# DATA COMMUNICATION CONCEPTS
# CHAPTER 4

## SIGNALS

# 4.0 OBJECTIVES

At the end of this chapter, you should be able to:

1. Demonstrate the concepts of analog and digital signals.
2. Identify the differences between analog and digital signals.

# 4.1 INTRODUCTION TO DATA AND SIGNAL TRANSMISSION

## 4.1.1 DATA TRANSMISSION

- ***Definition:*** Data transmission can be defined as the movements of information over some physical medium.
- media have to change data into signals. Both data and the signals that represent them can be either **analog or digital in form**

- The underlying principle of data transmission is as follow:
  - Electrical signal carried along a wire.
  - Radio waves propagated through space.
  - Optical signals transmitted along a fiber.
  - Thermal or infrared signals transmitted through space from laser source.

## 4.1.2 SIGNAL TRANSMISSION

- ***Signal transmission:*** Can be defined as the representation or encoding of data.
- Representation of data in form of signal.
- Signals can be in a form of:

  - Electrical/electronic wave
  - Radio wave
  - Optical (light) signals
  - Thermal
  - Infrared

# 4.2 ANALOG AND DIGITAL SIGNAL

- Two types of signal used in data communication:
  1. *Analog signal:* refer to something that is continuous.
     E.g.: Human voice
  2. *Digital signal:* refer to something that is discrete.
     E.g.: Data in computer in form of 0s and 1s.

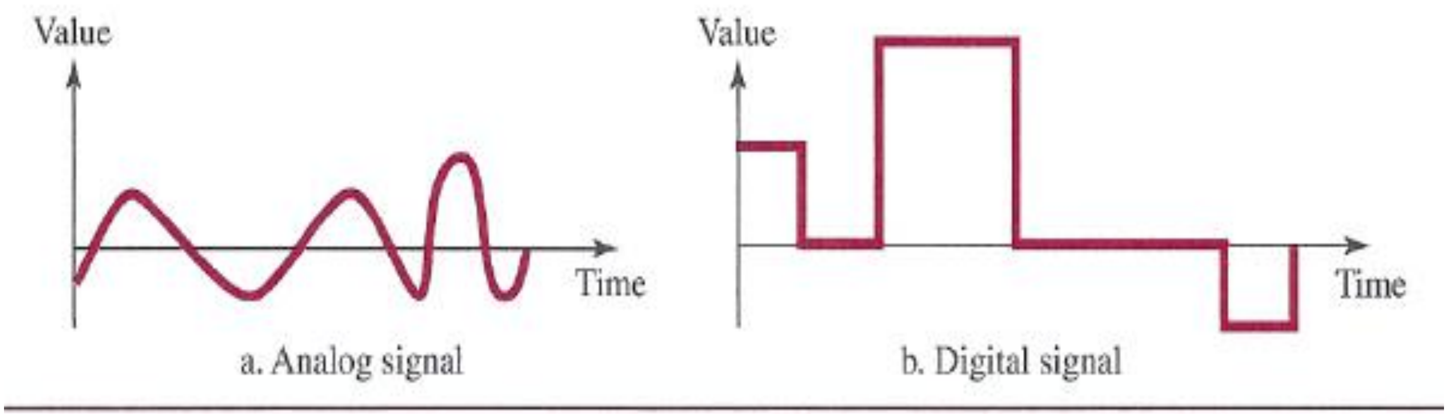
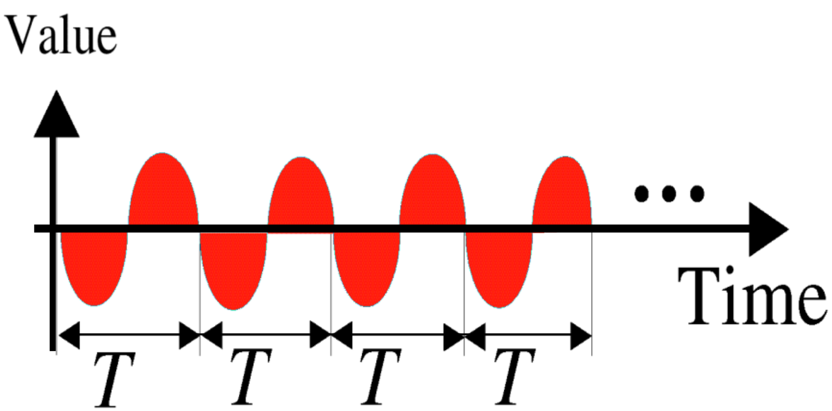



***Figure 4.1: Analog and Digital Signals***

- 2 form of analog & digital signals:
  1. *Periodic signal*
  2. *Aperiodic (*Nonperiodic***)** *signal*

## *1. PERIODIC SIGNAL*

- *Definition:* A signal that consists of a continuously repeated pattern within a measurable time frame.



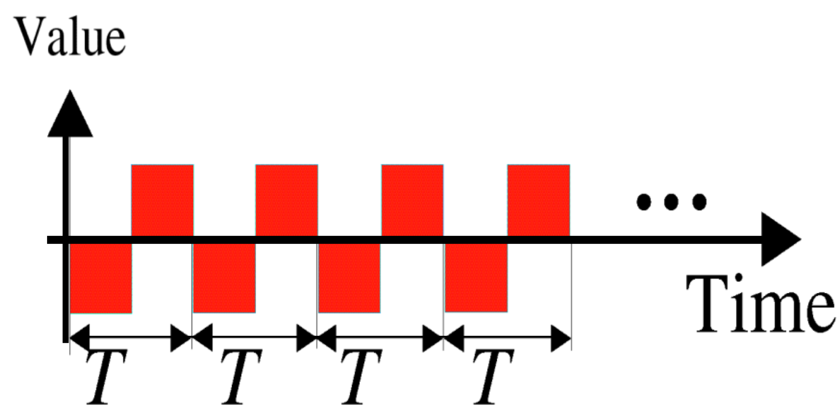




***Figure 4.2: Periodic Signals***

- 2 important term in periodic signal:

1. *Period:*
   - *A*mount of time, **in seconds, a signal needs to complete 1 cycle.**

2. *Cycle:*
   - The completion of one full pattern.
   - The repetitive unit of a periodic signal.

# 2. APERIODIC (NONPERIODIC) SIGNAL

- *Definition:* A signal that has no repetitive pattern.
- Signal changes without cycle that repeat over time.

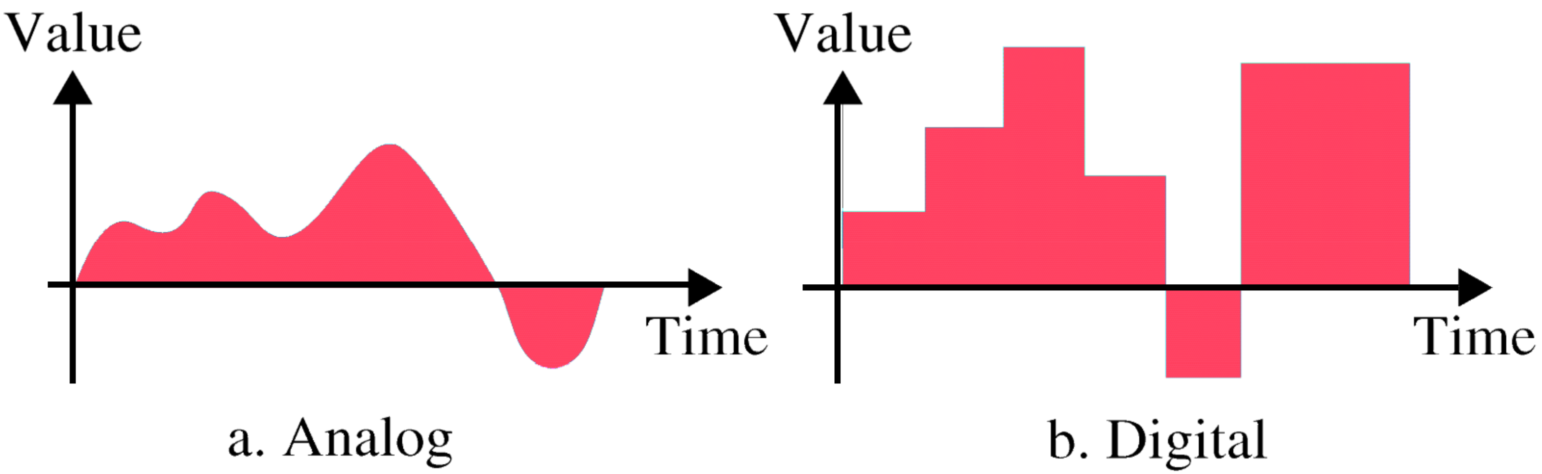



***Figure 4.3: Aperiodic Signals***

# 4.2.1 ANALOG SIGNAL

- Also known as *sine wave*.
- Sine wave is always in continuous form.
- 3 characteristics of sine wave:

1. Amplitude $(A)$
2. Period $(T)$ and Frequency $(f)$
3. Phase $(\phi)$

## *1. Amplitude*

- Refers to the height of the signal.
- Measured in volts, ampere or watt.

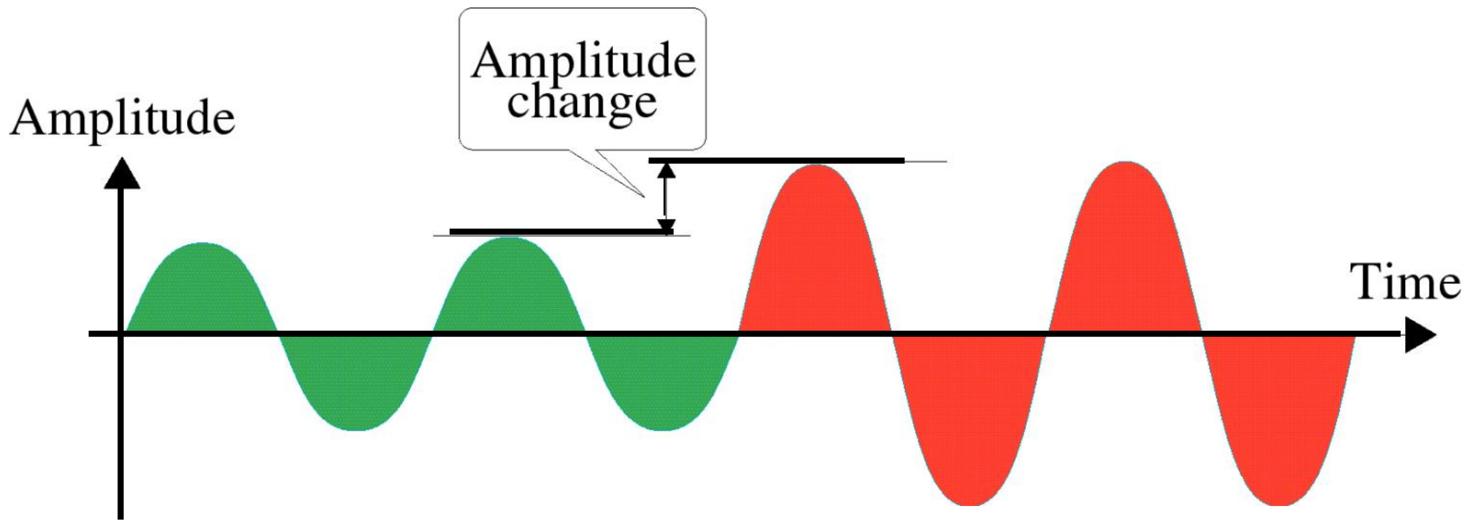



***Figure 4.4: Amplitude Change***

## 2. Period(T) and Frequency(f)

- *Period:* The amount of time required to complete one cycle.
- *Frequency:* The number of periods in one second.

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

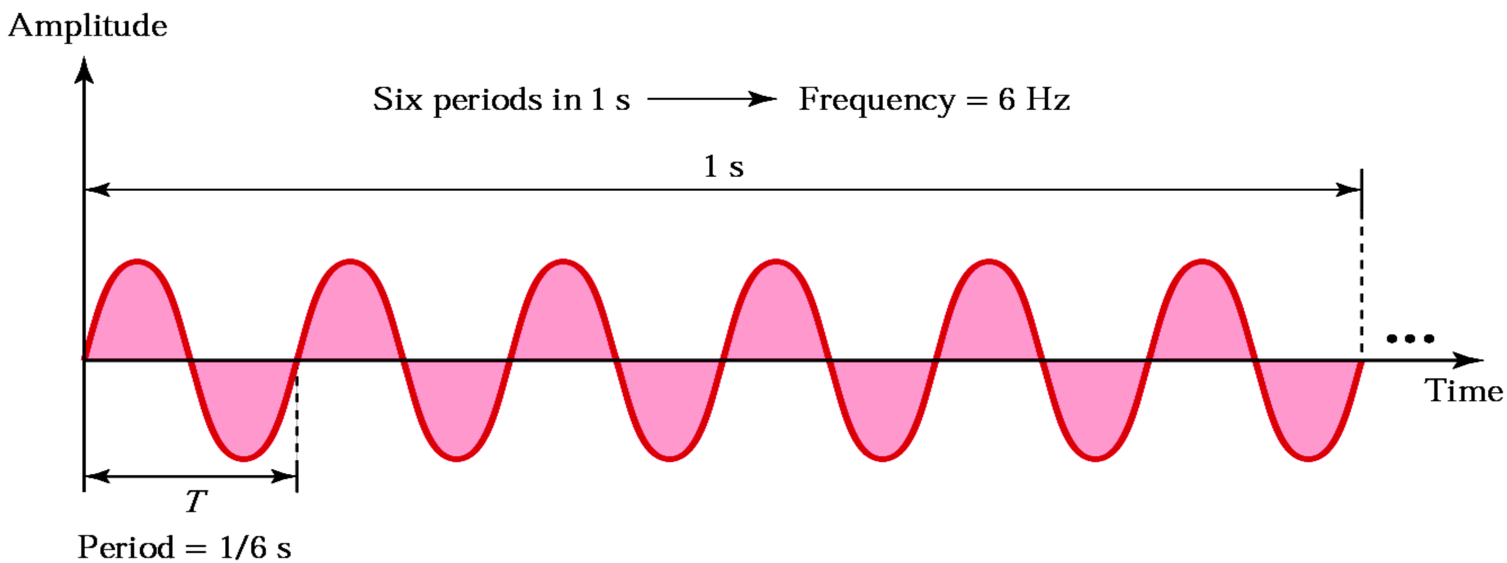
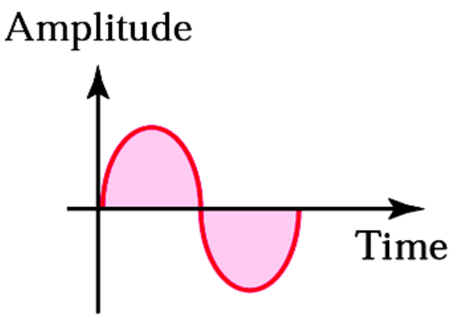



***Figure 4.5: Frequency Change***

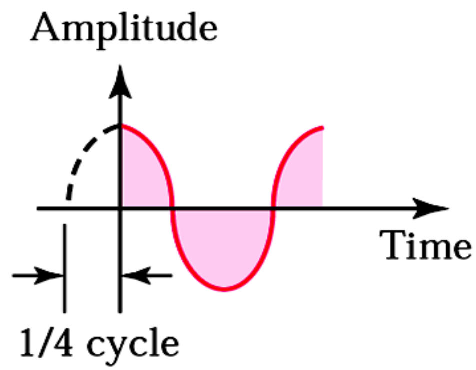
## *3. Phase*

- *Definition:* The position of the waveform relative to time zero.
- 4 position of waveform:

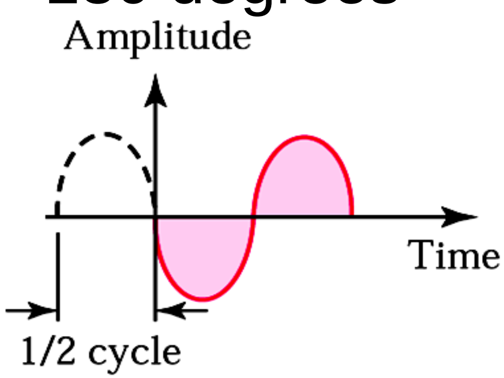
i. 0 degrees




ii. 90 degrees




iii. 180 degrees




iv. 270 degrees

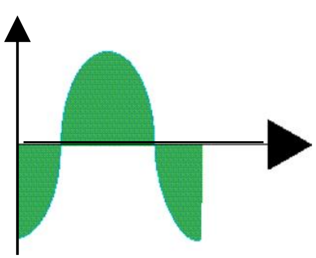


***Figure 4.6: Position of Waveform***

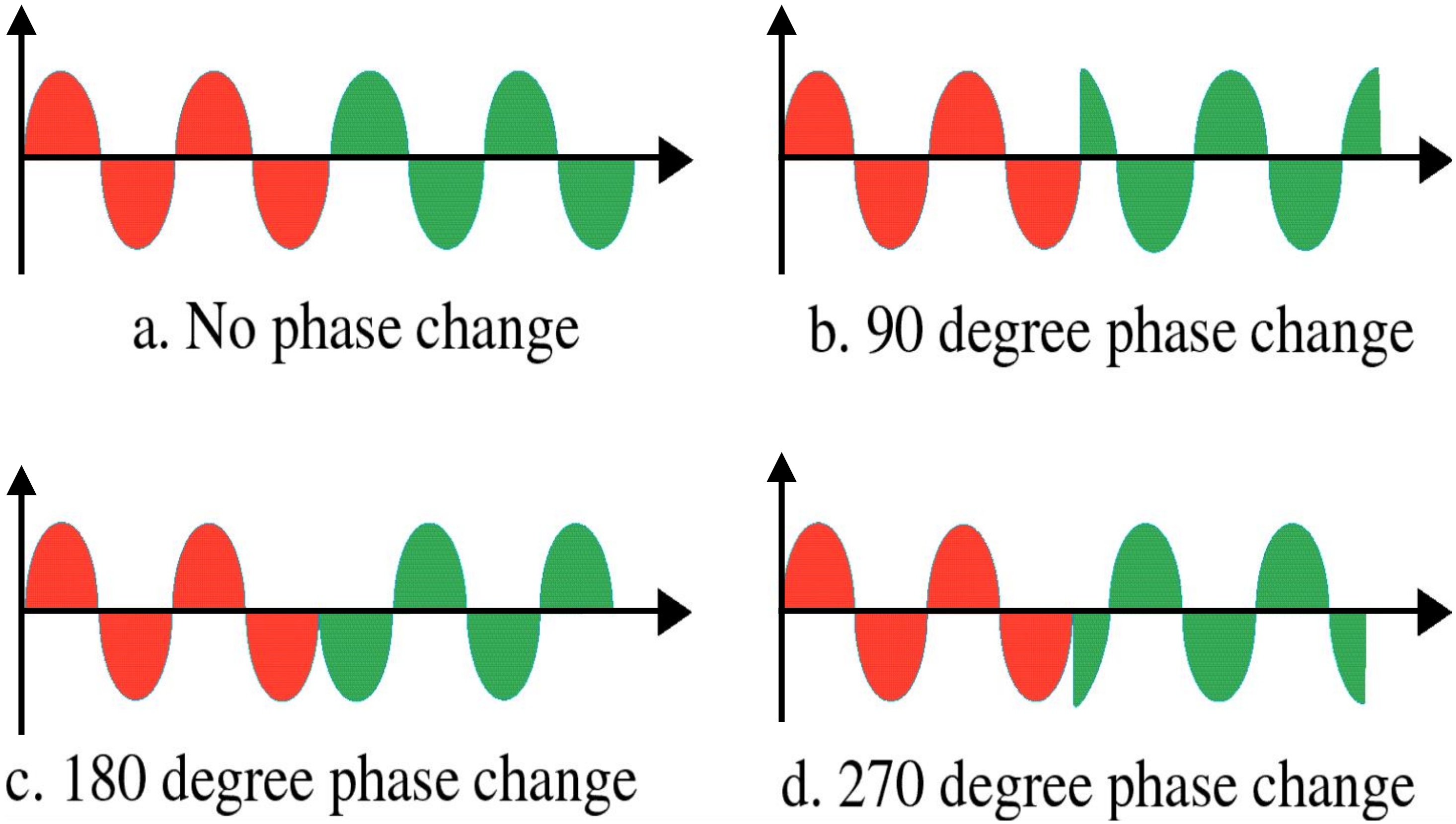



*Figure 4.7: Phase Change*

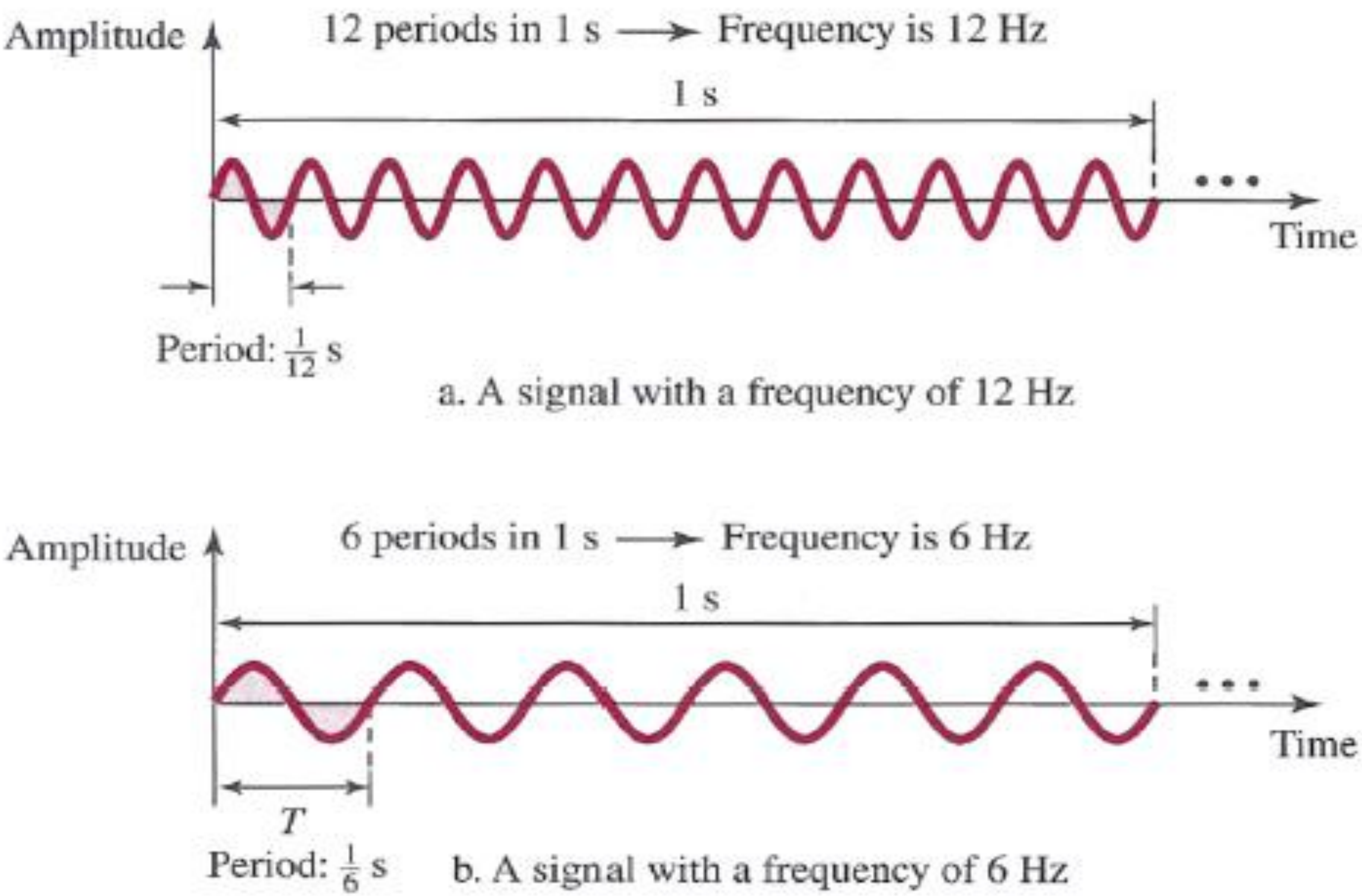



***Figure 4.8:*** **Two signals with the same amplitude and phase, but different frequencies**

**Exercise:**

1. Draw two sine waves with the following characteristics:

    a. Signal A : amplitude 40, frequency 8, phase 0
    b. Signal B : amplitude 10, frequency 8, phase 90

# 4.2.2 ELECTROMAGNETIC SIGNALS

- Information is transmitted in a form of electromagnetic signal.
- Electromagnetic signal can be expressed in a:

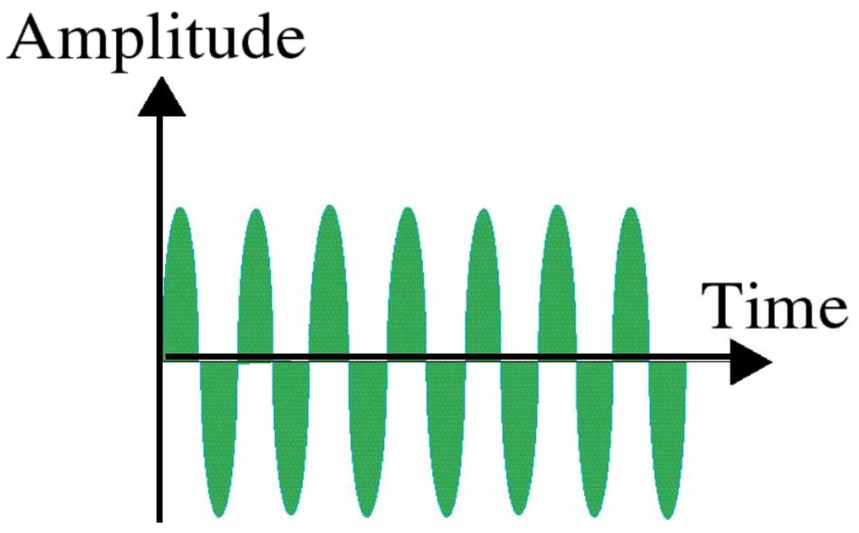
1. *Time-domain concept* (function of time)
2. *Frequency-domain concept* (function of frequency)

## *Time-Domain Concept*

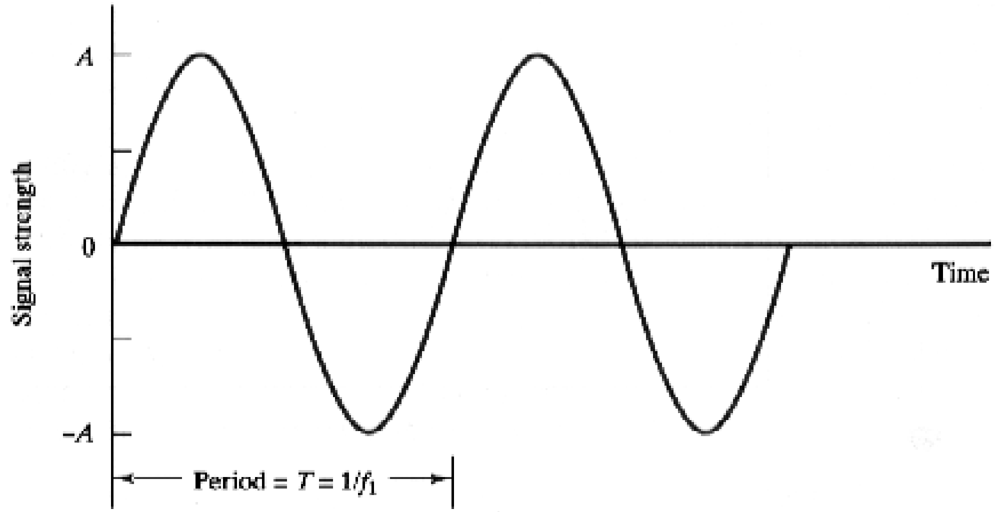
- *Time-domain plot* shows changes in signal amplitude with respect to time.
- It is an amplitude versus time plot.

## *Time-Domain Concept (continue)*

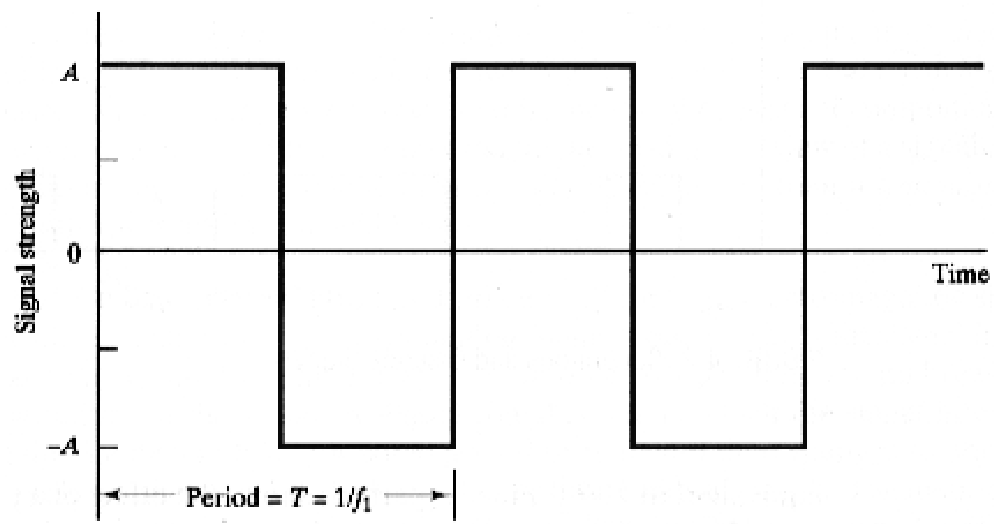
- Use the concept of periodic signal.
  - Periodic analog signal is represented in sine waves.
  - Periodic digital signal is represented in square waves.




***a. Time-Domain***



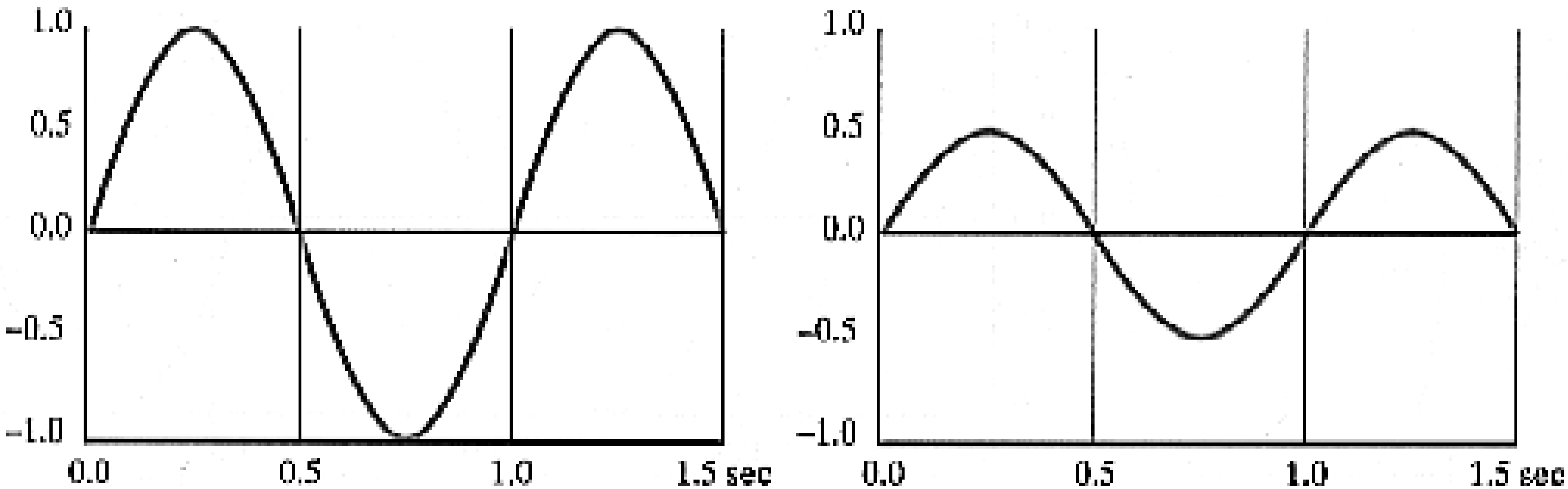

***b. Periodic Sine Waves***




***c. Periodic Square Waves***

# *Time-Domain Concept (continue)*

- Period (T) = 1 / $f$
- Example: A signal of 5Hz = 1/5 = 0.2 sec
- The *higher* the *frequency*, the *shorter* the *period.*

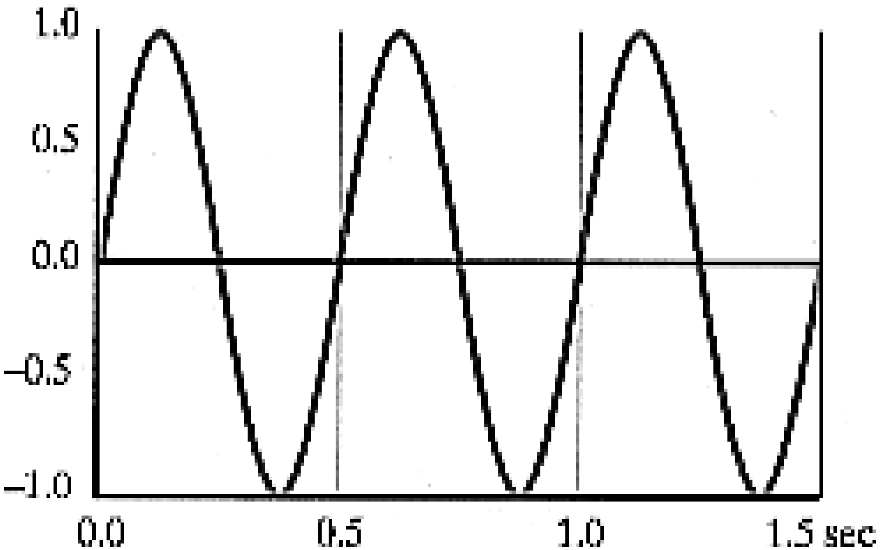



(a) $A = 1, f = 1, \phi = 0$

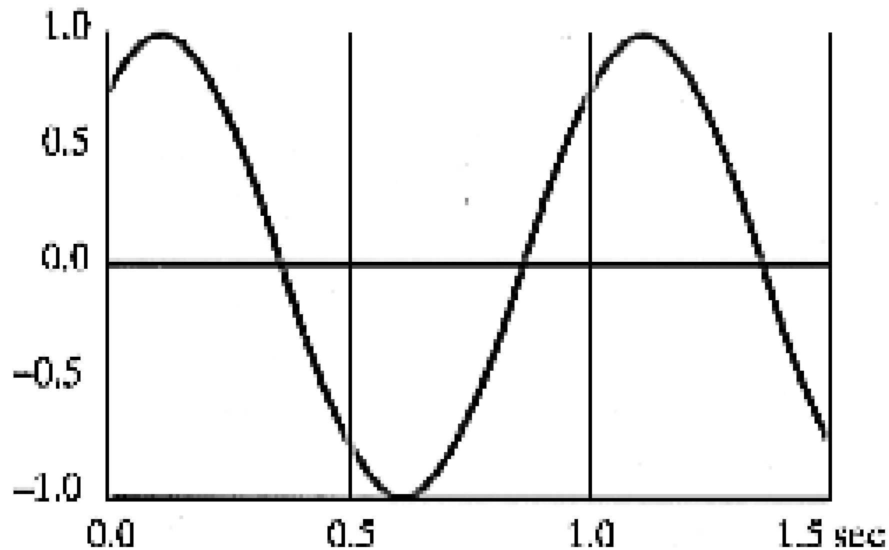
(b) $A = 0.5, f = 1, \phi = 0$

**Period (T) = 1 / $f$**
**= 1 / 1**
**= 1 sec.**

**Period (T) = 1 / $f$**
**= 1 / 1**
**= 1 sec.**




(c) $A = 1, f = 2, \phi = 0$




(d) $A = 1, f = 1, \phi = \pi/4$

**Period (T) = 1 / *f***

**= 1 / 2**

**= 0.5 sec.**

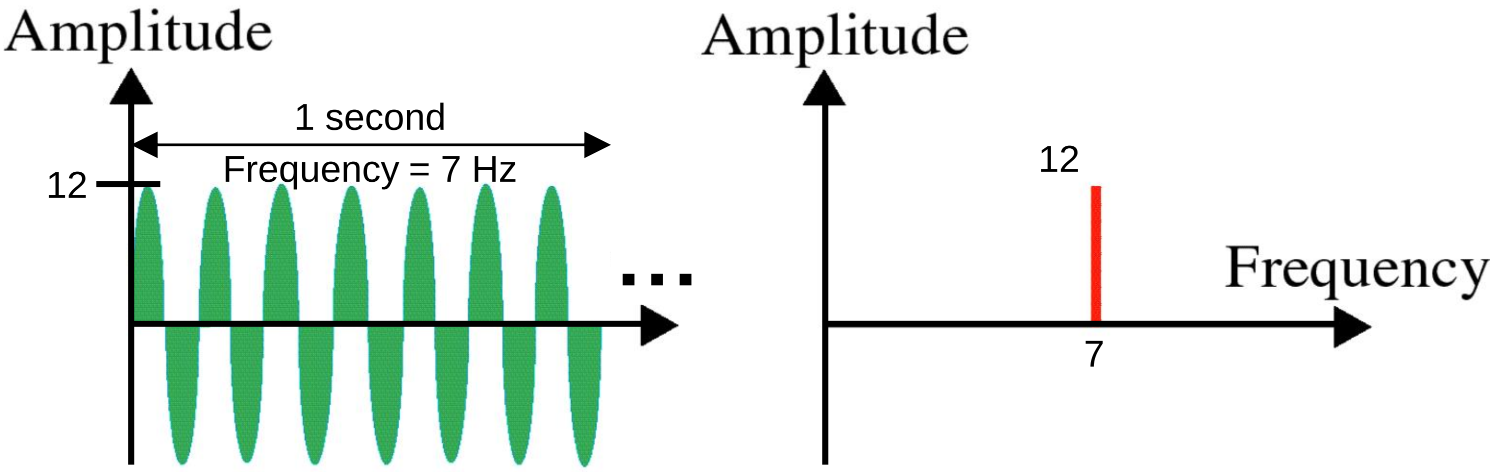
**Period (T) = 1 / *f***

**= 1 / 1**

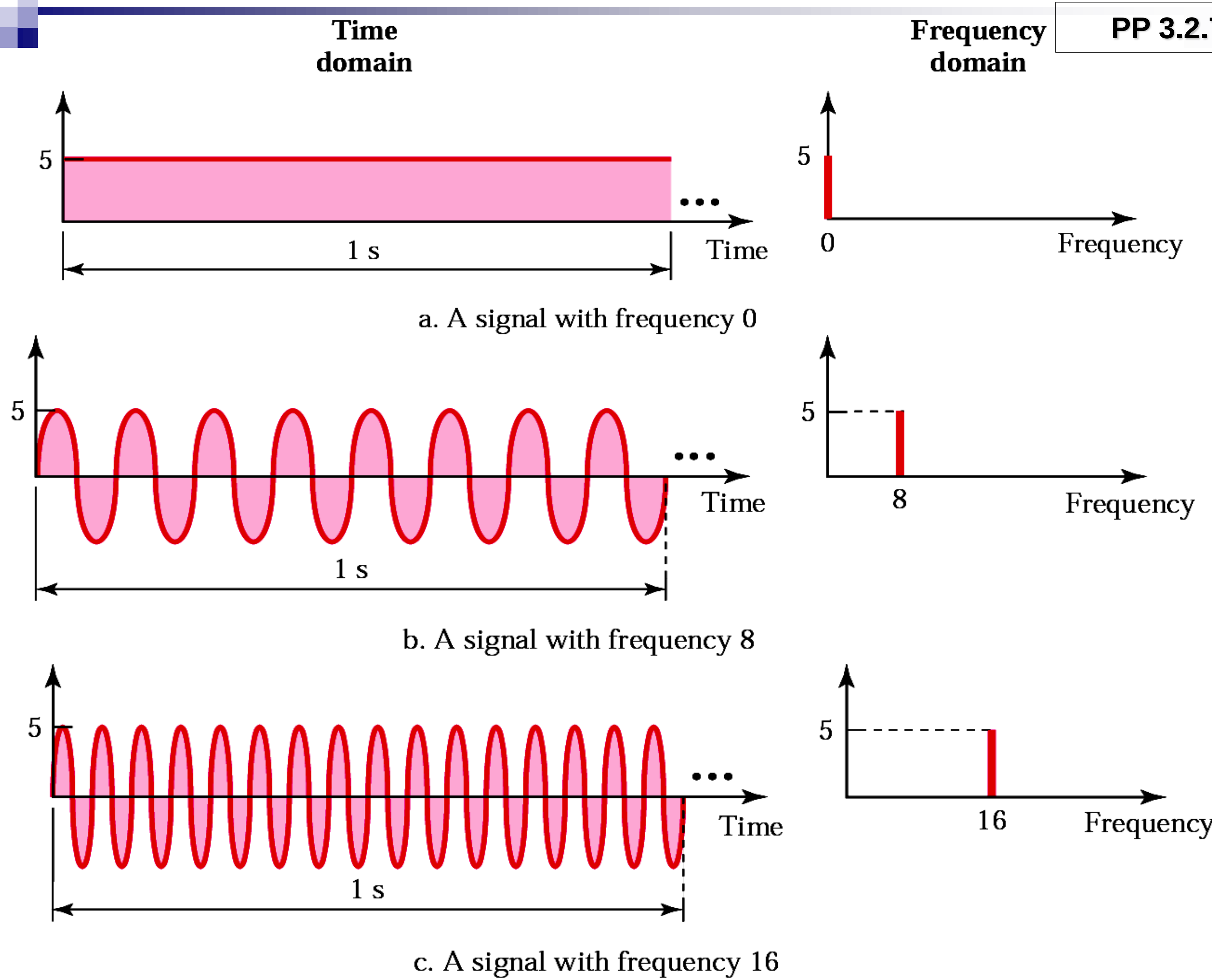
**= 1 sec.**

# Frequency-Domain Concept

- *Frequency-domain plot* shows the relationship between amplitude and frequency.
- It is a maximum amplitude with respect to frequency.

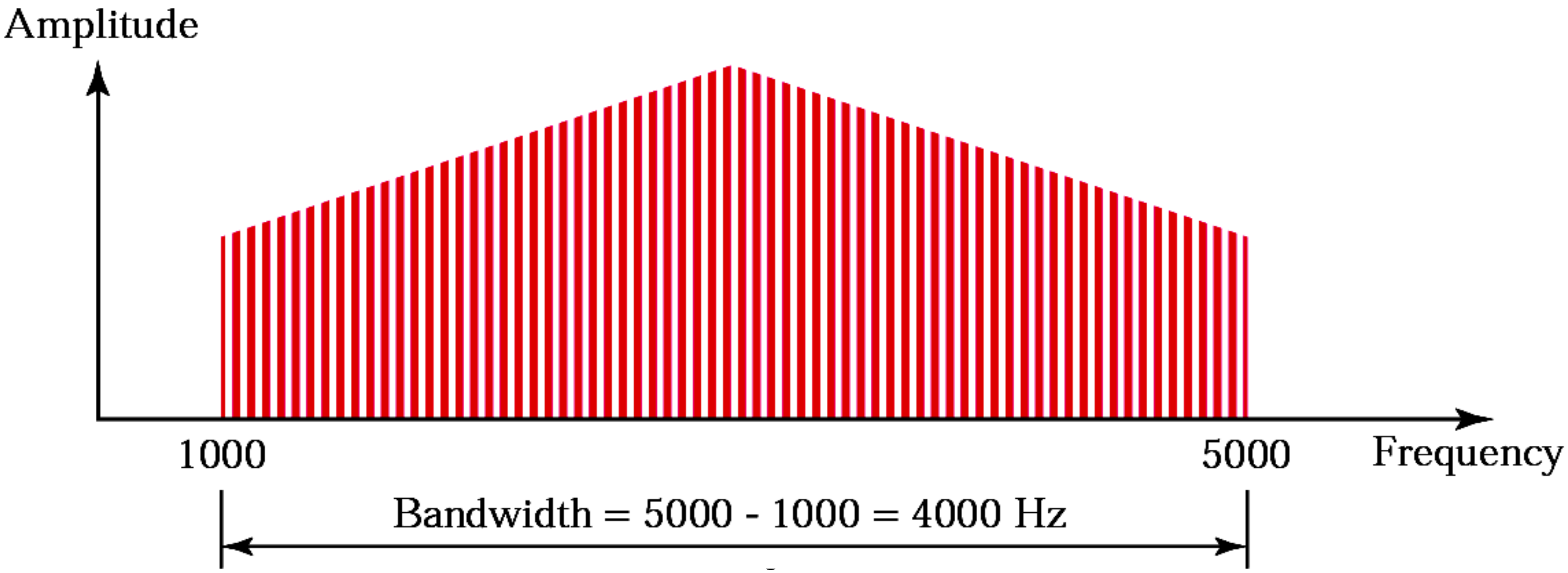



a. Time domain    b. Frequency domain


Time
domain
Frequency
domain
5
1 s
Time
5
0
Frequency
a. A signal with frequency 0
5
1 s
Time
5
8
Frequency
b. A signal with frequency 8
5
1 s
Time
5
16
Frequency
c. A signal with frequency 16

# 4.2.3 FREQUENCY SPECTRUM & BANDWIDTH

- *Frequency Spectrum:* Is the range of frequencies that a signal contains.
- *Bandwidth:*
  - Refers to the width of the spectrum.
  - The difference between the highest and the lowest frequencies of a composite signal.
  - **Bandwidth = highest frequency – lowest frequency**



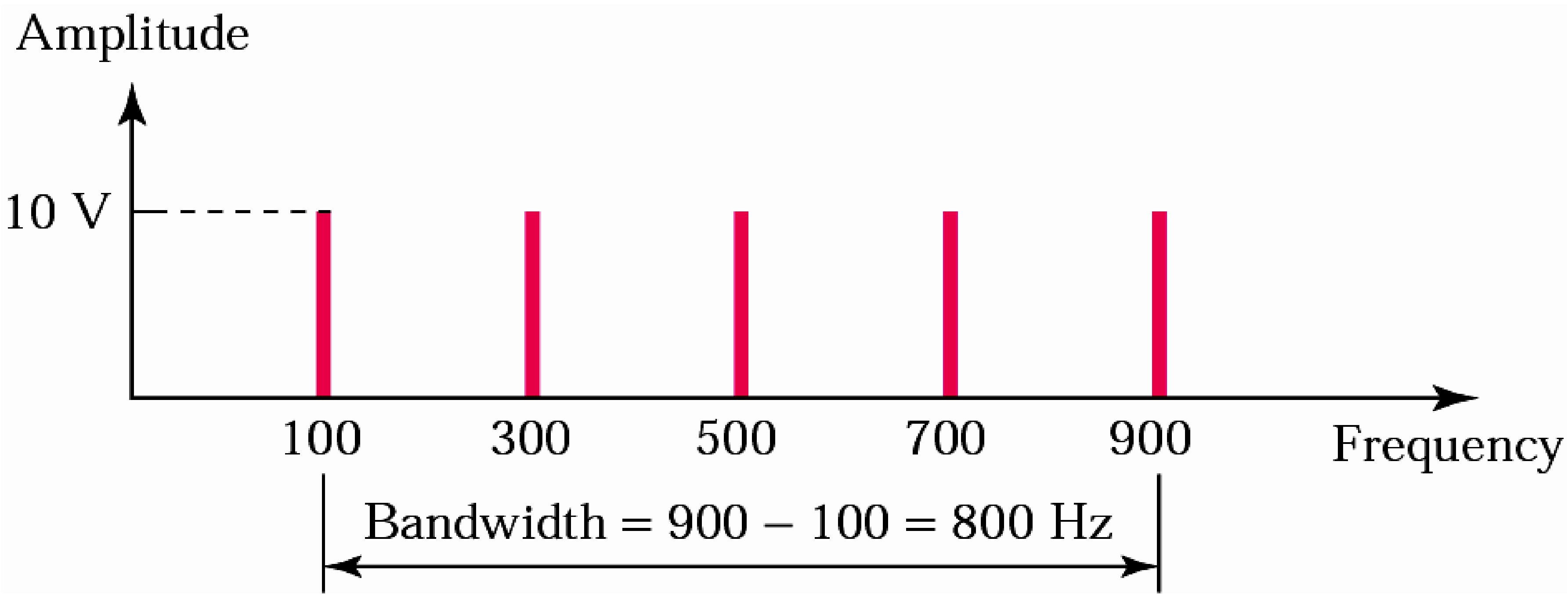
## *Example 3*

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

# Solution

$B = f_h - f_l = 900 - 100 = 800$ Hz

The spectrum has only five spikes, at 100, 300, 500, 700, and 900



# *Example 4*

A signal has a bandwidth of 20 Hz. The highest frequency is 60 Hz. What is the lowest frequency? Draw the spectrum if the signal contains all integral frequencies of the same amplitude.

# Solution

$B = f_h - f_l$

$20 = 60 - f_l$

$f_l = 60 - 20 = 40$ Hz