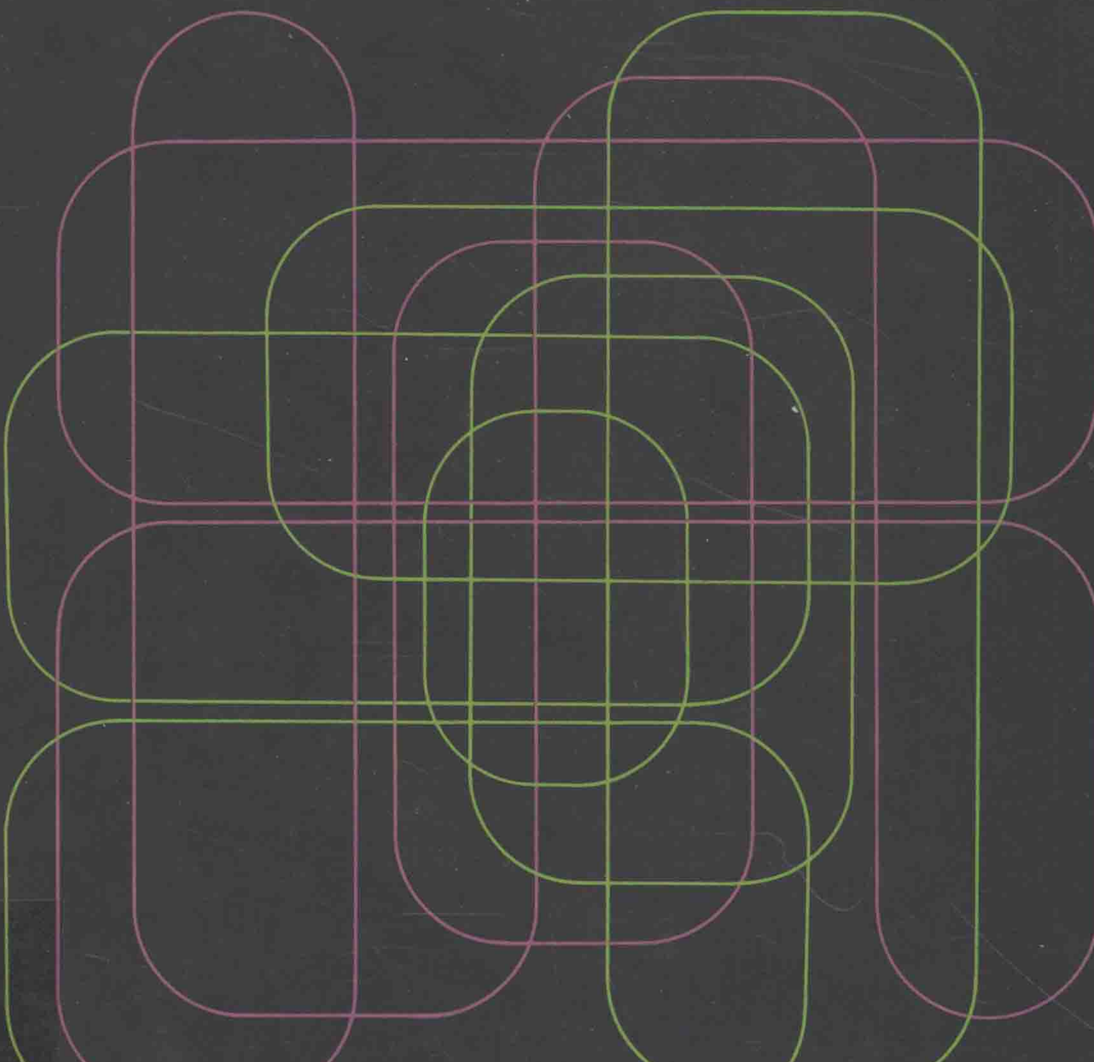
introduction to engineering



edited by
ROBERT M. GLORIOSO / FRANCIS S. HILL, JR

edited by

Robert M. Glorioso

and

Francis S. Hill, Jr.

introduction to engineering

Prentice-Hall, Inc., Englewood Cliffs, New Jersey

Library of Congress Cataloging in Publication Data

Glorioso, Robert M
Introduction to engineering.
Includes bibliographical references.
1. Engineering. I. Hill, Francis S., joint author.
II. Title.
TA145.G57 1974 620 74-3430
ISBN 0-13-482398-2

10 9 8 7 6 5 4 3 2

Printed in the United States of America

PRENTICE-HALL INTERNATIONAL, INC., *London*

PRENTICE-HALL OF AUSTRALIA, PTY. LTD., *Sydney*

PRENTICE-HALL OF CANADA, LTD., *Toronto*

PRENTICE-HALL OF INDIA PRIVATE LIMITED, *New Delhi*

PRENTICE-HALL OF JAPAN, INC., *Tokyo*

CONTRIBUTING AUTHORS

PROFESSOR LAWRENCE L. AMBS
Department of Mechanical and Aerospace Engineering
University of Massachusetts, Amherst

PROFESSOR GEOFFREY BOOTHROYD
Department of Mechanical and Aerospace Engineering
University of Massachusetts, Amherst

PROFESSOR DUANE E. CROMACK
Department of Mechanical and Aerospace Engineering
University of Massachusetts, Amherst

PROFESSOR ROBERT M. GLORIOSO
Department of Electrical and Computer Engineering
University of Massachusetts, Amherst

PROFESSOR WILLIAM P. GOSS
Department of Mechanical and Aerospace Engineering
University of Massachusetts, Amherst

PROFESSOR FRANCIS S. HILL, JR.
Department of Electrical and Aerospace Engineering
University of Massachusetts, Amherst

PROFESSOR JAMES R. KITTRELL
Department of Chemical Engineering
University of Massachusetts, Amherst

PROFESSOR JON G. MCGOWAN
Department of Mechanical and Aerospace Engineering
University of Massachusetts, Amherst

PROFESSOR MELTON M. MILLER
Department of Civil Engineering
University of Massachusetts, Amherst

PROFESSOR RICHARD V. MONOPOLI
Department of Electrical and Computer Engineering
University of Massachusetts, Amherst

PROFESSOR JOHN E. RITTER, JR.
Department of Mechanical and Aerospace Engineering
University of Massachusetts, Amherst

PROFESSOR DONALD E. SCOTT
Department of Electrical and Computer Engineering
University of Massachusetts, Amherst

PROFESSOR W. LEIGH SHORT
Department of Chemical Engineering
University of Massachusetts, Amherst

preface

Freshman engineering curricula have been undergoing considerable change through the past decade. Initially, many schools introduced computer programming into the freshman program while sacrificing some material on drafting, graphics, or descriptive geometry. This trend continued, and in many schools graphics has been completely eliminated from the curriculum.

The question then arises, What material should properly replace graphics, while providing the student with a clear perspective of and a heightened motivation toward an engineering career?

After several semesters of experimentation, the following program has evolved at the University of Massachusetts, Amherst. The freshman year is divided into six modular periods, with three modules to each semester. Each student is required to take two modular mini-courses in computer programming: Introductory Programming and Advanced Programming. During each of the remaining modules the student is free to elect any one of several mini-courses that are offered by the various departments.

This book has grown out of the mini-courses that have been given in these modular periods, but it has been designed to be used in standard semester, trimester, or quarter-type courses as well. The material contained in this book can be covered in approximately one and three quarter semesters. Thus, in a one semester course, for example, the instructor can cover material which is appropriate for his institution and students. This is easily accomplished since each chapter is designed to stand alone.

The material covered in the text represents a broad cross section of topics in contemporary engineering disciplines. It is not the intent of this book to be all-inclusive, but rather to provide subject areas that are of particular interest to today's engineering students. For example, contemporary problems of energy consumption and its concomitant generation of pollution are treated by Professors Ambs and McGowan in Chapter 4, Energy and Pollution. Specific air pollution problems and their analysis are covered by Professors Kittrell and Short in Chapter 5.

On the other hand, techniques of computer programming have not been included, since each school has individual requirements and circumstances, and several good texts already exist on this subject. The text is organized roughly in order of increasing difficulty where the first six chapters require less mathematical sophistication than the remaining chapters.

The author of each chapter is an expert in his area and has taught this material to freshmen for at least two modules. Furthermore, each author is presently doing research and is teaching upper-division and graduate courses in his area of specialization.

We wish to acknowledge the School of Engineering of the University of Massachusetts for the encouragement received in the preparation of this text. Also, a large portion of the manuscript was splendidly typed by Ms. Rhea Cabin and Ms. Helga Ragle.

ROBERT M. GLORIOSO
FRANCIS S. HILL, JR.

Amherst, Massachusetts

mass transportation 3

energy and pollution 4

air pollution concepts 5

6 engineering materials

7 fundamentals of electrical networks

8 computer engineering

communications in the modern world 9

introduction to biomedical engineering 10

introduction to experimental technique 11

chemical and thermal processes 12

1

what is engineering?

R. M. Glorioso

F. S. Hill, Jr.

1.1 INTRODUCTION

In this chapter we shall present an overview of the engineering profession and describe many of the roles of the engineer in society and in the scientific community. We shall also discuss the various opportunities available to an engineering student in choosing a career in the engineering professions.

A rich host of possibilities awaits the graduating engineer. Most graduates apply their training to problems in areas of society such as industry, government, and education. However, graduate engineers also go into other fields; for example, medicine, law, and management. We shall discuss these various opportunities and show how engineering training provides the technical background and intellectual discipline needed for these professions.

Does a bachelor's degree in engineering directly prepare one for all this? Obviously not. A bachelor's degree provides only a strong foundation upon which an individual must build. After graduation an engineer has several choices: He may go into industry, continue his engineering education in graduate school, or move into another profession. In industry an engineer must learn the technical and procedural processes of his company. Industry does not expect a newly graduated engineer to be able to contribute a great deal to his assigned projects or tasks immediately. It is generally understood that several months on the job are needed for orientation and training. Thus, it can be said that a bachelor's degree in engineering *prepares one to become* an engineer in industry. Although an engineer's formal education may end with a bachelor's degree, he is expected to continue learning the technological details of his job as well as other scientific advances. This is accomplished by reading the journals of his profession and attending conferences. He must be up to date.

On the other hand, one may wish to go to graduate school. An advanced degree in engineering prepares one for more complex and analytical technical work, thereby allowing him to command a higher salary. It is also true that in government and industry those who have advanced degrees generally progress faster through the job hierarchy. This is true for both the master's degree and the Doctor of Engineering or Ph.D. degrees. However, a doctorate is essential for a career in education or advanced research. The third alternative, that of moving to another field, is also frequently chosen by graduate engineers and will be discussed later in this chapter.

Assuming that one does stay in the field of engineering, what will be expected of him? The engineer is basically a *problem solver*. He must be capable of taking a problem (sometimes only vaguely defined), analyzing it, reducing it to its most fundamental ingredients, and formulating a collection of alternative solutions. The formulation of this set of solutions calls upon his resourcefulness and creativity. The selection of the best solution from among the alternatives depends on many, sometimes conflicting, factors. Of these factors, some of the most important are technical feasibility, cost, producibility, and reliability. Solving these problems is not usually a nine-to-five affair. Some of an engineer's most effective thinking goes on while he is driving, in the shower, etc. Indeed, some preliminary designs are often drawn on the backs of envelopes, paychecks, or scraps of toilet paper.

Let us now examine how the technical and intellectual skills developed through an engineering education relate to problem solving. The goal of the engineering curriculum is to develop basic technical skills, intellectual discipline, and the ability to communicate ideas lucidly. The basic courses in mathematics, chemistry, and physics lay the foundation for the study of their application in later engineering subjects. A second but equally important purpose of these courses is to develop intellectual discipline and the power to reason clearly. These basic attributes (knowledge of fundamentals, discipline, and analytical ability) enable the engineer to do creative problem solving. Some students feel that many of their courses are not directly relevant to the areas of their greatest interest. However, it is important for the student to bear in mind the above objectives of the engineering curriculum. In addition, as one becomes more involved with these courses, one often finds interesting relationships between seemingly unrelated subjects. For example, the mathematical relationships that describe the motions of mechanical systems with springs, masses, etc., are identical to those describing currents and voltages in electrical networks. You will discover many other similarities in your course work. The insights provided by these relationships broaden the engineer's perspective, thereby providing him with the ability to apply his background in new and different areas. This flexibility and diversity of background allow the engineer to solve new problems in society as they emerge.

Technical background and discipline go a long way toward preparing the student to be a successful engineer. However, he must also be able to communicate his ideas. To whom? First, to his coworkers, so that they can share new ideas and help develop them into practical solutions. Second, to the management of the company he works for, so that they will understand his ideas well enough to support and encourage him to follow up on them. And third, to other engineers around the world—through journal papers and conference talks. These talks and papers spread new ideas to the entire profession and help to enhance an engineer's reputation. Basically then, an engineer must continually convince others of the value of his ideas and abilities. As in any profession, he must be able to sell himself and his ideas.

1.2 THE ROLE OF ENGINEERING IN SOCIETY

Our society is highly technological and is rapidly becoming more so. We use dozens of sophisticated devices every day: automobiles, television sets, telephones, elevators, and bridges, to mention only a few. In addition there are thousands of less visible devices and methods. The equipment we use could not exist were it not for the remarkable assortment of materials and manufacturing techniques technology has spawned. It is very unlikely that our civilization will ever turn around and become less technological: People want comfortable living, easy communications and travel, health care, and recreation too much to turn back.

Why have all these technological advances appeared, and what role does the engineer play in developing them? Almost all invention begins with a *need.* An engineer, scientist, or the lone inventor in his basement recognizes a need and searches for a way to satisfy it. Transportation is one example. The whole history of transportation from the horse-and-buggy days to the present is full of cases where a new device or technology has come along to replace the old. In each case the new development answers the need for safe, inexpensive, and reliable travel better than the old one. Better roads came along because automobiles were beginning to move at higher speeds and because smoother all-weather roads were needed. Another example is in communications. The need for instantaneous communication over large distances brought the telegraph, which replaced the pony express. Then the need for direct voice conversations gave rise to the telephone, and communications has been blossoming ever since.

The engineer's job is to always come up with better ways of satisfying a need: to satisfy it more safely, reliably, and at a lower cost to the user. This may require a totally new technique, as in the case of radar, or it may result in a long series of small improvements, as in the development of the automobile over the last 50 years.

Today in our society there are many needs still awaiting the emergence of workable solutions. Two that have become prominent in recent years are energy production and pollution removal. These two demands seem to be on a collision course. On the one hand, everyone is using energy (in heating, lighting, travel, entertainment, etc.) at an ever-increasing rate, and very few people are seriously willing to give up the devices that consume this energy. On the other hand, there is no truly pollution-free way of generating energy on the large-scale basis required. Some methods such as those used in coal-burning power plants, dump pollutants into the air, while others require the disposal of residual pollutants such as radioactive wastes. This is, to a large extent, a technological problem requiring new techniques and devices, although there are important social, economic, and political problems to be solved here also.

Another growing need in our society is that of creating and maintaining cities that are safe and comfortable for human use. Since, at present,