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AP\* EDITION

# COLLEGE PHYSICS

A STRATEGIC APPROACH

SECOND EDITION



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# BUILDS PROBLEM-SOLVING SKILLS AND CONFIDENCE

## Clear, consistent instruction

Build confidence and success through a consistent three-step approach: **Prepare** the problem, try to **Solve** it, and **Assess** the answer.

Topic-specific **Problem-Solving Strategies** follow the same three-step framework and provide more detailed guidance.

- 1 **PREPARE** reinforces the value of gathering information, drawing figures, making assumptions, and planning—key steps that research shows are often skipped.
- 2 **SOLVE** carefully works through the mathematical steps of the solution, explaining algebraic manipulations and use of key information.
- 3 **ASSESS** verifies whether the answer makes sense—numerically and in context.

### PROBLEM-SOLVING STRATEGY 24.1

#### Magnetic field problems



**PREPARE** Because current-carrying wires do not lie in the same plane as the fields they produce, you'll need to prepare an especially careful drawing. Generally, you should choose the plane of your drawing so that the magnetic field vectors lie either in the plane of the paper or perpendicular to it.

- Straight wires are usually easiest to draw as seen from their ends. Then the field vectors will lie in the plane of the paper.
- Usually, it's best to draw current loops in the plane of the paper. Then the field vectors will lie perpendicular to the plane of the paper.

### PROBLEM-SOLVING STRATEGY 9.1

#### Conservation of momentum problems



**PREPARE** Clearly define the system.

- If possible, choose a system that is isolated ( $\vec{F}_{\text{net}} = \vec{0}$ ) or within which the interactions are sufficiently short and intense that you can ignore external forces for the duration of the interaction (the impulse approximation). Momentum is then conserved.
- If it's not possible to choose an isolated system, try to divide the problem into parts such that momentum is conserved during one segment of the motion. Other segments of the motion can be analyzed using Newton's laws or, as you'll learn in Chapter 10, conservation of energy.

**SOLVE** Following Tactics Box 9.1, draw a before-and-after visual overview. Define symbols that will be used in the problem, list known values, and identify what you're trying to find.

**SOLVE** The mathematical representation is based on the law of conservation of momentum:  $\vec{P}_f = \vec{P}_i$ . In component form, this is

$$(p_{1x})_f + (p_{2x})_f + (p_{3x})_f + \dots = (p_{1x})_i + (p_{2x})_i + (p_{3x})_i + \dots$$

$$(p_{1y})_f + (p_{2y})_f + (p_{3y})_f + \dots = (p_{1y})_i + (p_{2y})_i + (p_{3y})_i + \dots$$

**ASSESS** Check that your result has the correct units, is reasonable, and answers the question.

Exercise 20

### TACTICS BOX 4.3 Drawing a free-body diagram



- 1 Identify all forces acting on the object. This step was described in Tactics Box 4.2.
- 2 Draw a coordinate system. Use the axes defined in your pictorial representation (Tactics Box 2.2). If those axes are tilted, for motion along an incline, then the axes of the free-body diagram should be similarly tilted.
- 3 Represent the object as a dot at the origin of the coordinate axes. This is the particle model.

### TACTICS BOX 24.1 Right-hand rule for fields



- 1 Point your right thumb in the direction of the current.
- 2 Curl your fingers around the wire to indicate a circle.
- 3 Your fingers point in the direction of the magnetic field lines around the wire.



Exercises 5–10

**Tactics Boxes** provide step-by-step procedures that build key skills that will be used over and over—such as drawing free-body diagrams and using ray tracing.

**Math Relationship Boxes** ensure confidence with the key mathematical relationships most common in this course. Each relationship is consolidated in words, math, and graphics, along with tips on reasoning with limiting cases and scaling. Icons in the text refer back to these boxes to reinforce connections.

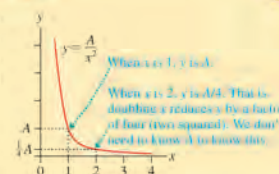
### Inverse-square relationships



Two quantities have an **inverse-square relationship** if  $y$  is inversely proportional to the *square* of  $x$ . We write the mathematical relationship as:

$$y = \frac{A}{x^2}$$

$y$  is inversely proportional to  $x^2$ .



**SCALING** Inverse-square scaling means, for example:

- If you double  $x$ , you decrease  $y$  by a factor of 4, as you can see in the graph.
- If you increase  $x$  by a factor of 3, you decrease  $y$  by a factor of 9.
- If you decrease  $x$  by a factor of 3, you increase  $y$  by a factor of 9.

Generally: An *increase* in  $x$  by a factor  $C$  results in a *decrease* of  $y$  by a factor  $C^2$ .

**LIMITS** As  $x$  becomes large,  $y$  becomes very small; as  $x$  becomes small,  $y$  becomes very large.

Exercise 23

# Explicit, guided practice

**Worked Examples** implement the Strategies and follow the same **PREPARE/SOLVE/ASSESS** framework as part of developing good problem-solving habits. They carefully walk through the underlying reasoning and pitfalls to avoid.

**Integrated Examples** at the end of each chapter demonstrate problem-solving in the context of a capstone, multi-concept real-world scenario.

**EXAMPLE 4.1 Forces on an upward-accelerating elevator**

An elevator, suspended by a cable, speedometer, and motion sensor. **Figure 4.26** illustrates the situation. **Figure 4.26** Free-body diagram of the elevator.

**PREPARE** Figure 4.26 illustrates the situation. **Figure 4.26** Free-body diagram of the elevator.

**Force identification**

**Free-body diagram**

**ASSESS** The coordinate axes, with a vertical  $y$ -axis, are the ones we would use in a pictorial representation of the motion. The elevator is accelerating upward, so  $F_{\text{net}}$  must point upward. For this to be true, the magnitude of  $T$  must be larger than the magnitude of  $w$ . The diagram has been drawn accordingly.

**Pencil Sketches** provide an explicit and accessible example of what to draw in solving a problem—steps often outlined in the Tactic Boxes.

**Conceptual Questions**

**Multiple-Choice Questions**

**Problems**

**General Problems**

**Part Summary Problems**

**INTEGRATED EXAMPLE 24.15 Making music with magnetism**

A loudspeaker makes sound by pushing air back and forth with a paper cone that is driven by a magnetic force on a wire coil at the base of the cone. **Figure 24.61** shows the details. The bottom of the cone is wrapped with several turns of fine wire. This coil of wire sits in the gap between the poles of a circular magnet, the black disk in the photo. The magnetic field exerts a force on a current in the wire, pushing the cone and thus pushing the air.

**FIGURE 24.61** The arrangement of the coil and magnet poles in a loudspeaker.

**FIGURE 24.62** The magnetic field in the gap and the current in the coil.

**SOLVE** The current in the wire is produced by the amplifier. The current is related to the potential difference and the resistance of the wire by Ohm's law:

$$I = \frac{\Delta V}{R} = \frac{6.0 \text{ V}}{8.0 \Omega} = 0.75 \text{ A}$$

Because the current is perpendicular to the field, we can use Equation 24.10 to determine the force on this current. We know the field and the current, but we need to know the length of the wire in the field region. The coil has diameter 5.0 cm and thus circumference  $\pi(0.050 \text{ m})$ . The coil has 20 turns, so the total length of the wire in the field is

$$l = 20\pi(0.050 \text{ m}) = 3.1 \text{ m}$$

The magnitude of the force is then given by Equation 24.10 as

$$F = IlB = (0.75 \text{ A})(3.1 \text{ m})(0.18 \text{ N/A} \cdot \text{m}) = 0.42 \text{ N}$$

out of the page, as already noted.

**ASSESS** The force is small, but this is reasonable. A loudspeaker cone is quite light, so only a small force is needed for a large acceleration. The force for a clockwise current is out of the page, but when the current switches direction, to counterclockwise, the force will be directed in. A current that alternates direction will cause the cone to oscillate in and out—just what is needed for making music.

**Conceptual Examples** target qualitative reasoning skills. Since no math is involved, they follow a **REASON** and **ASSESS** approach.

**CONCEPTUAL EXAMPLE 6.2 Who has the larger acceleration?**

**FIGURE 6.8** Top view of a merry-go-round.

Two children are riding in circles on a merry-go-round, as shown in Figure 6.8. Which child experiences the larger acceleration?

**REASON** All points on the merry-go-round move at the same angular speed. The second expression for the acceleration in Equation 6.7 tells us that  $a = \omega^2 r$ . As the two children are moving with the same angular speed, Emma, with a larger value of  $r$ , experiences a larger acceleration.

**ASSESS** In the previous example, we saw that points farther from the center move at a higher speed. This would imply a higher acceleration as well, so our answer makes sense.

**Conceptual Questions** require thoughtful reasoning and can be used for group discussions or individual work. **Multiple-Choice Questions** use carefully chosen distractors to elicit common misconceptions. **Problems**, are keyed to sections and draw on real-world applications to provide motivational examples. More advanced **General Problems** require the simplification and modeling of more complex real-world situations. **Part Summary Problems** close each of the book's seven parts and take problem-solving one step further by covering topics that span several chapters.

# INTEGRATES INTERESTING AND RELEVANT TOPICS

## An active, inductive approach

Drawn from various fields of study and the world around us, relevant examples and interesting topics are carefully woven into the text. These provide motivation, a means to consolidate understanding, and a clear context for understanding physics.

New concepts are introduced through observations about the real world, an inductive approach shown to improve learning (see the magnetism introduction in the sample chapter that follows).

**Worked Examples** incorporate scenarios from everyday life and the world around us.

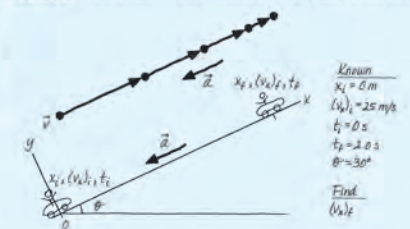
### EXAMPLE 3.8 Speed of a roller coaster

A classic wooden coaster has cars that go down a big first hill, gaining speed. The cars then ascend a second hill with a slope of  $30^\circ$ . If the cars are going 25 m/s at the bottom and it takes them 2.0 s to climb this hill, how fast are they going at the top?



**PREPARE** We start with the visual overview in Figure 3.24, which includes a motion diagram, a pictorial representation, and a list of values. Notice how the motion diagram of Figure 3.24 differs from that of the previous example: The velocity decreases as the car moves up the hill, so the acceleration vector is opposite the direction of the velocity vector. The motion is along the  $x$ -axis, as before, but the acceleration vector points in the negative- $x$  direction, so the component  $a_x$  is negative.

FIGURE 3.24 The coaster's speed decreases as it goes up the hill.



**SOLVE** To determine the final speed, we need to know the acceleration. We will assume that there is no friction or air resistance.

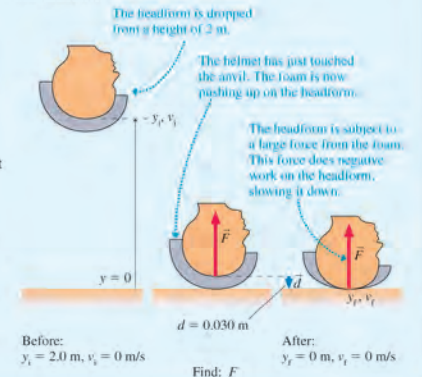
### EXAMPLE 10.13 Protecting your head

A bike helmet is basically a shell of hard, crushable foam 3.0 cm thick. In testing, the helmet is strapped onto a 5.0 kg headform that is dropped from a height of 2.0 m onto a hard anvil. What force is encountered by the head in such a fall?



**PREPARE** A visual overview of the test is shown in Figure 10.31. We can use the law of conservation of energy.

FIGURE 10.31 The foam in the helmet does negative work on the headform.



### TRY IT YOURSELF



**Getting the ketchup out** The ketchup stuck at the bottom of the bottle is initially at rest. If you hit the bottom of the bottle, the bottle suddenly moves down, taking the ketchup on the bottom of the bottle with it, so that the ketchup just stays stuck to the bottom. But if instead you hit *up* on the bottle, as shown, you force the bottle rapidly upward. By the first law, the ketchup that was stuck to the bottom stays at rest, so it separates from the upward-moving bottle: the ketchup has moved forward with respect to the bottle!

### TRY IT YOURSELF



**Buzzing magnets** You can use two identical flexible refrigerator magnets for a nice demonstration of their alternating pole structure. Place the two magnets together, back to back, then quickly pull them across each other, noting the alternating attraction and repulsion from the alternating poles. If you pull them quickly enough, you will hear a buzz as the magnets are rapidly pushed apart and then pulled together.

**Free-standing Applications**, found in the margin with photographs and a self-contained caption, connect the physical principles with the real world.



**Taking a picture in a flash** When you take a flash picture, the flash is fired using electric potential energy stored in a capacitor. Batteries are unable to deliver the required energy rapidly enough, but capacitors can discharge all their energy in only microseconds. A battery is used to slowly charge up the capacitor, which then rapidly discharges through the flashlamp. This slow recharging process is why you must wait some time between taking flash pictures.

**Try It Yourself Activities** throughout the text provide simple real-world experiments designed to quickly reinforce a key idea through direct experience.

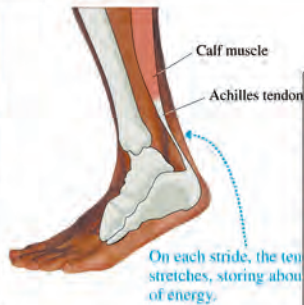


# Engaging treatment

Optional sections provide **in-depth coverage of key topics**—such as electrical conduction in the nervous system, the workings of an EKG, and how to correctly measure blood pressure.



**Magnetotactic bacteria** **BIO** Several organisms use the earth's magnetic field to navigate. The clearest example of this is *magnetotactic bacteria*. The dark dots in the image are small pieces of iron; each piece is a single domain and hence a very strong magnet. Such a bacterium possesses a very strong magnetic moment: The bacterium itself is like a bar magnet, and lines up with the earth's magnetic field. In the temperate regions where such bacteria live, the earth's magnetic field has a large vertical component. The bacteria use their alignment with this vertical field component to navigate up and down.



**Spring in your step** **BIO** As you run, you lose some of your mechanical energy each time your foot strikes the ground; this energy is transformed into unrecoverable thermal energy. Luckily, about 35% of the decrease in your mechanical energy when your foot strikes is stored as elastic potential energy in the stretchable Achilles tendon of the lower leg. On each plant of the foot the tendon is stretched, storing some energy. The tendon springs back as you push off the ground again, helping to propel you forward. The recovered energy reduces the amount of internal chemical energy you use, increasing your efficiency.



**Dinner at a distance** **BIO** A chameleon's tongue is a powerful tool for catching prey. Certain species can extend the tongue to a distance of over 1 ft in less than 0.1 s! A study of the kinematics of the motion of the chameleon tongue, using techniques like those in this chapter, reveals that the tongue has a period of rapid acceleration followed by a period of constant velocity. This knowledge is a very valuable clue in the analysis of the evolutionary relationships between chameleons and other animals.

Fascinating, self-contained **Life-science Applications** throughout the text illustrate how physics relates to the real world.

**FIGURE 20.35** The beating heart generates a dipole electric field.

(a) The electric dipole of the heart

A cross section of the heart showing muscle tissue. This line separates cells that have depolarized and those that have not. Depolarized tissue. Tissue not yet depolarized.

The always separation in the line between the two regions creates an electric dipole.

(b) The field of the heart in the body

The heart's dipole field extends throughout the torso.

The electric field is created by charges. Field lines start on a positive charge and end on a negative charge.

You can use the above information as the basis of a technique for sketching a field line picture for an arrangement of charges. Draw field lines starting on positive charges and moving toward negative charges. Draw the lines tangent to the field vector at each point. Make the lines close together where the field is strong, far apart where the field is weak. For example, Figure 20.34 pictures the electric field of a dipole using electric field lines. You should compare this to Figure 20.29b, which illustrated the field with field vectors.

**The Electric Field of the Heart**

Nerve and muscle cells have a prominent electrical nature. As we will see in detail in Chapter 23, a cell membrane is an insulator that encloses a conducting fluid and is surrounded by conducting fluid. While resting, the membrane is *polarized* with positive charges on the outside of the cell, negative charges on the inside. When a nerve or a muscle cell is stimulated, the polarity of the membrane switches; we say that the cell *depolarizes*. Later, when the charge balance is restored, we say that the cell *repolarizes*.

All nerve and muscle cells generate an electrical signal when depolarization occurs, but the largest electrical signal in the body comes from the heart. The rhythmic beating of the heart is produced by a highly coordinated wave of depolarization that sweeps across the tissue of the heart. As Figure 20.35a shows, the surface of the heart is positive on one side of the boundary between tissue that is depolarized and tissue that is not yet depolarized, negative on the other. In other words, the heart is a large electric dipole. The orientation and strength of the dipole change during each beat of the heart as the depolarization wave sweeps across it.

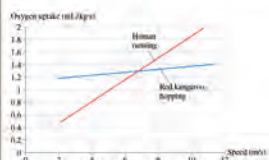
The electric dipole of the heart generates a dipole electric field that extends throughout the torso, as shown in Figure 20.35b. As we will see in Chapter 21, an *electrocardiogram* measures the changing electric field of the heart as it beats. Measurement of the heart's electric field can be used to diagnose the operation of the heart.

## Passage Problems

### Kangaroo Locomotion

Kangaroos have very stout tendons in their legs that can be used to store energy. When a kangaroo lands on its feet, the tendons stretch, transforming kinetic energy of motion to elastic potential energy. Much of this energy can be transformed back into kinetic energy as the kangaroo takes another hop. The kangaroo's peculiar hopping gait is not very efficient at low speeds but is quite efficient at high speeds.

Figure P11.61 shows the energy cost of human and kangaroo locomotion. The graph shows oxygen uptake (in mL/s) per kg of body mass, allowing a direct comparison between the two species.



**FIGURE P11.61** Oxygen uptake (a measure of energy use per second) for a running human and a hopping kangaroo.

For humans, the energy used per second (i.e., power) is proportional to the speed. That is, the human curve nearly passes through the origin, so running twice as fast takes approximately twice as much power. For a hopping kangaroo, the graph of energy use has only a very small slope. In other words, the energy used per second changes very little with speed. Going faster requires very little additional power. Treadmill tests on kangaroos and observations in the wild have shown that they do not become winded at any speed at which they are able to hop. No matter how fast they hop, the necessary power is approximately the same.

- At a speed of 1 km/h, how does his speed affect the total energy needed to cover this distance?
  - A faster speed requires less total energy.
  - A faster speed requires more total energy.
  - The total energy is about the same for a fast speed and a slow speed.
- A kangaroo hops 1 km. How does its speed affect the total energy needed to cover this distance?
  - A faster speed requires less total energy.
  - A faster speed requires more total energy.
  - The total energy is about the same for a fast speed and a slow speed.
- At a speed of 4 m/s,
  - A running human is more efficient than an equal-mass hopping kangaroo.
  - A running human is less efficient than an equal-mass hopping kangaroo.
  - A running human and an equal-mass hopping kangaroo have about the same efficiency.
- At approximately what speed would a human use half the power of an equal-mass kangaroo moving at the same speed?
  - 3 m/s
  - 4 m/s
  - 5 m/s
  - 6 m/s
- At approximately what speed would a human use twice the power of a kangaroo of half the mass moving at the same speed?
  - 3 m/s
  - 5 m/s
  - 7 m/s
  - 9 m/s

## Multiple-choice and Passage Problems

carefully test understanding by targeting common misconceptions and providing context-rich situations.

# PROMOTES DEEPER UNDERSTANDING

## Structured learning path

This text incorporates many subtle but powerful techniques that improve learning and retention, including a self-evident and structured learning path and a unique visual pedagogy.

### 24 Magnetic Fields and Forces

**LOOKING AHEAD** ▶  
The goal of Chapter 24 is to learn about magnetic fields and how magnetic fields exert forces on currents and moving charges.

**Magnetic Fields**  
We've seen how to describe electric forces by using electric fields; now we'll look at magnetic forces and magnetic fields.  
It's the magnetic force that causes a compass to line up with the earth's magnetic field.  
**Looking Back** ◀  
20.4 The electric field

**Forces on Moving Charges**  
Magnetic fields exert forces on moving charged particles. In a uniform field, a charged particle moves in a circular path.  
The aurora is due to the motion of charged particles from the sun in the magnetic field of the earth.  
A current is simply the motion of charges, so magnetic forces exert forces on currents.  
**Looking Back** ◀  
6.3 Dynamics of circular motion

**Magnetic Field Sources**  
Iron filings work like little compasses to show magnetic field patterns. We'll see that magnetic fields are created by permanent magnets and by electric currents.  
The simplest magnet is a bar magnet. It has two poles, north and south, and so creates a dipole field.  
A loop of current creates a dipole field as well. You will learn how to compute magnetic fields resulting from currents in wires, loops, and coils.  
**Looking Back** ◀  
20.5 Electric dipoles

**Magnetic Materials**  
Iron and a few other elements can exhibit permanent magnetism. The permanent alignment of electron dipoles leads to a large, fixed magnetic field in these materials.  
You will see how the atomic behavior of electrons in atoms leads to the familiar observation that magnets stick to a refrigerator.  
**Looking Back** ◀  
7.2 Calculating torque

**Dipoles and Torques**  
A compass, a loop of wire, and electrons and protons all are magnetic dipoles. All dipoles experience a torque in a magnetic field that rotates them to line up with the field.  
We'll explore how the alignment of atomic dipoles by the large magnetic field of an MRI solenoid can be used to create an image.  
Magnetic torque on these coils causes this computer fan motor to turn.  
**Looking Back** ◀  
7.2 Calculating torque

This detailed image of the system of a dolphin's brain with X rays. It was made by magnetism. How to this do?

**LOOKING AHEAD** ▶  
The goal of Chapter 24 is to learn about magnetic fields and how magnetic fields exert forces on currents and moving charges.

**Magnetic Fields**  
We've seen how to describe electric forces by using electric fields; now we'll look at magnetic forces and magnetic fields.  
It's the magnetic force that causes a compass to line up with the earth's magnetic field.  
**Looking Back** ◀  
20.4 The electric field

**Forces on Moving Charges**  
Magnetic fields exert forces on moving charged particles. In a uniform field, a charged particle moves in a circular path.  
The aurora is due to the motion of charged particles from the sun in the magnetic field of the earth.  
**Looking Back** ◀  
6.3 Dynamics of circular motion

**Magnetic Field Sources**  
Iron filings work like little compasses to show magnetic field patterns. We'll see that magnetic fields are created by permanent magnets and by electric currents.  
The simplest magnet is a bar magnet. It has two poles, north and south, and so creates a dipole field.  
A loop of current creates a dipole field as well. You will learn how to compute magnetic fields resulting from currents in wires, loops, and coils.  
**Looking Back** ◀  
20.5 Electric dipoles

**Magnetic Materials**  
Iron and a few other elements can exhibit permanent magnetism. The permanent alignment of electron dipoles leads to a large, fixed magnetic field in these materials.  
You will see how the atomic behavior of electrons in atoms leads to the familiar observation that magnets stick to a refrigerator.  
**Looking Back** ◀  
7.2 Calculating torque

**Dipoles and Torques**  
A compass, a loop of wire, and electrons and protons all are magnetic dipoles. All dipoles experience a torque in a magnetic field that rotates them to line up with the field.  
We'll explore how the alignment of atomic dipoles by the large magnetic field of an MRI solenoid can be used to create an image.  
Magnetic torque on these coils causes this computer fan motor to turn.  
**Looking Back** ◀  
7.2 Calculating torque

**Chapter Previews** are based on the educational psychology concept of an "advance organizer." Each chapter begins with an illustrated preview of the upcoming ideas, setting them in context, explaining their utility, and tying them to existing knowledge (through **Looking Back** references).

**Stop to Think Questions** at the end of a section allow for a quick comprehension check before moving on. Using powerful ranking-task and graphical techniques, they efficiently probe key misconceptions and encourage active reading. (Answers are provided at the end of the chapter.)

**STOP TO THINK 10.4** Rank in order, from largest to smallest, the gravitational potential energies of identical balls 1 to 4.

**NOTE Paragraphs** point out common misconception, common sticking points, and highlight math-related issues that may cause difficulties.

**16 CHAPTER 24 Magnetic Fields and Forces**

**The force on a charged particle moving in a magnetic field**

**NOTE** ▶ The right-hand rule for forces gives the direction of the force on a positive charge. For a negative charge, the force is in the opposite direction. ◀

**NOTE** ▶ The right-hand rule for forces gives the direction of the force on a positive charge. For a negative charge, the force is in the opposite direction. ◀

We can organize all of the experimental information about the magnetic force on a moving charged particle into a single equation. If a particle of charge  $q$  moves with a velocity  $\vec{v}$  in an magnetic field  $\vec{B}$ , the force is

$$\vec{F} = (q)\vec{v} \times \vec{B}$$

The velocity and the magnetic field are perpendicular in many practical situations. In this case a  $90^\circ$  cross product can simplify Equation 24.5 to

$$\vec{F} = (q)vB$$

The following Tactics Box summarizes and shows how to use the above information.

# Proven visual pedagogy

**Figures** are carefully streamlined in detail and color. In addition, chalkboard-like dialogue boxes (versus lengthy captions in other textbooks) are effectively used in:

- interpreting a graph, equation, or figure
- understanding a process
- translating between text, math, graphs, and figures
- grasping a difficult concept through a visual analogy

**FIGURE 5.12** The sensation of weight for a man at rest.

(a) The man feels the normal force pressing against his feet.

(b) When he stands at rest, the magnitudes of the normal force and the weight are equal.

**FIGURE 20.2** A conductor is charged by contact with a charged plastic rod.

Charge is transferred to the metal upon contact.

These charges repel each other.

Very fast

spreads the surface of the metal.

**FIGURE 27.3** A motorcycle's velocity as seen by Sue and by Jim.

$v$  is the relative velocity between Jim's reference frame and Sue's.

$u = 75$  mph

$v = 50$  mph

$u$  is the velocity of the motorcycle as measured in Sue's frame.

**FIGURE 2.9** Motion diagram and position-versus-time graph for uniform motion.

Uniform motion

The displacements between successive frames are the same. Dots are equally spaced.  $v_x$  is constant.

The position-versus-time graph is a straight line. The slope of the line is  $v_x$ .

Equal displacements

$m_S(v_{Sx}^f) + m_D(v_{Dx}^f) = m_S(v_{Sx}^i) + m_D(v_{Dx}^i) = 0$

The skaters' final momentum ... equals their initial momentum ... which was zero.

Critically acclaimed **Visual Chapter Summaries** consolidate understanding by providing each concept in words, math, and figures and organizing these into a coherent hierarchy—from General Principles to Applications.

**SUMMARY**

The goal of Chapter 24 has been to learn about magnetic fields and how magnetic fields exert forces on currents and moving charges.

**GENERAL PRINCIPLES**

**Sources of Magnetism**

At its most fundamental level, magnetism is an interaction between moving charges. Magnetic fields can be created by either:

- electric currents or
- permanent magnets

The most basic unit of magnetism is the magnetic dipole, which consists of a north and a south pole.

Three basic kinds of dipoles are:

- Current loop
- Permanent magnet
- Atomic magnet

**Consequences of Magnetism**

Magnetic fields exert long-range forces on magnetic matter and on moving charges (or currents).

- Parallel wires with currents in the same direction attract each other; when the currents are in opposite directions, the wires repel each other.
- Unlike poles of magnets attract each other; like poles repel each other.

Magnetic fields exert torques on magnetic dipoles, lining them with the field.

If two or more sources of magnetic field are present, the principle of superposition applies to forces and torques.

**IMPORTANT CONCEPTS**

**Magnetic Fields**

The direction of the magnetic field

- is the direction in which the north pole of a compass needle points.
- due to a current can be found from the right-hand rule for fields.

The strength of the magnetic field is

- proportional to the torque on a compass needle when turned slightly from the field direction.
- measured in tesla (T):  $1\text{ T} = \frac{\text{N}}{\text{A}\cdot\text{m}}$

**Magnetic Forces and Torques**

The magnitude of the magnetic force on a moving charge depends on its charge  $q$ , its speed  $v$ , and the angle  $\alpha$  between the velocity and the field:

$$F = |q|vB \sin \alpha$$

The direction of this force on a positive charge is given by the right-hand rule for forces.

The magnitude of the force on a current-carrying wire perpendicular to the magnetic field depends on the current in the wire:  $F = ILB$ .

The torque on a current loop in a magnetic field depends on the current, the loop's area, and how the loop is oriented in the field:  $\tau = (IA)B \sin \theta$ .

**APPLICATIONS**

**Fields due to common currents.**

**Charged-particle motion**

No force if  $\vec{v}$  is parallel to  $\vec{B}$ .

If  $\vec{v}$  is perpendicular to  $\vec{B}$  the particle undergoes uniform circular motion with radius  $r = mv/|q|B$ .

**Stability of magnetic dipoles.**

A magnetic dipole is stable (in a lower energy state) when aligned with the external magnetic field. It is unstable (in a higher energy state) when aligned opposite to the field.

The probe field of an MRI scanner is the flipping of magnetic dipoles between these two orientations.

**SUMMARY**

The goal of Chapter 2 has been to describe and analyze linear motion.

**GENERAL STRATEGIES**

**Problem-Solving Strategy**

Our general problem-solving strategy has three parts:

- PREPARE** Set up the problem:
  - Draw a picture
  - Collect necessary information
  - Do preliminary calculations
- SOLVE** Do the necessary mathematics of reasoning.
- ASSESS** Check your answer to see if it is complete in all details and makes physical sense.

**Visual Overview**

A visual overview consists of several pieces that completely specify a problem. This may include any or all of the elements below:

- Motion diagram
- Pictorial representation
- Graphical representation
- List of values

**IMPORTANT CONCEPTS**

**Velocity** is the rate of change of position:

$$v_x = \frac{\Delta x}{\Delta t}$$

**Acceleration** is the rate of change of velocity:

$$a_x = \frac{\Delta v_x}{\Delta t}$$

The units of acceleration are  $\text{m/s}^2$ .

An object is speeding up if  $v_x$  and  $a_x$  have the same sign, slowing down if they have opposite signs.

**Applications**

**Uniform motion:** An object in uniform motion has a constant velocity. Its velocity graph is a horizontal line; its position graph is linear.

**Relative with constant acceleration:** An object with constant acceleration has a constantly changing velocity. Its velocity graph is linear; its position graph is a parabola.

**Free fall:** Free fall is a special case of constant-acceleration motion; the acceleration has magnitude  $g = 9.80 \text{ m/s}^2$  and is always directed vertically downward whether an object is moving up or down.

**Kinematic equations for uniform motion:**

$$x_f = x_i + v_i \Delta t$$

**Kinematic equations for motion with constant acceleration:**

$$v_f = v_i + a_i \Delta t$$

$$x_f = x_i + v_i \Delta t + \frac{1}{2} a_i (\Delta t)^2$$

$$v_f^2 = v_i^2 + 2a_i \Delta x$$

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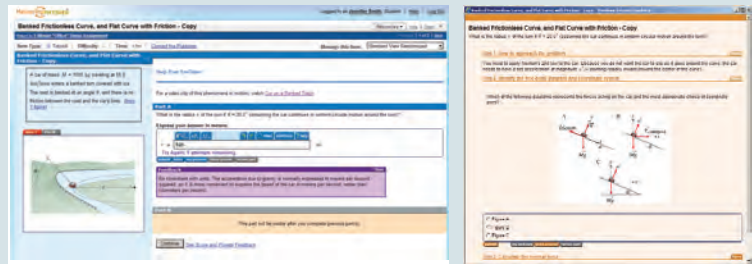
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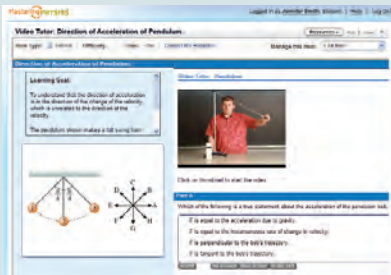
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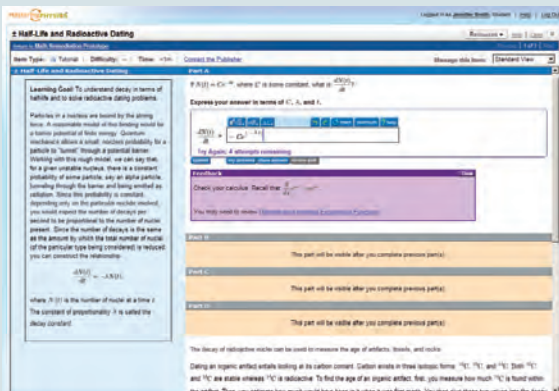


**Feedback**  
Be consistent with units. The acceleration due to gravity is normally expressed in meters per second squared, so it is more convenient to express the speed of the car in meters per second, rather than kilometers per second.



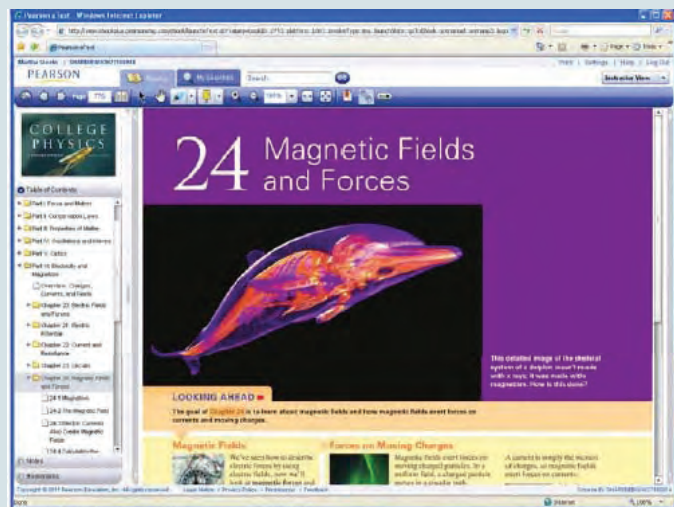
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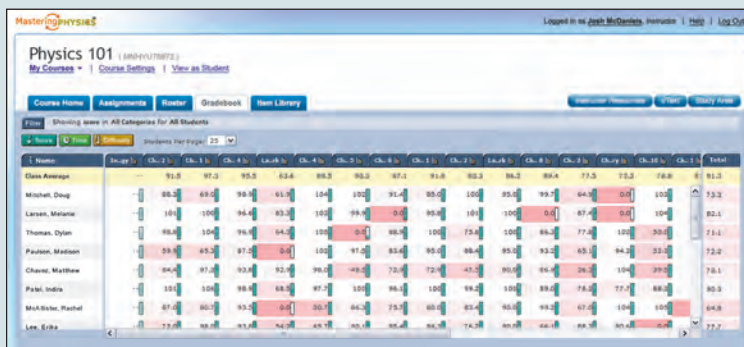
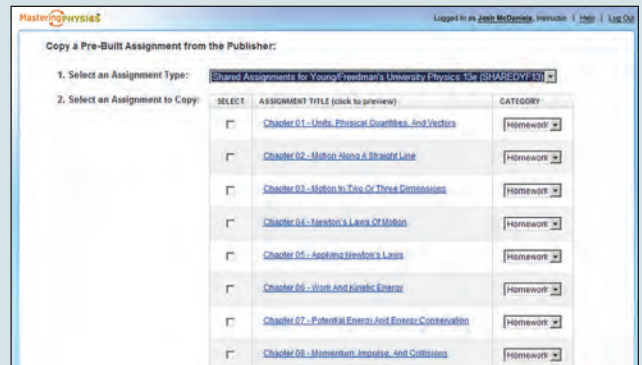


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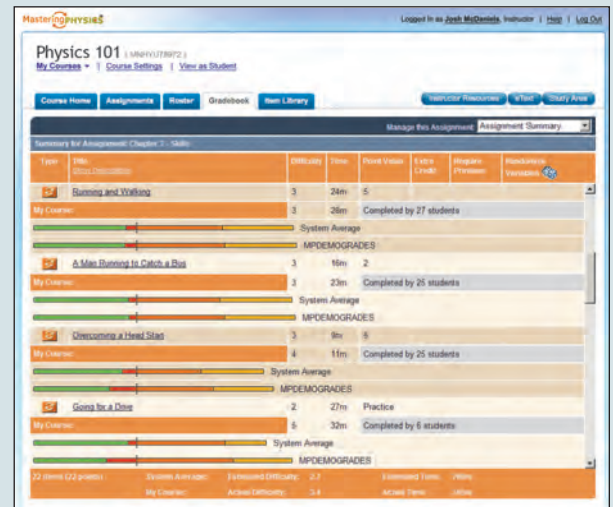


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# Preface to the AP\* Edition

In 2006, we published *College Physics: A Strategic Approach*, a new algebra-based physics textbook for college students majoring in the biological and life sciences, architecture, natural resources, and other disciplines. Our goal from the beginning has been a textbook combining the best results from physics education research with inspiring photographs and examples connecting physics to the real world. Our commitment to this goal is undiminished, and with the publication of the AP\* Edition of *College Physics: A Strategic Approach, 2nd Edition*, we are pleased to provide both the motivation and the tools required for AP Physics B students to succeed in the classroom, on the AP UC Exam, and in college-level courses.

## Objectives

Our primary goals in writing *College Physics: A Strategic Approach, AP\* Edition* are:

- To provide students with a textbook that's a more manageable size, less encyclopedic in its coverage, and better designed for learning.
- To integrate proven techniques from physics education research into the classroom in a way that accommodates a range of teaching and learning styles.
- To help students develop both quantitative reasoning skills and solid conceptual understanding, with special focus on concepts well documented to cause learning difficulties.
- To help students develop problem-solving skills and confidence in a systematic manner using explicit and consistent tactics and strategies.
- To motivate students by integrating real-world examples relevant to their everyday experiences.
- To utilize proven techniques of visual instruction and design from educational research and cognitive psychology that improve student learning and retention and address a range of learner styles.

## What's New to This Edition

This AP\* Edition leverages the hallmarks of the First Edition—effective conceptual explanations and problem-solving instruction—with new pedagogical features. More than any other book, *College Physics* leads students to proficient and long-lasting problem-solving skills, a deeper and better-connected understanding of the concepts, and a broader picture of the relevance of physics to the world around them.

First and foremost, the content of the AP\* Edition of *College Physics: A Strategic Approach, 2nd Edition* is the same as the college edition—as all parties agree that AP Physics is a college-level course, and as such, its content and rigor should match the college offering. So, you ask, how is the AP\* Edition different from the college edition?

- The front matter of the AP\* Edition includes a detailed topic guide that correlates the Second Edition content to the current College Board AP Physics B curriculum guidelines (pp. xix–xxi). It also includes a comprehensive listing of all print and media supplements for AP students and teachers (pp. xvi–xvii).
- The AP\* Edition of *College Physics: A Strategic Approach, 2nd Edition* includes multi-year access to **MasteringPhysics® with Pearson eText**—a next-generation, one-source learning and assessment system.
- The AP\* Edition has a reinforced binding, which meets NASTA requirements, to withstand multiple years of high school use.
- New illustrated **Chapter Previews** at the start of each chapter provide visual, hierarchical, and non-technical previews proven to help students organize their thinking and improve their understanding of the upcoming material.
- New **Integrated Examples** at the end of each chapter give students additional help in solving general problems not tied to particular sections. Many integrate material from other chapters.
- New **Part Summary Problems** at the end of each of the seven parts of the book test students’ abilities to draw on concepts and techniques from multiple chapters.
- **More streamlined presentations** throughout the text. Based on extensive feedback, we’ve pared some topics, reconfigured others, and provided a more readable, student-friendly text.
- **Improved and more varied end-of-chapter problems.** Using data from MasteringPhysics, we have reworked the problem sets to enhance clarity, topic coverage, and variety—adding, in particular, more problems based on real-world situations and more problems using ratio reasoning.

The more significant content changes include:

- The treatment of Newton’s third law in Chapters 4 and 5 has been better focused on the types of problems that students will be asked to solve.
- Angular position and angular velocity are now developed together in Chapter 6, rather than being divided between Chapters 3 and 6. More emphasis has been given to angular position and angular velocity graphs, emphasizing the analogy with the linear position and velocity graphs of Chapter 2.
- The Chapter 10 presentation of work and energy has been streamlined and clarified. The problem-solving strategy for conservation of energy problems now plays a more prominent role.
- Chapter 11, *Using Energy*, is now more focused on concrete applications of energy use. All discussions of thermal properties have matter have been moved to Chapter 12, which has been reorganized to emphasize the single theme, “What happens to matter when you heat or cool it?”
- The ordering of topics within Chapters 18 and 19 has been revised. Ray tracing and the thin-lens equation are now paired together in Chapter 18; the pinhole camera and color/dispersion have moved to Chapter 19.
- Chapter 21 has been significantly rewritten to make the difficult idea of electric potential more concrete and usable.
- The section on household electricity has been moved from Chapter 23 to Chapter 26. Chapter 23 is now better focused on resistors and capacitors while Chapter 26, *AC Circuits*, has become a more practical chapter with sections on household electricity and electrical safety.
- Chapters 28–30 on quantum, atomic, and nuclear physics have been significantly streamlined in the hope that more instructors will be able to teach these important topics.

## Textbook Organization

*College Physics: A Strategic Approach* is a 30-chapter text intended for use in a full-year AP Physics B course. The textbook is divided into seven parts: Part I: *Force and Motion*, Part II: *Conservation Laws*, Part III: *Properties of Matter*, Part IV: *Oscillations and Waves*, Part V: *Optics*, Part VI: *Electricity and Magnetism*, and Part VII: *Modern Physics*.

Part I covers Newton’s laws and their applications. The coverage of two fundamental conserved quantities, momentum and energy, is in Part II, for two reasons. First, the way that problems are solved using conservation laws—comparing an *after* situation to a *before* situation—differs fundamentally from the problem-solving strategies used in Newtonian dynamics. Second, the concept of energy has a significance far beyond mechanical (kinetic and potential) energies. In particular, the key idea in thermodynamics is energy, and moving from the study of energy in Part II into thermal physics in Part III allows the uninterrupted development of this important idea.


Optics (Part V) is covered directly after oscillations and waves (Part IV), but *before* electricity and magnetism (Part VI). Further, we treat wave optics before ray optics. Our motivations for this organization are twofold. First, wave optics is largely just an extension of the general ideas of waves; in a more traditional organization, students will have forgotten much of what they learned about waves by the time they get to wave optics. Second, optics as it is presented in introductory physics makes no use of the properties of electromagnetic fields. The documented difficulties that students have with optics are difficulties with waves, not difficulties with electricity and magnetism. There’s little reason other than historical tradition to delay optics. However, the optics chapters are easily deferred until after Part VI for instructors who prefer that ordering of topics.

## AP Teacher Supplements

**NOTE** ► For convenience, all of the following teacher supplements (except for the Instructor Resource DVD) can be downloaded from the “Instructor Resources” area within MasteringPhysics ([www.masteringphysics.com](http://www.masteringphysics.com)). In addition, many of the teacher supplements and resources for this text are available electronically to qualified adopters on the Instructor Resource Center (IRC). Upon adoption or to preview, please go to [www.Pearson-School.com/Access\\_Request](http://www.Pearson-School.com/Access_Request) and select “Instructor Resource Center.” You will be required to complete a brief one-time registration. Upon verification of educator status, access information and instructions will be sent to you via email. Once logged into the IRC, enter your text ISBN in the “Search Our Catalog” box to locate your resources. ◀


- The **Instructor Guide** provides chapter-by-chapter creative ideas and teaching tips. In addition, it contains an extensive review of what has been learned from physics education research, and provides guidelines for using active-learning techniques.
- The **Instructor Solutions Manual**, provides *complete* solutions to all the end-of-chapter questions and problems. All solutions follow the Prepare/Solve/Assess problem-

solving strategy used in the textbook for quantitative problems, and Reason/ Assess strategy for qualitative ones.

 **MasteringPhysics®** ([www.masteringphysics.com](http://www.masteringphysics.com)) is a homework, tutorial, and assessment system designed to assign, assess, and track each student’s progress using a wide diversity of tutorials and extensively pre-tested problems. In addition to the textbook’s end-of-chapter and new end-of-part problems, MasteringPhysics for *College Physics, Second Edition*, also includes author-selected prebuilt assignments, specific tutorials for all the textbook’s Problem-Solving Strategies, Tactics Boxes, and Math Relationship boxes, as well as Reading Quizzes and Test Bank questions for each chapter.

MasteringPhysics provides instructors with a fast and effective way to assign uncompromising, wide-ranging online homework assignments of just the right difficulty and duration. The tutorials coach 90% of students to the correct answer with specific wrong-answer feedback. The powerful post-assignment diagnostics allow instructors to assess the progress of their class as a whole or to quickly identify individual student’s areas of difficulty.



-  Upon textbook purchase, students and teachers are granted access to MasteringPhysics®. High school teachers can obtain preview or adoption access for MasteringPhysics in one of the following ways:

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- The cross-platform **Instructor Resource DVD** (ISBN 978-0-321-59628-4) provides invaluable and easy-to-use resources for your class, organized by textbook chapter. The contents include a comprehensive library of more than 220 applets from **ActivPhysics OnLine™**, as well as all figures, photos, tables, and summaries from the textbook in JPEG format. In addition, all the Problem-Solving Strategies, Math Relationships Boxes, Tactics Boxes, and Key Equations are provided in editable Word and JPEG formats. The **Instructor Guide** is also included as editable Word files, along with pdfs of answers to the **Student Workbook** exercises, and **Lecture Outlines (with Classroom Response System “Clicker” Questions)** in PowerPoint.

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-  **ActivPhysics OnLine™** (accessed through the Self Study area within [www.masteringphysics.com](http://www.masteringphysics.com)) provides a comprehensive library of more than 420 tried and tested *ActivPhysics* applets updated for web delivery using the latest online technologies. In addition, it provides a suite of highly regarded applet-based tutorials developed by education pioneers Professors Alan Van Heuvelen and Paul D' Alessandris. The *ActivPhysics* margin icon directs students to specific exercises that complement the textbook discussion.

The online exercises are designed to encourage students to confront misconceptions, reason qualitatively about physical processes, experiment quantitatively, and learn to think critically. They cover all topics from mechanics to


electricity and magnetism and from optics to modern physics. More than 220 applets from the *ActivPhysics OnLine* library are also available on the *Instructor Resource DVD*.

## Student Supplements


(available for purchase)

- The **Student Workbooks** (Volume 1, Chapters 1–16, ISBN: 978-0-321-59632-1 and Volume 2, Chapters 17–30, ISBN: 978-0-321-59633-8) bridge the gap between textbook and homework problems. The workbook exercises, which are keyed to each section of the textbook, focus on developing specific skills ranging from identifying forces and drawing free-body diagrams to interpreting field diagrams.

- The **Student Solutions Manuals Chapters 1–16** (ISBN 978-0-321-59629-1) and **Chapters 17–30** (ISBN 978-0-321-59630-7), provide *detailed* solutions to more than half of the odd-numbered end-of-chapter problems. Following the problem-solving strategy presented in the text, thorough solutions are provided to carefully illustrate both the qualitative (Reason/Assess) and quantitative (Prepare/Solve/Assess) steps in the problem-solving process.

-  **MasteringPhysics®** ([www.masteringphysics.com](http://www.masteringphysics.com)) is a homework, tutorial, and assessment system based on years of research into how students work physics problems and precisely where they need help. Studies show that students who use MasteringPhysics significantly increase their final scores compared to hand-written homework. MasteringPhysics achieves this improvement by providing students with instantaneous feedback specific to their wrong answers, simpler sub-problems upon request when they get stuck, and partial credit for their method(s) used. This individualized, 24/7 Socratic tutoring is recommended by nine out of ten students to their peers as the most effective and time-efficient way to study.

- **Pearson eText** is available through MasteringPhysics. Allowing students access to the text wherever they have access to the Internet, Pearson eText comprises the full student text, including figures that can be enlarged for better viewing. Students are also able to pop up definitions and terms to help with vocabulary and the reading of the material, as well as take notes using the annotation feature at the top of each page.

-  **ActivPhysics OnLine™** (accessed via [www.masteringphysics.com](http://www.masteringphysics.com)), provides students with a suite of highly regarded applet-based tutorials. The *ActivPhysics* margin icons throughout the book direct students to specific exercises that complement the textbook discussion.

# How to Succeed in AP Physics

*The most incomprehensible thing about the universe is that it is comprehensible.*  
—Albert Einstein

What can you expect to learn in this course? Let's start by talking about what physics is. Physics is a way of thinking about the physical aspects of nature. Physics is not about "facts." It's far more focused on discovering *relationships* between facts and the *patterns* that exist in nature than on learning facts for their own sake. Our emphasis will be on thinking and reasoning. We are going to look for patterns and relationships in nature, develop the logic that relates different ideas, and search for the reasons *why* things happen as they do. Once we've figured out a pattern, a set of relationships, we'll look at applications to see where this understanding takes us.

Like any subject, physics is best learned by doing. "Doing physics" in this course means solving problems, applying what you have learned to answer questions at the end of the chapter. When you are given a homework assignment, you may find yourself tempted to simply solve the problems by thumbing through the text looking for a formula that seems like it will work. This isn't how to do physics—you want to learn to **reason**, not to "plug and chug."

How do you learn to reason in this way? There's no single strategy for studying physics that will work for all students, but we can make some suggestions that will certainly help:

- **Read each chapter *before* it is discussed in class.** Class attendance is much less effective if you have not prepared. When you first read a chapter, focus on learning new vocabulary, definitions, and notation. You won't understand what's being discussed or how the ideas are being used if you don't know what the terms and symbols mean.
- **Participate actively in class.** Take notes, ask and answer questions, take part in discussion groups. There is ample scientific evidence that *active participation* is far more effective for learning science than is passive listening.
- **After class, go back for a careful rereading of the chapter.** In your second reading, pay close attention to the details and the worked examples. Look for the *logic* behind each example, not just at what formula is being used. We have a three-step process by which we solve all of the worked examples in the text. Most chapters have detailed Problem-Solving Strategies to help you see how to apply this procedure to particular topics, and Tactics Boxes that explain specific steps in your analysis.
- **Apply what you have learned to the homework problems at the end of each chapter.** By following the techniques of the worked examples, applying the tactics and problem-solving strategies, you'll learn how to apply the knowledge you are gaining. In short, you'll learn to reason like a physicist.
- **Form a study group with two or three classmates.** There's good evidence that students who study regularly with a group do better than the rugged individualists who try to go it alone.

And we have one final suggestion. As you read the book, take part in class, and work through problems, step back every now and then to appreciate the big picture. You are going to study topics that range from motions in the solar system to the electrical signals in the nervous system that let you order your hand to turn the pages of this book. You will learn quantitative methods to calculate things such as how far a car will move as it brakes to a stop and how to build a solenoid for an MRI machine. It's a remarkable breadth of topics and techniques that is based on a very compact set of organizing principles. It's quite remarkable, really, well worthy of your study.

Now, let's get down to work.

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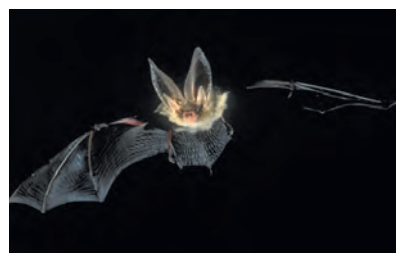
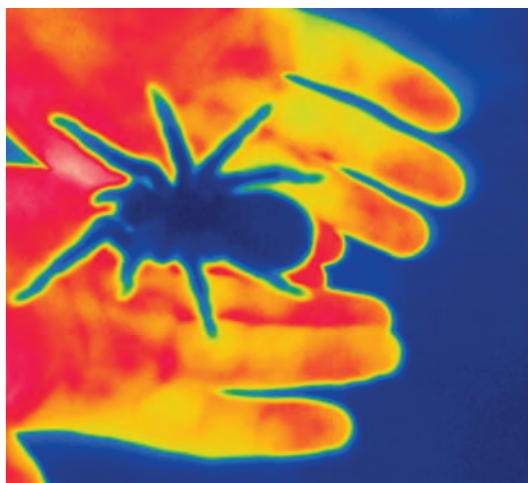


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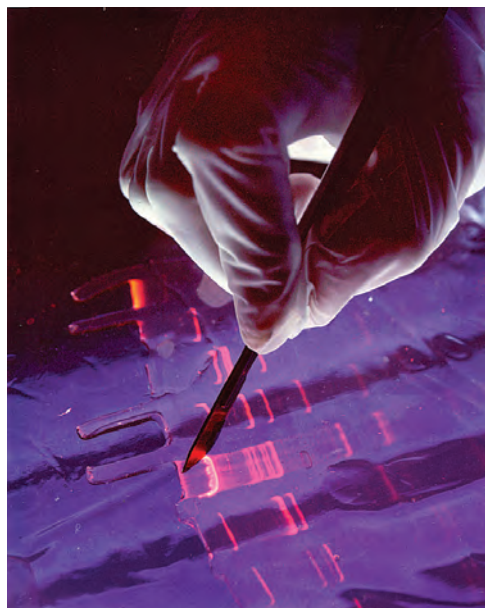
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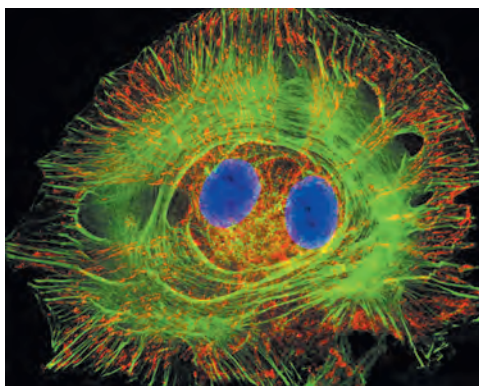
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