AP Physics 1 Summer Homework
2017-2018

Note: You will not need the textbook over the summer, but you will need online access to get the documents and view the videos needed to complete this work. All of this work must be completed before school begins in the fall, and the "Questions" assignment is **due on the first day of school.**

1) SYLLABUS & MATERIALS

   a) Go to Don Lugo's home page, then "Classrooms", then "Woods, Patrick", then "AP Physics".
   b) Open the "AP Physics 2016-2017 Syllabus" PDF document. You'll receive a hard copy the first week of school, but read through it now. In fact, study it carefully…you'll be quizzed on it the first week of school.
   c) Acquire the necessary materials for the class, especially the Notebook. When you start taking notes in your Notebook, you'll want to begin on page 13. (Leave the first 12 pages blank, counting front and back.)

2) ASSIGNMENT: READING

   a) Open the "AP Physics Summer Homework Resource" PDF document on the AP Physics web page.
   b) Read through Ch. 1. Be thorough! Make sure you spend time going through each example. (In fact, reading the chapter 2-3 times is a good strategy, but you probably already knew that.)

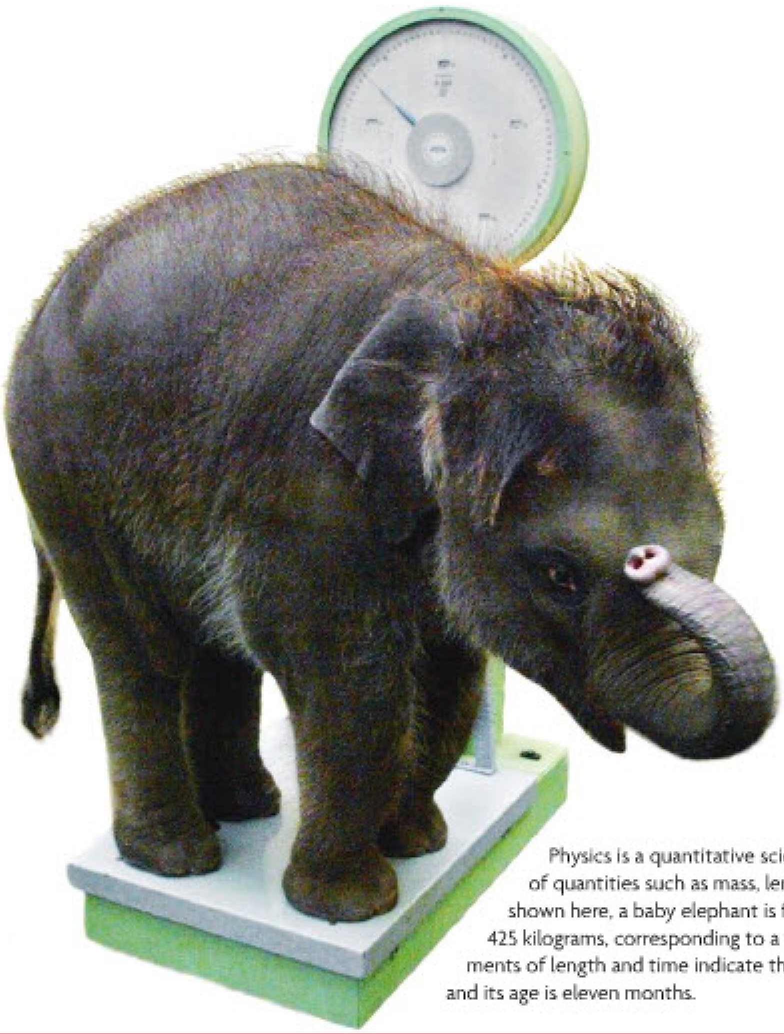
3) ASSIGNMENT: VIDEOS

   a) Find Mr. Woods' YouTube channel: "Woods Science Stuff".
   b) Subscribe to the channel if you wish (not necessary, but maybe helpful).
   c) Find the playlist titled "Flipped Learning – Mr. Woods".
      i) Watch "How to Learn from a Flipping Educational Video".
      ii) Watch "Memorizing vs. Understanding in Physics".
   d) Find the playlist titled "AP Physics".
      i) Watch "Intro to Physics", and take notes in your Notebook. Remember to leave the first 12 pages blank.
      ii) Watch "Problem Solving in Physics", and take notes in your Notebook.

4) ASSIGNMENT: QUESTIONS

   a) Go back to the PDF document containing Ch. 1 from the textbook ("AP Physics Summer Homework Resource"). Answer the following questions from the end of the chapter on separate sheets of paper. Follow the procedure described in the video on "Problem Solving in Physics", and show all work neatly!
      i) Conceptual Questions: #1-5
      ii) Problems: #3-14,21,22,38,49-51

1 Introduction to Physics



Physics is a quantitative science, based on careful measurements of quantities such as mass, length, and time. In the measurement shown here, a baby elephant is found to have a mass of approximately 425 kilograms, corresponding to a weight of about 935 pounds. Measurements of length and time indicate that the elephant's height is 1.25 meters, and its age is eleven months.

The goal of physics is to gain a deeper understanding of the world in which we live. For example, the laws of physics allow us to predict the behavior of everything from rockets sent to the Moon, to integrated chips in computers, to lasers used to perform eye surgery. In short, everything in nature—from atoms and subatomic particles to solar systems and galaxies—obeys the laws of physics.

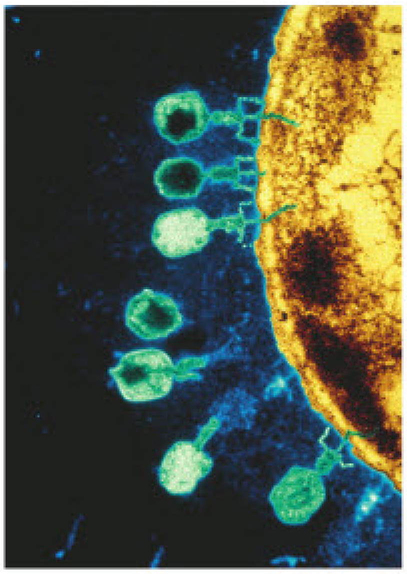
As we begin our study of physics, it is useful to consider a range of issues that underlies everything to follow. One of the most fundamental of these is the system of units we use when we measure such things as the mass of an object, its length, and the time between two events. Other equally important issues include methods for handling numerical calculations and basic conventions of mathematical notation. By the end of the chapter we will have developed a common "language" of physics that will be used throughout this book and probably in any science that you study.

1–1 Physics and the Laws of Nature

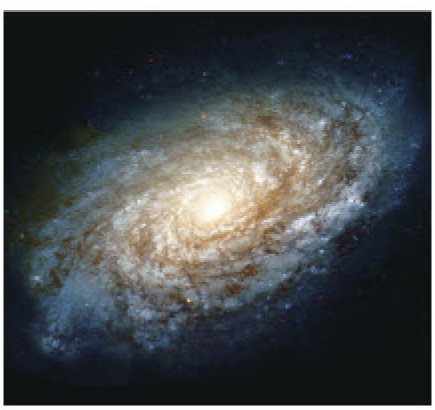
Physics is the study of the fundamental laws of nature, which, simply put, are the laws that underlie all physical phenomena in the universe. Remarkably, we have found that these laws can be expressed in terms of mathematical equations. As a result, it is possible to make precise, quantitative comparisons between the predictions of theory—derived from the mathematical form of the laws—and the observations of experiments. Physics, then, is a science rooted equally firmly in theory and experiment, and, as physicists make new observations, they constantly test and—if necessary—refine the present theories.

What makes physics particularly fascinating is the fact that it relates to everything in the universe. There is a great beauty in the vision that physics brings to our view of the universe; namely, that all the complexity and variety that we see in the world around us, and in the universe as a whole, are manifestations of a few fundamental laws and principles. That we can discover and apply these basic laws of nature is both astounding and exhilarating.

For those not familiar with the subject, physics may seem to be little more than a confusing mass of formulas. Sometimes, in fact, these formulas can be the trees that block the view of the forest. For a physicist, however, the many formulas of physics are simply different ways of expressing a few fundamental ideas. It is the forest—the basic laws and principles of physical phenomena in nature—that is the focus of this text.



▲ The size of these viruses, seen here attacking a bacterial cell, is about 10^{-7} m.



▲ The diameter of this typical galaxy is about 10^{21} m. (How many viruses would it take to span the galaxy?)

1–2 Units of Length, Mass, and Time

To make quantitative comparisons between the laws of physics and our experience of the natural world, certain basic physical quantities must be measured. The most common of these quantities are **length** (L), **mass** (M), and **time** (T). In fact, in the next several chapters these are the only quantities that arise. Later in the text, additional quantities, such as temperature and electric current, will be introduced as needed.

We begin by defining the units in which each of these quantities is measured. Once the units are defined, the values obtained in specific measurements can be expressed as multiples of them. For example, our unit of length is the **meter** (m). It follows, then, that a person who is 1.94 m tall has a height 1.94 times this unit of length. Similar comments apply to the unit of mass, the **kilogram,** and the unit of time, the **second.**

The detailed system of units used in this book was established in 1960 at the Eleventh General Conference of Weights and Measures in Paris, France, and goes by the name Système International d'Unités, or SI for short. Thus, when we refer to **SI units,** we mean units of meters (m), kilograms (kg), and seconds (s). Taking the first letter from each of these units leads to an alternate name that is often used—the **mks system.**

In the remainder of this section we define each of the SI units.

Length

Early units of length were often associated with the human body. For example, the Egyptians defined the cubit to be the distance from the elbow to the tip of the middle finger. Similarly, the foot was at one time defined to be the length of the royal foot of King Louis XIV. As colorful as these units may be, they are not particularly reproducible—at least not to great precision.

In 1793 the French Academy of Sciences, seeking a more objective and reproducible standard, decided to define a unit of length equal to one ten-millionth the distance from the North Pole to the equator. This new unit was named the metre (from the Greek *metron* for "measure"). The preferred spelling in the United States is *meter*. This definition was widely accepted, and in 1799 a "standard" meter was produced. It consisted of a platinum-iridium alloy rod with two marks on it one meter apart.

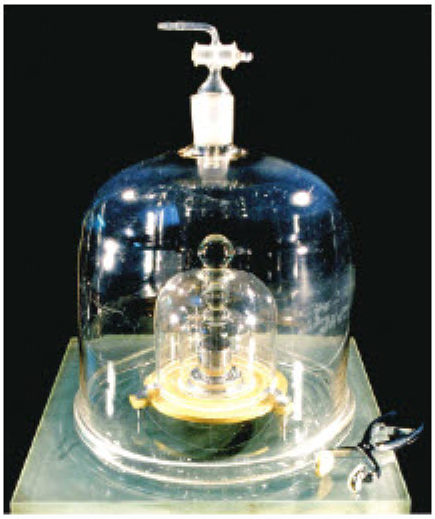
TABLE 1–1 Typical Distances

Distance from Earth to the nearest large galaxy (the Andromeda galaxy, M31)	2×10^{22} m
Diameter of our galaxy (the Milky Way)	8×10^{20} m
Distance from Earth to the nearest star (other than the Sun)	4×10^{16} m
One light-year	9.46×10^{15} m
Average radius of Pluto's orbit	6×10^{12} m
Distance from Earth to the Sun	1.5×10^{11} m
Radius of Earth	6.37×10^{6} m
Length of a football field	10^{2} m
Height of a person	2 m
Diameter of a CD	0.12 m
Diameter of the aorta	0.018 m
Diameter of a period in a sentence	5×10^{-4} m
Diameter of a red blood cell	8×10^{-6} m
Diameter of the hydrogen atom	10^{-10} m
Diameter of a proton	2×10^{-15} m

Since 1983 we have used an even more precise definition of the meter, based on the speed of light in a vacuum. In particular:

> One meter is defined to be the distance traveled by light in a vacuum in 1/299,792,458 of a second.

No matter how its definition is refined, however, a meter is still about 3.28 feet, which is roughly 10 percent longer than a yard. A list of typical lengths is given in Table 1–1.



▲ The standard kilogram, a cylinder of platinum and iridium 0.039 m in height and diameter, is kept under carefully controlled conditions in Sèvres, France. Exact replicas are maintained in other laboratories around the world.

Mass

In SI units, mass is measured in kilograms. Unlike the meter, the kilogram is not based on any natural physical quantity. By convention, the kilogram has been defined as follows:

> The kilogram, by definition, is the mass of a particular platinum-iridium alloy cylinder at the International Bureau of Weights and Standards in Sèvres, France.

To put the kilogram in everyday terms, a quart of milk has a mass slightly less than 1 kilogram. Additional masses, in kilograms, are given in Table 1–2.

Note that we do not define the kilogram to be the *weight* of the platinum-iridium cylinder. In fact, weight and mass are quite different quantities, even though they are often confused in everyday language. Mass is an intrinsic, unchanging property of an object. Weight, in contrast, is a measure of the gravitational force acting on an object, which can vary depending on the object's location. For example, if you are fortunate enough to travel to Mars someday, you will find that your weight is less than on Earth, though your mass is unchanged. The force of gravity will be discussed in detail in Chapter 12.

TABLE 1–2 Typical Masses

Galaxy (Milky Way)	4×10^{41} kg
Sun	2×10^{30} kg
Earth	5.97×10^{24} kg
Space shuttle	2×10^{6} kg
Elephant	5400 kg
Automobile	1200 kg
Human	70 kg
Baseball	0.15 kg
Honeybee	1.5×10^{-4} kg
Red blood cell	10^{-13} kg
Bacterium	10^{-15} kg
Hydrogen atom	1.67×10^{-27} kg
Electron	9.11×10^{-31} kg

Time

Nature has provided us with a fairly accurate timepiece in the revolving Earth. In fact, prior to 1956 the mean solar day was defined to consist of 24 hours, with 60 minutes per hour, and 60 seconds per minute, for a total of (24)(60)(60) = 84,400 seconds. Even the rotation of the Earth is not completely regular, however.

Today, the most accurate timekeepers known are "atomic clocks," which are based on characteristic frequencies of radiation emitted by certain atoms. These

▲ This atomic clock, which keeps time on the basis of radiation from cesium atoms, is accurate to about three millionths of a second per year. (How long would it take for it to gain or lose an hour?)

clocks have typical accuracies of about 1 second in 300,000 years. The atomic clock used for defining the second operates with cesium-133 atoms. In particular, the second is defined as follows:

> One second is defined to be the time it takes for radiation from a cesium-133 atom to complete 9,192,631,770 cycles of oscillation.

A range of characteristic time intervals is given in Table 1–3.

The nation's time and frequency standard is determined by a *cesium fountain atomic clock* developed at the National Institute of Standards and Technology (NIST) in Boulder, Colorado. The fountain atomic clock, designated NIST-F1, produces a "fountain" of cesium atoms that are projected upward in a vacuum to a height of about a meter. It takes roughly a second for the atoms to rise and fall through this height (as we shall see in the next chapter), and during this relatively long period of time the frequency of their oscillation can be measured with great precision. In fact, the NIST-F1 will gain or lose no more than one second in every 20 million years of operation.

Atomic clocks are almost commonplace these days. For example, the satellites that participate in the Global Positioning System (GPS) actually carry atomic clocks with them in orbit. This allows them to make the precision time measurements that are needed for an equally precise determination of position and speed. Similarly, the "atomic clocks" that are advertised for use in the home, while not atomic in their operation, nonetheless get their time from radio signals sent out from the atomic clocks at NIST in Boulder. You can access the official U.S. time on your computer by going to http://time.gov on the Web.

TABLE 1–3 Typical Times

Age of the universe	5×10^{17} s
Age of the Earth	1.3×10^{17} s
Existence of human species	6×10^{13} s
Human lifetime	2×10^{9} s
One year	3×10^{7} s
One day	8.6×10^{4} s
Time between heartbeats	0.8 s
Human reaction time	0.1 s
One cycle of a high-pitched sound wave	5×10^{-5} s
One cycle of an AM radio wave	10^{-6} s
One cycle of a visible light wave	2×10^{-15} s

Other Systems of Units and Standard Prefixes

Although SI units are used throughout most of this book and are used almost exclusively in scientific research and in industry, we will occasionally refer to other systems that you may encounter from time to time.

For example, a system of units similar to the mks system, though comprised of smaller units, is the **cgs system,** which stands for centimeter (cm), gram (g), and second (s). In addition, the British engineering system is often encountered in everyday usage in the United States. Its basic units are the slug for mass, the foot (ft) for length, and the second (s) for time.

Finally, multiples of the basic units are common no matter which system is used. Standard prefixes are used to designate common multiples in powers of ten. For example, the prefix *kilo* means one thousand, or, equivalently, 10^3. Thus, 1 kilogram is 10^3 grams, and 1 kilometer is 10^3 meters. Similarly, *milli* is the prefix for one thousandth, or 10^{-3}. Thus, a millimeter is 10^{-3} meter, and so on. The most common prefixes are listed in Table 1–4.

"MY GOODNESS, IT'S 12:15:0936420175! TIME FOR LUNCH."

EXERCISE 1–1

a. A minivan sells for 33,200 dollars. Express the price of the minivan in kilodollars and megadollars.

b. A typical *E. coli* bacterium is about 5 micrometers (or microns) in length. Give this length in millimeters and kilometers.

SOLUTION

a. 33.2 kilodollars, 0.0332 megadollars

b. 0.005 mm, 0.000000005 km

1–3 Dimensional Analysis

In physics, when we speak of the **dimension** of a physical quantity, we refer to the *type* of quantity in question, regardless of the units used in the measurement. For example, a distance measured in cubits and another distance measured in light-years both have the same dimension—length. The same is true of compound units such as velocity, which has the dimensions of length per unit time (length/time). A velocity measured in miles per hour has the same dimensions—length/time—as one measured in inches per century.

Now, any valid formula in physics must be **dimensionally consistent;** that is, each term in the equation must have the same dimensions. It simply doesn't make sense to add a distance to a time, for example, any more than it makes sense to add apples and oranges. They are different things.

To check the dimensional consistency of an equation, it is convenient to introduce a special notation for the dimension of a quantity. We will use square brackets, [ ], for this purpose. Thus, if x represents a distance, which has dimensions of length [L], we write this as $x = [\mathrm{L}]$. Similarly, a velocity, v, has dimensions of length per time [T]; thus we write $v = [\mathrm{L}]/[\mathrm{T}]$ to indicate its dimensions. Acceleration, a, which is the change in velocity per time, has the dimensions $a = ([\mathrm{L}]/[\mathrm{T}])/[\mathrm{T}] = [\mathrm{L}]/[\mathrm{T}^2]$. The dimensions of some common physical quantities are summarized in Table 1–5.

Let's use this notation to check the dimensional consistency of a simple equation. Consider the following formula:

$$x = x_0 + vt$$

In this equation, x and x_0 represent distances, v is a velocity, and t is time. Writing out the dimensions of each term, we have

$$[\mathrm{L}] = [\mathrm{L}] + \frac{[\mathrm{L}]}{[\mathrm{T}]}[\mathrm{T}]$$

It might seem at first that the last term has different dimensions than the other two. However, dimensions obey the same rules of algebra as other quantities. Thus the dimensions of time cancel in the last term:

$$[\mathrm{L}] = [\mathrm{L}] + \frac{[\mathrm{L}]}{[\cancel{\mathrm{T}}]}[\cancel{\mathrm{T}}] = [\mathrm{L}] + [\mathrm{L}]$$

As a result, we see that each term in this formula has the same dimensions. This type of calculation with dimensions is referred to as **dimensional analysis.**

TABLE 1–4 Common Prefixes

Power	Prefix	Abbreviation
10^{15}	peta	P
10^{12}	tera	T
10^{9}	giga	G
10^{6}	mega	M
10^{3}	kilo	k
10^{2}	hecto	h
10^{1}	deka	da
10^{-1}	deci	d
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p
10^{-15}	femto	f

TABLE 1–5 Dimensions of Some Common Physical Quantities

Quantity	Dimension
Distance	[L]
Area	$[\mathrm{L}^2]$
Volume	$[\mathrm{L}^3]$
Velocity	[L]/[T]
Acceleration	$[\mathrm{L}]/[\mathrm{T}^2]$
Energy	$[\mathrm{M}][\mathrm{L}^2]/[\mathrm{T}^2]$

EXERCISE 1–2

Show that $x = x_0 + v_0t + \frac{1}{2}at^2$ is dimensionally consistent. The quantities x and x_0 are distances, v_0 is a velocity, and a is an acceleration.

SOLUTION

Using the dimensions given in Table 1–5, we have

$$[\mathrm{L}] = [\mathrm{L}] + \frac{[\mathrm{L}]}{[\cancel{\mathrm{T}}]}[\cancel{\mathrm{T}}] + \frac{[\mathrm{L}]}{[\cancel{\mathrm{T}}]^2}[\cancel{\mathrm{T}}^2] = [\mathrm{L}] + [\mathrm{L}] + [\mathrm{L}]$$

Note that $\frac{1}{2}$ is ignored in this analysis because it has no dimensions.

Later in this text you will derive your own formulas from time to time. As you do so, it is helpful to check dimensional consistency at each step of the derivation. If at any time the dimensions don't agree, you will know that a mistake has been made, and you can go back and look for it. If the dimensions check, however, it's not a guarantee the formula is correct—after all, dimensionless factors, like 1/2 or 2, don't show up in a dimensional check.

1–4 Significant Figures

When a mass, a length, or a time is measured in a scientific experiment, the result is known only to within a certain accuracy. The inaccuracy or uncertainty can be caused by a number of factors, ranging from limitations of the measuring device itself to limitations associated with the senses and the skill of the person performing the experiment. In any case, the fact that observed values of experimental quantities have inherent uncertainties should always be kept in mind when performing calculations with those values.

▲ Every measurement has some degree of uncertainty associated with it. How precise would you expect this measurement to be?

Suppose, for example, that you want to determine the walking speed of your pet tortoise. To do so, you measure the time, t, it takes for the tortoise to walk a distance, d, and then you calculate the quotient, d/t. When you measure the distance with a ruler, which has one tick mark per millimeter, you find that $d = 21.2$ cm, with the precise value of the digit in the second decimal place uncertain. Defining the number of **significant figures** in a physical quantity to be equal to the number of digits in it that are known with certainty, we say that d is known to *three* significant figures.

Similarly, you measure the time with an old pocket watch, and as best you can determine it, $t = 8.5$ s, with the second decimal place uncertain. Note that t is known to only *two* significant figures. If we were to make this measurement with a digital watch, with a readout giving the time to 1/100 of a second, the accuracy of the result would still be limited by the finite reaction time of the experimenter. The reaction time would have to be predetermined in a separate experiment. (See Problem 77 in Chapter 2 for a simple way to determine your reaction time.)

Returning to the problem at hand, we would now like to calculate the speed of the tortoise. Using the above values for d and t and a calculator with eight digits in its display, we find (21.2 cm)/(8.5 s) = 2.4941176 cm/s. Clearly, such an accurate value for the speed is unjustified, considering the limitations of our measurements. After all, we can't expect to measure quantities to two and three significant figures and from them obtain results with eight significant figures. In general, the number of significant figures that result when we multiply or divide physical quantities is given by the following rule of thumb:

> The number of significant figures after multiplication or division is equal to the number of significant figures in the *least* accurately known quantity.

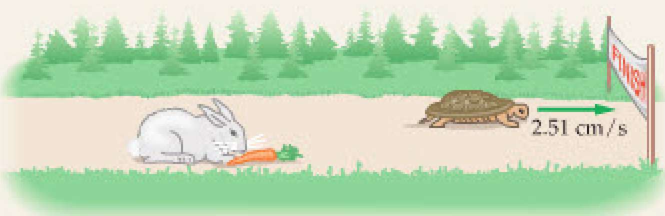
In our speed calculation, for example, we know the distance to three significant figures, but the time to only two significant figures. As a result, the speed should be given with just two significant figures, $d/t = (21.2\text{ cm})/(8.5\text{ s}) = 2.5\text{ cm/s}$. Note that we didn't just keep the first two digits in 2.4941176 cm/s and drop the rest. Instead, we "rounded up"; that is, because the first digit to be dropped (9 in this case) is greater than or equal to 5, we increase the previous digit (4 in this case) by 1. Thus, 2.5 cm/s is our best estimate for the tortoise's speed.

EXAMPLE 1–1 IT'S THE TORTOISE BY A HARE

A tortoise races a rabbit by walking with a constant speed of 2.51 cm/s for 12.23 s. How much distance does the tortoise cover?

PICTURE THE PROBLEM

The race between the rabbit and the tortoise is shown in our sketch. The rabbit pauses to eat a carrot while the tortoise walks with a constant speed.



STRATEGY

The distance covered by the tortoise is the speed of the tortoise multiplied by the time during which it walks.

SOLUTION

1. Multiply the speed by the time to find the distance d:

$$d = (\text{speed})(\text{time}) = (2.51\text{ cm/s})(12.23\text{ s}) = 30.7\text{ cm}$$

INSIGHT

Notice that if we simply multiply 2.51 cm/s by 12.23 s, we obtain 30.6973 cm. We don't give all of these digits in our answer, however. In particular, because the quantity that is known with the least accuracy (the speed) has only three significant figures, we give a result with three significant figures. Note, in addition, that the third digit in our answer has been rounded up from 6 to 7.

PRACTICE PROBLEM

How long does it take for the tortoise to walk 17 cm? [**Answer:** $t = (17\ \mathrm{cm})/(2.51\ \mathrm{cm/s}) = 6.8\ \mathrm{s}$]

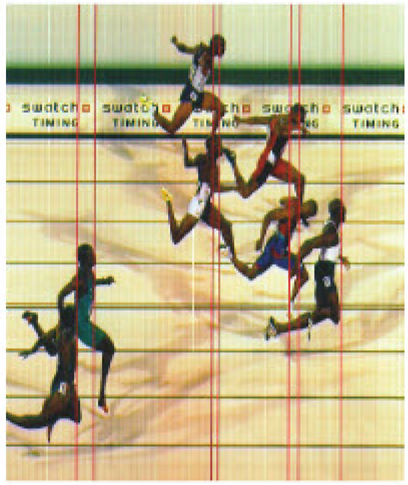
Some related homework problems: Problem 14, Problem 18

Note that the distance of 17 cm in the Practice Problem has only two significant figures because we don't know the digits to the right of the decimal place. If the distance were given as 17.0 cm, on the other hand, it would have three significant figures.

When physical quantities are added or subtracted, we use a slightly different rule of thumb. In this case, the rule involves the number of decimal places in each of the terms:

> The number of decimal places after addition or subtraction is equal to the smallest number of decimal places in any of the individual terms.

Thus, if you make a time measurement of 16.74 s, and then a subsequent time measurement of 5.1 s, the total time of the two measurements should be given as 21.8 s, rather than 21.84 s.



▲ The finish of the 100-meter race at the 1996 Atlanta Olympics. This official timing photo shows Donovan Bailey setting a new world record of 9.84 s. (If the timing had been accurate to only tenths of a second—as would probably have been the case before electronic devices came into use—how many runners would have shared the winning time? How many would have shared the second-place and third-place times?)

EXERCISE 1–3

You and a friend pick some raspberries. Your flat weighs 12.7 lb, and your friend's weighs 7.25 lb. What is the combined weight of the raspberries?

SOLUTION

Just adding the two numbers gives 19.95 lb. According to our rule of thumb, however, the final result must have only a single decimal place (corresponding to the term with the smallest number of decimal places). Rounding off to one place, then, gives 20.0 lb as the acceptable result.

Scientific Notation

The number of significant figures in a given quantity may be ambiguous due to the presence of zeros at the beginning or end of the number. For example, if a distance is stated to be 2500 m, the two zeros could be significant figures, or they could be zeros that simply show where the decimal point is located. If the two zeros are significant figures, the uncertainty in the distance is roughly a meter; if they are not significant figures, however, the uncertainty is about 100 m.

To remove this type of ambiguity, we can write the distance in **scientific notation**—that is, as a number of order unity times an appropriate power of ten. Thus, in this example, we would express the distance as 2.5×10^3 m if there are only two significant figures, or as 2.500×10^3 m to indicate four significant figures. Likewise, a time given as 0.000036 s has only two significant figures—the preceding zeros only serve to fix the decimal point. If this quantity were known to three significant figures, we would write it as 3.60×10^{-5} s to remove any ambiguity. See Appendix A for a more detailed discussion of scientific notation.

EXERCISE 1–4

How many significant figures are there in **(a)** 21.00, **(b)** 21, **(c)** 2.1×10^{-2}, **(d)** 2.10×10^{-3}?

SOLUTION

(a) 4, **(b)** 2, **(c)** 2, **(d)** 3

Round-Off Error

Finally, even if you perform all your calculations to the same number of significant figures as in the text, you may occasionally obtain an answer that differs in its last digit from that given in the book. In most cases this is not an issue as far as understanding the physics is concerned—usually it is due to **round-off error.**

Round-off error occurs when numerical results are rounded off at different times during a calculation. To see how this works, let's consider a simple example. Suppose you are shopping for knickknacks, and you buy one item for \$2.21, plus 8 percent sales tax. The total price is \$2.3868, or, rounded off to the nearest penny, \$2.39. Later, you buy another item for \$1.35. With tax this becomes \$1.458 or, again to the nearest penny, \$1.46. The total expenditure for these two items is \$2.39 + \$1.46 = \$3.85.

Now, let's do the rounding off in a different way. Suppose you buy both items at the same time for a total before-tax price of \$2.21 + \$1.35 = \$3.56. Adding in the 8% tax gives \$3.8448, which rounds off to \$3.84, one penny different from the previous amount. This same type of discrepancy can occur in physics problems. In general, it's a good idea to keep one extra digit throughout your calculations whenever possible, rounding off only the final result. But while this practice can help to reduce the likelihood of round-off error, there is no way to avoid it in every situation.

1–5 Converting Units

It is often convenient to convert from one set of units to another. For example, suppose you would like to convert 316 ft to its equivalent in meters. Looking at the conversion factors on the inside front cover of the text, we see that

$$1 \text{ m} = 3.281 \text{ ft} \qquad \text{1–1}$$

Equivalently,

$$\frac{1 \text{ m}}{3.281 \text{ ft}} = 1 \qquad \text{1–2}$$

Now, to make the conversion, we simply multiply 316 ft by this expression, which is equivalent to multiplying by 1:

$$(316 \cancel{\text{ft}})\left(\frac{1 \text{ m}}{3.281 \cancel{\text{ft}}}\right) = 96.3 \text{ m}$$

Note that the conversion factor is written in this particular way, as 1 m divided by 3.281 ft, so that the units of feet cancel out, leaving the final result in the desired units of meters.

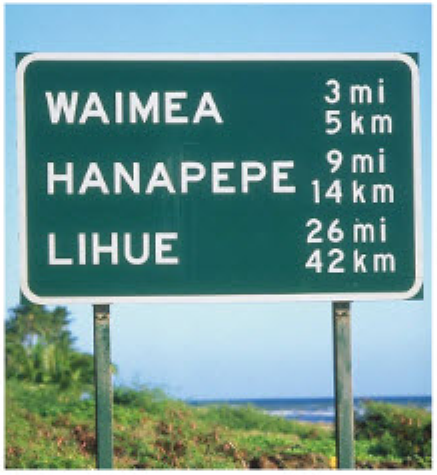
Of course, we can just as easily convert from meters to feet if we use the reciprocal of this conversion factor—which is also equal to 1:

$$1 = \frac{3.281 \text{ ft}}{1 \text{ m}}$$

For example, a distance of 26.4 m is converted to feet by canceling out the units of meters, as follows:

$$(26.4 \cancel{\text{m}})\left(\frac{3.281 \text{ ft}}{1 \cancel{\text{m}}}\right) = 86.6 \text{ ft}$$

Thus, we see that converting units is as easy as multiplying by 1—because that's really what you're doing.

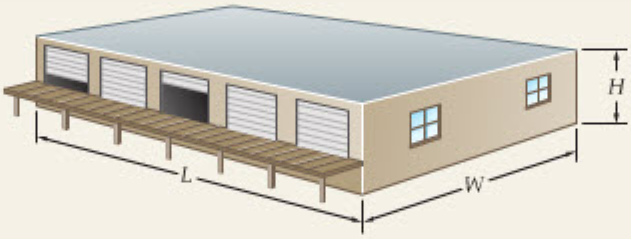


▲ From this sign, you can calculate factors for converting miles to kilometers and vice versa. (Why do you think the conversion factors seem to vary for different destinations?)

EXAMPLE 1–2 A HIGH-VOLUME WAREHOUSE

A warehouse is 20.0 yards long, 10.0 yards wide, and 15.0 ft high. What is its volume in SI units?

PICTURE THE PROBLEM
In our sketch we picture the warehouse, and indicate the relevant lengths for each of its dimensions.



STRATEGY
We begin by converting the length, width, and height of the warehouse to meters. Once this is done, the volume in SI units is simply the product of the three dimensions.

SOLUTION

1. Convert the length of the warehouse to meters: $L = (20.0\text{ yard})\left(\frac{3\text{ ft}}{1\text{ yard}}\right)\left(\frac{1\text{ m}}{3.281\text{ ft}}\right) = 18.3\text{ m}$
2. Convert the width to meters: $W = (10.0\text{ yard})\left(\frac{3\text{ ft}}{1\text{ yard}}\right)\left(\frac{1\text{ m}}{3.281\text{ ft}}\right) = 9.14\text{ m}$
3. Convert the height to meters: $H = (15.0\text{ ft})\left(\frac{1\text{ m}}{3.281\text{ ft}}\right) = 4.57\text{ m}$
4. Calculate the volume of the warehouse: $V = L \times W \times H = (18.3\text{ m})(9.14\text{ m})(4.57\text{ m}) = 764\text{ m}^3$

INSIGHT
We would say, then, that the warehouse has a volume of 764 cubic meters—the same as 764 cubical boxes that are 1 m on a side.

PRACTICE PROBLEM
What is the volume of the warehouse if its length is one-hundredth of a mile, and the other dimensions are unchanged? [**Answer:** $V = 672\text{ m}^3$]

Some related homework problems: Problem 20, Problem 21

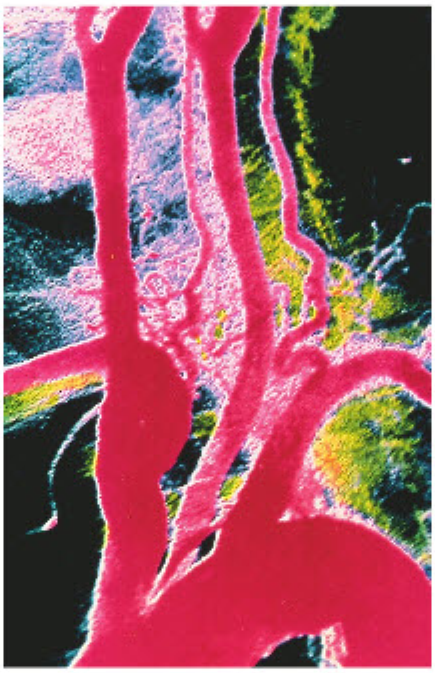
Finally, the same procedure can be applied to conversions involving any number of units. For instance, if you walk at 3.00 mi/h, how fast is that in m/s? In this case we need the following additional conversion factors:

$$1\text{ mi} = 5280\text{ ft} \qquad 1\text{ h} = 3600\text{ s}$$

With these factors at hand, we carry out the conversion as follows:

$$(3.00\ \cancel{\text{mi}}/\cancel{\text{h}})\left(\frac{5280\ \cancel{\text{ft}}}{1\ \cancel{\text{mi}}}\right)\left(\frac{1\text{ m}}{3.281\ \cancel{\text{ft}}}\right)\left(\frac{1\ \cancel{\text{h}}}{3600\text{ s}}\right) = 1.34\text{ m/s}$$

Note that in each conversion factor the numerator is equal to the denominator. In addition, each conversion factor is written in such a way that the unwanted units cancel, leaving just meters per second in our final result.



▲ Major blood vessels branch from the aorta (bottom), the artery that receives blood directly from the heart.

ACTIVE EXAMPLE 1–1 FIND THE SPEED OF BLOOD

Blood in the human aorta can attain speeds of 35.0 cm/s. How fast is this in **(a)** ft/s and **(b)** mi/h?

SOLUTION
(Test your understanding by performing the calculations indicated in each step.)

Part (a)

1. Convert centimeters to meters and then to feet: 1.15 ft/s

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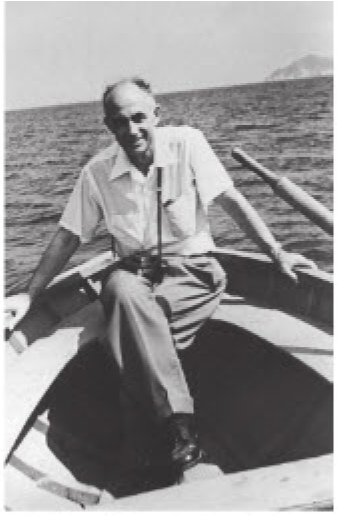


▲ Enrico Fermi (1901–1954) was renowned for his ability to pose and solve interesting order-of-magnitude problems. A winner of the 1938 Nobel Prize in physics, Fermi would ask his classes to obtain order-of-magnitude estimates for questions such as "How many piano tuners are there in Chicago?" or "How much is a tire worn down during one revolution?" Estimation questions like these are known to physicists today as "Fermi Problems."

CONTINUED FROM PREVIOUS PAGE

Part (b)

2. First, convert centimeters to miles:	2.17×10^{-4} mi/s
3. Next, convert seconds to hours:	0.783 mi/h

INSIGHT

Of course, the conversions in part (b) can be carried out in a single calculation if desired.

YOUR TURN

Find the speed of blood in units of km/h. *(Answers to* **Your Turn** *problems are given in the back of the book.)*

1–6 Order-of-Magnitude Calculations

An **order-of-magnitude** calculation is a rough "ballpark" estimate designed to be accurate to within a factor of about 10. One purpose of such a calculation is to give a quick idea of what order of magnitude should be expected from a complete, detailed calculation. If an order-of-magnitude calculation indicates that a distance should be on the order of 10^4 m, for example, and your calculator gives an answer on the order of 10^7 m, then there is an error somewhere that needs to be resolved.

For example, suppose you would like to estimate the speed of a cliff diver on entering the water. First, the cliff may be 20 or 30 feet high; thus in SI units we would say that the order of magnitude of the cliff's height is 10 m—certainly not 1 m or 10^2 m. Next, the diver hits the water something like a second later—certainly not 0.1 s later nor 10 s later. Thus, a reasonable order-of-magnitude estimate of the diver's speed is 10 m/1 s = 10 m/s, or roughly 20 mi/h. If you do a detailed calculation and your answer is on the order of 10^4 m/s, you probably entered one of your numbers incorrectly.

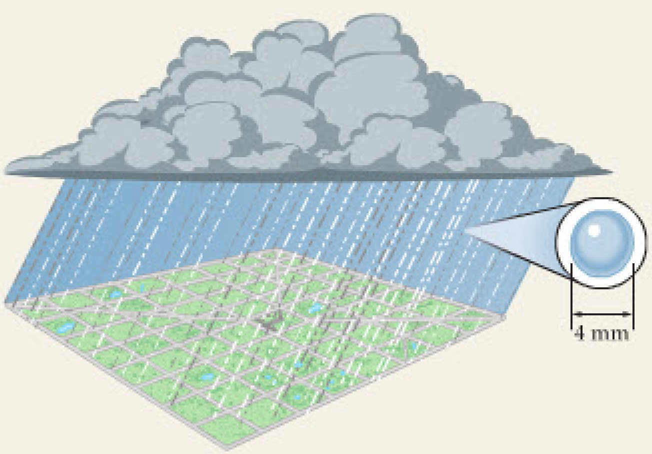
Another reason for doing an order-of-magnitude calculation is to get a feeling for what size numbers we are talking about in situations where a precise count is not possible. This is illustrated in the following Example.

EXAMPLE 1–3 ESTIMATION: HOW MANY RAINDROPS IN A STORM

A thunderstorm drops half an inch ($\sim$0.01 m) of rain on Washington D.C., which covers an area of about 70 square miles ($\sim 10^8$ m^2). Estimate the number of raindrops that fell during the storm.

PICTURE THE PROBLEM

Our sketch shows an area $A = 10^8$ m^2 covered to a depth $d = 0.01$ m by rainwater from the storm. Each drop of rain is approximated by a small sphere with a diameter of 4 mm.



STRATEGY

To find the number of raindrops, we first calculate the volume of water required to cover 10^8 m^2 to a depth of 0.01 m. Next, we calculate the volume of an individual drop of rain, recalling that the volume of a sphere of radius r is $4\pi r^3/3$. We estimate the diameter of a raindrop to be about 4 mm. Finally, dividing the volume of a drop into the volume of water that fell during the storm gives the number of drops.

SOLUTION

1. Calculate the order of magnitude of the volume of water, V_{water}, that fell during the storm:

$$V_{water} = Ad = (10^8\ m^2)(0.01\ m) \approx 10^6\ m^3$$

2. Calculate the order of magnitude of the volume of a drop of rain, V_{drop}. Note that if the diameter of a drop is 4 mm, its radius is $r = 2\ mm = 0.002\ m$:

$$V_{drop} = \frac{4}{3}\pi r^3 \approx \frac{4}{3}\pi(0.002\ m)^3 \approx 10^{-8}\ m^3$$

3. Divide V_{drop} into V_{water} to find the order of magnitude of the number of drops that fell during the storm:

$$\text{number of raindrops} \approx \frac{V_{water}}{V_{drop}} \approx \frac{10^6\ m^3}{10^{-8}\ m^3} = 10^{14}$$

INSIGHT

Thus the number of raindrops in this one small storm is roughly 100,000 times greater than the current population of the Earth.

PRACTICE PROBLEM

If a storm pelts Washington D.C. with 10^{15} raindrops, how many inches of rain fall on the city? [**Answer:** About 5 inches]

Some related homework problems: Problem 36, Problem 38

Appendix B provides a number of interesting "typical values" for length, mass, speed, acceleration, and many other quantities. You may find these to be of use in making your own order-of-magnitude estimates.

1–7 Scalars and Vectors

Physical quantities are sometimes defined solely in terms of a number and the corresponding unit, like the volume of a room or the temperature of the air it contains. Other quantities require both a numerical value *and* a direction. For example, suppose a car is traveling at a rate of 25 m/s in a direction that is due north. Both pieces of information—the rate of travel (25 m/s) and the direction (north)—are required to fully specify the motion of the car. The rate of travel is given the name **speed;** the rate of travel combined with the direction is referred to as the **velocity.**

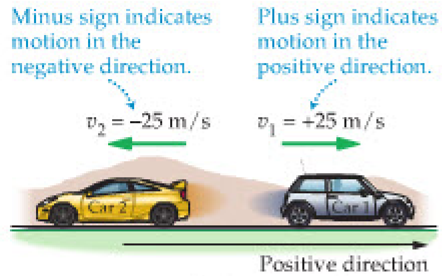
In general, quantities that are specified by a numerical value only are referred to as **scalars;** quantities that require both a numerical value and a direction are called **vectors:**

- A scalar is a numerical value, expressed in terms of appropriate units. An example would be the temperature of a room or the speed of a car.
- A vector is a mathematical quantity with both a numerical value and a direction. An example would be the velocity of a car.

All the physical quantities discussed in this text are either vectors or scalars. The properties of numbers (scalars) are well known, but the properties of vectors are sometimes less well known—though no less important. For this reason, you will find that Chapter 3 is devoted entirely to a discussion of vectors in two and three dimensions and, more specifically, to how they are used in physics.

The rather straightforward special case of vectors in one dimension is discussed in Chapter 2. There, we see that the direction of a velocity vector, for example, can only be to the left or to the right, up or down, and so on. That is, only two choices are available for the direction of a vector in one dimension. This is illustrated in **Figure 1–1**, where we see two cars, each traveling with a speed of 25 m/s. We also see that the cars are traveling in opposite directions, with car 1 moving to the right and car 2 moving to the left. We indicate the direction of travel with a plus sign for motion to the right, and a negative sign for motion to the left. Thus, the velocity of car 1 is written $v_1 = +25$ m/s, and the velocity of car 2 is $v_2 = -25$ m/s. The speed of each car is the absolute value, or **magnitude,** of the velocity; that is, speed $= |v_1| = |v_2| = 25$ m/s.

Whenever we deal with one-dimensional vectors, we shall indicate their direction with the appropriate sign. Many examples are found in Chapter 2 and, again, in later chapters where the simplicity of one dimension can again be applied.



▲ **FIGURE 1–1 Velocity vectors in one dimension**

The two cars shown in this figure have equal speeds of 25 m/s, but are traveling in opposite directions. To indicate the direction of travel, we first choose a positive direction (to the right in this case), and then give appropriate signs to the velocity of each car. For example, car 1 moves to the right, and hence its velocity is positive, $v_1 = +25$ m/s; the velocity of car 2 is negative, $v_2 = -25$ m/s, because it moves to the left.

1–8 Problem Solving in Physics

Physics is a lot like swimming—you have to learn by doing. You could read a book on swimming and memorize every word in it, but when you jump into a pool the first time you are going to have problems. Similarly, you could read this book carefully, memorizing every formula in it, but when you finish, you still haven't learned physics. To learn physics, you have to go beyond passive reading; you have to interact with physics and experience it by doing problems.

In this section we present a general overview of problem solving in physics. The suggestions given below, which apply to problems in all areas of physics, should help to develop a systematic approach.

We should emphasize at the outset that there is no recipe for solving problems in physics—it is a creative activity. In fact, the opportunity to be creative is one of the attractions of physics. The following suggestions, then, are not intended as a rigid set of steps that must be followed like the steps in a computer program. Rather, they provide a general guideline that experienced problem solvers find to be effective.

- **Read the problem carefully** Before you can solve a problem, you need to know exactly what information it gives and what it asks you to determine. Some information is given explicitly, as when a problem states that a person has a mass of 70 kg. Other information is implicit; for example, saying that a ball is dropped from rest means that its initial speed is zero. Clearly, a *careful* reading is the essential first step in problem solving.
- **Sketch the system** This may seem like a step you can skip—but don't. A sketch helps you to acquire a physical feeling for the system. It also provides an opportunity to label those quantities that are known and those that are to be determined. All Examples in this text begin with a sketch of the system, accompanied by a brief description in a section labeled "Picture the Problem."
- **Visualize the physical process** Try to visualize what is happening in the system as if you were watching it in a movie. Your sketch should help. This step ties in closely with the next step.
- **Strategize** This may be the most difficult, but at the same time the most creative, part of the problem-solving process. From your sketch and visualization, try to identify the physical processes at work in the system. Ask yourself what concepts or principles are involved in this situation. Then, develop a strategy—a game plan—for solving the problem. All Examples in this book have a "Strategy" spelled out before the solution begins.
- **Identify appropriate equations** Once a strategy has been developed, find the specific equations that are needed to carry it out.
- **Solve the equations** Use basic algebra to solve the equations identified in the previous step. Work with symbols such as x or y for the most part, substituting numerical values near the end of the calculations. Working with symbols will make it easier to go back over a problem to locate and identify mistakes, if there are any, and to explore limits and special cases.
- **Check your answer** Once you have an answer, check to see if it makes sense: (i) Does it have the correct dimensions? (ii) Is the numerical value reasonable?
- **Explore limits/special cases** Getting the correct answer is nice, but it's not all there is to physics. You can learn a great deal about physics and about the connection between physics and mathematics by checking various limits of your answer. For example, if you have two masses in your system, m_1 and m_2, what happens in the special case that $m_1 = 0$ or $m_1 = m_2$? Check to see whether your answer and your physical intuition agree.

The **Examples** in this text are designed to deepen your understanding of physics and at the same time develop your problem-solving skills. They all have the same basic structure: Problem Statement; Picture the Problem; Strategy; Solution, presenting the flow of ideas and the mathematics side-by-side in a two-column format; Insight; and a Practice Problem related to the one just solved. As you work through the Examples in the chapters to come, notice how the basic problem-solving guidelines outlined above are implemented in a consistent way.

In addition to the Examples, this text contains a new and innovative type of worked-out problem called the **Active Example,** the first one of which appears on page 9. The purpose of Active Examples is to encourage active participation in the solution of a problem and, in so doing, to act as a "bridge" between Examples—where each and every detail is worked out—and homework problems—where you are completely on your own. An analogy would be to think of Examples as like a tricycle, with no balancing required; homework problems as like a bicycle, where balancing is initially difficult to master; and Active Examples as like a bicycle with training wheels that give just enough help to prevent a fall. When you work through an Active Example, keep in mind that the work you are doing as you progress step-by-step through the problem is just the kind of work you'll be doing later in your homework assignments.

Finally, it is tempting to look for shortcuts when doing a problem—to look for a formula that seems to fit and some numbers to plug into it. It may seem harder to think ahead, to be systematic as you solve the problem, and then to think back over what you have done at the end of the problem. The extra effort is worth it, however, because by doing these things you will develop powerful problem-solving skills that can be applied to unexpected problems you may encounter on exams—and in life in general.

THE BIG PICTURE PUTTING PHYSICS IN CONTEXT

LOOKING BACK

The three physical dimensions introduced in this chapter—mass, length, time—are the only ones we'll use until Chapter 19, when we introduce electric charge. Other quantities found in the next several chapters, like force, momentum, and energy, are combinations of these three basic dimensions.

In this chapter we discussed the idea of a vector in one spatial dimension and showed how the direction of the vector can be indicated by its sign. These concepts are developed in more detail in Chapter 2.

LOOKING AHEAD

Dimensional analysis is used frequently in the coming chapters to verify that each term in an equation has the correct dimensions. See, for example, the discussion following Equation 2–7, where we show that each term has the dimensions of velocity. We also use dimensional analysis to help derive some results, such as the speed of waves on a string in Section 14–2.

Vectors are extended to two and three spatial dimensions in Chapter 3. After that, they are a standard tool throughout mechanics, and they appear again in electricity and magnetism.

CHAPTER SUMMARY

1–1 PHYSICS AND THE LAWS OF NATURE

Physics is based on a small number of fundamental laws and principles.

1–2 UNITS OF LENGTH, MASS, AND TIME

Length
One meter is defined as the distance traveled by light in a vacuum in 1/299,792,458 second.

Mass
One kilogram is the mass of a metal cylinder kept at the International Bureau of Weights and Standards.

Time
One second is the time required for a particular type of radiation from cesium-133 to undergo 9,192,631,770 oscillations.

1–3 DIMENSIONAL ANALYSIS

Dimension
The dimension of a quantity is the type of quantity it is, for example, length [L], mass [M], or time [T].

Dimensional Consistency
An equation is dimensionally consistent if each term in it has the same dimensions. All valid physical equations are dimensionally consistent.

Dimensional Analysis
A calculation based on the dimensional consistency of an equation.

1–4 SIGNIFICANT FIGURES

Significant Figures
The number of digits reliably known, excluding digits that simply indicate the decimal place. For example, 3.45 and 0.0000345 both have three significant figures.

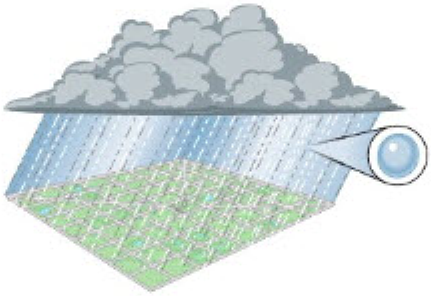
Round-off Error
Discrepancies caused by rounding off numbers in intermediate results.

1–5 CONVERTING UNITS

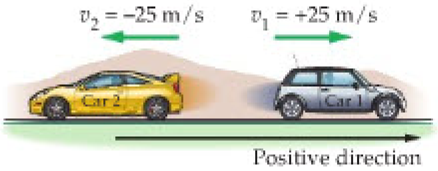
Multiply by the ratio of two units to convert from one to another. As an example, to convert 3.5 m to feet, you multiply by the factor (1 ft/0.3048 m).

1–6 ORDER-OF-MAGNITUDE CALCULATIONS

A ballpark estimate designed to be accurate to within the nearest power of ten.



1–7 SCALARS AND VECTORS



A physical quantity that can be represented by a numerical value only is called a scalar. Quantities that require a direction in addition to the numerical value are called vectors.

1–8 PROBLEM SOLVING IN PHYSICS

A good general approach to problem solving is as follows: read; sketch; visualize; strategize; identify equations; solve; check; explore limits.

CONCEPTUAL QUESTIONS

For instructor-assigned homework, go to www.masteringphysics.com

(Answers to odd-numbered Conceptual Questions can be found in the back of the book.)

1. Can dimensional analysis determine whether the area of a circle is πr^2 or $2\pi r^2$? Explain.

2. If a distance d has units of meters, and a time T has units of seconds, does the quantity $T + d$ make sense physically? What about the quantity d/T? Explain in both cases.

3. Is it possible for two quantities to **(a)** have the same units but different dimensions or **(b)** have the same dimensions but different units? Explain.
4. Give an order-of-magnitude estimate for the time in seconds of the following: **(a)** a year; **(b)** a baseball game; **(c)** a heartbeat; **(d)** the age of the Earth; **(e)** the age of a person.
5. Give an order-of-magnitude estimate for the length in meters of the following: **(a)** a person; **(b)** a fly; **(c)** a car; **(d)** a 747 airplane; **(e)** an interstate freeway stretching coast-to-coast.

PROBLEMS AND CONCEPTUAL EXERCISES

Note: Answers to odd-numbered Problems and Conceptual Exercises can be found in the back of the book. **IP** *denotes an integrated problem, with both conceptual and numerical parts;* **BIO** *identifies problems of biological or medical interest;* **CE** *indicates a conceptual exercise. On all problems, red bullets (•, ••, •••) are used to indicate the level of difficulty.*

SECTION 1–2 UNITS OF LENGTH, MASS, AND TIME

1. • **Spiderman** The movie *Spiderman* brought in \$114,000,000 in its opening weekend. Express this amount in **(a)** gigadollars and **(b)** teradollars.
2. • **BIO The Thickness of Hair** A human hair has a thickness of about 70 μm. What is this in **(a)** meters and **(b)** kilometers?
3. • The speed of light in a vacuum is approximately 0.3 Gm/s. Express the speed of light in meters per second.
4. • **A Fast Computer** IBM has a computer it calls the Blue Gene/L that can do 136.8 teracalculations per second. How many calculations can it do in a microsecond?

SECTION 1–3 DIMENSIONAL ANALYSIS

5. • **CE** Which of the following equations are dimensionally consistent? **(a)** $x = vt$, **(b)** $x = \frac{1}{2}at^2$, **(c)** $t = (2x/a)^{1/2}$.
6. • **CE** Which of the following quantities have the dimensions of a distance? **(a)** vt, **(b)** $\frac{1}{2}at^2$, **(c)** $2at$, **(d)** v^2/a.
7. • **CE** Which of the following quantities have the dimensions of a speed? **(a)** $\frac{1}{2}at^2$, **(b)** at, **(c)** $(2x/a)^{1/2}$, **(d)** $(2ax)^{1/2}$.
8. • Velocity is related to acceleration and distance by the following expression: $v^2 = 2ax^p$. Find the power p that makes this equation dimensionally consistent.
9. • Acceleration is related to distance and time by the following expression: $a = 2xt^p$. Find the power p that makes this equation dimensionally consistent.
10. • Show that the equation $v = v_0 + at$ is dimensionally consistent. Note that v and v_0 are velocities and that a is an acceleration.
11. •• Newton's second law (to be discussed in Chapter 5) states that acceleration is proportional to the force acting on an object and is inversely proportional to the object's mass. What are the dimensions of force?
12. •• The time T required for one complete oscillation of a mass m on a spring of force constant k is

$$T = 2\pi\sqrt{\frac{m}{k}}$$

Find the dimensions k must have for this equation to be dimensionally correct.

SECTION 1–4 SIGNIFICANT FIGURES

13. • The first several digits of π are known to be $\pi = 3.14159265358979\ldots$ What is π to **(a)** three significant figures, **(b)** five significant figures, and **(c)** seven significant figures?
14. • The speed of light to five significant figures is 2.9979×10^8 m/s. What is the speed of light to three significant figures?
15. • A parking lot is 144.3 m long and 47.66 m wide. What is the perimeter of the lot?
16. • On a fishing trip you catch a 2.35-lb bass, a 12.1-lb rock cod, and a 12.13-lb salmon. What is the total weight of your catch?
17. •• How many significant figures are there in **(a)** 0.000054 and **(b)** 3.001×10^5?
18. •• What is the area of a circle of radius **(a)** 14.37 m and **(b)** 3.8 m?

SECTION 1–5 CONVERTING UNITS

19. • **BIO Mantis Shrimp** Peacock mantis shrimps (*Odontodactylus scyllarus*) feed largely on snails. They shatter the shells of their prey by delivering a sharp blow with their front legs, which have been observed to reach peak speeds of 23 m/s. What is this speed in **(a)** feet per second and **(b)** miles per hour?
20. • **(a)** The largest building in the world by volume is the Boeing 747 plant in Everett, Washington. It measures approximately 631 m long, 707 yards wide, and 110 ft high. What is its volume in cubic feet? **(b)** Convert your result from part (a) to cubic meters.
21. • The Ark of the Covenant is described as a chest of acacia wood 2.5 cubits in length and 1.5 cubits in width and height. Given that a cubit is equivalent to 17.7 in., find the volume of the ark in cubic feet.
22. • How long does it take for radiation from a cesium-133 atom to complete 1.5 million cycles?
23. • **Angel Falls** Water going over Angel Falls, in Venezuela, the world's highest waterfall, drops through a distance of 3212 ft. What is this distance in km?
24. • An electronic advertising sign repeats a message every 7 seconds, day and night, for a week. How many times did the message appear on the sign?
25. • **BIO Blue Whales** The blue whale (*Balaenoptera musculus*) is thought to be the largest animal ever to inhabit the Earth. The longest recorded blue whale had a length of 108 ft. What is this length in meters?
26. • **The Star of Africa** The Star of Africa, a diamond in the royal scepter of the British crown jewels, has a mass of 530.2 carats, where 1 carat = 0.20 g. Given that 1 kg has an approximate weight of 2.21 lb, what is the weight of this diamond in pounds?

27. • **IP** Many highways have a speed limit of 55 mi/h. **(a)** Is this speed greater than, less than, or equal to 55 km/h? Explain. **(b)** Find the speed limit in km/h that corresponds to 55 mi/h.

28. • What is the speed in miles per hour of a beam of light traveling at 3.00×10^8 m/s?

29. • **BIO Woodpecker Impact** When red-headed woodpeckers (*Melanerpes erythrocephalus*) strike the trunk of a tree, they can experience an acceleration ten times greater than the acceleration of gravity, or about 98.1 m/s^2. What is this acceleration in ft/s^2?

30. •• **A Jiffy** The American physical chemist Gilbert Newton Lewis (1875–1946) proposed a unit of time called the "jiffy." According to Lewis, 1 jiffy = the time it takes light to travel one centimeter. **(a)** If you perform a task in a jiffy, how long has it taken in seconds? **(b)** How many jiffys are in one minute? (Use the fact that the speed of light is approximately 2.9979×10^8 m/s.)

31. •• **The Mutchkin and the Noggin** **(a)** A mutchkin is a Scottish unit of liquid measure equal to 0.42 L. How many mutchkins are required to fill a container that measures one foot on a side? **(b)** A noggin is a volume equal to 0.28 mutchkin. What is the conversion factor between noggins and gallons?

32. •• Suppose 1.0 cubic meter of oil is spilled into the ocean. Find the area of the resulting slick, assuming that it is one molecule thick, and that each molecule occupies a cube 0.50 μm on a side.

33. •• **IP** **(a)** A standard sheet of paper measures 8 1/2 by 11 inches. Find the area of one such sheet of paper in m^2. **(b)** A second sheet of paper is half as long and half as wide as the one described in part (a). By what factor is its area less than the area found in part (a)?

34. •• **BIO Squid Nerve Impulses** Nerve impulses in giant axons of the squid can travel with a speed of 20.0 m/s. How fast is this in **(a)** ft/s and **(b)** mi/h?

35. •• The acceleration of gravity is approximately 9.81 m/s^2 (depending on your location). What is the acceleration of gravity in feet per second squared?

SECTION 1–6 ORDER-OF-MAGNITUDE CALCULATIONS

36. • Give a ballpark estimate of the number of seats in a typical major league ballpark.

Shea Stadium, in New York. How many fans can it hold? (Problem 36)

37. • Milk is often sold by the gallon in plastic containers. **(a)** Estimate the number of gallons of milk that are purchased in the United States each year. **(b)** What approximate weight of plastic does this represent?

38. •• New York is roughly 3000 miles from Seattle. When it is 10:00 A.M. in Seattle, it is 1:00 P.M. in New York. Using this information, estimate **(a)** the rotational speed of the surface of Earth, **(b)** the circumference of Earth, and **(c)** the radius of Earth.

39. •• You've just won the $12 million cash lottery, and you go to pick up the prize. What is the approximate weight of the cash if you request payment in **(a)** quarters or **(b)** dollar bills?

GENERAL PROBLEMS

40. • **CE** Which of the following equations are dimensionally consistent? **(a)** $v = at$, **(b)** $v = \frac{1}{2}at^2$, **(c)** $t = a/v$, **(d)** $v^2 = 2ax$.

41. • **CE** Which of the following quantities have the dimensions of an acceleration? **(a)** xt^2, **(b)** v^2/x, **(c)** x/t^2, **(d)** v/t.

42. • **BIO Photosynthesis** The light that plants absorb to perform photosynthesis has a wavelength that peaks near 675 nm. Express this distance in **(a)** millimeters and **(b)** inches.

43. • **Glacial Speed** On June 9, 1983, the lower part of the Variegated Glacier in Alaska was observed to be moving at a rate of 210 feet per day. What is this speed in meters per second?

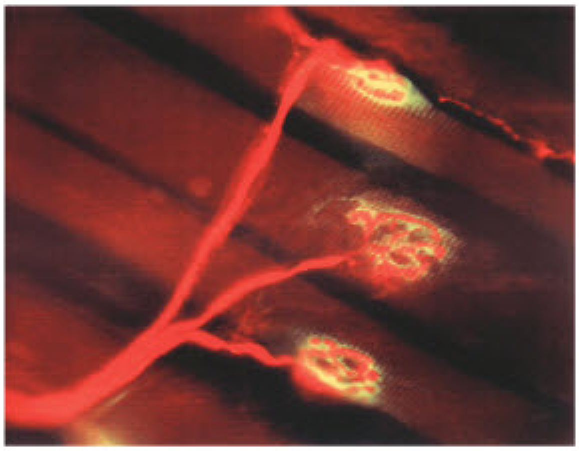
Alaska's Variegated Glacier (Problem 43)

44. •• **BIO Mosquito Courtship** Male mosquitoes in the mood for mating find female mosquitoes of their own species by listening for the characteristic "buzzing" frequency of the female's wing beats. This frequency is about 605 wing beats per second. **(a)** How many wing beats occur in one minute? **(b)** How many cycles of oscillation does the radiation from a cesium-133 atom complete during one mosquito wing beat?

45. •• **Ten and Ten** When Coast Guard pararescue jumpers leap from a helicopter to save a person in the water, they like to jump when the helicopter is flying "ten and ten," which means it is 10 feet above the water and moving forward with a speed of 10 knots. What is "ten and ten" in SI units? (A knot is one nautical mile per hour, where a nautical mile is 1.852 km.)

46. •• **IP** A Porsche sports car can accelerate at 14 m/s^2. **(a)** Is this acceleration greater than, less than, or equal to 14 ft/s^2? Explain. **(b)** Determine the acceleration of a Porsche in ft/s^2. **(c)** Determine its acceleration in km/h^2.

47. •• **BIO Human Nerve Fibers** Type A nerve fibers in humans can conduct nerve impulses at speeds up to 140 m/s. **(a)** How fast are the nerve impulses in miles per hour? **(b)** How far (in meters) can the impulses travel in 5.0 ms?



The impulses in these nerve axons, which carry commands to the skeletal muscle fibers in the background, travel at speeds of up to 140 m/s. (Problem 47)

48. •• **BIO Brain Growth** The mass of a newborn baby's brain has been found to increase by about 1.6 mg per minute. **(a)** How much does the brain's mass increase in one day? **(b)** How long does it take for the brain's mass to increase by 0.0075 kg?

49. •• **The Huygens Probe** NASA's Cassini mission to Saturn released a probe on December 25, 2004, that landed on the Saturnian moon Titan on January 14, 2005. The probe, which was named Huygens, was released with a gentle relative speed of 31 cm/s. As Huygens moved away from the main spacecraft, it rotated at a rate of seven revolutions per minute. **(a)** How many revolutions had Huygens completed when it was 150 yards from the mother ship? **(b)** How far did Huygens move away from the mother ship during each revolution? Give your answer in feet.

50. ••• Acceleration is related to velocity and time by the following expression: $a = v^p t^q$. Find the powers p and q that make this equation dimensionally consistent.

51. ••• The period T of a simple pendulum is the amount of time required for it to undergo one complete oscillation. If the length of the pendulum is L and the acceleration of gravity is g, then T is given by

$$T = 2\pi L^p g^q$$

Find the powers p and q required for dimensional consistency.

52. ••• Driving along a crowded freeway, you notice that it takes a time t to go from one mile marker to the next. When you increase your speed by 7.9 mi/h, the time to go one mile decreases by 13 s. What was your original speed?

PASSAGE PROBLEMS

BIO Using a Cricket as a Thermometer

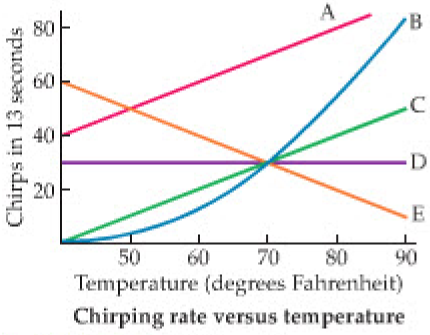
All chemical reactions, whether organic or inorganic, proceed at a rate that depends on temperature—the higher the temperature, the higher the rate of reaction. This can be understood in terms of molecules moving with increased energy as the temperature is increased, and colliding with other molecules more frequently. In the case of organic reactions, the result is that metabolic processes speed up with increasing temperature.

An increased or decreased metabolic rate can manifest itself in a number of ways. For example, a cricket trying to attract a mate chirps at a rate that depends on its overall rate of metabolism. As a result, the chirping rate of crickets depends directly on temperature. In fact, some people even use a pet cricket as a thermometer.

The cricket that is most accurate as a thermometer is the snowy tree cricket (*Oecanthus fultoni* Walker). Its rate of chirping is described by the following formula:

$$N = \text{number of chirps per 13.0 seconds}$$
$$= T - 40.0$$

In this expression, T is the temperature in degrees Fahrenheit.



▲ **FIGURE 1–2** Problem 53

53. • Which plot in **Figure 1–2** represents the chirping rate of the snowy tree cricket?

A B C D E

54. • If the temperature is 43 degrees Fahrenheit, how long does it take for the cricket to chirp 12 times?

A. 12 s **B.** 24 s **C.** 43 s **D.** 52 s

55. •• Your pet cricket chirps 112 times in one minute (60.0 s). What is the temperature in degrees Fahrenheit?

A. 41.9 **B.** 47.0 **C.** 64.3 **D.** 74.7

56. •• Suppose a snowy cricket is chirping when the temperature is 65.0 degrees Fahrenheit. How many oscillations does the radiation from a cesium-133 atom complete between successive chirps?

A. 7.98×10^7 **B.** 3.68×10^8

C. 4.78×10^9 **D.** 9.58×10^9

AP PHYSICS 1 SYLLABUS

AP Physics I is a course which is equivalent to a first-semester college course in algebra-based physics. This course covers Newtonian mechanics (including rotational dynamics and angular momentum); work, energy and power; and mechanical waves and sound. This course will also introduce electric circuits.

OFFICE HOURS

Office hours will be announced soon. Please feel free to ask for help ANY TIME. I'm usually on campus from about 6:00 am to about 3:00 pm. If I'm not in my room (206), then I'm usually either in room 303 or running a quick errand on campus.

TEXTBOOK

- Walker, James S. **Physics, AP Edition, 4th Edition**. San Francisco, CA: Pearson, 2010.

REQUIRED MATERIALS

- Two "Composition" style notebooks, quad ruled (graph paper), one for each semester
- Pencil or pen (blue or black only)
- Calculator ("scientific" type is fine, "graphing" is OK too; you want to work easily with exponents/roots and sin-cos-tan in both degrees and radians)
- Standard notebook paper

RECOMMENEDED MATERIALS

- Clear tape (e.g. Scotch brand)
- Highlighters, colored pens, etc.

CLASSROOM RULES

1. Listen to and follow all directions the first time.
2. Don't take anything out that is not related to this class.
3. Remain in your seat unless directed otherwise.
4. No eating or drinking in class. (Plain water is OK. Any spills must be cleaned up by you!)
5. Be polite and respectful of everyone in the classroom.

RESTROOM USE DURING CLASS

No one is allowed to use the restroom during the first or last 10 minutes of class. If you have to go, simply ask and I will give you a pass. Only one person will be allowed out of class at a time. If I feel this is being overused/abused, I may restrict the number of people allowed to leave class on any given day.

GENERAL STATEMENT ABOUT BEHAVIOR

Students are expected to meet classroom expectations and will be held accountable for their actions. Continual disregard for or lack of compliance with class expectations/teacher request(s) is DEFIANCE and may result in removal from the classroom/office referral. Failure to follow the classroom expectations may result in an UNSATISFACTORY (U) in citizenship and/or work habits on the report card. Serious infractions/misbehavior will result in immediate removal from the class via an office referral.

AP PHYSICS 1 SYLLABUS

INSTRUCTIONAL STRATEGIES

The AP Physics 1 course is conducted using **inquiry-based instructional strategies** that focus on experimentation to develop students' conceptual understanding of physics principles. Throughout the course, the students construct and use multiple representations of physical processes, solve multi-step problems, design investigations, and reflect on knowledge construction through self-assessment rubrics.

This course will include lecture and laboratory exercises. Laboratory activities will be comparable to the lab that is being done in college-level Physics I. The student will learn how to prepare and write laboratory reports. This course aims to prepare students to be able to explain and analyze real life situations that deal with Physics and also be able to solve problems in the field of science. During lecture, students will be involved in problem solving using formulas and will be expected to understand how formulas are related to each other. In addition, students will use calculators, computers, and online resources for interactive simulations, collaborative activities and formative assessments.

The AP Physics 1 course devotes over **25% of the time** to laboratory investigations. The students use **guided inquiry (GI)** or **open inquiry (OI)** in the design of their laboratory investigations. Some labs focus on investigating a physical phenomenon without having expectations of its outcomes. In other experiments, the student has an expectation of its outcome based on concepts constructed from prior experiences. In application experiments, the students use acquired physics principles to address practical problems.

All investigations are recorded in a laboratory notebook, and a typed hard copy report will be submitted, along with a submission to turnitin.com. Students are expected to record their observations, data, and data analyses. Data analyses include identification of the sources and effects of experimental uncertainty, calculations, results and conclusions, and suggestions for further refinement of the experiment as appropriate.

THE "FLIPPED CLASSROOM"

I use what's called a "flipped classroom", where students watch videos that I have created or found on YouTube. The videos take the place of classroom lectures, and so students are expected to watch every video as they are assigned, and to take thorough notes from the videos. The other major change that happens is that what used to be the traditional homework is now usually done in class. There are many benefits to doing this, such as:

- Not lecturing during class time allows much more time for lab activities, particularly inquiry-based labs.
- There's more time in class to practice solving problems, and to get help if needed.
- Students can take notes at their own pace, and don't feel rushed. They can "pause" and "rewind" the teacher!
- Students can watch the lectures as often as they need to.

TYPES OF ASSIGNMENTS

Notebook:	Types of HW Assignments:
Calendar	Read the chapter
Lecture Notes	Read & Summarize (RnS)
Lab Data & Rough Work	Practice Problems
Handouts	Representative Problem (RP)
Non-graded work	Lab Reports

AP PHYSICS 1 SYLLABUS

COURSE SYNOPSIS

UNIT 1. KINEMATICS (Ch. 1,2,3,4)
- Kinematics in one-dimension: constant velocity and uniform accelerated motion
- Vectors: vector components and resultant
- Kinematics in two-dimensions: projectile motion

UNIT 2. DYNAMICS (Ch. 5,6)
- Forces, types and representation (FBD)
- Newton's First Law
- Newton's Third Law
- Newton's Second Law
- Applications of Newton's 2nd Law
- Friction
- Interacting objects: ropes and pulleys

UNIT 3. ENERGY (Ch. 7,8)
- Work
- Power
- Kinetic energy
- Potential energy: gravitational and elastic
- Conservation of energy

UNIT 4. MOMENTUM (Ch. 9)
- Impulse
- Momentum
- Conservation of momentum
- Elastic and inelastic collisions

UNIT 5. CIRCULAR MOTION AND GRAVITATION (Ch. 12)
- Uniform circular motion (from Ch. 6)
- Dynamics of uniform circular motion
- Universal Law of Gravitation

UNIT 6. ROTATIONAL MOTION (Ch. 10,11)
- Torque
- Center of mass
- Rotational kinematics
- Rotational dynamics and rotational inertia
- Rotational energy
- Angular momentum
- Conservation of angular momentum

UNIT 7. SIMPLE HARMONIC MOTION (Ch. 13)
- Linear restoring forces and simple harmonic motion
- Simple harmonic motion graphs
- Simple pendulum
- Mass-spring systems

UNIT 8. MECHANICAL WAVES (Ch. 14)
- Traveling waves
- Wave characteristics
- Sound
- Superposition
- Standing waves on a string
- Standing sound waves

UNIT 9. ELECTROSTATICS (Ch. 19)
- Electric charge and conservation of charge
- Electric force: Coulomb's Law

UNIT 10. DC CIRCUITS (Ch. 21)
- Electric resistance
- Ohm's Law
- DC circuits
- Series and parallel connections
- Kirchhoff's Laws

Note: The above list may not represent the exact order of topics – the sequence may be changed as needed.

AP PHYSICS 1 SYLLABUS

INTEGRITY

Integrity (synonymous with honesty) is of the utmost importance. It is the foundation of all intellectual pursuits. What is graded must represent the work done by the student and indicate the level of that student's achievement. Cheating and plagiarism undermine these goals. Cheating is a voluntary act for which there may be reasons, but for which there is no acceptable excuse. Cheating includes, but is not limited to:

- Receiving or knowingly supplying unauthorized information
- Changing an answer after work has been graded and representing it as improperly graded
- Using unauthorized materials or sources
- Plagiarism – copying someone else's work or letting them copy off you. This includes homework, labs, quizzes, exams, etc.

"Working together" means discussing the ideas and questions together, but that what you turn in must represent your own understanding, expressed in your own words. The ultimate decision as to whether something has been copied lies with the instructor. If you are caught cheating, you, along with anyone else involved, will receive a "zero" on the assignment/task.

GRADING CATEGORIES

Tests/Quizzes	50%
Assignments	10%
Lab Class Activities/Projects	10%
Lab Homework	30%

GRADING SCALE

A…90-100%
B…80-89%
C…70-79%
D…60-69%
F…0-59%

EXTRA CREDIT

Don't expect any – this is a college-level course.

ABSENT WORK vs LATE WORK

Absences: If you miss class for any reason, it is YOUR RESPONSIBILITY to see Mr. Woods outside of class time to get the work you missed. You should get this material within 1 or 2 days of returning to class. You will be given a reasonable amount of time to complete and turn in any assignments you missed, but typically this will be less than one week. If you wait too long (more than one week), it will be considered LATE and not accepted for credit.

<u>Late work will not be accepted for credit.</u> You will be given plenty of time to complete large assignments, such as lab reports. Homework is vital to your understanding and long-term retention of the material, so you should recognize its value and make sure you complete all assignments in a timely manner.

HOW TO SUCCEED

- Remember…YOU CAN DO THIS!!!
- Be committed to your goal – if you want a certain grade, be willing to do what it takes to get it. This is the biggest difference between those who succeed and those who don't. Success comes after the hard work.
- Do the work and turn it in on time. Completing all of the work is the best way to prepare yourself for quizzes and tests. Put all of your attention and energy into the activities presented in class and assigned to be completed outside of class. If your attention is divided, you won't achieve the best results.