CHAPTER 3

Data and Signals

Solutions to Review Questions and Exercises

Review Questions

1. ***Frequency*** and ***period*** are the inverse of each other. T = 1/ f and f = 1/T.
2. The ***amplitude*** of a signal measures the value of the signal at any point. The ***frequency*** of a signal refers to the number of periods in one second. The phase describes the position of the waveform relative to time zero.
3. Using Fourier analysis. ***Fourier series*** gives the frequency domain of a periodic signal; ***Fourier analysis*** gives the frequency domain of a nonperiodic signal.
4. Three types of transmission impairment are ***attenuation***, ***distortion***, and ***noise***.
5. ***Baseband transmission*** means sending a digital or an analog signal without modulation using a low-pass channel. ***Broadband transmission*** means modulating a digital or an analog signal using a band-pass channel.
6. A ***low-pass channel*** has a bandwidth starting from zero; a ***band-pass*** channel has a bandwidth that does not start from zero.
7. The ***Nyquist theorem*** defines the maximum bit rate of a noiseless channel.
8. The ***Shannon capacity*** determines the theoretical maximum bit rate of a noisy channel.
9. ***Optical signals*** have very high frequencies. A high frequency means a short wave length because the wave length is inversely proportional to the frequency (λ = v/f), where v is the propagation speed in the media.
10. A signal is ***periodic*** if its frequency domain plot is ***discrete***; a signal is **nonperiodic** if its frequency domain plot is ***continuous***.
11. The frequency domain of a voice signal is normally ***continuous*** because voice is a ***nonperiodic*** signal.
12. An alarm system is normally ***periodic***. Its frequency domain plot is therefore ***discrete***.
13. This is ***baseband transmission*** because no modulation is involved.
14. This is ***baseband transmission*** because no modulation is involved.
15. This is ***broadband transmission*** because it involves modulation.

Exercises

16.

a. **T = 1 / f** = 1 / (24 Hz) = 0.0417 s = 41.7 × 10^{-3} s = **41.7 ms**

b. **T = 1 / f** = 1 / (8 MHz) = 0.000000125 = 0.125 × 10^{-6} s = **0.125 μs**

c. **T = 1 / f** = 1 / (140 KHz) = 0.00000714 s = 7.14 × 10^{-6} s = **7.14 μs**

17.

a. f = 1 / T = 1 / (5 s) = 0.2 Hz

b. **f = 1 / T** = 1 / (12 μs) =83333 Hz = 83.333 × 10^{3} Hz = **83.333 KHz**

c. **f = 1 / T** = 1 / (220 ns) = 4550000 Hz = 4.55× 10^{6} Hz = **4.55 MHz**

18.

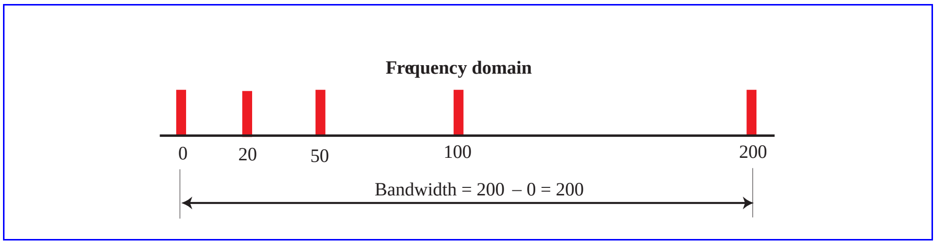
a. 90 degrees (π/2 radian)

b. 0 degrees (0 radian)

c. 90 degrees (π/2 radian)

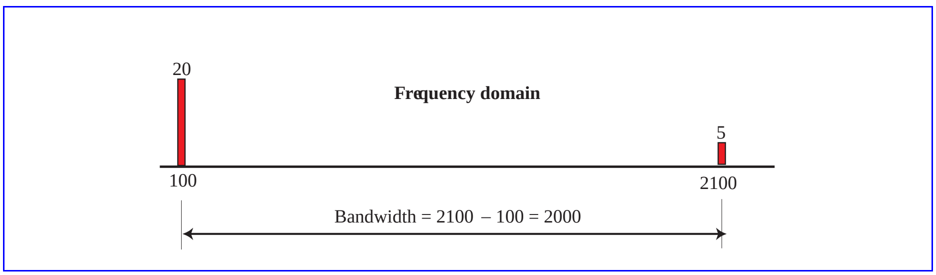
19. See Figure 3.1

Figure 3.1 *Solution to Exercise 19*



20. We know the lowest frequency, 100. We know the bandwidth is 2000. The highest frequency must be 100 + 2000 = **2100 Hz**. See Figure 3.2

Figure 3.2 *Solution to Exercise 20*



21. Each signal is a simple signal in this case. The bandwidth of a simple signal is zero. So the bandwidth of both signals are the same.

22.

a. bit rate = 1/ (bit duration) = 1 / (0.001 s) = 1000 bps = **1 Kbps**

b. bit rate = 1/ (bit duration) = 1 / (2 ms) = **500 bps**

c. bit rate = 1/(bit duration) = 1 / (20 μs/10) = 1 / (2 μs) = **500 Kbps**

23.

a. (10 / 1000) s = **0.01 s**

b. (8 / 1000) s = 0. 008 s = **8 ms**

c. ((100,000 × 8) / 1000) s = **800 s**

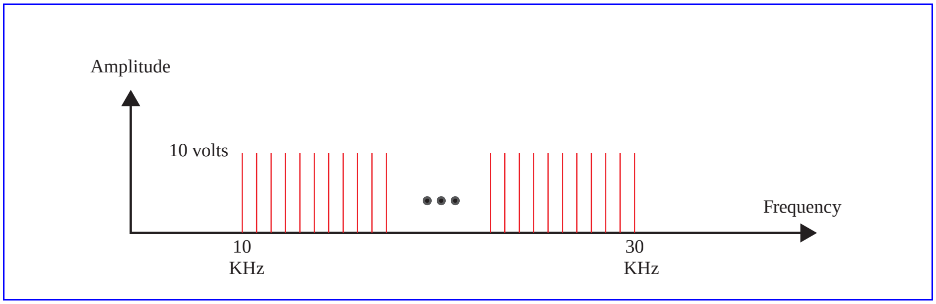
24. There are 8 bits in 16 ns. Bit rate is $8 / (16 \times 10^{-9}) = 0.5 \times 10^{-9}$ = **500 Mbps**

25. The signal makes 8 cycles in 4 ms. The frequency is 8 /(4 ms) = **2 KHz**

26. The bandwidth is 5 × 5 = **25 Hz**.

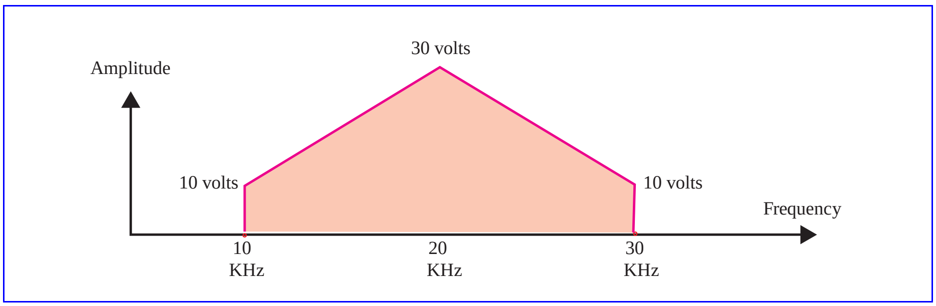
27. The signal is periodic, so the frequency domain is made of discrete frequencies. as shown in Figure 3.3.

Figure 3.3 *Solution to Exercise 27*



28. The signal is nonperiodic, so the frequency domain is made of a continuous spectrum of frequencies as shown in Figure 3.4.

Figure 3.4 *Solution to Exercise 28*



29.

Using the first harmonic, data rate = 2 × 6 MHz = **12 Mbps**
Using three harmonics, data rate = (2 × 6 MHz) /3 = **4 Mbps**
Using five harmonics, data rate = (2 × 6 MHz) /5 = **2.4 Mbps**

30. dB = $10 \log_{10} (90 / 100)$ = **–0.46 dB**

31. $-10 = 10 \log_{10} (P_2 / 5) \rightarrow \log_{10} (P_2 / 5) = -1 \rightarrow (P_2 / 5) = 10^{-1} \rightarrow P_2$ = **0.5 W**

32. The total gain is 3 × 4 = 12 dB. The signal is amplified by a factor $10^{1.2}$ = **15.85.**

33. 100,000 bits / 5 Kbps = **20 s**
34. 480 s × 300,000 km/s = **144,000,000 km**
35. 1 μm × 1000 = 1000 μm = **1 mm**
36. We have

$$\mathbf{4{,}000 \log_2 (1 + 1{,}000) \approx 40\ Kbps}$$

37. We have

$$\mathbf{4{,}000 \log_2 (1 + 10 / 0.005) = 43{,}866\ bps}$$

38. The file contains 2,000,000 × 8 = 16,000,000 bits. With a 56-Kbps channel, it takes 16,000,000/56,000 = **289 s**. With a 1-Mbps channel, it takes **16 s**.
39. To represent 1024 colors, we need $\log_2 1024 = 10$ (see Appendix C) bits. The total number of bits are, therefore,

$$\mathbf{1200 \times 1000 \times 10 = 12{,}000{,}000\ bits}$$

40. We have

$$\mathbf{SNR = (200\ mW) / (10 \times 2 \times \mu W) = 10{,}000}$$

We then have

$$\mathbf{SNR_{dB} = 10 \log_{10} SNR = 40}$$

41. We have

$$\mathbf{SNR = (signal\ power)/(noise\ power).}$$

However, power is proportional to the square of voltage. This means we have

$$\mathbf{SNR = [(signal\ voltage)^2] / [(noise\ voltage)^2] = [(signal\ voltage) / (noise\ voltage)]^2 = 20^2 = 400}$$

We then have

$$\mathbf{SNR_{dB} = 10 \log_{10} SNR \approx 26.02}$$

42. We can approximately calculate the capacity as
    a. C = B × (SNR_{dB} /3) = 20 KHz × (40 /3) = **267 Kbps**
    b. C = B × (SNR_{dB} /3) = 200 KHz × (4 /3) = **267 Kbps**
    c. C = B × (SNR_{dB} /3) = 1 MHz × (20 /3) = **6.67 Mbps**
43.
    a. The data rate is doubled ($C_2 = 2 \times C_1$).
    b. When the SNR is doubled, the data rate increases slightly. We can say that, approximately, ($C_2 = C_1 + 1$).
44. We can use the approximate formula

$$\mathbf{C = B \times (SNR_{dB} /3)\ or\ SNR_{dB} = (3 \times C) /B}$$

We can say that the minimum

$$\mathbf{SNR_{dB} = 3 \times 100\ Kbps / 4\ KHz = 75}$$

This means that the minimum

$$\mathbf{SNR = 10^{\,SNRdB/10} = 10^{7.5} \approx 31{,}622{,}776}$$

45. We have

$$\textbf{transmission time} = \textbf{(packet length)/(bandwidth)} = \textbf{(8,000,000 bits) / (200,000 bps)} = \textbf{40 s}$$

46. We have

$$\textbf{(bit length)} = \textbf{(propagation speed)} \times \textbf{(bit duration)}$$

The bit duration is the inverse of the bandwidth.

a. Bit length = (2×10^8 m) × [(1 / (1 Mbps)] = **200 m**. This means a bit occupies 200 meters on a transmission medium.
b. Bit length = (2×10^8 m) × [(1 / (10 Mbps)] = **20 m**. This means a bit occupies 20 meters on a transmission medium.
c. Bit length = (2×10^8 m) × [(1 / (100 Mbps)] = **2 m**. This means a bit occupies 2 meters on a transmission medium.

47.

a. Number of bits = bandwidth × delay = 1 Mbps × 2 ms = **2000 bits**
b. Number of bits = bandwidth × delay = 10 Mbps × 2 ms = **20,000 bits**
c. Number of bits = bandwidth × delay = 100 Mbps × 2 ms = **200,000 bits**

48. We have

$$\textbf{Latency} = \textbf{processing time} + \textbf{queuing time} + \textbf{transmission time} + \textbf{propagation time}$$

Processing time = 10 × 1 μs = 10 μs = **0.000010 s**

Queuing time = 10 × 2 μs = 20 μs = **0.000020 s**

Transmission time = 5,000,000 / (5 Mbps) = **1 s**

Propagation time = (2000 Km) / (2×10^8) = **0.01 s**

$$\textbf{Latency} = \mathbf{0.000010 + 0.000020 + 1 + 0.01 = 1.01000030\ s}$$

The transmission time is dominant here because the packet size is huge.