

# CHAPTER 1: INTRODUCTION: THE NATURE OF SCIENCE AND PHYSICS

## 1.2 PHYSICAL QUANTITIES AND UNITS

4. *American football is played on a 100-yd-long field, excluding the end zones. How long is the field in meters? (Assume that 1 meter equals 3.281 feet.)*

**Solution** Since 3 feet = 1 yard and 3.281 feet = 1 meter, multiply 100 yards by these conversion factors to cancel the units of yards, leaving the units of meters:

$$100 \text{ yd} = 100 \text{ yd} \times \frac{3 \text{ ft}}{1 \text{ yd}} \times \frac{1 \text{ m}}{3.281 \text{ ft}} = \underline{91.4 \text{ m}}$$

A football field is 91.4 m long.

10. *(a) Refer to Table 1.3 to determine the average distance between the Earth and the Sun. Then calculate the average speed of the Earth in its orbit in kilometers per second. (b) What is this in meters per second?*

**Solution** (a) The average speed of the earth's orbit around the sun is calculated by dividing the distance traveled by the time it takes to go one revolution:

$$\begin{aligned} \text{average speed} &= \frac{2\pi(\text{average dist of Earth to sun})}{1 \text{ year}} \\ &= \frac{2\pi(10^8 \text{ km})}{365.25 \text{ d}} \times \frac{1 \text{ d}}{24 \text{ h}} \times \frac{1 \text{ h}}{3600 \text{ s}} = \underline{20 \text{ km/s}} \end{aligned}$$

The earth travels at an average speed of 20 km/s around the sun.

(b) To convert the average speed into units of m/s, use the conversion factor: 1000 m

= 1 km:

$$\text{average speed} = \frac{20 \text{ km}}{\text{s}} \times \frac{1000 \text{ m}}{1 \text{ km}} = \underline{20 \times 10^3 \text{ m/s}}$$

### 1.3 ACCURACY, PRECISION, AND SIGNIFICANT FIGURES

15. (a) Suppose that a person has an average heart rate of 72.0 beats/min. How many beats does he or she have in 2.0 y? (b) In 2.00 y? (c) In 2.000 y?

**Solution** (a) To calculate the number of beats she has in 2.0 years, we need to multiply 72.0 beats/minute by 2.0 years and use conversion factors to cancel the units of time:

$$\frac{72.0 \text{ beats}}{1 \text{ min}} \times \frac{60.0 \text{ min}}{1.00 \text{ h}} \times \frac{24.0 \text{ h}}{1.00 \text{ d}} \times \frac{365.25 \text{ d}}{1.00 \text{ y}} \times 2.0 \text{ y} = 7.5738 \times 10^7 \text{ beats}$$

Since there are only 2 significant figures in 2.0 years, we must report the answer with 2 significant figures:  $\underline{7.6 \times 10^7 \text{ beats}}$ .

(b) Since we now have 3 significant figures in 2.00 years, we now report the answer with 3 significant figures:  $\underline{7.57 \times 10^7 \text{ beats}}$ .

(c) Even though we now have 4 significant figures in 2.000 years, the 72.0 beats/minute only has 3 significant figures, so we must report the answer with 3 significant figures:  $\underline{7.57 \times 10^7 \text{ beats}}$ .

21. A person measures his or her heart rate by counting the number of beats in 30 s. If  $40 \pm 1$  beats are counted in  $30.0 \pm 0.5$  s, what is the heart rate and its uncertainty in beats per minute?

**Solution** To calculate the heart rate, we need to divide the number of beats by the time and convert to beats per minute.

$$\frac{\text{beats}}{\text{minute}} = \frac{40 \text{ beats}}{30.0 \text{ s}} \times \frac{60.0 \text{ s}}{1.00 \text{ min}} = 80 \text{ beats/min}$$

To calculate the uncertainty, we use the method of adding percents.

$$\% \text{unc} = \frac{1 \text{ beat}}{40 \text{ beats}} \times 100\% + \frac{0.5 \text{ s}}{30.0 \text{ s}} \times 100\% = 2.5\% + 1.7\% = 4.2\% = 4\%$$

Then calculating the uncertainty in beats per minute:

$$\delta A = \frac{\% \text{unc}}{100\%} \times A = \frac{4.2\%}{100\%} \times 80 \text{ beats/min} = 3.3 \text{ beats/min} = 3 \text{ beats/min}$$

Notice that while doing calculations, we keep one EXTRA digit, and round to the correct number of significant figures only at the end.

So, the heart rate is 80 ± 3 beats/min.

27. *The length and width of a rectangular room are measured to be 3.955 ± 0.005 m and 3.050 ± 0.005 m. Calculate the area of the room and its uncertainty in square meters.*

**Solution** The area is 3.955 m × 3.050 m = 12.06 m<sup>2</sup>. Now use the method of adding percents to get uncertainty in the area.

$$\% \text{unc length} = \frac{0.005 \text{ m}}{3.955 \text{ m}} \times 100\% = 0.13\%$$

$$\% \text{unc width} = \frac{0.005 \text{ m}}{3.050 \text{ m}} \times 100\% = 0.16\%$$

$$\% \text{unc area} = \% \text{unc length} + \% \text{unc width} = 0.13\% + 0.16\% = 0.29\% = 0.3\%$$

Finally, using the percent uncertainty for the area, we can calculate the uncertainty in

$$\text{square meters: } \delta \text{ area} = \frac{\% \text{unc area}}{100\%} \times \text{area} = \frac{0.29\%}{100\%} \times 12.06 \text{ m}^2 = 0.035 \text{ m}^2 = 0.04 \text{ m}^2$$

The area is 12.06 ± 0.04 m<sup>2</sup>.