5.11.1 The Richter Scale

The Richter scale was developed in 1935 by seismologist Charles F. Richter. It measures the magnitude of an earthquake by comparing the intensity of the earthquake to some reference earthquake. The formula developed by Richter is

$$M = \log\left(\frac{I}{I_0}\right)$$

where I is the intensity of the earthquake under study,

I_0 is the intensity of a reference earthquake, and

M is the Richter value used to measure the magnitude of the earthquake.

Sample Problem:
The San Francisco earthquake of 1989 measured 6.9 on the Richter scale. The Alaska earthquake of 1964 measured 8.5.

a) How many times as intense as the San Francisco earthquake was the Alaska earthquake?

b) Calculate the magnitude of an earthquake that is twice as intense as the 1989 San Francisco earthquake.

Additional Problems:

1. For each decrease of 1 unit in magnitude, earthquakes are about 6 or 7 times as frequent. In a given year, how should the number of earthquakes with magnitudes between 4.0 and 4.9 compare with the number of earthquakes with magnitudes between each pair of numbers?

   a) 5.0 and 5.9 b) 6.0 and 6.9 c) 7.0 and 7.9

2. How much more intense is an earthquake measuring 6.5 on the Richter scale than one measuring 6.4?

5.11.2 The Decibel Scale

Our ear is divided into three connecting sections: the outer, middle, and inner ear. The outer ear funnels noise to the eardrum. In the middle ear, three tiny bones transmit sound to the inner ear. In the inner ear, sound waves are converted to readable nerve impulses by approximately 16 000 hair-like receptor cells, which sway with the sound waves. These cells can be severely damaged by loud sounds, resulting in permanent hearing loss. If you lose one third of these cells, your hearing will be significantly impaired. Hearing loss is progressive. Some hearing loss is inevitable with age, but we would lose much less if we protected our ears at the appropriate times.

The loudness of any sound is measured relative to the loudness of sound at the threshold of hearing. Sounds at this level are the softest that can still be heard.

The formula used to compare sounds is

$$L = 10\log\left(\frac{I}{I_0}\right)$$

where I is the intensity of the sound being measured,

I_0 is the intensity of a sound at the threshold of hearing, and

L is the loudness measured in decibels ($^1/_{10}$ of a bel).

At the threshold of hearing, the loudness of sound is zero decibels (0 dB).

Source: Harcourt Mathematics 12, Advanced Functions and Introductory Calculus, p. 278

Sample Problem:
A sound is 1000 times more intense than a sound you can just hear. What is the measure of its loudness in decibels?

Additional Problems:

1. The loudness level of a heavy snore is 69 dB. The loudness level of a conversation is 60 dB. The loudness level of a whisper is 30 dB.
   a) How many times as loud as a conversation is a heavy snore?
   b) How many times as loud as a whisper is a conversation?

2. Most portable music players can produce sounds up to 120 dB. Any sound above 90 dB may cause some hearing loss if the exposure is prolonged. To be safe, experts recommend you keep your MP3 player volume set no higher than 60% of the maximum.
   a) Assuming your MP3 player can produce sound as loud as 120 dB, how many times as loud is it at maximum volume than at the recommended setting?
   b) How many times as loud is a setting of 75% of the maximum than 60%?

5.11.3 The pH Scale

The pH scale allows chemists to determine the concentration of hydrogen ion in a liquid. It ranges from values of 1 to 14. The higher the pH, the more basic, or less acidic the liquid. The lower the pH, the more acidic or less basic the liquid.

- A liquid with a pH of less than 7.0 is considered *acidic*
- A liquid with a pH of greater than 7.0 is considered *basic*
- A liquid with pH = 7.0 is considered to be *neutral*. Pure water has a pH of 7.0.

The relationship between pH and H^+ ion concentration is inversely proportional and can be summarized as:

Low pH = High H^+ ion concentration

High pH = Low H^+ ion concentration

The relationship between pH and hydrogen ion concentration is given by the formula

$$pH = -\log[H^+]$$

where $[H^+]$ is the concentration of hydrogen ion in moles per litre.

Sample Problems:

1. Find the pH of a swimming pool with a hydrogen ion concentration of 6.1×10^{-8} mol/L.
2. The pH of a fruit juice is 3.10. What is the hydrogen ion concentration of the fruit juice?

Additional Problems:

1. Refer to the table at the right to answer the following questions:
   a) How many times as acidic as tomato juice is lemon juice?
   b) How many times as acidic as pure water is lemon juice?
   c) How many times as acidic as pure water is baking soda?
   d) How many times as acidic as baking soda is oven cleaner?

Solution	pH
Lemon juice	2
Tomato juice	4
Pure water	7
Baking soda	9
Oven cleaner	13

2. In spring, the pH value of a stream dropped from 6.5 to 5.5 during a 3-week period in April.
   a) How many times as acidic did the stream become?
   b) Why would this happen in April?