Answer to Essential Question 1.1: A model is simplified version of physical situation. Using a model enables us to focus on the key elements of a particular situation, and is one way of getting a good idea of what is going on without having to consider every fine detail.

1-2 Unit Conversions, and Significant Figures

It is often necessary to convert a value from one set of units to another. To do this, we need to know the appropriate conversion factors. For instance, in Example 1.2 we will make use of these conversion factors:

- 1 hour = 3600 seconds
- 1 km = 1000 m
- 1 mile = 1.609344 km

EXAMPLE 1.2 – Unit conversions

At the 2009 World Championships in Athletics, held in Berlin, the Jamaican sprinter Usain Bolt set a world record for the 200-meter dash by running that distance in a time of 19.19 s. Assuming he ran exactly 200 m in this time, what was Usain Bolt's average speed during the race in (a) m/s; (b) km/h; (c) miles per hour?

SOLUTION

(a) The first thing we need to do is to understand what an average speed is. Average speed is the total distance covered divided by the time in which it was covered. If we divide the given distance by the given time we'll get the answer we're looking for:

Usain Bolt's average speed was: $\dfrac{200 \text{ m}}{19.19 \text{ s}} = 10.422094841063 \text{ m/s}$

This brings up the idea of **significant figures**, because you certainly do not want to quote an answer with 14 significant figures, as is shown above. Instead, round off the answer to four significant figures, because there are four in the time of 19.19 s. The rule is, ***when you multiply or divide numbers you look at the number of significant figures in the values going into the calculation and round off to the smallest number of significant figures***. Here, we're saying that the distance of 200 m is exact (see the assumption stated in the example), so that number has an infinite number of significant figures, while the time has four significant figures.

It would be more realistic to make the following argument. Lengths on a track, particularly at a major international competition such as the World Championships, are measured very accurately. For argument's sake, let's say the 200 meter distance is accurate to within 1 centimeter. Thus, the distance Usain Bolt ran was 200.00 m, seeing as 1 cm = 0.01 m. There are five significant figures in 200.00, so when dividing a number with five significant figures by one with four, we should round off our final answer to four significant figures.

Thus, Usain Bolt's average speed was 10.42 m/s.

(b) To convert from m/s to km/h, we need to know that there are 1000 m in 1 km, and that there are 3600 s in 1 hour. Then, we simply set these conversion factors up as ratios so that the units cancel properly, as follows:

$$10.4221 \frac{\text{m}}{\text{s}} \times \frac{1 \text{ km}}{1000 \text{ m}} \times \frac{3600 \text{ s}}{1 \text{ h}} = 37.52 \text{ km/h} .$$

We treat conversion factors as having an infinite number of significant figures and we remember that the minimum number of significant figures in the factors going into the average speed in m/s was four. Thus, our final answer in this case should also have four significant figures. In carrying out the calculation, however, six digits are shown for the average speed in m/s, even though we know the last two are not significant (this is why the final answer is rounded off to four significant figures in part (a)). We could even keep the 14 digits we had originally – the reason for keeping at least a couple of extra digits, and ***only rounding off at the end of the calculation when you state the final answer***, is to state your answer as accurately as possible.

37.52 km/h does not differ by much from the 37.51 km/h we would get if we had started the conversion process with 10.42 m/s, but the 37.52 km/h value is more accurate.

(c) To state the average speed in miles per hour, we could start with the average speed in m/s and convert; however, it requires less work to start from km/h, so let's do that. Again, let's add an extra couple of digits for the intermediate values and round off to four significant figures at the end.

$$37.51956 \frac{\text{km}}{\text{h}} \times \frac{1 \text{ mile}}{1.609344 \text{ km}} = 23.31 \text{ miles/h}.$$

So, we have now stated Usain Bolt's average speed in three equivalent ways, all with different units. Don't forget to be amazed by how fast that is!

Significant figures

If we add or subtract numbers, the rules are a little different from what we do when we multiply or divide. Let's add the following three distances: 341.2 m, 25 cm, and 0.3367 m. First we need to convert everything to the same units. We could convert everything to meters, for instance. Then, do the addition:

$$341.2 \text{ m} + 0.25 \text{ m} + 0.3367 \text{ m} = 341.7867 \text{ m}.$$

At this point, we need to round off correctly. Here, we look at decimal places, not significant figures. The first number goes to 1 decimal place, the second number to 2 decimal places, and the third number goes to 4 decimal places. Round off the final answer to 1 decimal place, because that's the smallest number of decimal places in any of the numbers going into the sum. ***When adding or subtracting, round off to the smallest number of decimal places.*** In this case, our final answer would be 341.8 m.

Many people get confused by zeroes, and whether to count them as significant figures. Leading zeroes do not count, but trailing zeroes do count as significant figures. If you forget, just convert a value to scientific notation and count the significant digits.

Related End-of-Chapter Exercises: 1, 2, 3, 11, 17.

Essential Question 1.2: How many significant figures are there in the value 0.0035 m? How many are in the value 35.00 m?