Engineering

AN INTRODUCTION TO A CREATIVE PROFESSION

Third Edition

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an introduction to a creative profession

THIRD EDITION

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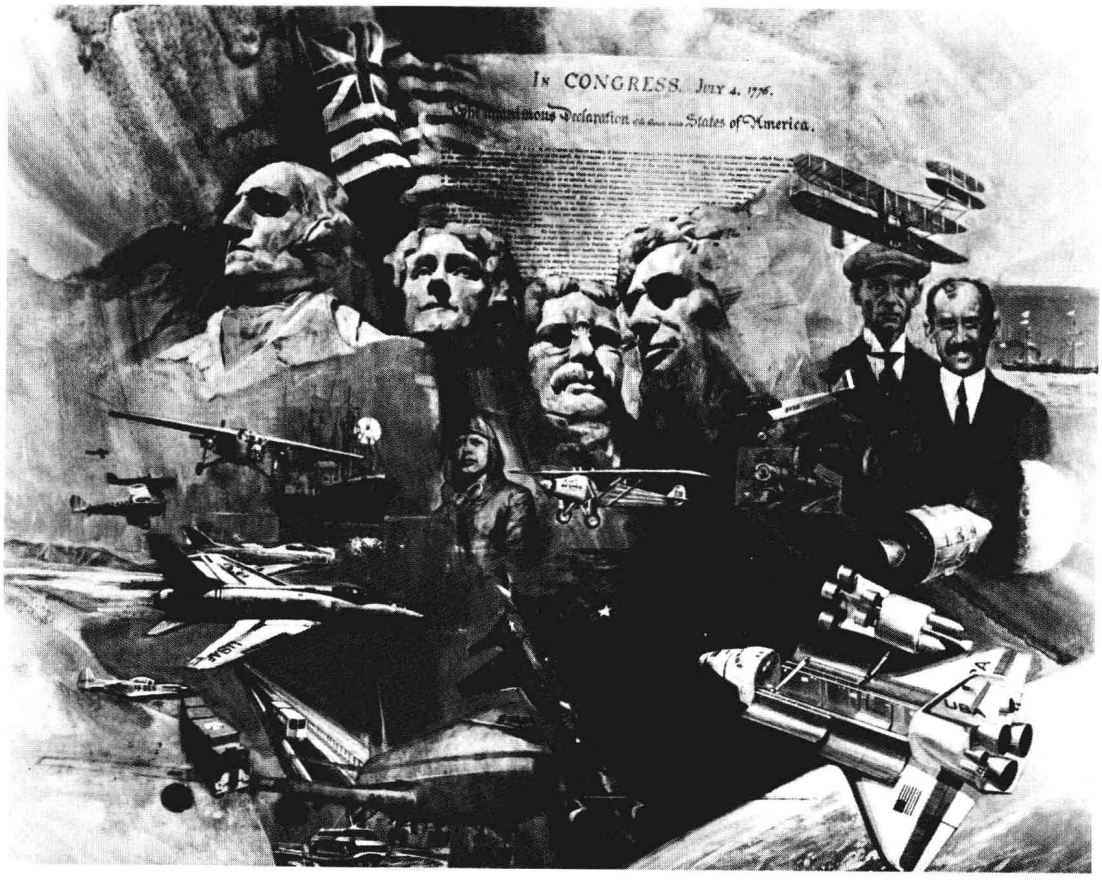
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Engineering

Preface

Today's world is a world of change, challenge, and opportunity. Never before have so many compelling technological problems occupied positions of prominence in man's system of values. The engineer's role in this environment is more important than ever before in history, and the student who chooses engineering as a career should realize that, perhaps more than any other, his profession will shape the destiny of civilizations yet unborn. Challenge and opportunity? Yes . . . but not without a consciousness for and a realization of the moral and ethical responsibilities that should accompany the emergence of new processes, designs, and systems. Recognizing the importance of an early commitment toward these ends, this work has been prepared as an informational and motivational instrument for the use of those who are interested in preparing themselves today for the solution of tomorrow's problems.

The first edition of this textbook was experimental in the sense that it was multipurpose in scope, rather than singular in purpose, as has been the case traditionally with many other introductory engineering textbooks. Its nine printings over a brief span of time attest to its popularity for use in (*a*) informational courses that introduce the student to the profession of engineering, (*b*) engineering problems and analysis courses that give the student some practice in engineering problem solving, and (*c*) introduction to engineering design courses that give the student a sense of personal involvement in undertaking real engineering tasks. Some teachers have preferred to organize courses that draw material from each of these areas.

The second edition expanded further the options available to the teacher and student, and increased emphasis was placed upon the expanding role of the technician and technologist in modern industry. This edition was accorded even greater adopter response than the first edition.

In this third edition the authors have attempted to retain those qualities of the text most often praised and to update and improve it throughout. They are most appre-

ciative of the suggestions received from the more than 300 schools who have used the first two editions, and they are very desirous of learning the opinions of those who read this new edition—both students and faculty—concerning its utility and serviceability in meeting the needs for which it has been written. Improvements that are suggested will be incorporated in later editions.

In order to give the student an understanding of the types of problems that are likely to be encountered in the practice of engineering, a large number of varied situations are described in problems throughout the book. Some of the problems are straightforward, and appropriate data are given to permit a unique solution. In other problems, data are given in general terms, sometimes with insufficient data so that the student must add information, and sometimes with an overabundance of data from which the student must select what he needs. In all cases, the problems are designed to introduce the student to the realm of engineering study, to offer work with engineering concepts, and to provide situations in which decisions must be made where a number of choices exist.

The problem-solving method introduced in the authors' previous textbooks has been expanded to include more of the creative phases of engineering. It is not enough just to manipulate numbers in engineering work; the engineer must be able to see applications of scientific principles, to develop designs that are based upon abstract principles, and to assume the lead in formulating innovative solutions to unfamiliar problems. Every effort is made here to motivate the student to think imaginatively and constructively, and also to present material that will provide the best introduction to a career in engineering or technology.

For 28 years one of the text's most acclaimed chapters has been "The Slide Rule." With the rapid development of microelectronics, this material has now been replaced by Chapter 10, "Using Electronic Hand Calculators." As before, hundreds of problems have been included in this chapter that may be used for practice. Others are included for homework or class assignment. It is the authors' belief that students should be thoroughly familiar with both English and metric unit systems. Therefore Chapter 12 has been expanded to include a thorough treatment of the metric SI system of units, and many of the problems in Chapter 13 are described in metric terms. Chapter 14 uses only the SI metric unit system.

A completely new chapter, "The Modeling of Engineering Systems," gives the student an insight into the analysis of engineering systems and emphasizes the commonality that exists between the engineering disciplines.

The format of this text is such that the student can record points of emphasis and certain class notes and questions directly as they occur without the use of extra notepaper. Marking pens may be used for highlighting sentences or phrases, and the use of colored ink for underlining is recommended. For the student to get the most out of the text he should "live in it." If he does, the book will have a "lived-in" appearance.

In preparing this book the authors have been aided not only by reviews and criticisms of previous editions but also by comments and suggestions from numerous engineering professors and practicing engineers and technologists in industry throughout the United States. The professional colleagues of the authors have been most influential in giving this book a unique blend of the academic and industrial viewpoints.

In particular the authors wish to thank Professors Harold Nelson and a number of faculty colleagues for their review of portions of the manuscript. Professor William Anderson prepared much of the material in Chapter 10, "Using Electronic Hand

Calculators," Professor J. Karl Hedrick prepared the majority of the material for Chapter 14, "The Modeling of Engineering Systems;" and George C. Beakley III prepared the material in Chapter 16 relating to the planning of engineering projects. The authors gratefully acknowledge these contributions as well as those of the many organizations who have supplied illustrative materials for inclusion in the text.

The cover design, an electronic-computer-produced artform, was used originally for the first and second editions. It is the work of Donald Robbins and Leigh Hendricks of the Sandia Corporation, Albuquerque, New Mexico, who have made it available for this specific use. The typing and proofreading of the manuscript were masterfully accomplished by Esther F. Taylor.

To the many others who have given the authors the benefit of their experience by making recommendations as to format and content of this new third edition, we wish to express our sincere gratitude.

G. C. B.
H. W. L.

Acknowledgments

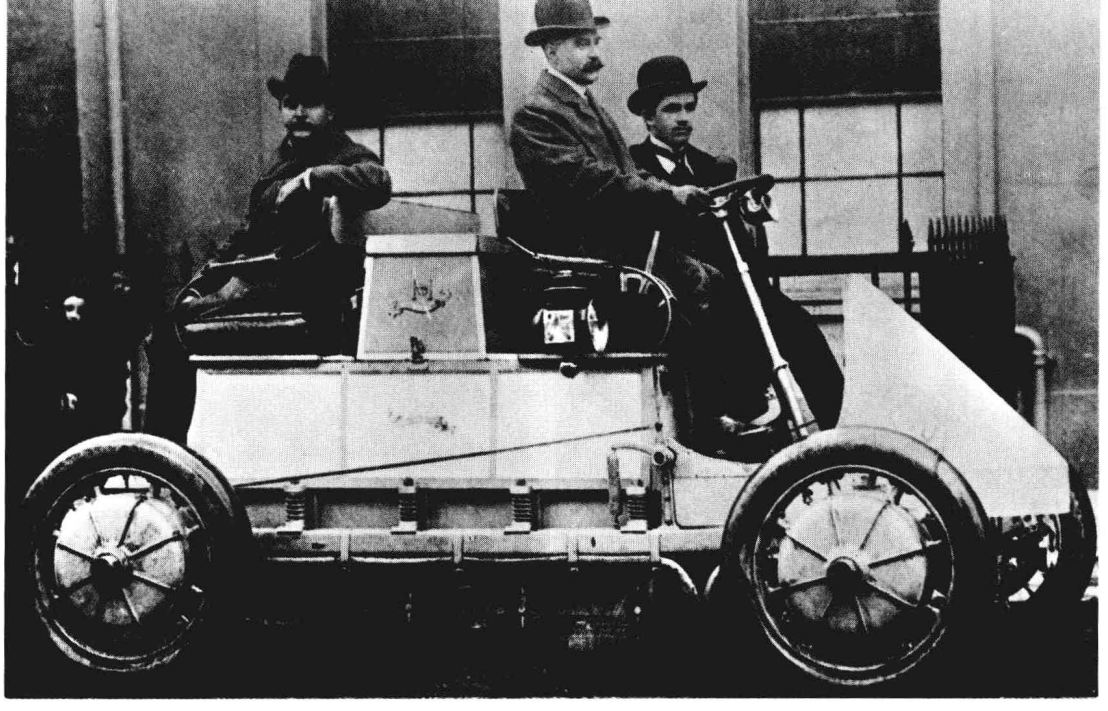
Frontispiece	Rocketdyne International, Space Division
Part I opening	Porsche Audi, a Division of Volkswagen of America, Inc.
Illustration 1-1	Maddox and Hopkins
Illustration 1-2	W. S. Dickey Clay Manufacturing Company
Illustration 1-3	Maddox and Hopkins
Illustration 1-4	Ewing Galloway
Illustration 1-5	Maddox and Hopkins
Illustration 1-6	Maddox and Hopkins
Illustration 1-7	Fischer Scientific Company
Illustration 1-8	General Electric *Forum*
Illustration 1-9	National Air and Space Museum, Smithsonian Institution
Illustration 1-10	Bell Laboratories
Illustration 1-11	Matheson Gas Products
Illustration 1-12	National Aeronautics and Space Administration
Illustration 1-13	Rockwell International Corporation/Space Division
Illustration 1-14	Duane Michals; Eli Lilly & Company
Illustration 2-1	Washington State Travel Photo
Illustration 2-2	Floyd A. Craig, Christian Life Commission Southern Baptist Convention
Illustration 2-3	Planned Parenthood–World Population
Illustration 2-4	Pharmaceutical Manufacturers Association
Illustration 2-5	Ambassader College
Illustration 2-6	Adolph Coors Company
Illustration 2-7	American Lung Association
Illustration 2-8	Diazit Company, Inc., from their ammonia-free whiteprinting (blueprinting) advertisements
Illustration 2-9	Johns-Manville Corporation
Illustration 2-10	Planned Parenthood–World Population
Illustration 2-11	George Krause; Presbyterian Ministers' Fund Life Insurance
Illustration 2-12	CPR Division, The Upjohn Company
Illustration 2-13	Floyd A. Craig, Christian Life Commission Southern Baptist Convention
Illustration 2-14	Shell Oil Company
Illustration 2-15	Hewlett-Packard
Illustration 2-16	Hewlett-Packard
Illustration 2-17	University of Delaware
Figure 2-3	L. P. Gaucher
Illustration 2-18A	Pacific Gas and Electric Company
Illustration 2-18B	Pacific Gas and Electric Company
Illustration 2-19	Southwest Research Institute
Illustration 2-20	Volkswagen of America, Inc.
Figure 2-4	Institute of Traffic Engineers
Illustration 2-21	Shell Oil Company
Illustration 2-22	Planned Parenthood–World Population
Illustration 2-23	General Electric Company
Illustration 2-24	Peter Kiewit Sons' Company
Illustration 2-25	Sylvania Electric Products, Inc.
Illustration 2-26	General Motors Research Laboratories
Illustration 2-27	Fireman's Fund American Insurance Companies
Illustration 2-28	Union Carbide Corporation

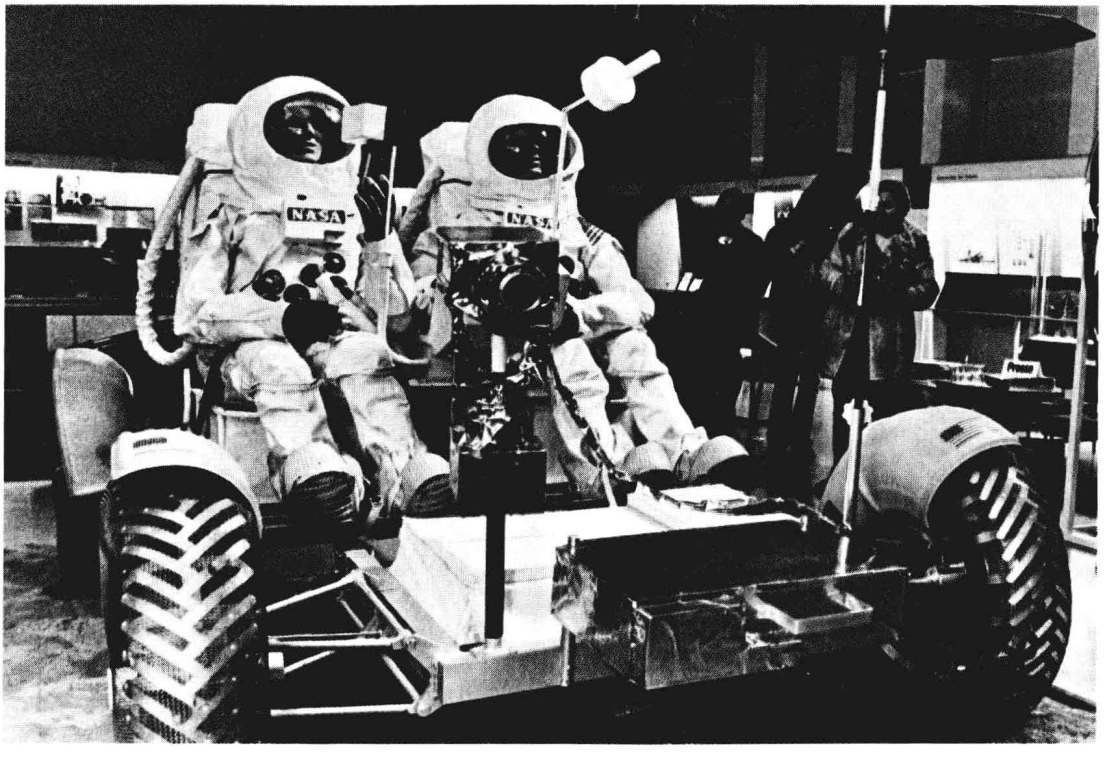
Illustration 3-1 Shell Oil Company
Illustration 3-2 General Motors Research Laboratories
Illustration 3-3 Spectral Dynamics Corporation
Illustration 3-4 The Boeing Company
Illustration 3-5 Bell Laboratories
Illustration 3-6 Union Carbide Corporation
Illustration 4-1 Dr. J. E. Cermack, Director, Fluid Dynamics and Diffusion Laboratory, Fluid Mechanics Program, Colorado State University
Illustration 4-2 General Motors Corporation
Illustration 4-3 *Industrial Engineering*
Illustration 4-4 Beech Aircraft Corporation
Illustration 4-5 Esso Research & Engineering Company
Illustration 4-6 The Upjohn Company
Illustration 4-7 *The Western Electric Engineer*
Illustration 4-8 Fisher Scientific Company
Illustration 5-1 National Aeronautics and Space Administration
Illustration 5-2 International Harvester Company
Illustration 5-3 Aluminum Company of America
Illustration 5-4 Aerojet-General Corporation
Illustration 5-5 Glass Container Manufacturers Institute
Illustration 5-6 Dow Chemical U.S.A.
Illustration 5-7 Bethlehem Steel Corporation
Illustration 5-8 North American Rockwell Corporation
Illustration 5-9 Toyota Motor Sales, U.S.A., Inc.
Illustration 5-10 General Motors Corporation
Illustration 5-11 Union Carbide Corporation
Illustration 5-12 Cities Service Company
Illustration 5-13 Information Handling Services
Illustration 5-14 Union Carbide Corporation
Illustration 5-15 Humble Oil & Refining Company
Part II opening Ernst & Ernst
Illustration 6-1 The Foxboro Company
Illustration 6-2 General Dynamics
Illustration 6-3 Ernst & Ernst
Illustration 6-4 *Design News,* A Cahners Publication
Illustration 7-1 Information Handling Services
Illustration 7-2 Chicago Bridge & Iron Company
Illustration 7-3 Floyd Clark, California Institute of Technology
Illustration 8-1 Acme-Cleveland Corporation
Illustration 8-2 Bruning Division, Addressograph Multigraph Corporation
Illustration 8-3 Acme-Cleveland Corporation
Illustration 8-4 Walker/Parkersburg
Illustration 8-5 Walker/Parkersburg
Part III opening Rockwell International
Illustration 9-1 Leeds & Northrup Company
Illustration 9-2 Exxon Chemical Company U.S.A.
Illustration 10-1 The Timken Company
Illustration 10-2 Automatic Switch Company
Illustration 10-3 Texas Instruments Incorporated
Illustration 10-4 International Business Machines Corporation
Illustration 10-5 Hewlett-Packard/Advanced Products
Illustration 10-6 Texas Instruments Incorporated
Illustration 11-1 Bell Laboratories
Illustration 11-2 RCA Electronics Components
Illustration 11-3 Hewlett-Packard/Calculator Products Division
Illustration 12-1 Monarch Machine Tool Company
Illustration 12-2 Westinghouse Electric Corporation
Part IV opening Hewlett-Packard/Calculator Products Division
Illustration 13-1 Hewlett-Packard/Calculator Products Division
Illustration 13-2 Union Pacific Railroad Company
Illustration 13-3 Ingersoll-Rand Company
Illustration 13-4 Formsprag Company
Illustration 13-5 Tuggener-Foto
Part V opening Mattell, Inc.
Illustration 15-1 United States Navy
Illustration 15-2 Republic Steel Corporation
Illustration 15-3 Exxon Chemical Company, U.S.A.
Illustration 15-4 Western Electric
Illustration 15-5 Encyclopaedia Britannica
Illustration 15-6 Can-Tex Industries
Illustration 15-7 North American Rockwell
Illustration 15-8 Coca-Cola
Illustration 15-9 Allis-Chalmers
Illustration 15-10 Exxon Research and Engineering Corporation
Illustration 15-11 Enjay Chemical
Illustration 16-1 Phoenix Newspapers, Inc.
Illustration 16-2 The Gillette Company
Illustration 16-3 The Gillette Company
Figure 16-22 The Gillette Company
Figure 16-24 The Gillette Company
Figure 16-25 The Gillette Company
Figure 16-26 The Gillette Company
Illustration 17-1 First National Bank of Arizona
Illustration 17-2 General Motors Corporation and American Society of Civil Engineers
Illustration 17-3 *Kaiser News*
Illustration 17-4 Information Handling Services
Illustration 17-5 The Falk Corporation
Illustration 17-6 Al Capp
Illustration 17-7 Arizona State University
Illustration 17-8 Texas Instruments Incorporated
Illustration 17-9 Fisher Scientific Company
Illustration 17-10 Reynolds Aluminum, Reynolds Metals Company
Illustration 17-11 Ford Motor Company
Illustration 17-12 Rocketdyne, North American Rockwell
Illustration 17-13 National Aeronautics and Space Administration
Illustration 17-14 Somerset Importers, Ltd.
Appendixes opening Century Strand Inc.

Contents

Part One

Engineering —the profession in review





The mode of propulsion—via individual electrical wheel hub motors—used in the design of the 50 million dollar American lunar vehicle in 1971, was first used in 1900 by Ferdinand Porsch to propel his racing car.

1

Historical perspectives of a developing profession

When did engineering begin? Who were the first engineers? What were the objectives of work by the early engineers? Answers to these questions and others concerning the beginning of engineering appear in the fragments of historical information available to us. In fact the beginnings of civilization and the beginnings of engineering are coincident. As early man emerged from caves to make homes in communities, he adapted rocks and sticks as tools to aid him. Simple as these items may seem to us today, their useful employment suggests that the creative ideas which emerged in the minds of early man were developed into useful products to serve the recognized needs of the day. Some served as tools in the struggle for existence of an individual or group, and others were used for protection against wild animals or warlike neighbors. Early engineering was therefore principally either civil or military.

Down through the ages, the engineer has been in the forefront as a maker of history. His material accomplishments have had as much impact on world history as any political, economic, or social development. Sometimes his accomplishments have stemmed from the pressures of need from evolving civilizations. At other times his abilities to produce and meet needs have led the way for civilizations to advance. In general, engineers do the things required to serve the needs of the people and their culture.

Basically, the role of the engineer has not changed through the centuries. His job is to take knowledge and make practical use of it. He converts scientific theory into useful application, and in so doing, he provides for man's material needs and well-being. From era to era, only the objectives that he has pursued, the techniques of solution that he has used, and the tools of analysis at his disposal have changed.

It is helpful to review the past to gain insight to the driving forces of science and to learn of the men who developed and applied these principles. A review also will reveal certain facts concerning the discovery and use of fundamental scientific

principles. Primarily, science builds its store of knowledge on facts which, once determined, are available from then on for further discovery. This principle is in contrast to the arts, since, for example, the ability of one person to produce a beautiful painting does not make available to others his skills in producing paintings.

Outstanding characteristics of engineers through the centuries have been a willingness to work and an intellectual curiosity about the behavior of things. Their queries about "Why?," "How?," "With what?," and "At what cost?" have all served to stimulate an effort to find desirable answers to many types of technological problems.

Another characteristic associated with engineers is the ability to "see ahead." The engineer must have a fertile imagination, must be creative, and must be ready to accept new ideas. Whether an engineer lived at the time of construction of the pyramids or has only recently graduated in nuclear engineering, these characteristics have been an important part of his intellectual makeup.

The following sections present a brief picture of the development of engineering since the dawn of history and outline the place that the engineer has held in various civilizations.

The beginnings of engineering: 6000 B.C.—3000 B.C.

The beginning of engineering probably occurred in Asia Minor or Africa some 8000 years ago. About this time, man began to cultivate plants, domesticate animals, and build permanent houses in community groups. With the change from a nomadic life came requirements for increased food production. Among the first major engineering projects were irrigation systems to promote crop growing. Increased food production permitted time for men to engage in other activities. Some became rulers, some priests, and many became artisans, whom we may call the first engineers.

Early achievements in this era included methods of producing fire at will, melting certain rocklike materials to produce copper and bronze tools, invention of the wheel and axle, development of a system of symbols for written communication, origination of a system of mathematics, and construction of irrigation works.

Early records are so fragmentary that only approximate dates can be given for any specific discovery, but evidence of the impact of early engineering achievements is readily discernible. For example, in setting up stable community life in which land was owned, men had to provide both for irrigation and for accurate location and maintenance of boundaries. This necessity stimulated the development of surveying and of mathematics. The moving of earth to make canals and dams required computations, and to complete the work the efforts of many men had to be organized and directed. As a result, a system of supervisors, foremen, and workers was established that formed the beginnings of a class society.

In this society, craftsmen became a distinct group producing useful items such as pottery, tools, and ornaments that were desired by others. As a result, trade and commerce were stimulated and roads were improved. Some 5000 years ago man first used the wheel and axle to make two-wheeled carts drawn by animals.

In order to record the growing accumulation of knowledge about mathematics and engineering, the early engineer needed a system of writing and some type of