

IN THIS CHAPTER

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

Chapter **1**

Reviewing Physics Basics

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! As you go through the process of converting measurements from one unit to another, you'll practice applying 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 (centimeter-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, most measurements have units, such as meters or seconds. For example, when you measure how far and how fast a hockey puck slid, you need to measure both the distance in centimeters and the time in seconds.

For reference, Table 1-1 gives you the primary units of measurement in the MKS system.

Table 1-1 **MKS Units of Measurement**

Measurement	Unit	Abbreviation
Length	meter	m
Mass	kilogram	kg
Time	second	s or sec
Force	newton	N
Energy	joule	J
Pressure	pascal	P
Electric current	ampere	A
Magnetism	tesla	T
Electric charge	coulomb	C

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 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 1-2 **CGS Units of Measurement**

Measurement	Unit	Abbreviation
Length	centimeter	cm
Mass	gram	g
Time	second	s or sec
Force	dyne	dyn
Energy	erg	erg
Pressure	barye	Ba
Electric current	biot	Bi
Magnetism	gauss	G
Electric charge	franklin	Fr



EXAMPLE

Q. You're told to measure the length of a racecar 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?

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?

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?

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?

7 What is 0.0000056 in scientific notation?

8 What is 6,700.0 in scientific notation?

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 = 1,000 mm (millimeters)

»» 1 km (kilometer) = 1,000 m

»» 1 kg (kilogram) = 1,000 g (grams)

»» 1 N (newton) = 10^5 dynes

»» 1 J (joule) = 10^7 ergs

»» 1 Pa (pascal) = 10 Ba

»» 1 A (amp) = 0.1 Bi

»» 1 T (tesla) = 10^4 G (gauss)

»» 1 C (coulomb) = 2.9979×10^9 Fr

The conversion between CGS and MKS almost always involves factors of 10 only, so converting between the two is simple. But what about converting to and from the FPI and other systems of measurement? Here are some handy conversions that you can come back to as needed:

»» **Length:**

- 1 m = 100 cm
- 1 km = 1,000 m
- 1 in (inch) = 2.54 cm
- 1 m = 39.37 in
- 1 mile = 5,280 ft = 1.609 km
- 1 Å (angstrom) = 10^{-10} m

»» **Mass:**

- 1 kg = 1,000 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) = 1,055 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 1, such that the units you don't want cancel out.



EXAMPLE

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:

$$5.0 \text{ meters} \times \frac{100 \text{ centimeters}}{1 \text{ meter}} = 500 \text{ centimeters}$$

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?

10 How many seconds are in 1.25 minutes?

11 How many inches are in 2.0 meters?

12 How many grams are in 3.25 kg?

Converting through Multiple Units

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:



EXAMPLE

Q. Convert 10 inches into meters.

A. The correct answer is 0.254 m.

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

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

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

$$25.4 \text{ cm} \times \frac{1 \text{ m}}{100 \text{ cm}} = 0.254 \text{ m}$$

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

14 How many centimeters are in a kilometer?

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

16 How many inches are in 3.0 meters, given that there are 2.54 cm in 1 inch?

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:

$$2.78 \times 10^{-2} \frac{\text{km}}{\text{sec}} \times \frac{60 \text{ sec}}{1 \text{ minute}} = 1.67 \text{ km/minute}$$

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

$$\frac{1.67 \text{ km}}{1 \text{ minute}} \times \frac{60 \text{ minute}}{1 \text{ hour}} = 100 \text{ km/hour}$$

17 How many hours are in 1 week?

18 How many hours are in 1 year?

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*, also often called *significant figures*, 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.

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 last significant digit in the least accurate measurement. How does that work? Take a look at this addition example:

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

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.



REMEMBER

Zeros used just to fill out values down to (or up to) the decimal point aren't considered significant. For example, the number 3,600 has only two significant digits by default. That's not true if the value was actually measured to be 3,600, of course, in which case it's usually expressed as 3,600; the final decimal indicates that all the digits are significant.

Rounding numbers in physics usually works the same way as it 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).



EXAMPLE

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 the product is 116.497.
2. The number of significant digits in your result is the same as the smallest number of significant digits in any of the values being 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?

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

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 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:

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

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

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

So that's putting a little algebra to work. All you had to do was move variables around the equation to get what you wanted. 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 is v_o , the acceleration is a , and the time is 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 , for a mass m at height h , where the acceleration due to gravity is g , is $PE = mgh$. Solve for h .

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 .

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

24 The equation for kinetic energy is $KE = \frac{1}{2}mv^2$. Solve for v .

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° .

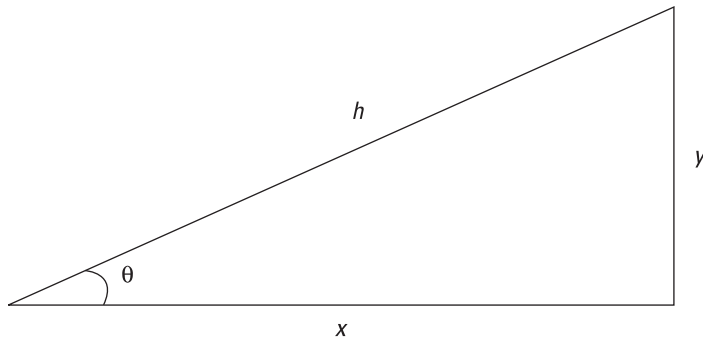


FIGURE 1-1:
A triangle.

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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:

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

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

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

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?

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

Answers to Problems about Physics Basics

The following are the answers to the practice questions presented earlier in this chapter. You see how to work out each answer, step by step.

1 **grams**

The unit of mass in the CGS system is the gram.

2 **seconds**

The unit of time in the MKS system is the second.

3 **newtons**

The unit of force in the MKS system is the newton.

4 **ergs**

The unit of energy in the CGS system is the erg.

5 4.3×10^{-3}

You have to move the decimal point three places to the right.

6 4.3×10^5

You have to move the decimal point five places to the left.

7 5.6×10^{-7}

You have to move the decimal point seven places to the right.

8 6.7×10^3

You have to move the decimal point three places to the left.

9 **235 cm**

Convert 2.35 meters into centimeters:

$$2.35 \text{ m} \times \frac{100 \text{ cm}}{1 \text{ m}} = 235 \text{ cm}$$

10 **75 sec**

Convert 1.25 minutes into seconds:

$$1.25 \text{ min} \times \frac{60 \text{ sec}}{1 \text{ min}} = 75 \text{ sec}$$

11 **79 in**

Convert 2.0 meters into inches:

$$2.0 \text{ m} \times \frac{39.37 \text{ in}}{1 \text{ m}} = 79 \text{ in}$$

12 **3,250 g**

Convert 3.25 kilograms into grams:

$$3.25 \text{ kg} \times \frac{1,000 \text{ g}}{1 \text{ kg}} = 3,250 \text{ g}$$

13 **91.4 cm**

1. 1 yard is 3 feet, so convert that to inches:

$$3 \text{ ft} \times \frac{12 \text{ in}}{1 \text{ ft}} = 36 \text{ in}$$

2. Use a second conversion factor to convert that into centimeters:

$$36 \text{ in} \times \frac{2.54 \text{ cm}}{1 \text{ in}} = 91.4 \text{ cm}$$

14 **1.0×10^5 cm**

1. Convert 1 kilometer to meters:

$$1 \text{ km} \times \frac{1,000 \text{ m}}{1 \text{ km}} = 1.0 \times 10^3 \text{ m}$$

2. Use a second conversion factor to convert that into centimeters:

$$1 \times 10^3 \text{ m} \times \frac{100 \text{ cm}}{1 \text{ m}} = 1.0 \times 10^5 \text{ cm}$$

15 **4.0×10^{-9} in**

1. Convert 1 angstrom to centimeters:

$$1 \text{ \AA} \times \frac{10^{-8} \text{ cm}}{1 \text{ \AA}} = 10^{-8} \text{ cm}$$

2. Use a second conversion factor to convert that into inches:

$$10^{-8} \text{ cm} \times \frac{1 \text{ in}}{2.54 \text{ cm}} = 4.0 \times 10^{-9} \text{ in}$$

16 **120 in**

1. Convert 3.0 meters into centimeters:

$$3.0 \text{ m} \times \frac{100 \text{ cm}}{1 \text{ m}} = 300 \text{ cm}$$

2. Use a second conversion factor to convert that into inches:

$$300 \text{ cm} \times \frac{1 \text{ in}}{2.54 \text{ cm}} = 120 \text{ in}$$

17 **168 hours**

1. Convert 1 week into days:

$$1 \cancel{\text{ week}} \times \frac{7 \text{ days}}{1 \cancel{\text{ week}}} = 7 \text{ days}$$

2. Use a second conversion factor to convert that into hours:

$$7 \cancel{\text{ days}} \times \frac{24 \text{ hours}}{1 \cancel{\text{ day}}} = 168 \text{ hours}$$

18 **8,760 hours**

1. Convert 1 year into days:

$$1 \cancel{\text{ year}} \times \frac{365 \text{ days}}{1 \cancel{\text{ year}}} = 365 \text{ days}$$

2. Use a second conversion factor to convert that into hours:

$$365 \cancel{\text{ days}} \times \frac{24 \text{ hours}}{1 \cancel{\text{ day}}} = 8,760 \text{ hours}$$

19 **504**

1. The calculator says the product is 504.116.
2. 19.3 has three significant digits, and 26.12 has four, so you use three significant digits in your answer. That makes the answer 504.

20 **33**

1. Here's how you do the sum:

$$\begin{array}{r} 7.9 \\ +19 \\ +5.654 \\ \hline 32.554 \end{array}$$

2. The value 19 has no significant digits after the decimal place, so the answer shouldn't either, making it 33 (32.554 rounded up).

21 **$h = PE / mg$**

Divide both sides by mg to get your answer.

22 **$s = \frac{v_f^2 - v_o^2}{2a}$**

Divide both sides by $2a$ to get your answer.

$$(23) v_o = \frac{s}{t} - \frac{1}{2}at$$

1. Subtract $\frac{1}{2}at^2$ from both sides:

$$s - \frac{1}{2}at^2 = v_o t$$

2. Divide both sides by t to get your answer.

$$(24) v = \sqrt{\frac{2KE}{m}}$$

1. Multiply both sides by $2/m$:

$$\frac{2}{m}KE = v^2$$

2. Take the square root to get your answer.

$$(25) x = h \cos \theta$$

Your answer comes from the definition of cosine.

$$(26) \mathbf{5\ m}$$

1. Start with the Pythagorean theorem:

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

2. Plug in the numbers, and work out the answer:

$$h = \sqrt{(3\ \text{m})^2 + (4\ \text{m})^2} = \sqrt{9\ \text{m}^2 + 16\ \text{m}^2} = \sqrt{25\ \text{m}^2} = 5\ \text{m}$$