Collisions

Atomic and Molecular Collisions. HARRIE MASSEY. Taylor and Francis, London, and Halsted (Wiley), New York, 1979. xviii, 310 pp., illus. $34.95.

The study of collisions involving electrons, atoms, molecules, and photons was initiated around 1900 and has proceeded fitfully since then. During the last 15 years, activity in the field has grown tremendously, owing to the development of new techniques for both experimental and theoretical work, the influx of many young researchers, and the demand for collision data by scientists and engineers in related fields, such as astrophysics, plasma physics, aeronomy, and laser development.

Sir Harrie Massey was a pioneer in an earlier expansion phase (around 1930) in which some of the qualitative effects of quantum mechanics were elucidated and the bases for accurate measurements and calculations were formed. Since then he has played many roles in the development of the subject, but he is perhaps best known for his textbooks.

In this book Massey provides a survey of the field that should be suitable for senior undergraduates, graduate students contemplating research in atomic collisions, and scientists in other fields who wish to obtain an overview of this field. Although the preface suggests that the book could be read with profit by a first-year undergraduate, it is doubtful whether many such students outside Britain would be able to work through the book.

The first four chapters of the book contain an outline of the basic physics of particles and waves, employing both classical and quantum descriptions, and of atomic and molecular structure. These chapters should be most useful in reinforcing knowledge obtained elsewhere by the reader, and they introduce several topics that are not discussed in most introductory courses or textbooks but are particularly important in current research.

The major portion of the book is devoted to descriptions of the most important types of atomic collision processes and the techniques by which the cross sections or reaction rates can be calculated or measured. On the theoretical side, detailed mathematical analysis is avoided but the essential features of the classical and quantum theories are explained and contrasted. Particular attention is given to those processes for which simple models have been developed to give a semiquantitative understanding of the relationship between observed cross sections and the fundamental interactions. For example, Massey shows how classical theories can be used in the description of orbiting effects whereas semiclassical versions of quantum mechanics are needed in the analysis of rainbow scattering and fully quantal treatments are required in understanding the Ramsauer-Townsend effect, resonant scattering, and the effects of the indistinguishability of identical nuclei in symmetric atom-atom collisions.

The book contains detailed descriptions of some of the pioneering experiments in the field and of recent experiments that make full use of modern techniques in electronics and optics. Typical results are shown in order to illustrate the great amount of detailed information that can now be gathered and to demonstrate the degree of agreement, or disagreement, between theory and experiment. The examples chosen for the book show the versatility that is needed in studying the various different aspects of a single collision process. There are also several useful discussions of the mathematical analysis that is required in the deduction of basic data from complex experiments and of some of the pitfalls that can lead to spurious results.

In the final chapter some of the effects of atomic collisions in the earth's atmosphere, the solar corona, and interstellar space are described. Other applications of atomic physics, such as in the development of gas lasers and the detection of pesticides, are discussed parenthetically elsewhere in the book.

The book contains no problems and no references. Its strength lies in the breadth of coverage and the insight that the author brings to the subject. It gives an excellent introduction to the field and should be required reading for students at universities that do not provide graduate courses in atomic collisions.

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Exemplars of Engineering

Robert Maillart's Bridges. The Art of Engineering. DAVID P. BILLINGTON. Princeton University Press, Princeton, N.J., 1979. xvi, 148 pp., illus. $17.50.

The Britannia Bridge. The Generation and Diffusion of Technological Knowledge. NATHAN ROSENBERG and WALTER G. VINCENTI. MIT Press, Cambridge, Mass., 1978. x, 108 pp., illus., + map. $12.50. Society for the History of Technology Monograph Series, No. 10.

Arch Bridges and Their Builders, 1735–1835. TED RUDDOCK. Cambridge University Press, New York, 1979. xiv, 254 pp., illus. $67.50.

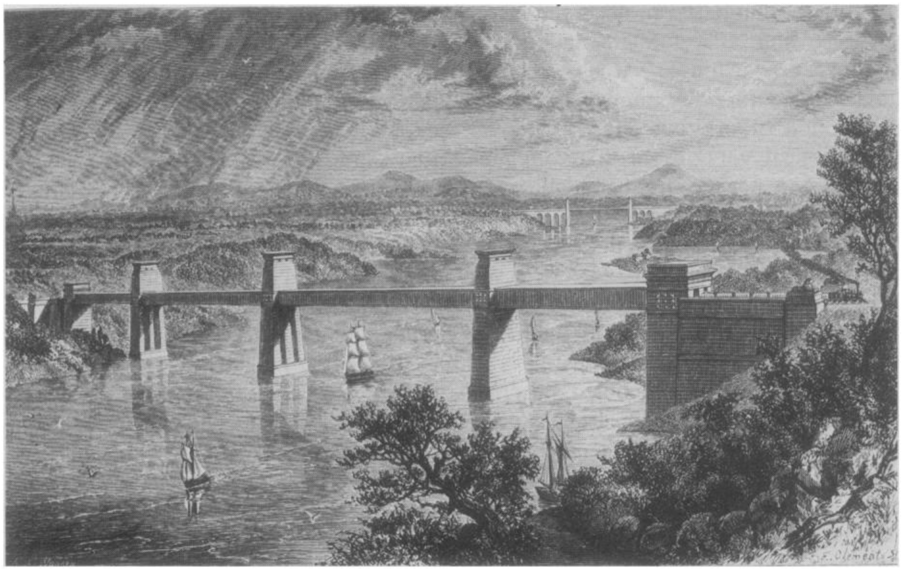
Bridges hold a compelling interest for historians of technology and for many practicing engineers and architects because their function is simply to carry loads, unencumbered by other demands such as one finds in buildings. In this sense they are pure structure and provide an unequaled opportunity to examine the historical development of design, construction, and analytical methods. They are, even so, much more than engineering works, because they often represent the result of great social enterprise and hence reflect societal values and because, as an art form, they epitomize concern for esthetic expression. Thus, bridges have come to have not just a physical meaning but a metaphysical and even mystical symbolism.

The three books being reviewed each deal exclusively with bridges, but each deals with the subject in quite a different way.

Billington's *Robert Maillart's Bridges* is the result of the author's sustained interest in the life and works of Maillart and also of a broader concern, of which he has become the leading exponent, with the relationship between art and engineering on the one hand and the role of analysis in the creative process of design on the other. In a remarkable way Billington has brought these concerns to bear in this book. What was intended originally to be a comprehensive biography of Maillart, a Swiss pioneer in reinforced concrete design, was redirected to become a consideration of the bridges erected by Maillart from 1896 to 1940.

Maillart was graduated from the Swiss Federal Institute, one of Europe's leading engineering centers, in 1894, just at the time when reinforced concrete was beginning to find widespread application in both bridges and buildings. Maillart was to devote his career to perfecting techniques and a design philosophy for this one structural material.

In dealing with new structural materi-



The Britannia Bridge, showing Thomas Telford's suspension bridge one mile northeast. [Reproduced in *The Britannia Bridge* from E. H. Knight, *American Mechanical Dictionary* (New York, 1977), vol. 3, plate 62]

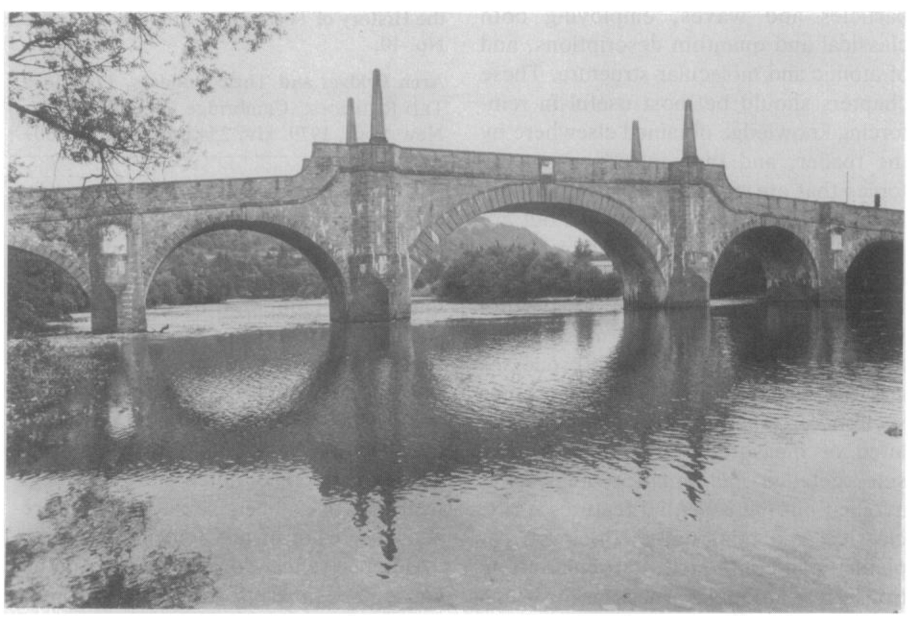
als designers first pass through an imitative stage in which the structures built resemble forms perfected for traditional materials. Billington lucidly presents in the text and by diagrams the evolution of Maillart's work from his first efforts in using concrete as a substitute for masonry in the form of an arch to his fully developed forms using the three-hinged arch, as in the elegant bridge at Tavanasa (1905), and his daring use of very thin arch slabs, as in the bridge at Schwandbach (1933). These designs resulted from his integrated use of the deck, walls, and arch, an approach that freed reinforced concrete from precedents evolved for other materials. Billington makes a fundamental point in stating that the forces and moments in Maillart's bridges resulted from the form, which was determined as the result of a creative act of design by an engineer who was the master of his medium and had an unusual sense of esthetics. Analysis became the handmaiden of design in the hands of Maillart. Field load testing was used, case by case, for verification of his plans. The comparison with one of Mörsch's arch bridges in Germany and the state of the art in America at the time provides a striking example of how Maillart's approach differed from that of most other engineers, for whom analysis was of primary concern. In reading the text, however, one gets the impression that only the Swiss insisted on load tests, whereas they were common practice in France and elsewhere at the time. The essential point is what lessons were learned from such tests.

Although the book is focused on bridges the author quite rightly deals with Maillart's contribution to the development of the "mushroom" or flat-slab concrete floor. This form of construction, which featured concrete slabs supported directly on concrete mushroom columns without benefit of beams, represents an application of concrete that could not be imitated by any other common building material. It is unfortunate that, having compared Maillart's work with the earlier patented mushroom slab of C. A. P. Turner, the author interprets the American position from the work of Arthur Lord, who did not invent or develop the system but simply carried out load tests on laboratory specimens. The lines of the argument would have been better drawn if Turner's published works and examples of the load tests of some of the floors he built had been used. Because of the intensely competitive and proprietary nature of the concrete industry in its formative years the history of the flat-slab floor is a most complicated story, one that has never been satisfactorily investigated.

Having dealt with the relationship of engineering science and the creative process of design in Maillart's work, Billington devotes the final section of his book to a fascinating insight into the role of art in engineering as exemplified in Maillart's three-hinged arch bridges. In the hands of Maillart design becomes a matter of choices within the context of a given form. This makes design quite a different activity from scientific analysis. Maillart consciously chose designs that rendered the final result truly a work of art. It is its artistic quality that attracted Siegfried Giedion and Max Bill to the little-known work of Maillart. Billington takes their interpretation a step forward by showing Maillart's works as art in engineering.

The book should appeal to a wide audience interested in Maillart and his work, but perhaps its greatest contribution is the unusually clear insight Billington brings to the process of structural design. Thus, this book is highly recommended to all of those engaged in the art and science of building.

As is indicated in the subtitle of Rosenberg and Vincenti's book on the Britannia Bridge, the authors' primary ob-



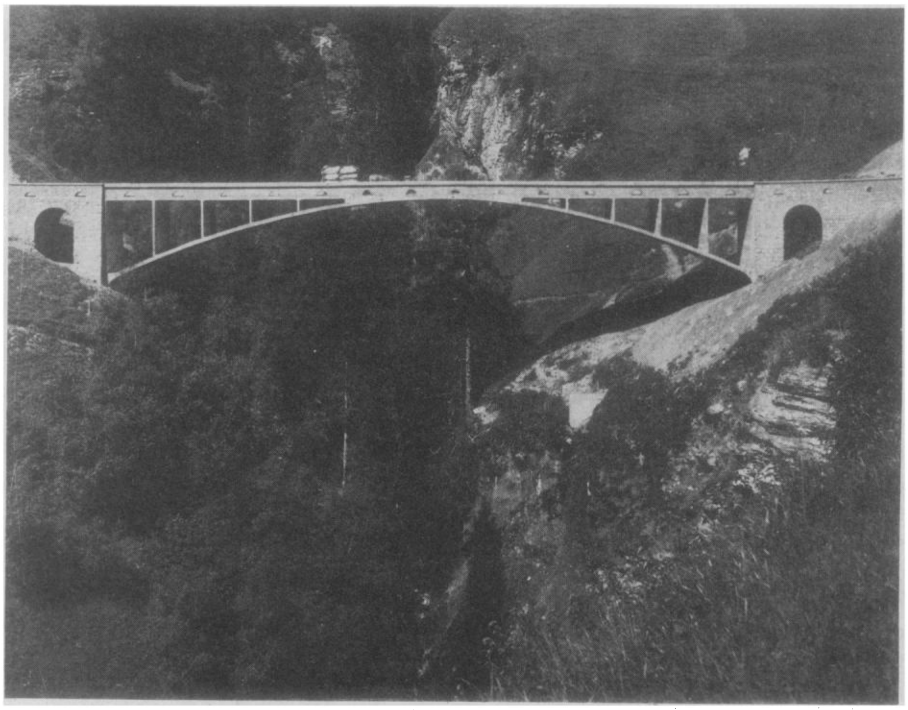
Bridge at Aberfeldy, Wales, designed by William Adam and built by General George Wade, 1733-34. [From *Arch Bridges and Their Builders, 1735-1835*] jective was to use the design, experimental investigation, and construction techniques of this giant tubular bridge to shed light on the generation and diffusion of technological knowledge. The nearly 80 pages of this book are grouped into four sections: a general introduction and justification for the case study, a chapter devoted to the generation of knowledge, a chapter on the diffusion of this knowledge in subsequent engineering practice, and a final chapter and an appendix that attempt to assess the influence of this great bridge on engineering and to evaluate the design in terms of Usher's theory of invention.

In 1826 Thomas Telford completed the Menai Straits suspension bridge, which was the vital link in the road from London to Holyhead and represented the pinnacle of British eye-bar suspension bridge technology. This bridge resulted from the Admiralty's requirement for headroom to permit sailing ships to pass through the straits unobstructed. This requirement effectively eliminated any type of low bridge or one with short spans. In 1845 Parliament recognized the need for main-line rail service from London to Holyhead and thence by ferry to Dublin, and authorized the construction of a railway bridge across the treacherous Menai Straits. The result was one of the engineering wonders of the Age of Progress in terms of its size and the daring use of continuous tubular girders 1500 feet long, supported on three lofty piers and two abutments. The girders were of such immense size that the trains ran inside them. The bridge was the collaborative effort of the famous ironmaster and engineer William Fairbairn, Eaton Hodgkinson, a well-known mathematician and research engineer, and Robert Stevenson, one of the leading civil and mechanical engineers of the day.

A decision was made to build a tubular structure in wrought iron, which led to the most comprehensive experimental study in civil engineering during the Victorian period. The unexpected buckling of the top flange of the early models that were tested led to a major effort to study this phenomenon. Because this was a controlling factor in the behavior of the girders the subsequent tests were used to design the cross section of the girders to preclude buckling and to achieve optimum efficiency for the girder in bending. Not only was buckling a problem in the compression flange, high shearing forces in thin vertical webs caused web buckling, which was overcome by the use of stiffeners.

In the chapter on the design, testing, and construction of the Britannia Bridge as an example of the generation of new technological information the real weakness of a case-study method too narrowly conceived is revealed. The reader learns very little of the state of the art of iron bridge building in the fourth decade of the century. The Britannia Bridge is seen to stand in splendid isolation as a concept without precedent in form and material. No mention is made in the book of the wrought-iron girders used by Thompson in Scotland in 1841 or of Milholland's plate girder for the Baltimore and Ohio Railroad in 1846. In a later section the authors trace the influence of the Britannia Bridge on the design and construction of the *Great Eastern*, the world's greatest ship at the time, but they fail to mention earlier shipbuilding technology and particularly the influence of Brunel's *Great Britain* of 1837 and his tubular compression members, which were used in bridges, first at Windsor and then at Chepstow, before the giant tubes of the Royal Albert Bridge at Saltash were raised in position in 1859. The opening of Roebling's famous double-deck rail-highway suspension bridge at Niagara Falls in 1854 gave rise to a lengthy debate on the suitability of such bridges for rail traffic and to a critique of tubular bridges as well. Not only was the suspension bridge a potential rival to the tubular girder, so was the iron truss. The first all-iron trusses for railway use were built on the Baltimore and Ohio Railroad in the early 1850's to patented designs by Bollman and Fink. The truss quickly proved to be the best form for long-span bridges. Iron and, later, steel truss bridges were built by the thousands in America and elsewhere during the 19th century, but only four other tubular bridges were constructed during this period.

The matter of the analytical methods available at the time is only briefly mentioned in the book, but it is nevertheless an important issue, since the experimental work was criticized at the time by those engineers who thought that the existing analytical methods were sufficient. If the extensive experimental program had not been undertaken the buckling problem would probably not have been recognized—with potentially dangerous results.



Valtschielbach bridge near Donath, Switzerland, designed by Robert Maillart, 1925. [Photograph by R. Guler, reproduced in *Robert Maillart's Bridges*]

That the issues raised above are not discussed in the book or used as the basis for an evaluation of the generation of new knowledge in structural engineering weakens the authors' argument.

The section on the diffusion of the knowledge and experience gained in building the Britannia Bridge shows how the influence of this one project was manifest in such diverse engineering works as bridges, buildings, cranes, and ships. Hodgkinson's research laid the foundation for design criteria for compression members as long as iron was used in structures. The huge jacks from the bridge were featured at the Great Exhibition of 1851 and were later used by Brunel as he struggled to launch the *Great Eastern*. Other influences are difficult to measure, as the authors indicate. The Britannia Bridge is indeed a most noteworthy subject for a case study of the generation and diffusion of engineering knowledge. Despite certain shortcomings this book could well serve as the basis of wider discussion of the evolution of technology in the 19th century.

Ruddock's book on arch bridges in the period 1735 to 1835 is markedly different in concept, content, and presentation from either of those reviewed above. Although intended for general readers its greatest appeal will be for the specialist. As the author writes in his preface, "I have endeavoured to make the book a thorough reference work by providing extensive notes and bibliography, four appendices, and a tabulated index of bridges as well as the general index." He has succeeded in producing an impressive reference work. It would, however, be more accurate to indicate that the book relates almost exclusively to British bridges. It is a richly detailed and beautifully illustrated record of the most significant arch bridges constructed in Britain from the mid-18th century, when masonry bridges were first built by architects and subject to the demands of classical style, to the first third of the 19th century, when the use of iron, in the hands of engineers, reached new levels of sophistication. Many famous architects and engineers march across the pages of this book, from Labelye and his work on the Westminster Bridge in 1735 to Thomas Telford and his last work, the Broomielaw Bridge of 1835. The book is not, however, a biographical treatment of British bridge builders in the tradition of Samuel Smiles, but rather a carefully documented account of the involvement of many people in large-scale engineering works.

The book is divided chronologically into three periods, namely 1735 to 1759, 1759 to 1796, and 1790 to 1835. Timber and iron arch bridges as well as masonry structures are covered, and details are given of the techniques employed in founding piers and abutments as well as on superstructures. One of the most interesting sections deals with the history of the first iron bridges from Coalbrookdale (1777) to the beginning of the 19th century. It is here that the ideas of Rennie, Paine, Fulton, Jessop, Burdon, and Telford find expression in the application of iron to bridges and aqueducts. This is perhaps the most informative material yet published on the exchange of ideas and techniques between these men during the formative period when iron was first used for structures.

Timber arch bridges are not neglected, and for American readers it is very striking to see how different in concept and execution the British timber arch bridges are from the covered truss bridges that were developed during the same time and are so familiar a part of the American countryside.

Ruddock does not engage the questions of design, analysis, or the relationship between esthetics and engineering, nor is he directly concerned with the generation and diffusion of engineering knowledge except as a part of the unfolding of the history of the subject. These issues are left to the reader or perhaps to subsequent scholars. *Arch Bridges and Their Builders* is a scholarly work that may well become the standard reference on the subject.

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Female Roles: Ethnography Reread

Sisters and Wives. The Past and Future of Sexual Equality. KAREN SACKS. Greenwood, Westport, Conn., 1979. x, 276 pp. $22.50. Contributions in Women's Studies, No. 10.

A book that attacks androcentric viewpoints using a Marxist perspective to analyze anthropological data could be labeled controversial. But a work that also pitches into every sociobiologist, social Darwinist, and structuralist is perhaps better described as a grenade. In the event, the book has its value and the shrapnel generally hits appropriate targets.

The core of the book is a reanalysis of the published ethnography on six African societies. We are not told the basis of selection for this half-dozen, but the variations do extend from nonlineal to lineage societies and from stateless groups to states. The focus is upon the dual female role of sister and wife. Ordinarily, the anthropologist uses these terms solely in the context of kinship, but for Karen Sacks they represent different female statuses with respect to control of the means of production. "Sister" stands for a position of equality in relation to males, whereas "wife" indicates subordination, or domination. Once one accepts the author's definitions, the argument is not hard to follow. The case-by-case analysis reveals not only that the balance between these two central female roles varies widely, but that the female-male relation itself assumes the most diverse forms. Among a group of gatherers and hunters in Zaire, for example, women are "sisters" in relation to each other and the balance of authority between the sexes is extraordinarily equal. This is the zero point; at the other extreme, in some state or class societies, women are primarily "wives" and the balance of authority between the sexes is decidedly asymmetric. One lesson to be drawn is that females have occupied central positions of political and economic authority in societies other than our own. Thus, there exists no enduring set of feminine characteristics. In fact, the argument is here turned upon other researchers. What many claimed to see in the ethnography was more a reflection or reproduction of their everyday experience of industrial capitalism than of the exotic facts themselves. Not everywhere do people have the image that women are passive, subordinate keepers of the domestic domain.

This rereading of the data, performed by Sacks and others, ought to cause some disquiet among sociobiologists and other "essentialists," since it punctures the image of a universal and therefore genetic male dominance. But consider some of the theoretical implications within the parochial context of anthropology. For years, most of us have been teaching the received wisdom—and it used to seem very wise indeed—that patrilineal and matrilineal kinship systems are not mirror images of one another. This paradox is known as the "matrilineal puzzle." In patrilineal systems men hold authority, and descent or group affiliation is traced through them. Everything is tidy. By contrast, in matrilineal systems descent is traced through females but power is in the hands of males, the lineage brothers. Affiliation and authority are not congruent. Given this difference it can be shown that "logically" matrilineal systems are more fragile than patrilineal ones and that to remain viable they