JERRY D. WILSON / ANTHONY J. BUFFA

COLLEGE PHYSICS

THIRD EDITION

College Physics

Third Edition

Jerry D. Wilson

Lander University

Anthony J. Buffa

California Polytechnic State University
San Luis Obispo

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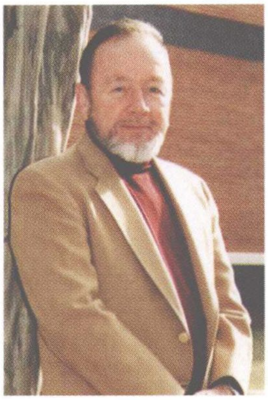
About the Authors



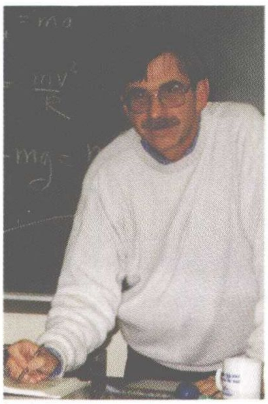
Jerry D. Wilson

Jerry Wilson, a native of Ohio, is now Emeritus Professor of Physics and former Chair of the Division of Biological and Physical Sciences at Lander University in Greenwood, South Carolina. He received his B.S. degree from Ohio University, M.S. degree from Union College, and in 1970, a Ph.D. from Ohio University. He earned his M.S. degree while employed as a Materials Behavior Physicist by the General Electric Co.

As a doctoral graduate student, Professor Wilson held the faculty rank of Instructor and taught physical science courses. During this time, he co-authored a physical science text, which is now in its eighth edition. In conjunction with his teaching career, Professor Wilson has continued his writing and now has six titles in print that he has authored or co-authored. Recently retired from full-time teaching, he continues to write, including a weekly column, The Science Corner, for local newspapers.

With several competitive books available, one may wonder why another algebra-based physics text was written. Having taught introductory physics many times, I was well aware of the needs of students and the difficulties they have in mastering the subject. I decided to write a text that presented the basic physics principles in a clear and concise manner, with illustrative examples that help the major difficulty in learning physics: problem solving. Also, I wanted to write a text that is relevant so as to show students how physics applies in their everyday world—how things work and why things happen. Once the basics are learned, these follow naturally.

—Jerry Wilson



Anthony J. Buffa

Anthony Buffa received his B.S. degree in Physics from Rensselaer Polytechnic Institute and both his M.S. and Ph.D. degrees in Physics from the University of Illinois, Champaign-Urbana. In 1970, Professor Buffa joined the faculty at California Polytechnic State University, San Luis Obispo, where he is currently Professor of Physics, and has been a research associate with the Department of Physics Radioanalytical Facility since 1980.

Professor Buffa's main interest continues to be teaching. He has taught courses at Cal Poly ranging from introductory physical science to quantum mechanics, has helped in developing and revising laboratory experiments, and along with his colleagues has spent several summers teaching elementary physics to local teachers in a workshop sponsored by the NSF. With a strong interest in art and architecture, Dr. Buffa also spends a great deal of time developing his own artwork and sketches to be used in the teaching of introductory physics.

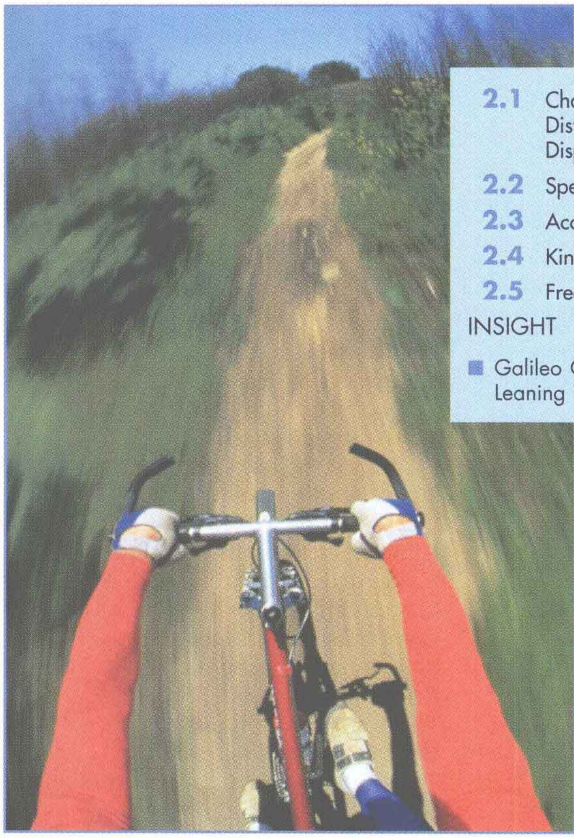
I try to emphasize to students how neat physics is, and I always make sure that significant components of my lectures, tests, and homework are conceptual and qualitative in nature. Only after the concepts are understood do we crunch numbers. This was the major reason that Jerry Wilson's book intrigued me: it had the same philosophy, was well-written, had simple but powerful artwork, and was concisely presented.

—Tony Buffa

How to Use this Text: A Guide for Students

Your instructor may select the text you use, but you are the one we are writing it for. We've tried to keep the material concise, focusing on the most important concepts, and yet rich with a variety of tools to help you understand physics as easily and as well as possible. The following few pages are designed to give you an overview of these tools and how you might best put them to use.

2 Kinematics: Description of Motion



2.1 Change of Position: Distance and Displacement
2.2 Speed and Velocity
2.3 Acceleration
2.4 Kinematic Equations
2.5 Free Fall
INSIGHT
■ Galileo Galilei and the Leaning Tower of Pisa

YOU can't look at a photo like this without mentally putting yourself into the picture. But how would you describe what you're experiencing? The sense of motion is so strong you can almost feel the air rushing by you. And yet, it's all an illusion! Motion takes place in time, but the photo can only "freeze" a single instant. How fast are you going? Are you speeding up as you plummet down the trail? Or are you braking to slow down? You'll find that, without the dimension of time, you can hardly describe motion at all.

In this chapter we'll define motion and explore ways of describing it. We'll also learn to analyze changes in motion—speeding up, slowing down, stopping. Along the way, we'll deal with a particularly interesting case of accelerated motion: free fall under the influence only of gravity.

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Have you ever felt as though many of your courses and texts just presented a long list of unrelated facts? **Chapter outlines** give you a quick "map" of the chapter to help you see the big picture and how all the pieces relate to each other.

What is physics to you? Does it seem like an abstract subject, unrelated to the world around you? In reading this text, we hope you'll come to see that, on the contrary, physics is exactly the study of the world around you. **Chapter opening photos** such as this one, along with extended captions, emphasize the connection between your world and the physics concepts that will be developed in the chapter ahead.

17.4 Electric Power

Objectives: **To be able to (a) define electric power, (b) calculate the power delivery of simple electric circuits, and (c) explain joule heating and its significance.**

How many times have you been reading a textbook and stopped to ask yourself, "What's the point?" or "Where is this leading?" **Integrated learning objectives** at the beginning of every chapter section help you focus on the most important concepts in the section ahead.

Conceptual Understanding is an Essential Problem-Solving Skill

If you understand why something works, you'll be able to use that knowledge over and over again, in many different situations. Throughout this book, we've stressed the fact that **conceptual understanding**—the "why"—is the basis for mastering a variety of problem-solving tools.

Suggested Problem-Solving Procedure

Say it in words

1. *Read the problem carefully and analyze it. Write down the given data and what it is you are to find.* Some data may not be given explicitly in numerical form. For example, if a car "starts from rest," its initial speed is zero ($v_o = 0$). In some instances, you may be expected to know certain quantities or to look them up in tables.

Say it in pictures

2. *Draw a diagram as an aid in visualizing and analyzing the physical situation of the problem where appropriate.* (This may not be necessary in every case, but it is usually helpful and can never do any harm.)

Say it in equations

3. *Determine what principle(s) and equation(s) are applicable to this situation, and how they can be used to get from the information given to what is to be found.* Keep in mind that many problems cannot be solved simply by plugging all of the given data into one equation; you may have to devise a strategy involving several steps.

Simplify the equations

4. *Simplify mathematical expressions as much as possible through algebraic manipulation before inserting actual values.* Trigonometric relationships (summarized in Appendix I) can also be used to simplify equations sometimes. The less calculation you do, the less likely you are to make a mistake—so *don't put the numbers in until you have to.*

Check the units

5. *Check units before doing calculations.* Make unit conversions if necessary so that all units are in the same system and quantities with the same dimensions have the same units (preferably standard units). This avoids mixed units and is helpful in unit analysis. (Unit checking and conversions are often done in Step 1 when writing the data.)

Insert numbers and calculate; check significant figures

6. *Substitute given quantities into equation(s) and perform calculations. Report the result with proper units and number of significant figures.*

Check the answer: is it reasonable?

7. *Consider whether the result is reasonable.* Does the answer have priate magnitude? (This means, is it "in the right ballpark"?) ple, if a person's calculated mass turns out to be 2.30×10^2 kg, should be questioned, since 230 kg corresponds to a weight of

So, how do you get started? What generally is involved in solving physics problems? An extensive section in Chapter 1 (pp. 19–23) provides you with **a framework for thinking about problem solving.** Think of this seven step process as a set of general guidelines that can be applied to most problems.

To see the general problem solving procedures in action, work through the following three examples that show sample solutions with each step re-stated (and indicated by the number in red).

Example 1.8 ■ Finding the Area of a Rectangle: Problem-Solving Procedure

Two students measure the lengths of adjacent sides of their dorm room. One reports 15 ft, 8 in., and the other reports 4.25 m. What is the area of the room in square meters?

Solution.

1. Adjacent sides of a room give its length and width, so we may write

   Given: Length = l = 15 ft, 8 in. Width = w = 4.25 m ***Find:*** Area (in m^2)

2. Sketch a diagram to help visualize the situation (Fig. 1.10).

3 and 4. For this simple situation, the required equation is well known. The area (A) of a rectangle is $A = l \times w$, both of which are given.

5. It is obvious that a unit change is necessary. Let's first convert the length measurement to inches and then inches to meters:

$$15 \text{ ft} + 8 \text{ in.} = \left(15 \text{ ft} \times \frac{12 \text{ in.}}{\text{ft}}\right) + 8 \text{ in.} = 188 \text{ in.}$$

and

$$188 \text{ in.} \times \frac{2.54 \text{ cm}}{\text{in.}} = 478 \text{ cm} = 4.78 \text{ m}$$

Notice how easy it is to convert units in the decimal metric system (cm to m). You should perform the conversion explicitly if necessary, using the conversion factor (1 m/100 cm).

6. Now perform the calculation.

$$A = l \times w = 4.78 \text{ m} \times 4.25 \text{ m}$$
$$= 20.315 \text{ m}^2 = 20.3 \text{ m}^2 \quad \text{(computed value rounded to 3 sf—why?)}$$

7. The answer appears reasonable. Since 1 m ≈ 3 ft, the dorm room would be about 13 ft by 14 ft, which is about right (but, as always, too small). Suppose you had inadvertently punched 47.8 instead of 4.78 on your calculator. The result would be $A = 47.8 \text{ m} \times 4.25 \text{ m} = 203 \text{ m}^2$. A room with an area of about 200 m^2 would have dimensions of about 10 m by 20 m, which is roughly 30 ft by 60 ft. Since this is not the size of a typical dorm room, the magnitude of the result should make you suspect there may be an error.

Follow-up Exercise. The dimensions of a textbook are 0.22 m × 0.26 m × 4.0 cm. What volume in a book bag would the book take up? Give the answer in both m^3 and cm^3. *(Answers may be found in the Answers to Follow-up Exercises section at the back of the book.)*

PROBLEM-SOLVING STRATEGIES: "BALLPARK" AND ORDER-OF-MAGNITUDE CALCULATIONS

Calculations such as we have performed above are sometimes known as "ballpark" or "back of the envelope" calculations. In performing such calculations we know that, because the data are only approximate (they are not known precisely, or they are being rounded off to simple whole numbers for the purpose of rapid calculation), the answer can't be taken as very accurate (see Section 1.6). However, it is often precise enough for our needs. In the example given above, some of the data were unavoidable approximations (the glacier obviously isn't a simple rectangular object), while others, such as the density of ice, were deliberately approximated to simplify calculation. Nevertheless, this method gave us a good idea of the relative momenta and kinetic energies of the three objects.

Physicists often find it convenient to use a formalized version of the "ballpark" approach, commonly known as *order-of-magnitude calculation.* In this method, all values are rounded off to the nearest "order of magnitude," or power of 10: 10^2, 10^3, 10^4, etc. Since it is very easy to multiply and divide powers of 10, this shortcut makes calculation very fast. However, although sometimes just the powers of 10 can be used in a calculation, it is usually a good idea to retain one significant figure of the prefix. This is particularly true when quantities are squared or raised to higher powers, as in the kinetic energy calculations. For instance, $v_s = 4 \times 10^2$ m/s or ≈ 10^2 m/s. Then $v_s^2 = (4 \times 10^2 \text{ m/s})^2 = 16 \times 10^4 \text{ m}^2/\text{s}^2 \approx 10^5 \text{ m}^2/\text{s}^2$. However, if we had just used 10^2 m/s, we would have obtained 10^4 m^2/s^2.

In order-of-magnitude calculations, we can generally expect the answer to be correct to the nearest order of magnitude. In other words, if we get an answer of 1000, the true value might really be 750 or 1200, but we can be pretty confident that it is closer to 1000 than to 100 or to 10,000.

Example:

A light-year—a unit widely used in astronomy—is the distance light travels in one year in a vacuum. The speed of light is $c = 3.00 \times 10^8$ m/s. Approximately how many meters are there in a light-year?

Solution:

From the Conversion Factors Table inside the front cover (or simple calculation), we know that there are 3.16×10^7 s in one year. Using the relationship, distance = speed × time,

$$d = ct = (3 \times 10^8 \text{ m/s})(3 \times 10^7 \text{ s}) \approx 10^{16} \text{ m}$$

Note that the product of the powers of 10 gives 10^{15}, but 3 × 3 = 9, so the prefixes give about another order of magnitude. Thus $(10 \times 10^{15}) = 10^{16}$ is the order of magnitude of the number of meters in a light-year.

While the general seven-step problem solving procedure can be applied to most problems, more situation-specific **problem solving hints and strategies** are provided in boxes throughout the text.

Visualization is one of the most important problem solving tools in physics. In many cases, if you can make a sketch of problem, you can probably solve it. You noted that we recommended "saying it in pictures" as the second step in general problem solving. **"Learn by Drawing"** features throughout the book show you how visualization can provide key insights into a variety of physical situations.

LEARN BY DRAWING

Leaning on Isotherms

When you are analyzing the various thermodynamic processes discussed in this chapter, it is sometimes hard to keep track of the heat flow (Q), work (W), and internal energy change (ΔU), together with their correct signs. One trick that can help with this bookkeeping is to superimpose a series of isotherms on the pV plot you are working with (as in Figures 12.2–12.5). This is generally useful even if the situation you are studying does not involve an isothermal process. It is also a good way of reinforcing your insight into what is happening physically in these processes.

Before starting, recall the two important properties of an isothermal process. Both of them follow directly from the fact that an isothermal process is, by definition, one in which the temperature remains constant.

1. In an isothermal process ΔU is zero. (Why?)
2. Since T is constant, the ideal gas law (Eq. 10.3) tells us that in an isothermal process pV must also be constant: $pV = k$. You may recall from algebra that this is the equation of a hyperbola, and on a pV diagram, each isotherm is indeed a hyperbola. The farther from the axes the hyperbola is, the higher the temperature that it represents (Fig. 1).

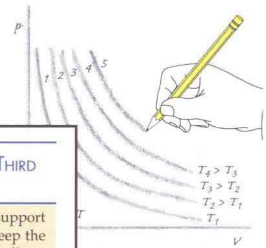
To take advantage of these properties, follow these steps:

- Sketch a set of isotherms for a series of different temperatures on the pV plot (Fig. 1).
- Then sketch the actual process or processes you are analyzing—for example, those shown in Fig. 2 and Fig. 3. (Take a moment to remind yourself what the names mean: isomet = constant volume, isobar = constant pressure, and adiabat = no heat flow.)
- Finally, use the first law of thermodynamics, $Q = \Delta U + W$, to calculate the final results, including signs. Usually, you will be able to find the sign of W by remembering that W is simply the area under the pV curve for the process represented. The sign of ΔT will be clear from the isotherms that you have added; they will serve as a temperature scale, with progressively higher temperatures represented by isotherms at greater distances from the axes. A rise in T implies a positive value for ΔU, since the internal energy of the gas increases with its temperature. You will thus have all you need to determine the sign of Q, and thus whether heat flows into the system ($Q > 0$) or out of it ($Q < 0$).

The following two examples indicate the power of this approach. In Fig. 2, we are asked to determine whether heat flows into or out of the gas during an isobaric expansion. Expansion implies positive work ($p\Delta V > 0$). But what is the direction of the heat flow (or is it zero)? Sketching the isobar (with an arrow pointing to the right to indicate expansion), we see that it crosses from lower-temperature isotherms to higher-temperature ones. Hence there is a temperature increase, and ΔU must be positive. Since the gas has both gained internal energy and done positive work, both terms on the right-hand side of the first law equation are positive, so it follows that Q must be positive: $Q = (\Delta U + p\Delta V) > 0$. Positive heat flow means "into the gas," so we have our answer.

An isometric process involving a pressure drop is similarly analyzed in Fig. 3. Again, starting with lightly-drawn isotherms on the pV axes, we plot a vertical line (constant volume) with an arrow pointing downward to show pressure reduction. Since there is no volume change, the gas does no work. However, we can see that its temperature drops (why?), so its internal energy must decrease. This means that ΔU is negative, hence Q must be negative ($Q = \Delta U + p\Delta V = \Delta U < 0$). Thus heat flows out of the gas.

As an exercise, try analyzing an adiabatic processes in this way to see if you can graphically determine where the work comes from if there is no heat flow into or out of the gas.



...sotherms on a pV plot

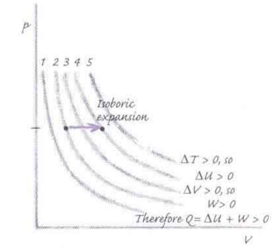


FIGURE 2 An isobaric expansion

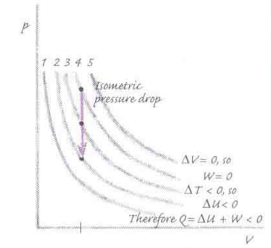


FIGURE 3 An isometric decline in pressure

Conceptual examples reinforce the importance of understanding basic principles and give you practice in reasoning about physical situations.

CONCEPTUAL EXAMPLE 4.9 ■ A JUMBLED JUGGLER: NEWTON'S THIRD LAW

A juggler carrying three heavy balls wants to cross a weak bridge that will support only his weight and two of the balls. Relying on his trade, he decides that to keep the bridge from collapsing and to save time, he will cross the bridge juggling the balls so that one is in the air at all times. Does he make it across safely? (a) yes (b) no *Clearly establish the reasoning and physical principle(s) used in determining your answer before checking below. That is, **why** did you select your answer?*

Reasoning and Answer. The juggler has apparently not studied Newton's laws. When throwing a ball upward, a force must be applied that is *greater* than the weight of the ball. (Why?) So, the juggler exerts an upward force on the ball, and the ball exerts an equal and opposite force on the juggler (Newton's third law). This adds a force *greater* than the weight of a third ball to the downward force already acting on the bridge (the juggler's weight and that of the other two balls). Down the bridge would go, so the answer is (b).

We can confirm this conclusion by analyzing the situation algebraically. The juggler's weight with three balls is $F = (M + 3m)g$. When juggling with one ball in the air, the weight is less, only $(M + 2m)g$. However, the force needed to accelerate the third ball upward is $mg + ma$. (Can you see why?) Thus, on the initial upward throw, the total downward force on the bridge would be $F' = (M + 2m)g + (mg + ma)$, or $F' = (M + 3m)g + ma$; and afterward, with one ball in the air, $F' = (M + m)g + (mg + ma)$, or $F' = (M + 2m)g + ma$. So it is clear that the juggler is no better off trying to juggle the third ball than just carrying it. Either way, he will get wet.

Follow-up Exercise(s). (a) Would the juggler be able to continue juggling while he was falling? (b) A canary is in a cage with an open wire floor that is suspended a sensitive scale. The weight of the cage and bird is noted when the bird is on a When the yellow bird is flying around in the cage, is the scale reading different? how? *(Reasoning and Answers may be found in the Answers to Follow-up Exercises sect the back of the book.)*

Worked examples talk you through sample problems with fully explained step-by-step solution strategies. All worked examples close with a follow-up exercise, allowing you to test your understanding of the relevant concepts by tackling a closely related problem. Answers are in the back of the book so you can check your answer and make sure you're on the right track.

EXAMPLE 8.5 ■ STACK THEM UP! CENTER OF GRAVITY

Uniform, identical bricks 20 cm long are stacked so that 4.0 cm of a brick extends beyond the brick beneath, as shown in Fig. 8.12a. How many bricks can be stacked in this way before the stack falls over?

Solution. The stack will fall over when its center of mass is no longer above its base of support, which is the bottom brick. All of the bricks have the same mass, and the center of mass of each is located at its midpoint.

Taking the origin to be at the center of the bottom brick, the horizontal coordinate of the center of mass (or center of gravity) for the first two bricks in the stack is given by Eq. 6.19, where $m_1 = m_2 = m$ and x_2 is the displacement of the second brick:

$$X_{CM_2} = \frac{mx_1 + mx_2}{m + m}$$

$$= \frac{m(x_1 + x_2)}{2m} = \frac{x_1 + x_2}{2} = \frac{0 + 4.0\text{ cm}}{2} = 2.0\text{ cm}$$

Note that the masses of the bricks cancel out (since they are all the same). For three bricks,

How Does Physics Apply to the World Around You?

Applications are an important part of this text; we hope these features will spark your curiosity and answer some of your questions about how things work.

Insight boxes throughout the text show how physical principles discussed in the text apply to a wide variety of real-world situations, devices, and topics. A complete list of the Insight sections and other applications can be found on page xi.

Insight Space Colonies and Artificial Gravity

Space colonies, long a staple of science fiction stories and films, are now actually being planned. However, humans cannot live for long periods of time in a "zero-gravity" environment (see Exercise 71) without detrimental physical effects.

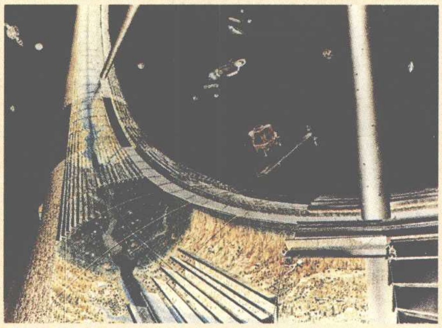


FIGURE 1 Space colony and artificial gravity
It has been suggested that a space colony could be housed in a huge, rotating wheel as in this artist's conception. The rotation would supply the "artificial gravity" for the colonists.

It has been suggested that this problem could be avoided if the colony were housed in a huge rotating wheel, which would supply "artificial gravity" (Fig. 1).

As you know, centripetal force is necessary to keep an object in rotational circular motion. On the rotating Earth, that force is supplied by gravity, and we refer to it as weight. Because of our weight, we exert a force on the ground, and the reaction force (by Newton's third law) upward on our feet gives us the feeling of "having our feet on solid ground." In a rotating space colony, the situation is somewhat reversed. The rotating colony would supply the centripetal force on the inhabitants, which would be perceived as a weight sensation on the soles of our feet, or artificial gravity (Fig. 2a). Rotation at the proper speed would produce a simulation of normal gravity ($g = 9.80\ m/s^2$) within the colony wheel. Note that in the colonists' world, "down" would be outward, toward the periphery of the space station, and "up" would always be inward, toward the axis of rotation.

The inhabitants would experience normal gravitational effects. For example, in Fig. 2a, suppose that the person simply let go of the ball. Viewed from outside the rotating wheel, you would say the ball has a tangential velocity v as a result of the rotation, and would go off in a straight line (Newton's first law) until it hits the side of the wheel (as indicated by the dashed line in the figure). However, the inhabitant rotates with the wheel, and from that perspective, the ball merely falls to the floor as it would on Earth. Think about it.

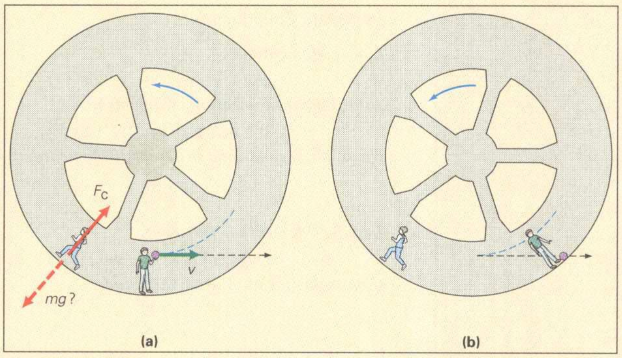
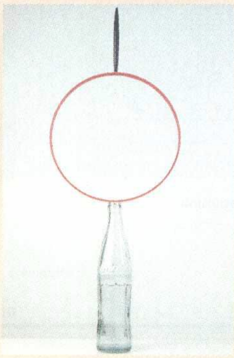


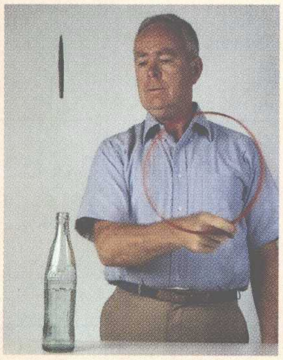
FIGURE 2 Rotating space colony
(a) In the frame of reference of someone in a rotating space colony, the centripetal force on the person would be perceived as weight sensation, or artificial gravity. Rotation at the proper speed would simulate normal gravity. From the point of view of an outside observer, a dropped ball would follow a tangential straight-line path. **(b)** A colonist, on the other hand, would observe the ball to fall downward as in a normal gravitational situation.

DEMONSTRATION 1 ■ Newton's First Law and Inertia

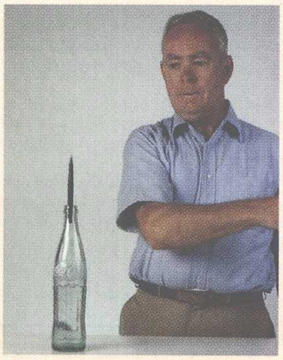
According to Newton's first law, an object remains at rest or in motion with a constant velocity unless acted upon by an unbalanced force.



(a) A pen is at rest on an embroidery hoop on top of a bottle.



(b) The hoop is struck sharply and accelerates horizontally. Because the friction between the pen and hoop is small and acts only for a short time, the pen does not move appreciably in the horizontal direction. However, there is now an unbalanced force acting vertically upon it—gravity.



(c) The pen falls into the bottle.

College Physics 3/*e* has seventeen sequential photographs of physics **demonstrations** in action—and in context of the chapter topic—to help you see and understand the physics being discussed.

Review Your Understanding, Practice Your Skills

The end of chapter review material gives you a brief summary of what you should know before going on to the exercises. Note that while we list the most **important terms, concepts,** and **equations,** we refer you back to the chapter discussion for explanations—again to encourage understanding over memorization.

Chapter Review

Important Terms

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inelastic collision 181
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center of mass (CM) 188
center of gravity (CG) 191
jet propulsion 192
reverse thrust 194

Important Concepts

- Linear momentum of a particle is a vector and is defined as the product of mass and velocity.
- The total linear momentum of a system is the vector sum of the momenta of the individual particles.
- In the absence of a net external force, the total linear momentum is conserved.
- The impulse-momentum theorem relates impulse to the change in momentum.
- A collision is elastic if the total kinetic energy is conserved. Momentum is conserved in both elastic and inelastic collisions. In a completely inelastic collision, objects stick together after impact.
- The center of mass is the point at which all of the mass of an object or system may be considered to be concentrated. (The center of gravity is the point where all the weight may be considered to be concentrated.)

Important Equations

Linear Momentum:

$$\mathbf{p} = m\mathbf{v} \quad (6.1)$$

Total Linear Momentum of a System:

$$\mathbf{P} = \mathbf{p}_1 + \mathbf{p}_2 + \mathbf{p}_3 + \cdots = \Sigma_i \mathbf{p}_i \quad (6.2)$$

Newton's Second Law in Terms of Momentum:

$$\mathbf{F} = \frac{\Delta \mathbf{p}}{\Delta t} \quad (6.3)$$

Impulse-Momentum Theorem:

$$\text{Impulse} = \bar{\mathbf{F}}\,\Delta t = \Delta \mathbf{p} = m\mathbf{v} - m\mathbf{v}_o \quad (6.6)$$

Conditions for an Elastic Collision:

$$\mathbf{P}_f = \mathbf{P}_i, \quad K_f = K_i \quad (6.8)$$

Conditions for an Inelastic Collision:

$$\mathbf{P}_f = \mathbf{P}_i, \quad K_f < K_i \quad (6.9)$$

Final Velocities in Head-On Two-Body Elastic Collisions: ($v_{2_o} = 0$):

$$v_1 = \left(\frac{m_1 - m_2}{m_1 + m_2}\right) v_{1_o} \quad (6.15)$$

$$v_2 = \left(\frac{2m_1}{m_1 + m_2}\right) v_{1_o} \quad (6.16)$$

Coordinate of the Center of Mass (using signs for directions):

$$X_{CM} = \frac{\Sigma_i m_i x_i}{M} \quad (6.19)$$

Each section of **exercises** begins with review and conceptual questions that let you check your understanding of important information and concepts before proceeding to the quantitative problems.

Exercises

6.1 Linear Momentum

1 Linear momentum has units of (a) N/m, (b) kg·m/s, (c) N/s, (d) all of these.

2 Momentum is (a) always conserved, (b) a scalar quantity, (c) a vector quantity that can be resolved into components, (d) unrelated to force.

3 A fan boat of the type used in swampy and marshy areas is shown in •Fig. 6.24. Explain the principle of its propulsion using momentum conservation.

4 Two objects have the same momentum. (a) Will they also have the same kinetic energy? (b) What can you say definitely about their motion?

•**FIGURE 6.24 Fan propulsion**
See Exercise 3.

Most exercises are organized by chapter section to facilitate your review of corresponding text material. However, we encourage you to also work problems from the set of **"Additional Exercises"** at the end of every chapter to make sure you can pull information together from various parts of the chapter without being told to what section the problem applies.

What is an easy problem? What's a tough one? How will you know if you can handle them all? One, two or three black squares in front of a given problem indicates its **level of difficulty**—whether it's generally an easy, moderately challenging, or hard one.

68 ■■■ A stationary submerged submarine tracks an approaching submarine with sonar. A short pulse of ultrasound with a frequency of 400 kHz is sent toward the sub and returns 10 s later with an observed frequency of 412 kHz. (a) What is the speed of the approaching sub? Take the speed of sound in seawater to be 1200 m/s. [*Hint:* The ultrasound received by the moving sub is Doppler-shifted, and the moving sub acts as a moving source of sound with this shifted frequency. That is, the stationary sub receives a reflected pulse that is doubly Doppler-shifted.] (b) What is the approximate range of the approaching sub at the time of reflection?

14.6 Musical Instruments and Sound Characteristics

69 The human ear can best hear tones at (a) 1000 Hz, (b) 4000 Hz, (c) 6000 Hz, (d) any frequency

70 The quality of sound depends on its (a) waveform, (b) frequency, (c) speed, (d) intensity.

71 (a) After a snowfall, why does it seem particularly quiet? (b) Why do sounds in empty rooms sound hollow? (c) Why do people's voices sound fuller or richer when they sing in the shower?

72 The first three natural frequencies of an organ pipe are 136 Hz, 408 Hz, and 680 Hz. (a) Is the pipe an open or closed one? (b) Taking the speed of sound in air to be 340 m/s, find the length of the pipe.

73 Physically, why aren't the frets on a guitar evenly spaced?

74 It is possible for an open and a closed organ pipe of the same length to produce notes of the same frequency? Justify your answer.

75 ■ A closed organ pipe has a fundamental frequency of 528 Hz (a C note) at room temperature. What is the fundamental frequency of the pipe when the temperature is 0°C?

76 ■■ An open organ pipe has a length of 0.75 m. What would be the length of a closed organ pipe whose third harmonic ($m = 3$) is the same as the fundamental frequency of the open pipe?

77 ■■ A closed organ pipe has a length of 0.800 m. At room temperature, what are the frequencies of (a) the second harmonic and (b) the third harmonic?

78 ■■ An open organ pipe and a closed organ pipe both have lengths of 0.52 m at 20°C. What is the fundamental frequency of each pipe?

79 ■■ Suppose the pipes in Exercise 77 were at 10°C. Would the change in the fundamental frequency be the same for both pipes? Justify your answer. (Is there another effect that might play a role here? Explain.)

80 ■■ An organ pipe has a fundamental frequency of 340 Hz in air at 0°C. When filled with another gas at the same temperature, the fundamental frequency is 992 Hz. What is the gas?

81 Show that the general equation for the Doppler effect for a moving source and a moving observer is given by

$$f_o = f_s\left(\frac{v \pm v_o}{v \pm v_s}\right)$$

using the sign convention of Eqs. 14.12 and 14.15.

82 A fire engine travels at a speed of 90 km/h with its siren emitting sound at a frequency of 500 Hz. What is the frequency heard by a passenger in a car traveling at 65 km/h in the opposite direction to the fire engine, (a) approaching it and (b) moving away from it? [*Hint:* See Exercise 67 and take the speed of sound to be 354 m/s (a hot day).]

83 ■■ A tuning fork with a frequency of 440 Hz is held above a resonance tube partially filled with water. Assuming that the speed of sound in air is 342 m/s, for what heights of the air column will resonances occur?

84 ■■■ A closed organ pipe is filled with helium. The pipe has a fundamental frequency of 660 Hz in air at 0°C. What is the fundamental frequency with the helium?

Additional Exercises

85 ■■ A jet flies at a speed of Mach 2.0. What is the half-angle of the conical shock wave formed by the aircraft?

86 Two sources of 440-Hz tones are located 6.97 m and 8.90 m from an observation point. If the air temperature that day is 15°C, how do the waves interfere at the point?

87 Derive Eqs. 14.18 and 14.19.

88 How long does it take sound to travel 3.5 km in air if the temperature is 30°C?

89 If a person standing 30.0 m from a 550-Hz point source walks 5.0 m toward the source, by what factor does the sound intensity change?

90 The value of the speed of sound in air at 100°C is listed in Table 14.1 as 387 m/s. Is this the value given by Eq. 14.1? If not, explain.

91 The speed of sound in air for normal *environmental* temperatures to a good approximation is $v = 331 + 0.6T_C$ m/s (Eq 14.1). Yet, a better approximation is given by $v = (331)\sqrt{1 + (T_C/273)}$ m/s. Show that this approximation is justified. [*Hint:* Consider a binomial expansion, $(1 \pm x)^n = 1 \pm nx + n(n-1)x^2/2! \pm \ldots$

For more guided practice, try the paired problems, indicated by blue problem numbers. The **Student Study Guide and Solutions Manual** has a full solution for the first problem in each pair. The second problem is on a similar situation—here you work out the solution yourself but can check your answer against the one in the back of the book.

Preface

The third edition of *College Physics* has undergone a major refinement process and has benefited in several key areas from Tony Buffa's participation as the new coauthor. Its approach to the teaching of physics, however, remains unchanged. We continue to believe there are two things that any introductory physics course must accomplish, regardless of its approach, emphasis, or what else it may try to do: impart an understanding of the basic physics principles, and enable a student to solve a variety of reasonable problems in topics presented in the text material.

These goals are linked. An understanding of physical principles is of limited use if it does not enable students to solve problems. Physics is a problem-solving science—and in the real world, students will be evaluated on their ability to produce correct answers on final exams or on the MCAT. Yet few people would consider that learning to solve problems by rote is the same thing as learning physics. Knowing and doing, insight and skill, must go hand in hand.

Any deficiency in meeting the first goal is likely to be obvious. Test scores quickly get the attention of both test takers and test graders. Low grades demoralize instructors while discouraging students who, quite understandably, conclude that physics is "too hard" for any but the phenomenally gifted. Deficiencies in meeting the second goal tend to be more subtle. Research in physics education has shown that a surprising number of students who do learn to solve typical problems well enough to pass examinations do so without ever arriving at a real understanding of the most elementary physical concepts. Such students often get high marks on exams, yet when asked to answer simple, qualitative questions designed to test their grasp of basic principles, they betray a surprising lack of insight. Simply put, they can solve quantitative problems and get the right answer, but they do not know why it is right.

Achieving Our Goals—The Features of the Third Edition

Most of the specific features of the text can be understood in light of these goals.

Conceptual Basis. We believe that giving students a more secure grasp of the principles will almost invariably enhance their problem-solving abilities. Central to this belief is a new approach to the development of problem-solving skills that stresses the understanding of basic concepts as the essential foundation, rather than mechanical and rote use of formulas. Throughout the writing of the book, we have organized discussions and incorporated pedagogical tools to help make sure conceptual insight drives the development of practical skills.

Concise Coverage. To maintain a sharp focus on essential concepts, a book should be concise, with a minimum of superfluous material. We have therefore kept the book brief with a strong emphasis on the basics. Topics of marginal interest have been avoided, along with ones that present formal or mathematical difficulties for students. Similarly, we have not wasted space deriving relationships when they shed no additional light on the principle involved. It is usually more important for students in a course such as this to understand what a relationship means and how it can be used rather than the mathematical or analytical techniques employed to derive it.

Integrated Learning Objectives. New to the third edition, specific learning objectives, placed at the beginning of each chapter section, help students structure their reading and facilitate review.

Suggested Problem-Solving Procedure. An extensive section (Section 1.7) provides a framework for thinking about problem solving. This section includes:

—an overview of problem-solving strategies;
—a 7-step procedure that is general enough to be applicable to most problems in physics but concrete enough to be easily used;
—three examples that illustrate the solution process, showing how the general procedure is applied in practice.

Problem-Solving Strategies and Hints. The initial treatment of problem solving is followed up throughout the text with an abundance of suggestions, tips, cautions, shortcuts, and useful techniques for solving specific kinds of problems. These help the students to apply general principles to specific contexts, as well as to avoid common pitfalls and misunderstandings.

"Learn by Drawing." features. New to the third edition, "Learn by Drawing" help students to use visualization as an aid in understanding concepts and solving problems.

Conceptual Examples. *College Physics* was the first physics text to include conceptual examples in addition to quantitative ones. We are glad to know this feature was so well received and have more than doubled their number in the third edition (from 22 to 48). Now highlighted for emphasis, these examples ask students to think about a physical situation and choose the correct prediction based on an understanding of relevant principles. The discussion that follows (Reasoning and Answer) explains clearly how the correct answer can be identified as well as why the others are wrong.

Follow-Up Exercises. Also well received in the second edition were conceptual follow-up exercises at the end of each conceptual example. The third edition now provides these with *all* worked examples, whether conceptual or quantitative. (Answers are given at the back of the book.)

More Explanation in Examples. Too many example solutions in other texts rely on formulas such as "From Equation 6.7 we have . . ." We have tried to make the solutions to in-text examples as clear, patient, and detailed as possible. The aim is not merely to show the student what equations to use but to explain the strategy being employed and the role of each step in the overall plan. Students are encouraged to learn the *why* of each step along with the *how*. This technique will make it easier for the student to apply the techniques being demonstrated to other problems that are not identical in structure.

Interactive Examples and Exercises. Many of the in-text examples and exercises can be dynamically simulated using either of two text-specific software programs with built-in "player" or "runtime" engines. The *Interactive Physics Player* for *College Physics 3/e* from Knowledge Revolution focuses on the mechanics section of the book and offers over 40 simulations while the *Physics Explorer Runtime* package for *College Physics 3/e* from Logal software has over 120 simulations covering mechanics, thermodynamics, electricity and magnetism, and light and optics. Both provide students with special insights into problem solving and allow them to perform their own experiments by varying parameters.

Integration of Conceptual and Quantitative Exercises. In order to help break down the artificial and ultimately counterproductive barrier between conceptual questions and quantitative problems, we have eliminated these categories in the end-of-chapter exercises. Instead, each section begins with a series of multiple choice and short answer questions that provide content review, test conceptual understanding, and ask students to reason from principles. The aim is to show students that the same kind of conceptual insight is required regardless of whether the desired answer involves words, equations, or numbers.

Insights. Applications are both intrinsically interesting and pedagogically useful. They satisfy the student's curiosity about the role of physics in the real world while reinforcing material presented in the text. The book includes 50 boxed Insight features, dealing with such diverse topics as The Greenhouse Effect; Automobile Air Bags; Fiber Optics; Magnetic Resonance Imaging; and Observing Black Holes.

Demonstrations. Photo sequences of 17 physics demonstrations bring physical principles to life, helping students understand that the information and equations on the page describe real-world phenomena.

Chapter Review. The end-of-chapter review material has been redesigned to support the dual aims of enhancing conceptual understanding and developing problem-solving skills. Each chapter review is now made up of three parts:

- Important Terms: A listing of the key terms introduced in the chapter that students should be able to define and explain, with page references.
- Important Concepts: A new summary of the key ideas of each chapter.
- Relationships for review: A listing of the major laws and mathematical relationships introduced, cross-referenced to the chapter. Specific applicability and limiting conditions are clearly stated for each expression.

Exercises. Each chapter ends with a wealth of exercises, organized by chapter section and ranked by general level of difficulty. In addition, the Exercises offer the following special features to help students refine both their conceptual understanding and their problem-solving skills:

—Each chapter integrates conceptual and quantitative exercises.
—Each chapter includes a supplemental section of *Additional Exercises* drawn from all sections of the chapter.
—Each section includes at least one set of paired problems that deal with similar situations. The first is solved in the Study Guide and the second allows the student to practice the same method (with the answer given at the back of the book).
—Answers to odd-numbered problems are at the back of the book.

Also New to the Third Edition

Revised Section on Electricity and Magnetism. Much of the section on Electricity and Magnetism (Chapters 15-21) has been rewritten, providing a clearer and more complete presentation of the concepts.

—The first chapter on electricity (formerly Chapter 15) has now been divided into two chapters: Chapter 15, "Electric Charge, Forces, and Fields," and Chapter 16, "Electric Potential, Energy, and Capacitance." Students now are given a slower and more thorough introduction to the basic principles of electricity.
—In an optional section, Chapter 15 now offers a qualitative, highly intuitive introduction to Gauss's Law.
—Unique "Learn by Drawing" boxes in Chapter 16, "Field Lines and Equipotentials," and Chapter 18, "Kirchhoff Plots," provide graphic reinforcement of important concepts.

The Absolutely Zero Tolerance for Errors Club (The AZTECs). Headed by Tony Buffa, this group of three accuracy checkers, along with the author of the *Instructor's Solutions Manual*, Bo Lou, and senior author Jerry Wilson, individually and independently worked all end-of-chapter exercises. Results were then collated and any discrepancies resolved by a "team" discussion. Then all data in the chapters, as well as the answers at the back of the book, were checked and rechecked in first and second pages. In addition, three other physics teachers reviewed the first pages for accuracy, paying special attention to the solutions for worked examples and answers to the follow-up exercises. Finally, two more instructors gave the second pages a final reading, again working with the authors to correct any remaining errors or ambiguities. While it is probably humanly impossible to produce a physics text with absolutely no errors, that was our goal and we worked hard to make the book as error-free as possible.

Supplements

The pedagogical value of the text is enhanced by a variety of supplements, developed to address the needs of both students and instructors.

For the Instructor

Annotated Instructor's Edition (0-13-505082-0) The margins of the Annotated Instructor's Edition (AIE) contain an abundance of suggestions for classroom *demonstrations and activities,* along with *teaching tips* (points to emphasize, discussion suggestions, and common misunderstandings to avoid). In addition, the AIE contains:

- Marginal icons that identify each figure reproduced as a transparency in the Transparency Pack.
- Answers to end-of-chapter Exercises (following each exercise).
- Notes indicating an applicable video demonstration from the *Physics You Can See* video tape.

Instructor's Solutions Manual (0-13-505090-1) Prepared by a new author, Bo Lou of Ferris State University, the *Instructor's Solutions Manual* supplies answers with complete, worked out solutions to all end-of-chapter exercises. Each solution has been checked for accuracy by a minimum of five instructors.

Test Item File (0-13-505124-X) Fully revised by David Curott of the University of North Alabama, the *Test Item File* now offers approximately 2000 questions—a 42% increase over the last edition—including several new conceptual questions per chapter.

Prentice Hall Custom Test (Windows: 0-13-505173-8; MAC: 0-13-505157-6) Based on the powerful testing technology developed by Engineering Software Associates, Inc. (ESA), the PH Custom Test allows instructors to create and tailor exams to their own needs. With the Online Testing Program, exams can also be administered on-line and data can then be automatically transferred for evaluation. A comprehensive desk reference guide is included, along with on-line assistance.

Transparency Pack (0-13-505132-0) Contains 150 full-color acetates of text illustrations useful for class lectures. *Available upon adoption of the text.*

Physics You Can See Video Demonstrations (0-205-12393-7) Each 2–5 minute segments demonstrates a classical physics experiment. Includes eleven segments such as "Coin & Feather" (*acceleration due to gravity*); "Monkey & Gun" (*rate of vertical free fall*); "Swivel Hips" (*force pairs*); and "Collapse a Can" (*atmospheric pressure*).

Presentation Manager CD-ROM (0-13-751629-0) This new CD-ROM contains all the text art and videos from the *Physics You Can See* video tape as well as additional lab and demonstration videos and animations from the *Interactive Journey Through Physics CD-ROM,* also available from Prentice Hall (see below).

For the Student

Student Study Guide and Solutions Manual (0-13-505116-9) Significantly revised and expanded by Bo Lou of Ferris State University, the *Student Study Guide and Solutions Manual* presents chapter-by chapter reviews, chapter summaries, key terms, additional worked problems, and solutions to selected problems.

The New York Times "Themes of the Times" Program This innovative program, made possible through an exclusive partnership between Prentice Hall and *The New York Times*, is designed to bring current and relevant applications into the classroom. Through this program, adopters of *College Physics* 3/e are eligible to receive our unique "mini-newspapers," which bring together a collection of the latest and best physics articles from the highly respected pages of *The New York Times*. Updated annually. *Available free to qualified adopters up to the quantity of texts purchased. Contact your local representative for ordering.*

Physics Explorer Run-Time Software (Windows: 0-13-351719-5; MAC: 0-13-351701-2) Simulates problems and examples directly from the text with a wide range of experiments from among ten different models: One Body; Two Body; Gravity; Harmonic Motion; Waves; Ripple Tank; Diffraction; One Body Electrodynamics; AC/DC Circuits; and Electrostatics. Users can change values and parameters of their experiments, and observe the outcomes graphically. Extension Activities add additional scope, and built-in multiple choice Concept Checks assess understanding.

Interactive Physics II Player Software (Windows: 0-13-713736-2; MAC: 0-13-713422-3) This version of the highly acclaimed Interactive Physics II software animates and allows experimentation with select problems and examples directly from the text. Users can manipulate values, substitute variables, and observe how they affect the outcome through tools such as graphs and vectors.

Arco's *Physics for the MCAT* (0-13-505165-7) Adapted specifically for use with the text, this guide gives students planning to attend medical school the in-depth guidance needed for success on the physics section of the Medical College Admission Test (MCAT). Marginal annotations directly correlate material with *College Physics* 3/e.

Other Related Multimedia Materials

Interactive Physics II Player Workbook (Windows: 0-13-667312-0; MAC: 0-13-477670-4) Written by Cindy Schwarz of Vassar College, this highly interactive workbook/software package contains simulation projects of varying difficulty. Each contains a physics review, simulation details, hints, explanation of results, math help, and a self-test.

Interactive Mechanics (Windows: 0-13-192477-X; MAC: 0-13-261710-2) Written by Alejandro Garcia of San Jose State University, this is a supplement for any algebra-based or calculus-based physics course. Each 1 -1/2 hour experiment is similar to a traditional laboratory experiment in mechanics (such as a block sliding down an inclined plane), with computer simulations replacing lab equipment. Projects are self-contained with questions and problems provided for each. *Students must have access to Interactive Physics Software to run the simulations.*

Physics Explorer Student Edition (Windows: 0-13-351719-5; MAC: 0-13-351701-2) Fully interactive, text-independent software allows students to build their own experiments from the ground up. Experiments are built around the same ten models used in the *Run-Time Explorer.*

Interactive Journey Through Physics CD-ROM This highly interactive CD-ROM can be used as a stand-alone supplement, for any introductory physics course, or as a general reference tool. Through simulation, animation, video, and interactive problem solving, students can visualize difficult physics concepts in ways not available through the traditional lecture, lab, and text. Covers mechanics, electricity and magnetism, thermodynamics, and light and optics. The numerous analysis tools are easily navigated through a user-friendly interface.

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We would like to acknowledge the generous assistance we received from many people during the preparation of this edition. First, our sincere thanks go to Professor Bo Lou of Ferris State University for his vital contributions and meticulous, conscientious help with checking problem solutions and answers, preparing the *Instructor's Solutions Manual* as well as the answer keys for the back of the book, and preparing a major revision of the *Student Study Guide and Solutions Manual*. We are similarly grateful to Dave Curott of the University of North Alabama for preparation of the *Test Item File*, as well as for his participation as an accuracy checker for all solutions to end-of-chapter exercises.

Indeed, all the members of AZTEC—Bo Lou, Dave Curott, William McCorkle (West Liberty State College) and Bela Karvaly (Lenoir Community College)—as well as the first and second page proof reviewers—Lattie Collins, Dennis Suchecki, Frederick Liebrand, Ronald Mowery, and especially Daryl Pedigo—deserve more than a special thanks for their tireless, timely, and extremely thorough review of all material in the book for scientific accuracy.

Dozens of other colleagues listed below helped us with reviews of the second edition to help make plans for the third edition, as well as reviews of manuscript as it was developed. We are indebted to them, as their thoughtful and constructive suggestions benefited the book greatly.

At Prentice Hall, the editorial staff continued to be particularly helpful. We are especially grateful to Dan Schiller, Senior Development Editor, for everything—his cheerful competence, experienced hand, insight, creativity, extreme attention to detail, and even his queries, all of which have helped make this book one of the most carefully crafted introductory physics texts available. Jennifer Carey, Project Manager, and Shari Toron, Assistant Managing Editor, kept the whole complex endeavor moving forward, while designers Amy Rosen and Heather Scott and artist Rolando Corujo made sure the ultimate physical presentation would be both visually engaging and clean and easy to use. We would also like to thank Kelly McDonald, Executive Marketing Manager, for her cheerful enthusiasm; Wendy Rivers for her work on the supplements; Alison Reeves, Executive Editor, and Pam Holland-Moritz, Editorial Assistant, for their help in coordinating all of these facets; and Paul Corey, Editor in Chief, for his support and encouragement.

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Finally, both of us would like to urge anyone using the book—student or instructor—to pass on to us any suggestions that you have for its improvement. We look forward to hearing from you.

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