Preface

This text gives a good, traditional coverage for students of Modern Physics. The organization of the text follows the traditional sequence of Special Relativity, General Relativity, Quantum Physics, Atomic Physics, Nuclear Physics, and Elementary Particle Physics and the Unification of the Forces. The emphasis throughout the book is on simplicity and clarity.

There are a large number of diagrams and illustrative problems in the text to help students visualize physical ideas. Important equations are highlighted to help students find and recognize them. A summary of these important equations is given at the end of each chapter.

To simplify the learning process I have computerized every illustrative example in the textbook using computer spreadsheets. These computerized *Interactive Examples* will allow the student to solve the example problem in the textbook, with all the in-between steps, many times over but with different numbers placed in the problem. The Interactive Examples are available on a computer disk for both the instructor and the student. More details on these Interactive Examples can be found in the section “Computer Aided Instruction” at the end of the Preface.

Students sometimes have difficulty remembering the meanings of all the vocabulary associated with new physical ideas. Therefore, a section called *The Language of Physics*, found at the end of each chapter, contains the most important ideas and definitions discussed in that chapter.

To comprehend the physical ideas expressed in the theory class, students need to be able to solve problems for themselves. Problem sets at the end of each chapter are grouped according to the section where the topic is covered. Problems that are a mix of different sections are found in the Additional Problems section. If you have difficulty with a problem, refer to that section of the chapter for help. The problems begin with simple, plug-in problems to develop students’ confidence and to give them a feel for the numerical magnitudes of some physical quantities. The problems then become progressively more difficult and end with some that are very challenging. The more difficult problems are indicated by a star (*). The starred problems are either conceptually more difficult or very long. Many problems at the end of the chapter are very similar to the illustrative problems worked out in the text. When solving these problems, students can use the illustrative problems as a guide, and use the Interactive Examples as a check on their work.

A section called *Interactive Tutorials*, which also uses computer spreadsheets to solve physics problems, can be found at the end of the problems section in each chapter. These Interactive Tutorials are a series of problems, very much like the interactive examples, but are more detailed and more general. They are also available on a computer disk for both the instructor and the student. More details on these Interactive Tutorials can be found in the section “Computer Aided Instruction” at the end of the Preface.

A series of questions relating to the topics discussed in the chapter is also included at the end of each chapter. Students should try to answer these questions to see if they fully understand the ramifications of the theory discussed in the chapter. Just as with the problem sets, some of these questions are either conceptually more difficult or will entail some outside reading. These more difficult questions are also indicated by a star (*).

In this book only SI units will be used in the description of physics. Occasionally, a few problems throughout the book will still have some numbers in the British Engineering System of Units. When this occurs the student should convert these numbers into SI units, and proceed in solving the problem in the International System of Units.

A Bibliography, given at the end of the book, lists some of the large number of books that are accessible to students taking modern physics. These books cover such topics in modern physics as relativity, quantum mechanics, and elementary particles. Although many of these books are of a popular nature, they do require some physics background. After finishing this book, students should be able to read any of them for pleasure without difficulty.

A Special Note to the Student

"One thing I have learned in a long life: that all our science measured against reality, is primitive and childlike--and yet it is the most precious thing we have."

Albert Einstein
as quoted by Banesh Hoffmann in
Albert Einstein, Creator and Rebel

The language of physics is mathematics, so it is necessary to use mathematics in our study of nature. However, just as sometimes "you cannot see the forest for the trees," you must be careful or "you will not see the physics for the mathematics." Remember, mathematics is only a tool used to help describe the physical world. You must be careful to avoid getting lost in the mathematics and thereby losing sight of the physics. When solving problems, a sketch or diagram that represents the physics of the problem should be drawn first, then the mathematics should be added.

Physics is such a logical subject that when a student sees an illustrative problem worked out, either in the textbook or on the blackboard, it usually seems very simple. Unfortunately, for most students, it is simple only until they sit down and try to do a problem on their own. Then they often find themselves confused and frustrated because they do not know how to get started.

If this happens to you, do not feel discouraged. It is a normal phenomenon that happens to many students. The usual approach to overcoming this difficulty is going back to the illustrative problem in the text. When you do so, however, do not look at the solution of the problem first. Read the problem carefully, and then try to solve the problem on your own. At any point in the solution, when you cannot proceed to the next step on your own, peek at that step and only that step in the illustrative problem. The illustrative problem shows you what to do at that step. Then continue to solve the problem on your own. Every time you get stuck, look again at the appropriate solution step in the illustrative problem until you can finish the entire problem. The reason you had difficulty at a particular place in the problem is usually that you did not understand the physics at that point as well as you thought you did. It will help to reread the appropriate theory section. Getting stuck on a problem is not a bad thing, because each time you do, you have the opportunity to learn something. Getting stuck is the first step on the road to knowledge. I hope you will feel comforted to know that most of the students who have gone before you also had these difficulties. You are not alone. Just keep trying. Eventually, you will find that solving physics problems is not as difficult as you first thought; in fact, with time, you will find that they can even be fun to solve. The more problems that you solve, the easier they become, and the greater will be your enjoyment of the course.

Computer Assisted Instruction

Interactive Examples

The computerized *Interactive Examples* in the book will allow the student to solve the example problem in the textbook, with all the in-between steps, many times over but with different numbers placed in the problem.
Figure 1 shows an example from Chapter 1 of the textbook for solving a problem dealing with the Lorentz contraction.. It is a problem in special relativity in which a man on the earth measures an event at a particular point from him at a particular time. If a rocket ship flies over the man at a particular speed, what coordinates does the astronaut in the rocket ship attribute to this event?

The example in the textbook shows all the steps and reasoning done in the solution of the problem.

Example 1.5

Lorentz transformation of coordinates. A man on the earth measures an event at a point 5.00 m from him at a time of 3.00 s. If a rocket ship flies over the man at a speed of 0.800*c*, what coordinates does the astronaut in the rocket ship attribute to this event?

Solution

The location of the event, as observed in the moving rocket ship, found from equation 1.49, is

$$x' = \frac{x - vt}{\sqrt{1 - v^2 / c^2}}$$

$$x' = \frac{5.00\ \text{m} - (0.800)(3.00 \times 10^8\ \text{m/s})(3.00\ \text{s})}{\sqrt{1 - (0.800c)^2 / c^2}}$$

$$= -1.20 \times 10^9\ \text{m}$$

This distance is quite large because the astronaut is moving at such high speed. The event occurs on the astronaut's clock at a time

$$t' = \frac{t - vx / c^2}{\sqrt{1 - v^2 / c^2}}$$

$$= \frac{3.00\ \text{s} - (0.800)(3.00 \times 10^8\ \text{m/s})(5.00\ \text{m})/(3.00 \times 10^8\ \text{m/s})^2}{\sqrt{1 - (0.800c)^2 / c^2}}$$

$$= 5.00\ \text{s}$$

To go to this Interactive Example click on this sentence.

Figure 1 Example 1.5 in the textbook.

The last sentence in blue type in the example* (To go to this interactive example click on this sentence.) *allows the student to access the interactive example for this same problem. Clicking on the blue sentence, the spreadsheet shown in figure 2 opens*.** Notice that the problem is stated in the identical manner as in the textbook. Directly below the stated problem is a group of yellow-colored cells labeled **Initial Conditions.** Into these yellow cells are placed the numerical values associated with the particular problem. The problem is now solved in the identical way it is solved in the textbook. Words are used to describe the physical principles and then the equations are written down. Then the in-between steps of the calculation are shown in light green-colored cells, and the final result of the calculation is shown in a light blue-colored cell. The entire problem is solved in this manner, as shown in figure 2. If the student wishes to change the problem by using a different initial condition, he or she then changes these values in the yellow-colored cells of the initial conditions. When the initial conditions are changed the computer spreadsheet recalculates all the new in-between steps in the problem and all the new final answers to the problem. In this way the problem is completely interactive. It changes for every new set of initial conditions. *The Interactive Examples make the book a living book. The examples can be changed many times over to solve for all kinds of special cases.* ***When the student is finished with the interactive example, and is accessing it from a CD, he or she just clicks on the X in the extreme upper right-hand corner of the spreadsheet screen, returning him or her to the original example in the

"The Fundamentals of the Theory of Modern Physics"

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Chapter 1 Special Relativity

Computer Assisted Instruction

Interactive Examples

Example 1.5

Lorentz transformation of coordinates. A man on the earth measures an event at a point 5.00 m from him at a time of 3.00 s. If a rocket ship flies over the man at a speed of 0.800c, what coordinates does the astronaut in the rocket ship attribute to this event?

Initial Conditions

x =	5	m				t =	3	s
v =	0.8	c	=	2.4E+08	m/s	c =	3.00E+08	m/s

Solution.

The location of the event, as observed in the moving rocket ship, found from equation 1.49, is

x' = (x - v t) /sqrt[1 - v^2 / c^2]

x' = [(5 m) - (2.4E+08 m/s) x (3 s)]
/ sqrt[1 - (0.8 c)^2 / (1 c)^2}]
x' = -1.20E+09 m

This distance is quite large because the astronaut is moving at such high speed. The event occurs on the astronaut's clock at a time

t' = (t - v x /c^2) / sqrt[1 - v^2 / c^2]

t' = [(3 s) - (2.4E+08 m/s) x (5 m) / (3.00E+08 m/s)^2]
/ sqrt[1 - (2.40E+08 m/s)^2 / (3.00E+08 c)^2}]
t' = 5 s

Figure 2 Interactive Example 1.5 in Microsoft Excel Spreadsheet.

textbook chapter. If the student is accessing the interactive example from a web page, then he or she presses the go Back button on the top of the browser page. When Excel closes, you will be returned to the first page of the present chapter. You can then go to wherever page you want in that chapter by sliding the Scroll Bar box on the right-hand side of the screen.

These *Interactive Examples* are a very helpful tool to aid in the learning of modern physics if they are used properly. The student should try to solve the particular problem in the traditional way using paper and an electronic calculator. Then the student should open the spreadsheet, insert the appropriate data into the Initial Conditions cells and see how the computer solves the problem. Go through each step on the computer and compare it to the steps you made on paper. Does your answer agree? If not, check through all the in-between steps on the computer and your paper and find where your made a mistake. *Do not feel bad if you make a mistake. There is nothing wrong in making a mistake, what is wrong is not learning from your mistake.* Now that you understand your mistake, repeat the problem using different Initial Conditions on the computer and your paper. Again check your answers and all the in-between steps. Once you are sure that you know how to solve the problem, try some special cases. What would happen if you changed an angle?, a weight?, a force? etc. In this way you can get a great deal of insight into the physics of the problem and also learn a great deal of modern physics in the process**.**

You must be very careful not to just plug numbers into the Initial Conditions and look at the answers without understanding the in-between steps and the actual physics of the problem. You will only be deceiving yourself. Be careful, these spreadsheets can be extremely helpful if they are used properly.

We should point out two differences in a text example and in a spreadsheet example. Powers of ten that are used in scientific notation in the text are written with the capital letter E in the spreadsheet. Hence, the number 5280, written in scientific notation as 5.280×10^3, will be written on the spreadsheet as 5.280E+3. Also, the square root symbol, $\sqrt{\ }$, in the textbook is written as sqrt[ ] in a spreadsheet. Finally, we should note that the spreadsheets are "protected" by allowing you to enter data only in the designated light yellow-colored cells of the Initial Conditions area. Therefore, the student cannot damage the spreadsheets in any way, and they can be used over and over again.

To access these Interactive Examples the student must have Microsoft's Excel computer spreadsheet installed on his computer.

Computer Assisted Instruction
Interactive Tutorials

Besides the Interactive Examples in this text, I have also introduced a section called Interactive Tutorials at the end of the problem section in each chapter. These Interactive Tutorials are a series of problems, very much like the interactive examples, but are more detailed and more general. The Interactive

Tutorials are available on the DVD and the Internet, but the student must have Microsoft's Excel computer spreadsheet on his or her computer.

***To access the Interactive Tutorial, the student will click on the sentence in blue type at the end of the Interactive Tutorials section* (To go to this interactive tutorial click on this sentence.) *Clicking on the blue sentence, opens the appropriate spreadsheet*.**

Figure 3 show a typical Interactive Tutorial for problem 46 in chapter 1. It shows the change in mass of an object when it is in motion. When the student opens this particular spreadsheet, he or she sees the problem stated in the usual manor.

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Chapter 1 Special Relativity

Computer Assisted Instruction

Interactive Tutorial

46. Relativistic mass. A mass at rest has a value m_o = 2.55 kg. Find the relativistic mass m when the object is moving at a speed v = 0.355 c.

Initial Conditions

m_o = 2.55 kg c = 3.00E+08 m/s
v = 3.55E-01 c = 1.07E+08 m/s

For speeds that are not given in terms of the speed of light c use the following converter to find the equivalent speed in terms of the speed of light c. Then place the equivalent speed into the yellow cell for v above.

v = 1610 km/hr = 447.58 m/s = 1.49E-06 c
v = 1.61E+06 m/s = 5.37E-03 c

The relativistic mass is given by equation 1.86 as

$$m = m_o / \mathrm{sqrt}[1 - (v^2)/(c^2)]$$

m = (2.55 kg)/sqrt[1 - (1.07E+08 m/s)^2 / (3.00E+08 m/s)^2]
m = 2.7276628 kg

Figure 3. A typical Interactive Tutorial.

Directly below the stated problem is a group of yellow-colored cells labeled **Initial Conditions.**

Into these yellow cells are placed the numerical values associated with the particular problem. For this problem the initial conditions consist of the rest mass of the object, it speed, and the speed of light as shown in figure 3. The problem is now solved in the traditional way of a worked out example in the book. Words are used to describe the physical principles and then the equations are written down. Then the in-between steps of the calculation are shown in light green-colored cells, and the final result of the calculation is shown in a light blue-green-colored cell. The entire problem is solved in this manor as shown in figure 3. If the student wishes to change the problem by using a different initial mass or speed, he or she then changes these values in the yellowed-colored cells of the initial conditions. When the initial conditions are changed the computer spreadsheet recalculates all the new in-between steps in the problem and all the new final answers to the problem. In this way the problem is completely interactive. It changes for every new set of initial conditions. The tutorials can be changed many times over to solve for all kinds of special cases.

These Interactive Tutorials are a very helpful tool to aid in the learning of modern physics if they are used properly. The student should try to solve the particular problem in the traditional way using paper and an electronic calculator. Then the student should open the spreadsheet, insert the appropriate data into the Initial Conditions cells and see how the computer solves the problem. Go through each step on the computer and compare it to the steps you made on paper. Does your answer agree? If not, check through all the in-between steps on the computer and your paper and find where you made a mistake. Repeat the problem using different Initial Conditions on the computer and your paper. Again check your answers and all the in-between steps. Once you are sure that you know how to solve the problem, try some special cases. What would happen if you changed some of the initial conditions. In this way you can get a great deal of insight into the physics of the problem and also learn a great deal of physics in the process.

You must be very careful not to just plug numbers into the Initial Conditions and look at the answers without understanding the in-between steps and the actual physics of the problem. You will only be deceiving yourself. Be careful, these spreadsheets can be extremely helpful if they are used properly.

When the student is finished with the interactive tutorial, and is accessing it from a CD or DVD, he or she just clicks on the X in the extreme upper right-hand corner of the spreadsheet screen, returning him or her to the original tutorials in the textbook chapter.

Click on this sentence to go to the "Table of Contents" which will allow you to go to any chapter in this book.

To access a particular chapter, double click on that chapter below.

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