Transmission Media
DATA AND SIGNALS

CSE306

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To be transmitted, data must be transformed to electromagnetic signals.

ANALOG AND DIGITAL

Data can be analog or digital. The term analog data refers to information that is continuous; digital data refers to information that has discrete states. Analog data take on continuous values. Digital data take on discrete values.

Analog and Digital Data
Analog and Digital Signals
Periodic and Nonperiodic Signals

POLL 1

- Data can be

a) Digital Only

b) Analog Only

c) Both A and B

d) None of the Above

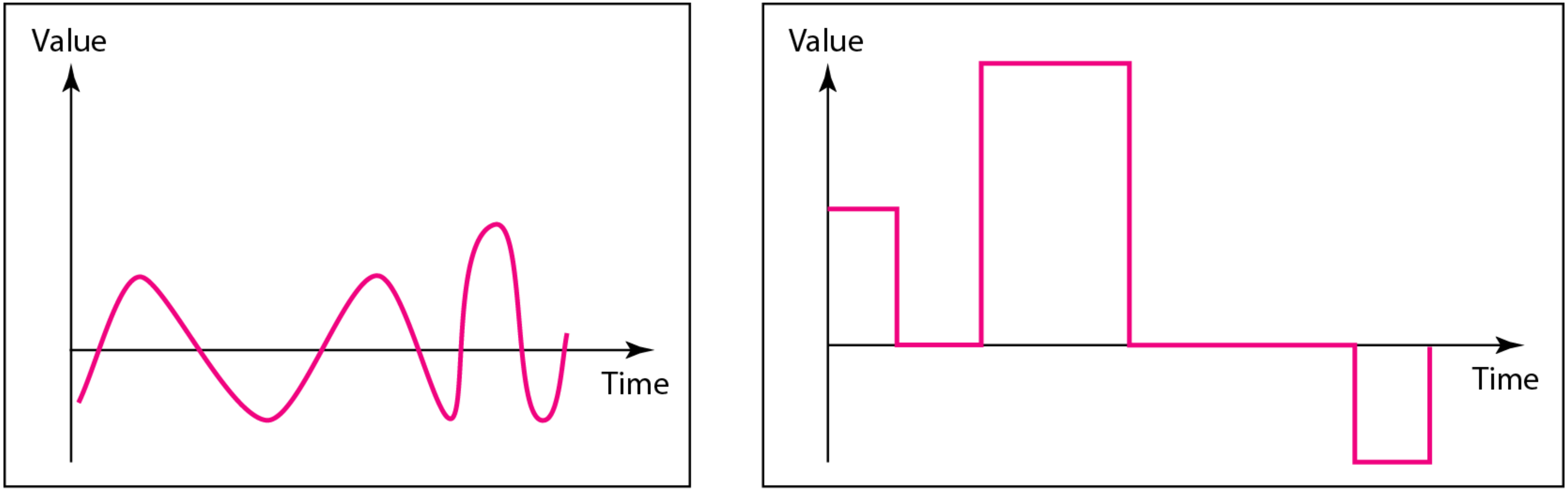
Note

Data can be analog or digital.
Analog data are continuous and take continuous values.
Digital data have discrete states and take discrete values.

Note

Signals can be analog or digital. Analog signals can have an infinite number of values in a range; digital signals can have only a limited number of values.

Comparison of analog and digital signals



a. Analog signal

b. Digital signal

Periodic and Non Periodic

- **A periodic signal** completes a pattern within a measurable time frame, called a period, and repeats that pattern over subsequent identical periods.

- The completion of one full pattern is called as a **cycle.**

- A **non-periodic signal** changes without exhibiting a pattern or a cycle.

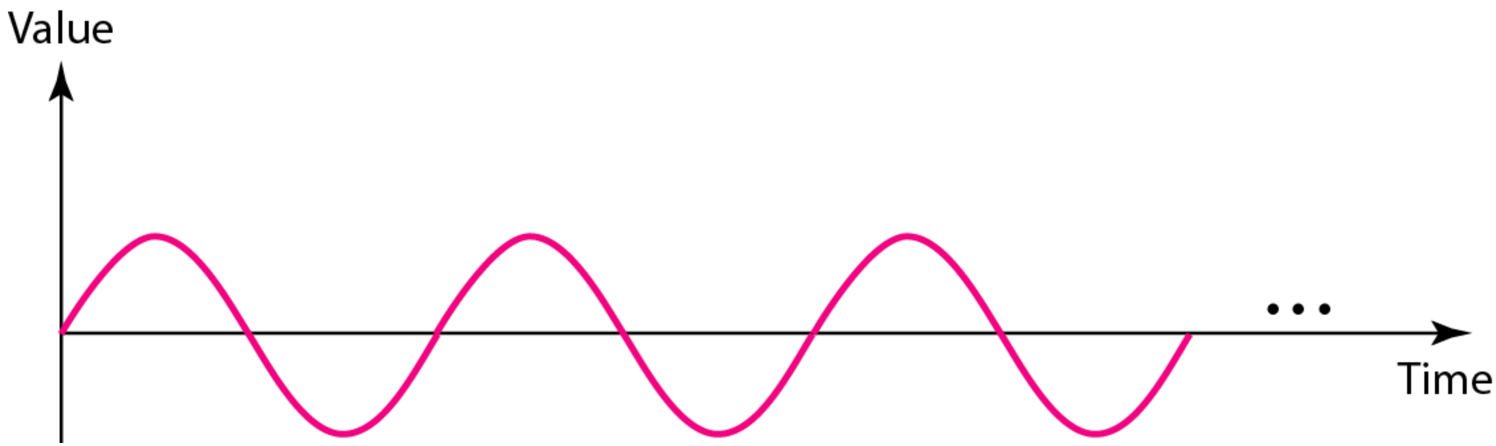
Note

In data communications, we commonly use periodic analog signals and nonperiodic digital signals.

PERIODIC ANALOG SIGNALS

Periodic analog signals can be classified as simple or composite.

Figure ***A sine wave***



A sine wave is represented by:

- Peak Amplitude
- Frequency
- Phase
- Wavelength

POLL 2

- Which of the following is//are representation of a wave

a) Amplitude

b) Frequency

c) Wavelength

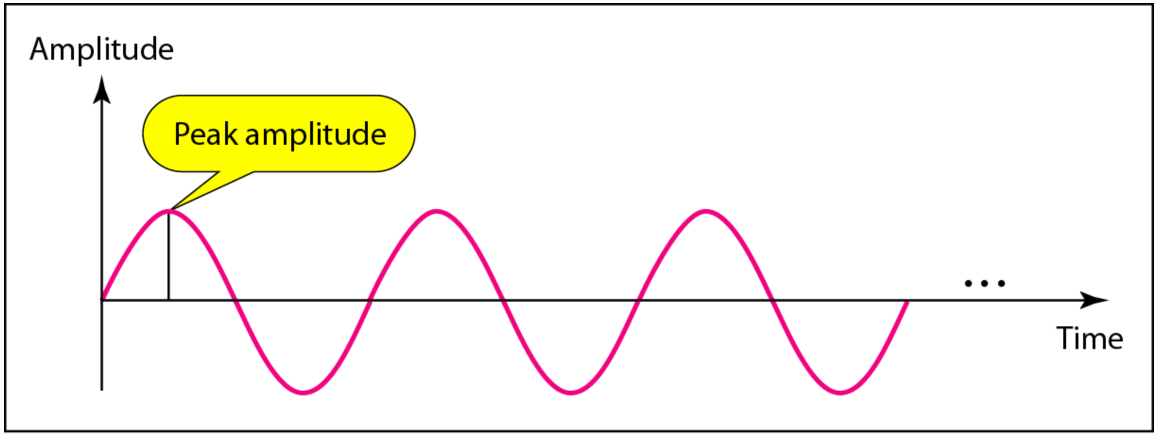
d) All of the above

Peak Amplitude

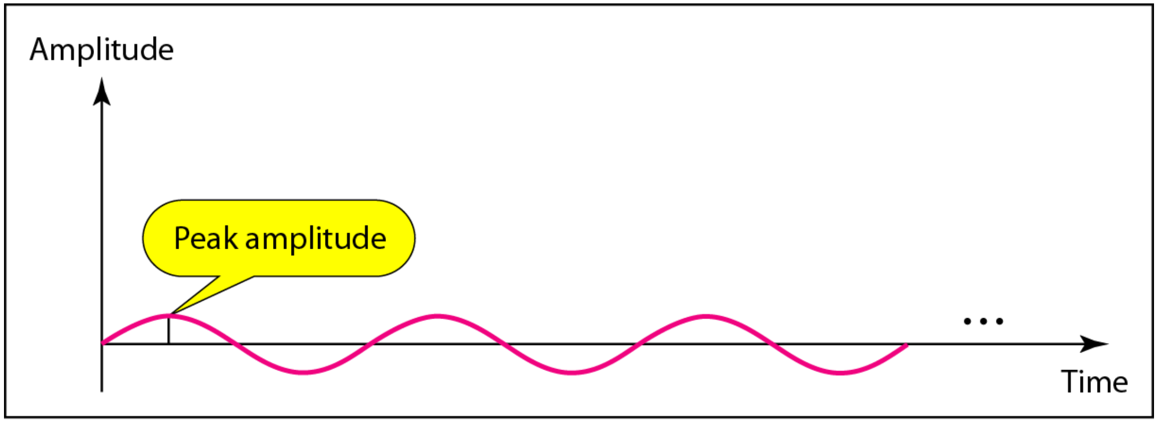
- The peak amplitude of a signal is the absolute value of its highest intensity, proportional to energy it carries.

- Measured in volts.

Two signals with the same phase and frequency, but different amplitudes



a. A signal with high peak amplitude



b. A signal with low peak amplitude

Period and Frequency

- Period refers to amount of time, in seconds, a signal takes to complete one cycle.

- Frequency refers to the number of periods in 1 second.

- Period is expressed in seconds and frequency is expressed in hertz (Hz)

Note

Frequency and period are the inverse of each other.

$$f = \frac{1}{T} \quad \text{and} \quad T = \frac{1}{f}$$

Note

Frequency is the rate of change with respect to time.

Change in a short span of time means high frequency.

Change over a long span of time means low frequency.

Note

If a signal does not change at all, its frequency is zero.
If a signal changes instantaneously, its frequency is infinite.

POLL 3

- If the signal doesn't changes then its frequency is

a) High

b) Low

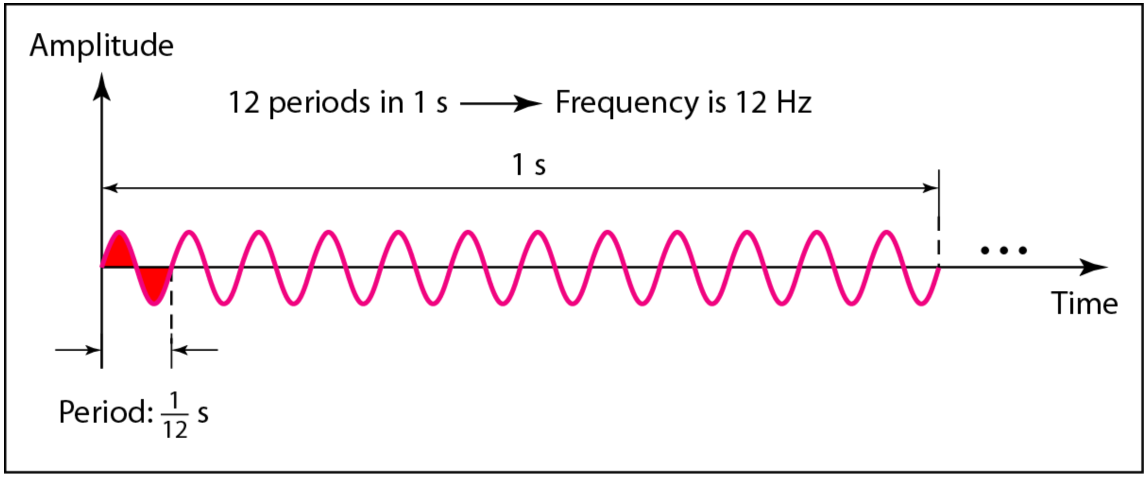
c) Zero

d) Can’t be determined

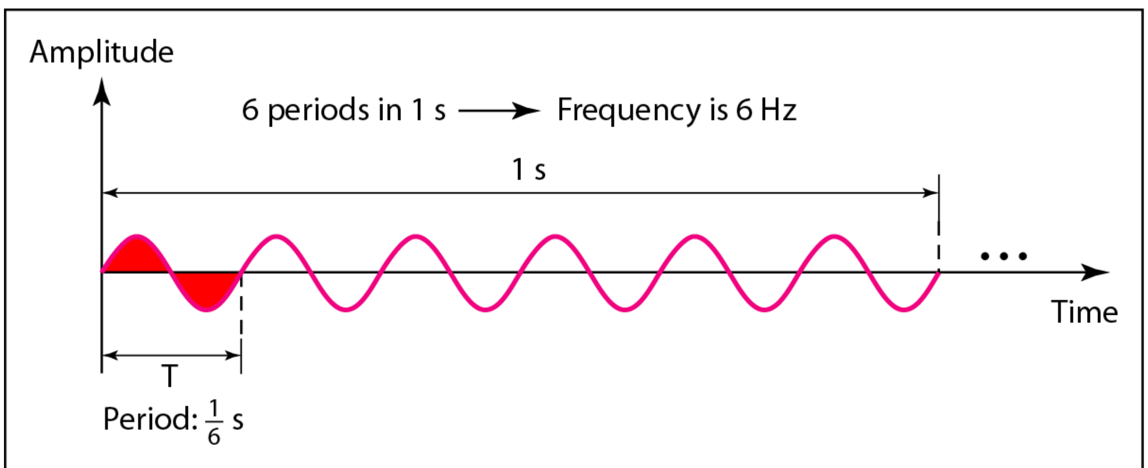
Table ***Units of period and frequency***

Unit	*Equivalent*	*Unit*	*Equivalent*
Seconds (s)	1 s	Hertz (Hz)	1 Hz
Milliseconds (ms)	10^{-3} s	Kilohertz (kHz)	10^{3} Hz
Microseconds (μs)	10^{-6} s	Megahertz (MHz)	10^{6} Hz
Nanoseconds (ns)	10^{-9} s	Gigahertz (GHz)	10^{9} Hz
Picoseconds (ps)	10^{-12} s	Terahertz (THz)	10^{12} Hz

Figure ***Two signals with the same amplitude and phase, but different frequencies***



a. A signal with a frequency of 12 Hz



b. A signal with a frequency of 6 Hz

Example

The power we use at home has a frequency of 60 Hz. Determined the period of this sine wave?

$$T = \frac{1}{f} = \frac{1}{60} = 0.0166\ \text{s} = 0.0166 \times 10^{3}\ \text{ms} = 16.6\ \text{ms}$$

Example

Express a period of 100 ms in microseconds.

Example

The period of a signal is 100 ms. What is its frequency in kilohertz?

Solution

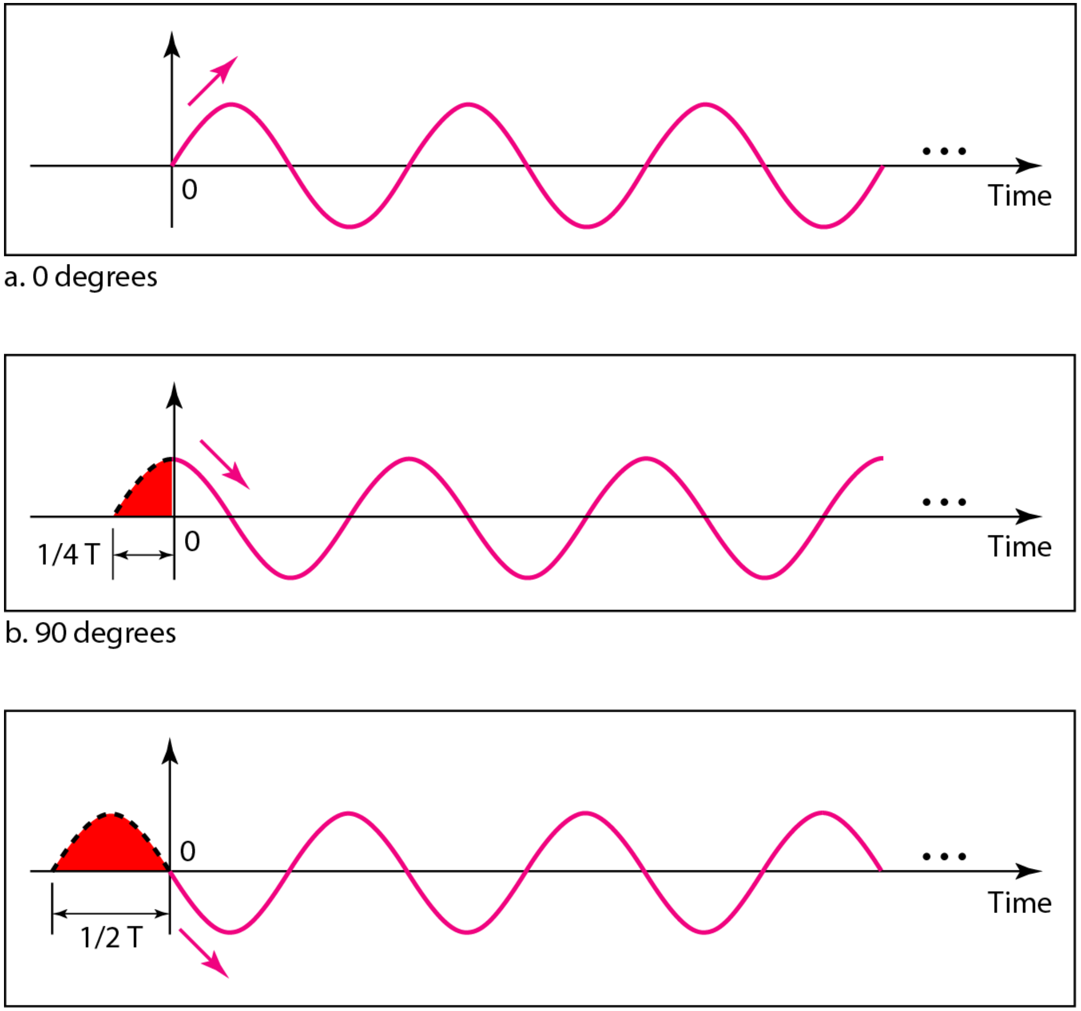
$$100 \text{ ms} = 100 \times 10^{-3} \text{ s} = 10^{-1} \text{ s}$$

$$f = \frac{1}{T} = \frac{1}{10^{-1}} \text{ Hz} = 10 \text{ Hz} = 10 \times 10^{-3} \text{ kHz} = 10^{-2} \text{ kHz}$$

Note

Phase describes the position of the waveform relative to time 0.

Figure *Three sine waves with the same amplitude and frequency, but different phases*



a. 0 degrees

b. 90 degrees

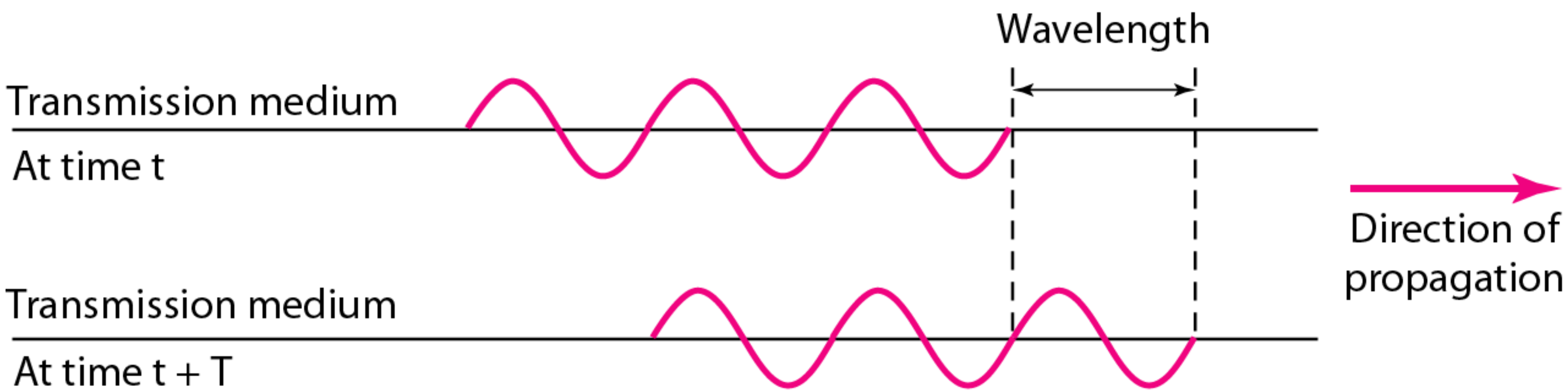
c. 180 degrees

Example

A sine wave with value 1/6 cycle with respect to time 0. What is its phase in degrees and radians?

$$\frac{1}{6} \times 360 = 60^\circ = 60 \times \frac{2\pi}{360}\ \text{rad} = \frac{\pi}{3}\ \text{rad} = 1.046\ \text{rad}$$

Figure *Wavelength and period*



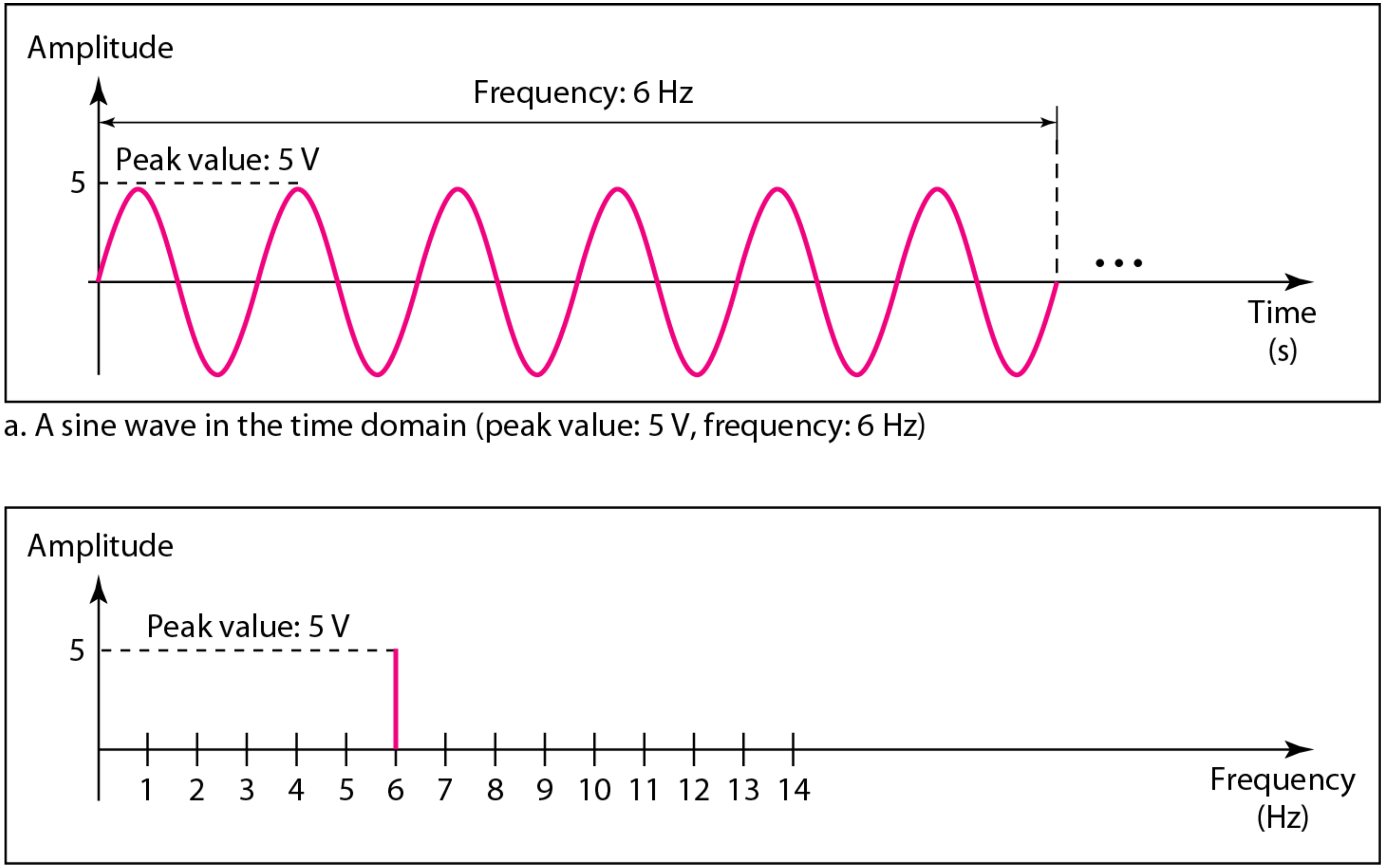
Wavelength

- Wavelength is the distance a signal can travel in one period.
- Wavelength= propagation speed* period

Or

- Wavelength= propagation speed/ frequency

Figure *The time-domain and frequency-domain plots of a sine wave*



a. A sine wave in the time domain (peak value: 5 V, frequency: 6 Hz)

b. The same sine wave in the frequency domain (peak value: 5 V, frequency: 6 Hz)

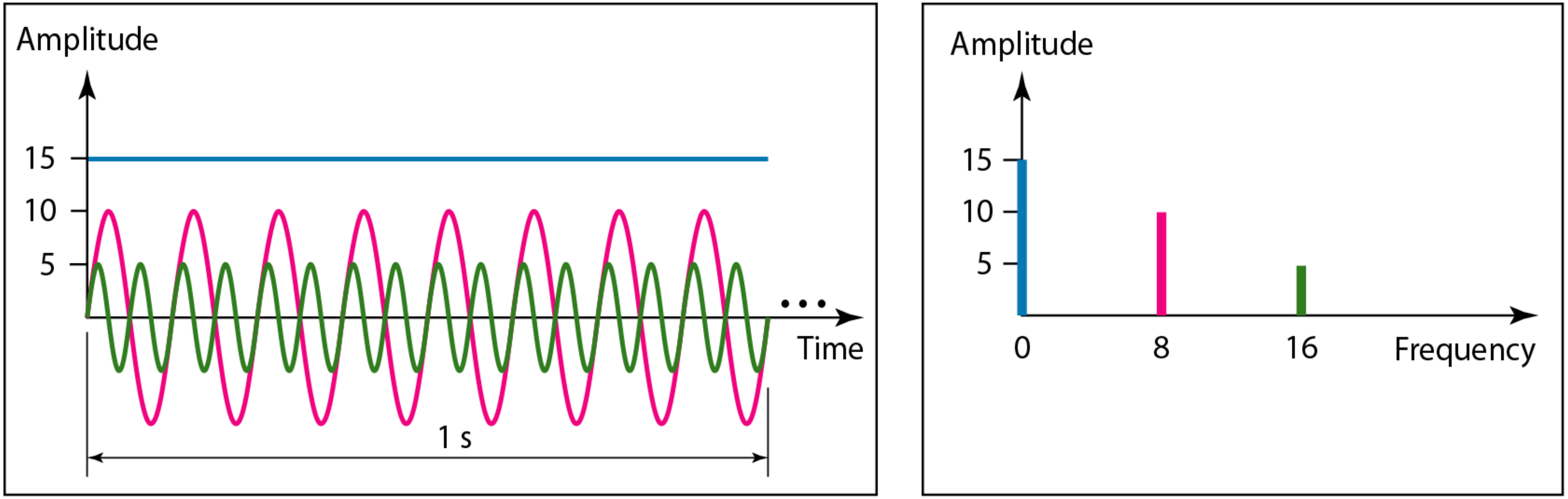
Note

A complete sine wave in the time domain can be represented by one single spike in the frequency domain.

Example

The frequency domain is more compact and useful when we are dealing with more than one sine wave.

Figure *The time domain and frequency domain of three sine waves*



a. Time-domain representation of three sine waves with frequencies 0, 8, and 16

b. Frequency-domain representation of the same three signals

Note

A single-frequency sine wave is not useful in data communications; we need to send a composite signal, a signal made of many simple sine waves.

Note

According to Fourier analysis, any composite signal is a combination of simple sine waves with different frequencies, amplitudes, and phases.

Note

**If the composite signal is periodic, the decomposition gives a series of signals with discrete frequencies;
if the composite signal is nonperiodic, the decomposition gives a combination of sine waves with continuous frequencies.**

Example

Figure shows a periodic composite signal with frequency f. This type of signal is not typical of those found in data communications. We can consider it to be three alarm systems, each with a different frequency. The analysis of this signal can give us a good understanding of how to decompose signals.

Figure ***A composite periodic signal***

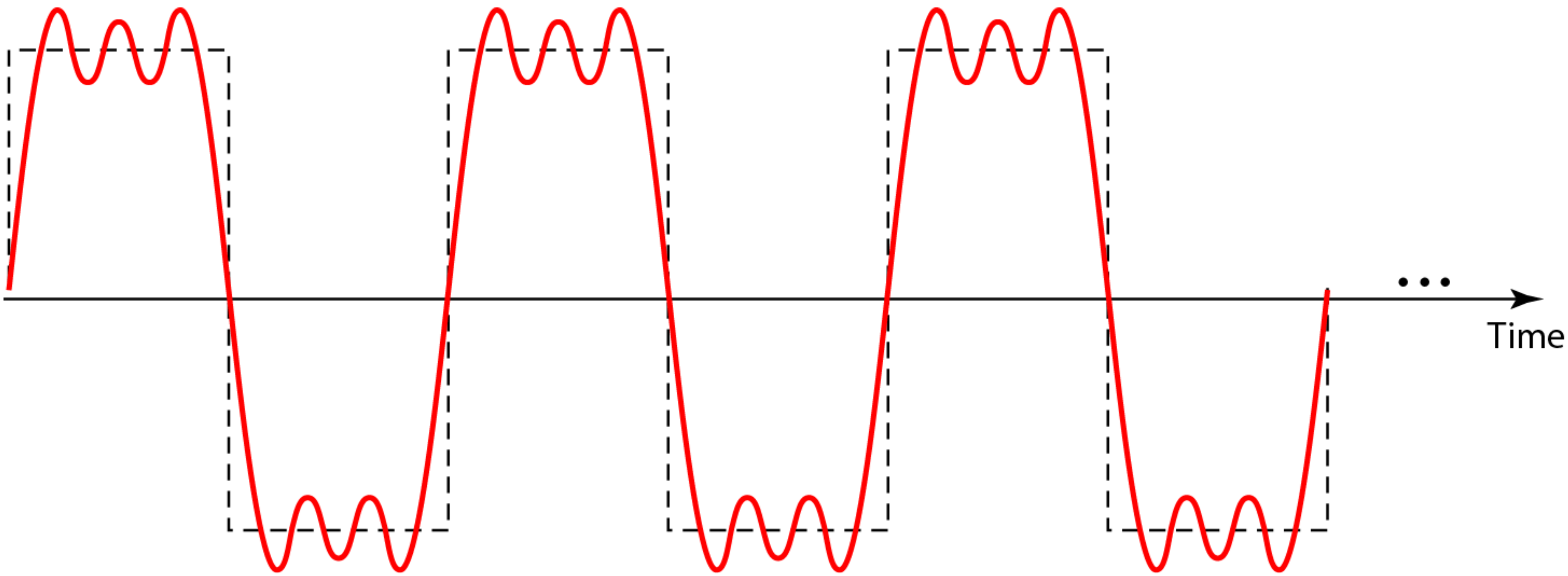
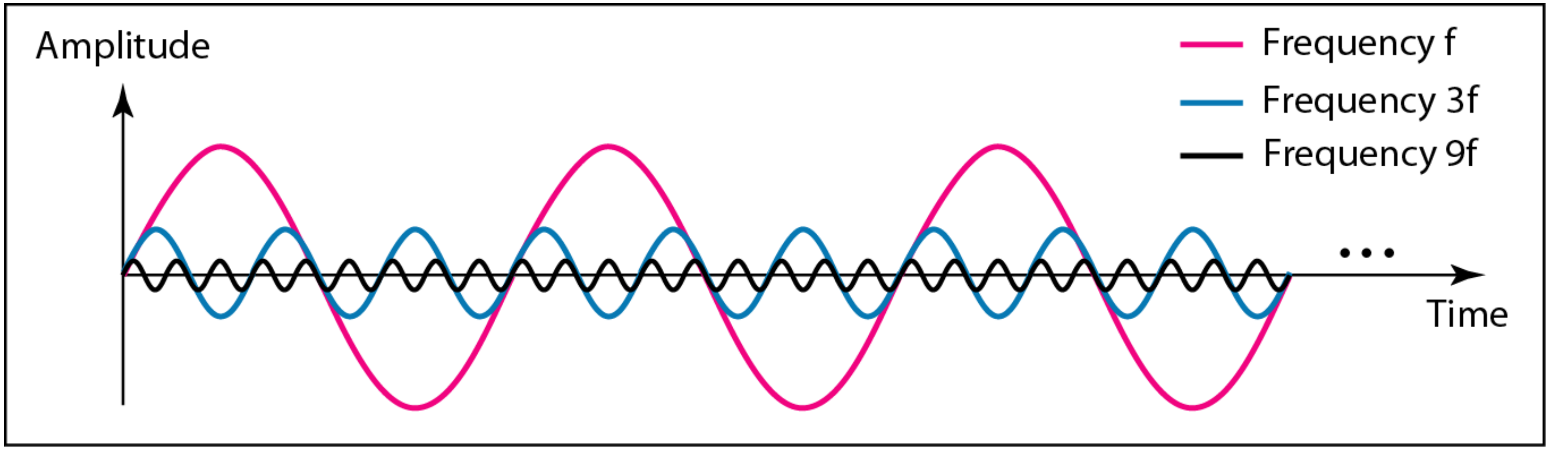
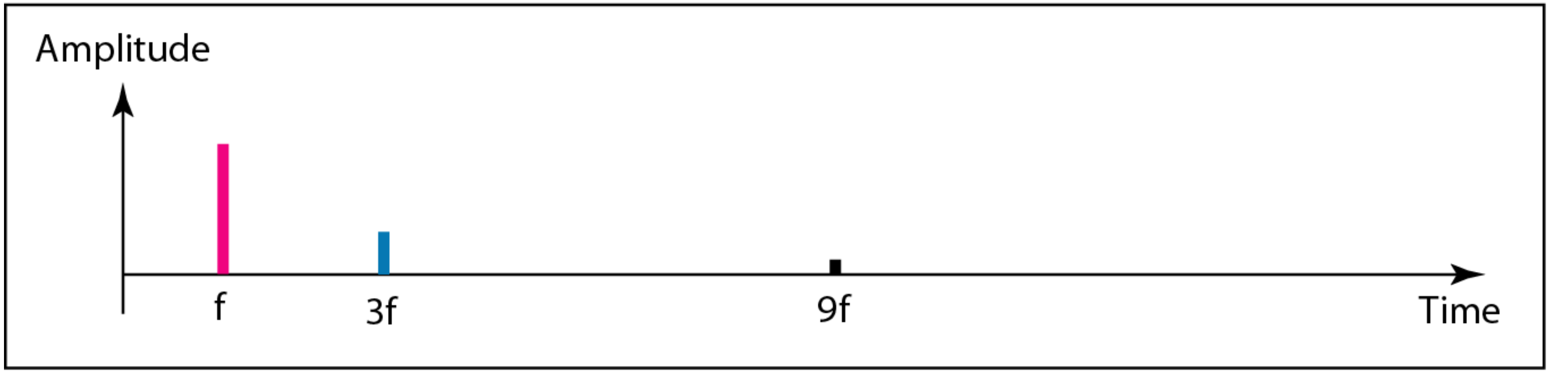


Figure ***Decomposition of a composite periodic signal in the time and frequency domains***



a. Time-domain decomposition of a composite signal

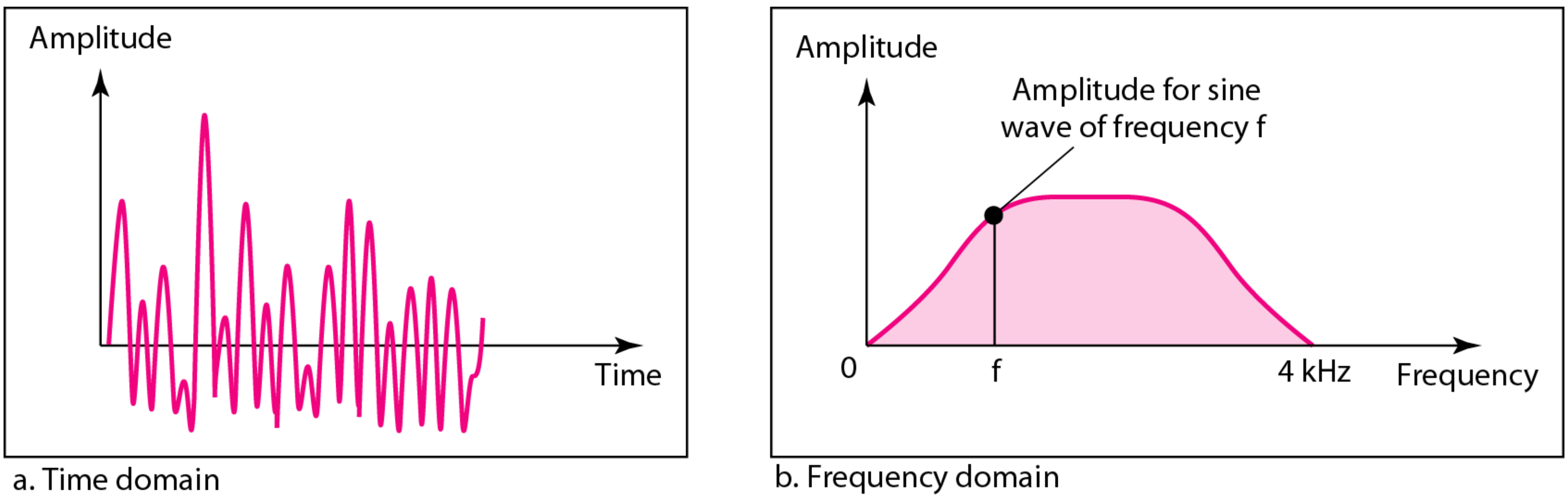


b. Frequency-domain decomposition of the composite signal

Example

Figure shows a nonperiodic composite signal. It can be the signal created by a microphone or a telephone set when a word or two is pronounced. In this case, the composite signal cannot be periodic, because that implies that we are repeating the same word or words with exactly the same tone.

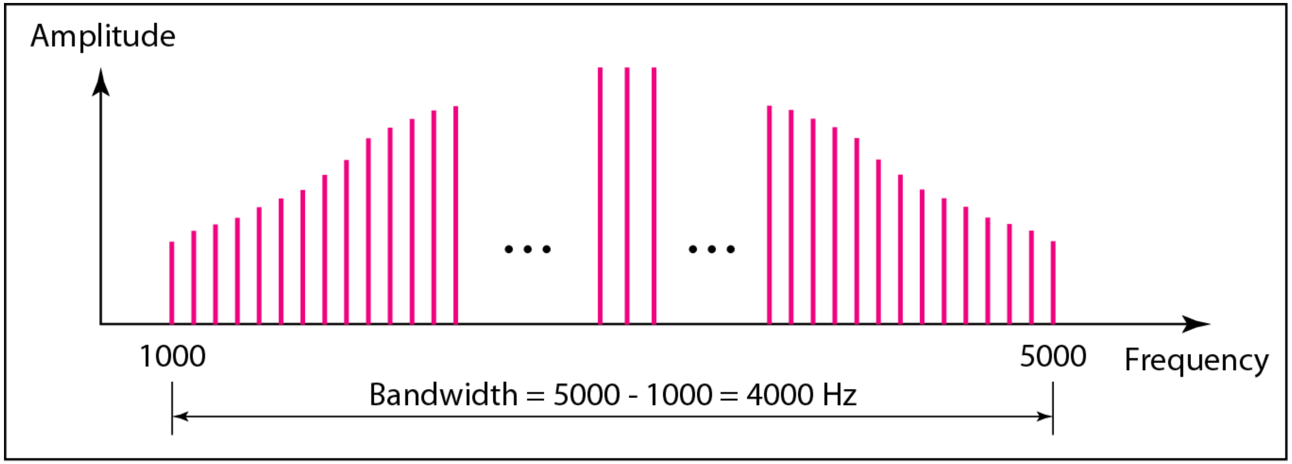
Figure ***The time and frequency domains of a nonperiodic signal***



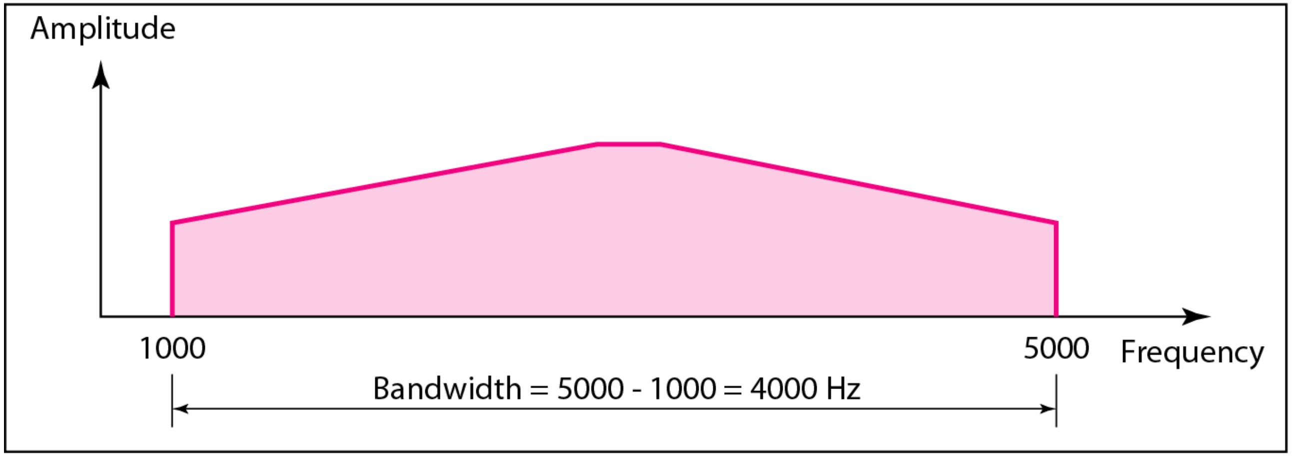
Note

The bandwidth of a composite signal is the difference between the highest and the lowest frequencies contained in that signal.

Figure ***The bandwidth of periodic and nonperiodic composite signals***



a. Bandwidth of a periodic signal



b. Bandwidth of a nonperiodic signal

Example

If a periodic signal is decomposed into five sine waves with frequencies of 100, 300, 500, 700, and 900 Hz, what is its bandwidth? Draw the spectrum, assuming all components have a maximum amplitude of 10 V.

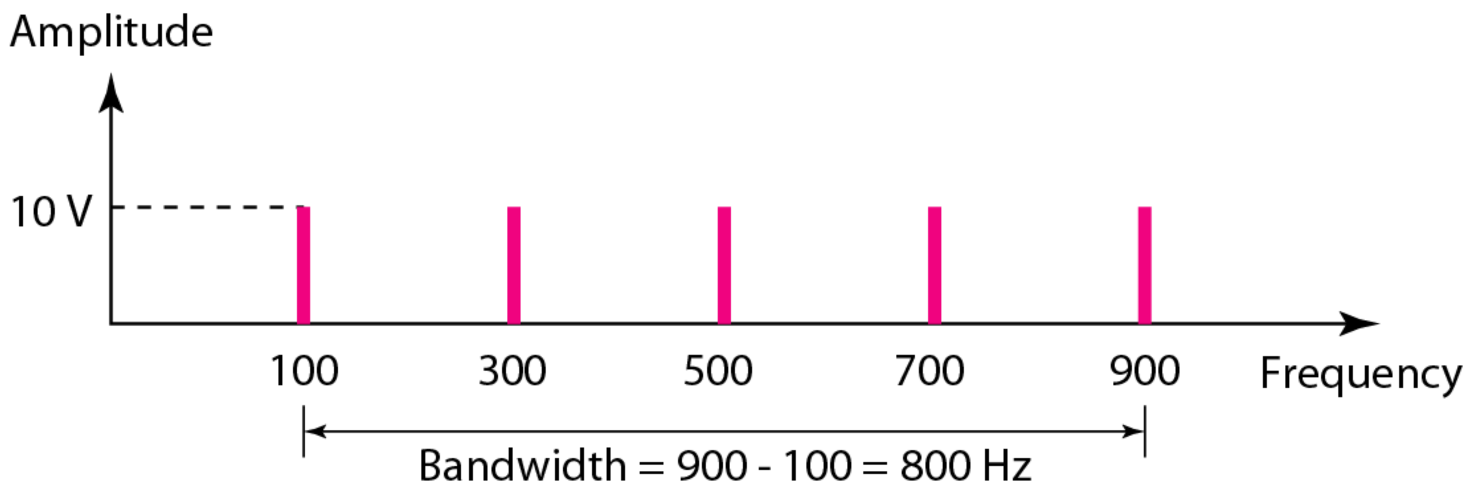
Solution

Let f_h be the highest frequency, f_l the lowest frequency, and B the bandwidth. Then

$$\boxed{B = f_h - f_l = 900 - 100 = 800 \text{ Hz}}$$

The spectrum has only five spikes, at 100, 300, 500, 700, and 900 Hz (see Figure 3.13).

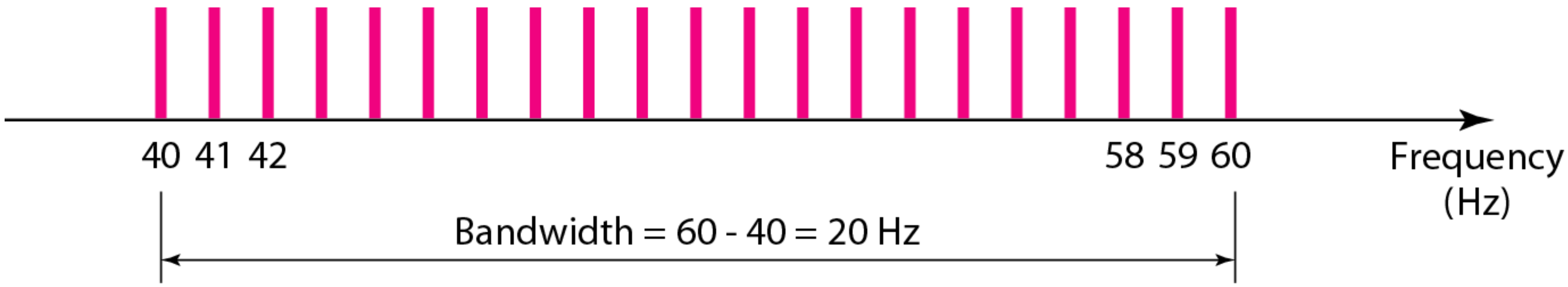
Figure ***The bandwidth for Example***



A periodic signal has a bandwidth of 20 Hz. The highest frequency is 60 Hz. What is the lowest frequency?

a) 60 Hz
b) 20 HZ
c) 40 Hz
d) 80 Hz

Draw the spectrum if the signal contains all frequencies of the same amplitude.



Example

A nonperiodic composite signal has a bandwidth of 200 kHz, with a middle frequency of 140 kHz and peak amplitude of 20 V. The two extreme frequencies have an amplitude of 0. Draw the frequency domain of the signal.

Solution

The lowest frequency must be at 40 kHz and the highest at 240 kHz. Figure shows the frequency domain and the bandwidth.

Figure ***The bandwidth for Example***