**Chapter 3 Problem/Exercise Tips**

**1) Bit depth is sometimes defined as the total number of discrete items, symbols, characters, or states that can be represented by a fixed number of bits. This is typically stated as a power of 2 (e.g., 21, 22, 23, etc.). For example, 22 can represent four discrete items (or four different symbols, characters, or states), each of which is represented by two bits: 00, 01, 10, 11; whereas 23 can represent eight discrete items, symbols, characters, or states, each of which is represented by three bits: 000, 001, 010, 011, 100, 101, 110, 111.**

**Given this definition, determine the bit depth needed to represent:**

**a. The digits 0–9 (10 different characters)**

**b. 256 different analog wave amplitude levels**

**c. 1024 different colors**

**d. 4 billion different IPv4 addresses**

**Tips for Success**: This problem/exercise and ones encourages bit-level and binary number thinking. You should reread Section 3.1.2 in the textbook. Table 3-2 is especially useful. For d, you must consider what power of 2 is the first to encompass 4 billion different things.

**2) A PCM digital-to-analog converter (DAC) receives 8-bit codes over a communication circuit and uses the binary code to recreate the original sound wave. This is done in three steps. The first identifies the binary code representing each of the sender’s waveform samples, the second converts the binary code to a decimal integer value, and the third uses the integer value to reproduce the sound. The first two steps are illustrated in this problem/exercise.**

***Step 1.* Complete the following table by converting the binary value of each sample’s wave height to its decimal value. Guidance on how to convert binary values to decimal values is available at** [**https://www.wikihow.com/Convert-from-Binary-to-Decimal**](https://www.wikihow.com/Convert-from-Binary-to-Decimal)**. Several binary-to-decimal converters are available, including the one at** [**https://www.rapidtables.com/convert/number/**](https://www.rapidtables.com/convert/number/)**.**

|  |  |  |
| --- | --- | --- |
| **Sample Number** | **8-bit Binary Value** | **Decimal Integer Value of Wave Height** |
| **1** | **11100000** |  |
| **2** | **11101111** |  |
| **3** | **11111111** |  |
| **4** | **11100100** |  |
| **5** | **11001001** |  |
| **6** | **11000000** |  |
| **7** | **10101000** |  |
| **8** | **01111001** |  |
| **9** | **10001111** |  |
| **10** | **10100111** |  |

Once data is digitized it is often converted back into its original form. This step illustrates how an ADC converts an eight-bit binary value to a decimal value. An eight-bit binary value that begins with 0 will convert to a decimal value that is 127 or less; if the binary value begins with 1, it will convert to a decimal value between 128 and 255. If the binary value ends with a 1, the decimal value that it converts to will be an odd number; if the binary value ends with a 0, the decimal value that it converts to will be an even number.

This part of the exercise provides experience with converting binary to decimal values, and it mimics the conversion process performed by a digital-to-analog converter (DAC) such as those used in PCM to a digitized analog waveform back to its original form.

***Step 2:* Draw a sketch of the analog wave represented by the ten decimal wave heights. Note: Put the sample number on the X-axis and the decimal integer value of the wave height on the Y-axis.**

The intersection of the x- and y-axis should be 0,0. Ten equally spaced samples should be on the x-axis ranging from 1 to 10. Equally spaced values for 25, 50, 75, 100, 125, 150, 175, 200, 225, 250, and 275 are recommended for the y-axis. This step illustrates how the decoded data can be visualized as an analog waveform, in this case, one that begins with a value of 224, slopes up to 255, and descends via several samples to 121 before sloping up to 167.

**Submit your completed table and an electronic copy of your sketch.**

**3) When examining mammograms, radiologists often deal with four to six images at a time. For a reasonable digital representation of a mammogram, a pixel array of 3000 x 4000 is needed, and 12-bit grayscale is used for each pixel.**

**a. How many bits are needed to represent a single mammogram image?**

**b. How many bits are needed to represent four mammogram images?**

**Tips for Success**: This exercise contributes to better understanding of imaging applications, how images are digitized, and why image files can be large, when measured in bits. You should review the Digitizing Images section of Section 3.1.2 in the textbook. Table 3-3 is relevant. As the table illustrates, in part a, you need to multiply the number of pixels in the pixel array by 12 to determine the number of bits in a single image. For part b, your answer to part a should be multiplied by four.

**4) Explain why lossy compression algorithms are not recommended for reducing the file sizes of medical images.**

Radiologists and medical personnel need high resolution images for diagnoses and interpretations by radiologists and medical personnel. As Table 3-4 in Section 3.1.2 of the textbook illustrates, lossy compression algorithms can result in less precise reproductions of original images and result in misdiagnoses and potential lawsuits. You should consider finding and citing relevant online articles on this topic to bolster your answer.

**5) A high-definition digital video camera produces an uncompressed video stream of 60 frames per second. Each frame has a resolution of 1,280 x 720 pixels (921,600 pixels). If an 8-bit binary number is used to represent each pixel’s color**

* 1. **How many bits are needed to represent the pixels in one frame?**
  2. **How many bits are needed to represent one second of video (60 frames)?**

**Tips for Success**: This exercise illustrates video digitization and the reasons why video files are sizable. Table 3-5 in the Digitizing Video section of Section 3.1.2 in the textbook is relevant to this exercise. For part a, the number of pixels in the image must be multiplied by 8 to determine the number of bits. For part b, your answer for part a should be multiplied by 60.

**6) A Full HD digital video camera produces an uncompressed video stream of 60 frames per second. Each frame has a resolution of 1980 x 1020 pixels (2,073,600 pixels), and a 24-bit binary number is used to represent the color of each pixel.**

1. **How many bits are needed to represent the pixels in each frame?**
2. **How many bits are needed to represent one second of video (60 frames)?**

**Tips for Success**: Like the previous one, this exercise illustrates video digitization and the reasons why video files are sizable. Table 3-5 in the Digitizing Video section of Section 3.1.2 in the textbook is relevant. For part a, the number of pixels in the image must be multiplied by 24 to determine the number of bits. For part b, your answer for part a should be multiplied by 60.

**7) The *Encyclopedia Britannica* includes approximately 50 million words. Its average word length is 6.5 characters (which includes the letters in the words, spacing, and punctuation).**

* 1. **Approximately how many total characters are in the encyclopedia?**
  2. **If 8-bit code, such as ASCII or UTF-8, is used to represent each character, how many bits are needed to represent the entire contents of the encyclopedia?**
  3. **If you had a perfect connection, how long (in seconds) would it take you to download the encyclopedia over a 25 Mbps (25,000,000 bps) connection?**
  4. **If you had a perfect connection, how long (in seconds) would it take you to download the encyclopedia over a 1 Gbps (1,000,000,000 bps) connection?**

**Tips for Success**: This exercise promotes better understanding of digitizing alphanumeric data. You should review the Digitizing Text section of Section 3.1.2 in the textbook; Table 3-6 is relevant. This exercise also illustrates how different transmission rates affect file transfer times. For part a, you should multiply 50,000,000 by 6.5 to determine the approximate number of characters. For part b, you should multiply your answer for part a by 8 to determine the total number of bits. For part c, you should divide your answer to part b by 25,000,000 to determine the transfer time in seconds. For part d, you should divide your answer for part b, by 1,000,000,000 to determine the transfer time in seconds.

**8) Go to Online Labels.com (**[**https://www.onlinelabels.com/tools/barcode-generator**](https://www.onlinelabels.com/tools/barcode-generator)**) and use the UPC-A option to recreate the bar code shown in Figure 3-9. Take a screenshot or snip of the barcode you create to verify your work on this website. Then go to Barcode Lookup.com (**[**https://www.barcodelookup.com**](https://www.barcodelookup.com)**) and enter the barcode number to identify the product that has this barcode. Capture a screenshot or snip of the image product on this website to verify your work.**

**Tips for Success**: This is a quick and easy exercise that associates barcodes with products. You should review the Digitizing Barcodes or QR Codes section of Section 3.1.2 in the textbook.

**9) When calculating its total data traffic and storage requirements, a corporation determined that the business office at one of its enterprise network locations generates an average of 75 GB of data traffic per employee per month. There are 50 employees at this location. Use the converters at KylesConverter.com (**[**http://www.kylesconverter.com/**](http://www.kylesconverter.com/)**) to assist in converting gigabytes to bits, gigabytes to terabytes, and terabytes to bits.**

* 1. **How many bits of data traffic are generated by one employee each month?**
  2. **How many bits of data traffic are generated by all 50 employees each month?**
  3. **Assuming that each month is 30 days, how much data (in bits) does the business office at this location generate in an average day?**
  4. **On average, how much data (in bits) does the business office at this location generate each second?**
  5. **If all data traffic generated by the location were logged and stored, how many terabytes of storage would be needed to store the data traffic generated by the business office at this location in one year? If the data were stored in uncompressed form, how many bits would be stored in a year?**

**Tips for Success**: This exercise provides insights into the thought process needed to estimate average traffic loads and data storage requirements for a business location. For part a, you should multiply 75,000,000,000 bytes by 8 bits per byte to determine the average data traffic (in bits) generated by one employee each month. For part b, you need to multiply your answer to part a by 50 to determine the average data traffic (in bits) generated by 50 employees. For part c, you should divide your answer for part b, by 30 to determine the average data traffic (in bits) per day. For part d, you should divide your answer for part c by the product of (24 [hours per day] x 60 [minutes per hour] x 60 [seconds per minutes] to determine the average data traffic (in bits) generated each second at the business location. For part e, you should multiply 75,000,000,000 (bytes per employee per month) by the product of 12 (months per year) x 50 (employees) to determine the number of bytes of storage needed for the data generated at the business location each year; you would multiply the total number of bytes of storage needed by 8 (bits per byte) to determine the storage requirements in bits.