Chapter 1

Getting Started with Physics

In This Chapter

- Laying down measurements
- Simplifying with scientific notation
- Practicing conversions
- Drawing on algebra and trigonometry

This chapter gets the ball rolling by discussing some fundamental physics measurements. At its root, physics is all about making measurements (and using those measurements as the basis of predictions), so it's the perfect place to start! I also walk you through the process of converting measurements from one unit to another, and I show you how to apply math skills to physics problems.

Measuring the Universe

A great deal of physics has to do with making measurements — that's the way all physics gets started. For that reason, physics uses a number of measurement systems, such as the CGS (centiment-gram-second) system and the MKS (meter-kilogram-second) system. You also use the standard English system of inches and feet and so on — that's the FPI (foot-pound-inch) system.

REMEMBER

In physics, all measurements (except for some angles) have units, such as meters or seconds. For example, when you measure how far a hockey puck slid, you need to measure both the distance in centimeters and the time in seconds.

For reference, Table 1-1 shows the primary units of measurement (and their abbreviations) in the CGS system. (Don't bother memorizing the ones you're not familiar with now; you can come back to them later as needed.)

Table 1-1 CGS Units of Measurement

Measurement	Unit	Abbreviation
Length	centimeter	cm
Mass	gram	g
Time	second	s
Force	dyne	dyne

(continued)

Table 1-1 *(continued)*

Measurement	***Unit***	***Abbreviation***
Energy	erg	erg
Pressure	barye	ba
Electric current	biot	Bi
Magnetism	gauss	G
Electric charge	franklin	Fr

These are the measuring sticks that will become familiar to you as you solve problems and triumph over the math in this workbook. Also for reference, Table 1-2 gives you the primary units of measurement in the MKS system.

Table 1-2 MKS Units of Measurement

Measurement	***Unit***	***Abbreviation***
Length	meter	m
Mass	kilogram	kg
Time	second	s
Force	Newton	N
Energy	Joule	J
Pressure	Pascal	P
Electric current	Ampere	A
Magnetism	Tesla	T
Electric charge	Coulomb	C

EXAMPLE

Q. You're told to measure the length of a race-car track using the MKS system. What unit(s) will your measurement be in?

A. The correct answer is meters. The unit of length in the MKS system is the meter.

1. You're told to measure the mass of a marble using the CGS system. What unit(s) will your measurement be in?

Solve It

2. You're asked to measure the time it takes the moon to circle the Earth using the MKS system. What will your measurement's units be?

Solve It

3. You need to measure the force a tire exerts on the road as it's moving using the MKS system. What are the units of your answer?

Solve It

4. You're asked to measure the amount of energy released by a firecracker when it explodes using the CGS system. What are the units of your answer?

Solve It

Putting Scientific Notation to Work

Physics deals with some very large and very small numbers. To work with such numbers, you use *scientific notation.* Scientific notation is expressed as a number multiplied by a power of 10.

For example, suppose you're measuring the mass of an electron in the MKS system. You put an electron on a scale (in practice, electrons are too small to measure on a scale — you have to see how they react to the pull of magnetic or electrostatic forces in order to measure their mass) and you measure the following:

0.000000000000000000000000000000091 kg

What the heck is that? That's a lot of zeros, and it makes this number very unwieldy to work with. Fortunately, you know all about scientific notation, so you can convert the number into the following:

9.1×10^{-31} kg

That is, 9.1 multiplied by a power of 10, 10^{-31}. Scientific notation works by extracting the power of 10 and putting it on the side, where it's handy. You convert a number to scientific notation by counting the number of places you have to move the decimal point to get the first digit in front of that decimal point. For example, 0.050 is 5.0×10^{-2} because you move the decimal point two places to the right to get 5.0. Similarly, 500 is 5.0×10^{2} because you move the decimal point two places to the left to get 5.0.

Check out this practice question about scientific notation:

Q. What is 0.000037 in scientific notation?

A. The correct answer is 3.7×10^{-5}. You have to move the decimal point five times to the right to get 3.7.

5. What is 0.0043 in scientific notation?

Solve It

6. What is 430000.0 in scientific notation?

Solve It

7. What is 0.00000056 in scientific notation?

Solve It

8. What is 6700.0 in scientific notation?

Solve It

Converting between Units

Physics problems frequently ask you to convert between different units of measurement. For example, you may measure the number of feet your toy car goes in three minutes and thus be able to calculate the speed of the car in feet per minute, but that's not a standard unit of measure, so you need to convert feet per minute to miles per hour, or meters per second, or whatever the physics problem asks for.

For another example, suppose you have 180 seconds — how much is that in minutes? You know that there are 60 seconds in a minute, so 180 seconds equals three minutes. Here are some common conversions between units:

- 1 m = 100 cm = 1000 mm (millimeters)
- 1 km (kilometer) = 1000 m
- 1 kg (kilogram) = 1000 g (grams)
- 1 N (Newton) = 10^5 dynes
- 1 J (Joule) = 10^7 ergs
- 1 P (Pascal) = 10 ba
- 1 A (Amp) = .1 Bi
- 1 T (Tesla) = 10^4 G (Gauss)
- 1 C (Coulomb) = 2.9979×10^9 Fr

The conversion between CGS and MKS is almost always just a factor of 10, so converting between the two is simple. But what about converting to and from the FPI system? Here are some handy conversions that you can come back to as needed:

- **Length:**
  - 1 m = 100 cm
  - 1 km = 1000 m
  - 1 in (inch) = 2.54 cm
  - 1 m = 39.37 in
  - 1 mile = 5280 ft = 1.609 km
  - 1 Å (angstrom) = 10^{-10} m
- **Mass:**
  - 1 kg = 1000 g
  - 1 slug = 14.59 kg
  - 1 u (atomic mass unit) = 1.6605×10^{-27} kg
- **Force:**
  - 1 lb (pound) = 4.448 N
  - 1 N = 10^5 dynes
  - 1 N = 0.2248 lb
- **Energy:**
  - 1 J = 10^7 ergs
  - 1 J = 0.7376 ft-lb

  - 1 BTU (British Thermal Unit) = 1055 J
  - 1 kWh (kilowatt hour)= 3.600×10^{6} J
  - 1 eV (electron Volt) = 1.602×10^{-19} J
- **Power:**
  - 1 hp (horsepower) = 550 ft-lb/s
  - 1 W (Watt)= 0.7376 ft-lb/s

Because conversions are such an important part of physics problems, and because you have to keep track of them so carefully, there's a systematic way of handling conversions: You multiply by a conversion constant that equals one, and where the units you don't want cancel out.

Q. A ball drops 5 meters. How many centimeters did it drop?

A. The correct answer is 500 centimeters. To perform the conversion, you do the following calculation:

$$5.0\ \cancel{\text{meters}} \times \frac{100\ \text{centimeters}}{\cancel{\text{meters}}} = 500\ \text{centimeters}$$

Note that 100 centimeters divided by 1 meter equals 1 because there are 100 centimeters in a meter. In the calculation, the units you don't want — meters — cancel out.

9. How many centimeters are in 2.35 meters?

Solve It

10. How many seconds are in 1.25 minutes?

Solve It

11. How many inches are in 2.0 meters?

Solve It

12. How many grams are in 3.25 kg?

Solve It

Converting Distances

Sometimes you have to make multiple conversions to get what you want. That demands multiple conversion factors. For example, if you want to convert from inches to meters, you can use the conversion that 2.54 centimeters equals 1 inch — but then you have to convert from centimeters to meters, which means using another conversion factor.

Try your hand at this example question that involves multiple conversions:

Q. Convert 10 inches into meters.

A. The correct answer is 0.245 m.

1. You know that 1 inch = 2.54 centimeters, so start with that conversion factor and convert 10 inches into centimeters:

$$10\ \cancel{\text{in}} \times \frac{2.54 \times \text{cm}}{1\ \cancel{\text{in}}} = 25.4\ \text{cm}$$

2. Convert 25.4 cm into meters by using a second conversion factor:

$$10\ \cancel{\text{in}} \times \frac{2.54\ \text{cm}}{1\ \cancel{\text{in}}} \times \frac{1\ \text{m}}{100\ \text{cm}} = 0.254\ \text{m}$$

13. Given that there are 2.54 centimeters in 1 inch, how many centimeters are there in 1 yard?

Solve It

14. How many centimeters are in a kilometer?

Solve It

15. How many inches are in an angstrom, given that 1 angstrom (Å) = 10^{-8} cm?

Solve It

16. How many inches are in a meter, given that there are 2.54 cm in 1 inch?

Solve It

Converting Times

Physics problems frequently ask you to convert between different units of time: seconds, minutes, hours, and even years. These times involve all kinds of calculations because measurements in physics books are usually in seconds, but can frequently be in hours.

EXAMPLE

Q. An SUV is traveling 2.78×10^{-2} kilometers per second. What's that in kilometers per hour?

A. The correct answer is 100 km/hr.

1. You know that there are 60 minutes in an hour, so start by converting from kilometers per second to kilometers per minute:

$$2.78 \times 10^{-2}\ \frac{\text{km}}{\cancel{\text{sec}}} \times \frac{60\ \cancel{\text{sec}}}{1\ \text{minute}} = 1.66\ \text{km/minute}$$

2. Because there are 60 minutes in an hour, convert this to kilometers per hour using a second conversion factor:

$$2.78 \times 10^{-2}\ \frac{\text{km}}{\cancel{\text{sec}}} \times \frac{60\ \cancel{\text{sec}}}{1\ \cancel{\text{minute}}} \times \frac{60\ \cancel{\text{minutes}}}{1\ \text{hour}} = 100\ \text{km/hr}$$

17. How many hours are in 1 week?

Solve It

18. How many hours are in 1 year?

Solve It

Counting Significant Figures

You may plug numbers into your calculator and come up with an answer like 1.532984529045, but that number isn't likely to please your instructor. Why? Because in physics problems, you use significant digits to express your answers. *Significant digits* represent the accuracy with which you know your values.

For example, if you know only the values you're working with to two significant digits, your answer should be 1.5, which has two significant digits, not 1.532984529045, which has 13! Here's how it works: Suppose you're told that a skater traveled 10.0 meters in 7.0 seconds. Note the number of digits: The first value has three significant figures, the other only two. The rule is that when you multiply or divide numbers, the result has the number of significant digits that equals the smallest number of significant digits in any of the original numbers. So if you want to figure out how fast the skater was going, you divide 10.0 by 7.0, and the result should have only two significant digits — 1.4 meters per second.

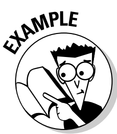
Zeros used just to fill out values down to (or up to) the decimal point aren't considered significant. For example, the number 3600 has only two significant digits by default. That's not true if the value was actually measured to be 3600, of course, in which case it's usually expressed as 3600.; the final decimal indicates that all the digits are significant.

On the other hand, when you're adding or subtracting numbers, the rule is that the last significant digit in the result corresponds to the right-most column in the addition or subtraction. How does that work? Take a look at this addition example:

$$\begin{array}{r} 5.1 \\ +12 \\ \underline{+\ \ 7.73} \\ 24.83 \end{array}$$

So is the result 24.83? No, it's not. The 12 has no significant digits to the right of the decimal point, so the answer shouldn't have any either. That means you should round the value of the result up to 25.

Rounding numbers in physics works as it usually does in math: When you want to round to three places, for example, and the number in the fourth place is a five or greater, you add one to the third place (and ignore or replace with zeros any following digits).



Q. You're multiplying 12.01 by 9.7. What should your answer be, keeping in mind that you should express it in significant digits?

A. The correct answer is **120.**

1. The calculator says that the product is 116.497.
2. Your result has to have the same number of significant digits as the least number of any two values you multiplied. That's two here (because of 9.7), so your answer rounds up to 120.

19. What is 19.3 multiplied by 26.12, taking into account significant digits?

Solve It

20. What is the sum of 7.9, 19, and 5.654, taking into account significant digits?

Solve It

Coming Prepared with Some Algebra

It's a fact of life: You need to be able to do algebra to handle physics problems. Take the following equation, for example, which relates the distance something has traveled (s) to its acceleration and the time it has been accelerated:

$$s = \frac{1}{2}at^2$$

Now suppose that the physics problem actually asks you for the acceleration, not the distance. You have to rearrange things a little here to solve for the acceleration. So when you multiply both sides by 2 and divide both sides by t^2, here's what you get:

$$\frac{2}{t^2} \cdot s = \frac{2}{t^2} \cdot \frac{1}{2} \cdot a \cdot t^2$$

Cancelling out and swapping sides, you solve for a like this:

$$a = \frac{2 \cdot s}{t^2}$$

So that's putting a little algebra to work. All you had to do was move variables around the equation to get what you want. The same approach works when solving physics problems (most of the time). On the other hand, what if you had to solve the same problem for the time, t? You would do that by rearranging the variables like so:

$$t = \sqrt{2s/a}$$

The lesson in this example is that you can extract all three variables — distance, acceleration, and time — from the original equation. Should you memorize all three versions of this equation? Of course not. You can just memorize the first version and use a little algebra to get the rest.

The following practice questions call on your algebra skills:

EXAMPLE

Q. The equation for final speed, v_f, where the initial speed was v_o, the acceleration was a, and the time was t is $v_f - v_o = at$. Solve for acceleration.

A. The correct answer is $a = (v_f - v_o)/t$

To solve for a, divide both sides of the equation by time, t.

21. The equation for potential energy, PE, of a mass m at height h, where the acceleration due to gravity is g, is $PE = m \cdot g \cdot h$. Solve for h.

Solve It

22. The equation relating final speed, v_f, to original speed, v_o, in terms of acceleration a and distance s is $v_f^2 - v_o^2 = 2as$. Solve for s.

Solve It

23. The equation relating distance s to acceleration a, time t, and speed v is $s = v_o \cdot t + \frac{1}{2} \cdot a \cdot t^2$. Solve for v_o.

Solve It

24. The equation for kinetic energy is $KE = \frac{1}{2} \cdot m \cdot v^2$. Solve for v, given KE and m.

Solve It

Being Prepared with Trigonometry

Physics problems also require you to have some trigonometry under your belt. To see what kind of trig you need, take a look at Figure 1-1, which shows a right triangle. The long side is called the *hypotenuse,* and the angle between x and y is 90°.

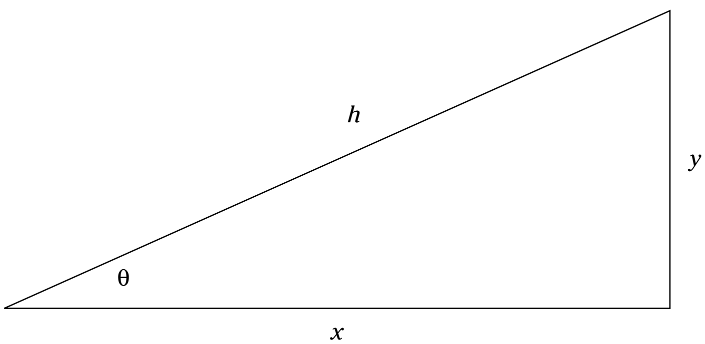


Figure 1-1: A triangle.

Physics problems require you to be able to work with sines, cosines, and tangents. Here's what they look like for Figure 1-1:

$\sin\theta = y/h$

$\cos\theta = x/h$

$\tan\theta = y/x$

You can find the length of one side of the triangle if you're given another side and an angle (not including the right angle). Here's how to relate the sides:

$x = h \cdot \cos\theta = y/\tan\theta$

$y = h \cdot \sin\theta = x \tan\theta$

$h = y/\sin\theta = h/\cos\theta$

And here's one more equation, the Pythagorean Theorem. It gives you the length of the hypotenuse when you plug in the other two sides:

$$h = \sqrt{x^2 + y^2}$$

25. Given the hypotenuse h and the angle θ, what is the length x equal to?

Solve It

26. If x = 3 and y = 4, what is the length of h?

Solve It