

CHAPTER 1 Summary

BIG IDEA Physics is the science of matter, energy, and forces. Physicists form hypotheses, design and perform experiments, and create models to help understand the world.

SECTION 1 What Is Physics?

KEY TERMS

- Physics is the study of the physical world, from motion and energy to light and electricity.
- Physics uses the scientific method to discover general laws that can be used to make predictions about a variety of situations.
- A common technique in physics for analyzing a complex situation is to disregard irrelevant factors and create a model that describes the essence of a system or situation.

model
system
hypothesis
controlled experiment

SECTION 2 Measurements in Experiments

KEY TERMS

- Physics measurements are typically made and expressed in SI, a system that uses a set of base units and prefixes to describe measurements of physical quantities.
- *Accuracy* describes how close a measurement is to reality. *Precision* results from the limitations of the measuring device used.
- The significant figures of a measurement include all of the digits that are actually measured plus one estimated digit.
- Significant-figure rules provide a means to ensure that calculations do not report results that are more precise than the data used to make them.

accuracy
precision
significant figures

SECTION 3 The Language of Physics

- Physicists make their work easier by summarizing data in tables and graphs and by abbreviating quantities in equations.
- Dimensional analysis can help identify whether a physics equation is invalid.
- Order-of-magnitude calculations provide a quick way to evaluate the appropriateness of an answer.

VARIABLE SYMBOLS			
Quantities		Units	
Δy	change in vertical position	m	meters
Δt	time interval	s	seconds
m	mass	kg	kilograms

Problem Solving

If you need more problem-solving practice, see **Appendix I: Additional Problems.**

The Science of Physics**REVIEWING MAIN IDEAS**

1. Refer to **Figure 1.3** of this chapter to identify at least two areas of physics involved in the following:
 - a. building a louder stereo system in your car
 - b. bungee jumping
 - c. judging how hot an electric stove burner is by looking at it
 - d. cooling off on a hot day by diving into a swimming pool
2. Which of the following scenarios fit the approach of the scientific method?
 - a. An auto mechanic listens to how a car runs and comes up with an idea of what might be wrong. The mechanic tests the idea by adjusting the idle speed. Then the mechanic decides his idea was wrong based on this evidence. Finally, the mechanic decides the only other problem could be the fuel pump, and he consults with the shop's other mechanics about his conclusion.
 - b. Because of a difference of opinions about where to take the class trip, the class president holds an election. The majority of the students decide to go to the amusement park instead of to the shore.
 - c. Your school's basketball team has advanced to the regional playoffs. A friend from another school says their team will win because their players want to win more than your school's team does.
 - d. A water fountain does not squirt high enough. The handle on the fountain seems loose, so you try to push the handle in as you turn it. When you do this, the water squirts high enough that you can get a drink. You make sure to tell all your friends how you did it.
3. You have decided to select a new car by using the scientific method. How might you proceed?

4. Consider the phrase "The quick brown fox jumps over the lazy dog." Which details of this situation would a physicist who is modeling the path of a fox ignore?

SI Units**REVIEWING MAIN IDEAS**

5. List an appropriate SI base unit (with a prefix as needed) for measuring the following:
 - a. the time it takes to play a CD in your stereo
 - b. the mass of a sports car
 - c. the length of a soccer field
 - d. the diameter of a large pizza
 - e. the mass of a single slice of pepperoni
 - f. a semester at your school
 - g. the distance from your home to your school
 - h. your mass
 - i. the length of your physics lab room
 - j. your height
6. If you square the speed expressed in meters per second, in what units will the answer be expressed?
7. If you divide a force measured in newtons ($1 \text{ newton} = 1 \text{ kg}\cdot\text{m}/\text{s}^2$) by a speed expressed in meters per second, in what units will the answer be expressed?

CONCEPTUAL QUESTIONS

8. The height of a horse is sometimes given in units of "hands." Why was this a poor standard of length before it was redefined to refer to exactly 4 in.?
9. Explain the advantages in having the meter officially defined in terms of the distance light travels in a given time rather than as the length of a specific metal bar.
10. Einstein's famous equation indicates that $E = mc^2$, where c is the speed of light and m is the object's mass. Given this, what is the SI unit for E ?

PRACTICE PROBLEMS


For problems 11–14, see Sample Problem A.

11. Express each of the following as indicated:
 - a. 2 dm expressed in millimeters
 - b. 2 h 10 min expressed in seconds
 - c. 16 g expressed in micrograms
 - d. 0.75 km expressed in centimeters
 - e. 0.675 mg expressed in grams
 - f. 462 μm expressed in centimeters
 - g. 35 km/h expressed in meters per second
12. Use the SI prefixes in **Figure 2.4** of this chapter to convert these *hypothetical* units of measure into appropriate quantities:
 - a. 10 rations
 - b. 2000 mockingbirds
 - c. 10^{-6} phones
 - d. 10^{-9} goats
 - e. 10^{18} miners
13. Use the fact that the speed of light in a vacuum is about 3.00×10^8 m/s to determine how many kilometers a pulse from a laser beam travels in exactly one hour.
14. If a metric ton is 1.000×10^3 kg, how many 85 kg people can safely occupy an elevator that can hold a maximum mass of exactly 1 metric ton?


Accuracy, Precision, and Significant Figures

REVIEWING MAIN IDEAS


15. Can a set of measurements be precise but not accurate? Explain.
16. How many significant figures are in the following measurements?
 - a. 300 000 000 m/s
 - b. 3.00×10^8 m/s
 - c. 25.030°C
 - d. 0.006 070°C
 - e. 1.004 J
 - f. 1.305 20 MHz
17. The photographs below show unit conversions on the labels of some grocery-store items. Check the accuracy of these conversions. Are the manufacturers using significant figures correctly?




(a)



(b)



(c)



(d)
18. The value of the speed of light is now known to be $2.997\,924\,58 \times 10^8$ m/s. Express the speed of light in the following ways:
 - a. with three significant figures
 - b. with five significant figures
 - c. with seven significant figures
19. How many significant figures are there in the following measurements?
 - a. 78.9 ± 0.2 m
 - b. 3.788×10^9 s
 - c. 2.46×10^6 kg
 - d. 0.0032 mm
20. Carry out the following arithmetic operations:
 - a. Find the sum of the measurements 756 g, 37.2 g, 0.83 g, and 2.5 g.
 - b. Find the quotient of 3.2 m/3.563 s.
 - c. Find the product of $5.67 \text{ mm} \times \pi$.
 - d. Find the difference of 27.54 s and 3.8 s.
21. A fisherman catches two sturgeons. The smaller of the two has a measured length of 93.46 cm (two decimal places and four significant figures), and the larger fish has a measured length of 135.3 cm (one decimal place and four significant figures). What is the total length of the two fish?
22. A farmer measures the distance around a rectangular field. The length of each long side of the rectangle is found to be 38.44 m, and the length of each short side is found to be 19.5 m. What is the total distance around the field?

Dimensional Analysis and Order-of-Magnitude Estimates

Note: In developing answers to order-of-magnitude calculations, you should state your important assumptions, including the numerical values assigned to parameters used in the solution. Since only order-of-magnitude results are expected, do not be surprised if your results differ from those of other students.

REVIEWING MAIN IDEAS

23. Suppose that two quantities, A and B , have different dimensions. Which of the following arithmetic operations *could* be physically meaningful?
- $A + B$
 - A/B
 - $A \times B$
 - $A - B$
24. Estimate the order of magnitude of the length in meters of each of the following:
- a ladybug
 - your leg
 - your school building
 - a giraffe
 - a city block
25. If an equation is dimensionally correct, does this mean that the equation is true?
26. The radius of a circle inscribed in any triangle whose sides are a , b , and c is given by the following equation, in which s is an abbreviation for $(a + b + c) \div 2$. Check this formula for dimensional consistency.

$$r = \sqrt{\frac{(s-a)(s-b)(s-c)}{s}}$$

27. The period of a simple pendulum, defined as the time necessary for one complete oscillation, is measured in time units and is given by the equation

$$T = 2\pi \sqrt{\frac{L}{a_g}}$$

where L is the length of the pendulum and a_g is the acceleration due to gravity, which has units of length divided by time squared. Check this equation for dimensional consistency.

CONCEPTUAL QUESTIONS

28. In a desperate attempt to come up with an equation to solve a problem during an examination, a student tries the following: $(\text{velocity in m/s})^2 = (\text{acceleration in m/s}^2) \times (\text{time in s})$. Use dimensional analysis to determine whether this equation might be valid.
29. Estimate the number of breaths taken by a person during 70 years.
30. Estimate the number of times your heart beats in an average day.
31. Estimate the magnitude of your age, as measured in units of seconds.
32. An automobile tire is rated to last for 50 000 mi. Estimate the number of revolutions the tire will make in its lifetime.
33. Imagine that you are the equipment manager of a professional baseball team. One of your jobs is to keep a supply of baseballs for games in your home ballpark. Balls are sometimes lost when players hit them into the stands as either home runs or foul balls. Estimate how many baseballs you have to buy per season in order to make up for such losses. Assume your team plays an 81-game home schedule in a season.
34. A chain of hamburger restaurants advertises that it has sold more than 50 billion hamburgers over the years. Estimate how many pounds of hamburger meat must have been used by the restaurant chain to make 50 billion hamburgers and how many head of cattle were required to furnish the meat for these hamburgers.
35. Estimate the number of piano tuners living in New York City. (The population of New York City is approximately 8 million.) This problem was first proposed by the physicist Enrico Fermi, who was well known for his ability to quickly make order-of-magnitude calculations.
36. Estimate the number of table-tennis balls that would fit (without being crushed) into a room that is 4 m long, 4 m wide, and 3 m high. Assume that the diameter of a ball is 3.8 cm.

Mixed Review

37. Calculate the circumference and area for the following circles. (Use the following formulas: circumference = $2\pi r$ and area = πr^2 .)
- a circle of radius 3.5 cm
 - a circle of radius 4.65 cm
38. A billionaire offers to give you (1) \$5 billion if you will count out the amount in \$1 bills or (2) a lump sum of \$5000. Which offer should you accept? Explain your answer. (Assume that you can count at an average rate of one bill per second, and be sure to allow for the fact that you need about 10 hours a day for sleeping and eating. Your answer does not need to be limited to one significant figure.)
39. Exactly 1 quart of ice cream is to be made in the form of a cube. What should be the length of one side in meters for the container to have the appropriate volume? (Use the following conversion: 4 qt = $3.786 \times 10^{-3} \text{ m}^3$.)
40. You can obtain a rough estimate of the size of a molecule with the following simple experiment: Let a droplet of oil spread out on a fairly large but smooth water surface. The resulting “oil slick” that forms on the surface of the water will be approximately one molecule thick. Given an oil droplet with a mass of $9.00 \times 10^{-7} \text{ kg}$ and a density of 918 kg/m^3 that spreads out to form a circle with a radius of 41.8 cm on the water surface, what is the approximate diameter of an oil molecule?

GRAPHING CALCULATOR PRACTICE

Mass versus Length

What is the relationship between the mass and length of three wires, each of which is made of a different substance? All three wires have the same diameter. Because the wires have the same diameter, their cross-sectional areas are the same. The cross-sectional area of any circle is equal to πr^2 . Consider a wire with a diameter of 0.50 cm and a density of 8.96 g/cm^3 . The following equation describes the mass of the wire as a function of the length:

$$Y_1 = 8.96X \times \pi(0.25)^2$$

In this equation, Y_1 represents the mass of the wire in grams, and X represents the length of the wire in centimeters. Each of the three wires is made of a different substance, so each wire has a different density and a different relationship between its mass and length.

In this graphing calculator activity, you will

- use dimensional analysis
- observe the relationship between a mathematical function and a graph
- determine values from a graph
- gain a better conceptual understanding of density

Go online to HMHSscience.com to find the skillsheet and program for this graphing calculator activity.

41. An ancient unit of length called the cubit was equal to approximately 50 centimeters, which is, of course, approximately 0.50 meters. It has been said that Noah's ark was 300 cubits long, 50 cubits wide, and 30 cubits high. Estimate the volume of the ark in cubic meters. Also estimate the volume of a typical home, and compare it with the ark's volume.
42. If one micrometeorite (a sphere with a diameter of 1.0×10^{-6} m) struck each square meter of the moon each second, it would take many years to cover the moon with micrometeorites to a depth of 1.0 m. Consider a cubic box, 1.0 m on a side, on the moon. Estimate how long it would take to completely fill the box with micrometeorites.
43. One cubic centimeter (1.0 cm^3) of water has a mass of 1.0×10^{-3} kg at 25°C . Determine the mass of 1.0 m^3 of water at 25°C .
44. Assuming biological substances are 90 percent water and the density of water is $1.0 \times 10^3 \text{ kg/m}^3$, estimate the masses (density multiplied by volume) of the following:
- a spherical cell with a diameter of $1.0 \text{ }\mu\text{m}$
(volume = $\frac{4}{3} \pi r^3$)
 - a fly, which can be approximated by a cylinder 4.0 mm long and 2.0 mm in diameter
(volume = $l\pi r^2$)
45. The radius of the planet Saturn is 6.03×10^7 m, and its mass is 5.68×10^{26} kg.
- Find the density of Saturn (its mass divided by its volume) in grams per cubic centimeter. (The volume of a sphere is given by $\frac{4}{3} \pi r^3$.)
 - Find the surface area of Saturn in square meters. (The surface area of a sphere is given by $4\pi r^2$.)

ALTERNATIVE ASSESSMENT

- Imagine that you are a member of your state's highway board. In order to comply with a bill passed in the state legislature, all of your state's highway signs must show distances in miles and kilometers. Two plans are before you. One plan suggests adding metric equivalents to all highway signs as follows: Dallas 300 mi (483 km). Proponents of the other plan say that the first plan makes the metric system seem more cumbersome, so they propose replacing the old signs with new signs every 50 km as follows: Dallas 300 km (186 mi). Participate in a class debate about which plan should be followed.
- Can you measure the mass of a five-cent coin with a bathroom scale? Record the mass in grams displayed by your scale as you place coins on the scale, one at a time. Then, divide each measurement by the number of coins to determine the approximate mass of a single five-cent coin, but remember to follow the rules for significant figures in calculations. Which estimate do you think is the most accurate? Which is the most precise?
- Find out who were the Nobel laureates for physics last year, and research their work. Alternatively, explore the history of the Nobel Prizes. Who founded the awards? Why? Who delivers the award? Where? Document your sources, and present your findings in a brochure, poster, or presentation.
- You have a clock with a second hand, a ruler marked in millimeters, a graduated cylinder marked in milliliters, and balances sensitive to 1 mg. How would you measure the mass of a drop of water? How would you measure the period of a swing? How would you measure the volume of a paper clip? How can you improve the accuracy of your measurements? Write the procedures clearly so that a partner can follow them and obtain reasonable results.
- Create a poster or other presentation depicting the possible ranges of measurement for a dimension, such as distance, time, temperature, speed, or mass. Depict examples ranging from the very large to the very small. Include several examples that are typical of your own experiences.