

# ENGINEERING FUNDAMENTALS AND PROBLEM SOLVING

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## **Engineering** fundamentals and problem solving

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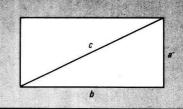
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### **PLANE SURFACES**

### Rectangle

Area = 
$$(base)(height) = ba$$

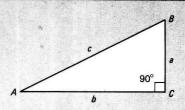
Diagonal (c,) = 
$$\sqrt{b^2 + a^2}$$



### Right triangle

Area = 
$$\frac{1}{2}$$
(base)(height) =  $\frac{1}{2}ba$ 

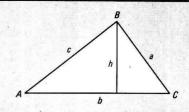
$$A + B + C = 180^{\circ}$$
  
Hypotenuse  $(c) = \sqrt{b^2 + a^2}$ 



### Any triangle

Area = 
$$\frac{1}{2}$$
 (base) (height) =  $\frac{1}{2}bh$ 

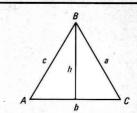
$$A + B + C = 180^{\circ}$$



### Equilateral triangle

Area = 
$$\frac{1}{2}$$
(base)(height) =  $\frac{1}{2}bh$ 

$$A = B = C = 60^{\circ}$$

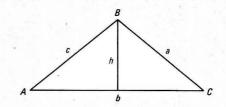


### Isosceles triangle

Area = 
$$\frac{1}{2}$$
(base)(height) =  $\frac{1}{2}bh$ 

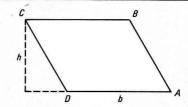
$$A = C$$

$$A+B+C=180^{\circ}$$



### Parallelogram

$$A + B + C + D = 360^\circ$$

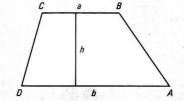


### Trapezoid

Area = 
$$\frac{1}{2}$$
 (sum of parallel sides) (height)

Height (
$$h$$
) is perpendicular to parallel sides  $a$  and  $b$ 

•

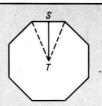


### PLANE SURFACES

### Regular polygon

Area =  $\frac{1}{2}$  (distance ST)(length one side)(number of sides)

Equal sides and angles

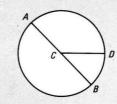


### Circle

Area = 
$$\pi (CD)^2 = \frac{\pi (AB)^2}{4}$$
  
 $\pi = \frac{\text{circumference}}{\text{diameter}} = 3.14159...$ 

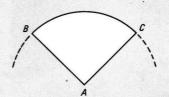
Circumference = 
$$\pi(AB) = 2\pi(CD)$$

1 radian = 
$$\frac{180^{\circ}}{\pi}$$
 = 57.2958°



### Sector of a circle

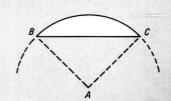
Area = 
$$\frac{(arc length)(radius)}{2}$$
$$= \frac{\pi(AB)^{2}(angle BAC)}{360^{\circ}}$$



### Segment of a circle

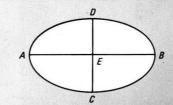
Area = area of sector 
$$(ABC)$$
 — area of triangle  $ABC$ 

$$=\frac{(\text{radius})^2}{2}\left[\frac{\pi(\text{angle BAC}^{\,\circ})}{180^{\circ}}-\sin\text{BAC}^{\,\circ}\right]$$



### Ellipse

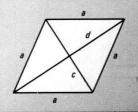
Area = 
$$\pi(AE)(ED)$$
  
=  $\frac{\pi}{4}(AB)(CD)$ 



#### Rhombus

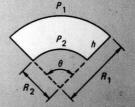
Area = 
$$\frac{1}{2}(c)(d)$$

$$4a^2 = c^2 + d^2$$



### Sector of an annulus

Area = 
$$\frac{1}{2}\theta(R_1 + R_2)(R_1 - R_2)$$
  
=  $\frac{1}{2}h(P_1 + P_2)$   
=  $\frac{1}{2}h\theta(R_1 + R_2)$ 



Engineering fundamentals and problem solving

# Preface

As you begin the study of engineering you will no doubt be filled with enthusiasm, curiosity, and a desire to succeed. Your first year will be spent primarily establishing a solid foundation in mathematics, physical sciences, and communications. You may at times question what the benefits of this background material are and when the real engineering work and experience will begin. We believe that they begin now. We hope that the material in this book will motivate you in your educational pursuits as well as provide you with a basis for understanding how the engineer functions in today's technological world.

### To the student

During the past decade, engineering courses for freshman students have been in a state of transition. The traditional engineering drawing and descriptive geometry courses as well as formal training in the use of the slide rule have been pared considerably and in turn supplemented or replaced by courses in computations, computer programming, design, and career orientation. Of course, the emphasis placed on each of these courses varies considerably among engineering schools.

In 1974, an engineering faculty committee at Iowa State University was assigned the task of developing a proposal for a computations course that would include the use of programmable calculators. The course, which eventually replaced the course on the slide rule, furnished a great deal of material for improving the problem-solving skills of the student. This book evolved from the authors' experiences with that engineering computations course.

The book has four broad objectives: (1) to motivate engineering students in their first year, when exposure to engineering subject matter is limited; (2) to provide them with experience in solving problems (using the new international SI units) and presenting solutions in a logical manner; (3) to introduce students to subject areas common to most engineering disciplines, which require the

## To the teacher

application of fundamental engineering concepts; and (4) to develop their basic skills for solving open-ended problems through a design process.

The material in this book is presented in a manner that allows the instructor to emphasize certain areas more than others without loss of continuity. The problems that follow most chapters vary in difficulty, so that students can experience success rather quickly and still be challenged as problems become more complex.

There is sufficient material in the first fourteen chapters for a three-credit semester course. By omitting selected chapters and/or varying the coverage from term to term, you can present a sound computations course for a two- to four-credit quarter course or a two- to three-credit semester course. Expanded efforts in computer programming and coverage of Chapter 15 on design would provide sufficient material for a one-year sequence.

The book is conveniently divided into five parts. Part One, An Introduction to Engineering, begins with a description and breakdown of the engineering profession that can be expanded to the instructor's liking. If a formal orientation course is given elsewhere, Chapter 1 can be simply a reading assignment. Chapters 2, 3, and 4 provide procedures for approaching an engineering problem, determining the necessary data and method of solution, and presenting the results. The authors have found from experience that emphasis in this area will reap benefits when the material and problems become more difficult later on.

Part Two, although only one chapter in length, is important because it emphasizes the SI metric units. Throughout the book, discussions and example problems are primarily SI metric, so that coverage of Chapter 5 is advisable. Other unit systems do appear in some of the discussion and many problems contain nonmetric units, so the students are exposed to conversions and to units that are still commonly used.

Part Three is an introduction to computers and calculators. Unless the instructor plans to provide some programming experience on available programmable calculators or computers, this material can be omitted. Because of the variety of computational equipment available to students on most engineering campuses, the authors felt that treatment of the many computer languages available would not be practical. This in no way implies that programming is not an important part of the engineering students' course of study. They should be able to obtain calculated results in the most economical, efficient manner. Chapters 6 and 7 bring the student to the point of computation by computer. The instructor need only introduce the language and available equipment for the student to complete the solution. At Iowa State, we introduce the programmable

pocket calculators in the computations course and all engineering students are introduced to FORTRAN, PL 1, or other languages in later courses.

Part Four allows a great deal of flexibility for the instructor. The time available and the instructor's personal interests dictate to what depth any or all of these chapters can be covered. For example, the authors have found that discussion of engineering economy (Chapter 13) is popular with the students and provides a good introduction to an area in which engineers need to be more knowledgeable. Material in Part Four may be covered in any order, since no chapter depends on another for background material.

The design process, Part Five, is a logical extension of the fundamental problem-solving approach in engineering. A nine-step design process is explained and supplemented with an actual preliminary design performed by a freshman student team. The process as described allows the instructor to supplement the text material with specific examples and bring design experience into the classroom.

Mathematical expertise beyond algebra, trigonometry, and analytical geometry is not required for any material in the book. The authors have found, however, that providing additional experience in precalculus mathematics is important at this stage of the student's education.

The authors are indebted to many who assisted in the development of this textbook. First we would like to thank the faculty in the College of Engineering at Iowa State University who have taught the Engineering Computations course since its inception in 1974. They have contributed many ideas and problems to this textbook; but most importantly, they have made the course a success with their efforts. We want to thank the hundreds of students who by their evaluations of the course prompted improvements and refinements in our initial manuscripts. Thanks is owing to the teaching assistants who demanded excellence on homework assignments. A special thanks goes to Professor Gordon Sanders for his review of the graphics portion of the Appendix. We also express grateful appreciation to Jodie Brown and Vicky Bice who sacrificed many lunch hours and evenings to produce clear copy from sometimes cloudy input. Finally, we thank our families for their unfailing support of our efforts.

> Arvid R. Eide Roland D. Jenison Lane H. Mashaw Larry L. Northup

# **Acknowledgments**

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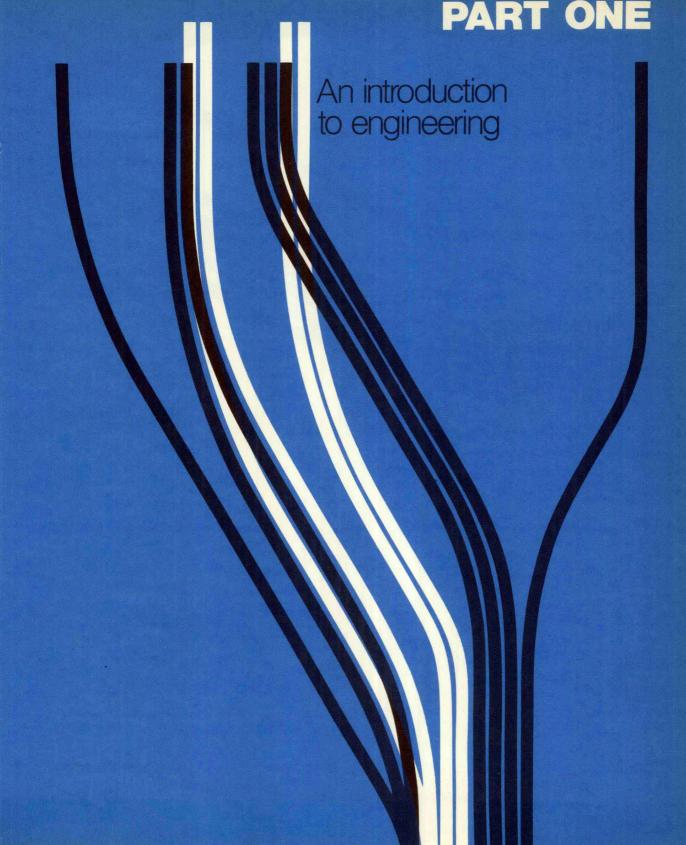
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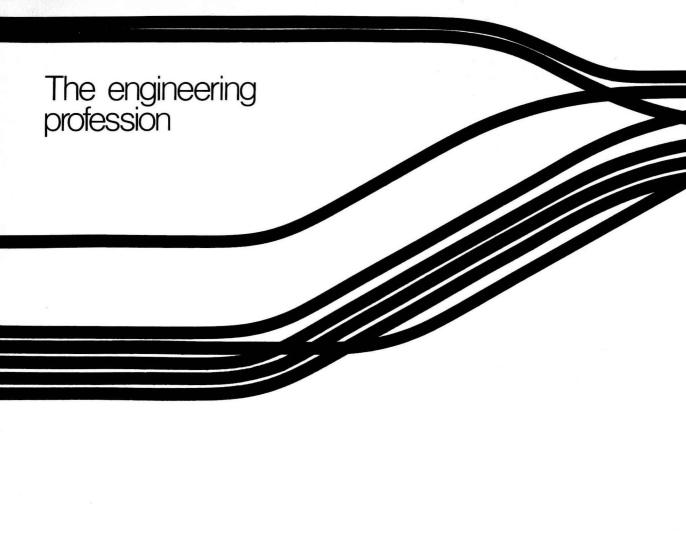
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# **CHAPTER 1**

The rapidly expanding sphere of science and technology may seem overwhelming to the individual seeking a career in a technological field. A technical specialist today may be called either engineer, scientist, technologist, or technician, depending upon education, industrial affiliation, or specific work. For example, more than 200 colleges and universities offer engineering programs accredited by the Engineer's Council for Professional Development (ECPD). Included are such traditional specialties as aerospace, agricultural, ceramic, chemical, civil, electrical, industrial, and mechanical engineering; as well as the expanding areas of computer, energy,

### 1.1 Introduction

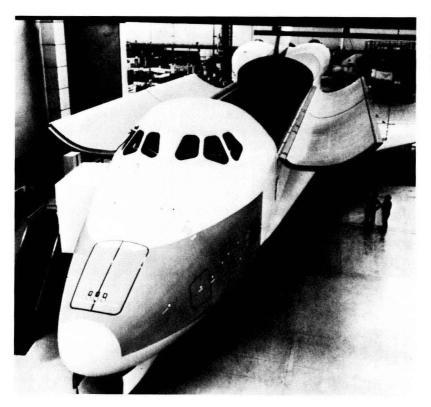


Fig. 1.1 The space shuttle, a modern engineering feat, will help mankind learn more about space by ferrying cargo into and out of earth orbit. (Honeywell, Inc.)

environmental, materials, and nuclear engineering. Programs in construction engineering, engineering science, mining engineering, and petroleum engineering add to a lengthy list of career options in engineering alone. Coupled with thousands of programs in science and technical training offered at hundreds of other schools, the task of choosing the right field no doubt seems formidable.

Since you are reading this book, we assume that you are interested in studying engineering or at least are trying to decide whether or not to do so. Up to this point in your academic life, you have probably had little experience with engineering and have gathered your impressions of engineering from advertising materials, counselors, educators, and perhaps a practicing engineer or two. Now you must investigate as many careers as you can as soon as possible to be sure of making the right choice.

The study of engineering requires a strong background in mathematics and the physical sciences. Section 1.4 discusses typical areas of study within an engineering program that leads to the bachelor's degree. You should also consult with your counselor about specific course requirements. If you are enrolled in an engineering college but have not chosen a specific discipline, consult with an adviser or someone on the engineering faculty about particular course requirements in your areas of interest.

When considering a career in engineering or any closely related fields, you should explore the answers to several questions. What is engineering? What is an engineer? What are the functions of engineering? Where does the engineer fit into the technical spectrum? How are engineers educated? What is meant by professionalism and engineering ethics? What have engineers done in the past? What are engineers doing now? What will engineers do in the future? Finding answers to such questions will assist you in assessing your educational goals and obtaining a clearer picture of the technological sphere.

Brief answers to some of these questions are given in the remainder of this chapter. By no means are they intended to be a complete discussion of engineering and related fields. You can find additional and more detailed technical career information in the reference materials listed in the bibliography at the end of the book.

# 1.2 The technology team

1.2 The In 1876, 15 men led by Thomas Alva Edison gathered in Menlo Park to work on "inventions." By 1887, the group had secured over 400 patents, including ones for the electric light bulb and the phono-

graph. Edison's approach typified that used for early engineering developments. Usually one person possessed nearly all the knowledge in one field and directed the research, development, design, and manufacture of new products in this field.

Today, however, technology has become so advanced and sophisticated that one person cannot possibly be aware of all the intricacies of a single device or process. The concept of systems engineering has thus evolved: that is, technological problems are studied and solved by a technology team.

Scientists, engineers, technologists, technicians, and craftsmen form the technology team. The abilities of the team range across what is often called the technical spectrum. At one end of the spectrum are individuals with an understanding of scientific and engineering principles. They possess the ability to apply these principles for the benefit of mankind. At the other end of this technical spectrum are persons skilled in the use of their hands. They are the individuals who bring the actual ideas into reality.

Each of the technology team members has a specific function in the technical spectrum, and of utmost importance is that each specialist understands the role of all team members. It is not difficult to find instances where the education and tasks of team members overlap. For any engineering accomplishment, successful team performance requires cooperation that can be realized only through an understanding of the functions of the technology team. We will now investigate each of the team specialists in more detail.

Scientists have as their prime objective increased knowledge of nature (see Fig. 1.2). In the quest for new knowledge, the scientist conducts research in a systematic manner. The research steps referred to as the scientific method are often summarized as follows.

- 1. Formulate a hypothesis to explain a natural phenomenon.
- 2. Conceive and execute experiments to test the hypothesis.
- 3. Analyze test results and state conclusions.
- 4. Generalize the hypothesis into the form of a law or theory if experimental results are in harmony with the hypothesis.
- 5. Publish the new knowledge.

An open and inquisitive mind is an obvious characteristic of a scientist. Although the scientist's primary objective is that of obtaining an increased knowledge of nature, many scientists are also engaged in the development of their ideas into new and useful creations. But to differentiate quite simply between the scientist

#### 1.2.1 Scientist

Fig. 1.2 Many scientists perform their work in a laboratory. Here a chemist investigates the effect of a ruthenium catalyst on the reaction of hydrogen and carbon dioxide. (Ames Laboratory, U.S. Department of Energy.)



and engineer, we might say that the true scientist seeks to understand more about natural phenomena, whereas the engineer primarily engages in applying new knowledge.

### 1.2.2 Engineer

In the 1963 Annual Report of ECPD, the following definition of engineering appears.

Engineering is the profession in which a knowledge of the mathematical and natural sciences gained by study, experience, and practice, is applied with judgment to develop ways to utilize, economically, the materials and forces of nature for the benefit of mankind.

In the National Council of Engineering Examiners' Model Law, the following statement is found.

Engineer shall mean a person who, by reason of his special knowledge and use of mathematical, physical, and engineering sciences and the principles and methods of engineering analysis and design, acquired by education and experience, is qualified to practice engineering.

Both the engineer and scientist are thoroughly educated in the mathematical and physical sciences, but the scientist primarily