Questions on Chapter 3

Questions:

3-1) What is the relationship between period and frequency?

The period of a signal is the inverse of its frequency and vice versa: T = 1/f and f = 1/T.

3-2) What does the amplitude of a signal measure? What does the frequency of a signal measure? What does the phase of a signal measure?

- The *amplitude* of a signal measures the value of the signal at any point.
- The *frequency* of a signal measure the number of periods in 1 second
- The *phase* of a signal measure the position of the waveform relative to time zero.

3-3) How can a composite signal be decomposed into its individual frequencies?

Fourier series gives the frequency domain of a periodic signal; Fourier analysis gives the frequency domain of a nonperiodic signal.

3-4) Name three types of transmission impairment.

Three types of transmission impairment are:

- Attenuation - Distortion - Noise

3-7) What does the Nyquist theorem have to do with communications?

The Nyquist theorem defines the maximum bit rate of a noiseless channel

3-8) What does the Shannon capacity have to do with communications?

The Shannon capacity determines the theoretical maximum bit rate of a noisy channel.

3-9) Why do optical signals used in fiber optic cables have a very short-wave length?

A fiber-optic cable uses light (very high frequency). Since f is very high, the wavelength, which is λ = c / f, is very low.

Problems:

P3-1. Given the frequencies listed below, calculate the corresponding periods.

a. 24 Hz **b. 8 MHz** **c. 140 KHz**

a. T = 1 / f = 1 / (24 Hz) = 0.0417 s = 41.7 ms

b. T = 1 / f = 1 / (8 MHz) = 0.000000125 s = 0.125 μs

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

P3-2. Given the following periods, calculate the corresponding frequencies.

a. 5 s **b. 12 μs** **c. 220 ns**

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

P3-3. What is the phase shift for the following?

a. A sine wave with the maximum amplitude at time zero

b. A sine wave with maximum amplitude after 1/4 cycle

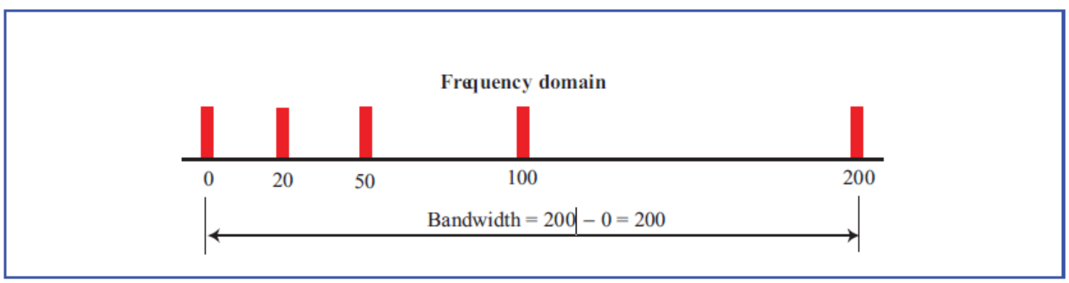
c. A sine wave with zero amplitude after 3/4 cycle and increasing

a. 90 degrees (π/2 radians)

b. 0 degrees (0 radians)

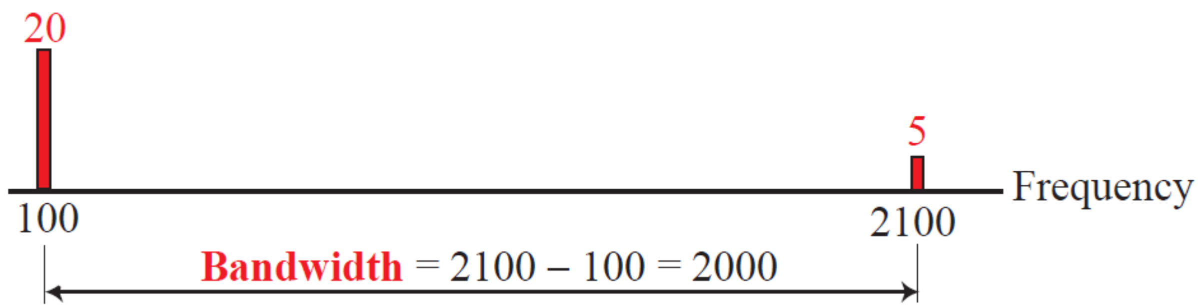
c. 90 degrees (π/2 radians) (Note that it is the same wave as in part a.)

P3-4. What is the bandwidth of a signal that can be decomposed into five sine waves with frequencies at 0, 20, 50, 100, and 200 Hz? All peak amplitudes are the same. Draw the bandwidth.



P3-5. A periodic composite signal with a bandwidth of 2000 Hz is composed of two sine waves. The first one has a frequency of 100 Hz with a maximum amplitude of 20 V; the second one has a maximum amplitude of 5 V. Draw the bandwidth.

We know the bandwidth is 2000. The highest frequency must be 100 + 2000 = 2100 Hz. See below:



P3-6. Which signal has a wider bandwidth, a sine wave with a frequency of 100 Hz a sine wave with a frequency of 200 Hz?

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

P3-7. What is the bit rate for each of the following signals?

a. A signal in which 1 bit lasts 0.001 s

b. A signal in which 1 bit lasts 2 ms

c. A signal in which 10 bits last 20 μs

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

P3-8. A device is sending out data at the rate of 1000 bps.

a. How long does it take to send out 10 bits?

b. How long does it take to send out a single character (8 bits)?

c. How long does it take to send a file of 100,000 characters?

Solution:

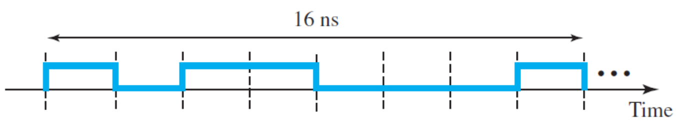
a. (10/1000) s = 0.01s

b. (8/1000) s = 0.008s = 8ms

c. ((100,000X8)/1000) s = 800s

P3-9. What is the bit rate for the signal in Figure 3.35?

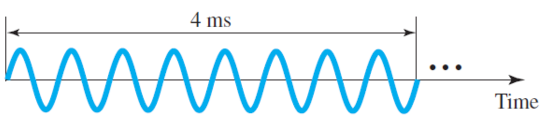
Figure 3.35 *Problem P3-9*



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

P3-10. What is the frequency of the signal in Figure 3.36?

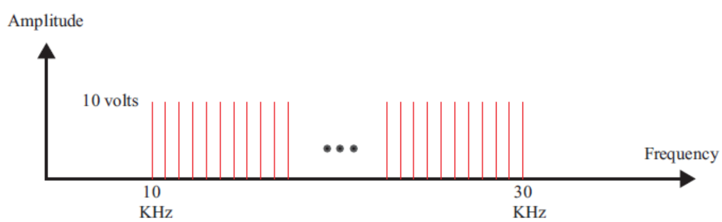
Figure 3.36 *Problem P3-10*



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

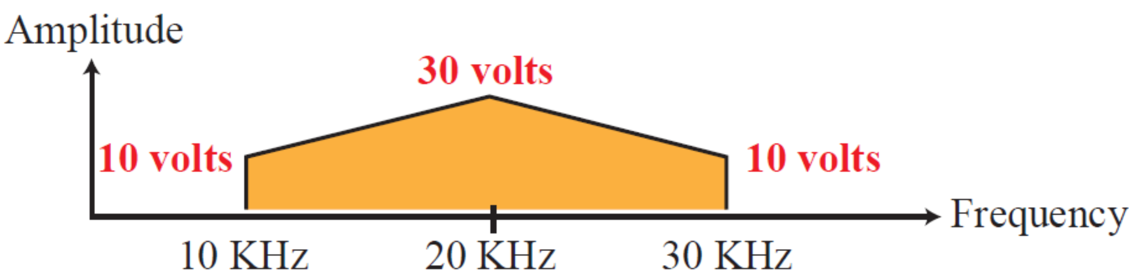
P3-12. A periodic composite signal contains frequencies from 10 to 30 KHz, each with an amplitude of 10 V. Draw the frequency spectrum.

The signal is periodic, so the frequency domain is made of discrete frequencies. As shown



P3-13. A nonperiodic composite signal contains frequencies from 10 to 30 KHz. The peak amplitude is 10 V for the lowest and the highest signals and is 30 V for the 20-KHz signal. Assuming that the amplitudes change gradually from the minimum to the maximum, draw the frequency spectrum.

The signal is nonperiodic, so the frequency domain is made of a continuous spectrum of frequencies as shown below:



P3-15. A signal travels from point A to point B. At point A, the signal power is 100 W. At point B, the power is 90 W. What is the attenuation in decibels?

We can calculate the attenuation as shown below:

dB = 10 log10 (90 / 100) = –0.46 dB

P3-16. The attenuation of a signal is −10 dB. What is the final signal power if it was originally 5 W?

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

P3-17. A signal has passed through three cascaded amplifiers, each with a 4 dB gain. What is the total gain? How much is the signal amplified?

The total gain is 3 × 4 = 12 dB. To find how much the signal is amplified, we can use the following formula:

12 = 10 log (P2/P1) → log (P2/P1) = 1.2 → P2/P1= 101.2 = 15.85

The signal is amplified almost 16 times.

P3-18. If the bandwidth of the channel is 5 Kbps, how long does it take to send a frame of 100,000 bits out of this device?

100,000 bits / 5 Kbps = 20 s

P3-19. The light of the sun takes approximately eight minutes to reach the earth. What is the distance between the sun and the earth?

480 s × 300,000 km/s = 144,000,000 km

P3-20. A signal has a wavelength of 1 µm in air. How far can the front of the wave travel during 1000 periods?

1 µm X 1000 = 1000 µm = 1 mm

P3-21. A line has a signal-to-noise ratio of 1000 and a bandwidth of 4000 KHz. What is the maximum data rate supported by this line?

We use the Shannon capacity C = B log2 (1 + SNR)

C = 4,000 log2 (1 + 1,000) ≈ 40 Kbps

P3-22. We measure the performance of a telephone line (4 KHz of bandwidth). When the signal is 10 V, the noise is 5 mV. What is the maximum data rate supported by this telephone line?

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

P3-23. A file contains 2 million bytes. How long does it take to download this file using a 56-Kbps channel? 1-Mbps channel?

The file contains 2,000,000 × 8 = 16,000,000 bits.

a. With a 56-Kbps channel, it takes 16,000,000/56,000 = 289 s ≈ 5 minutes

b. With a 1-Mbps channel, it takes 16,000,000/1,000,000 = 16 s.

P3-24. A computer monitor has a resolution of 1200 by 1000 pixels. If each pixel uses 1024 colors, how many bits are needed to send the complete contents of a screen?

To represent 1024 colors, we need $\log_2 1024$ = 10 (see Appendix C) bits. The total number of bits are, therefore, 1200 X 1000 X 10 = 12,000,000 bits

P3-25. A signal with 200 milliwatts power passes through 10 devices, each with an average noise of 2 microwatts. What is the SNR? What is the SNR_{dB}?

We have:

SNR = (200 mW) / (10 × 2 × µW) = 10,000

SNR_{dB} = 10 log10 SNR = 10 $\log_{10}$10000 = 40

P3-26. If the peak voltage value of a signal is 20 times the peak voltage value of the noise, what is the SNR? What is the SNR_{dB}?

We have SNR= (signal power)/ (noise power).

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

SNR = [(signal voltage)^2] / [(noise voltage)^2] =

[(signal voltage) / (noise voltage)]^2 = 20^2 = 400

We then have: $SNR_{dB} = 10 \log_{10} SNR \approx 26.02$

P3-27. What is the theoretical capacity of a channel in each of the following cases?

a. Bandwidth: 20 KHz SNRdB = 40

b. Bandwidth: 200 KHz SNRdB = 4

c. Bandwidth: 1 MHz SNRdB = 20

We can approximately calculate the capacity as

a. $C = B \times (SNR_{dB} /3)$ = 20 KHz × (40 /3) = 267 Kbps

b. $C = B \times (SNR_{dB} /3)$ = 200 KHz × (4 /3) = 267 Kbps

c. $C = B \times (SNR_{dB} /3)$ = 1 MHz × (20 /3) = 6.67 Mbps

P3-28. We need to upgrade a channel to a higher bandwidth. Answer the following questions:

a. How is the rate improved if we double the bandwidth?

b. How is the rate improved if we double the SNR?

a. The data rate is doubled ($C_2 = 2 X C_1$).

b. When the SNR is doubled, the data rate increases slightly. We can say that, approximately, ($C_2 = C_1 + 1$).

P3-29. We have a channel with 4 KHz bandwidth. If we want to send data at 100 Kbps, what is the minimum SNRdB? What is the SNR?

We can use the approximate formula

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

We can say that the minimum of SNR_{dB} is

SNR_{dB} = 3 × 100 Kbps / 4 KHz = 75

This means that the minimum

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

P3-30. What is the transmission time of a packet sent by a station if the length of the packet is 1 million bytes and the bandwidth of the channel is 200 Kbps?

transmission time = (packet length)/(bandwidth) =
(8,000,000 bits) / (200,000 bps) = 40 s

P3-31. What is the length of a bit in a channel with a propagation speed of 2 × 108 m/s if the channel bandwidth is: a. 1 Mbps? b. 10 Mbps? c. 100 Mbps?

The bit duration is the inverse of the bandwidth. We have
(bit length) = (propagation speed) ´ (bit duration)
a. Bit length = (2 ×108 m) × [(1 / (1 Mbps)] = 200 m. This means a bit occupies 200 meters on a transmission medium.
b. Bit length = (2 ×108 m) × [(1 / (10 Mbps)] = 20 m. This means a bit occupies 20 meters on a transmission medium.
c. Bit length = (2 ×108 m) × [(1 / (100 Mbps)] = 2 m. This means a bit occupies 2 meters on a transmission medium.

P3-32. How many bits can fit on a link with a 2 ms delay if the bandwidth of the link is a.1 Mbps? b. 10 Mbps? c. 100 Mbps?

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

P3-33. What is the total delay (latency) for a frame of size 5 million bits that is being sent on a link with 10 routers each having a queuing time of 2 μs and a processing time of 1 μs. The length of the link is 2000 Km. The speed of light inside the link is 2 × 108 m/s. The link has a bandwidth of 5 Mbps. Which component of the total delay is dominant? Which one is negligible?

We have Latency = Delaypr + Delayqu + Delaytr + Delaypg
Delaypr = 10 × 1 μs = 10 μs // Processing delay
Delayqu = 10 × 2 μs = 20 μs // Queuing delay
Delaytr = 5,000,000 / (5 Mbps) = 1 s // Transmission delay
Delaypg = (2000 Km) / (2 × 108) = 0.01 s // Propagation delay
This means Latency = 10 μs + 20 μs + 1s + 0.01 s ≈ 1.01 s
The transmission time is dominant here because the packet size is huge.

MCQ:

1) **In a frequency-domain plot, the horizontal axis measures the ________.**

   A) signal amplitude
   B) frequency
   C) phase
   D) time

   Solution: **B**

2) **In a time-domain plot, the horizontal axis is a measure of ________.**

   A) signal amplitude
   B) frequency
   C) phase
   D) time

   Solution: **D**

3) **_______ data are continuous and take continuous values.**

   A) Analog
   B) Digital
   C) Analog or digital
   D) None of the choices are correct

   Solution: **A**

4) **_______ data have discrete states and take discrete values.**

   A) Analog
   B) Digital
   C) Analog or digital
   D) None of the choices are correct

   Solution: **B**

5) **_____ signals have an infinite number of values in a time interval.**

   A) Analog
   B) Digital
   C) Either analog or digital
   D) None of the choices are correct

   Solution: **A**

6) **_______ signals can have only a limited number of values in a time interval.**

   A) Analog
   B) Digital
   C) Either analog or digital
   D) None of the choices are correct

   Solution: **B**

7) Frequency and period are ______.

A) inverse of each other
B) proportional to each other
C) the same
D) are not related

Solution: **A**

8) ________is the rate of change with respect to time.

A) Amplitude
B) Time
C) Frequency
D) Phase

Solution: **C**

9) _______ describes the position of the waveform relative to time 0.

A) Amplitude
B) Time
C) Frequency
D) Phase

Solution: **D**

10) A simple sine wave can be represented by one single spike in the _____ domain.

A) amplitude
B) time
C) frequency
D) phase

Solution: **C**

11)As frequency increases, the period ________.

A) decreases
B) increases
C) remains the same
D) None of the choices are correct

Solution: **A**

12) ________ is a type of transmission impairment in which the signal loses strength due to the resistance of the transmission medium.

A) Attenuation
B) Distortion
C) Noise
D) Decibel

Solution: **A**

13) ________ is a type of transmission impairment in which the signal loses strength due to the different propagation speeds of each frequency that makes up the signal.

A) Attenuation
B) Distortion
C) Noise
D) Decibel

Solution: **B**

14) ________ is a type of transmission impairment in which an outside source such as crosstalk corrupts a signal.

A) Attenuation
B) Distortion
C) Noise
D) Decibel

Solution: **C**

15) When propagation speed is multiplied by propagation time, we get the ___.

A) throughput
B) wavelength of the signal
C) distortion factor
D) distance a signal or bit has traveled

Solution: **D**

19) For a ______ channel, the Nyquist bit rate formula defines the theoretical maximum bit rate.

A) noisy
B) noiseless
C) bandpass
D) low-pass

Solution: **B**

20) For a ______ channel, we need to use the Shannon capacity to find the maximum bit rate.

A) noisy

B) noiseless

C) bandpass

D) low-pass

Solution: **A**

21) _________ can impair a signal.

A) Attenuation

B) Distortion

C) Noise

D) All of the choices are correct

Solution: **D**