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EUGENE HECHT, PhD

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Twelfth Edition

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EUGENE HECHT is a full-time member of the Physics Department of Adelphi University in New York. He has authored ten books, and most recently the 5th edition of Optics, published by Addison-Wesley, which has been the leading text in the field, worldwide, for more than three decades. Professor Hecht has also written *Physics: Algebra/Trig and Physics: Calculus*, both published by Brooks/Cole, and *Schaum's Outline of Optics*, and he coauthored *Schaum's Outline of Quantum Mechanics*. He has also written several books on the American ceramist George Ohr and a number of papers on foundational issues in physics, the special theory of relativity, and the history of ideas. He spends most of his time studying, writing about and teaching physics, as well as training for a fifth-degree black belt in *Tae Kwan Do*.

contract, tort or otherwise.

Preface

The introductory noncalculus physics course at most colleges and universities is a two-semester survey of classical topics (i.e., roughly pre-20th century ideas) capped off with selected materials from what's called modern physics. *Schaum's Outline of College Physics* was designed to complement just such a course, whether given in high school or college. The requisite mathematical knowledge includes basic algebra, some trigonometry, and a bit of vector analysis, much of which will be discussed as needed, and can be learned as the reader progresses through the book. There are several appendixes for those who wish to review these subjects.

The main focus of this text is to teach problem solving. Everyone who has ever taught physics has heard the all-too-common student lament, "I understand everything; I just can't do the problems." Nonetheless most professors believe that doing problems is crucial to understanding physics. Like playing the piano, one must learn the basics, the theory, and then practice, practice, practice. A single missed note in a sonata may be overlooked; a single error in a calculation, however, will usually propagate throughout the entire analysis, producing a wrong answer. A teacher, even a great teacher, can only guide the learning process; the student must, on his/her own, master the material by studying problem solving by studying how problems of each type are analyzed. It's part of the process to make mistakes, discover those mistakes, correct them, and learn to avoid them, all at home and not in class on an exam. That's what this book is all about.

In this 12th edition, much effort has gone into increasing pedagogical effectiveness. I've added several hundred problems, most designed to develop the basic required analytic skills specific to each chapter. Today's students need a more gradual introduction to approaching the particular demands of the material of each different physics topic—they need additional support in order to learn how to solve the distinctive problems associated with each individual block of concepts. To that end, I've added explanatory diagrams, alternative solutions, and lots of hints on how to proceed. Chapters now contain a brief section called "Problem Solving Guide," which summarizes needed concepts, anticipates pitfalls, and offers cautionary notes that will be helpful in successfully dealing with the problems. I've gone over every question in the book to improve the pedagogy, removing possible ambiguities and making the questions more easily apprehended. All of this was field-tested and fine-tuned in countless exams in my many college-physics classes over the several years since the last edition.

I am grateful for all the comments and suggestions received from users of this book, especially those of Gregory Stansbury, who is reading it just for fun, and Jeremy Holbrook of Kennewick High School (in Kennewick, Washington), who is helping to prepare the next generation. Speaking of the next generation, I thank several Adelphi students—Lani Chau, Kelly Hiersche, Tara Pena, Muhammad Aziz, and Danielle Sofferman—who collectively worked through all the new problems; their feedback is most appreciated. Dr. Andreas Karpf was kind enough to look over the entire book and offer valuable suggestions. All the new art was brilliantly digitally executed by Jim Atherton of Atherton Customs, whose elegant work is unsurpassed. Last, I thank my wife, Carolyn Eisen Hecht, who patiently coped with one more edition of one more book. Her good humor, forbearance, wise counsel, and uncanny ability to spell any word in the language, were essential.

Anyone wishing to make suggestions for this or future editions can reach me at Adelphi University, Physics Department, Garden City, New York, 11530, or at genehecht@aol.com.

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EUGENE HECHT

Contents

CHAPTER 1

Speed, Displacement, and Velocity: An Introduction to Vectors

A Scalar Quantity, or **scalar,** is one that has nothing to do with spatial direction. Many physical concepts such as length, time, temperature, mass, density, charge, and volume are scalars; each has a scale or size, but no associated direction. The number of students in a class, the quantity of sugar in a jar, and the cost of a house are familiar scalar quantities.

Scalars are specified by ordinary numbers and add and subtract in the usual way. Two candies in one box plus seven in another are nine candies in total.

Distance (*l*): Get in a vehicle and travel a distance, some length in space, which we'll symbolize by the letter *l*. Suppose the tripmeter subsequently reads 100 miles (i.e., 161 kilometers); that's how far you went along whatever path you took, with no particular regard for hills or turns. Similarly, the bug in Fig. 1-1 walked a distance *l* measured along a winding route; *l* is also called the **path-length,** and it's a scalar quantity. (Incidentally, most people avoid using *d* for distance because it's widely used in the representation of derivatives.)

Average Speed (υ_{av}) is a measure of how fast a thing travels in space, and it too is a scalar quantity. Imagine an object that takes a time *t* to travel a distance *l*. The ***average speed*** during that interval is defined as

$$\text{Average speed} = \frac{\text{Total distance traveled}}{\text{Time elapsed}}$$
$$\upsilon_{av} = \frac{l}{t} \tag{1.1}$$

The everyday units of speed in the U.S.A. are miles per hour, but in scientific work we use kilometers per hour (km/h) or, better yet, meters per second (m/s). As we'll learn presently, speed is part of the more inclusive concept of velocity, and that's why we use the letter υ. A problem may concern itself with the average speed of an object, but it can also treat the special case of a ***constant speed*** υ, since then $\upsilon_{av} = \upsilon = l/t$ (see Problem 1.3).

You may also see this definition written as $\upsilon_{av} = \Delta l/\Delta t$, where the symbol Δ means "the change in." That notation just underscores that we are dealing with intervals of time (Δt) and space (Δl). If we plot a curve of **distance versus time,** and look at any two points P_i and P_f on it, their separation in space (Δl) is the *rise*, and in time (Δt) is the *run*. Thus, $\Delta l/\Delta t$ is the *slope* of the line drawn from the initial location, P_i, to the final location, P_f . *The slope is the average speed during that particular interval* (see Problem 1.5). Figure 1-1(*a*) depicts the case where the rise of the line from P_i to P_f happens to be 8.0 m and the run happens to be 5.0 s. The slope—the average speed over that interval—is then (8.0 m)/(5.0 s). Keep in mind that distance traveled, as indicated, for example, by an odometer in a car, is always positive and never decreases; consequently, the graph of l versus t is always positive and never decreases.

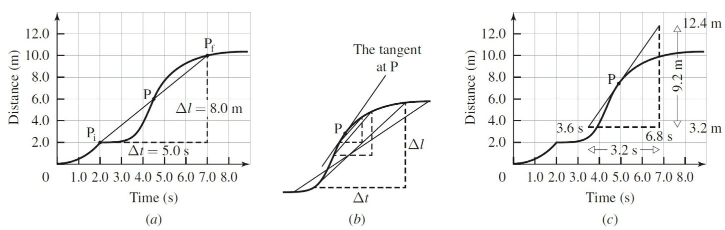

Fig. 1-1

Instantaneous Speed (υ): Thus far we've defined "average speed," but we often want to know the speed of an object at a specific time, say, 10 s after 1:00. Similarly, we might ask for the speed of something *now*. That's a new concept called the ***instantaneous speed,*** but we can define it building on the idea of average speed. What we need is the average speed determined over a vanishingly tiny time interval centered on the desired instant. Formally, that's stated as

$$\upsilon = \lim_{\Delta t \to 0} \left[\frac{\Delta l}{\Delta t} \right] \tag{1.2}$$

Instantaneous speed (or just speed, for short) is the limiting value of the average speed (Δl/Δt) determined as the interval over which the averaging takes place (Δt) approaches zero. This mathematical expression becomes especially important because it leads to the calculus and the idea of the derivative. To keep the math simple, we won't worry about the details; for us it's just the general concept that should be understood. In the next chapter, we'll develop equations for the instantaneous speed of an object at any specific time.

Graphically, the slope of a line tangent to the distance versus time curve at any point (i.e., at any particular time) is the instantaneous speed at that time. Accordingly, suppose we wish to find the instantaneous speed in Fig. 1-1(*b*) at point P. Notice how shrinking the time interval Δ*t*, straddling P, causes the line connecting the beginning and ending of the interval to approach being the tangent to the curve at P. To find the slope of that tangent, depicted in Fig. 1-1(*c*), take any two points on the tangent and compute the rise over the run.

A Vector Quantity is a physical concept that is inherently directional and can be specified completely only if both its **magnitude** (i.e., size) and direction are provided. Many physical concepts such as displacement, velocity, acceleration, force, and momentum are vector quantities. In general, a *vector* (which stands for a specific amount of some vector quantity) is depicted as a directed line segment and is pictorially represented by an arrow (drawn to scale) whose magnitude and direction determine the vector. In printed material vectors are usually symbolically presented in boldface type (e.g., **F** for force). When written by hand it's common to distinguish a vector by just putting an arrow over the appropriate symbol (e.g., $\vec{\mathrm{F}}$). For the sake of maximum clarity, we'll combine the two and use $\vec{\mathbf{F}}$.

The Displacement of an object from one location to another is a vector quantity. As shown in Fig. 1-2, the displacement of the bug in going from P_1 to point P_2 is specified by the vector $\vec{\mathbf{s}}$ (the symbol *s* comes from the century-old usage corresponding to the "space" between two points). If the straight-line distance from P_1 to P_2 is, say, 2.0 m, we simply draw $\vec{\mathbf{s}}$ to be a convenient length and label it 2.0 m. In any case, $\vec{\mathbf{s}}$ = 2.0 m—10° NORTH OF EAST.

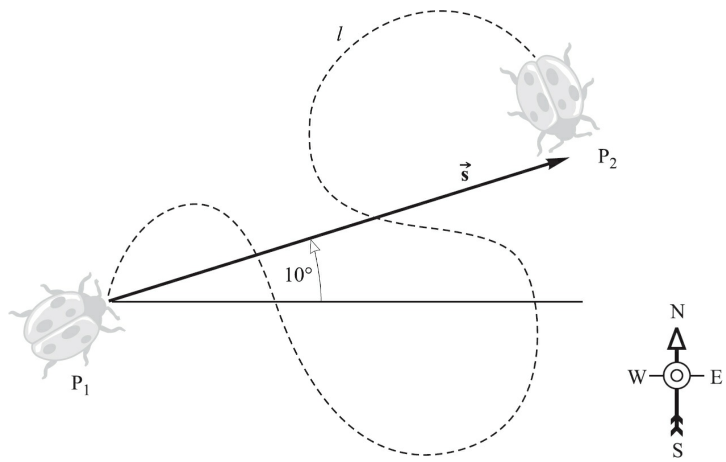

Fig. 1-2

Velocity is a vector quantity that embraces both the speed and the direction of motion. If an object undergoes a vector displacement $\vec{\mathbf{s}}$ in a time interval *t*, then

$$\begin{aligned} \textit{Average velocity} &= \frac{\text{Vector displacement}}{\text{Time taken}} \\ \vec{\mathbf{v}}_{av} &= \frac{\vec{\mathbf{s}}}{t} \end{aligned} \tag{1.3}$$

The direction of the velocity vector is the same as that of the displacement vector. The units of velocity (and speed) are those of distance divided by time, such as m/s or km/h.

Instantaneous Velocity is the average velocity evaluated for a time interval that approaches zero. Thus, if an object undergoes a displacement $\Delta\vec{\mathbf{s}}$ in a time Δt, then for that object the instantaneous velocity is

$$\vec{\mathbf{v}} = \lim_{\Delta t \to 0} \frac{\Delta \vec{\mathbf{s}}}{\Delta t} \tag{1.4}$$

where the notation means that the ratio $\Delta\vec{\mathbf{s}}/\Delta t$ is to be evaluated for a time interval Δt that approaches zero. Here, without calculus, we are just interested in the general idea of instantaneous velocity.

The Addition of Vectors: The concept of "vector" is not completely defined until we establish some rules of behavior. For example, how do several vectors (displacements, forces, whatever) add with one another? The bug in Fig. 1-3 walks from P_1 to P_2, pauses, and then goes on to P_3. It experiences two displacements $\vec{s}_1$ and $\vec{s}_2$, which combine to yield a net displacement $\vec{s}$. Here $\vec{s}$ is called the ***resultant*** or sum of the two constituent displacements, and it is the physical equivalent of them taken together $\vec{s} = \vec{s}_1 + \vec{s}_2$.

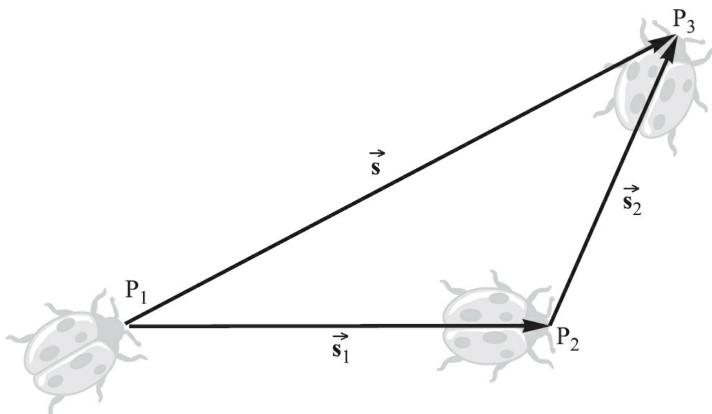

Fig. 1-3

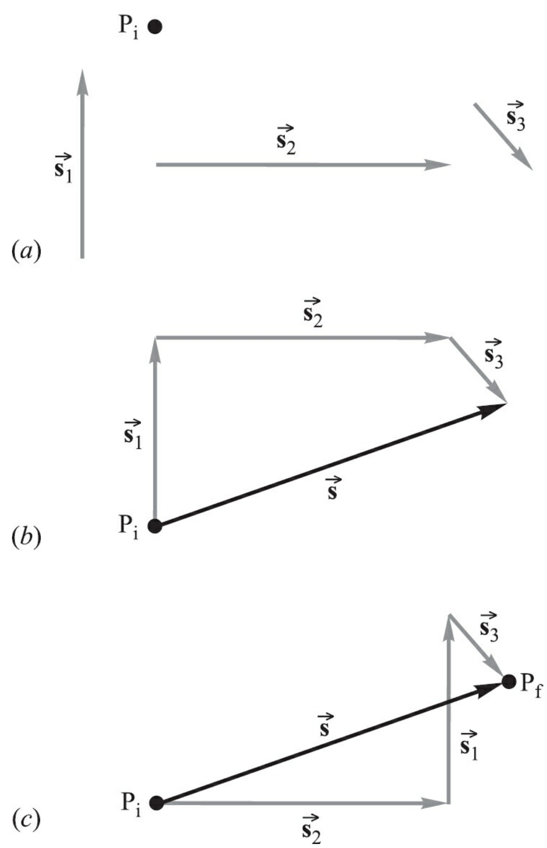

Fig. 1-4

The Tip-to-Tail (or Polygon) Method: The two vectors in Fig. 1-3 show us how to graphically add two (or more) vectors. Simply place the tail of the second ($\vec{\mathbf{s}}_2$) at the tip of the first ($\vec{\mathbf{s}}_1$); the resultant then goes from the starting point, P_1 (the tail of $\vec{\mathbf{s}}_1$), to the final point, P_3 (the tip of $\vec{\mathbf{s}}_2$). Fig. 1-4(*a*) is more general; it shows an initial starting point P_i and three displacement vectors. If we tip-to-tail those three displacements *in any order* [Fig. 1-4(*b*) and (*c*)] we'll arrive at the same final point P_f, and the same resultant $\vec{\mathbf{s}}$. In other words:

$$\vec{\mathbf{s}} = \vec{\mathbf{s}}_1 + \vec{\mathbf{s}}_2 + \vec{\mathbf{s}}_3 = \vec{\mathbf{s}}_2 + \vec{\mathbf{s}}_1 + \vec{\mathbf{s}}_3 \text{ etc.} \tag{1.5}$$

As long as the bug starts at P_i and walks the three displacements, in any sequence, it will end up at P_f.

The same tip-to-tail procedure holds for any kind of vector, be it displacement, velocity, force, or anything else. Accordingly, the resultant ($\vec{\mathbf{R}}$) obtained by adding the generic vectors $\vec{\mathbf{A}}$, $\vec{\mathbf{B}}$, and $\vec{\mathbf{C}}$ is shown in Fig. 1-5. The size or **magnitude** of a vector, for example, $\vec{\mathbf{R}}$, is its *absolute value* indicated symbolically as $|\vec{\mathbf{R}}|$; (we'll see how to calculate it presently). It's common practice, though not always a good idea, to represent the magnitude of a vector using just a light face italic letter, for example, $R = |\vec{\mathbf{R}}|$.

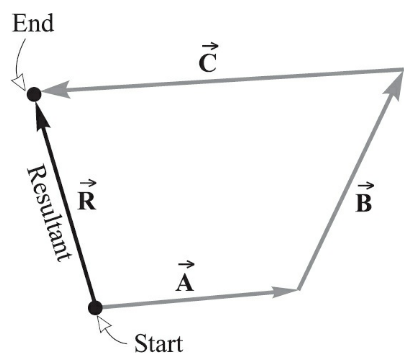

Fig. 1-5

Parallelogram Method for adding two vectors: The resultant of two vectors acting at any angle may be represented by the diagonal of a parallelogram. The two vectors are drawn as the sides of the parallelogram and the resultant is its diagonal, as shown in Fig. 1-6. The direction of the resultant is away from the origin of the two vectors.

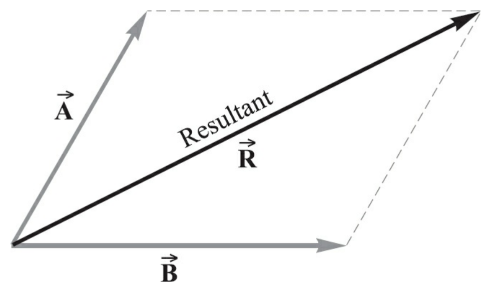

Fig. 1-6

Subtraction of Vectors: To subtract a vector $\vec{\mathbf{B}}$ from a vector $\vec{\mathbf{A}}$, reverse the direction of $\vec{\mathbf{B}}$ and add it to vector $\vec{\mathbf{A}}$, that is, $\vec{\mathbf{A}} - \vec{\mathbf{B}} = \vec{\mathbf{A}} + (-\vec{\mathbf{B}})$.

The Trigonometric Functions are defined in relation to a right angle. For the right triangle shown in Fig. 1-7, by definition

$$\sin\theta = \frac{\text{Opposite}}{\text{Hypotenuse}} = \frac{B}{C}, \qquad \cos\theta = \frac{\text{Adjacent}}{\text{Hypotenuse}} = \frac{A}{C}, \qquad \tan\theta = \frac{\text{Opposite}}{\text{Adjacent}} = \frac{B}{A} \tag{1.6}$$

We often use these in the forms

$$B = C\sin\theta \qquad A = C\cos\theta \qquad B = A\tan\theta \tag{1.7}$$

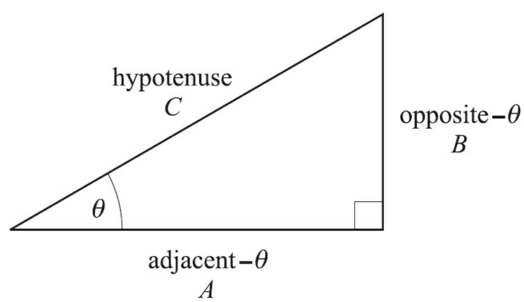

Fig. 1-7

A Component of a Vector is its effective value in a given direction. For example, the *x*-component of a displacement is the displacement parallel to the *x*-axis caused by the given displacement. A vector in three dimensions may be considered as the resultant of its component vectors resolved along any three *mutually perpendicular* directions. Similarly, a vector in two dimensions may be resolved into two component vectors acting along any two mutually perpendicular directions. Fig. 1-8 shows the vector $\vec{\mathbf{R}}$ and its *x* and *y* vector components, $\vec{\mathbf{R}}_x$ and $\vec{\mathbf{R}}_y$, which have magnitudes

$$|\vec{\mathbf{R}}_x| = |\vec{\mathbf{R}}|\cos\theta \qquad \text{and} \qquad |\vec{\mathbf{R}}_y| = |\vec{\mathbf{R}}|\sin\theta \tag{1.8}$$

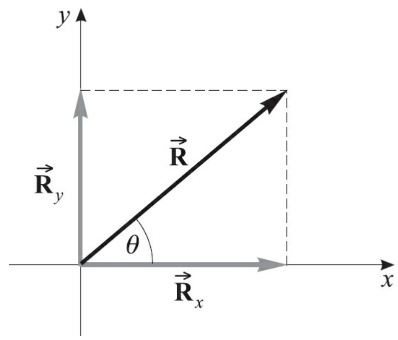

Fig. 1-8

or equivalently

$$R_x = R\cos\theta \qquad \text{and} \qquad R_y = R\sin\theta \tag{1.9}$$

Component Method for Adding Vectors: Each vector is resolved into its *x*-, *y*-, and *z*-components, with negatively directed components taken as negative. The scalar *x*-component *Rx* of the resultant $\vec{\mathbf{R}}$ is the algebraic sum of all the scalar *x*-components. The scalar *y*- and *z*-components of the resultant are found in a similar way. With the components known in three dimensions, the magnitude of the resultant is given by

$$R = \sqrt{R_x^2 + R_y^2 + R_z^2} \tag{1.10}$$

In two dimensions, the angle of the resultant with the *x*-axis can be found from the relation

$$\tan\theta = \frac{R_y}{R_x} \tag{1.11}$$

Unit Vectors have a magnitude of one and are represented by a boldface symbol topped with a caret. The special unit vectors $\hat{\mathbf{i}}$, $\hat{\mathbf{j}}$, and $\hat{\mathbf{k}}$, called *basis vectors*, are assigned to the *x*-, *y*-, and *z*-axes, respectively. A vector $3\hat{\mathbf{i}}$, represents a three-unit vector in the +*x*-direction, while $-5\hat{\mathbf{k}}$ represents a five-unit vector in the −*z*-direction. A vector $\vec{\mathbf{R}}$ that has scalar *x*-, *y*-, and *z*-components *Rx*, *Ry*, and *Rz*, respectively, can be written as $\vec{\mathbf{R}} = Rx\hat{\mathbf{i}} + Ry\hat{\mathbf{j}} + Rz\hat{\mathbf{k}}$. Not all introductory physics courses use basis vectors, in which case you can simply skip them.

Mathematical Operations with Units: In every mathematical operation, the units terms (for example, lb, cm, ft^3, mi/h, m/s^2) must be carried along with the numbers and must undergo the same mathematical operations as the numbers.

Quantities cannot be added or subtracted directly unless they have the same units (as well as the same dimensions). For example, if we are to add algebraically 5 m (length) and 8 cm (length), we must first convert m to cm or cm to m. However, quantities of any sort can be combined in multiplication or division, in which the units as well as the numbers obey the algebraic laws of squaring, cancellation, and so on. Thus:

$$(1)\quad 6\text{ m}^2 + 2\text{ m}^2 = 8\text{ m}^2 \qquad (\text{m}^2 + \text{m}^2 \rightarrow \text{m}^2)$$

$$(2)\quad 5\text{ cm} \times 2\text{ cm}^2 = 10\text{ cm}^3 \qquad (\text{cm} \times \text{cm}^2 \rightarrow \text{cm}^3)$$

$$(3)\quad 2\text{ m}^3 \times 1500\,\frac{\text{kg}}{\text{m}^3} = 3000\text{ kg} \qquad \left(\text{m}^3 \times \frac{\text{kg}}{\text{m}^3} \rightarrow \text{kg}\right)$$

$$(4)\quad 2\text{ s} \times 3\,\frac{\text{km}}{\text{s}^2} = 6\,\frac{\text{km}}{\text{s}} \qquad \left(\text{s} \times \frac{\text{km}}{\text{s}^2} \rightarrow \frac{\text{km}}{\text{s}}\right)$$

$$(5)\quad \frac{15\text{g}}{3\text{ g/cm}^3} = 5\text{ cm}^3 \qquad \left(\frac{\text{g}}{\text{g/cm}^3} \rightarrow \text{g} \times \frac{\text{cm}^3}{\text{g}} \rightarrow \text{cm}^3\right)$$

PROBLEM SOLVING GUIDE

Read each problem carefully! Most often we miss stuff on the first reading. Whenever possible, draw a simple diagram illustrating the problem. Put into the drawing all the given information as well as what you were asked to find. That will help you organize your thinking. Try doing the [I]-level worked-out problems first. Cover the solutions and look at them only after you're finished or you get stuck. Wait a day or two and then go back to any problem you could not do and try again, and again if need be, until you really master it. *Do not round off numbers in the middle of a calculation*.

SOLVED PROBLEMS

1.1 [I] A toy train moves along a winding track at an average speed of 0.25 m/s. How far will it travel in 4.00 minutes? (See Appendix A on significant figures.)

The defining equation is $\upsilon_{av} = l/t$. Here l is in meters, and t is in seconds, so the first thing to do is convert 4.00 min into seconds: (4.00 min)(60.0 s/min) = 240 s. Solving the equation for l,

$$l = \upsilon_{av} t = (0.25 \text{ m/s})(240 \text{ s})$$

Since the speed has only two significant figures, l = 60 m.

1.2 [I] A student driving a car travels 10.0 km in 30.0 min. What was her average speed?

The defining equation is $\upsilon_{av} = l/t$. Here l is in kilometers, and t is in minutes, so the first thing to do is convert 10.0 km to meters and then 30.0 min into seconds: (10.0 km)(1000 m/km) = 10.0×10^3 m and (30.0 min) × (60.0 s/min) = 1800 s. We need to solve for υ_{av}, giving the numerical answer to three significant figures:

$$\upsilon_{av} = \frac{l}{t} = \frac{10.0 \times 10^3 \text{ m}}{1800 \text{ s}} = 5.56 \text{ m/s}$$

1.3 [I] Rolling along across the machine shop at a constant speed of 4.25 m/s, a robot covers a distance of 17.0 m. How long does that journey take?

Since the speed is constant the defining equation is $\upsilon = l/t$. Multiply both sides of this expression by t and then divide both by υ:

$$t = \frac{l}{\upsilon} = \frac{17.0 \text{ m}}{4.25 \text{ m/s}} = 4.00 \text{ s}$$

1.4 [I] Change the speed 0.200 cm/s to units of kilometers per year. Use 365 days per year.

$$0.200 \frac{\text{cm}}{\text{s}} = \left(0.200 \frac{\cancel{\text{cm}}}{\cancel{\text{s}}}\right)\left(10^{-5} \frac{\text{km}}{\cancel{\text{cm}}}\right)\left(3600 \frac{\cancel{\text{s}}}{\cancel{\text{h}}}\right)\left(24 \frac{\cancel{\text{h}}}{\cancel{\text{d}}}\right)\left(365 \frac{\cancel{\text{d}}}{\text{y}}\right) = 63.1 \frac{\text{km}}{\text{y}}$$

1.5 [I] A car travels along a road and its odometer readings are plotted against time in Fig. 1-9. Find the instantaneous speed of the car at points *A* and *B*. What is the car's average speed?

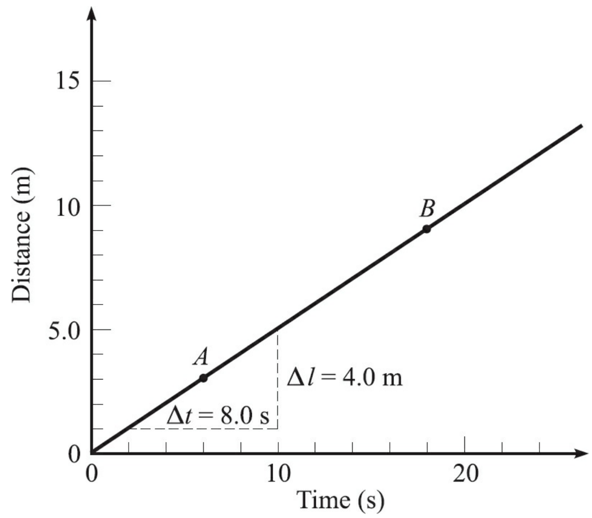

Fig. 1-9

Because the speed is given by the slope $\Delta l/\Delta t$ of the tangent line, we take a tangent to the curve at point *A*. The tangent line is the curve itself in this case, since it's a straight line. For the triangle shown near *A*, we have

$$\frac{\Delta l}{\Delta t} = \frac{4.0\ \text{m}}{8.0\ \text{s}} = 0.50\ \text{m/s}$$

This is the speed at point *A* and it's also the speed at point *B* and at every other point on the straight-line graph. It follows that $\upsilon = 0.50$ m/s $= \upsilon_{av}$. When the speed is constant the distance versus time curve is a straight line.

1.6 [I] A kid stands 6.00 m from the base of a flagpole which is 8.00 m tall. Determine the magnitude of the displacement of the brass eagle on top of the pole with respect to the youngster's feet.

The geometry corresponds to a 3-4-5 right triangle (i.e., 3 × 2 − 4 × 2 − 5 × 2). Thus, the hypotenuse, which is the 5-side, must be 10.0 m long, and that's the magnitude of the displacement.

1.7 [II] A runner makes one complete lap around a 200-m track in a time of

25 s. What were the runner's (*a*) average speed and (*b*) average velocity?

(*a*) From the definition,

$$\text{Average speed} = \frac{\text{Distance traveled}}{\text{Time taken}} = \frac{200\ \text{m}}{25\ \text{s}} = 8.0\ \text{m/s}$$

(*b*) Because the run ended at the starting point, the displacement vector from starting point to end point has zero length. Since $\vec{\mathbf{v}}_{av} = \vec{\mathbf{s}}/t$,

$$|\vec{\mathbf{v}}_{av}| = \frac{0\ \text{m}}{25\ \text{s}} = 0\ \text{m/s}$$

1.8 [I] Using the graphical method, find the resultant of the following two displacements: 2.0 m at 40° and 4.0 m at 127°, the angles being taken relative to the +*x*-axis, as is customary. Give your answer to two significant figures. (See Appendix A on significant figures.)

Choose *x*- and *y*-axes as seen in Fig. 1-10 and lay out the displacements to scale, tip to tail from the origin. Notice that all angles are measured from the +*x*-axis. The resultant vector $\vec{\mathbf{s}}$ points from starting point to end point as shown. We measure its length on the scale diagram to find its magnitude, 4.6 m. Using a protractor, we measure its angle θ to be 101°. The resultant displacement is therefore 4.6 m at 101°.

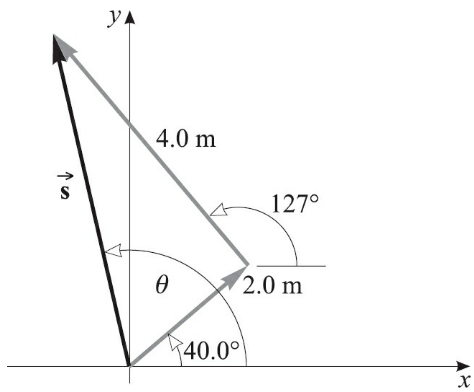

Fig. 1-10

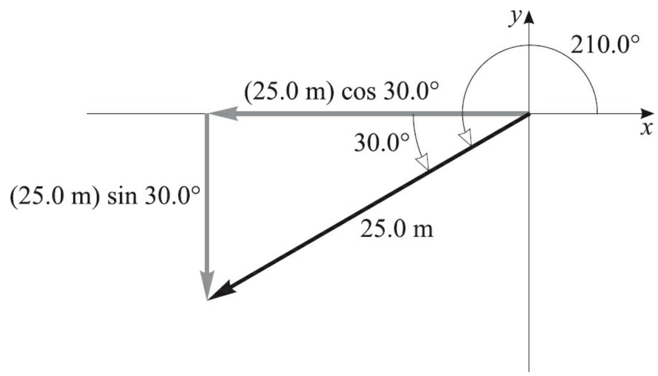

Fig. 1-11

1.9 [I] Find the *x*- and *y*-components of a 25.0-m displacement at an angle of 210.0°.

The vector displacement and its components are depicted in Fig. 1-11. The scalar components are

$$x\text{-component} = -(25.0\ \text{m})\cos 30.0° = -21.7\ \text{m}$$
$$y\text{-component} = -(25.0\ \text{m})\sin 30.0° = -12.5\ \text{m}$$

Notice in particular that each component points in the negative coordinate direction and must therefore be taken as negative.

1.10 [II] Solve Problem 1.8 by use of rectangular components.

We resolve each vector into rectangular components as illustrated in Fig. 1-12(*a*) and (*b*). (Place a cross-hatch symbol on the original vector to show that it is replaced by its components.) The resultant has scalar components of

$$s_x = 1.53\ \text{m} - 2.41\ \text{m} = -0.88\ \text{m} \qquad s_y = 1.29\ \text{m} + 3.19\ \text{m} = 4.48\ \text{m}$$

Notice that components pointing in the negative direction must be assigned a negative value. Thus, since *sx* is to the left in the negative *x*-direction it is negative, whereas *sy* is upward in the positive *y*-direction and is positive.

The resultant is shown in Fig. 1-12(*c*); there,

$$s = \sqrt{(0.88\ \text{m})^2 + (4.48\ \text{m})^2} = 4.6\ \text{m} \qquad \tan\phi = \frac{4.48\ \text{m}}{0.88\ \text{m}}$$

and $\varphi = 79°$, from which $\theta = 180° - \varphi = 101°$. Hence, $\vec{\mathbf{s}} = 4.6$ m − 101° FROM + x-AXIS; remember, vectors must have their directions stated explicitly.

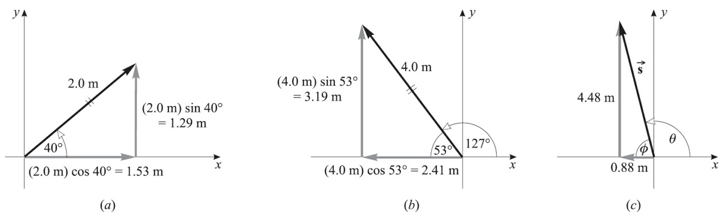

Fig. 1-12

1.11 [II] Add the following two displacement vectors using the parallelogram method: 30 m at 30° and 20 m at 140°. Remember that numbers like 30 m and 20 m have two significant figures.

The vectors are drawn with a common origin in Fig. 1-13(a). We construct a parallelogram using them as sides, as shown in Fig. 1-13(b). The resultant $\vec{\mathbf{s}}$ is then represented by the diagonal. By measurement, we find that $\vec{\mathbf{s}}$ is 30 m at 69°.

Fig. 1-13

1.12 [II] Express the vectors illustrated in Figs. 1-12(c), 1-14, 1-15, and 1-16 in the form $\vec{\mathbf{R}} = R_x\hat{\mathbf{i}} + R_y\hat{\mathbf{j}} + R_z\hat{\mathbf{k}}$ (leave out the units). If you are not using basis vectors skip this problem.

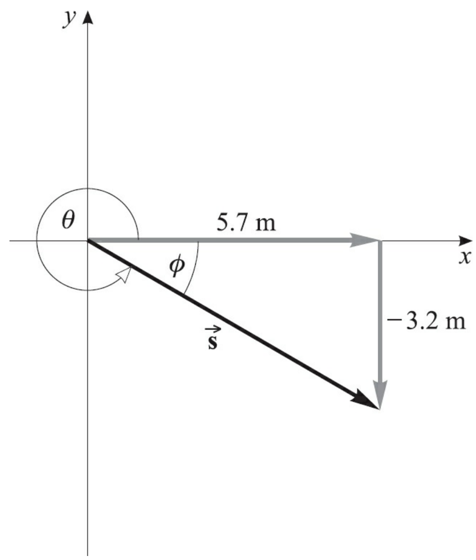

Fig. 1-14

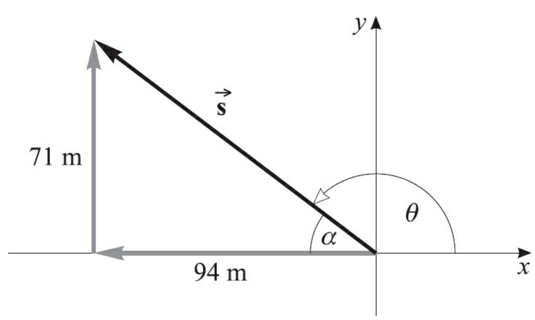

Fig. 1-15

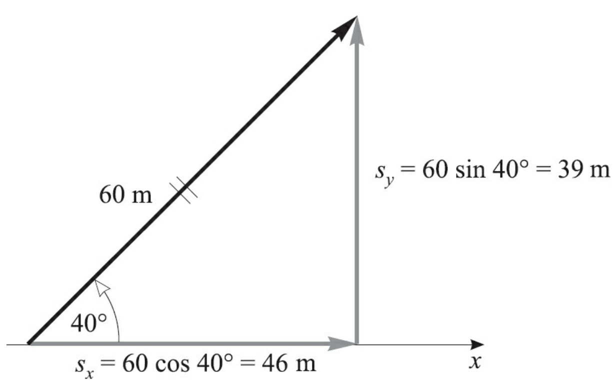

Fig. 1-16

Remembering that plus and minus signs must be used to show direction along an axis,