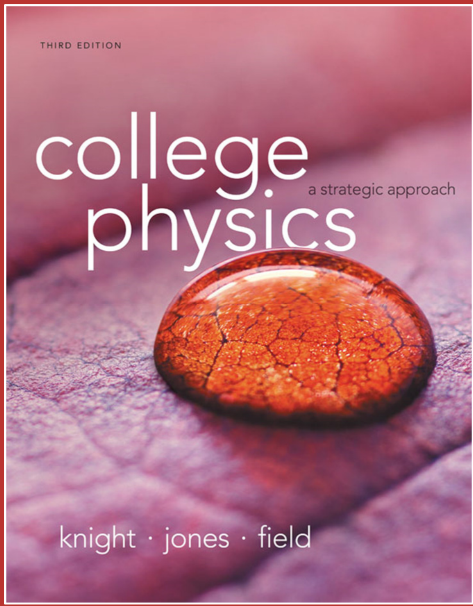


Lecture Presentation

Chapter 1

Representing Motion

Chapter 1 Representing Motion

Chapter Goal: To introduce the fundamental concepts of motion and to review related basic mathematical principles.

Chapter 1 Preview
Looking Ahead: Describing Motion

- This series of images of a skier clearly shows his motion. Such visual depictions are a good first step in describing motion.

- You'll learn to make **motion diagrams** that provide a simplified view of the motion of an object.

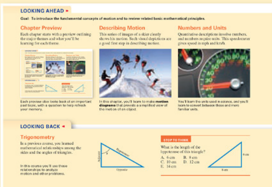
Chapter 1 Preview
Looking Ahead: Numbers and Units

- Quantitative descriptions involve numbers, and numbers require units. This speedometer gives speed in mph and km/h.

- You'll learn the units used in science, and you'll learn to convert between these and more familiar units.

Chapter 1 Preview
Looking Ahead

Chapter Preview
Each chapter starts with a preview outlining the major themes and what you'll be learning for each theme.



Each preview also looks back at an important past topic, with a question to help refresh your memory.

Describing Motion
This series of images of a skier clearly shows his motion. Such visual depictions are a good first step in describing motion.

In this chapter, you'll learn to make **motion diagrams** that provide a simplified view of the motion of an object.

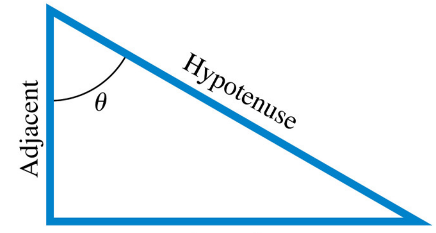
Numbers and Units
Quantitative descriptions involve numbers, and numbers require units. This speedometer gives speed in mph and km/h.

You'll learn the units used in science, and you'll learn to convert between these and more familiar units.

Text: p. 2

Chapter 1 Preview
Looking Back: Trigonometry

- In a previous course, you learned mathematical relationships among the sides and the angles of triangles.



- In this course you'll use these relationships to analyze motion and other problems.

Reading Question 1.1

What is the difference between speed and velocity?

A. Speed is an average quantity while velocity is not.
B. Velocity contains information about the direction of motion while speed does not.
C. Speed is measured in mph, while velocity is measured in m/s.
D. The concept of speed applies only to objects that are neither speeding up nor slowing down, while velocity applies to every kind of motion.
E. Speed is used to measure how fast an object is moving in a straight line, while velocity is used for objects moving along curved paths.

Reading Question 1.1

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E. Speed is used to measure how fast an object is moving in a straight line, while velocity is used for objects moving along curved paths.

Reading Question 1.2

The quantity 2.67×10^3 has how many significant figures?

A. 1
B. 2
C. 3
D. 4
E. 5

Reading Question 1.2

The quantity 2.67×10^3 has how many significant figures?

A. 1
B. 2
✔ C. 3
D. 4
E. 5

Reading Question 1.3

The correct SI units for distance and mass are

A. Feet, pounds.
B. Centimeters, grams.
C. Meters, grams.
D. Meters, kilograms.

Reading Question 1.3

The correct SI units for distance and mass are

A. Feet, pounds.
B. Centimeters, grams.
C. Meters, grams.
✔ D. Meters, kilograms.

Reading Question 1.4

If Sam walks 100 m to the right, then 200 m to the left, his net displacement vector

A. Points to the right.
B. Points to the left.
C. Has zero length.
D. Cannot tell without more information.

Reading Question 1.4

If Sam walks 100 m to the right, then 200 m to the left, his net displacement vector

A. Points to the right.
✔ B. Points to the left.
C. Has zero length.
D. Cannot tell without more information.

Reading Question 1.5

Velocity vectors point

A. In the same direction as displacement vectors.
B. In the opposite direction as displacement vectors.
C. Perpendicular to displacement vectors.
D. In the same direction as acceleration vectors.
E. Velocity is not represented by a vector.

Reading Question 1.5

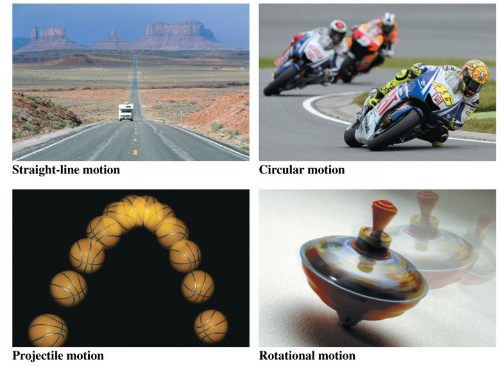
Velocity vectors point

✔ A. In the same direction as displacement vectors.
B. In the opposite direction as displacement vectors.
C. Perpendicular to displacement vectors.
D. In the same direction as acceleration vectors.
E. Velocity is not represented by a vector.

Section 1.1 Motion: A First Look

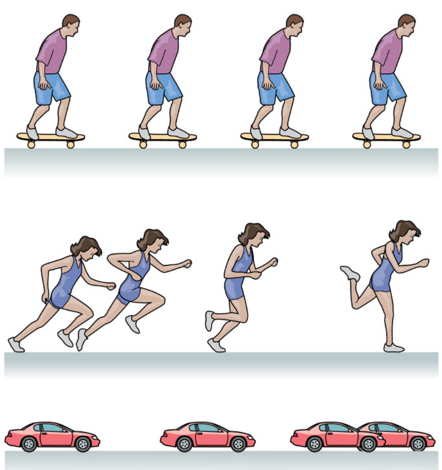
Types of Motion

- **Motion** is the change of an object's position or orientation with time.



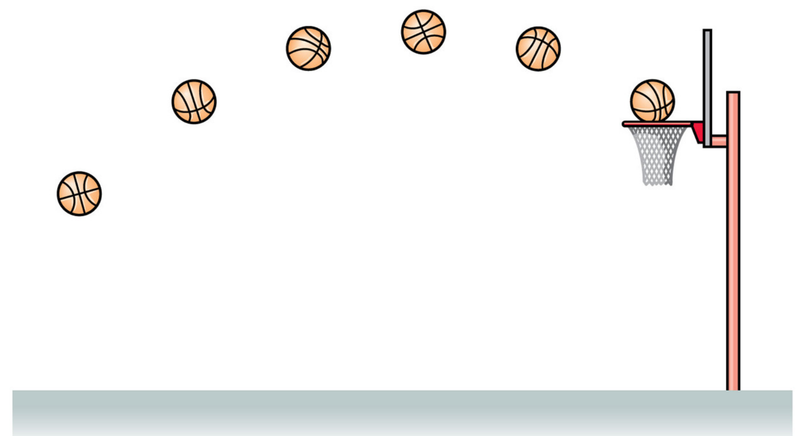
- The path along which an object moves is called the object's **trajectory**.

Making a Motion Diagram



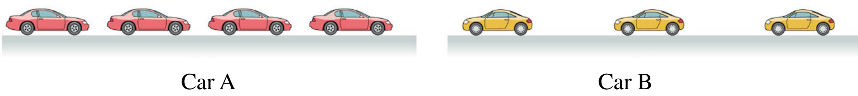
- These motion diagrams in one dimension show objects moving at constant speed (skateboarder), speeding up (runner) and slowing down (car).

Making a Motion Diagram



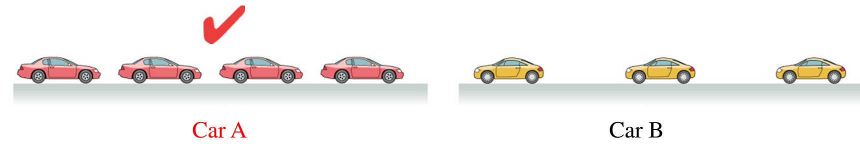
- This motion diagram shows motion in two dimensions with changes in both speed and direction.

QuickCheck 1.1



Motion diagrams are made of two cars. Both have the same time interval between photos. Which car, A or B, is going slower?

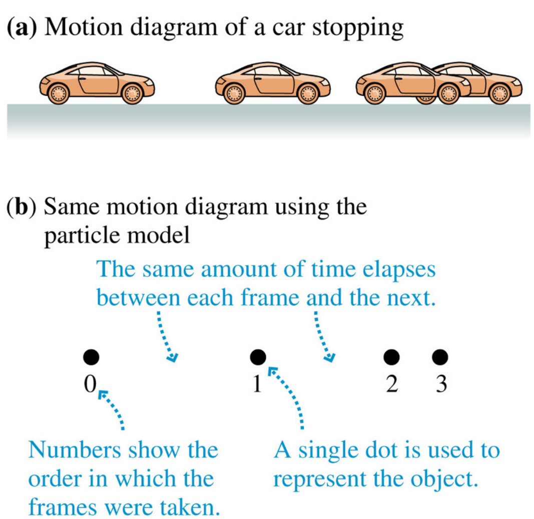
QuickCheck 1.1



Motion diagrams are made of two cars. Both have the same time interval between photos. Which car, A or B, is going slower?

The Particle Model

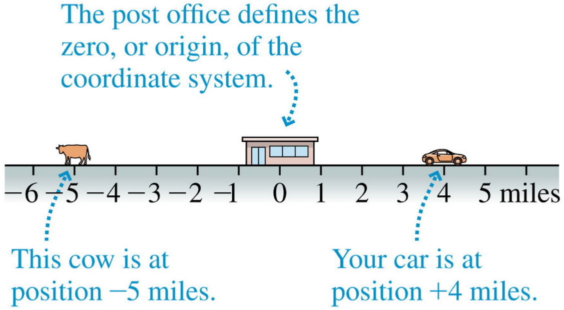
- The particle model of motion is a simplification in which we treat a moving object as if all of its mass were concentrated at a single point



Section 1.2 Position and Time: Putting Numbers on Nature

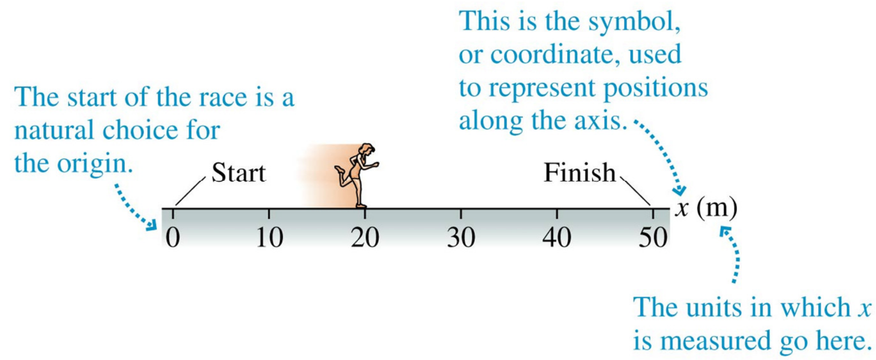
Position and Coordinate Systems

- To specify **position** we need a reference point (the **origin**), a **distance** from the origin, and a **direction** from the origin.



- The combination of an origin and an **axis** marked in both the positive and negative directions makes a **coordinate system**.

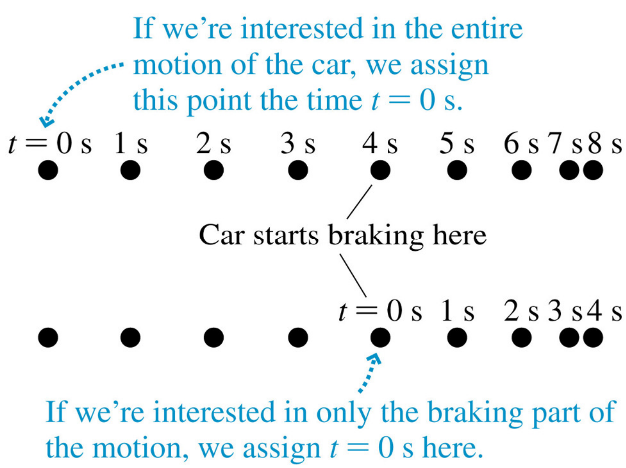
Position and Coordinate Systems



- The symbol that represents a position along an axis is called a **coordinate**.

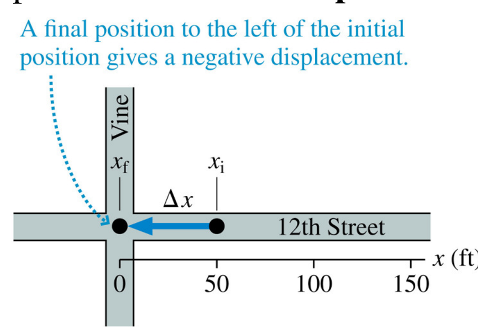
Time

- For a complete motion diagram we need to label each frame with its corresponding time (symbol t) as read off a clock.



Changes in Position and Displacement

- A *change* of position is called a **displacement**.

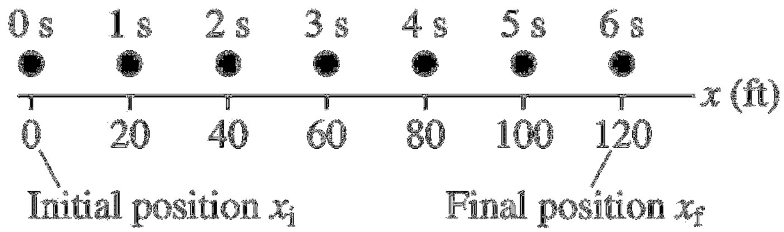


- Displacement is the *difference* between a final position and an initial position:

$$\Delta x = x_f - x_i = 150 \text{ ft} - 50 \text{ ft} = 100 \text{ ft}$$

Change in Time

- In order to quantify motion, we'll need to consider changes in *time*, which we call **time intervals**.



- **A time interval Δt measures the elapsed time as an object moves from an initial position x_i at time t_i to a final position x_f at time t_f.** Δt is always positive.

QuickCheck 1.4

Maria is at position $x = 23$ m. She then undergoes a displacement $\Delta x = -50$ m. What is her final position?

A. –27 m
B. –50 m
C. 23 m
D. 73 m

QuickCheck 1.4

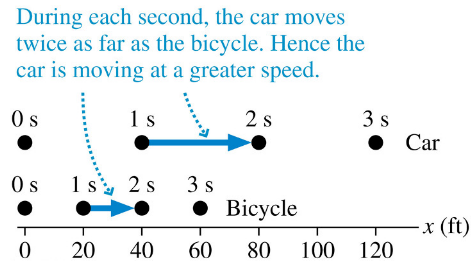
Maria is at position $x = 23$ m. She then undergoes a displacement $\Delta x = -50$ m. What is her final position?

✔ A. –27 m
B. –50 m
C. 23 m
D. 73 m

Section 1.3 Velocity

Velocity and Speed

- Motion at a constant speed in a straight line is called **uniform motion**.



$$\text{speed} = \frac{\text{distance traveled in a given time interval}}{\text{time interval}}$$

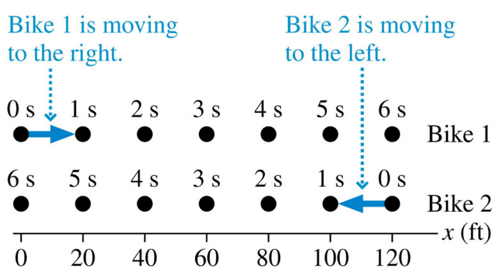
Speed of an object in uniform motion

Example Problem

Jane walks to the right at a constant rate, moving 3 m in 3 s. At $t = 0$ s she passes the $x = 1$ m mark. Draw her motion diagram from $t = -1$ s to $t = 4$ s.

Velocity and Speed

- **Speed measures only how fast an object moves, but velocity tells us both an object's speed *and its direction*.**



$$\text{velocity} = \frac{\text{displacement}}{\text{time interval}} = \frac{\Delta x}{\Delta t}$$

Velocity of a moving object

- The velocity defined by Equation 1.2 is called the *average* velocity.

Section 1.4 A Sense of Scale: Significant Figures, Scientific Notation, and Units

Measurements and Significant Figures

- When we measure any quantity we can do so with only a certain *precision*.

These calipers have a precision of 0.01 mm.

- We state our knowledge of a measurement through the use of **significant figures**: digits that are reliably known.

TACTICS BOX 1.1 Using significant figures

1. When you multiply or divide several numbers, or when you take roots, the number of significant figures in the answer should match the number of significant figures of the *least* precisely known number used in the calculation:

$$3.73 \times 5.7 = 21$$

Three significant figures (3.73); Two significant figures (5.7). Answer should have the *lower* of the two, or two significant figures.

2. When you add or subtract several numbers, the number of decimal places in the answer should match the *smallest* number of decimal places of any number used in the calculation:

$$\begin{array}{r} 18.54 \\ +106.6 \\ \hline 125.1 \end{array}$$

18.54 — Two decimal places; +106.6 — One decimal place. Answer should have the *lower* of the two, or one decimal place.

3. **Exact numbers** have no uncertainty and, when used in calculations, do not change the number of significant figures of measured numbers. Examples of exact numbers are π and the number 2 in the relation $d = 2r$ between a circle's diameter and radius.

There is one notable exception to these rules:

- It is acceptable to keep one or two extra digits during *intermediate* steps of a calculation to minimize round-off errors in the calculation. But the *final* answer must be reported with the proper number of significant figures.

Exercise 15

Text: p. 12

QuickCheck 1.7

Rank in order, from the most to the least, the number of significant figures in the following numbers. For example, if b has more than c, c has the same number as a, and a has more than d, you would give your answer as b > c = a > d.

a. 8200 b. 0.0052 c. 0.430 d. 4.321×10^{-10}

A. d > c > b = a
B. a = b = d > c
C. b = d > c > a
D. d > c > a > b
E. a = d > c > b

QuickCheck 1.7

Rank in order, from the most to the least, the number of significant figures in the following numbers. For example, if b has more than c, c has the same number as a, and a has more than d, you would give your answer as b > c = a > d.

a. 8200	b. 0.0052	c. 0.430	d. 4.321×10^{-10}
2? Ambiguous	2	3	4

✔ A. d > c > b = a
B. a = b = d > c
C. b = d > c > a
D. d > c > a > b
E. a = d > c > b

Scientific Notation

- Writing very large (much greater than 1) and very small (much less than 1) numbers is cumbersome and does not make clear how many significant figures are involved.

TACTICS BOX 1.2 Using scientific notation

To convert a number into scientific notation:

1. For a number greater than 10, move the decimal point to the left until only one digit remains to the left of the decimal point. The remaining number is then multiplied by 10 to a power; this power is given by the number of spaces the decimal point was moved. Here we convert the diameter of the earth to scientific notation:

   We move the decimal point until there is only one digit to its left, counting the number of steps.

   Since we moved the decimal point 6 steps, the power of ten is 6.

   $$6\,370\,000 \text{ m} = 6.37 \times 10^6 \text{ m}$$

   The number of digits here equals the number of significant figures.

2. For a number less than 1, move the decimal point to the right until it passes the first digit that isn't a zero. The remaining number is then multiplied by 10 to a negative power; the power is given by the number of spaces the decimal point was moved. For the diameter of a red blood cell we have:

   We move the decimal point until it passes the first digit that is not a zero, counting the number of steps.

   Since we moved the decimal point 6 steps, the power of ten is −6.

   $$0.000\,007\,5 \text{ m} = 7.5 \times 10^{-6} \text{ m}$$

   The number of digits here equals the number of significant figures.

Exercise 16

Text: p. 13

Units

- Scientists use a system of units called *le Système International d'Unités*, commonly referred to as **SI Units**.

TABLE 1.1 Common SI units

Quantity	Unit	Abbreviation
time	second	s
length	meter	m
mass	kilogram	kg

Unit Conversions

TACTICS BOX 1.3 Making a unit conversion

1. Start with the quantity you wish to convert.
2. Multiply by the appropriate conversion factor. Because this conversion factor is equal to 1, multiplying by it does not change the value of the quantity—only its units.

$$60 \text{ mi} = 60 \text{ mi} \times \frac{1.609 \text{ km}}{1 \text{ mi}} = 96.54 \text{ km} = 97 \text{ km}$$

3. You can cancel the original unit (here, miles) because it appears in both the numerator and the denominator.
4. Calculate the answer; it is in the desired units. Remember, 60 mi and 96.54 km are the same distance; they are simply in different units.
5. **Remember to convert your final answer to the correct number of significant figures!**

Exercise 17

Text: p. 15

Estimation

- A one-significant-figure estimate or calculation is called an order-of-magnitude estimate.
- An order-of-magnitude estimate is indicated by the symbol ~, which indicates even less precision than the "approximately equal" symbol ≈.

TABLE 1.4 Some approximate conversion factors

Quantity	SI unit	Approximate conversion
Mass	kg	1 kg ≈ 2 lb
Length	m	1 m ≈ 3 ft
	cm	3 cm ≈ 1 in
	km	5 km ≈ 3 mi
Speed	m/s	1 m/s ≈ 2 mph
	km/h	10 km/h ≈ 6 mph

Example 1.5 How fast do you walk?

Estimate how fast you walk, in meters per second.

PREPARE In order to compute speed, we need a distance and a time. If you walked a mile to campus, how long would this take? You'd probably say 30 minutes or so—half an hour. Let's use this rough number in our estimate.

Example 1.5 How fast do you walk? (cont.)

SOLVE Given this estimate, we compute your speed as

$$\text{speed} = \frac{\text{distance}}{\text{time}} \sim \frac{1 \text{ mile}}{1/2 \text{ hour}} = 2\,\frac{\text{mi}}{\text{h}}$$

But we want the speed in meters per second. Since our calculation is only an estimate, we use an approximate conversion factor from Table 1.4:

$$1\,\frac{\text{mi}}{\text{h}} \sim 0.5\,\frac{\text{m}}{\text{s}}$$

This gives an approximate walking speed of 1 m/s.

Example 1.5 How fast do you walk? (cont.)

ASSESS Is this a reasonable value? Let's do another estimate. Your stride is probably about 1 yard long—about 1 meter. And you take about one step per second; next time you are walking, you can count and see. So a walking speed of 1 meter per second sounds pretty reasonable.

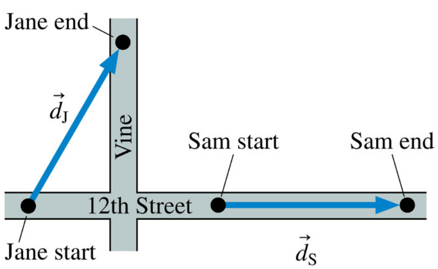
Section 1.5 Vectors and Motion: A First Look

Scalars and Vectors

- When a physical quantity is described by a single number (with a unit), we call it a **scalar quantity**.
- A **vector quantity** is a quantity that has both a size (How far? or How fast?) and a direction (Which way?).
- The size or length of a vector is called its **magnitude**.
- We graphically represent a vector as an *arrow*.

Displacement Vectors

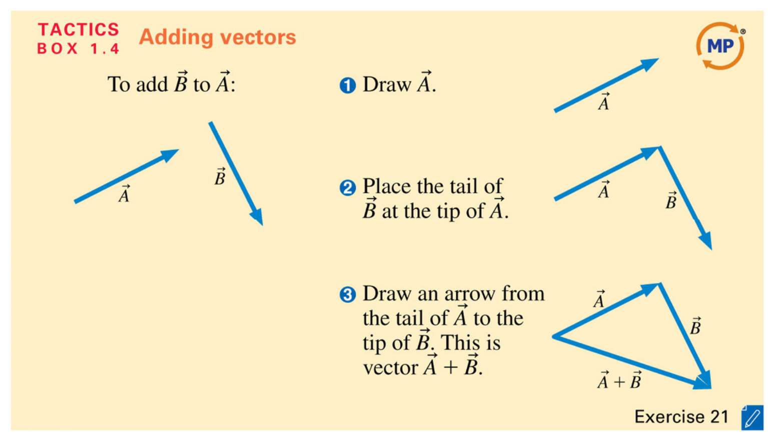
- The displacement vector represents the distance and direction of an object's motion.



- **An object's displacement vector is drawn from the object's initial position to its final position, regardless of the actual path followed between these two points.**

Vector Addition

- The net displacement for a trip with two legs is the sum of the two displacements that made it up.



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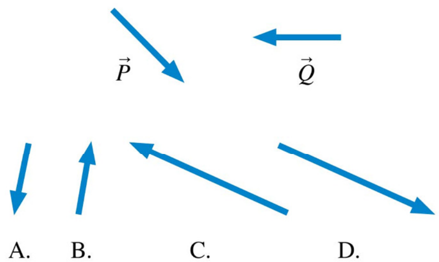
QuickCheck 1.6

Given vectors $\vec{P}$ and $\vec{Q}$, what is $\vec{P}+\vec{Q}$?



QuickCheck 1.6

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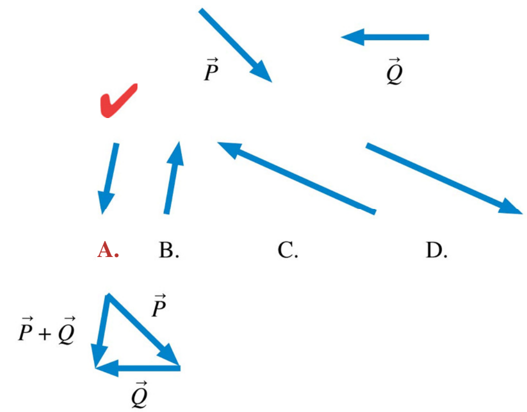
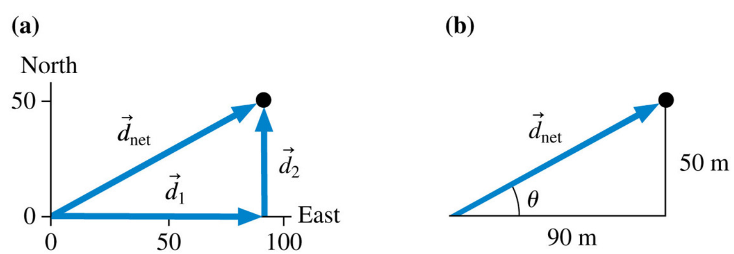


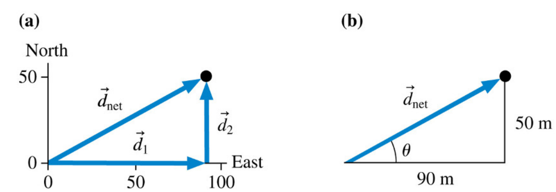
Example 1.7 How far away is Anna?

Anna walks 90 m due east and then 50 m due north. What is her displacement from her starting point?

PREPARE Let's start with the sketch in FIGURE 1.25a. We set up a coordinate system with Anna's original position as the origin, and then we drew her two subsequent motions as the two displacement vectors $\vec{d}_1$ and $\vec{d}_2$.

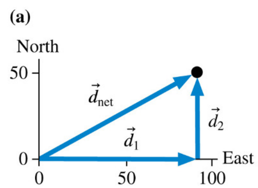


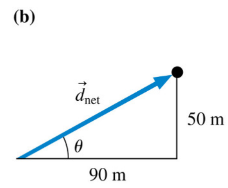
Example 1.7 How far away is Anna? (cont.)



SOLVE We drew the two vector displacements with the tail of one vector starting at the head of the previous one—exactly what is needed to form a vector sum. The vector $\vec{d}_{net}$ in FIGURE 1.25a is the vector sum of the successive displacements and thus represents Anna's net displacement from the origin.

Example 1.7 How far away is Anna? (cont.)



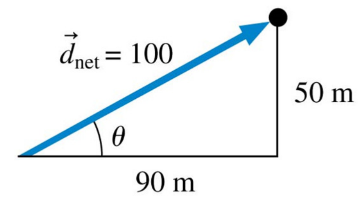


Anna's distance from the origin is the length of this vector $\vec{d}_{net}$. FIGURE 1.25b shows that this vector is the hypotenuse of a right triangle with sides 50 m (because Anna walked 50 m north) and 90 m (because she walked 90 m east). We can compute the magnitude of this vector, her net displacement, using the Pythagorean theorem (the square of the length of the hypotenuse of a triangle is equal to the sum of the squares of the lengths of the sides):

$$d_{net}^2 = (50\text{ m})^2 + (90\text{ m})^2$$

$$d_{net} = \sqrt{(50\text{ m})^2 + (90\text{ m})^2} = 103\text{ m} \approx 100\text{ m}$$

Example 1.7 How far away is Anna? (cont.)



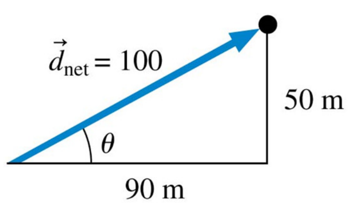
We have rounded off to the appropriate number of significant figures, giving us 100 m for the magnitude of the displacement vector. How about the direction? Figure 1.25b identifies the angle that gives the angle north of east of Anna's displacement. In the right triangle, 50 m is the opposite side and 90 m is the adjacent side, so the angle is given by

$$\theta = \tan^{-1}\left(\frac{50\text{ m}}{90\text{ m}}\right) = \tan^{-1}\left(\frac{5}{9}\right) = 29°$$

Putting it all together, we get a net displacement of

$$\vec{d}_{net} = (100\text{ m, } 29° \text{ north of east})$$

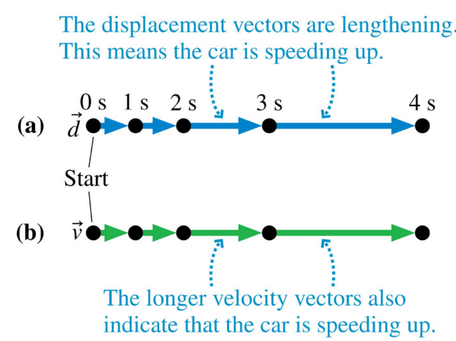
Example 1.7 How far away is Anna? (cont.)



ASSESS We can use our drawing to assess our result. If the two sides of the triangle are 50 m and 90 m, a length of 100 m for the hypotenuse seems about right. The angle is certainly less than 45°, but not too much less, so 29° seems reasonable.

Velocity Vectors

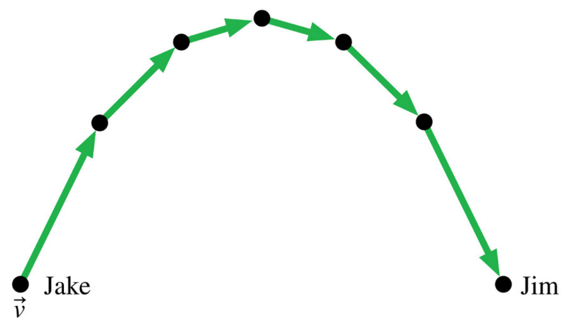
- We represent the velocity of an object by a velocity vector that points in the direction of the object's motion, and whose magnitude is the object's speed.



The motion diagram for a car starting from rest

Example 1.8 Drawing a ball's motion diagram

Jake hits a ball at a 60° angle from the horizontal. It is caught by Jim. Draw a motion diagram of the ball that shows velocity vectors rather than displacement vectors.



The motion diagram of a ball traveling from Jake to Jim

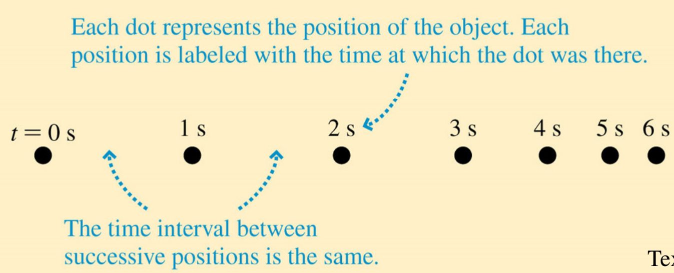
Summary and Organization of Chapters

- This chapter has been an introduction to some of the fundamental ideas about motion and some of the basic techniques that you will use.
- Each new chapter depends on those that preceded it.
- Each chapter begins with a chapter preview that will let you know which topics are especially important to review.
- The last element in each chapter will be an integrated example that brings together the principles and techniques you have just learned with those you learned previously.

Summary: Important Concepts

Motion Diagrams

The **particle model** represents a moving object as if all its mass were concentrated at a single point. Using this model, we can represent motion with a **motion diagram,** where dots indicate the object's positions at successive times. In a motion diagram, the time interval between successive dots is always the same.



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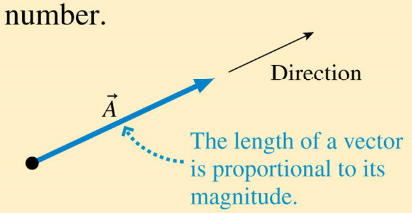
Summary: Important Concepts

Text: p. 22

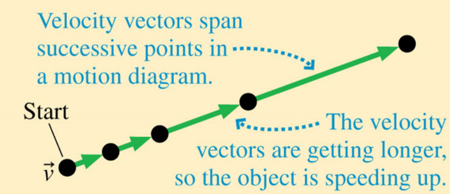
Scalars and Vectors

Scalar quantities have only a magnitude and can be represented by a single number. Temperature, time, and mass are scalars.

A **vector** is a quantity described by both a magnitude and a direction. Velocity and displacement are vectors.



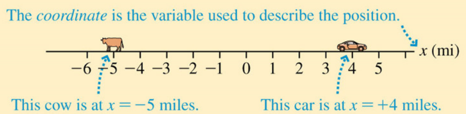
Velocity vectors can be drawn on a motion diagram by connecting successive points with a vector.



Summary: Important Concepts

Describing Motion

Position locates an object with respect to a chosen coordinate system. It is described by a **coordinate.**



A change in position is called a **displacement.** For motion along a line, a displacement is a signed quantity. The displacement from x_i to x_f is $\Delta x = x_f - x_i$.

Time is measured from a particular instant to which we assign $t = 0$. A **time interval** is the elapsed time between two specific instants t_i and t_f. It is given by $\Delta t = t_f - t_i$.

Velocity is the ratio of the displacement of an object to the time interval during which this displacement occurs:

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

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Summary: Important Concepts

Units

Every measurement of a quantity must include a **unit.**

The standard system of units used in science is the **SI system.** Common SI units include:

- Length: meters (m)
- Time: seconds (s)
- Mass: kilograms (kg)

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Summary: Applications

Working with Numbers

In **scientific notation,** a number is expressed as a decimal number between 1 and 10 multiplied by a power of ten. In scientific notation, the diameter of the earth is 1.27×10^7 m.

A **prefix** can be used before a unit to indicate a multiple of 10 or 1/10. Thus we can write the diameter of the earth as 12,700 km, where the k in km denotes 1000.

We can perform a **unit conversion** to convert the diameter of the earth to a different unit, such as miles. We do so by multiplying by a conversion factor equal to 1, such as 1 = 1 mi/1.61 km.

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Summary: Applications

Significant figures are reliably known digits. The number of significant figures for:

- **Multiplication, division, and powers** is set by the value with the fewest significant figures.
- **Addition and subtraction** is set by the value with the smallest number of decimal places.

An **order-of-magnitude estimate** is an estimate that has an accuracy of about one significant figure. Such estimates are usually made using rough numbers from everyday experience.

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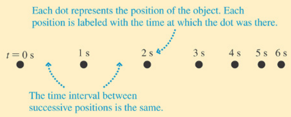
Summary

IMPORTANT CONCEPTS

Motion Diagrams

The **particle model** represents a moving object as if all its mass were concentrated at a single point. Using this model, we can represent motion with a **motion diagram,** where dots indicate the object's positions at successive times. In a motion diagram, the time interval between successive dots is always the same.



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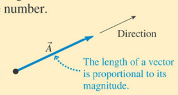

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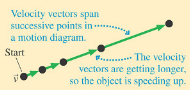

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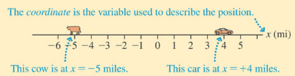

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APPLICATIONS

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