhibit of works on the history of mathematics cannot fail to heighten the appreciation of the extent to which the invention of notations has facilitated thought at the same time that it has resulted in an economy of space.

Compactness is characteristic of modern notation; but it is transcended in mathematical significance by another governing device which an exhibit, chronologically arranged, makes apparent. This is the tendency in mathematics toward ever greater generality. The *Elements* of Euclid (c. 300 B.C.) included the solution, by means of geometrical algebra and ruler-and-compass constructions, of several distinct types of quadratic equations with positive roots; but the schoolboy of today, aided by modern notations, solves *all* quadratic equations by means of a single general formula, whether the roots are positive or negative, real or imaginary. Similarly, Cardano's *Ars magna* (1545) gave separate treatments of a score of distinct forms for the cubic equations, where today a single general formula (incorrectly named for Cardano and Tartaglia) dispenses with the need for special cases. Jacques Bernoulli, brother of Jean Bernoulli and representative of a family of distinguished mathematicians, could make a similar boast. Through his general theory of Bernoulli numbers, he had expressed on a single page of his *Ars conjectandi* (1713, p. 98) what his predecessor, Ismael Bullialdus, had achieved in the voluminous *Arithmetica infinitorum* (1682). There is at work here a continuous process of more inclusive formulation. Thus the complex numbers of the Gaussian plane include the older real numbers as a special case; the vector analysis of Gibbs contains, as a special case, the theory of complex numbers; and the tensors of the twentieth century, in turn, relegate vectors to the status of a special case. In his *Géométrie de position* (1803), Lazare Carnot, the 'Organizer of Victory' of the French Revolution, gave to geometry a far greater generality than had Euclid; and less than a century later, the *Analysis situs* of Henri Poincaré (1892) had achieved a vastly more general view than that of Carnot. This penchant for ever greater generality has resulted today in a new branch of mathematics, known as topology, which has grown so rapidly as virtually to overshadow the field of geometry from which it developed.

A glance at the classics in the history of mathematics will quickly apprise one of the obvious fact that tastes and attitudes have varied from age to age. During the earlier Alexandrian period, the golden age of Greek mathematics, there was a palpable inclination to synthetic methods and a high degree of rigor. The *Elements* of Euclid, the *Conics* of Apollonius, and the *Spirals* of Archimedes clearly betray these predilections. With the decline of classical Greek thought came an

emphasis on applications and a trend toward less rigorous arithmetical methods, illustrated by the *Almagest* of Ptolemy (c. 150) and the *Arithmetica* of Diophantus (c. 300). The abysmal drop in the level of mathematical standards in the Roman world is betrayed by the *Arithmetic* of Boethius (c. 520); and the slow recovery during the early modern age becomes apparent in the *Compendion* of Pellos (1492) and the *Summa arithmeticae* of Paciuoli (1494). During the scientific renaissance it was not geometry which dominated the field, but arithmetic and algebra, as a glance at the sixteenth-century works on calculation by Recorde, Riese, Rudolff, and others will suggest. The seventeenth-century Age of Genius invented logarithms (Napier), probability (Pascal and Fermat), analytic geometry (Fermat and Descartes), and infinitesimal analysis (Newton and Leibniz); and these new subjects captured mathematical imagination, again to the virtual exclusion of synthetic geometry.

The eighteenth century, especially through the work of Euler, Lagrange, and Laplace, capitalized on these recent inventions to make analysis the leading field of mathematics. The period of the French Revolution nevertheless produced the first specialist in geometry, Gaspard Monge; and his pupils at the École Polytechnique initiated a revival in pure geometry which spread to Germany, and resulted in new and more general work such as the projective geometry of Jacob Steiner. All branches of mathematics expanded with almost explosive growth during the nineteenth and twentieth centuries, making this period unquestionably the Golden Age of mathematics. The work of this age has been characterized not only by ever greater generality, but also by an increased attention to precision and rigor. The fifth and tenth books of Euclid's *Elements* have been much admired for their rigorous treatment of proportions along the lines indicated earlier by Eudoxus; and in the late nineteenth century this geometrical formulation of equal ratios gave way to the still more rigorous arithmetic continuum of Dedekind and Weierstrass. Where the Greeks had cleverly avoided consideration of the infinite, the modern definition of real number explicitly recognized the existence of infinite sets. Cantor's creation of the theory of infinite assemblages and transfinite numbers met at first with ridicule, but by the end of the nineteenth century it had become a paradise for mathematicians; and during the twentieth century the theory of sets has vied with topology for first place in the favor of mathematicians.

Despite the ever-changing preferences of devotees, there has been one branch of mathematics which has never lost favor, even though it is furthest removed from immediate application to the world of practical affairs. This is the theory of numbers. Euclid's classic often is mistaken for a textbook of geometry; but in reality, large portions of the *Elements* are on geometrical algebra; and three of the thirteen books are on the theory of numbers, including a formula for perfect numbers and a proof that there are infinitely many prime numbers. Half a millenium later, the *Arithmetic* of Diophantus made Diophantine analysis an important part of mathematics; and this book served in the seventeenth century to inspire Fermat to found the modern theory of numbers. Euler, Lagrange, and Legendre all contributed heavily to the theory of numbers in the eighteenth century; but it remained for Gauss, the greatest mathematician of his age, perhaps of any age, to publish the outstanding work in this field. His *Disquisitiones arithmeticae*, published in 1801, has been called the Magna Charta of number theory. It is certainly the most celebrated work in a branch of mathematics which has had universal appeal. Gauss once said that "Mathematics is the queen of the sciences, and number theory the queen of mathematics." It is only natural that any collection of classics in mathematics should include some half-dozen works in number theory, for this topic fascinates amateurs and professionals alike. As in other branches of mathematics, theorems concerning number enjoy a permanence which in the natural and social sciences would be intolerable.

Finally, an exhibit of works from the history of the subject should effectively dispel one of the hardiest of illusions concerning the growth of mathematics. All too frequently one reads that mathematics developed most rapidly when it was associated with the world of practical affairs. Such an argument overlooks the fact that the great triumvirate of the early Alexandrian Age were taught by students of Plato, one of the most unworldly of philosophers. Again, it disregards the steady stream of pure and unapplied mathematics issuing from the pens of number theorists. And it forgets, too, that such new branches as non-Euclidean geometry, projective geometry, topology, and set theory were mothered by intellectual curiosity, not by practical necessity. There is a constant danger, evident today, that society will value the mathematician as a master computer, obscuring his function as a builder of beautiful theoretical structures. Technicians have found myriad applications for his work, but these must never be confused with the mathematician's real goals. Perhaps this exhibit will serve to remind the visitor that the mathematician is not a mere counter-caster, but rather a creator of norms of thought. To think the thinkable—that is the aim of the mathematician.

1

Ahmes, fl. 1650 B.C.

The Rhind mathematical papyrus. British Museum 10057 and 10058. T. Eric Peet . . . . Liverpool and London, 1923.

Fol. [i-iv], [1]-135 pp. lp. Plates A-Y. 36 x 25 cm.

The Rhind Papyrus is the most celebrated of the mathematical works surviving from the pre-Hellenic period. It is a copy, made by the scribe Ahmes, of material concerning problems of bread and beer-making, mensuration, grain storage, and division of property. Included also is a curious table for the reduction of fractions of the form 2/n to sums of unit fractions.

2 & 3

Euclid of Alexandria, fl. c. 300 B.C.

Preclarissimus liber elementorum Euclidis . . . . Venice, Ratdolt, 1482.

Fol. 138 leaves. 30½ x 21½ cm. Stillwell: E 86.

The most popular mathematics textbook of all time, the *Elements* has gone through over a thousand printed editions since it first appeared in 1482. The original work did not include the word "geometry" in the title; and the book in fact contains algebra and theory of numbers as well as plane and solid geometry. The treatise was translated into Latin in the twelfth century by Adelard of Bath and Gherard of Cremona, and again by Johannes Campanus in the thirteenth century. The Campanus translation was the first to be printed, appearing at Venice in this beautiful rare book from the press of Erhard Ratdolt.

The elements of geometrie of the most auncient philosopher Euclide of Megara. Faithfully (now first) translated into the Englishe toung, by H. Billingsley, Citizen of London . . . . London, Daye, 1570.

Fol. 29 leaves, 464 leaves. 31 x 21½ cm.

The first English translation of the *Elements* is attributed to Sir Henry Billingsley, later Sheriff and Lord Mayor of London. The preface, however, is by the eccentric and erudite John Dee, a mathematician, alchemist, and astrologer who may have been responsible, at least in part, for the translation.

4

Apollonius of Perga, fl. 3d cent. B.C.

Apollonii Pergaei Conicorvm Lib. V. VI. VII. . . . Florence, Cocchini, 1661.

Fol. [i-xxxvi], 1-415 pp. 34½ x 23½ cm.

Treatises on conics had been composed earlier, but they were displaced by that of Apollonius, the "Great Geometer." The edition on display is the *editio princeps* by Halley. The first four books were translated from surviving Greek manuscripts, and the next three were derived from Arabic sources. The last book has been lost, but has been conjecturally restored.

5

Archimedes, c. 287-212 B.C.

. . . *Opera* . . . . Basel, Hervagius, 1544.

Fol. [i-viii], 1-139 pp.; [i-viii], [1]-163 pp.; [i-iv], 1-65 pp.; [i-ii], 1-68 pp., 1 leaf. 31 x 21 cm.

This is the *editio princeps* of the greatest mathematician of antiquity. It is based upon several versions, including that of Regiomontanus. It is the earliest edition to contain the *Sand Reckoner*, in which the author gives incidentally a rule for large numbers equivalent to the formula $x^m \cdot x^n = x^{m+n}$.

6

Ptolemy, fl. 127-151 A.D.

Epytoma Joānis de mōte regio in Almagestu Ptolomei. Venice, Hamman, 1496.

Fol. 108 leaves. 31 x 21 cm. Stillwell: R 106.

Ptolemy's work originally bore in Greek the title *Mathematical Collection.* To distinguish it from the lesser astronomical treatises, the Arabs called it the *Great Collection,* from which the present name *Almagest* is derived. This epitome of the *Almagest* was begun by Purbach and completed by Regiomontanus.

Ptolemy's astronomy had been translated into Arabic under al-Mamun, and toward the end of the ninth century this translation was revised by Thabit ibn Qurra. A Latin translation from the Arabic was made during the twelfth century and appeared in the first printed edition of 1515.

7

Diophantus of Alexandria, 3d cent. A.D.

Rerum arithmeticarum . . . . Basel, 1575.

Fol. [i-xii], 1-152 pp. 31 x 10½ cm. Bound with: Ptolemy, *Almagest,* Venice, 1515.

Of the original thirteen books of the *Arithmetica,* only the first six are extant. This, the most significant Greek work on algebra, is a collection of problems leading to indeterminate equations of degree as high as the sixth. Although the author frequently is referred to as the "Father of Algebra," his work actually forms a part of the theory of numbers now known as Diophantine analysis.

8

Nicole Oresme, c. 1320-1382.

. . . *De latitudinibus formarum* . . . . Padova, Cerdonis, 1486.

4to. 11 leaves. 21 x 15½ cm. Bound with: Pelicanis, *Questiones super tractatu de latitudinibus formarum.* Padova, 1486. Stillwell: O 87.

Generally ascribed to Oresme, this work may be only a student's summary of ideas expressed more fully by the teacher in lectures and other larger treatises. The fundamental concept is the graphical representation of a function (form) on a coordinate system (latitude and longitude). Oresme, known also as Nicolas Horem, was *magister* at the Collège de Navarre, and later bishop of Lisieux.

9

[Anonymous]

[*Arte dell Abbaco.*] *Incommincia vna practica molto bona et vtile: a ciaschaduno chi vuole vxare larte dela merchadantia. chiamata vulgarmente larte de labbacho.* Treviso, [Gerardus de Lisa, de Flandria], 1478.

4to. 62 leaves. 20½ x 13½ cm. Stillwell: A 1009.

Of unknown authorship, but presumably by a teacher of arithmetic at Treviso, the *Arte dell Abaco* is the first practical arithmetic to appear in print. It is commercial in character, featuring the fundamental processes, the rules of two and three, and business applications.

10

Johann Widman, born c. 1460.

. . . *Rechenung auff allen kauffmanschafft.* Leipzig, Kacheloffen, 1489.

8vo. 231 leaves. 13½ x 10 cm. Stillwell: W 11.

Widman's is the first significant German textbook on arithmetic. It is chiefly a practical treatise, noteworthy for the first use in print of the plus and minus signs. These symbols were first used to indicate excess and deficiency in warehouse measures, and only later did they become signs of the familiar arithmetic operations.

11

Francesco Pellos, fl. 1450-1500.

. . . *Cōpendiō de lo abaco.* Torino, Benedictis and Suigus, 1492.

4to. 80 leaves. 19½ x 14 cm. Stillwell: P 226.

This book, by a native of Nice, is one of the rarest arithmetics. It is concerned with the fundamental operations, fractions, mensuration, and business arithmetic. The volume is of particular interest for the adumbration of the use of decimal fractions and the almost inadvertent use of the decimal point.

12

Luca Paciuoli (Luca di Burgo), c. 1450-1509.

Suma de arithmetica geometria proportioni & proportionalita. Venice, Paganinus de Paganinis, 1494.

Fol. 8 leaves, 300 leaves. 28½ x 21 cm. Stillwell: L 282.

The author, known either as Luca Paciuoli, or Luca di Burgo, was essentially a compiler; but his *Summa* is so significant that often it is taken to mark the beginning of the modern age in mathematics. The book makes use of some algebraic symbolism, and it rises above the level of purely practical treatises. Paciuoli's influence in mathematics and bookkeeping was felt from Italy to the Low Countries.

13

Regiomontanus (Johann Müller), 1436-1476.

Ephemerides siue almanach perpetuum. Venice, Petrus Lichtenstein, 1498.

4to. 122 leaves. 21 x 15½ cm. Stillwell: R 105.

Joannes de Monteregio, baptized Johann Müller but better known as Regiomontanus, was the leading German mathematician and astronomer of his day. He was one of the first scientists to study the Greek classics in the original tongue. He died in Rome, whither he had been called by the Pope to reform the calendar. Most of his works, including the *Ephemerides*, were published posthumously.

14

Albrecht Dürer, 1471-1528.

Vnderweysung der messung mit dem Zirckel vñ richtscheyt in linien ebnen vnnd gantzen corporen. Nürnberg, 1525.

Fol. 89 leaves. 28 x 20 cm.

Dürer, like Leonardo da Vinci, was both artist and mathematician. His *Underweysung* of 1525, a geometrical work of considerable originality, appeared in several subsequent Latin editions. Included in it are studies in perspective and the properties of higher plane curves.

15

Christoph Rudolff, fl. 1500.

Künstliche rechnung . . . . Nürnberg, Petreus, 1532.

8vo. 119 leaves. 14 x 9 cm.

Rudolff's book, one of the better-known of the many practical arithmetics of the time, covers the fundamental operations, with and without the use of the abacus, as applied to integers and fractions. It is especially significant as one of the earliest works to make use of decimal fractions.

16

Girolamo Cardano, 1501-1576.

. . . *Practica arithmetice, & mensurandi singularis.* Milan, Calusci, 1539.

8vo. 306 leaves. 15 x 10½ cm.

Cardan, or Cardano, professor of medicine and mathematics at Milan, Pavia, and Bologna, is best known today for his publication (1545) of the solution of the cubic equation; but in his own time he was regarded more highly as a physician. His *Practica arithmetice*, despite the title, is not a practice book, but a theoretical work on arithmetic and algebra written for scholars.

17

Michael Stifel, 1487-1567.

Arithmetica integra. Nürnberg, Petreus, 1544.

4to. 6 leaves, 319 leaves; 3 leaves errata. 20 x 15 cm.

Michael Stifel was a religious fanatic who wrote numerological works as well as sober mathematics. His *Arithmetica integra* was one of the better and more influential books of the sixteenth century, doing for Germany what Cardano and Tartaglia had done in Italy for the establishment of symbolic algebra.

18

Adam Riese, c. 1489-1559.

Rechenung nach der lenge auff den linihen vnd feder . . . . Leipzig, Berwalt, 1550.

4to. 4 leaves, 196 leaves. 19½ x 14½ cm. Bound with: Stifel, *Rechenbuch*, Le'pzig, 1546.
Riese's own copy.

This work was one of the more influential of German treatises in replacing counter-reckoning by written computation. It appeared in so many editions, and became so well known, that even today, "nach Adam Riese" is a household phrase synonymous with correctness of computation.

19

Nicolo Tartaglia, c. 1506-1559.

La prima parte del general trattato di nvmeri, et misvre . . . . Venice, Curtio Trojano de i Navò, 1556.

Fol. 6 leaves, 277 leaves. 30 x 21½ cm.

Here is one of the more scholarly arithmetics written by one of the most frustrated mathematicians of the century. The author had hoped to establish his reputation through publication of his solution of the cubic equation; but he imparted his rule, under oath of secrecy, to Cardano who broke his oath and published the solution. Tartaglia's *General Trattato* gives the most extensive information, theoretical and practical, on the arithmetic of his day.

20 & 21

Robert Recorde, c. 1510-1558.

The castle of knowledge. London, Wolfe, 1556.

4to. 8 leaves, [1]-286 pp., 1 leaf. 25½ x 18 cm.

Recorde, physician to Edward VI and Queen Mary, did for arithmetic in English what Pacioli had done in Italy, and Riese in Germany. His *Castle of Knowledge*, in the form of a catechism, is a work on astronomy, its mathematical significance being largely in the rules of operation with sexagesimal fractions.

The whetstone of witte, whiche is the seconde parte of arithmetike . . . . London, Kyngston, 1557.

4to. 165 leaves. 19 x 13½ cm.

The Whetstone of Witte is Recorde's best known work, for it contains the first use in print of the now familiar symbol of equality. He used a pair of parallels for this purpose "bicause noe .2. thynges, can be moare equalle."

22

François Viète, 1540-1603.

Canon mathematicvs sev ad triangvla cum adpendicibus. Paris, Mettayer, 1579.

Fol. 81 leaves. 40 x 28 cm. Bound with his *Vniversalivm inspectionvm ad canonem mathematicvm*, Paris, Mettayer, 1579.

François Viète, known in Latin as Franciscus Vieta, has been described as the first mathematician to write in a spirit akin to that of today. In his *Canon* he gave to trigonometry much of its modern analytic generality. This work is important also for a plea that decimal fractions should replace the sexagesimal fractions which had predominated in astronomy, physics, and mathematics.

23

Simon Stevin, 1548-1620.

L'arithmetiqve . . . . contenant les computations des nombres arithmetiques ou vulgaires: aussi l'algebre, auec les equations de cinc quantitez . . . . Leiden, Plantin, 1585.

8vo. [i-xviii], 3 leaves, 4-642 pp., 7 leaves. 15 x 9½ cm. Bound with: Stevin, *Pratiqve d'Arithmetiqve*, 1585.

Stevin's arithmetic first appeared in Flemish and was published in French translation in the same year. It contains, besides the arithmetical operations and a translation of the first four books of Diophantus' *Arithmetica*, the small but significant treatise, *La disme*, in which the use of decimal fractions is for the first time systematically explained.

24

John Napier, 1550-1617.

Mirifici logarithmorum canonis descriptio, ejusque usus, in utraque trigonometria, ut etiam in omni logistica mathematica, amplissimi, facillimi, & expeditissimi explicatio. Edinburgh, Hart, 1614.

4to. 4 leaves, 1-57 pp., 90 pp. tables. 19 x 14½ cm.

This is the celebrated work in which Napier first announced his invention of logarithms (invented independently also by Jobst Bürgi, who published his results in 1620). Napier did not define his logarithms

as exponents, but his "ratio numbers" are somewhat akin to those now known as natural or napierian logarithms, the base being approximately 1/e.

25

Henry Briggs, 1556-1630.

Arithmetica logarithmica sive logarithmorvm chiliades triginta, pro numeris naturali . . . . London, Jones, 1624.

Fol. 5 leaves, 1-88 pp., 150 leaves tables. 31 x 20 cm.

Two years after Napier's publication of the invention of logarithms, Briggs visited the inventor and suggested a revised system with the base ten. Napier already had thought of this, but it was Briggs who carried out the idea. The resulting table of Briggsian or common logarithms appeared in this work of 1624.

26

Johann Kepler, 1571-1630.

Tabulae Rudolphinae, quibus astronomicae scientiae . . . . Ulm, Saurius, 1627.

Fol. [i-x], 1-120 pp., [1]-125 pp., 2 pp. 34 x 23 cm.

In 1601 Kepler became chief Imperial Mathematician to Rudolf II, Emperer of the Holy Roman Empire, inheriting both the post and the astronomical observations of his predecessor, Tycho Brahe. Kepler improved and organized the data from Tycho, and published the material in 1627 as the *Rudolphine Tables.* Although the celebrated laws of Kepler had appeared in earlier treatises, his *Tables* ranked for a century as an outstanding aid to astronomy.

27

Thomas Harriot, 1560-1621.

Artis analyticae praxis, ad aequationes algebraicas, nouâ . . . . London, Barker and Bill, 1631.

Fol. [i-vi], 1-180 pp., 1 leaf errata, 1 leaf. 30 x 21 cm.

Harriot sometimes is referred to as the first American mathematician, in view of his first trip to America in 1585 for Sir Walter Raleigh. His posthumous *Analytic Art* was an influential work in algebra which extended the methods of Viète. The symbols $>$ and $<$ which he introduced for "is greater than" and "is less than" have continued in use to this day.

28

William Oughtred, fl. 1575-1660.

[*Clavis mathematicae.*] *Arithmeticae in nvmeris et speciebvs institvtio: qvae tvm logisticae, tvm analyticae, atqve adeo totivs mathematicae, qvasi clavis est.* London, Harper, 1631.

8vo. [i-xii], 1-88 pp. 16 x 10½ cm.

Oughtred's *Key to Mathematics* rivalled in influence Harriot's *Analytic Art,* published in the same year. The author was a minister who gave much of his time to mathematics, the invention of the slide rule being attributed to him. Of the many novel notations appearing in the *Clavis,* the symbol $\times$ for multiplication is one of the few still in use.

29

René Descartes, 1596-1650.

Discours de la methode pour bien conduire sa raison, & chercher la verité dans les sciences. [Appendix,] "La geometrie." Leiden, Maire, 1637.

4to. 3 leaves, [1-2], 3-78 pp., 1 leaf, 1-413 pp., 1 p., 15 leaves index, 2 leaves. 20½ x 15 cm.

La Geometrie is one of three works appended to the *Discours de la méthode.* (The others are *La Dioptrique,* on the law of refraction, and *Les Meteores,* on meteorology and the rainbow.) In *The Geometry* Descartes published for the first time the fundamental principle of analytic geometry, known independently to Fermat—that every equation in two unknown quantities corresponds (with respect to a given coordinate system) to a plane curve. Thus he linked algebra and geometry in what has since been known as Cartesian geometry.

30

Galileo Galilei, 1564-1642.

Discorsi e dimostrazioni mathematiche, intorno à due nuoue scienze attenenti alla mecanica & i movimenti locali . . . . *Con una appendice del centro di grauita d'alcuni solidi.* Leiden, Elzevir, 1638.

4to. [i-viii], 1-306 pp., 1 leaf errata. 20½ x 15 cm.

Galileo is best known for his defense, in the *Two Chief Systems* (1633), of Copernican astronomy; but his most original work was published in the *Two New Sciences* of 1638. In it he organized the inchoate medieval thoughts on inertia and acceleration into a systematic dynamics. (His other new science, largely on the strength of materials, was less successful.) In this influential treatise he gave the equivalents of Newton's

first two laws of motion, and he demonstrated that the path of a projectile is parabolic.

31

Bonaventura Cavaleri, 1598-1647.

Geometria indivisibilibvs continvorvm noua quadam ratione promota. Bologna, [Ferronius], 1653.

4to. [i-xvi], 1-543 pp. 23 x 16½ cm.

This is one of the most influential works in the history of the calculus. The author, a pupil of Galileo and professor of mathematics at Bologna, conceived of lines as made up of indefinitely many infinitely small indivisibles; and in the same way he regarded areas as constituted of line segments, and volumes as made up of an aggregate of plane areas. The Theorem of Cavaleri, based on this view, is still sometimes appealed to in books on solid geometry.

32

Blaise Pascal, 1623-1662.

Traité dv triangle arithmetiqve . . . . Paris, Desprez, 1665.

4to. [i-iv], table, 1-11 pp. 22 x 16 cm. Contains also the three other tracts 'svr la mesme matiere'.

Pascal was tortured by a deeply religious conscience, and hence but a fraction of his brief life was devoted to mathematics. With Fermat he founded the theory of probability, in connection with which he composed this work on the arithmetic triangle. His triangular arrangement of integers had been known in China from 1303, and it was familiar in Europe from the sixteenth century; but Pascal added so many new properties that it has since been known as Pascal's triangle.

33

Christiaan Huygens, 1629-1695.

. . . *Horologivm oscillatorivm sive de motv pendvlorvm ad horologia aptato demonstrationes geometricae.* Paris, Muguet, 1673.

Fol. [i-xiv], 1-161 pp., 1 p. corrigenda. 31 x 10½ cm.

Galileo had left designs for a pendulum clock, but Huygens was the first to construct one successfully. In studying the operation of clocks Huygens developed the theory of involutes and evolutes, including the discovery that the evolute of a cycloid is a similar cycloid. His adaptation of this discovery to the construction of clocks failed to enhance their accuracy; but his treatises influenced the work of both Newton and Leibniz.

34

Pierre de Fermat, 1601-1665.

Varia opera mathematica. Toulouse, Peche, 1679.

Fol. [i-xii], 1-210 pp., 2 leaves. 35 x 23 cm.

Fermat was the outstanding mathematician of his day, and possibly the foremost mathematical amateur of all time. He was a lawyer by vocation, but spent his leisure time reading the Greek classics and making profound mathematical discoveries. He invented a process equivalent to the differential calculus; he discovered the fundamental principle of analytic geometry; he was a coinventor, with Pascal, of mathematical probability; and he established the modern theory of numbers. His influence, however, was limited by his reluctance to publish, and most of his contributions appeared posthumously in the *Varia opera.*

35

Gottfried Wilhelm Leibniz, 1646-1716.

"Nova methodvs pro maximis et minimis, itemque tangetibus, quae nec fractas, nec irrationales quantitates moratur, & singulare pro illis calculi genus," *Acta Eruditorum,* Leipzig, October, 1684. pp. 467-73.

4to.

Newton had invented the method of fluxions in 1665-66, and Leibniz had developed the equivalent differential calculus ten years later; yet the earliest publication of the new subject was in the form of Leibniz' short paper in the *Acta Eruditorum* for 1684. This paper, full of typographical errors and almost meaningless to most readers, nevertheless launched the most powerful tool which mathematics has yet devised for the study of nature.

36

Sir Isaac Newton, 1642-1727.

Philosophiae naturalis principia mathematica . . . . Londini,/Jussu *Societatis Regiae* ac Typis *Josephi Streater.* Prostat apud/plures Bibliopolas. *Anno* MDCLXXXVII. [1687.]

4to. [i-vi], 1-383, 400-510 pp., 1 p. errata. 24 x 18½ cm.

The *Principia* is without question the most celebrated publication in the whole history of science. It includes Newton's laws of motion and his law of gravitation; but it contains much besides, from theorems on conic sections to a theoretical computation on the velocity of sound. A cryptic account of the calculus, the first publication by Newton of his

deepest mathematical invention, is included unobtrusively in this great treatise, published at the instigation (and expense) of his friend Edmund Halley.

37

John Wallis, 1616-1703.

Holograph letter to "Mr. Isaac Newton, Controller of the Mint, at the Tower, London," dated Oxford, July 1, 1697.

Written in Latin, enclosing message from Leibniz on the Calculus.

1 p., 33 x 21 cm.

John Wallis, professor of geometry at Oxford and an ordained clergyman, was one of the most influential of Newton's older contemporaries. An admirer of the works of classical antiquity, Wallis nevertheless saw that an analytic form of expression was essential to the newer developments. His arithmetization of Cavaleri's method of indivisibles was an important stepping-stone to the calculus of Newton and Leibniz.

38

Jacques Bernoulli, 1654-1705.

. . . *Ars conjectandi, opus posthumum. Accedit tractatus de seriebus infinitis* . . . . Basel, Thurnisius, 1713.

4to. [i-iv], 1-306 pp., diagram, 1 leaf, 1-35 pp., 1 p. errata. 20½ x 16 cm.

Jacques was the first of the many members of the Bernoulli family who contributed to mathematics. He and his contentious younger brother, Jean, were among the earliest disciples of Leibniz in the establishment of the calculus; but the classic work of Jacques was his posthumously published *Ars conjectandi*. This, one of the first significant books on the theory of probability, introduced the properties of the Bernoulli numbers, and is climaxed by the Bernoulli theorem on binomial distributions.

39

Brook Taylor, 1685-1731.

Methodus incrementorum directa & inversa. London, Pearson, 1715.

4to. [i-vi], 1-118 pp., 1 p. corrigenda and addenda. 22 x 16½ cm.

Brook Taylor gave up his post as secretary of the Royal Society in order to have time for his writing. The result was the publication of three books in four years, as well as numerous papers in the *Phil. Trans.* Two of the books were on perspective; but by far the best known today

is his classic work on finite increments and infinite series. This book of 1715 contains the so-called Taylor theorem which to this day has played so large a role in analysis.

40

Abraham de Moivre, 1667-1754.

The doctrine of chances: or, a method of calculating the probability of events in play. London, Pearson, 1718.

4to. 2 leaves, i-xiv, [1]-175 pp. 25½ x 19½ cm.

De Moivre is best known today for the theorem on the trigonometric form of complex numbers, which bears his name; but his most popular work of two centuries ago was the *Doctrine of Chances*, the first edition of which (1718) is dedicated to Newton. Fifteen years later the author derived the normal probability function in connection with the binomial law.

41

Roger Cotes, 1682-1716.

Harmonia mensurarum, sive analysis & synthesis per rationum & angulorum mensuras promotae: accedunt alia opuscula mathematica. Cambridge, 1722.

4to. [i-xx], 1-249 pp. 24½ x 19½ cm. Bound with: Cotes, *Opera Miscellanea.*

Newton is said to have remarked that, "If Cotes had lived, we had known something." But Cotes died at the age of thirty-three, three years after he had seen the second edition of Newton's *Principia* through the press, in 1713. His writings were collected and published half a dozen years after his death as the *Harmonia mensurarum.* The integration of rational fractions is an important part of this work.

42

Jean Bernoulli, 1667-1748.

. . . *Opera omnia* . . . . Lausanne & Geneva, Bousquet, 1742. Vol. IV.

4 vols., 4to. 25 x 19 cm.

Jean Bernoulli, ardent devotee of the calculus of Leibniz, was most influential in the rapid rise of the new analysis in Europe. He was professor of mathematics, first at Groningen, later at Basel. He wrote prolifically on many aspects of both pure and applied mathematics. Among his discoveries was the rule on indeterminate forms which bears the name of L'Hospital, his protégé, who first published it.

43

Colin MacLaurin, 1698-1746.

A treatise of fluxions. In two books. Edinburgh, Ruddimans, 1742.
2 vols., 4to. 22½ x 16½ cm.
Sir William Herschel's copy.

MacLaurin was a precocious Scots mathematician who earned the M.A. degree at the age of fifteen. He wrote important books on algebra and geometry; but by far his best-known work is the *Treatise of Fluxions.* It is in these volumes that one finds the familiar MacLaurin series; but it should be noted that this is but a special case of the Taylor series which had been published earlier.

44 & 45

Leonhard Euler, 1707-1783.

Methodus inveniendi lineas curvas . . . sive solutio problematis isoperimetrici . . . . Lausanne & Geneva, Bousquet, 1744.
4to. 1 leaf, [1]-322 pp., 1 leaf. 24 x 19½ cm.

Euler was certainly the most prolific of all mathematicians. Many of his contributions were made after he had become totally blind. Among his nearly 900 works are substantial multivolume treatises on the calculus; but in generality and originality these are excelled by his celebrated work of 1744 on the calculus of variations. Here one finds the Euler equations, with applications to minimal surfaces.

Institvtionvm calcvli integralis . . . . Petrograd, Academia Imperialis Scientiarum, 1768.
3 vols. in 2, 4to. 24½ x 19 cm.

Euler was among the most pervasively influential of mathematicians, both through his original contributions and as a result of his didactic works. The volumes in the integral calculus contain the Eulerian beta and gamma functions, as well as a treatment of the theory of differential equations which still is a model for modern textbooks. Many of the exercises in today's books can be traced back to Euler's *Institutiones.*

46

Jean Le Rond D'Alembert, 1717-1783.

Opuscules mathématiques, ou mémoires sur différens sujets de géométrie, de méchanique, d'optique, d'astronomie &c. Paris, David, 1761-1780. Vol. I.
8 vols., 4to. 23 x 17½ cm.

D'Alembert, the leading mathematician among the French Encyclopedists, was a facile writer on many aspects of pure and applied mathematics. With Daniel Bernoulli he helped to found the theory of partial differential equations; and the fundamental theorem of algebra often is called D'Alembert's Theorem in recognition of his attempted proof. The volumes of the *Opuscules* demonstrate the many-sidedness of the author, whose name is connected also with a principle in dynamics.

47

Joseph Louis Lagrange, 1736-1813.

Théorie des fonctions analytiques, contenant les principes du calcul différentiel . . . . Paris, l'Imprimerie de la République, Prairal an V. [1796-97].
4to. 2 leaves, [i]-viii, [1]-277 pp., 1 leaf. 27 x 20½ cm.

In generality, depth, and elegance, the works of Lagrange had no peer in the eighteenth century. Dissatisfied with the inadequate foundations of the calculus, Lagrange sought a rigorous basis in the Taylor theorem for the expansion of functions. The *Theory of analytic functions,* in which he presented his views, was definitive in initiating the period of rigor in analysis.

48

Adrien-Marie Legendre, 1752-1833.

Essai sur la théorie des nombres. Paris, Duprat, An VI [1798].
4to. [i-v], vi-xxii, 1 leaf errata, [1]-472 pp., 56 pp. tables, 1 leaf. 25 x 19½ cm.

Legendre wrote on many of the topics such as elliptic integrals, least squares, and geodesy, which also had occupied Gauss, the Prince of Mathematicians; and hence the importance of his work was to some extent eclipsed by the brilliance of his contemporary. In the *Théorie des nombres,* for example, Legendre formulated the law of quadratic reciprocity; but this achievement was transcended only three years later when Gauss not only restated the theorem, but also gave a complete proof of this gem of arithmetic.

49

Pierre Simon, Marquis de Laplace, 1749-1827.

Traité de mécanique céleste. Paris, Duprat, An VII [1798-99]-1825. Vol. I.
5 vols., 4to. 26 x 20 cm.

Laplace, a leading mathematician of the French Revolutionary and Napoleonic eras, is known especially for two great works—the *Théorie analytique des probabilités* (1812) and the five-volume *Mécanique céleste*. The latter in particular is regarded as the culmination of the Newtonian period in astronomy, for in it Laplace sought to establish the stability of the solar system. Napoleon made Laplace a count, and Louis XVIII raised him to the peerage as a marquis.

50

Gaspard Monge, 1746-1818.

Géométrie descriptive. Leçons données aux Écoles Normales, l'an 3 de la République [1794-95]. Paris, Baudouin, An VII [1798-99].

4to. 1 leaf, [i-v], vi-vii, [viii], [1]-132 pp. Plates I-XXV. 26 x 20 cm.

Monge, a leading French Revolutionary figure and a favorite of Napoleon, was the first great specialist in geometry since the days of Apollonius. His early lectures on fortifications led him to devise descriptive geometry; and his lectures at the Écoles Normales (which he was instrumental in establishing) gave him an opportunity to develop other aspects of synthetic and analytic geometry. It was largely through the pupils of Monge at the Ecole Polytechnique that the nineteenth-century resurgence of geometry eventuated.

51

Karl Friedrich Gauss, 1777-1855.

Disqvisitiones arithmeticae. Leipzig, Fleischer, 1801.

8vo. 1 leaf, [i-vi], vii-xviii, [1]-668 pp., 5 leaves. 19½ x 11½ cm.

Gauss has been described as the last mathematician to have comprehended the whole of the subject, and he contributed to many of its aspects. He proved the fundamental theorem of algebra; he dispelled the mystery of complex numbers; he conceived of non-Euclidean geometry; and he discovered the elliptic functions. Nevertheless, for Gauss the theory of numbers remained his favorite branch—"the queen of mathematics"—and his *Disquisitiones* of 1801 is his greatest work. In it he developed the algebra of congruences, culminating in the law of quadratic reciprocity.

52

Lazare Nicolas Marguerite Carnot, 1753-1823.

Géométrie de position. Paris, Duprat, An XI-1803.

4to. 2 leaves, [i]-xxxviii, [xxxix-xl], 1-489 pp. Plates I-XV. 25½ x 20 cm.

Carnot took such an energetic and significant part in the French Revolution that the Convention acclaimed him the "Organizer of Victory". He found time, nevertheless, to write some half-dozen books on mathematics, from one on fortifications to another on the metaphysics of the calculus. In the *Geometry of Position*, his most original treatise, he sought, through such devices as intrinsic coordinates and the correlation of figures, to give to geometry a degree of generality comparable to that enjoyed by analysis.

53

Augustin Louis, Baron Cauchy, 1789-1857.

Cours d'analyse de l'École Royale Polytechnique. I^re^ Partie. *Analyse algébrique.* Paris, Debure, 1821.

8vo. 2 leaves, [i]-xiv, [xv-xvi], [1]-576 pp. 20 x 12 cm.

Cauchy was, with the exception of Euler, perhaps the most prolific mathematician; but he is recalled chiefly for the theory of functions of a complex variable, and for the high rigor in analysis. The definitions and fundamental concepts given by Cauchy in his *Cours d'analyse* are essentially those appearing today in current textbooks.

54

Jean Baptiste Joseph, Baron Fourier, 1768-1830.

Théorie analytique de la chaleur. Paris, Didot, 1822.

4to. 2 leaves, [i]-xxii, 1-639 ; p. Plates I & II. 26 x 20 cm.

Fourier's study of Heat, a classic in science, is also a milestone in the history of mathematics for its generalization of the notion of function. Here Fourier showed that an arbitrary function, such as one made up of a succession of continuous arcs, can be represented by a series of sines and cosines. Such Fourier series are now a commonplace in mathematics and physics.

55

Jacob Steiner, 1796-1863.

Systematische entwickelung der abhangigkeit geometrischer gestalten von einander . . . . Berlin, Fincke, 1832.

8vo. [i-v], vi-xvi, 1-322 pp., 1 leaf publisher's advertisement. Plates I-IV. 22 x 14 cm.

The early nineteenth century witnessed a sharp conflict in geometry between the analysts and the synthesists. Steiner, the most powerful geometer of modern times, abhorred the use of algebra and analysis in

geometry, holding that they displaced thinking. His *Systematic Development* gave a strictly synthetic construction of projective geometry, setting the foundation for later textbook treatments.

56

James Joseph Sylvester, 1814-1897.

"On a theory of the Syzygetic relations of two rational integral functions, comprising an application to the theory of Sturm's Functions, and that of the greatest algebraical common measure," Royal Society of London, *Philosophical Transactions*, vol. 143, pp. 407-548, (London, 1853.)

Lehigh University copy.

Sylvester was one of "the invariant twins", Cayley being the other. His stormy career, including periods of teaching at the University of Virginia and the Johns Hopkins University, culminated in a professorship at Oxford. This paper is one of many from the field of algebra which he contributed to the *Phil. Trans.* Sylvester founded the *American Journal of Mathematics.*

57

Arthur Cayley, 1821-1895.

Holograph manuscript, draft of "A Memoir on the Quintic Equation." Undated.

25 leaves. 45 x 29 cm.

Arthur Cayley was originally a practicing lawyer; but an attraction to mathematics was stimulated by his friendship with James Sylvester, at that time an actuary. Together the two men developed the theory of algebraic invariants, and Cayley went on to a professorship in mathematics at Cambridge. His voluminous work covered many branches, but this manuscript in algebra is typical of his chief interest.

58

George Boole, 1815-1864.

An investigation of the laws of thought, on which are founded the mathematical theories of logic and probabilities. London, Walton and Maberly, 1854.

8vo. 2 leaves, [i-iii], iv-v, [vi-x], [1]-424 pp., 1 leaf. 21 x 13½ cm.

Laws of Thought is the chief contribution of one of Ireland's leading mathematicians. Following through Leibniz' suggestion of a universal

characteristic, Boole reduced the laws of logic to an algorithmic calculus. This linking of logic and mathematics through an algebra of logic, generally called "Boolean Algebra," led ultimately to the present vogue for the theory of sets.

59

Jules Henri Poincaré, 1854-1912.

"Sur l'analysis situs," Académie des Sciences, *Comptes Rendus Hebdomadaires des Séances*, vol. 115, pp. 633-36 (Paris, Octobre, 1892.)

Lehigh University copy.

Like Gauss, Poincaré was pretty much a universalist in mathematics, both pure and applied; and each year he lectured on a different aspect of the subject at the Sorbonne. Function theory, differential equations, light, electromagnetics, hydromechanics, probability, celestial mechanics—these were a few of the fields on which he lectured and to which he made significant contributions. Perhaps the paper of greatest portent for the future of mathematics was that of 1892 in the *Comptes Rendus*, in which he foreshadowed the rise of topology to favor.

60

Josiah Willard Gibbs, 1839-1903.

Vector analysis a text-book for the use of students of mathematics and physics, founded upon the lectures of J. Willard Gibbs . . . by Edwin Bidwell Wilson. New York, Scribner, 1901.

8vo. [i-ix], x-xiii, [xiv-xv], xvi-xviii, [1]-436 pp. 22 x 14½ cm.

Gibbs was perhaps the greatest scientist America has so far produced. In science he is recalled for his *Statistical Mechanics*, published the year before he died; but in mathematics he is noted for his work in vector analysis, developed in the 1880's as a substitute for quaternions. This "multiple Algebra", as Gibbs called it, was taught to students at Yale, one of whom was responsible for this edition of 1901.

61

Albert Einstein, 1879-1955.

"Zur elektrodynamik bewegter körper," *Annalen der Physik*, (Fourth Series) vol. 17, pp. 891-921 (Leipzig, 1905.)

Lehigh University copy.

In 1905, at the age of twenty-six, Einstein published in the *Annalen der Physik* three papers, all of outstanding theoretical significance. The

first explained the photoelectric effect in terms of quantum theory, and won for its author the Nobel Prize in Physics for 1921; the second paper discussed the theory of Brownian movement; and the third, the most far-reaching of all, asserted the invariance of natural laws under Lorentz transformations. This last, here on exhibit, established the special theory of relativity. The general theory followed about ten years later, and has in turn led to the search for a unified field theory.

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