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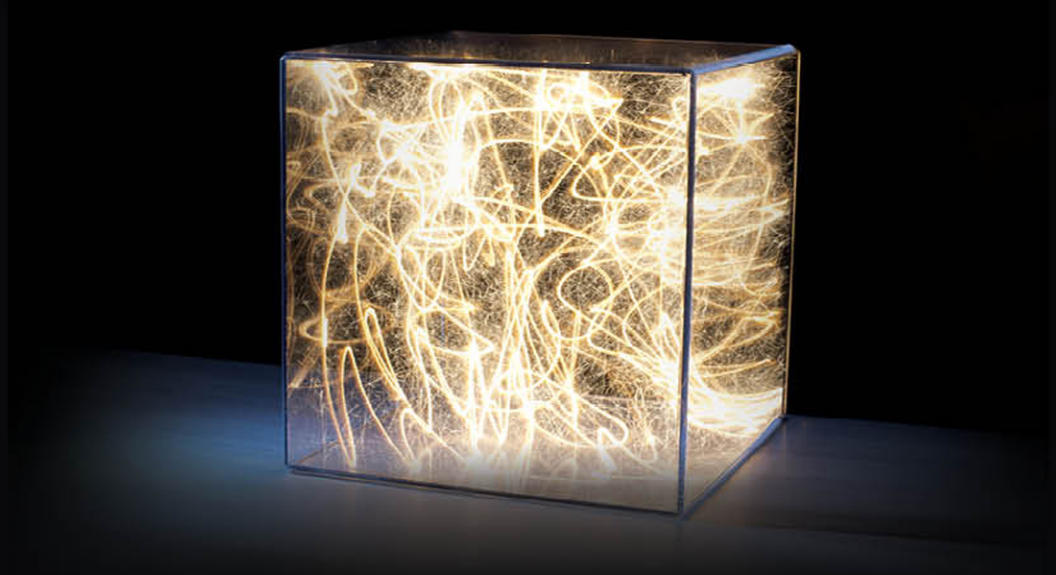

DANIEL MILTON OMAN, PhD / ROBERT MILTON OMAN, PhD

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SECOND EDITION

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New York Chicago San Francisco Athens London Madrid
Mexico City Milan New Delhi Singapore Sydney Toronto

ISBN: 978-0-07-184932-6

MHID: 0-07-184932-7

The material in this eBook also appears in the print version of this title: ISBN: 978-0-07-184931-9,
MHID: 0-07-184931-9.

eBook conversion by codeMantra
Version 1.0

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Robert Milton Oman received the B.S. degree from Northeastern University and the Sc.M. and Ph.D. degrees from Brown University, all in physics. He taught mathematics and physics at many colleges and universities, including the University of Minnesota, Northeastern University, and the University of South Florida. He conducted research for NASA, where he developed the theoretical model for the first pressure gauge sent to the moon.

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PREFACE

The purpose of this book is to help you to develop a highly effective set of problem-solving skills that will allow you to excel in your physics class. Here are some of the elements of this book that we believe will make it highly valuable:

1. This book is more than just a collection of problems. It introduces theory along the way but places the theory immediately in the context of problems. This approach teaches you how to apply concepts to solving problems.
2. We take the time to explain the solutions to the problems thoroughly. We point out important problem-solving strategies that are useful for solving large groups of similar problems.
3. This book has gone through extensive development over the years to present the problem-solving techniques in the clearest manner. The book was started in 1980 by Robert Oman and presented to his physics students to help them understand concepts and give them practice and confidence in working problems. After publication of the first edition in 1997, the book was used over a period of 10 years by many students in more of Robert's university physics classes as a supplement to the text. Daniel Oman tutored university students from 2011 to 2015 and integrated new types of questions that he was seeing into the existing book, creating a second edition.

The second edition of this book includes three new chapters—Quantum Physics; Atoms, Molecules, and Solids; and Nuclear Physics. This edition also includes some edits and additional problems based on feedback from students over the years.

It is the sincere desire of the authors that this book help you to better understand physics concepts and work the associated problems. We thank the many students who have contributed to this work by using the material and offering suggestions. Also, we thank the fine staff at McGraw-Hill Education that has contributed greatly to the clarity of the presentation.

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HOW TO USE THIS BOOK

This book will teach you how to do physics problems. The explanation of not only how to do a problem but also why we do it a certain way teaches you not just a collection of solved problems, but a collection of methods that can be used, modified, and built upon to do other physics problems. As researchers and teachers, we know that the key to solving new and challenging problems is contained within the collection of techniques already learned for solving simpler problems. Seeing a problem solved and knowing why it was done in a certain manner is the best way to learn how to solve related, more difficult problems.

This book is not a presentation of every problem you are going to encounter on a test. It is a presentation of the methods that we have found to work for large groups of problems. If you develop the techniques we describe for solving problems then you will know how to successfully approach the problems you will encounter on the tests. This is the book you should have as a reference when you are doing your homework problems. It will show you how to work the problems and explain why they are being done the way they are.

The topics in this book are in the order of most physics texts. Each chapter begins with a theoretical discussion. Problems are mixed in with the discussion as soon as possible. These problems follow the development of the theory. In this way you do not have to assimilate a large amount of conceptual material before beginning to work problems.

A "standard" route is followed for problems wherever possible. In this way you will learn that broad categories of problems worked in a standard "logical" way always produce correct solutions. Our emphasis is on logic and order in solving problems. We avoid methods that may be quick and have limited application to problem solving in favor of possibly longer solutions that have broad applications and always work. We believe that a lot of good physics can be taught in problems so we use problems to illustrate and expand a topic and sometimes introduce new concepts. For this reason problems and text are integrated with a minimum of artificial barriers between them.

The book is intended as a complement to either the calculus-based or the non-calculus-based elementary physics course. It has been our experience that calculus concepts can be introduced into the traditional non-calculus course and used in the development of concepts. Conceptually, calculus is not difficult, and when it is introduced in the context of a physics problem it is even easier. We use calculus concepts to explain theory, but calculus is rarely used in problems. Even those students who are taking calculus concurrent with their physics course usually learn calculus concepts in physics before they see them in their calculus course.

 In those instances where calculus is needed, the problems and paragraphs are marked with a calculus icon. Even the student without formal calculus training should read these sections. They are often explained in a simple manner so that the calculus does not present a problem.

The chapters on electricity and magnetism are also excellent background chapters for someone taking an undergraduate course in electricity and magnetism.

We have used two significant figures for the physical constants and most of the numbers in the problems. Results are given to two, and occasionally three, significant figures. Using two significant figures cuts down on the clutter in the problems, allowing the technique to receive greater exposure. Do not be concerned in working through the problems if your answers do not agree exactly with ours. This is no doubt due to when, or if, intermediate calculations were rounded off. SI units are used nearly universally throughout the book.

HOW TO EXCEL IN YOUR PHYSICS COURSE

Most students realize that putting off studying until the day before the exam and then cramming at the last minute is not efficient. Some students do this anyway, because so far they have gotten away with it. Perhaps most of the other students you previously competed with had poor study skills. This may have allowed you to adopt poor or non-existent study habits and still keep up, or even get good grades if you are naturally a better student. Now that you are in college, the courses will be more difficult, and it is to your advantage to develop a more organized approach to handling your course work.

Successful people generally have three things in common. They make effective use of their time, they set goals for themselves, and they have a positive attitude. Physics is a challenging course for most students. It will take a well-organized consistent effort to do well in this course, but success in a challenging area is a worthwhile goal.

General Approach for Studying Physics

Many people believe the following: more work and more study results in higher grades. This is not necessarily so. You certainly must be willing to make a certain commitment of time and energy to this course, but the key to academic success is concentrating your efforts on the right things at the right times. You may have noticed that those students who receive the highest grades are not necessarily the ones who work the greatest number of hours. Some students may boast that they have studied all night for an exam, but don't be impressed by this habit. "Allnighters" and the like are almost always the result of procrastination and bad study habits. Getting no sleep before an exam is foolish, and it usually takes several days to recover from this kind of activity. By taking advantage of the study techniques that follow you can achieve higher grades with less effort.

The most efficient way of learning physics by attending lectures, problem solving sessions, and performing supplementary readings is to:

1. Do a quick reading on the topics to be covered in the lecture before attending class. Ten or fifteen minutes may be sufficient for a one hour lecture. The purpose here is to generally familiarize yourself with the topics to be discussed. Perhaps you can identify one or two questions or key points to listen for during the lecture.
2. Attend class and take notes. Attend all of the classes. Someone is paying for these classes so BE THERE! Be on the alert for any indication by the instructor of possible test questions. If the professor says something like "This is very important, you may be seeing this again," make a special note of this in your notebook.
3. Review your lecture notes. Don't save this step until a few days before the exam. It is far more efficient to review your notes a little bit at a time during the semester than to try and do it all at once. At this point you should also do a more detailed reading of the text to fill in any gaps in your class notes.
4. This may be the most important step. Do the homework problems regularly. In other courses it may be sufficient to read the text and review your notes, but in physics you

must be able to work the problems. You don't learn problem solving skills by just reading examples of solved problems, you must do the problems yourself. By doing the homework problems on a regular basis you will be able to identify areas that you need more work on well in advance of the test. Physics problems can be difficult. Therefore, when you set out to work problems do not set yourself the task of working a certain number of problems, but rather set out a certain amount of time to work on problems.

5. Compile a formal set of notes and prepare a detailed outline. The general strategy here is that a number of short exposures to manageable pieces of the course is more efficient than one long exposure to a large amount of material. As you progress through the course, you first get your information in an initial reading of the material, then again in the lecture, then again in a second reading, and yet again in an organizing session where you prepare a detailed outline. The detailed outline is essential to success on the exams. It contains the examination questions. Your main preparation for the exam will be to extract the questions and prepare to answer them. Notice we did not say "study for the exam"; the studying for the exam has been going on all along. That is what you have been doing as you make up your formal notes, outline, etc. What you have done with this systematic approach is to reproduce the notes and outline that the instructor is using. If you are reasonably good at it, you will have as good a source of exam questions as the instructor.

How to Prepare for a Physics Test

Examine the shelves of any bookstore catering to career oriented students and you will find books with titles such as: *How to Pass the Real Estate Licensing Exam*, or *How to Succeed on the S.A.T.* Examining these books will help you develop your personal exam-taking program. One common thread in all books on how to pass particular exams is to know the types of questions in advance. Most writers of these types of books are in the business of training people in their particular areas, so they are close to the people who make up the exams. This gives them a ready source of test question possibilities, and knowing the types of questions is half way to knowing the answers. Therefore we make the following suggestions:

1. Almost all instructors in physics will include some problems on the test that are very similar to examples that they have done in class. Many times you may encounter the same problem with different numbers. This makes it very important to attend every class so as not to miss the opportunity to see possible test questions. If you do miss class, always get the notes from a friend.
2. Another frequent occurrence is for slight modifications of homework problems to appear on the test. Join a study group that does homework problems together. This can be more efficient than grinding away on your own. Don't waste too much time with a study group unless it is productive. Your final preparations for a test should be done privately so that you can concentrate on developing a plan for taking the test.
3. Try to find physics tests given by your instructor in the pas few years. It is a good bet that most of the questions for the exams in the near future will be very much like those of the immediate past.
4. Some physics problems involve mathematics that can be deceptively easy. For example, if you expect problems involving the manipulation of logarithms or exponents be sure you practice the mathematical operations and entering the numbers into your calculator so you don't have to stop and figure out how to take exponents during the test. Practice any unfamiliar mathematical operations before the test.

Timing and the Use of the Subconscious

Have you ever experienced the frustration of having a conversation with someone and forgetting momentarily a name or fact that is very familiar to you? Usually, shortly after such an experience, the name or fact will come to you when you are not consciously trying to recall it. Another variation of this same phenomenon is when a person doesn't feel right about making a decision immediately upon receiving or defining a problem. They like to "sleep on it." Both of these situations have a common characteristic—the use of the subconscious. The fact that solutions are often presented to us in the absence of active work on the problem at the moment we receive the solution indicates that another part of the brain was analyzing the pertinent information and providing a solution. We call this part of the brain the subconscious; it is very effective at solving problems.

Here are some tips for effectively using the subconscious:

1. Your subconscious will not work without information. You must consciously sort out all of the facts or information for a particular problem. If you are having difficulty with a problem, try to get straight in your mind what you *do know* about the problem. Then also define in your mind what specifically you don't know or don't understand about the problem.
2. Put conscious effort into the problem up to the point of confusion. Many people grind and grind on a problem after this point and accomplish very little. It is more efficient for you to plan your study time so that you do not put yourself in a situation where your only choice is to grind on a problem.
3. After you have done all you can consciously on the problem, put it in the back of your mind. Don't keep worrying about it. It is important that you clear your mind so that you can accept the solution when it comes.
4. Be sure you have a deadline for the solution.
5. When a solution comes, be sure to act on it quickly, so you can go on to something else. Sometimes instead of a solution to the problem you will receive a request for more information. The problem may still be unanswered, but will be clearer to you. What could be happening here is that your subconscious has analyzed the problem and found an essential piece of information missing and is asking you for it.

The study program that we have outlined, consisting of regular review of lecture notes, frequent working of homework problems, and periodic updates of your formal notes and outline, makes maximum use of your subconscious. The periodic intake of new material and the required conscious review serves to keep you subconsciously analyzing and fitting new information into the body of knowledge you are accumulating.

Here would be a good approach to practicing for a physics exam:

ED - 4: (Exam day minus four) Prepare a sample exam from your outline. This may consist of questions from previous exams given by the instructor and variations of homework problems or examples done in class. Keep in mind that this is probably the same way that the professor is making up your exam.

ED - 3: Study for your first sample exam. Go over your notes, text, and homework problems.

ED - 2: Take your first sample exam. As soon as possible after the exam, do a detailed review concentrating on the weaker areas. Make up your final sample exam.

ED - 1: Take your final sample exam. Again review the difficult points of this sample exam. Get a good night's sleep tonight.

ED: Do as little as possible on the day of the exam. You may want to quickly review your outline or a couple of difficult points.

You will notice that the bulk of the work in preparing for a test this way consists of writing and taking sample tests. It is planned that way. One of the common fallacies in preparing for exams is to prepare for the wrong thing. Many students will prepare for a physics exam by reading the text or by reading solutions to problems. A physics exam, however, is not a reading exam but a writing and problem-solving exam. If you have not practiced writing solutions to typical problems, you have not prepared as well as you might for the exam.

The second advantage to taking sample tests is that it increases your speed in writing solutions to types of problems that are likely to be on the test. This will allow you more time during the test to spend on unexpected or more troublesome problems.

Strategies to Use During a Physics Test

You are now entering the test room. You are well prepared to take the test. You have taken practice tests and know what to expect on the exam. You have gotten a good night's sleep the night before and eaten a healthy breakfast that will provide you with the energy needed for good concentration. You have a positive attitude. At this point worrying about how you will do on the exam is useless. Study time is over. You now need to concentrate on the strategies that will get you the highest possible score on the test. Here are some suggestions:

1. It is usually a good idea to take a minute or two at the beginning of the exam to look over all the questions. Look for the type of questions that you expected and have practiced and do these first. Save the hardest questions for last. It can be very frustrating to run out of time working on question # 4 only to realize that you didn't even get a chance to start question #5 that was much easier.
2. Have a rough idea of how much time you should be spending on each question. Sometimes certain questions will count for more points than others and the instructor should provide that information on the test.
3. If you are required to memorize a lot of formulas you may want to take the time at the beginning of the test to write down a few of the more complicated ones next to problems that involve those formulas as you are glancing over the test. Later during the test, your mind may be cluttered with formulas and it may be harder to correctly recall one of the more complicated ones.
4. Always include the units of your answer (miles per hour if the answer is a velocity, for example). Don't make the mistake of not including units. This is very important to almost all physics teachers.
5. Write your work clearly when you are solving a problem. It is easier for the professor to give you partial credit if he or she can clearly see that your approach to solving the problem was correct and just made a minor computational error.
6. Think about your answer to a problem. Does the answer make sense? For example, if you are solving for the length of one side of a right triangle and you are given the hypotenuse, your answer better not be a length greater than the hypotenuse. It is very important to be able to think like this on a test. This will help you catch a lot of mistakes like missing a minus sign.

7. Unfortunately some instructors give tests that are much too long for a given period of time. It seems as if they are more interested in measuring how *fast* you can do physics than how well you can do physics. Try to find out in advance of the test if your professor's tests are like this. If the cutoff for an A is usually 75% instead of 90% then you need to be aware of this. This may prevent you from panicking as you run out of time on the test. Remember that you may be able to work for partial credit on that last answer. On these kinds of tests it is very important to keep your cool and try to get as many points as you possibly can. Stay positive all the way through and give it your best shot!
8. Make sure you know the difference between radian mode and degree mode on your calculator when taking a test that includes trigonometry (see the Mathematical Background section).
9. Avoid prolonged contact with other students immediately before the exam. Many times the nervous tension, frustration, defeatism, and perhaps wrong information expressed by fellow students can be harmful to your performance.
10. Multiple choice tests: Find out if there is any penalty for a wrong answer. If not, don't leave any question unanswered. Find out if there is any partial credit for showing your work on a separate sheet of paper. One thing to think about for multiple choice tests is how the professor is generating the choices other than the correct answer. Here are some typical wrong choices on a multiple choice physics test:
    (a) A formula requires the input of length in meters. In the problem the length is specified in centimeters. The wrong answer is off by a factor of 100.
    (b) A formula requires the input of a radius. Diameter is given in the problem. The wrong answer is off by a factor of two.
    (c) A question asks for a velocity. Choice A is 10 lb. This is the correct number, but the wrong units. Choice D is 10 miles per hour, the correct answer. The lesson here is to look carefully at all the choices.

Your Self Image as a Student

To a large extent, many people perform at the level of their own self image. One thing to get straight in your mind at the beginning of the course is that you are capable of mastering the material in your physics course. Some students get stuck in the mode of saying something like, "I have always been a C student." There is a simple logical argument that will show you that C students in physics or mathematics or any subject where skill is built from course to course are not getting C's because of their understanding of the material, but because that is how they view themselves, consciously or unconsciously. In a series of three to five sequential mathematics courses, for example, it is virtually impossible to go from one course to the next, let alone a sequence of several, without eventually mastering the material in each previous course. Think back to your first math course where you were taught how to add, subtract, multiply, and divide. At some point in that course you may have thought that you *couldn't* understand certain concepts. By now you have mastered those skills. College physics is the same way. You are mentally capable of understanding and even mastering basic physics. Now it is true that different people learn at different speeds. You may need to spend a little extra time on physics or, more likely, make more effective use of your time.

At this point you need to set a goal for yourself in your physics course. The first question is how important is physics in your academic program. If you are a biology major and you are taking physics only because it is a general requirement, then your primary goals should be to get the best grades in your biology courses, since that is your major. If one

of your goals is to have a high G.P.A., then you should strive for an A or at least a B. If your major is physics or engineering then you should definitely go for an A in this course. Write down your goals and check them off as they are accomplished. Your goals for the first part of a physics course may look something like this:

Main Goal: An A in Physics I

Week 1: Establish a schedule for reading text, reviewing notes, and doing homework problems.

Week 2: Investigate the possibility of joining a study group.

Week 3: Find out if past exams from this professor are available; find out how many points it will take to make an A on the first test.

Week 4: Prepare and take sample exams for the first test.

The purpose of writing down your goals is not to create more work, but to keep you focused on the most important things that you need to accomplish as the semester progresses. Please remember that all of the study techniques outlined in this chapter are designed to make achieving higher grades *easier* for you. The sooner you become more organized and focused on your goals, the sooner you will begin to realize that you are capable of impressive accomplishments with a reasonable amount of effort.

Perhaps physics is a favorite area of study that you may wish to pursue in the future or perhaps you are primarily interested in the most efficient way to make it through this course. Whatever you choose for your major area of study, find something you enjoy and pursue excellence. Give it your best today, and better tomorrow. We wish you success.

MATHEMATICAL BACKGROUND

The purpose of this chapter is to provide you with a review of and reference for the mathematical techniques you will need in working the physics problems in this book. Some topics may be familiar to you while others may not. Depending on the mathematical level of your physics course, some topics may not be of interest to you. Each topic is covered in sufficient depth to allow you to perform the mathematical manipulations necessary for a particular problem without getting bogged down in lengthy derivations. It is not our intention to teach mathematics, but to show you how to apply specific mathematical procedures to physics problems.

The most efficient use of this chapter is for you to do a brief review of the chapter, spending time on those sections that are unfamiliar to you and that you know you will need in your course, then refer to specific topics as they are encountered in the solution to problems. With this reference you should be able to perform all the mathematical operations necessary to complete the problems in your physics course. If you need or desire more depth in a particular topic go to an algebra or calculus text.

Solving Equations

The simplest equations to solve are the linear equations of the form $ax + b = 0$ which have as solution $x = -b/a$. You should be very familiar with these.

The next most complicated equations are the quadratics. The simplest quadratic is the type that can be solved by taking square roots directly, without any other manipulations.

An example is $4x^2 = 36$, which is first divided by 4 to read $x^2 = 9$ and square roots taken to produce $x = \pm 3$. Both plus and minus values are legitimate solutions. The reality of the physical problem producing the equation may dictate that one of the solutions be discarded.

The next complication in quadratic equations is the factorable equations such as $x^2 - x - 6 = 0$, which can be factored to $(x - 3)(x + 2) = 0$. The solutions, the values of x that make each set of parentheses equal to zero and satisfy the factored equation, are $x = 3$ and $x = -2$.

If the quadratic cannot be solved by factoring, the most convenient solution is by quadratic formula, a general formula for solution of any quadratic equation in the form $ax^2 + bx + c = 0$.

The solution according to the quadratic formula is

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

See any algebra book for a derivation of this formula.