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College Physics
(Sixth Edition)

大学物理
(第6版)

Serway & Faughn

清华大学出版社

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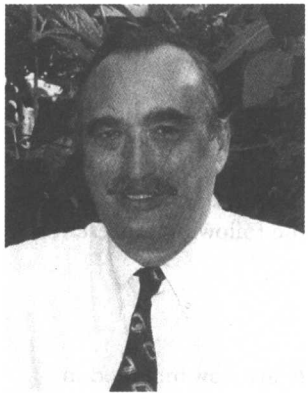
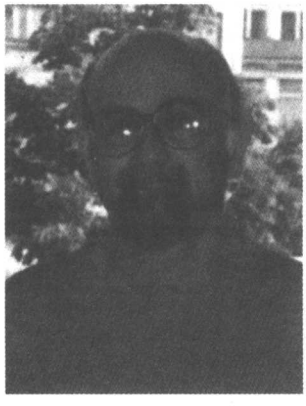
About the Authors

Raymond A. Serway received his doctorate at the Illinois Institute of Technology and is Professor Emeritus at James Madison University. Dr. Serway began his teaching career at Clarkson University, where he conducted research and taught from 1967 to 1980. His second academic appointment was at James Madison University as Professor of Physics and Head of the Physics Department from 1980 to 1986. He remained at James Madison University until his retirement in 1997. He was the recipient of the Madison Scholar Award at James Madison University in 1990, the Distinguished Teaching Award at Clarkson University in 1977, and the Alumni Achievement Award from Utica College in 1985. As Guest Scientist at the IBM Research Laboratory in Zurich, Switzerland, he worked with K. Alex Müller, 1987 Nobel Prize recipient. Dr. Serway also held research appointments at Rome Air Development center from 1961 to 1963, at IIT Research Institute from 1963 to 1967, and as a visiting scientist at Argonne National Laboratory, where he collaborated with his mentor and friend, Sam Marshall. Dr. Serway is also the senior author of *Principles of Physics,* 3rd edition; *Physics for Scientists and Engineers,* 5th edition; *Modern Physics,* 2nd edition with Dr. Moses; and the high-school textbook *Physics* with Dr. Faughn (the latter published by Holt, Rinehart, & Winston). In addition, Dr. Serway has published more than 40 research papers in the field of condensed matter physics and has given more than 70 presentations at professional meetings. Dr. Serway and his wife Elizabeth enjoy traveling, golfing, and spending quality time with their four children and five grandchildren.



Jerry S. Faughn earned his doctorate at the University of Mississippi. He is Professor Emeritus and former Chair of the Department of Physics and Astronomy at Eastern Kentucky University. Dr. Faughn has also written a microprocessor interfacing text for upper-division physics students. He is co-author of a nonmathematical physics text and a physical science text for general education students, and (with Dr. Serway) the high-school textbook *Physics,* published by Holt, Rinehart, & Winston. He has taught courses ranging from the lower division to the graduate level, but his primary interest is in students just beginning to learn physics. He has been director of a number of NSF and state grants, many of which were devoted to the improvement of physics education. He believes that there is no greater calling than to be a teacher and an interpreter of physics for others. Dr. Faughn has a wide variety of hobbies, among which are reading, travel, genealogy, and old-time radio. His wife Mary Ann is an avid gardener, and he contributes to her efforts by staying out of the way. His daughter Laura is in family practice and his son David is an attorney.



Clement J. Moses is Emeritus Professor of Physics at Utica College of Syracuse University. He was born and brought up in Utica, New York, and holds an A. B. from Hamilton College, an M. S. from Cornell, and a Ph.D. from State University of New York at Binghamton. He has over 30 years of science writing and teaching experience at the college level, and is a co-author of the text *Modern Physics,* 2nd edition with Dr. Serway. His research work, in both industrial and university settings, has dealt with defects in solids, solar cells, and the dynamics of atoms at surfaces. In addition to science writing, Professor Moses likes cooking, fishing, singing, and going to operas.

PREFACE

College Physics is written for a one-year course in introductory physics usually taken by students majoring in biology, the health professions, and other disciplines including environmental, earth, and social sciences, and technical fields such as architecture. The mathematical techniques used in the book include algebra, geometry, and trigonometry, but not calculus.

The main objectives of this introductory textbook are twofold: to provide the student with a clear and logical presentation of the basic concepts and principles of physics, and to strengthen an understanding of the concepts and principles through a broad range of interesting applications to the real world. To meet these objectives, we have emphasized sound physical arguments and problem-solving methodology. At the same time, we have attempted to motivate the student through practical examples that demonstrate the role of physics in other disciplines.

This textbook, which covers the standard topics in classical physics and 20th century physics, is divided into six parts. Part I (Chapters 1–9) deals with Newtonian mechanics and the physics of fluids; Part II (Chapters 10–12) is concerned with heat and thermodynamics; Part III (Chapters 13–14) covers wave motion and sound; Part IV (Chapters 15–21) is concerned with electricity and magnetism; Part V (Chapters 22–25) treats the properties of light and the field of geometric and wave optics; Part VI (Chapters 26–30) represents an introduction to special relativity, quantum physics, atomic, and nuclear physics.

CHANGES TO THE SIXTH EDITION

A number of new features, changes, and improvements have been added to this edition. Based on comments from users of the fifth edition and reviewers' suggestions, a major effort was made to improve clarity of presentation, precision of language, and accuracy throughout. The new pedagogical features added to this edition are based on current trends in science education. The following represent the major changes in the sixth edition.

PEDAGOGICAL CHANGES

- **Quick Quizzes** Several questions labeled Quick Quizzes are now included in each chapter to provide students with opportunities to test their understanding of the physical concepts presented. The questions require students to make decisions on the basis of sound reasoning, and some are intended to help students overcome common misconceptions. Most questions are presented in multiple choice format, and can be adapted for assessing student performance in the classroom. Answers to all questions are found at the end of the textbook, while answers with detailed explanations are provided in the Instructor's Manual.
- **Tips** These new features, placed in the margins of the text, address common student misconceptions that often cause students to follow unproductive paths. The "Tips" should help students avoid common mistakes and misunderstandings.
- **Problems and Conceptual Questions** A substantial revision of the end-of-chapter problems and conceptual questions was made in this edition. Most of the new problems that have been added are intermediate in level, and all have been carefully edited and reworded where necessary. Many new problems require

students to make order-of-magnitude calculations. Solutions to approximately 12 problems per chapter are included in the *Student Solutions Manual and Study Guide*. Boxed numbers identify these problems. A smaller subset of solutions will be posted on the World Wide Web **(http://info.brookscole.com/serway)** and will be accessible to students and instructors using *College Physics*. The **web** icon identifies these problems.

- **Group Activities** This new feature at the end of each chapter is included to encourage students to engage in activities outside of the classroom. Some are simple experiments or demonstrations the student can perform individually or with the assistance of a classmate. Others are problems, frequently consisting of both conceptual and numerical parts, that will stimulate group discussion.
- **Webnotes** Useful World Wide Web addresses are provided as marginal notes to encourage students to explore extensions of material beyond what is covered in the text.

CONTENT CHANGES

Although the overall content and organization of the textbook is similar to that of the fifth edition, several changes were implemented.

- Chapter 2 now includes several new examples on kinematics and the revised presentation places an increased emphasis on qualitative explanations of equations and graphs.
- Chapter 5 was extensively rewritten, and now includes a discussion of the various ways that energy can be transferred into or out of a system. We also added a new discussion of energy and power considerations when someone jumps vertically into the air, and a new section on work done by a variable force.
- Chapter 6 includes a new section on rocket propulsion emphasizing that the operation of a rocket can be understood from the law of conservation of momentum as applied to the rocket plus its ejected fuel. The chapter also presents new applications on injury in automobile collisions and finding the impact force on landing in a jump.
- We have added a discussion of arches and the ultimate strength of materials, including biological substances, in Section 9.2.
- A number of changes were made to Chapter 12. The first law of thermodynamics is now expressed as $\Delta U = Q + W$, where positive W is defined as the work done *on* the system. This form of the first law is used in most modern chemistry textbooks, and has been recommended by a committee appointed by AAPT (the American Association of Physics Teachers). Chapter 12 places an increased emphasis on the application of the first law to internal combustion engines and cyclic processes. The chapter also discusses how the human body constantly transforms internal energy into other forms of energy.
- Chapter 16 now offers more explanation of how to relate circuit schematics to actual circuits. This chapter also discusses the operation of the defibrillator as a practical example of capacitance.
- In Chapter 17, we added a section entitled "Electrical Activity in the Heart," which is of special interest to pre-medical and life science students.
- Chapter 18 includes a section entitled "Conduction of Electrical Signals by Neurons." This discussion is a recast of an earlier essay by Paul Davidovits on the nervous system and will be of special interest to pre-medical and life science students.
- Chapter 19 now includes a new application on electric motors.
- A new application that discusses the refraction of a laser beam in a DVD player is presented in Chapter 22.
- Chapter 23 places an increased emphasis on ray diagrams.

- New to this edition is Section 24.5 entitled "Using Interference to Read CD's and DVD's." This discussion represents an interesting application of interference to modern technology.
- Chapter 26 was extensively rewritten and includes a new example on the conversion of mass to energy.
- Chapter 27 now includes a discussion of how X-ray diffraction is used to determine the structure of biologically important molecules.
- Chapter 28 was extensively revised and now includes two new sections entitled "Energy Bands in Solids" and "Semiconductor Devices." These topics are important for understanding the electronic properties of solids, and are basic to understanding the behavior of semiconductor devices such as diodes and transistors.
- Section 29.8, new to this edition, discusses various types of radiation detectors such as Geiger counters, bubble chambers, and scintillation counters. These practical applications will be of special interest to students preparing for health related professions.
- Some sections in the fifth edition were either deleted or moved to more appropriate locations. Section 1.7 on mathematical notation was moved to an appendix.

Most of the section entitled "The Diffraction Grating" was moved from Chapter 25 to Chapter 24 because it logically follows the discussion of diffraction. The section entitled "Pair Production and Annihilation" was moved from Chapter 27 to Chapter 26 because the topic is a verification of the equivalence of mass and other forms of energy as predicted by the theory of relativity.

The QuickLabs that were included in the fifth edition have been deleted, but the most popular QuickLabs are now incorporated into the new **Group Activities** feature described earlier.

Multiple-choice questions that appeared in the fifth edition have been removed, but some have been rewritten as Quick Quiz questions.

TEXTBOOK FEATURES

Most instructors would agree that the textbook assigned in a course should be the student's primary guide for understanding and learning the subject matter. Furthermore, the textbook should be easily accessible and written in a style that facilitates instruction and learning. With this in mind, we have included many pedagogical features that are intended to enhance the textbook's usefulness to both students and instructors. These features are as follows:

STYLE We have attempted to write the book in a style that is clear, logical, relaxed, and pleasing to the reader. At the same time, we have attempted to keep the presentation accurate and precise. New terms are carefully defined, and we have avoided the use of jargon.

PREVIEWS All chapters begin with a preview that includes a brief discussion of the chapter's objectives and content.

ORGANIZATION The book is divided into the following six parts: mechanics, thermodynamics, vibrations and wave motion, electricity and magnetism, light and optics, and modern physics. Each part includes an overview of the subject matter to be covered in that part and some historical perspectives.

UNITS The international system of units (SI) is used throughout the book. The U.S. customary system of units is used only to a limited extent in the problem sets of the early chapters on mechanics.

MARGINAL NOTES Comments and notes appearing in the margin can be used to locate important statements, equations, definitions, and concepts in the text.

PROBLEM-SOLVING STRATEGIES General strategies and suggestions are included for solving the types of problems featured in both the worked examples and end-of-chapter problems. This feature, highlighted by a surrounding box, is intended to help students identify the essential steps in solving problems and increase their skills as problem solvers.

PHYSICS IN ACTION This boxed material focuses on photographs of interesting demonstrations and phenomena in physics, accompanied by detailed explanations. The material can also serve as a source of information for initiating classroom discussions.

LIFE SCIENCE TOPICS Many chapters include text, worked examples and problems dealing with applications of physics to the life sciences. These are identified by the DNA icon ( ).

WORKED EXAMPLES A large number of worked examples, including many new ones, are presented as an aid in understanding and/or reinforcing physical concepts. In many cases, these examples serve as models for solving end-of-chapter problems. The examples are set off from the text for ease of location, and all examples are given titles to describe their content. Many examples include a **Reasoning** section to illustrate the underlying concepts and methodology used in arriving at a correct solution. This will help students understand the logic behind the solution and the advantage of using a particular approach to solve the problem. The solution answer is highlighted with a light blue screen. Many worked examples are followed immediately by exercises with answers. These exercises represent extensions of the worked examples and are intended to sharpen student's problem-solving skills and test their understanding of concepts. Students who work through these exercises on a regular basis should find the end-of-chapter problems less intimidating.

IMPORTANT STATEMENTS AND EQUATIONS Most important statements and definitions are set in **boldface type** or are highlighted with a background screen for added emphasis and ease of review. Similarly, important equations are highlighted with a gold screen to facilitate location.

ILLUSTRATIONS AND PHOTOGRAPHS The text material, worked examples, and end-of-chapter questions and problems are accompanied by numerous figures, photographs, and tables. Full color is used to add clarity to the figures and to make the visual presentation as realistic and pleasing as possible. Three-dimensional effects are rendered with the use of shaded and lightened areas, where appropriate. Vectors are color coded, and curves in *xy* plots are drawn in color. Color photographs have been carefully selected, and their accompanying captions have been written to serve as an added instructional tool. A complete description of the pedagogical use of color appears on the inside front cover.

SUMMARIES Each chapter contains a summary which reviews the important concepts and equations discussed in that chapter.

CONCEPTUAL QUESTIONS A set of conceptual questions is provided at the end of each chapter. The **Applying Physics** examples presented in the text should serve as models for students when conceptual questions are assigned or used in

tests. The questions provide the student with a means of self-testing the concepts presented in the chapter. Some conceptual questions are appropriate for initiating classroom discussions. Answers to all odd-numbered conceptual questions are located in the answer section at the end of the book.

END-OF-CHAPTER PROBLEMS An extensive set of problems is included at the end of each chapter. Answers to odd-numbered problems are given at the end of the book. For the convenience of both the student and instructor, about two thirds of the problems are keyed to specific sections of the chapter. The remaining problems, labeled "Additional Problems," are not keyed to specific sections. There are three levels of problems according to their level of difficulty. Straightforward problems are numbered in black, intermediate level problems are numbered in blue, and the most challenging problems are numbered in magenta. Those problems with a focus on the life sciences are identified by the DNA icon ( ). The set of problems under the heading of **Group Activities,** new to this edition, have been included to encourage students to engage in scientific activities outside the classroom.

APPENDICES Several appendices are provided at the end of the book. Most of the appendix material represents a review of mathematical techniques used in the book, such as scientific notation, algebra, geometry, and trigonometry. References to these appendices is made as needed throughout the book. Most of the mathematical review sections include worked examples and exercises with answers. Some appendices contain useful tables that supplement textual information. For easy reference, the front endpapers contain a chart explaining the use of color throughout the book and a list of often-used conversion factors.

TEACHING OPTIONS

This book contains more than enough material for a one-year course in introductory physics. This serves two purposes. First, it gives the instructor more flexibility in choosing topics for a specific course. Second, the book becomes more useful as a resource for students. On the average, it should be possible to cover about one chapter each week for a class that meets three hours per week. Those sections, examples, and end-of-chapter problems dealing with applications of physics to the life sciences are identified with the DNA icon ( ). We offer the following suggestions for shorter courses for those instructors who choose to move at a slower pace through the year:

Option A: If you choose to place more emphasis on contemporary topics in physics, you should consider omitting all or parts of Chapter 8 (Rotational Equilibrium and Rotational Dynamics), Chapter 21 (Alternating Current Circuits and Electromagnetic Waves), and Chapter 25 (Optical Instruments).

Option B: If you choose to place more emphasis on classical physics, you could omit all or parts of Part VI of the textbook, which deals with special relativity and other topics in 20th century physics.

The Instructor's Manual offers additional suggestions for specific sections and topics that may be omitted without loss of continuity if time presses.

STUDENT ANCILLARIES

Thomson·Brooks/Cole offers several items to supplement and enhance the classroom experience. These ancillaries will allow instructors to customize the textbook to their students' needs and to their own style of instruction. One or more of these ancillaries may be shrink-wrapped with the text at a reduced price:

STUDENT SOLUTIONS MANUAL AND STUDY GUIDE by John R. Gordon, Charles Teague, and Raymond A. Serway. Now offered in two volumes, this manual features detailed solutions to approximately 12 problems per chapter. These problems are indicated in the text with boxed numbers. The manual also features a skills section, important notes from key sections of the text, and a list of important equations and concepts. Volume 1 contains Chapters 1–14 and Volume 2 contains Chapters 15–30.

CORE CONCEPTS IN COLLEGE PHYSICS **CD-ROM, VERSION 2.0** The *Core Concepts in College Physics* CD-ROM applies the power of multimedia to the introductory physics course, offering full-motion animation and video, engaging interactive graphics, clear and concise text, and guiding narration. Drawing from topics in mechanics, thermodynamics, electromagnetism, and optics, *Core Concepts in College Physics* focuses on those concepts students typically find most difficult in the course. The CD-ROM also presents step-by-step explorations of essential mathematics, problem-solving strategies, and animations of problems to promote conceptual understanding and sharpen problem-solving skills. The accompanying *Workbook* contains practical physics problems coordinating with the CD, along with worked solutions.

PHYSICS LABORATORY MANUAL, 2nd edition by David Loyd. This manual supplements the learning of basic physical principles while introducing laboratory procedures and equipment. Each chapter of the manual includes a pre-laboratory assignment, objectives, an equipment list, the theory behind the experiment, experimental procedures, graphs, and questions. A laboratory report is provided for each experiment so the student can record data, calculations, and experimental results. Students are encouraged to apply statistical analysis to their data in order to develop their ability to judge the validity of their results.

ADDITIONAL ONLINE RESOURCES In addition to the companion Web site for this textbook **(http://info.brookscole.com/serway),** students using *College Physics* by Serway and Faughn are encouraged to visit the Brooks/Cole Physics Resource Center at the address below for features such as online quizzing and additional Weblinks. See **http://physics.brookscole.com**

INSTRUCTOR ANCILLARIES

Ancillaries offered in two volumes are split as follows: Volume 1 contains Chapters 1–14 and Volume 2 contains Chapters 15–30.

INSTRUCTOR'S MANUAL by Jerry Faughn and Charles Teague. Available in two volumes, this manual consists of complete solutions to all the problems in the text, answers to the even-numbered problems and conceptual questions, full answers with explanations to the Quick Quizzes, and a list of suggested readings from journals and other resources.

PRINTED TEST BANK by Ed Oberhofer. Available in two volumes, the comprehensive test bank contains approximately 1 750 problems and questions in multiple choice format. Answers are provided in a separate key. Instructors may duplicate pages for distribution to students.

COMPUTERIZED TEST BANK Available for Windows and Macintosh, the computerized test bank allows instructors to create, deliver and customize tests and quizzes using questions from the printed Test Bank. Instructors may rearrange and edit existing questions, or add their own.

OVERHEAD TRANSPARENCY ACETATES The collection of transparencies in two volumes consists of approximately 200 full-color figures and photographs from the text to enhance lectures. These transparencies feature large print for easy viewing in the classroom.

INSTRUCTOR'S MANUAL FOR PHYSICS LABORATORY MANUAL, 2nd edition by David Loyd. Each chapter contains a discussion of the experiment, teaching hints, answers to selected questions from the student laboratory manual, and a post-laboratory quiz with short answers and essay questions. The author has also included a list of the suppliers of scientific equipment and a summary of the equipment needed for all the experiments in the manual.

MULTIMEDIA PRESENTATION MANAGER FOR INTRODUCTORY PHYSICS 2003: A MICROSOFT® POWERPOINT® LINK TOOL This one-stop lecture tool and instructional resource makes it easy to assemble, edit, publish and present custom media-enhanced lectures for your course, using Microsoft® PowerPoint®. The two-volume cross-platform (Win/Mac) CD set includes electronic files of the ***Instructor's Manual*** and ***Test Bank,*** plus digital files of textbook art and additional video clips and animations.

Also found on the ***Multimedia Presentation Manager for Introductory Physics 2003*** are simulations for ***Interactive Physics™ 2000,*** the highly acclaimed software from MSC Software. Many simulations are keyed to specific worked examples and end-of-chapter problems in *College Physics,* while others stand alone as laboratory exercises. The instructor or department must own a multi-user license for ***Interactive Physics™*** in order to assign the simulations for student use.

WEBTUTOR™ ADVANTAGE ON WEBCT AND BLACKBOARD *WebTutor Advantage* enables the instructor to create and manage a course Web site. WebTutor's course management tool gives the instructor the ability to provide virtual office hours, post syllabi, set up threaded discussions, track student progress with the quizzing material, and much more. WebTutor also provides robust communication tools, such as a course calendar, asynchronous discussion, real time chat, a whiteboard, and an integrated e-mail system.

For students, WebTutor offers real-time access to a full array of study tools, including chapter outlines, summaries, learning objectives, glossary flashcards (with audio), practice quizzes, and Web links.

WebTutor is available for Semesters I (Chapters 1–14) and II (Chapters 15–30) in both WebCT and Blackboard.

MYCOURSE 2.0 *MyCourse 2.0* offers instructors a simple solution for a custom course Web site that allows for assignments, tracking and reporting student progress, syllabus loading, and more. Contact your Thomson·Brooks/Cole representative for details. To see a demo of *MyCourse 2.0,* visit **http://mycourse.thomsonlearning.com**

INSTRUCTOR OPTIONS FOR ONLINE HOMEWORK For detailed explanations and demonstrations, contact your Thomson·Brooks/Cole representative or visit the following Web sites:

- ***WebAssign: A Web-Based Homework System***
  http://www.webassign.net or contact WebAssign at **webassign@ncsu.edu**
- ***Homework Service***
  http://hw.ph.utexas.edu/hw.html or contact **moore@physics.utexas.edu**

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Finally, we dedicate this book to our wives and children, for their love, support, and long-term sacrifices.

Raymond A. Serway
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APPLICATIONS

Although physics is relevant to so much in our modern lives, this may not be obvious to students in an introductory course. In this sixth edition of *College Physics,* we continue a design feature begun in the previous edition. This feature makes the relevance of physics to everyday life more obvious by pointing out specific applications in the form of a marginal note. Some of these applications pertain to the life sciences and are marked with the DNA icon ( ). The list below is not intended to be a complete listing of all the applications of the principles of physics found in this textbook. Many other applications are to be found within the text and especially in the worked examples, Conceptual Questions, and end-of-chapter problems.

DIRECTS YOU TO SECTIONS DISCUSSING APPLIED PRINCIPLES OF PHYSICS

TO THE STUDENT

It is appropriate to offer some words of advice that should be of benefit to you, the student. Before doing so, we assume that you have read the Preface, which describes the various features of the text that will help you through the course.

HOW TO STUDY

Very often instructors are asked, "How should I study physics and prepare for examinations?" There is no simple answer to this question, but we would like to offer some suggestions that are based on our own experiences in learning and teaching over the years.

First and foremost, maintain a positive attitude toward the subject matter, keeping in mind that physics is the most fundamental of all natural sciences. Other science courses that follow will use the same physical principles, so it is important that you understand and are able to apply the various concepts and theories discussed in the text.

CONCEPTS AND PRINCIPLES

It is essential that you understand the basic concepts and principles before attempting to solve assigned problems. You can best accomplish this goal by carefully reading the textbook before you attend your lecture on the covered material. When reading the text, you should jot down those points that are not clear to you. We've purposely left wide margins in the text to give you space for doing this. Also be sure to make a diligent attempt at answering the questions in the Quick Quizzes as you come to them in your reading. We have worked hard to prepare questions that help you judge for yourself how well you understand the material. Pay careful attention to the many Tips in the margins of the text. These will help you to avoid misconceptions, mistakes, and misunderstandings and will help you to maximize the efficiency of your time by minimizing adventures along fruitless paths. During class, take careful notes and ask questions about those ideas that are unclear to you. Keep in mind that few people are able to absorb the full meaning of scientific material after only one reading. Several readings of the text and your notes may be necessary. Your lectures and laboratory work supplement reading of the textbook and should clarify some of the more difficult material. You should minimize your memorization of material. Successful memorization of passages from the text, equations, and derivations does not necessarily indicate that you understand the material. Your understanding of the material will be enhanced through a combination of efficient study habits, discussions with other students and with instructors, and your ability to solve the problems presented in the textbook. Ask questions whenever you feel clarification of a concept is necessary.

STUDY SCHEDULE

It is important that you set up a regular study schedule, preferably one that calls for daily involvement with course work. Make sure that you to read the syllabus for the course and adhere to the schedule set by your instructor. The lectures will be much more illuminating if you read the corresponding textbook material *before*