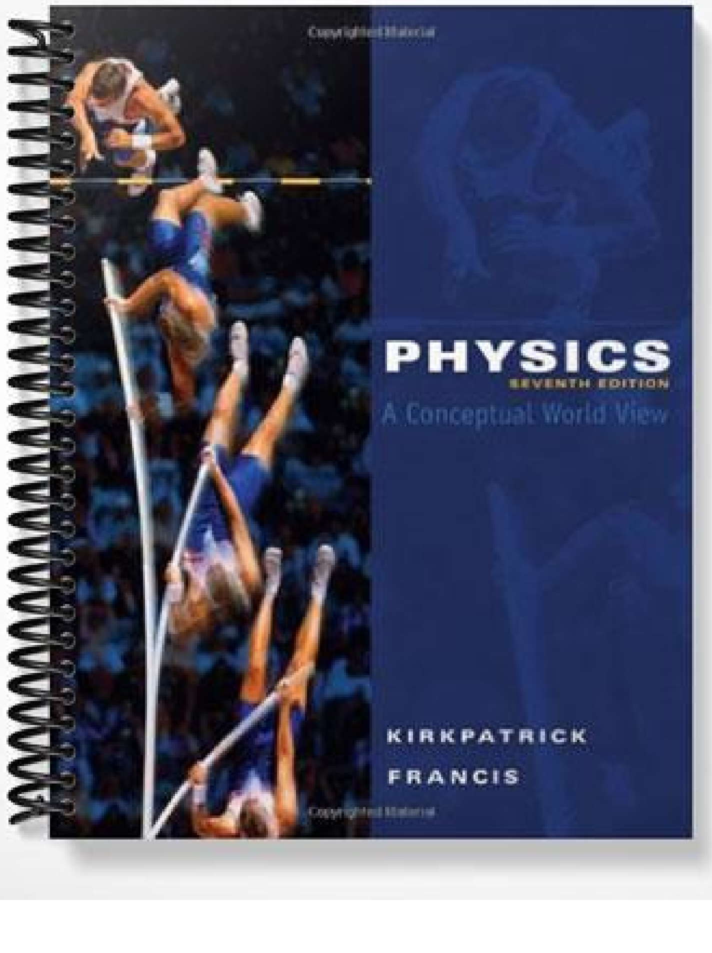
SOLUTIONS MANUAL



PREFACE

To Our Colleagues

We started this project because of our enjoyment of the ideas of physics and the challenge of conveying these ideas to students who would not normally take our “regular” science and mathematics courses. While writing the book we spent many hours arguing among ourselves as we searched for the right analogy or metaphor to put into the textbook, searching for that perfect color photograph that had a pedagogical value, and working with the staff artist getting all the fields pointing in the right directions. During this time we kept making vague comments about what the *Instructor's Resource Manual* should contain. It wasn't until after the first edition went to press that we had to come to grips with the important question about instructor's manuals: What is in a good instructor's manual?

We have asked our professional friends and ourselves this question many times. Some friends use the manuals extensively, others like to refer to them for occasional ideas, and still others don't refer to them for teaching ideas but would welcome a few questions that could be asked on an exam or quiz. And, finally, there are those few friends who said that they don't ever open instructor's manuals that come with the textbooks. The issue of adding questions to the manual became a moot point when the publisher decided to do a separate test bank of more than 1800 questions: These are available in a separate package.

We chose to aim for the middle road. We didn't spend a great deal of time looking for references on ways to demonstrate a particular idea, such as inertia or electromagnetic waves. Most of us find these ideas one at a time as we read the journals, talk with colleagues, and attend national and area AAPT meetings. Instead, we decided to share some of the ideas, demonstrations, or audio-visual material that we have found useful in teaching the course. We're like most other teachers: A few ideas are really ours, most have been “borrowed” from colleagues.

Each chapter in this *Instructor's Resource Manual* begins with a general overview. (This is something you already know because you're teaching the chapter, but the guide just seemed naked without it.) Then we go through each chapter section by section. After we list the goals for the section, we highlight the content in the section so that you can get a quick look at these topics. Again, we know you know it, but we felt this gives you a quicker way of getting a sense for the chapters.

We have included teaching tips because, as we reflected on what has been helpful to us in our own teaching, we realized that we have benefited a great deal from reading about teaching tips and listening to colleagues talk about the things they have learned and/or attempted. Neither of us has always rushed home and tried exactly what we heard (although on occasion we have), but these experiences gave us the opportunity to ingest, digest, and modify ideas.

In this same spirit we give references to the film loops that we have personally used in class. We realize that some of them are no longer available. However, you may still have some of these on some dusty shelf. Once again, we have tried to share our experiences with you. Some of the good material has re-emerged in videotape, videodisc, and CE-ROM forms. Many of these were produced by the American Association of Physics Teachers and marketed by Ztek Co., P. O. Box 967, Lexington KY 40588-0967, telephone 859-281-1611, fax 859-281-1521, e-mail cs@ztek.com, www.ztek.com. Those that we use are:

- *Physics: Cinema Classics* (videodisc, CD-ROM, bar codes, and manual)
- *Physics Single-concept Films Collection 1 & 2* (DVD)
- *The Miller Collection of Physics Single-Concept Films* (videotapes, videodisc, or DVD)
- *Skylab Physics* (videodisc and software)

- *Color Images of Physical Phenomena* (CD-ROM)
- *Frames of Reference* (DVD)

We also make extensive use of *The Video Encyclopedia of Physics Demonstrations*, a set 600 lecture demonstrations on 25 videodiscs or 25 DVDs. The demonstrations are indexed to *PHYSICS: A World View*, so that you can quickly find the appropriate demonstrations for each section of the textbook. We have also included a listing for each section in this manual. This set of videodiscs is available from The Education Group, P. O. Box 1667-90069, Los Angeles CA 90069, telephone 310-276-1122, fax 310-276-7330, email physics@edgroup.org, www.physicsdemos.com/HTML/mainpage.html. A complete set is priced at $2995 plus shipping and handling at $89.95 per set in the U. S.

One thing we have left out of this manual is any reference to the many, many slides that we show in class. We've gathered quite a collection over the years, many by taking slides of illustrations from textbooks or purchasing collections from the American Association of Physics Teachers (AAPT, Publications Sales, One Physics Ellipse, College Park MD 20740-3845, telephone 301-209-3300, www.aapt.org). (Please feel free to make slides of the illustrations in our book. They are also available on the CR-ROM that is available to adopters of the text.) We firmly believe that when we teach physics, we have to use all of the conduits to our students' brains. We've found that even in this television age, our students are surprisingly needy in the area of visual interpretation. They need help looking at a diagram and interpreting the physics that is being demonstrated. Slides of familiar scenes or of details of a demonstration/laboratory setup are very important aids to our students. In addition, Brooks/Cole is providing over 100 transparencies of our illustrations, giving you another way to bring the textbook material into your lectures.

We use a lot of lecture demonstrations in class. Many of these were built in our physics shops, but others were purchased from a variety of commercial suppliers. There are a number of books containing collections of demonstrations available from AAPT.

Finally, we have written a math supplement *Problem Solving to Accompany PHYSICS: A Conceptual World View* that parallels and extends certain sections of the textbook. We have placed a math icon following the heading of sections in the textbook that have additional material in the math supplement. In this *Instructor's Resource Manual* we have simply added a heading, numbered to match the supplement's numbering, and a short description of the additional material. All answers to the questions, exercises, and problems (from *Problem Solving*) are included in this *Instructor's Resource Manual*.

All textbooks contain more material than can be covered comfortably in a single course, or even in a sequence of courses. As an aid in planning for courses that are less than one year long, we have developed a table that gives a variety of possible course outlines. This table follows this Preface.

We sincerely hope you enjoy our textbook, the *Problem Solving* supplement, and this *Instructor's Resource Manual*. We've had a good time writing them and we encourage you to share your ideas with us.

Larry D. Kirkpatrick
Gregory E. Francis

Department of Physics
Montana State University
Bozeman MT 59717-3840
kirkpatrick@physics.montana.edu
francis@physics.montana.edu

January 2009

COURSE OUTLINES

A big part of the flow of any course rests on decisions by you. For this reason, the textbook contains more material than can be covered in an introductory course in one term. The two of us even teach the course differently. One of us likes to stress thermodynamics, while the other spends more time on optics. It is possible to take many routes through the material, depending on your interests and the interests of your students. To illustrate some possibilities, we have compiled seven different paths that can be used for semester-long courses. Each thematic path uses about one-half of the material presented in the text. These seven different emphases might be called *Physical Science*, *Electricity and Magnetism*, *Optics*, *Energy*, *Vibrations and Waves*, *Relativity*, and *Elementary Particles*.

- *Physical Science* emphasizes those topics that are basic to both physics and chemistry. After studying motion and the concepts of momentum and energy, this emphasis delves into the structure and states of matter, heat and thermodynamics, the basic properties of waves, and ends up with atomic physics.

- In the *Electricity and Magnetism* course, we begin with motion and the concepts of momentum and energy, skip to the chapter on waves, and then to the three chapters on electricity, magnetism, and electromagnetism. We conclude with the two chapters on atomic physics.

- The *Optics* emphasis also begins with motion and waves. It then covers most of the three chapters on light and finishes with atomic physics.

- The *Energy* course of study begins with motion, momentum, and mechanical energy. It then covers the two chapters on thermal energy and thermodynamics. After the chapter on waves, the course skips to the three chapters on electricity and magnetism, including electromagnetic waves. The course ends with a study of the nucleus and nuclear energy.

- *Vibrations and Waves* covers motion and energy, and then concentrates on the wave properties of music, light, electromagnetism, and the quantum-mechanical atom.

- The *Relativity* option yields a very different course. After a study of the basics of motion, momentum, and energy, the course includes the three chapters on classical, special, and general relativity. There are many ways to complete this course; we favor finishing with some of the properties of light.

- For those interested in the search for the ultimate building blocks of the universe, we suggest the *Elementary Particles* emphasis. The study of motion is followed by the chapter on the structure of matter. The amount of classical and special relativity will depend on the time you have. We then study waves and the wave aspect of light before moving on to selected topics in electricity. The main part of this course is the chapters on atomic and nuclear physics with elementary particles as the capstone.

There are other possible courses that can be taught using *PHYSICS: A World View*. If you find one that works particularly well, please share it with us. And if you have suggestions that will make the text more suitable for use in semester-long courses, please do not hesitate to write.

For your convenience, we present the seven courses in tabular form on the following pages. We have provided three levels of shading to indicate which sections match which themes: The range goes from the essential sections (darkest shading) to those that can be skipped without loss of continuity (no shading).

CHAPTER 1 **A WORLD VIEW**	**Physical Science**	**Electricity Magnetism**	**Optics**	**Energy**	**Vibrations Waves**	**Relativity**	**Particles**
First Grade							
On Building a World View							
Bode's Law							
Measurements							
Sizes: Large and Small							

CHAPTER 2 **DESCRIBING MOTION**	**Physical Science**	**Electricity Magnetism**	**Optics**	**Energy**	**Vibrations Waves**	**Relativity**	**Particles**
Average Speed							
Images of Speed							
Instantaneous Speed							
Speed With Direction							
Acceleration							
A First Look at Falling Objects							
Free Fall: Making a Rule of Nature							
Starting With an Initial Velocity							
A Subtle Point							

Essential

May be skipped

CHAPTER 3 EXPLAINING MOTION	Physical Science	Electricity Magnetism	Optics	Energy	Vibrations Waves	Relativity	Particles
An Early Explanation							
The Beginnings of Our Modern Expl.							
Newton's First Law							
Adding Vectors							
Newton's Second Law							
Mass and Weight							
Weight							
Free-Body Diagrams							
Free Fall Revisited							
Galileo Versus Aristotle							
Friction							
Newton's Third Law							

CHAPTER 4 MOTIONS IN SPACE	Physical Science	Electricity Magnetism	Optics	Energy	Vibrations Waves	Relativity	Particles
Circular Motion							
Acceleration Revisited							
Acceleration in Circular Motion							
Projectile Motion							
Launching An Apple into Orbit							
Rotational Motion							

Essential

May be skipped

CHAPTER 5 **GRAVITY**	**Physical Science**	**Electricity Magnetism**	**Optics**	**Energy**	**Vibrations Waves**	**Relativity**	**Particles**
The Concept of Gravity							
Newton's Gravity							
The Law of Universal Gravitation							
The Value of G							
Gravity near Earth's Surface							
Satellites							
Tides							
How Far Does Gravity Reach?							
The Field Concept							

CHAPTER 6 **MOMENTUM**	**Physical Science**	**Electricity Magnetis**	**Optics**	**Energy**	**Vibrations Waves**	**Relativity**	**Particles**
Linear Momentum							
Changing an Object's Momentum							
Conservation of Linear Momentum							
Collisions							
Investigating Accidents							
Airplanes, Balloons, and Rockets							

Essential

May be skipped

Chapter 7 Energy	**Physical Science**	**Electricity Magnetism**	**Optics**	**Energy**	**Vibrations Waves**	**Relativity**	**Particles**
What Is Energy?							
Energy of Motion							
Conservation of Kinetic Energy							
Changing Kinetic Energy							
Forces That Do No Work							
Gravitational Energy							
Conservation of Mechanical Energy							
Roller Coasters							
Other Forms of Energy							
Is Conservation of Energy a Hoax?							
Power							

Chapter 8 Rotation	**Physical Science**	**Electricity Magnetism**	**Optics**	**Energy**	**Vibrations Waves**	**Relativity**	**Particles**
Rotational Motion							
Torque							
Rotational Inertia							
Center of Mass							
Stability							
Rotational Kinetic Energy							
Angular Momentum							
Conservation of Angular Momentum							
Angular Momentum: A Vector							

Essential

May be skipped

CHAPTER 9 **CLASSICAL RELATIVITY**	**Physical Science**	**Electricity Magnetism**	**Optics**	**Energy**	**Vibrations Waves**	**Relativity**	**Particles**
A Reference System							
Motions in Diff. Reference Systems							
Comparing Velocities							
Accelerating Reference Systems							
Realistic Inertial Forces							
Centrifugal Forces							
The Earth: Nearly Inertial System							
Noninertial Effects of Earth's Motion							

CHAPTER 10 **EINSTEIN'S RELATIVITY**	**Physical Science**	**Electricity Magnetism**	**Optics**	**Energy**	**Vibrations Waves**	**Relativity**	**Particles**
The First Postulate							
Searching for the Medium of Light							
The Second Postulate							
Simultaneous Events							
Synchronizing Clocks							
Time Varies							
Exper. Evidence for Time Dilation							
Length Contraction							
Spacetime							
Relativistic Laws of Motion							
General Relativity							
Warped Spacetime							

Essential

May be skipped

CHAPTER 11 **STRUCTURE OF MATTER**	**Physical Science**	**Electricity Magnetism**	**Optics**	**Energy**	**Vibrations Waves**	**Relativity**	**Particles**
Building Models							
Early Chemistry							
Chemical Evidence of Atoms							
Masses and Sizes of Atoms							
The Ideal Gas Model							
Pressure							
Atomic Speeds and Temperature							
Temperature							
The Ideal Gas Law							

CHAPTER 12 **STATES OF MATTER**	**Physical Science**	**Electricity Magnetism**	**Optics**	**Energy**	**Vibrations Waves**	**Relativity**	**Particles**
Atoms							
Density							
Solids							
Liquids							
Gases							
Plasmas							
Pressure							
Sink and Float							
Bernoulli's Effect							

Essential

May be skipped

CHAPTER 13 **THERMAL ENERGY**	**Physical Science**	**Electricity Magnetism**	**Optics**	**Energy**	**Vibrations Waves**	**Relativity**	**Particles**
The Nature of Heat							
Mechanical Work and Heat							
Temperature Revisited							
Heat, Temp., and Internal Energy							
Absolute Zero							
Specific Heat							
Change of State							
Conduction							
Convection							
Radiation							
Wind Chill							
Thermal Expansion							

CHAPTER 14 **AVAILABLE ENERGY**	**Physical Science**	**Electricity Magnetism**	**Optics**	**Energy**	**Vibrations Waves**	**Relativity**	**Particles**
Heat Engines							
Ideal Heat Engines							
Perpetual-Motion Machines							
Real Engines							
Refrigerators							
Order and Disorder							
Entropy							
Decreasing Entropy							
Energy and Our Energy Crisis							

Essential

May be skipped

Chapter 15 **Vibrations and Waves**	**Physical Science**	**Electricity Magnetism**	**Optics**	**Energy**	**Vibrations Waves**	**Relativity**	**Particles**
Simple Vibrations	▓	▓	▓	▓	▓		▓
The Pendulum	▓	▓	▓	▓	▓		▓
Clocks	░	░	░	░	▓		░
Resonance	▓	▓	▓	▓	▓		▓
Waves: Vibrations That Move	▓	▓	▓	▓	▓		▓
One-Dimensional Waves	▓	▓	▓	▓	▓		▓
Superposition	▓	▓	▓	▓	▓		▓
Periodic Waves	▓	▓	▓	▓	▓		▓
Standing Waves	▓	▓	▓	▓	▓		▓
Interference	░	▓	▓		▓		▓
Diffraction	░	▓	▓		▓		▓

Chapter 16 **Sound and Music**	**Physical Science**	**Electricity Magnetism**	**Optics**	**Energy**	**Vibrations Waves**	**Relativity**	**Particles**
Sound			░		▓		
Speed of Sound			░		▓		
Hearing Sounds			░		▓		
The Recipe of Sounds			░		▓		
Stringed Instruments			░		▓		
Percussion Instruments			░		▓		
Beats			░		▓		
Doppler Effect			░		▓		
Shock Waves			░		▓		

█	Essential
▓	
░	
	May be skipped

CHAPTER 17 **LIGHT**	**Physical Science**	**Electricity Magnetism**	**Optics**	**Energy**	**Vibrations Waves**	**Relativity**	**Particles**
Shadows			▓		▓		
Pinhole Cameras			▓		▓		
Reflections			▓		▓		
Flat Mirrors			▓		░		
Multiple Reflections			▓		░		
Curved Mirrors			▓		░		
Images Produced by Mirrors			▓		░		
Locating the Images			▓		░		
Speed of Light			▓		▓	▓	▓
Color			░		▓		

CHAPTER 18 **REFRACTION OF LIGHT**	**Physical Science**	**Electricity Magnetism**	**Optics**	**Energy**	**Vibrations Waves**	**Relativity**	**Particles**
Index of Refraction			▓		░		
Total Internal Reflection			▓		░		
Atmospheric Refraction			▓		░		
Dispersion			▓		░		
Rainbows			▓		░		
Halos			▓		░		
Lenses			▓		░		
Images Produced by Lenses			░		░		
Cameras			░				
Our Eyes			░				
Magnifiers			░				
Telescopes			░				

█	Essential
▓	
░	
	May be skipped

CHAPTER 19 **A MODEL FOR LIGHT**	**Physical Science**	**Electricity Magnetism**	**Optics**	**Energy**	**Vibrations Waves**	**Relativity**	**Particles**
Reflection							
Refraction							
Interference							
Diffraction							
Thin Films							
Polarization							
Looking Ahead							

CHAPTER 20 **ELECTRICITY**	**Physical Science**	**Electricity Magnetism**	**Optics**	**Energy**	**Vibrations Waves**	**Relativity**	**Particles**
Electrical Properties							
Two Kinds of Charge							
Conservation of Charge							
Induced Attractions							
The Electroscope							
The Electric Force							
Electricity and Gravity							
The Electric Field							
Electric Field Lines							
Electric Potential							

Essential

May be skipped

CHAPTER 21 **ELECTRIC CHARGES IN MOTION**	**Physical Science**	**Electricity Magnetism**	**Optics**	**Energy**	**Vibrations Waves**	**Relativity**	**Particles**
An Accidental Discovery		▓		▓	▓		
Batteries		▓		▓	▓		
Pathways		▓		▓	▓		
A Water Model		▓		▓	▓		
Resistance		▓		▓	▓		
The Danger of Electricity		▓		▓			
A Model for Electric Current		▓		▓			
A Model for Voltage		▓		▓			
Electric Power		▓		▓			

CHAPTER 22 **ELECTROMAGNETISM**	**Physical Science**	**Electricity Magnetism**	**Optics**	**Energy**	**Vibrations Waves**	**Relativity**	**Particles**
Magnets		▓		▓	▓		
Electric Currents and Magnetism		▓		▓	▓		
Making Magnets		▓		▓	▓		
The Ampere		▓		▓	▓		
The Magnetic Earth		▓		░	░		
Charged Particles in Magnetic Fields		▓		▓	░		
Magnetism and Electric Currents		▓		▓	▓		
Transformers		▓		▓	░		
Generators and Motors		▓		▓	░		
A Question of Symmetry		▓		▓	▓		
Electromagnetic Waves		▓		▓	▓		
Radio and TV		▓		░	▓		

█	Essential
▓	
░	
	May be skipped

CHAPTER 23 THE EARLY ATOM	Physical Science	Electricity Magnetism	Optics	Energy	Vibrations Waves	Relativity	Particles
Periodic Properties							
Atomic Spectra							
Cathode Rays							
The Discovery of the Electron							
Thomson's Model							
Rutherford's Model							
Radiating Objects							
The Photoelectric Effect							
Bohr's Model							
Atomic Spectra Explained							
The Periodic Table							
X Rays							

CHAPTER 24 THE MODERN ATOM	Physical Science	Electricity Magnetism	Optics	Energy	Vibrations Waves	Relativity	Particles
Successes and Failures							
De Broglie's Waves							
Waves and Particles							
Probability Waves							
A Particle in a Box							
The Quantum-Mechanical Atom							
Exclusion Principle/Periodic Table							
The Uncertainty Principle							
The Complementarity Principle							
Determinism							
Lasers							

Essential

May be skipped

CHAPTER 25 **THE NUCLEUS**	**Physical Science**	**Electricity Magnetism**	**Optics**	**Energy**	**Vibrations Waves**	**Relativity**	**Particles**
The Discovery of Radioactivity							
Types of Radiation							
The Nucleus							
The Discovery of Neutrons							
Isotopes							
The Alchemists’ Dream							
Radioactive Decay							
Radioactive Clocks							
Radiation and Matter							
Biological Effects of Radiation							
Radiation Around Us							
Radiation Detectors							

CHAPTER 26 **NUCLEAR ENERGY**	**Physical Science**	**Electricity Magnetism**	**Optics**	**Energy**	**Vibrations Waves**	**Relativity**	**Particles**
Nuclear Probes							
Accelerators							
The Nuclear Glue							
Nuclear Binding Energy							
Stability							
Nuclear Fission							
Chain Reactions							
Nuclear Reactors							
Breeding Fuel							
Fusion Reactors							
Solar Power							

Essential

May be skipped

CHAPTER 27 **ELEMENTARY PARTICLES**	**Physical Science**	**Electricity Magnetism**	**Optics**	**Energy**	**Vibrations Waves**	**Relativity**	**Particles**
Antimatter							
The Puzzle of Beta Decay							
Exchange Forces							
Exchange Particles							
The Elementary Particle Zoo							
Conservation Laws							
Quarks							
Gluons and Color							

CHAPTER 28 **FRONTIERS**	**Physical Science**	**Electricity Magnetism**	**Optics**	**Energy**	**Vibrations Waves**	**Relativity**	**Particles**
Gravitational Waves							
Unified Theories							
Cosmology							
Cosmic Background Radiation							
Dark Matter and Dark Energy							
Neutrinos							
Quarks, the Universe, and Love							
The Search Goes On							

Essential

May be skipped

INSTRUCTOR'S RESOURCE MANUAL

PHYSICS: A Conceptual World View

Table of Contents

Chapter 1 — A WORLD VIEW

This is a new chapter; it combines material formerly found in *To the Student*, the Prologue—*On Building a World View*, a section of Chapter 1—*Measuring Space and Time*, Appendix A—*The Metric System*, and Appendix B—*Numbers Large and Small* with new material on the very wide range of distances found in the universe.

1-1 FIRST GRADE

Goal
Set the mood for the course.

Content Compares learning physics with learning to read in first grade.

Teaching Tips We hope that the students have fun with this short essay.

1-2 ON BUILDING A WORLD VIEW

Goals
Describe what we mean by a physics world view.
Present the physics world view as a dynamic one.
Describe the process of science.

Content As the title of the text indicates, the major theme of the text is presenting physics as a world view. This section develops some ideas in the philosophy of science.

Teaching Tips We leave this section as a reading assignment at this time and return to the material again and again as we develop the ideas of physics.

1-3 BODE'S LAW

Goal
Present the criteria for accepting a hypothesis as a law of physics.

Content Use Bode's law for the mean radii of the planetary orbits to present and discuss the criteria for the acceptance of a hypothesis as a law of physics; (1) agree with the existing data, (2) make predictions that can be tested, and (3) have a scientific basis.

Teaching Tips We use this section as an interesting way of discussing the criteria.

1-4 MEASUREMENTS

Goals

Present the need for a common measurement system.
Introduce the SI system of units and contrast it with the U. S. customary system.
Introduce the prefixes, *kilo*, *centi*, and *milli*.
Introduce the basic units of length, mass, and time.

Content We discuss the need for having a measurement system that it well defined and universally adopted. We then discuss the metric system and its advantages. We state that we will primarily use the metric system in this text but will give approximate English equivalents in parentheses when it is useful.

Teaching Tips We return to the material again and again as we solve problems. If you plan to include problem solving as part of your course, we highly recommend that you assign Chapter 1 of *Problem Solving to Accompany PHYSICS: A World View.*

Problem Solving 1.1 We chose not to cover significant figures in any detail but felt that students should be encouraged not to just copy a stream of numbers from a calculator. With very few exceptions in the text and in *Problem Solving*, we chose to keep just three significant figures.

Problem Solving 1.2 This is a short introduction to the use of units. The students are shown that units can be an additional check on their calculations.

Problem Solving 1.3 Many problems involve changing units. This section shows the students how to change from one set of units to another.

Video Encyclopedia 1 #1 *Basic Units*

1-5 SIZES: LARGE AND SMALL

Goals

Describe the vast range of lengths found in the universe.
Introduce the powers-of-ten notation.
Introduce the idea of order of magnitude.
(Computing) Show how to calculate with numbers in powers-of-ten notation.

Content We begin by imagining taking a photograph of children that is 1 m on a side. In the spirit of the film *Powers of Ten*, we imagine expanding our view by factors of 10 until we reach the edge of the visible universe at a scale of 10^{26} m. We then decrease the scale by factors of 10 until we reach the size of a proton at a scale of 10^{-15} m. We also describe how to calculate in powers-of-ten notation.

Teaching Tips This is a very useful section if you are going to be studying the chapters on atomic and nuclear physics.

Computing *Powers of Ten* We expand on the ideas of the powers-of-ten notation and show how to multiply and divide numbers in this format.

Problem Solving 1.4 As an introduction to problem solving we calculate how long it takes to “pass a squeeze around the world.”

Film *Powers of Ten* by Philip Morrison, Phylis Morrison, and the Office of Charles and Ray Eames.

Computer Animations *Active Figure* Animations are available on the Multimedia Manager Instructor’s Resource CD. They are organized by textbook chapter, and each animation comes within a shell that provides information on how to use the animation, exploration activities, and a short quiz.

Answers to the Conceptual Questions

1. Both world views are based on a large experimental base, but a physics world view incorporates data from outside the range of human sensations.
2. The physics world view is a shared set of ideas that represent the current explanations of how the material world operates.
3. It does not have any scientific basis.
4. A theory should make specific predictions that are testable. The material world is far too complex for a single theory to predict every observable outcome.
5. It must: 1) account for the known data, 2) make predictions that can be tested, and 3) have a scientific basis.
6. Bode’s law is just a recognized mathematical pattern. It does not have any scientific basis.
7. A theory is only accepted as physical law after the scientific community tests its predictions against observations. The more prestigious the scientist who proposes the theory, the more likely the scientific community will commit resources to test the theory.
8. We are more likely to accept a theory proposed by a respected scientist with the proper credentials, but if the theory from the handyman is able to make predictions that are testable, the source of the theory should not matter.
9. The United States is the only major country that has not adopted the metric system.
10. The metric system has only one standard unit for each basic measurement, eliminating the need for many different conversion factors. It is costly to convert machinery and signposts.
11. About 170 cm
12. About 50 cm
13. About 2.5 m
14. About 1.9 m
15. About 85 kg
16. About 70 kg
17. 10^3 miles (3000 miles) or 10^3 kilometers (4800 km) or 10^6 m
18. 10^{10} people (6.5 billion)

Answers to the Exercises

19. $$(1\text{ day})\left[\frac{24\text{ h}}{1\text{ day}}\right]\left[\frac{60\text{ min}}{1\text{ h}}\right]\left[\frac{60\text{ s}}{1\text{ min}}\right] = 86{,}400\text{ s}$$

20. $$(1\text{ yr})\left[\frac{365.25\text{ days}}{1\text{ yr}}\right]\left[\frac{24\text{ h}}{1\text{ day}}\right]\left[\frac{60\text{ min}}{1\text{ h}}\right]\left[\frac{60\text{ s}}{1\text{ min}}\right] = 3.16\text{ x }10^7\text{ s}$$

21. $(100\text{ m})\left[\frac{1.094\text{ yd}}{1\text{ m}}\right] = 109\text{ yd}$
22. $(6\text{ ft})\left[\frac{12\text{ in.}}{1\text{ ft}}\right]\left[\frac{2.54\text{ cm}}{1\text{ in.}}\right] = 183\text{ cm}$
23. $(1\text{ m})\left[\frac{100\text{ cm}}{1\text{ m}}\right]\left[\frac{1\text{ in}}{2.54\text{ cm}}\right] = 39.4\text{ in}$
24. $(1000\text{ m})\left[\frac{100\text{ cm}}{1\text{ m}}\right]\left[\frac{1\text{ in}}{2.54\text{ cm}}\right] = 39{,}400\text{ in}$
25. (a) 8.976×10^{4} in (b) 7.07×10^{-13} g
26. (a) 2.378×10^{9} m (b) 3.24×10^{-3} ft
27. (a) 4300 g (b) 0.0000812 m
27. (a) 5,782,000 s (b) 0.0069 ft
29. (a) 1.56×10^{2} (b) 3.4×10^{8}
30. (a) 9.24×10^{12} (b) 4×10^{2}
31. $\frac{10^{13}\text{ m}}{10^{9}\text{ m}} = 10^{4}$ times
32. $\frac{10^{-2}\text{ m}}{10^{-15}\text{ m}} = 10^{13}$ times

Answers to the Problems in *Problem Solving*

1. a) 3.34 b) 38,600 c) 0.667 d) 0.001 23
2. a) 0.765 b) 0.003 64 c) 7.41 d) 55,600
3. a) 7.17 b) 59,800
4. a) 0.0744 b) 3.39
5. a) 4.77×10^{-3} b) 2.05×10^{2}
6. a) 1.80×10^{-3} b) 1.73×10^{8}
7. $\bar{s} = \frac{d}{t} = \frac{1670\text{ miles}}{3.28\text{ h}} = 509\text{ mph}$
8. $\bar{s} = \frac{d}{t} = \frac{538\text{ km}}{5.82\text{ h}} = 92.4\text{ km/h}$
9. $V = \ell^{3} = (1.25\text{ m})^{3} = 1.95\text{ m}^{3}$
10. $A = \ell^{2} = (3.33\text{ m})^{2} = 11.1\text{ m}^{2}$
11. $(1\text{ mile})\left[\frac{5280\text{ ft}}{1\text{ mile}}\right]\left[\frac{12\text{ in}}{1\text{ ft}}\right] = 6.34 \times 10^{4}\text{ in.}$
12. $(1\text{ long ton})\left[\frac{2200\text{ lb}}{1\text{ long ton}}\right]\left[\frac{16\text{ oz}}{1\text{ lb}}\right] = 3.52 \times 10^{4}\text{ oz}$

13. $(6\text{ ft})\left[\dfrac{12\text{ in.}}{1\text{ ft}}\right]\left[\dfrac{2.54\text{ cm}}{1\text{ in.}}\right] = 183\text{ cm}$

14. $(1\text{ ft})\left[\dfrac{12\text{ in}}{1\text{ft}}\right]\left[\dfrac{2.54\text{ cm}}{1\text{in}}\right] = 30.5\text{cm}$

15. $(5.2\text{ km})\left[\dfrac{10^3\text{ m}}{1\text{km}}\right]\left[\dfrac{10^3\text{ mm}}{1\text{m}}\right] = 5.2\times 10^6\text{ mm}$

16. $(100\text{ y})\left[\dfrac{365.25\text{ days}}{1\text{ y}}\right]\left[\dfrac{24\text{ h}}{1\text{ day}}\right]\left[\dfrac{60\text{ min}}{1\text{ h}}\right]\left[\dfrac{60\text{ s}}{1\text{ min}}\right] = 3.16\times 10^9\text{ s}$

17. $(1250\text{ ft})\left[\dfrac{0.3048\text{ m}}{1\text{ft}}\right] = 381\text{m}$

18. $(1670\text{ ft})\left[\dfrac{0.3048\text{ m}}{1\text{ft}}\right] = 509\text{ m}$

19. $\left(70\,\dfrac{\text{miles}}{\text{h}}\right)\left[\dfrac{1.61\text{ km}}{1\text{mile}}\right] = 113\text{km/h}$

20. $\left(100\,\dfrac{\text{km}}{\text{h}}\right)\left[\dfrac{1\text{mile}}{1.61\text{km}}\right] = 62.1\text{ mph}$

21. $\left(32\,\dfrac{\text{m}}{\text{s}}\right)\left[\dfrac{1\text{ km}}{1000\text{ m}}\right]\left[\dfrac{3600\text{ s}}{1\text{ h}}\right] = 115\text{ km/h}$

22. $\left(100\,\dfrac{\text{km}}{\text{h}}\right)\left[\dfrac{1000\text{ m}}{1\text{ km}}\right]\left[\dfrac{1\text{ h}}{3600\text{ s}}\right] = 27.8\text{ m/s}$

23. $(1\text{m}^2)\left[\dfrac{100\text{ cm}}{1\text{m}}\right]^2 = 10{,}000\text{ cm}^2 = 10^4\text{ cm}^2$

24. $(1\text{m}^3)\left[\dfrac{100\text{ cm}}{1\text{m}}\right]^3 = 1{,}000{,}000\text{ cm}^3 = 10^6\text{ cm}^3$

25. $\left(\dfrac{1\text{ breath}}{2\text{ s}}\right)\left(\dfrac{70\text{ y}}{1\text{ lifetme}}\right)\left[\dfrac{365.25\text{ days}}{1\text{ y}}\right]\left[\dfrac{24\text{ h}}{1\text{ day}}\right]\left[\dfrac{60\text{ min}}{1\text{ h}}\right]\left[\dfrac{60\text{ s}}{1\text{ min}}\right] = 10^9\text{ breaths/lifetime}$

26. $t = \dfrac{d}{s} = \dfrac{3000\text{ miles}}{3\text{ miles/h}}\left(\dfrac{1\text{ day}}{10\text{ h}}\right) = 100\text{ days}$

27. $(2.8\times 10^8\text{ people})\left(\dfrac{1\text{ car}}{2\text{ people}}\right)\left(\dfrac{2\text{ gal/day}}{1\text{ car}}\right) = 2.8\times 10^8\text{ gal/day}$

28. $(2.8\times 10^8\text{ people})\left(\dfrac{1\text{ can/person}}{1\text{ day}}\right)\left(\dfrac{0.2\text{ oz}}{1\text{ can}}\right)\left[\dfrac{1\text{ lb}}{16\text{ oz}}\right]\left[\dfrac{1\text{ ton}}{2000\text{ lb}}\right] = 1800\text{ tons/day}$

Chapter 2 — DESCRIBING MOTION

This chapter moves the students from their general feelings for describing motion to a quantitative description of motion. We treat only one-dimensional motion so that when students get their first look at acceleration, it is mainly a rate of change of speed that is stressed. They are told to expect an expansion of this definition later.

Features

- Fastest and Slowest—a look at fast and slow speeds
- Immoderate Genius—a biosketch of Galileo Galilei

2-1 AVERAGE SPEED

Goals

- Define average speed and its special relationship with space and time.
- Discuss how to gather the necessary distance and time information for determining average speed.

Content The average speed is the distance traveled divided by the time elapsed.

Teaching Tips These early sections are always slow moving. We've never felt comfortable leaving these ideas until later because the fact remains that in physics we need to develop ways to objectively measure what we're talking about. Because motion is such a central part of our material world, it behooves us to start with this topic.

We start with a general discussion of motion, illustrating the ideas by displaying a simple motion in front of a strobe light. We discuss the ambiguities of the terms fast and slow and the need to use numbers to describe motion. The section becomes more palatable if examples are drawn from students' everyday experiences.

2-2 IMAGES OF SPEED

Goals

- Introduce stroboscope photographs.
- Build an awareness of the different ways that speeds can be measured.
- Show how the units of speed, space, and time are combined.
- (Computing) Demonstrate how to use the definition of average speed to predict useful outcomes of motions.
- (Computing) Give students some practice calculating average speeds.
- Problem Solving) Introduce distance-time graphs.
- (Problem Solving) Show that slopes on distance-time graphs give the speeds.
- (Problem Solving) Give students more practice calculating average speeds.
- (Problem Solving) Show speeds in different units of time.

Content To measure speed you need to know where the object is located at various times. One way to do this is to use a strobe photograph that contains both distance and time information about the object's motion.

The time elapsed can be obtained from the formula for the average speed given the average speed and the distance traveled. Similarly, the distance traveled can be obtained from the average speed formula given the time elapsed.

Teaching Tips This section blends with the previous section by focussing on how we measure speeds. A couple of interesting examples to discuss are:

- The speed of the "crawler vehicle" that carries the Space Shuttles to their launch pad. News people joke about its speed being measured in furlongs per fortnight (one-eighth mile per 14 days). Using a strobe photograph with the crawler would be overkill.
- A housefly easily moves with a speed of about 3 ft/s. (That's about 2 mph.) A strobe photograph might work here but you'd have a little trouble convincing the fly to move in just one-dimension.
- A bullet leaves a gun at speeds around 1500 ft/s. Strobe photos would not work because the times needed are too short to expose the film. Later we will discuss how this can be measured indirectly with the conservation laws (Ch 6).
- This section and the one that follows blend with the first one making a complete lecture. Here is our first opportunity to show the students the type and minimum level of mathematics that we will be using as well as the importance of using consistent units in calculations.

Computing *Average Speed* We calculate the time required to travel a distance of 60 miles at an average speed of 50 mph and then the distance traveled during 8 hours of averaging 50 mph.

Problem Solving 2.1 This section discusses graphs of motions. A relatively simple classroom exercise involves our students. We create "walking graphs." With a simple timer, and a "pace" as a unit of length, we have students observe us walking and make graphs of our motion. Next, we reverse the procedure and graph hypothetical motions and have the students predict how we will "walk" the graph.

Problem Solving 2.2 This section gives the students more practice in manipulating the average speed formula. In the first example we calculate the average speed of a family car with three different time units.

Video Encyclopedia 1 #8 *Constant Velocity*

2-3 INSTANTANEOUS SPEED

Goals

- Introduce the limiting value of a ratio, justifying the concept of instantaneous speed.
- (Problem Solving) Show that the slope on a position-time graph is equal to the instantaneous speed.
- (Problem Solving) Introduce the velocity-time graphs.

Content Even though the value of an instant of time goes to zero, the distance traveled also approaches zero so that the ratio that defines speed still has a definite, non-zero value.

Teaching Tips With some classes we have gone from the table of positions and times to making a graph of the motion. (See Problem Solving 2.3 below.)

Flawed Reasoning Average speed versus instantaneous speed

Problem Solving 2.3 The position-time graph is developed for data obtained from a strobe diagram. We also discuss instantaneous speed as the slope of the curve.

Problem Solving 2.4 We draw the velocity-time graph for the motion in Problem Solving 2.3 and discuss the meaning of the slope as the instantaneous acceleration.

2-4 SPEED WITH DIRECTION

Goals

- Introduce the concept of velocity as a speed with a direction.
- Introduce the concept of displacement.
- Contrast average speed with the magnitude of the average velocity.
- (Problem Solving) Give students practice calculating the change in velocity when the direction changes.

Content Velocity is a vector quantity that has magnitude and direction. Displacement is a vector quantity that gives the straight-line distance and direction from an initial position to a final position.

Teaching Tips We include this section on the definition of velocity because many colleagues wanted to have the complete definition of acceleration in the next section. This can be skipped now if you feel comfortable telling a "half-truth" about acceleration for now.

Problem Solving 2.5 We calculate the change in velocity for a 180° change in direction. Later, when we look at two-dimensional situations, we will cover the vector mathematics.

2-5 ACCELERATION

Goals

- Introduce the concept of acceleration.
- Include the notion that slowing down is also an acceleration.
- Introduce the units for acceleration.
- Mention that acceleration is a vector.
- (Computing) Calculate the acceleration of a car.
- (Problem Solving) Give students more practice calculating average accelerations.

Content Acceleration is the rate of change of velocity. When the motion is one-dimensional in a single direction, this definition reduces to a rate of change of speed. We experience physical effects due to acceleration, but not velocity. Accelerations can be calculated when given the change in velocity and the time elapsed during that change.

Teaching Tips This is the hardest section in the chapter. Students always seem to be boggled by the concept of a rate of change of a rate of change. We have no quick cure other than to explicitly announce this as a trouble spot. A couple of homework problems help develop this concept.

We like to talk about the fact that we "feel" accelerations because it sets the stage for Newton's laws in Chapter 3. However, we don't mention Newton at this stage; the students have enough trouble coping with the concept of acceleration.

Computing *Acceleration* We calculate the acceleration of a car.

Problem Solving 2.6 This section gives the students more practice with calculating acceleration, emphasizing the directions of acceleration and velocity.

Video Encyclopedia 1 #15 *Weight and String Acceleration*

2-6 A FIRST LOOK AT FALLING OBJECTS

Goals

- Introduce the class to their first realistic one-dimensional example.
- Introduce the notion of a thought experiment.

Content In the absence of any frictional forces all objects fall at the same rate.

Teaching Tips It's easy to fall into the trap of making Aristotle come out the fool. This should be avoided, first, because it's not true and, second, because the Aristotelian world view is quite similar to our common experiences and thus close to your students' unexamined ideas about free fall.

We usually do a two-part demonstration here. We begin with the challenge of finding a way to study free fall. Clearly the motion is too fast to see. The first demonstration is to simply drop a ball in front of the class. It's simply impossible for someone to locate positions at certain times with any accuracy. A good scientist looks for alternatives: Because a ball falling in the classroom is actually falling in a fluid (air), it makes sense to examine the motion of balls in some other fluid; one that would slow the ball down to a reasonable rate. We drop marbles in a long tube of colored water (the color is just for effect). The beginning of this chapter has prepared the students for measuring the speed of a falling ball. Aristotle appears to be correct; the marble quickly reaches a constant speed. Now we caution the students that there's no guarantee that these results will be the same in "free fall."

The second demonstration shows that, in fact, free fall does yield different results. We race a feather and a coin in an evacuated tube. So we know we're off the mark with a balls-in-water experiment; but why? The answer comes later.

Film Loops *Modern Day Tower of Pisa Experiment* and *Acceleration Due to Lunar Gravity*

Sprott Feather and coin in an evacuated tube.

Video Encyclopedia 1 #14 *Guinea and Feather*

2-7 FREE FALL: MAKING A RULE OF NATURE

Goals

- Describe Galileo's way of slowing down free-fall motion.
- Show a modern strobe photograph of a free-fall experiment.
- Establish the distance versus time relationship for free fall that starts from rest.
- Show that physics is the search for rules, or patterns, in nature.
- (Computing) Calculate the depth of a well.
- (Problem Solving) Discuss the change in distance traveled between different one-second intervals.

Content A falling object in the absence of significant frictional effects exhibits a constant acceleration. The distance traveled from rest is proportional to the time squared.

Teaching Tips We chose to leave the acceleration due to gravity as 10 m/s^2 rather than the more conventional 9.8 m/s^2 to simplify the calculations for these students. For simplicity we also chose to consider an object falling from rest rather than adding the additional complication of an initial velocity.

Computing *Should You Jump?* We calculate the speed after falling 3 s. We use the concept of average speed to calculate the distance fallen during these 3 s.

Problem Solving 2.7 This section generates a table for an object in free fall. Values are calculated for the acceleration, speed, total distance, and distance traveled each second.

Video Encyclopedia 1 #10 *Rolling Ball Incline* #11 *Constant Acceleration* #12 *String and Weights Drop* #13 *Reaction Time Falling Meter Stick*

2-8 STARTING WITH AN INITIAL VELOCITY

Goals

- Discuss the motion of an object that is thrown vertically upward.
- (Problem Solving) Give the complete distance-time relationship for free-fall.

Content When an object is thrown upward, the acceleration due to gravity causes it to slow down by 10 m/s each second until its instantaneous speed is zero at the top of its path.

Teaching Tips This information is not needed for the rest of the book's story line and many professors choose to delete it. We often treat it at least conceptually. If you have been doing the graphing from *Problem Solving*, this section is a good conclusion to that treatment.

Problem Solving 2.8 We develop the relationships for the final velocity and the displacement for motion with an initial velocity. The examples focus on a ball thrown upward.

2-9 A SUBTLE POINT

Goal

- To highlight that finding relationships about nature allows us to predict the outcomes of events.

Content Science is an active process of discovering patterns in nature and creating rules that make up our physics world view.

Teaching Tips We treat this short section as a reading assignment. The points are made often throughout the course.

Computer Animations *Active Figure* Animations are available on the Multimedia Manager Instructor's Resource CD. They are organized by textbook chapter, and each animation comes within a shell that provides information on how to use the animation, exploration activities, and a short quiz.

Answers to the Conceptual Questions

1. From the varying spaces we know that the puck moved different distances in equal amounts of time. The puck in this diagram speeded up, reached a maximum, and then slowed to (approximately) its initial speed.
2. The upper puck speeds up and then slows down. The lower puck appears to be moving at a constant speed.
3. The speed is the slowest in the middle where the dots are closest together.
4. The speed is the fastest at the right end of the path where the dots are the farthest apart.
5. `oo.o..o...o....o.....o.....o.....o....o...o..o..o..o.oo`
6. `o....o....o....o...o..o...o....o.....o......o......o`
7. `oo..o....o......o.......o........o.......o........o......o....o..oo`
8. `oo.o...o.....o.......o.........o........o....oo`
9. The truck has a higher average speed because it travels a longer distance in the same amount of time.
10. The average speeds are the same because both cars travel an average of one mile each minute.
11. You are constantly slowing down so your speed while breaking is always less than 45 mph, which means the average must also be less than 45 mph.
12. Both animals travel the same total distance but the tortoise does it in less time and therefore has a slightly higher average speed.
13. Since both travelers cover the same distance in the same time, their average speeds are the same. However, since Chris spent much of the time at rest, his instantaneous speed would have been much greater than his average for parts of the trip and therefore also greater than Pat's.
14. The book is constantly speeding up and so achieves its greatest speed right before it lands. Since the speed at all other times was less than this, the average speed must be less than the impact speed.
15. The object is speeding up from C to D so the average speed in the interval is greater than the instantaneous speed at C and less than the instantaneous speed at D.
16. The object is slowing down from C to D so the average speed in the interval is less than the instantaneous speed at C and greater than the instantaneous speed at D.
17. You could use a stopwatch to determine the time it takes to travel between two adjacent mile markers along the side of the highway and then divide one mile by the number of seconds. You will need to convert the seconds into hours to yield an answer in mph.

18. Because speed is a ratio, both time and distance are required.
19. No, the average speed doesn't tell us anything about the instantaneous speed.
20. The question cannot be answered with just the average speed because it doesn't tell us anything about instantaneous speeds.
21. A stopwatch and an odometer measure time and distance, allowing us to calculate the average speed; a speedometer measures instantaneous speed.
22. The stopwatch measures time (in seconds), an odometer measures length (in miles or km), and a speedometer measures speed, which is length divided by time interval (mph or kph).
23. The essential difference is direction—velocity is a speed with a direction.
24. This is a velocity because the speed and direction are both given.
25. Object **a** is traveling equal distances during each time interval, which means it is moving at constant speed and has zero acceleration. The same is true of object **b** although its speed is greater. Both objects have the same zero acceleration.
26. To have the same average speeds the cars must travel the same distances between flashes. This is the interval from B to C for car **a**.
27. All of these can be considered to be an accelerator because any change in speed or direction is an acceleration.
28. Anything that changes the speed (or direction) is an accelerator.
29. The bicycle undergoes the greatest change in velocity in the same time interval and therefore has the greatest acceleration.
30. The Integra undergoes a greater change in speed in the 4 second interval and therefore has the greater acceleration.
31. The motorcycle will be going 35 mph and the sports car will only be going 30 mph.
32. The Caravan will be going 70 mph and the Taurus will only be going 65 mph.
33. Carlos could be going 60 mph and slowing while Andrea is going 5 mph and speeding up.
34. At noon, Mary passes Nathan with her cruise control set to 100 mph. Nathan’s speedometer reads only 60 mph, but he is in the process of speeding up.
35. They are falling in a vacuum, or air resistance is negligible for these objects.
36. The missing word is "acceleration."
37. The pebble speeds up by 10 meters per second every second. After 4 seconds its speed is therefore 40 meters per second.
38. The ball slows down by 10 meters per second every second. In two seconds it slows by 20 meters per second and is traveling at 10 meters per second.
39. It stays the same in accordance with Galileo's thought experiment.
40. In a vacuum they would fall with the same acceleration. However, in air the ball made from rubber will be affected more by the air resistance and will lag behind.
41. When you let go of the bowling ball, you both have the same speed. Because the speeds of you and the bowling ball change in exactly the same way, the bowling ball will remain beside you.
42. When you let go of the bowling ball, you both have the same speed. Letting go of the bowling ball simply reduces your weight and, because an object’s weight does not affect its motion, you will rise the same as if you had held the bowling ball.
43. They hit at the same time because there is no air resistance.
44. They hit at the same time because there is no air resistance.
45. Galileo concluded that the object falls with a constant acceleration when air resistance is ignored. Aristotle hypothesized that the object quickly reaches a constant speed.
46. Galileo would conclude that the unwadded paper falls slower because it experiences more air resistance. It's not obvious what Aristotle would say because the amount of "earth" in the paper doesn't

change.

47. The heavier ball hits first because the air resistance will affect the lighter ball more.
48. The golf ball reaches the ground first. The lighter Ping Pong ball reaches its (small) terminal velocity quickly, while the golf ball continues to accelerate to a larger final speed. The average speed of the golf ball is therefore larger, so it covers the same distance in less time.
49. Because of the marble's greater weight, air-resistance will affect it less than the ping-pong ball allowing it to speed up faster. Therefore the marble has the greater acceleration.
50. Because of the ping-pong ball's low weight to size ratio, air-resistance will affect it more than the marble causing it to slow faster. If its speed is changing faster, the ping-pong ball must have the greater acceleration.
51. The accelerations are the same in both cases.
52. The accelerations are the same.
53. The increasing upward force due to the air resistance causes the downward acceleration to continually decrease.
54. Because the acceleration is decreasing as the air resistance increases, the ball's speed increases the most during the first second.
55. The air resistance will cause the ball to slow the ball down more rapidly than it would in a vacuum. The magnitude of the acceleration is therefore greater.
56. The ball is now speeding up as it falls. The air resistance will cause it to speed up less rapidly as it would in a vacuum. The magnitude of the acceleration is therefore less.

Answers to the Exercises

57. $(2193 \text{ mph})\left[\frac{1.61 \text{ km}}{1 \text{ mile}}\right] = 3530 \text{ km/h}$

58. $(100 \text{ mph})\left[\frac{0.447 \text{ m/s}}{1 \text{ mph}}\right] = 44.7 \text{ m/s}$

59. $\bar{s} = \frac{d}{t} = \frac{(215 - 50) \text{ miles}}{2.5 \text{ h}} = 66 \text{ mph}$

60. $\bar{s} = \frac{d}{t} = \frac{26.2 \text{ miles}}{3 \text{ h}} = 8.73 \text{ mph}$

61. $\bar{s} = \frac{d}{t} = \frac{145.3 \text{ miles}}{24 \text{ h}} = 6.05 \text{ mph}$

62. $\bar{s} = \frac{d}{t} = \frac{10{,}000 \text{ m}}{1577.53 \text{ s}} = 6.34 \text{ m/s}$

63. $d = \bar{s}t = (60 \text{ mph})(8 \text{ h}) = 480 \text{ miles}$

64. $d = \bar{s}t = (10 \text{ m/s})(8 \text{ h})\left[\frac{60 \text{ min}}{1 \text{ h}}\right]\left[\frac{60 \text{ sec}}{1 \text{ min}}\right]\left[\frac{1 \text{ km}}{1000 \text{ m}}\right] = 288 \text{ km}$

65. $\bar{s} = \frac{d_1 + d_2}{t} = \frac{(4 \text{ mph})(3 \text{ h}) + 0}{5 \text{ h}} = 2.4 \text{ mph}$

66. $\bar{s} = \frac{d_1 + d_2}{t} = \frac{0 + (75 \text{ mph})(2 \text{ h})}{3 \text{ h}} = 50 \text{ mph}$

67. $t = \frac{d}{\bar{s}} = \frac{100 \text{ m}}{25 \text{ m/s}} = 4 \text{ s}$ compared to 10 s for humans

68. $t = \frac{d}{\bar{s}} = \frac{4400 \text{ km}}{80 \text{ km/h}} = 55 \text{ h}$

69. $t = \frac{d}{\bar{s}} = \frac{100 \text{ miles}}{4 \text{ mph}} = 25 \text{ h}$; No

70. $t = \frac{d}{\bar{s}} = \frac{500 \text{ miles}}{125 \text{ mph}} = 4 \text{ h}$

71. $\bar{a} = \frac{\Delta v}{t} = \frac{60 \text{ mph} - 0}{4.8 \text{ s}} = 12.5 \text{ mph/s}$

72. $\bar{a} = \frac{\Delta v}{\Delta t} = \frac{120 \text{ km/h}}{20 \text{ s}} = 6 \text{ km/h} \cdot \text{s}$

73. $\bar{a} = \frac{\Delta v}{\Delta t} = \frac{70 \text{ mph} - 40 \text{ mph}}{6 \text{ s}} = 5 \text{ mph/s}$

74. $\bar{a} = \frac{\Delta v}{\Delta t} = \frac{332.75 \text{ mph}}{4.447 \text{ s}} = 74.3 \text{ mph/s}$

$\bar{s} = \frac{d}{t} = \frac{0.25 \text{ mile}}{4.447 \text{ s}}\left[\frac{60 \text{ s}}{1 \text{ min}}\right]\left[\frac{60 \text{ min}}{1 \text{ h}}\right] = 202 \text{ mph}$

75. $v_f = v_i + at = 7 \text{ m/s} + (10 \text{ m/s}^2)(2 \text{ s}) = 27 \text{ m/s}$

76. $v_i = v_f - at = 23 \text{ m/s} - (10 \text{ m/s}^2)(2 \text{ s}) = 3 \text{ m/s}$

77. $v_f = v_i + at = 5 \text{ m/s} + (2 \text{ m/s}^2)(4 \text{ s}) = 13 \text{ m/s}$

78. $t = \frac{v_f - v_i}{a} = \frac{(-10 \text{ m/s}) - (30 \text{ m/s})}{-10 \text{ m/s}^2} = 4 \text{ s}$ (+ is up)

79. $v_f = v_i + at = 0 + (10 \text{ m/s}^2)(2 \text{ s}) = 20 \text{ m/s}$

$d = \bar{v}t = \frac{1}{2}(20 \text{ m/s} + 0)(2 \text{ s}) = 20 \text{ m}$

80. $v_f = v_i + at = 0 + (10 \text{ m/s}^2)(4 \text{ s}) = 40 \text{ m/s}$

$d = \bar{v}t = \frac{1}{2}(40 \text{ m/s} + 0)(4 \text{ s}) = 80 \text{ m}$

81.

t(s)	*v*(m/s)	*h*(m)
0	0	80
1	10	75
2	20	60
3	30	35
4	40	0

82.

t(s)	v(m/s)	h(m)
0	30	0
1	20	25
2	10	40
3	0	45
4	–10	40
5	–20	25
6	–30	0

83. A ball starting from rest requires 3 s to fall 45 m. Therefore the ball is in the air for 3 s and must have a minimum launch speed of 30 m/s.

84. $t = 2 \times \dfrac{\Delta v}{g} = 2 \times \dfrac{40 \text{ m/s}}{10 \text{ m/s}^2} = 8 \text{ s}$

$h = \tfrac{1}{2} g t^2 = \tfrac{1}{2}\left(10 \text{ m/s}^2\right)\left(4 \text{ s}\right)^2 = 80 \text{ m}$

85. $v_f = v_i + at = 0 + \left(10 \text{ m/s}^2\right)\left(0.13 \text{ s}\right) = 1.3 \text{ m/s}$

86. $v_f = v_i + at = 0 + \left(10 \text{ m/s}^2\right)\left(0.18 \text{ s}\right) = 1.8 \text{ m/s}$

$d = \bar{v}t = \tfrac{1}{2}\left(1.8 \text{ m/s} + 0\right)\left(0.18 \text{ s}\right) = 0.16 \text{ m}$

Answers to the Problems in *Problem Solving*

1. $\bar{s} = \dfrac{d}{t} = \dfrac{370 \text{ km}}{24 \text{ h}} = 15.4 \text{ km/h}$

2. $\bar{s} = \dfrac{d}{t} = \dfrac{6000 \text{ km}}{10.2 \text{ h}} = 588 \text{ km/h}$

3. $\bar{s} = \dfrac{d}{t} = \dfrac{1.5 \text{ miles}}{2 \text{ min}}\left[\dfrac{60 \text{ min}}{1 \text{ h}}\right] = 45 \text{ mph}$

4. $\bar{s} = \dfrac{d}{t} = \dfrac{60 \text{ miles}}{4 \text{ h}}\left[\dfrac{1 \text{ h}}{3600 \text{ s}}\right]\left[\dfrac{1609 \text{ m}}{1 \text{ mile}}\right] = 6.7 \text{ m/s}$

5. $\bar{s} = \dfrac{d}{t} = \dfrac{100 \text{ m}}{9.86 \text{ s}}\left[\dfrac{3600 \text{ s}}{1 \text{ h}}\right]\left[\dfrac{1 \text{ mile}}{1609 \text{ m}}\right] = 22.7 \text{ mph}$

6. $\bar{s} = \dfrac{d}{t} = \dfrac{1 \text{ mile}}{239.4 \text{ s}}\left[\dfrac{3600 \text{ s}}{1 \text{ h}}\right] = 15 \text{ mph}$

7. $d = \bar{s}_1 t_1 + \bar{s}_1 t_2 = \left(15 \text{ mph}\right)\left(2 \text{ h}\right) + \left(10 \text{ mph}\right)\left(4 \text{ h}\right) = 70 \text{ miles}$

$\bar{s} = \dfrac{d}{t} = \dfrac{70 \text{ miles}}{6 \text{ h}} = 11.7 \text{ mph}$

8. $d = \bar{s}_1 t_1 = (40\text{ mph})(2\text{ h}) = 80\text{ miles}$

$$\bar{s} = \frac{d_2}{t_2} = \frac{300\text{ miles} - 80\text{ miles}}{3\text{ h}} = 73.3\text{ mph}$$

9. $d = \bar{s}t = (95\text{ km/h})(12\text{ h}) = 1140\text{ km}$

10. $d = \bar{s}t = (1.07 \times 10^5\text{ km/h})\left[\frac{365.25\text{ days}}{1\text{ y}}\right]\left[\frac{24\text{ h}}{1\text{ day}}\right] = 9.38 \times 10^8\text{ km/y}$

11. $t = \frac{d}{\bar{s}} = \frac{4470\text{ km}}{25\text{ km/h}}\left[\frac{1\text{ day}}{8\text{ h}}\right] = 22.4\text{ days}$

12. $t = \frac{d}{\bar{s}} = \frac{3 \times 10^8\text{ km}}{2 \times 10^4\text{ km/h}}\left[\frac{1\text{ day}}{24\text{ h}}\right]\left[\frac{1\text{ month}}{30\text{ days}}\right] = 20.8\text{ months}$

13. $\text{slope} = v = \frac{30\text{ m} - 10\text{ m}}{5\text{ s} - 0} = 4\text{ m/s}$

14. $\text{slope} = v = \frac{48\text{ m} - 29\text{ m}}{14\text{ s} - 4\text{ s}} = 1.9\text{ m/s}$

15. $\text{slope} = a = \frac{18\text{ m/s} - 2\text{ m/s}}{3\text{ s} - 1\text{ s}} = 8\text{ m/s}^2$

16. $\text{slope} = a = \frac{11\text{ m/s} - 20\text{ m/s}}{10\text{ s} - 6\text{ s}} = -2.3\text{ m/s}^2$

17. $\bar{a} = \frac{\Delta v}{t} = \frac{72\text{ km/h} - 0}{2\text{ s}} = 36\text{ km/h}\cdot\text{s}$

18. $\bar{a} = \frac{\Delta v}{t} = \frac{20\text{ mph} - 4\text{ mph}}{4\text{ s}}\left[\frac{1\text{ m/s}}{2.237\text{ mph}}\right] = 1.79\text{ m/s}^2$

19. $\bar{a} = \frac{\Delta v}{t} = \frac{254\text{ mph} - 0}{5.9\text{ s}} = 43.1\text{ mph/s}$

$$\bar{s} = \frac{d}{t} = \frac{0.25\text{ mile}}{5.9\text{ s}}\left[\frac{3600\text{ s}}{1\text{ h}}\right] = 153\text{ mph}$$

20. $\bar{a} = \frac{\Delta v}{t} = \frac{69\text{ mph} - 0}{19.4\text{ s}} = 3.56\text{ mph/s}$

$$\bar{s} = \frac{d}{t} = \frac{0.25\text{ mile}}{19.4\text{ s}}\left[\frac{3600\text{ s}}{1\text{ h}}\right] = 46.4\text{ mph}$$

21. $\bar{a} = \frac{\Delta v}{t} = \frac{-80\text{ km/h} - 100\text{ km/h}}{2\text{ min}} = -90\text{ km/h}\cdot\text{min}$ (+ is north)

22. $\bar{a} = \frac{\Delta v}{t} = \frac{-220\text{ km/h} - 220\text{ km/h}}{10\text{ min}} = -44\text{ km/h}\cdot\text{min}$ (+ is north)

23. $\bar{a} = \frac{\Delta v}{t} = \frac{16\text{ m/s} - (-20\text{ m/s})}{0.04\text{ s}} = 900\text{ m/s}^2$ (+ is up)