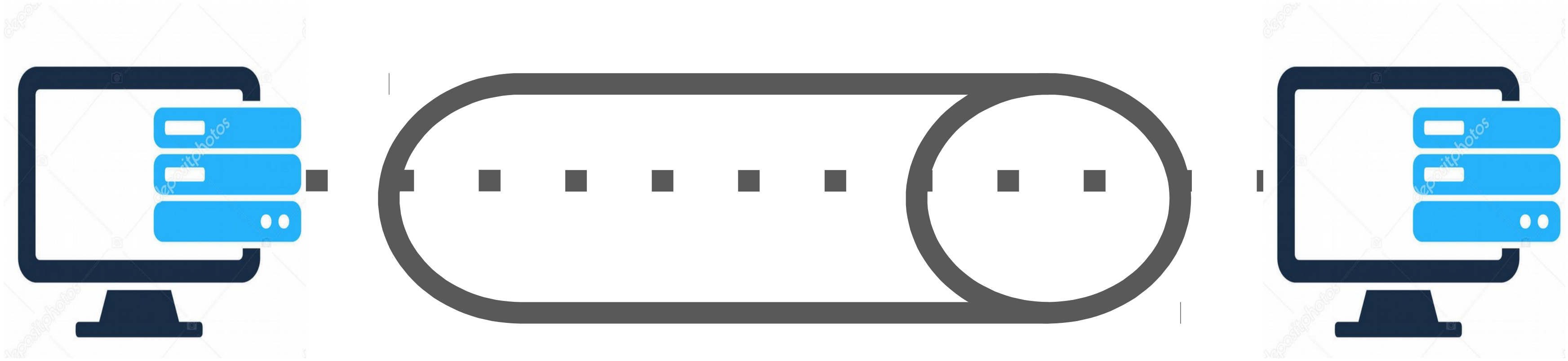
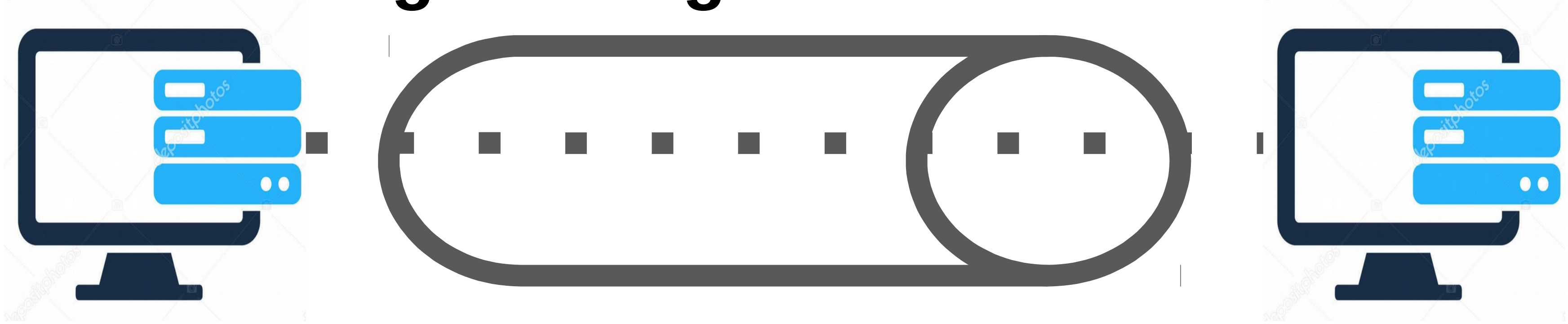
Introduction to digital communication

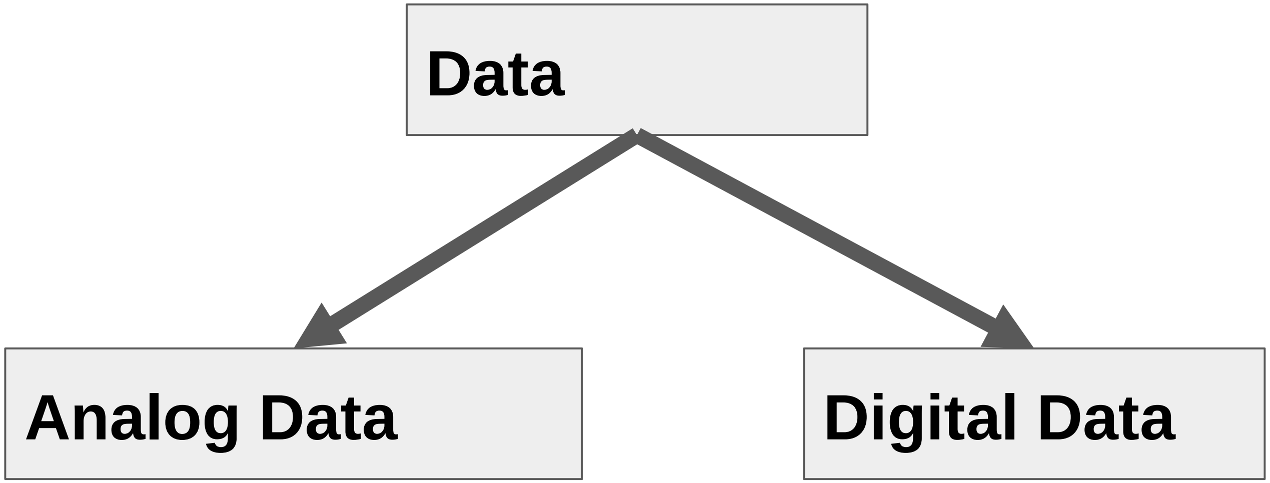


Transmission of **data** across network connections

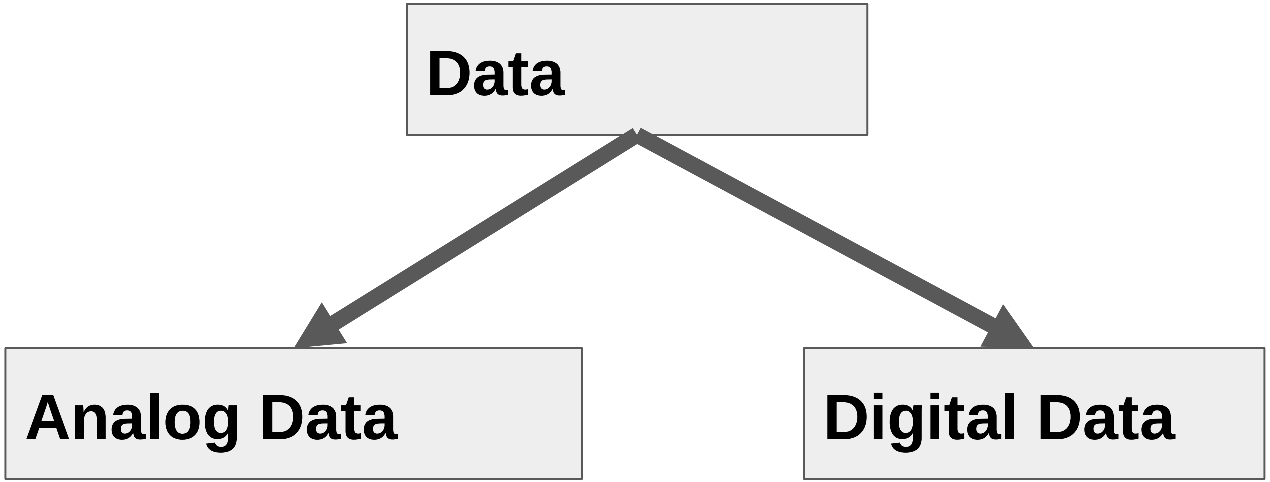
To be transmitted, data must be transformed to electromagnetic signals.



Transmission of **data** across network connections



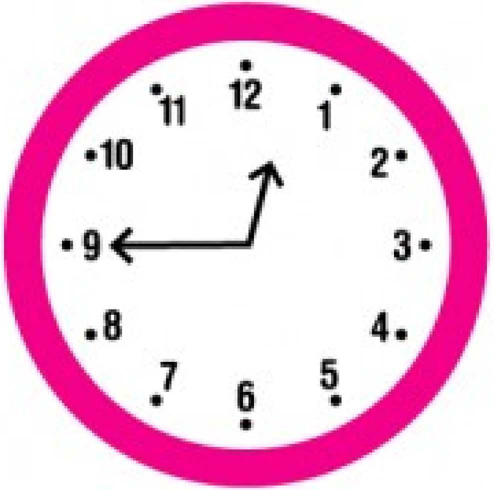
Data
Analog Data
Digital Data



Analog data refers to information that is continuous.

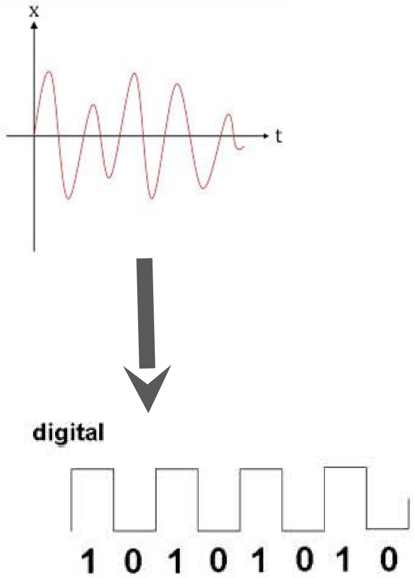
Digital data refers to information that has discrete states.

Digital



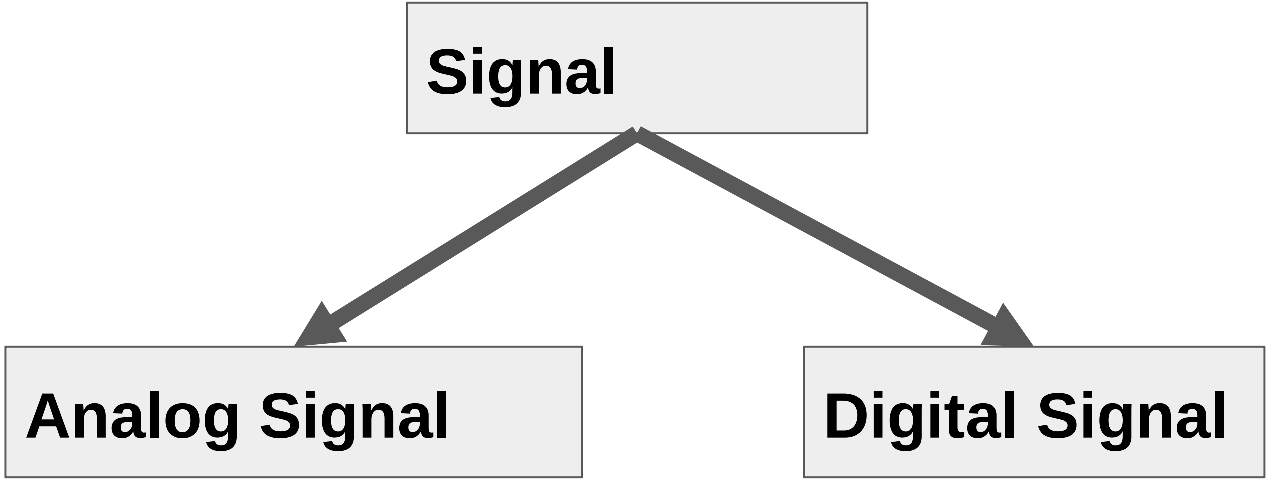
Analog

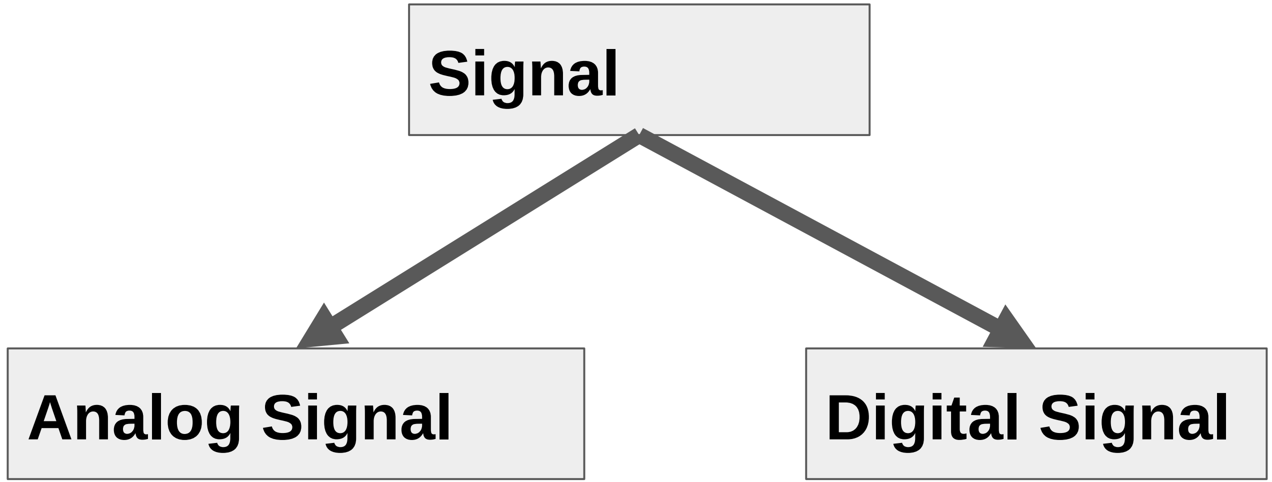
Analog wave



Data can be analog or digital.

- **Analog data are continuous and take continuous values.**
  Digital data have discrete states and take discrete values.

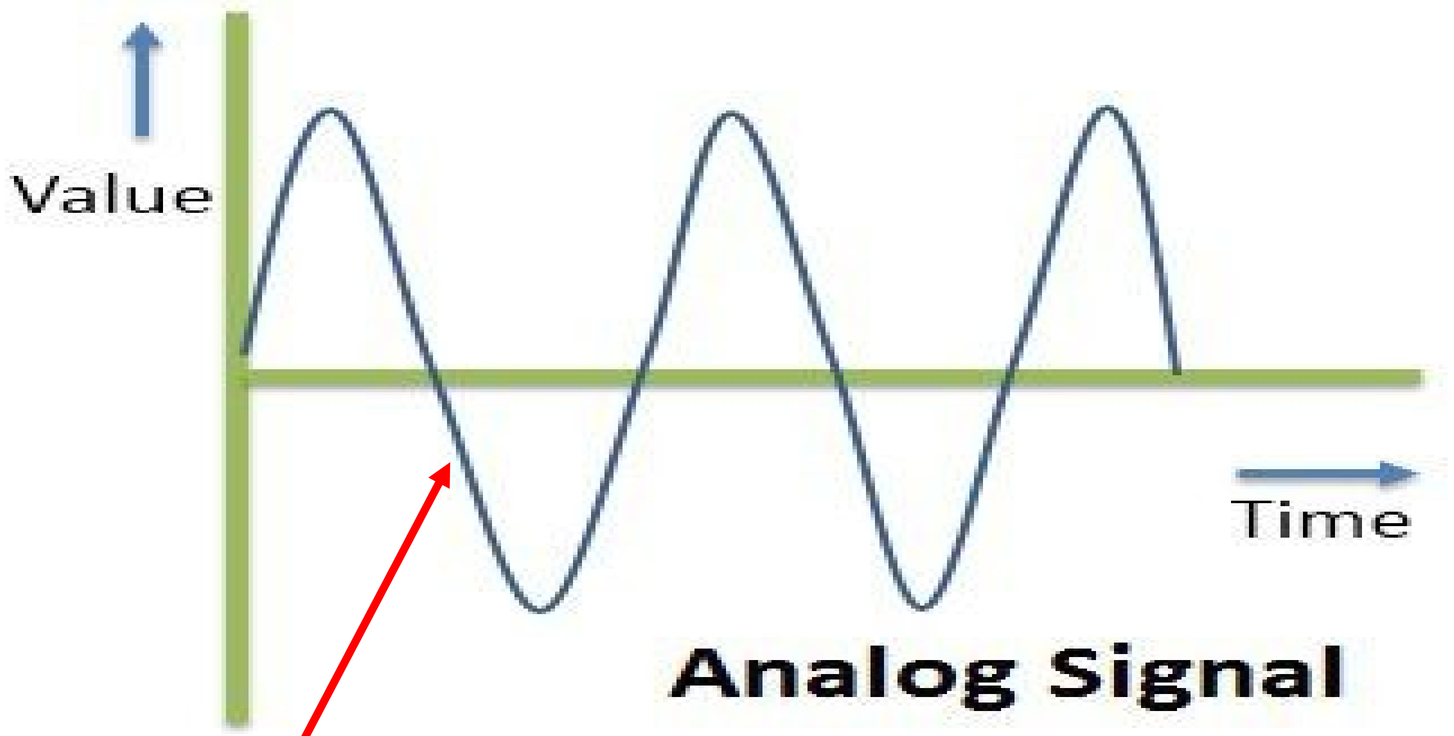

Signal
Analog Signal
Digital Signal



Analog signals can have an infinite number of values in a range

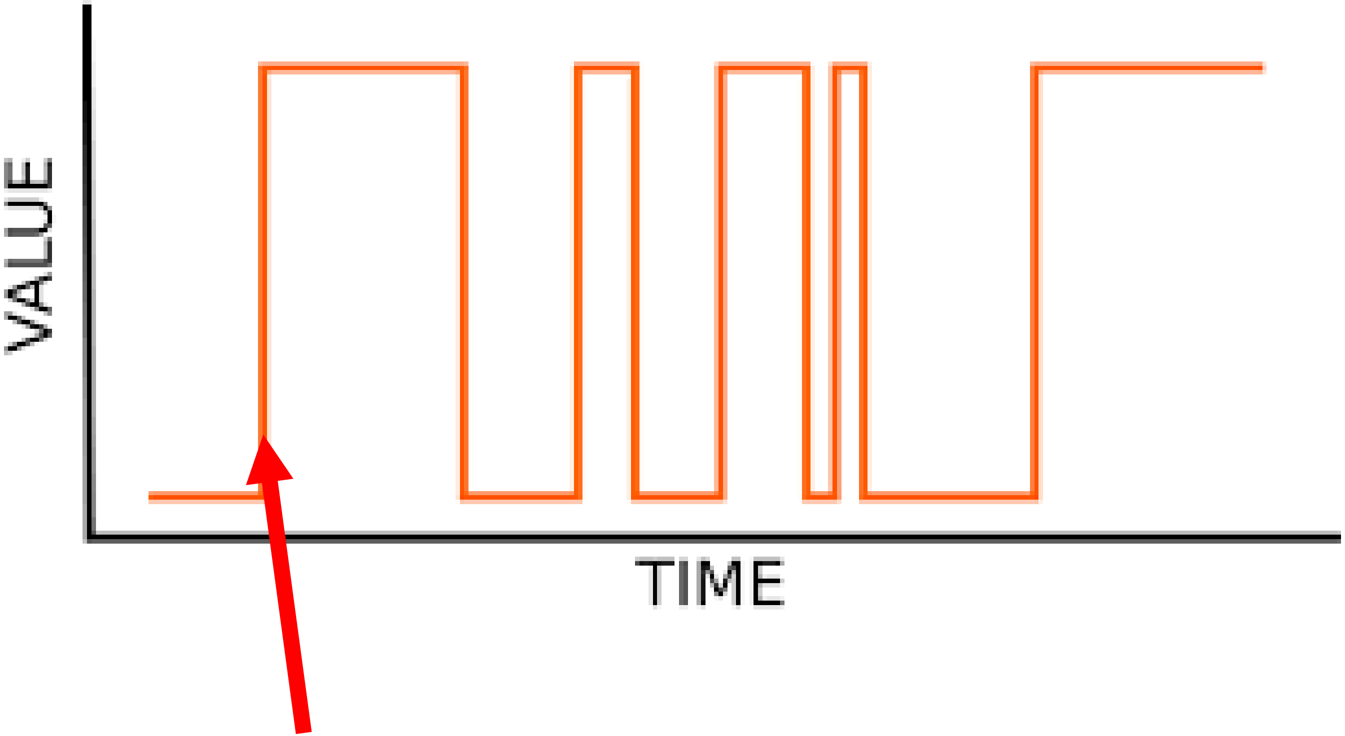
Digital signals can have only a limited number of values

Strength of a Signal

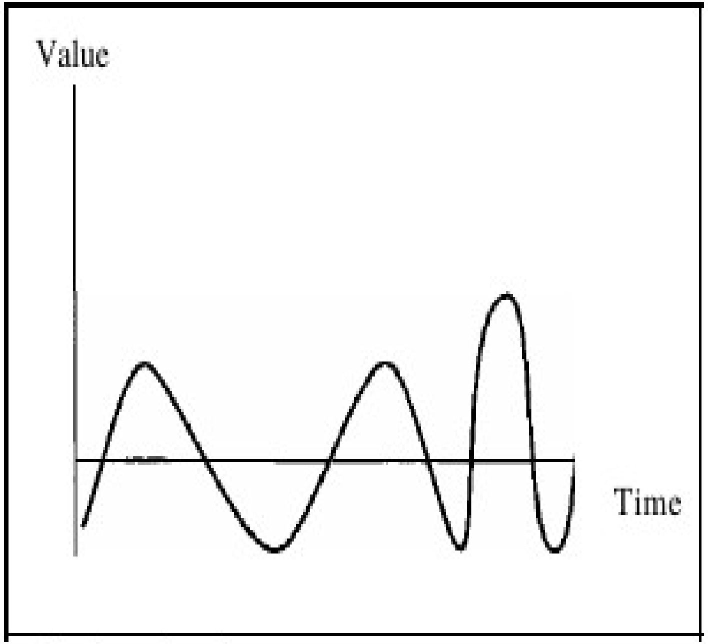


Infinite number of points

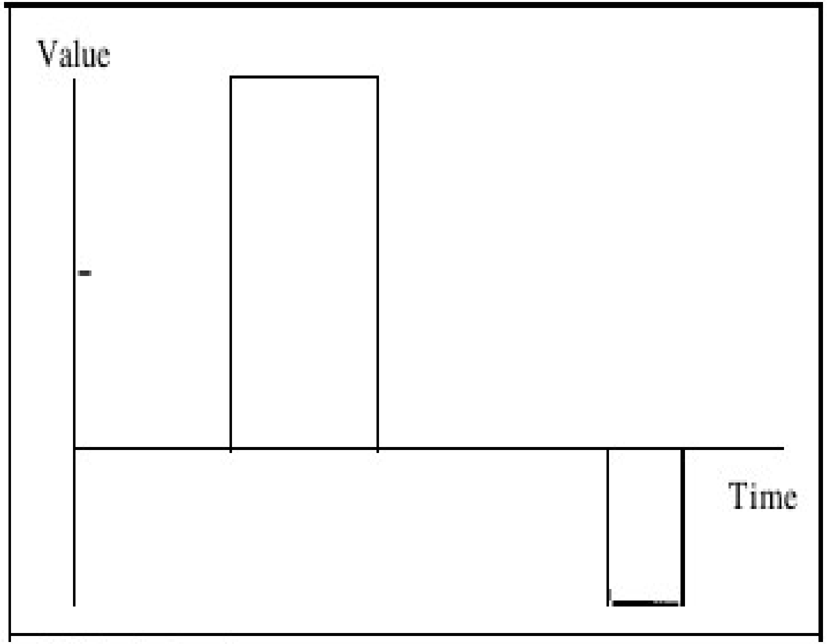
Strength of a Signal



Sudden jump that the signal makes from value to value



a. Analog signal



b. Digital signal

Analog and Digital Signal

Periodic

Non-periodic or Aperiodic

Analog and Digital Signal

Periodic

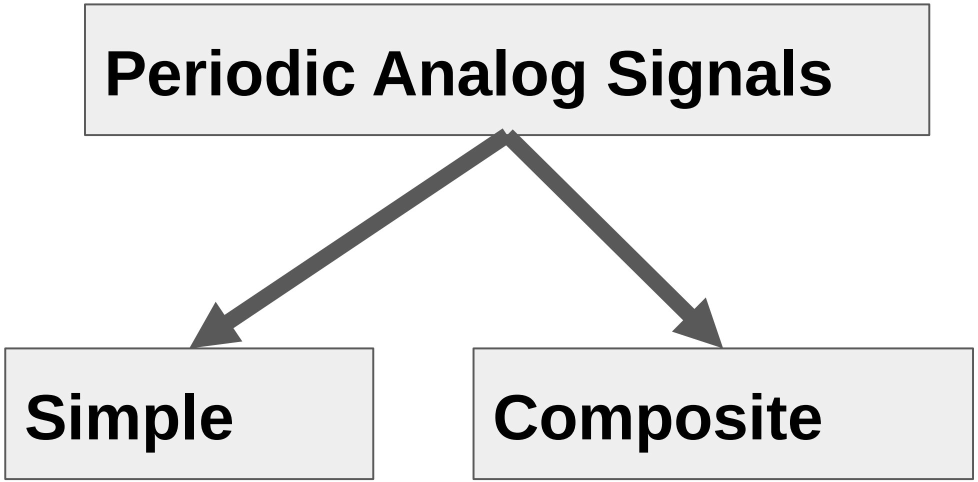
A periodic signal completes a pattern within a measurable time frame, called a period, and repeats that pattern over subsequent identical periods. The completion of one full pattern is called a cycle.

Non-periodic or Aperiodic

A nonperiodic signal changes without exhibiting a pattern or cycle that repeats over time.

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

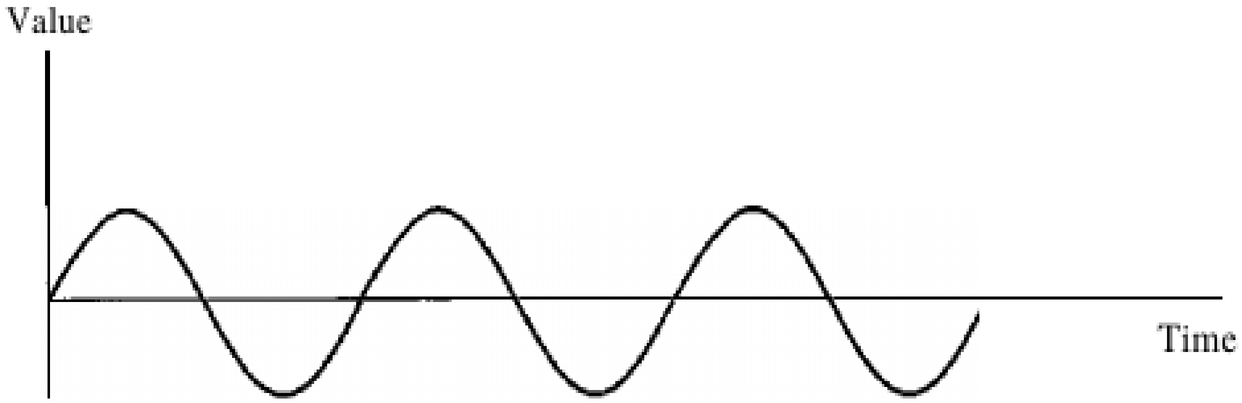
Periodic Analog Signals



Cannot be decomposed into simpler signals

Composed of multiple simpler signals

Sine Wave



Each cycle consists of a single arc above the time axis followed by a single arc below it.

Sine Wave

Each cycle consists of a single arc above the time axis followed by a single arc below it.

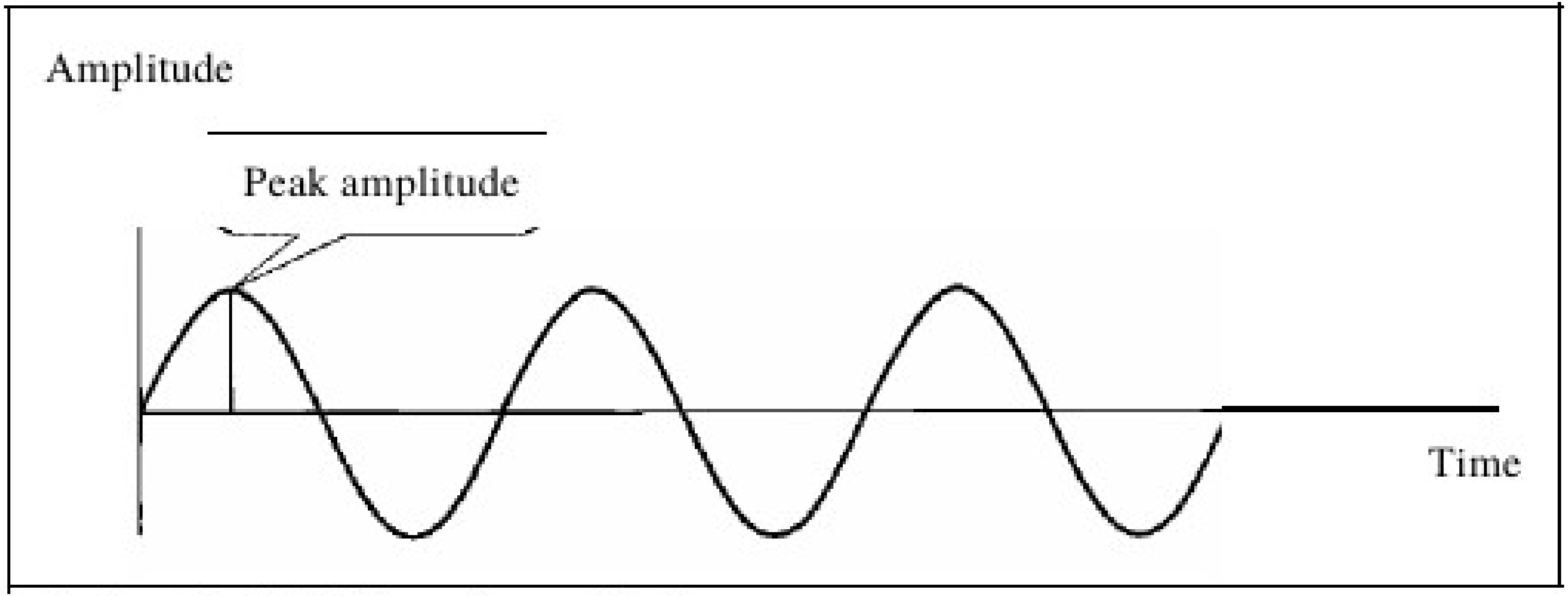
A sine wave can be represented by three parameters

Peak Amplitude **Frequency** **Phase**

Peak Amplitude

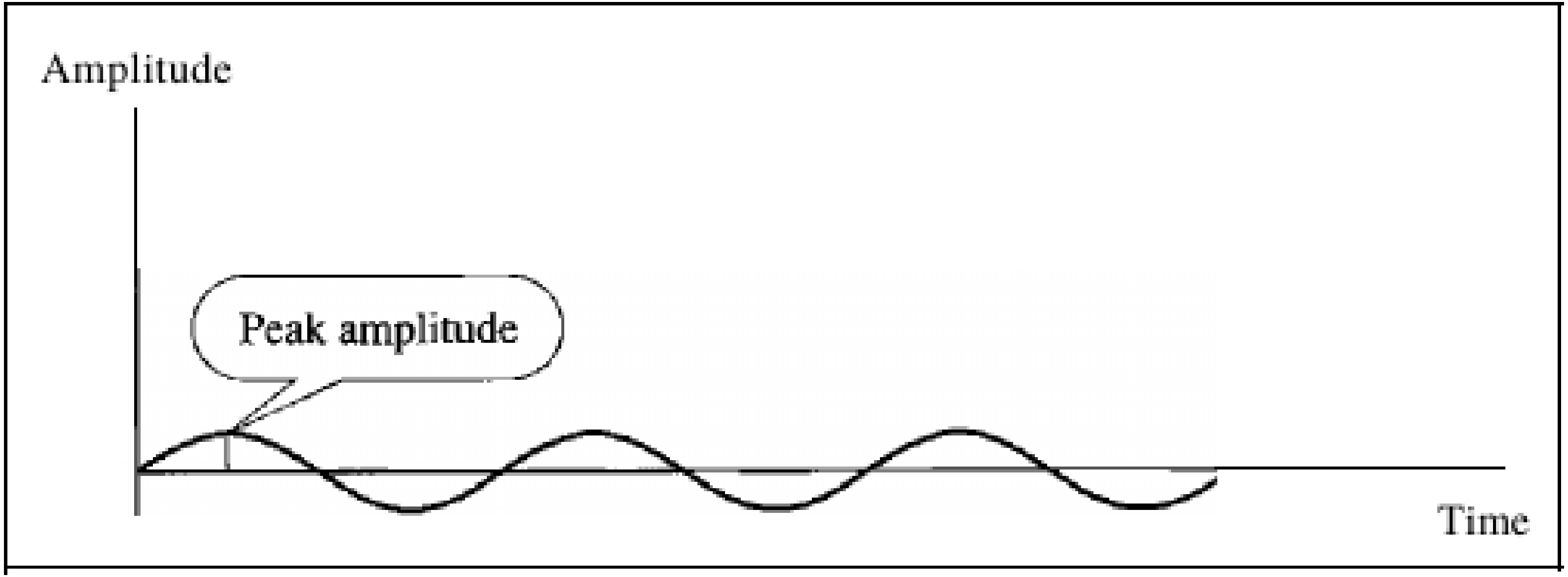
The peak amplitude of a signal is the absolute value of its highest intensity

Peak Amplitude



a. A signal with high peak amplitude

Peak Amplitude



b. A signal with low peak amplitude

Example

The power in your house can be represented by a sine wave with a peak amplitude of 155 to 170 V.

Pediod & Frequency

Period

Period refers to the amount of time, in seconds, a signal needs to complete 1 cycle.

Frequency

Frequency refers to the number of periods in unit time.

Period

Period refers to the amount of time, in

Period and frequency are just one characteristic defined in two ways.

Frequency

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Period

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Period and frequency are just one characteristic defined in two ways.

- Period is the inverse of frequency
- Frequency is the inverse of period

unit time.

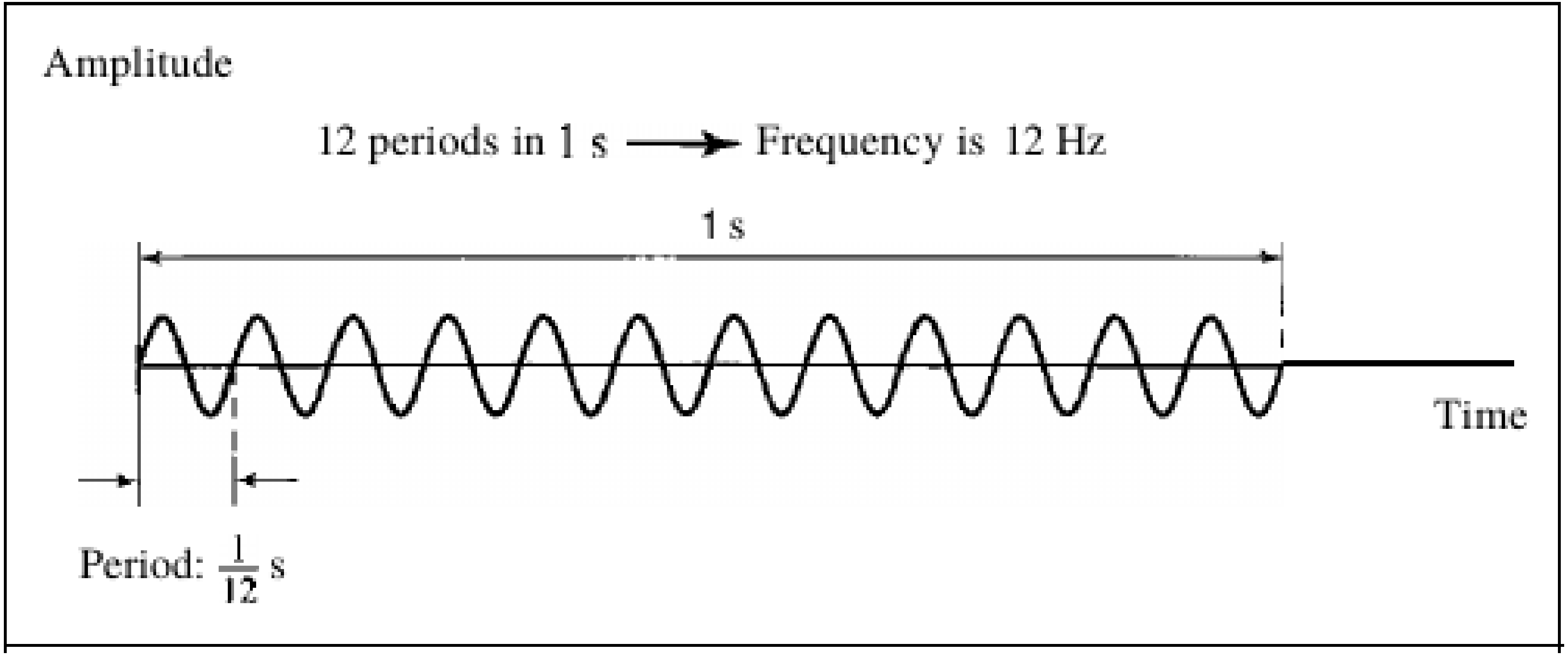
$f = 0.5$ Hz
$T = 2.0$ s

$f = 1.0$ Hz
$T = 1.0$ s

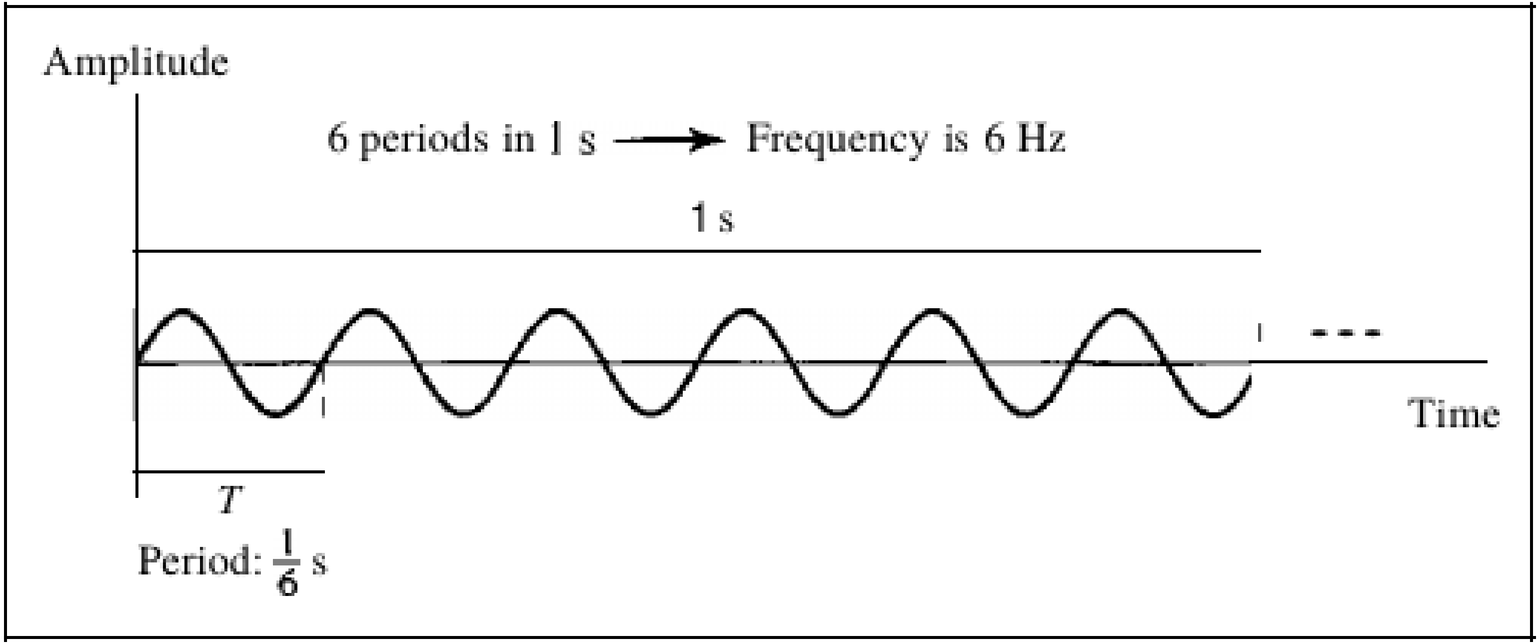
$f = 2.0$ Hz
$T = 0.5$ s

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

Frequency and period are the inverse of each other.



a. A signal with a frequency of 12 Hz



b. A signal with a frequency of 6 Hz

- Period is formally expressed in seconds.
  Frequency is formally expressed in Hertz (Hz), which is cycle per second.

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

Unit of Period and Frequency

Example

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

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

$$T = 0.0166 \text{ s}$$

Example

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

Example

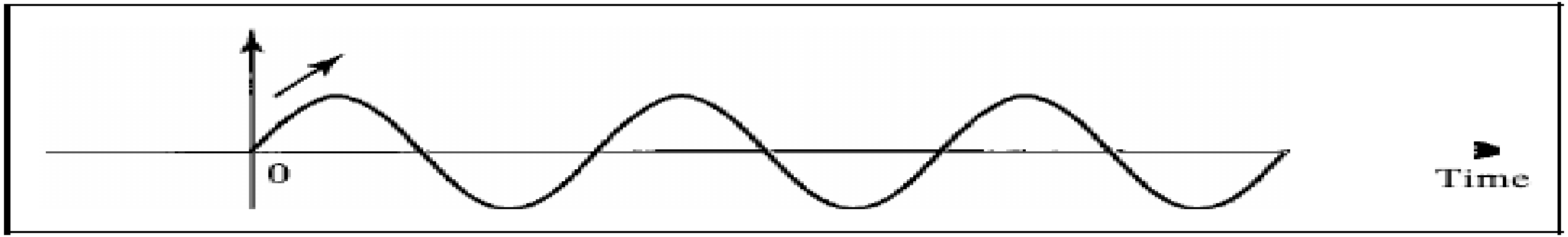
The period of a signal is 100 ms. What is its frequency in kilohertz?

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

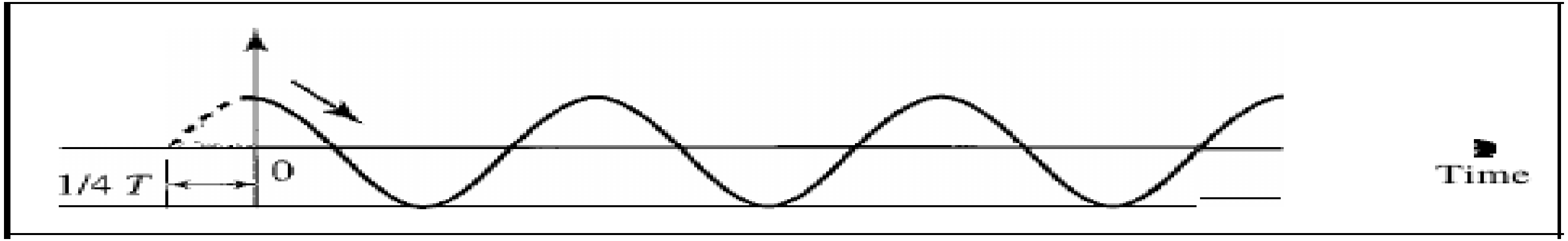
$$f = \frac{1}{T} = \frac{1}{10^{-1}} \text{ Hz} = 10 \text{ Hz} = 10 \times 10^{-3} \text{ kHz} = 10^{-2} \text{ kHz}$$

Phase

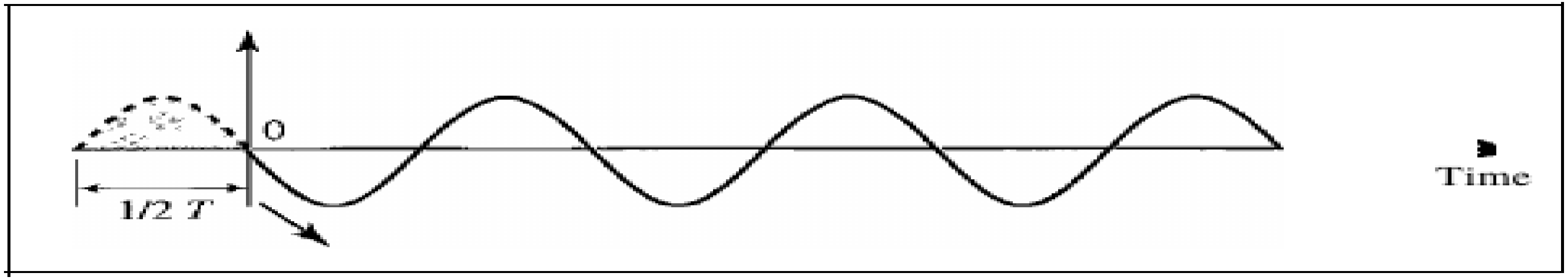
- The term phase describes the position of the waveform relative to time 0.
- It indicates the status of the first cycle.
- Phase is measured in degrees or radians



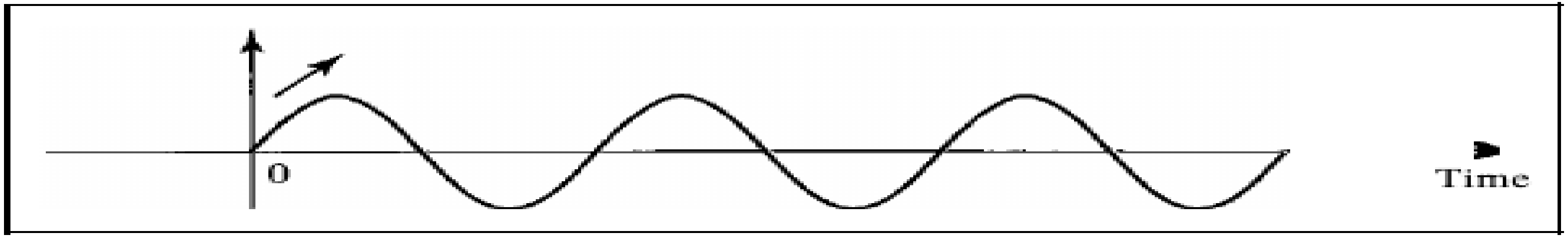
a. 0 degrees



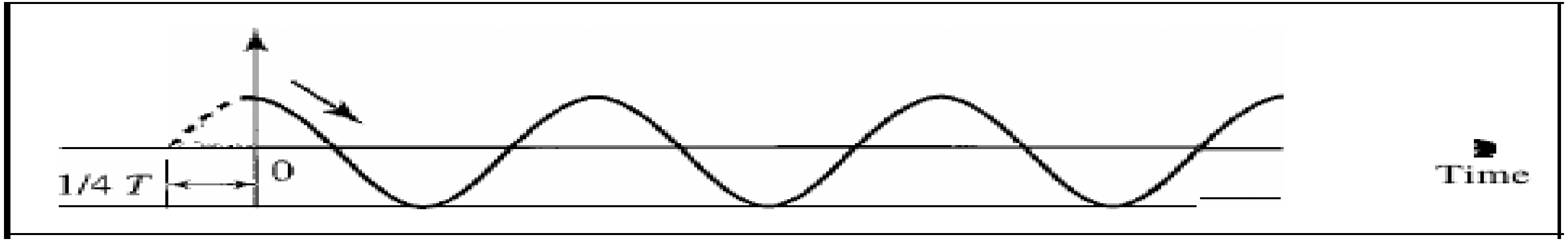
b. 90 degrees



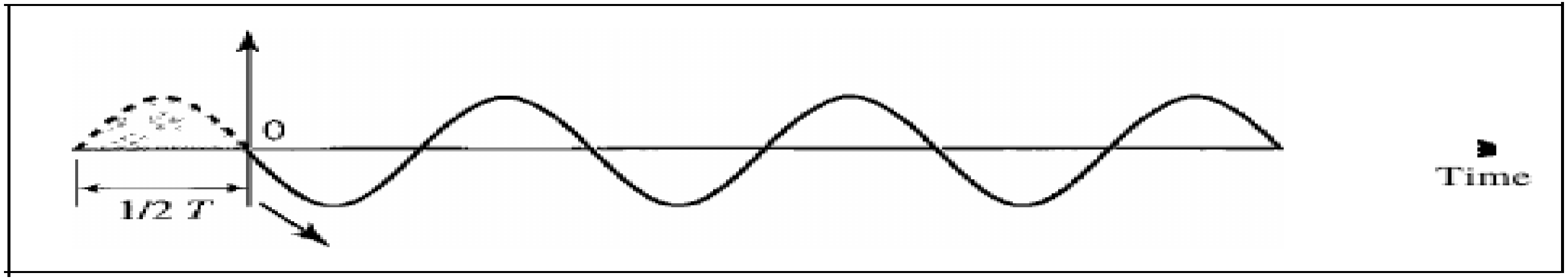
c. 180 degrees



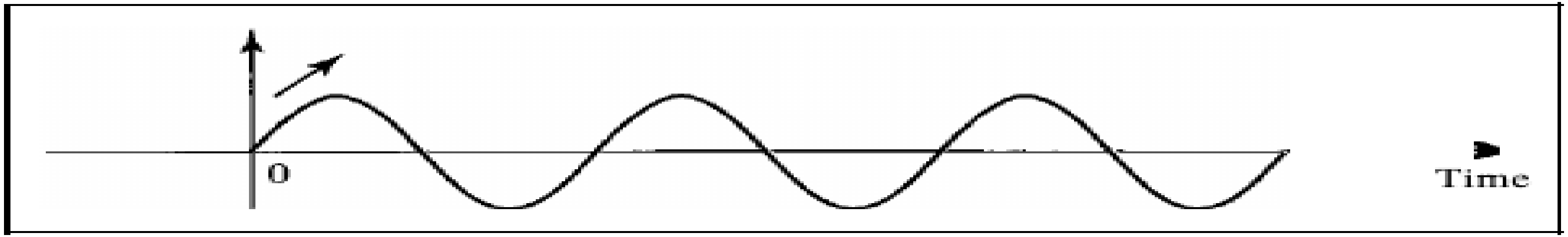
a. 0 degrees



b. 90 degrees

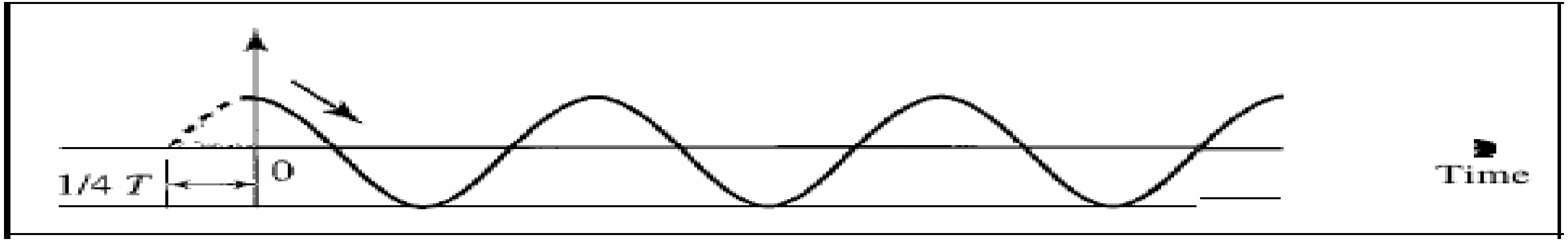


c. 180 degrees



a. 0 degrees

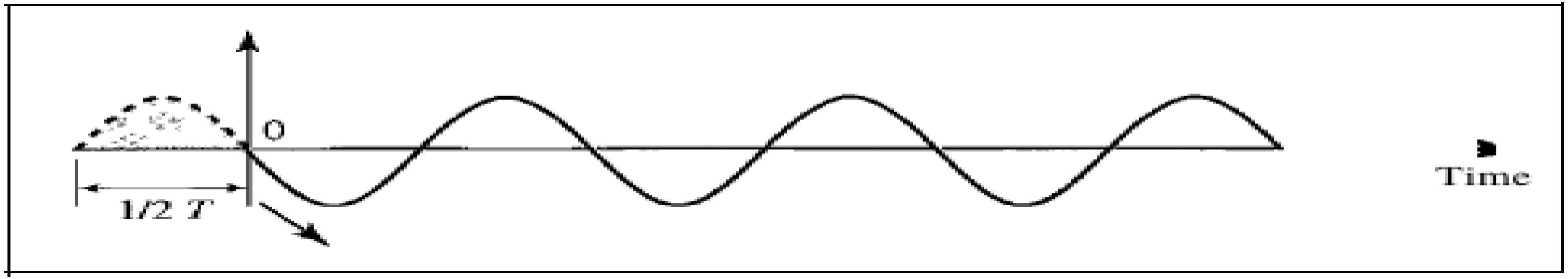
1. A sine wave with a phase of 0° starts at time 0 with a zero amplitude. The amplitude is increasing.



b. 90 degrees

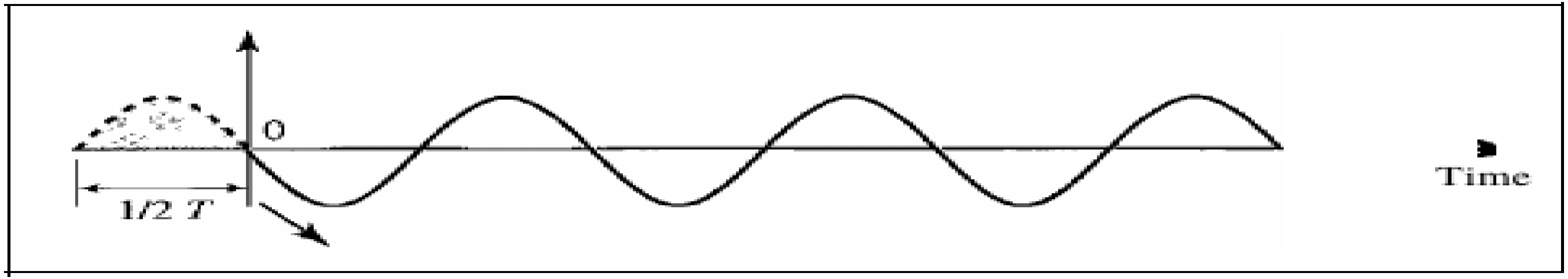
2. A sine wave with a phase of 90° starts at time 0 with a peak amplitude. The amplitude is decreasing.

3. A sine wave with a phase of 180° starts at time 0 with a zero amplitude. The amplitude is decreasing.

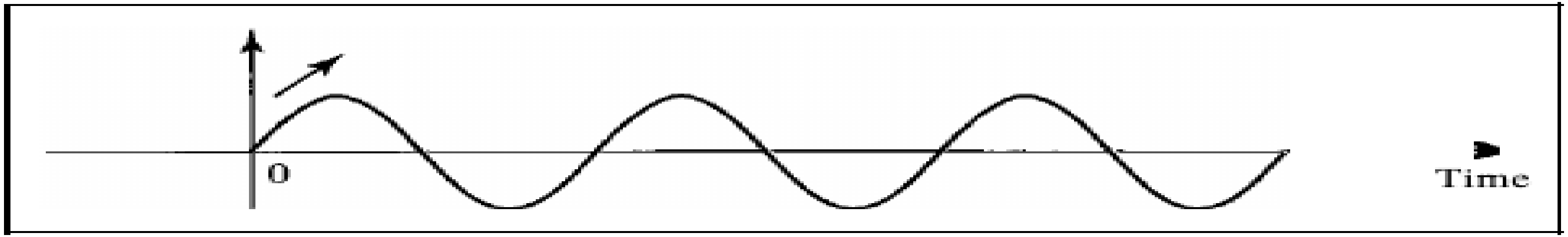


c. 180 degrees

3. A sine wave with a phase of 180° starts at time 0 with a zero amplitude. The amplitude is decreasing.



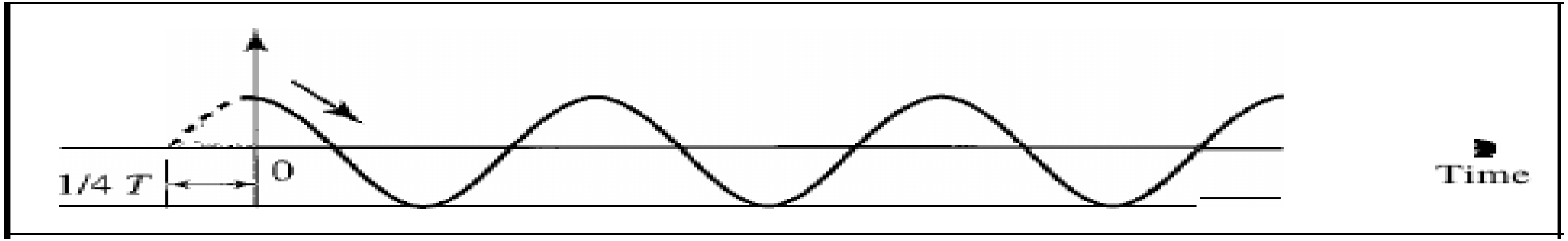
c. 180 degrees



a. 0 degrees

A sine wave with a phase of 0° starts at time 0 with a zero amplitude. The amplitude is increasing.

A sine wave with a phase of 0° is not shifted.



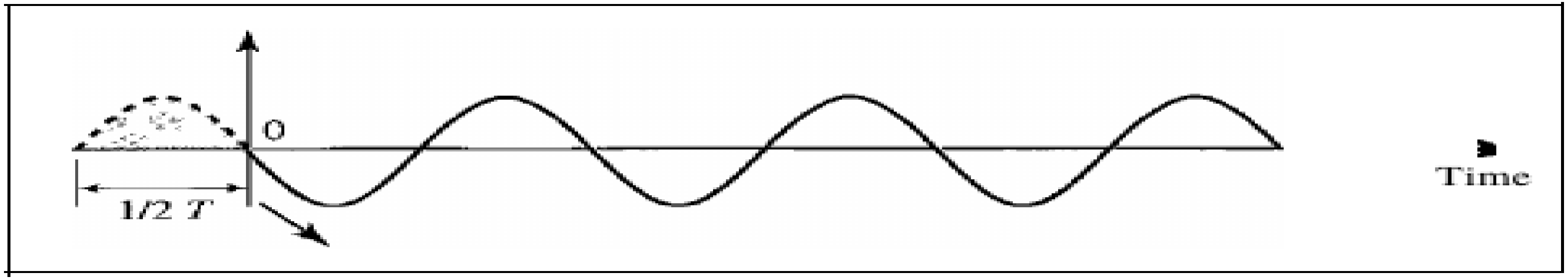
b. 90 degrees

A sine wave with a phase of 90° starts at time 0 with a peak amplitude. The amplitude is decreasing.

A sine wave with a phase of 90° is shifted to the left by 1/4 cycle. However, note that the signal does not really exist before time 0.

3. A sine wave with a phase of 180° starts at time 0 with a zero amplitude. The amplitude is decreasing.

3. A sine wave with a phase of 180° is shifted to the left by 1/2 cycle. However, note that the signal does not really exist before time 0.



c. 180 degrees

A sine wave is offset $\frac{1}{6}$ cycle with respect to time 0. What is its phase in degrees and radians?

Hint : radians = degrees × π / 180°

A sine wave is offset $\frac{1}{6}$ cycle with respect to time 0. What is its phase in degrees and radians?

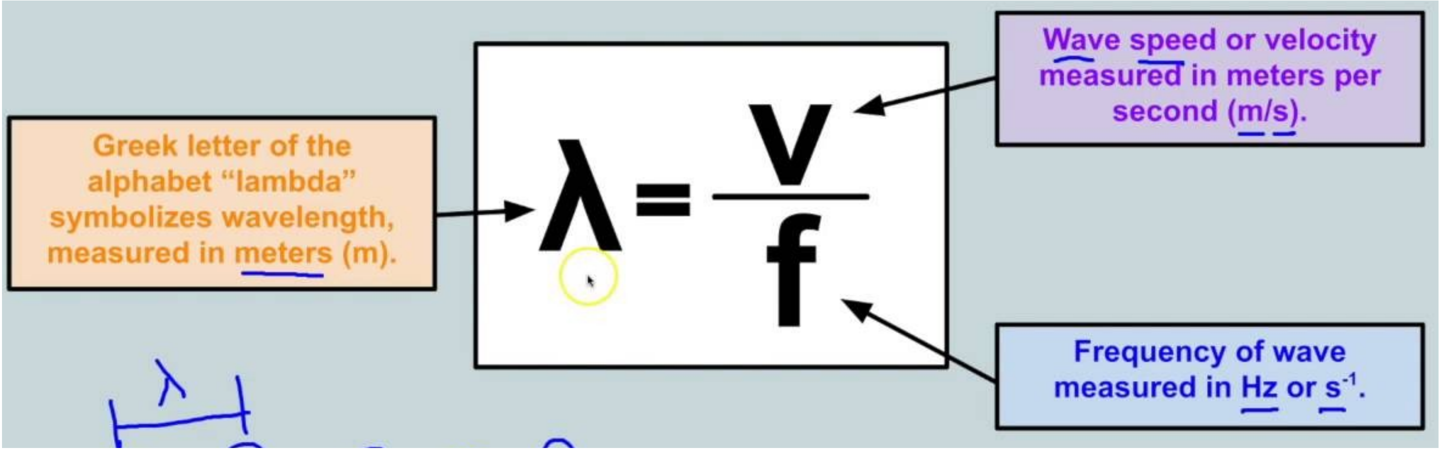
Hint : radians = degrees × π / 180°

Answer : 1.046 rad

WaveLength

The wavelength is the distance a simple signal can travel in one period.

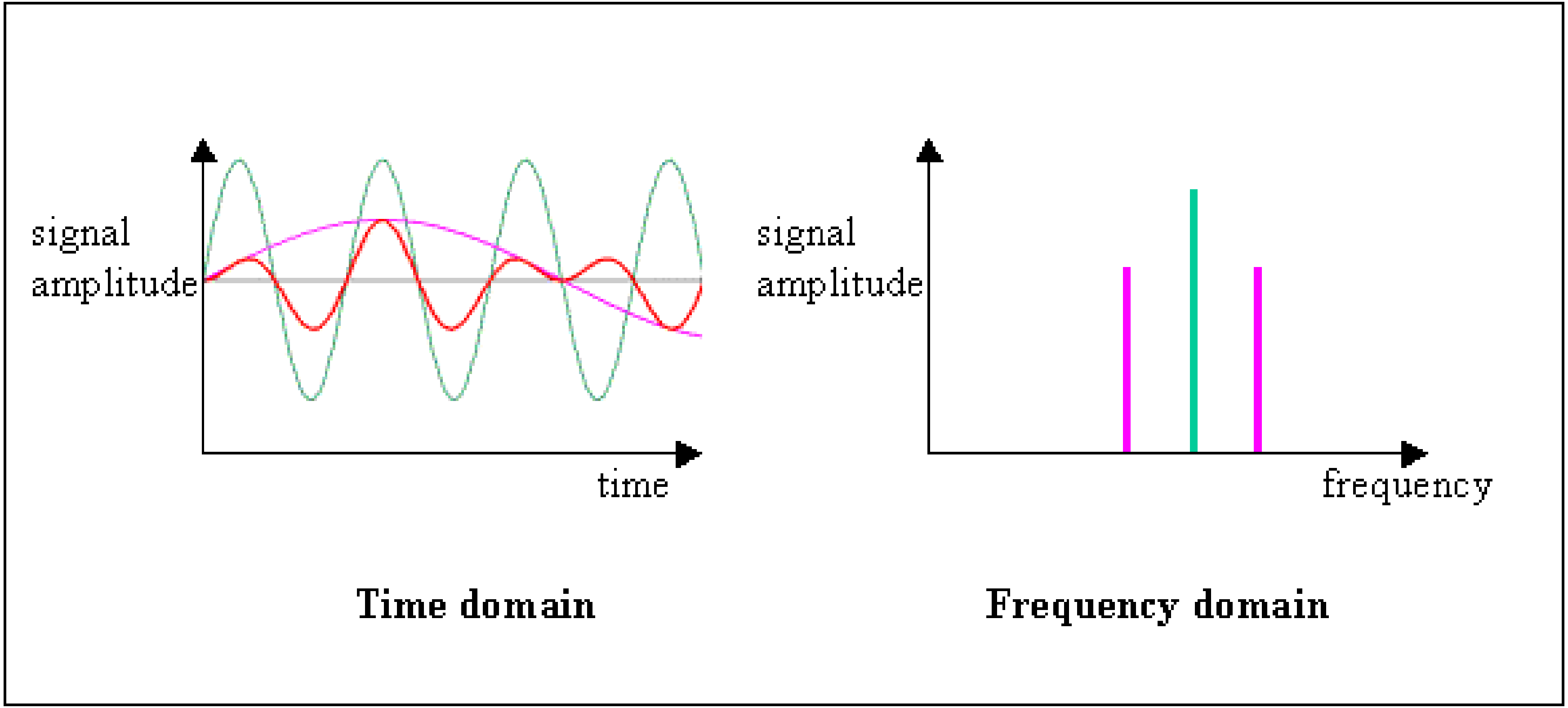
Wavelength can be calculated if one is given the propagation speed (the speed of light) and the period of the signal.



Time and Frequency Domains

- A sine wave is comprehensively defined by its amplitude, frequency, and phase : **time-domain plot**.

  Time-domain plot shows changes in signal amplitude with respect to time (it is an amplitude-versus-time plot). Phase is not explicitly shown on a time-domain plot.


signal amplitude
time
Time domain
signal amplitude
frequency
Frequency domain