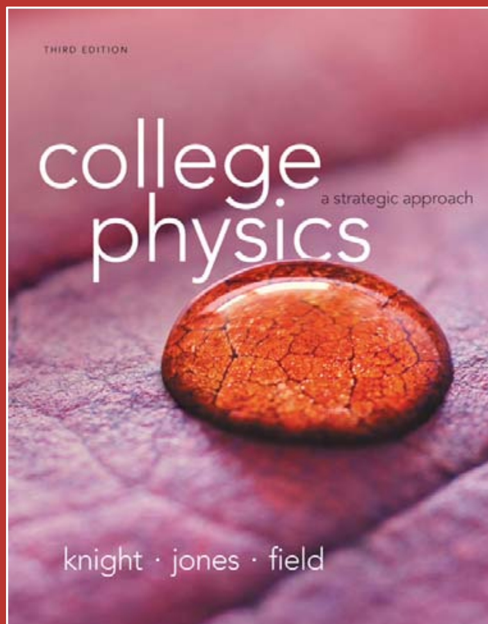

Material in this presentation comes from the following book [Ali]

Lecture Presentation

Chapter 1

Representing Motion

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Suggested Simulations

- **PhETs**
  - *Estimation,* *https://phet.colorado.edu/en/simulation/legacy/estimation*
  - *Vector Addition,* *https://phet.colorado.edu/en/simulation/legacy/vector-addition*

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 in sports.

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

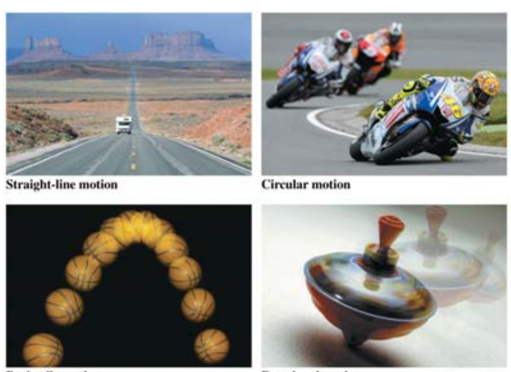
Chapter 1 Preview
Looking Ahead: Numbers and Units

- 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.

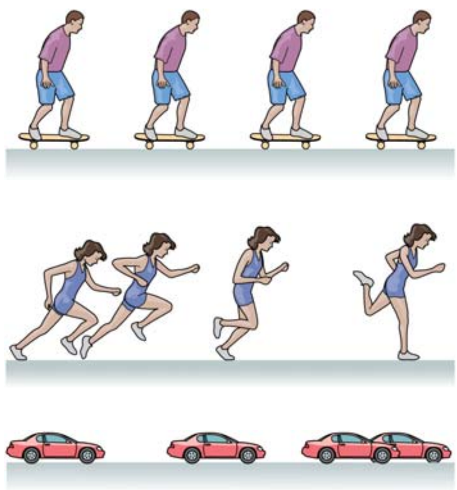
Types of Motion

- **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



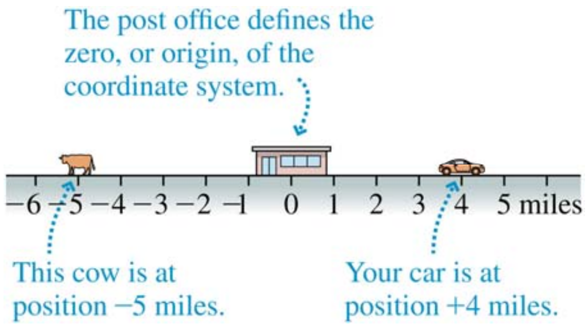
- These motion diagrams in one dimension show objects moving at constant speed (skateboarder), speeding up (runner) and slowing down (car).

Making a Motion Diagram

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

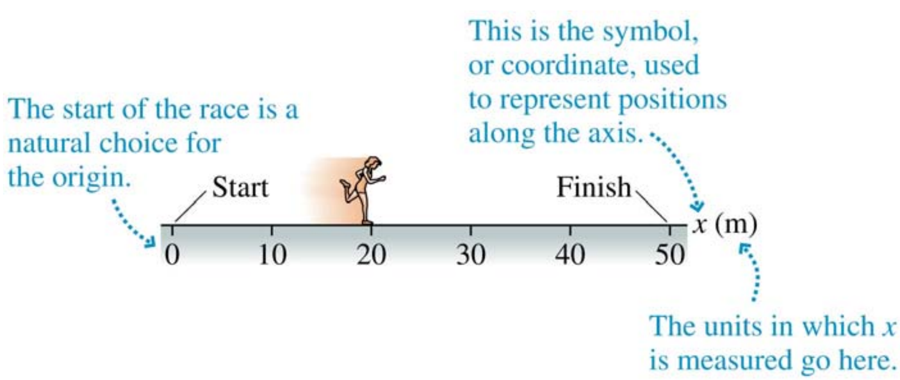
Position and Coordinate Systems

- 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**.

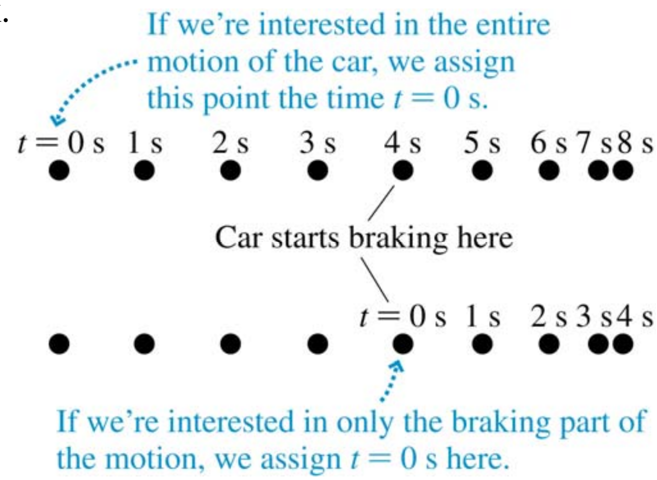
Position and Coordinate Systems



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

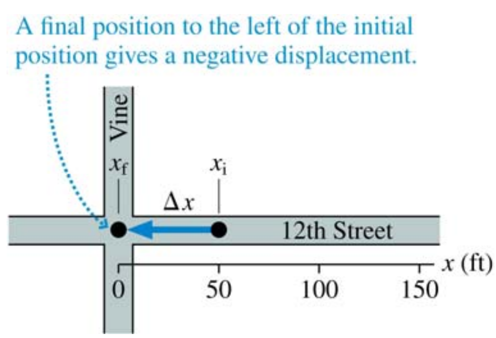
Time

- 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**.

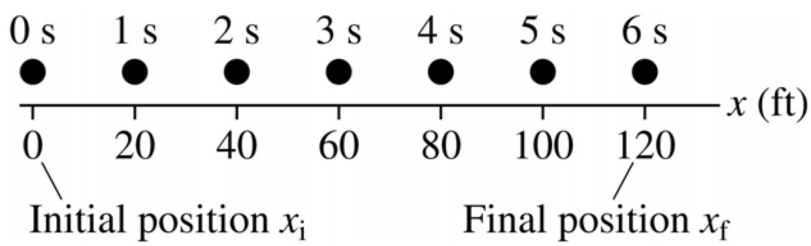


- Displacement is the *difference* between a final position and an initial position:

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

Change in Time

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

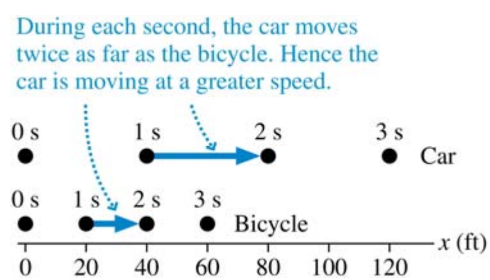


- **A time interval Δt measures the elapsed time as an object moves from an initial position x_i at time t_i to a final position x_f at time t_f.** Δt is always positive.

Slide 1-13

Velocity and Speed

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



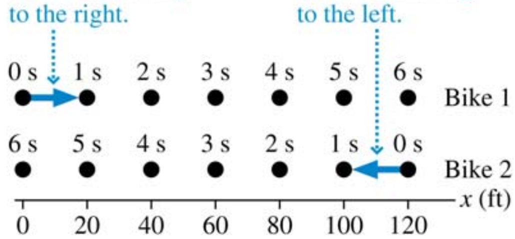
$$\text{speed} = \frac{\text{distance traveled in a given time interval}}{\text{time interval}}$$

Speed of an object in uniform motion

Slide 1-14

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

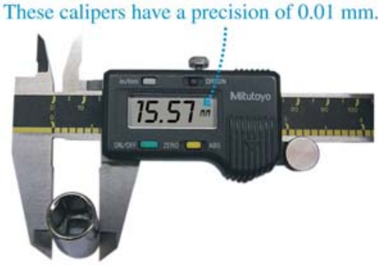
- The velocity defined by Equation 1.2 is called the *average* velocity.

Slide 1-15

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.

Slide 1-16

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:

$$\underbrace{3.73}_{\text{Three significant figures}} \times \underbrace{5.7}_{\text{Two significant figures}} = 21$$

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:

$$\begin{array}{rl} 18.54 & \text{— Two decimal places} \\ +106.6 & \text{— One decimal place} \\ \hline 125.1 & \end{array}$$

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

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:

❶ 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.

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

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

❷ 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.

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

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

Exercise 16

Text: p. 13

Slide 1-19

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

Slide 1-20

Unit Conversions

TACTICS BOX 1.3 Making a unit conversion

MP

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.
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!

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

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.)

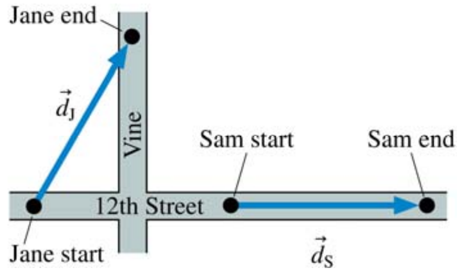
ASSESS Is this a reasonable value? Let's do another estimate. Your stride is probably about 1 yard long—about 1 meter. And you take about one step per second; next time you are walking, you can count and see. So a walking speed of 1 meter per second sounds pretty reasonable.

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

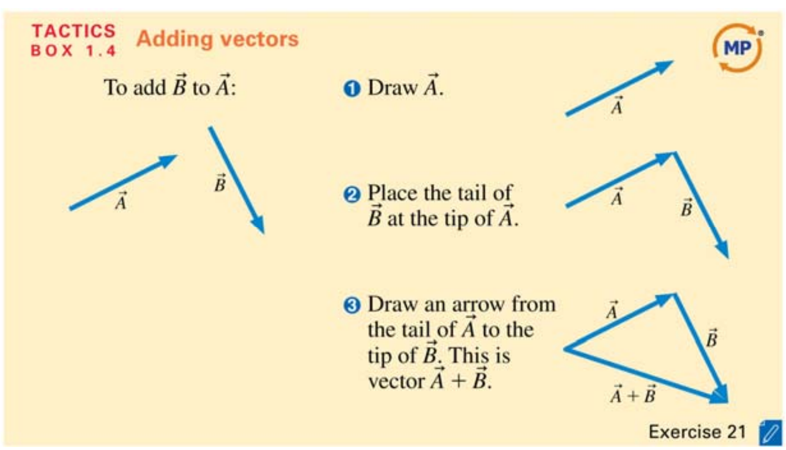
- The displacement vector represents the distance and direction of an object's motion.



- **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

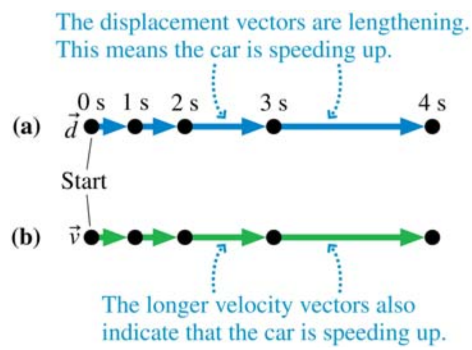
- The net displacement for a trip with two legs is the sum of the two displacements that made it up.



Text: p. 17

Velocity Vectors

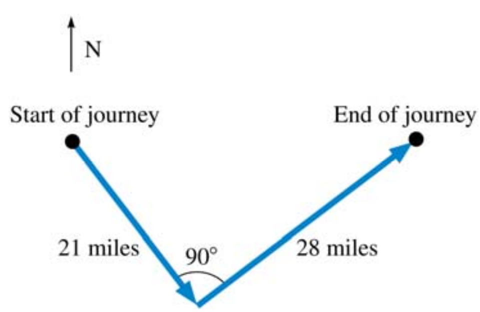
- We represent the velocity of an object by a velocity vector that points in the direction of the object's motion, and whose magnitude is the object's speed.



The motion diagram for a car starting from rest

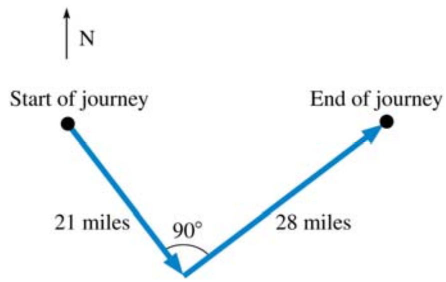
Integrated Example 1.9 A goose gets its bearings

FIGURE 1.28 shows the path of a Canada goose that flew in a straight line for some time before making a corrective right-angle turn. One hour after beginning, the goose made a rest stop on a lake due east of its original position.



Integrated Example 1.9 A goose gets its bearings (cont.)

a. How much extra distance did the goose travel due to its initial error in flight direction? That is, how much farther did it fly than if it had simply flown directly to its final position on the lake?

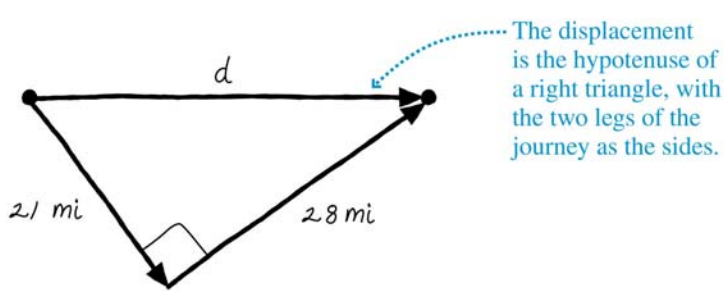


b. What was the flight speed of the goose?

c. A typical flight speed for a migrating goose is 80 km/h. Given this, does your result seem reasonable

Integrated Example 1.9 A goose gets its bearings (cont.)

Drawing and labeling the displacement between the starting and ending points in Figure 1.29 show that it is the hypotenuse of a right triangle, so we can use our rules for triangles as we look for a solution.



Integrated Example 1.9 A goose gets its bearings (cont.)

SOLVE

a. The minimum distance the goose *could* have flown, if it flew straight to the lake, is the hypotenuse of a triangle with sides 21 mi and 28 mi. This straight-line distance is

$$d = \sqrt{(21\text{ mi})^2 + (28\text{ mi})^2} = 35\text{ mi}$$

The actual distance the goose flew is the sum of the distances traveled for the two legs of the journey:

$$\text{distance traveled} = 21\text{ mi} + 28\text{ mi} = 49\text{ mi}$$

The extra distance flown is the difference between the actual distance flown and the straight-line distance—namely, 14 miles.

Integrated Example 1.9 A goose gets its bearings (cont.)

SOLVE

b. To compute the flight speed, we need to consider the distance that the bird actually flew. The flight speed is the total distance flown divided by the total time of the flight:

$$v = \frac{49\text{ mi}}{1.0\text{ h}} = 49\text{ mi/h}$$

c. To compare our calculated speed with a typical flight speed, we must convert our solution to km/h, rounding off to the correct number of significant digits:

$$49\,\frac{\text{mi}}{\text{h}} \times \frac{1.61\text{ km}}{1.00\text{ mi}} = 79\,\frac{\text{km}}{\text{h}}$$

A calculator will return many more digits, but the original data had only two significant figures, so we report the final result to this accuracy.