INT 421 Digital Signal Processing

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Welcome

To the Digital Signal Processing Course
Code: INT 421

Fall Term 2023

TODAY

- Course information.
- Course Policy.
- Course objectives.
- Signal & System.
- Signal Processing.
- Basic Elements of a Signal Processing System.
- Advantages of Digital over Analogue Signal Processing.
- Signals and Its application.
- Analog vs. Digital Signals.
- Basic Operations on Signals.

Welcome to Digital Signal Processing Course

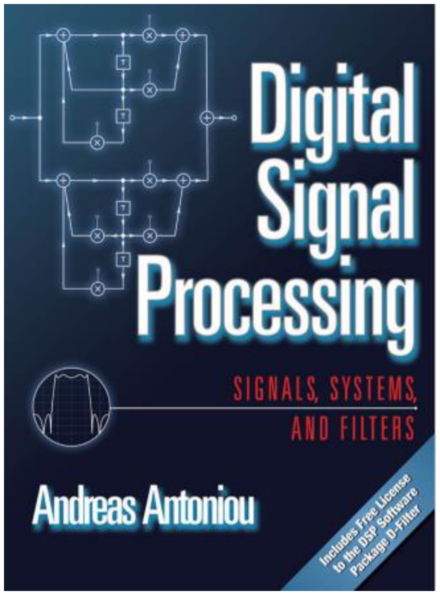
- **Important Course Information**

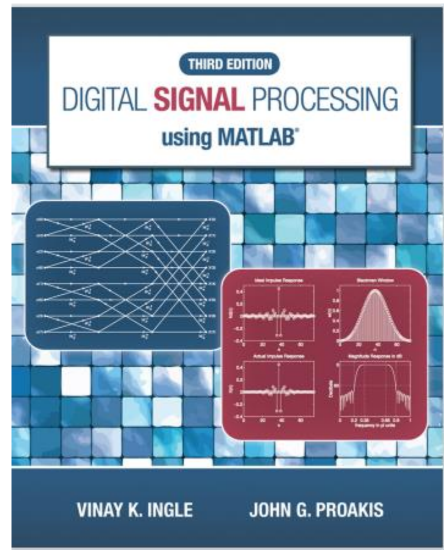
Group	Day	Hours	Locations
A	Sunday	11:20-13:00	B2214

Course objectives

- Learning the fundamental concepts of Digital Signal Processing, being able to apply Digital Signal Processing techniques to solve real-world problems, and using MATLAB to implement digital Signal processing algorithms.

Reference book





Book:
Digital Signal Processing Signal, systems, and Filters

Authors:
Andreas Antoniou

Book:
Digital Signal Processing using MATLAB, 3rd Edition

Authors:
Vinay K. Ingle John G. Proakis

Course Policy

- **Grading:**
  - 5% Course Work (CW)
  - 10% Oral/Practical

    15%
  - 25% on one Term Exam (T.E).
  - 60% on the Final Exam (F.E).
  - **100% Total Mark**
  - **TALKING** and **SLEEPING** are strongly forbidden during class.
  - **Late assignments**
  - **Plagiarism**

Tools

1. MATLAB software

   https://www.mathworks.com/products/matlab.htm

2. GNU Octave - Packages

   — https://octave.org/download#ms-windows
     - Installing octave package
     - In the terminal write: pkg install -forge package_name

   — https://gnu-octave.github.io/packages/signal/
     - Loading octave package in the command window or program
     - In the octave command window write: pkg load package_name

Lecture #1

Introduction
Basic Concepts of Digital Signal Processing (DSP)

Signal & System

- **Signal**
  - A signal is defined as a function of one or more variables that convey information on the nature of a physical phenomenon. The value of the function can be a real-valued scalar quantity, a complex-valued quantity, or perhaps a vector.
- **System**
  - A system is defined as an entity that manipulates one or more signals to accomplish a function, thereby yielding new signals.

Signals

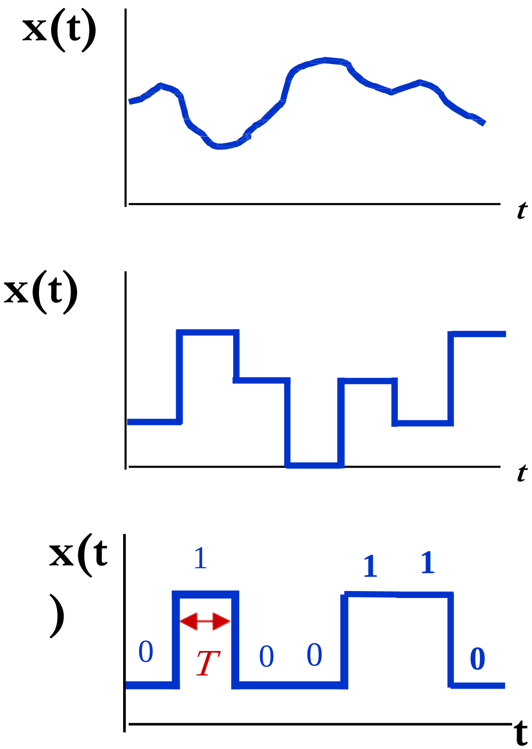
- In our generalized definition of a signal, there may be more than one independent variable and the independent variables may be any quantity other than time.
- For example, a digitized image may be thought of as light intensity that depends on two independent variables, the distances along the x and y axes; as such a digitized image is, in effect, a 2-dimensional signal.
- A video signal is made up of a series of images that change with time; thus a video signal is light intensity that depends on the distances along the x and y axes and also on the time; in effect, a video signal is a 3-dimensional signal.
- Some signals arise naturally, others are man-made.

Signals Cont'd

- Two general classes of signals can be identified:
  - Continuous-time signals
  - Discrete-time signals

Analog vs. Digital Signals

- Signals can be analog or digital.
- Analog signals can have an infinite number of values in a certain range (continuous values).
- Digital signals can have only a limited number of values (discrete values).
- Binary signals
  - Have 2 values
  - Used to represent bit values
  - Bit time T needed to send 1 bit
  - Data rate R=1/T bits per second

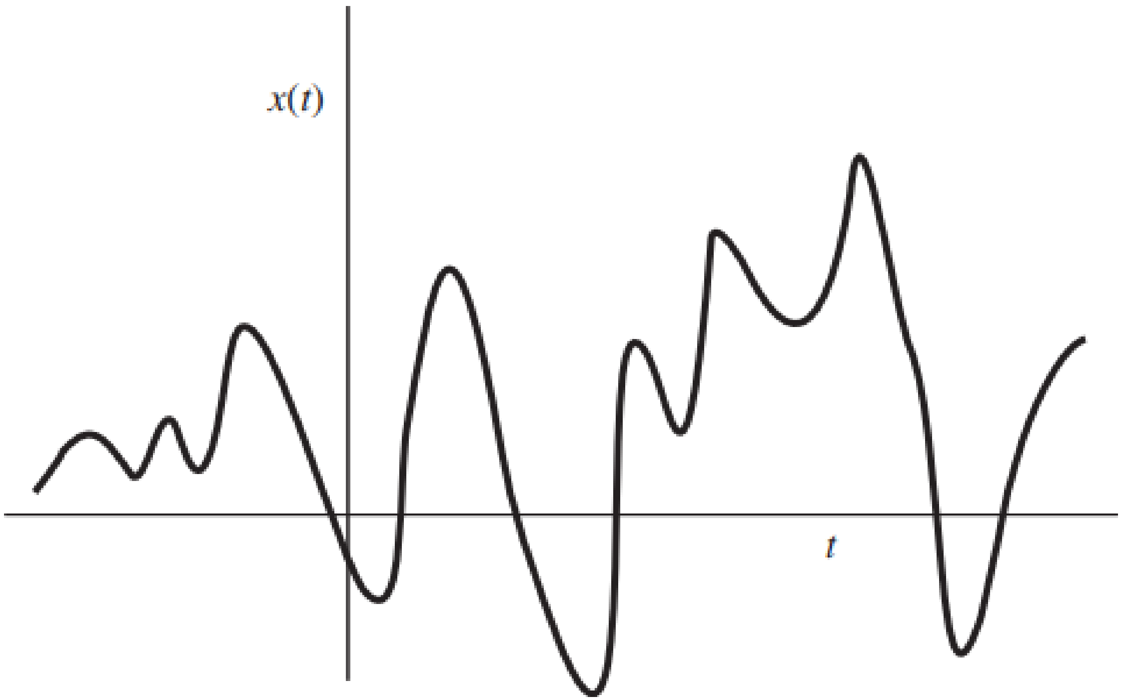


Continuous-Time Signals

- A continuous-time signal is a signal that is defined at each and every instant of time.
- Typical examples are:
  - The sound wave produced by a dolphin.
  - The ambient temperature.
  - The light intensity along the x and y axes in a photograph
- A continuous-time signal can be represented by a function:

$$x(t) \text{ where } -\infty < t < \infty$$

Continuous-Time Signals Cont'd



Discrete-Time Signals cont'd

- A discrete-time signal is a signal that is defined at discrete instants of time.
- Typical examples are:
  - The daily temperature of a patient as recorded by a nurse.
  - The daily precipitation.

Discrete-Time Signals Cont'd

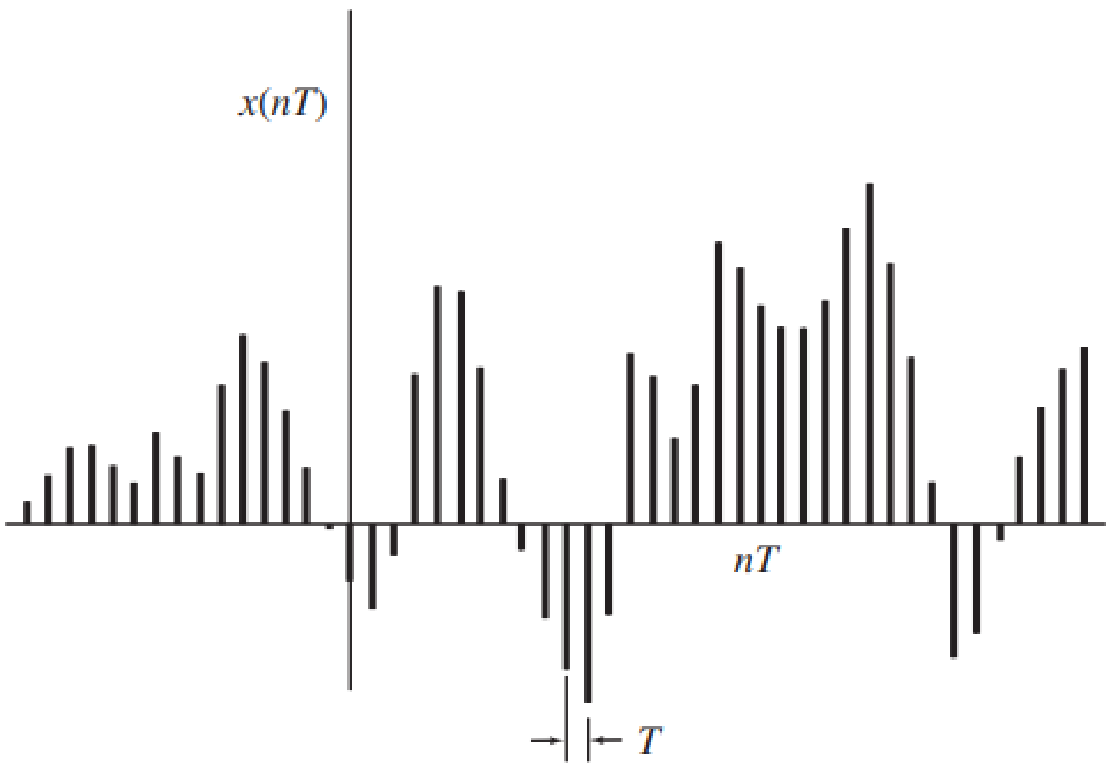
- A discrete-time signal can be represented as a function:

$$x(nT) \text{ where } -\infty<n<\infty$$

and T is a constant.

- The quantity x (nT) can represent a voltage or current level or any other quantity.
- In DSP, x (nT) always represents a series of numbers.
- Constant T usually represents time but it could be any other physical quantity depending on the application.

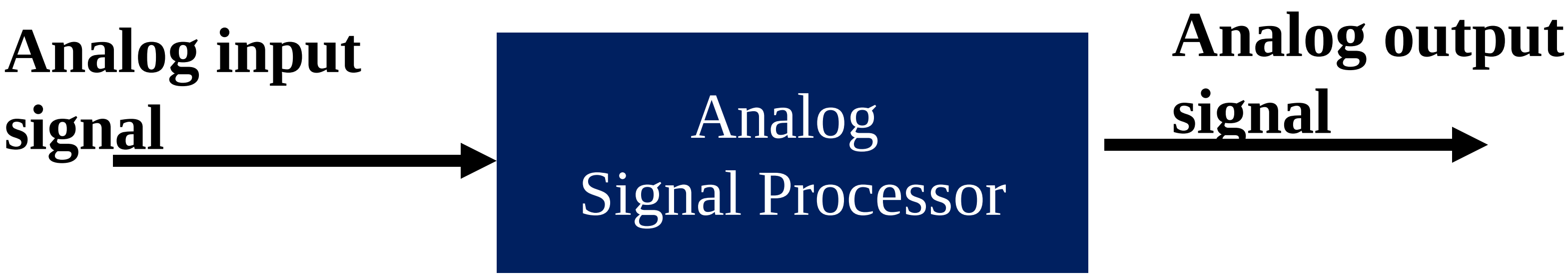
Discrete-Time Signals Cont'd



Signal Processing:

- A system characterized by the type of operation that it performs on the signal.
- For example
  - if the operation is linear, the system is called linear.
  - If the operation is non-linear, the system is said to be non-linear, and so forth.
- Such operations are usually referred to as "Signal Processing".

Basic Elements of a Signal Processing System



Analog Signal Processing

Digital Signal Processing

Advantages of Digital over Analogue Signal Processing

- A digital programmable system allows flexibility in reconfiguring the DSP operations simply by changing the program. Reconfiguration of an analog system usually implies a redesign of hardware, testing, and verification that it operates properly.
- DSP provides better control of accuracy requirements.
- Digital signals are easily stored on magnetic media (tape or disk).
- The DSP allows for the implementation of more sophisticated signal-processing algorithms.
- In some cases, a digital implementation of the signal processing system is cheaper than its analog counterpart.

Signals and Its application

- Natural signals are found, for example, in:
  - Acoustics, e.g., speech signals, sounds made by dolphins and whales
  - Biology, e.g., signals produced by the brain and heart
  - Seismology, e.g., signals produced by earthquakes and volcanoes
  - Physical sciences, e.g., signals produced by lightning, the room temperature, the atmospheric pressure

Signals and Its application, Cont.

- Man-made signals are found in:
  - Audio systems, e.g., music signals
  - Communications, e.g., radio, telephone, TV signals
  - Telemetry, e.g., signals originating from weather stations and satellites
  - Control systems, e.g., feedback control signals
  - Medicine, e.g., electrocardiographs, X-rays, magnetic resonance imaging
  - Space technology, e.g., the velocity of a spacecraft.

Simple vs. Composite Signal

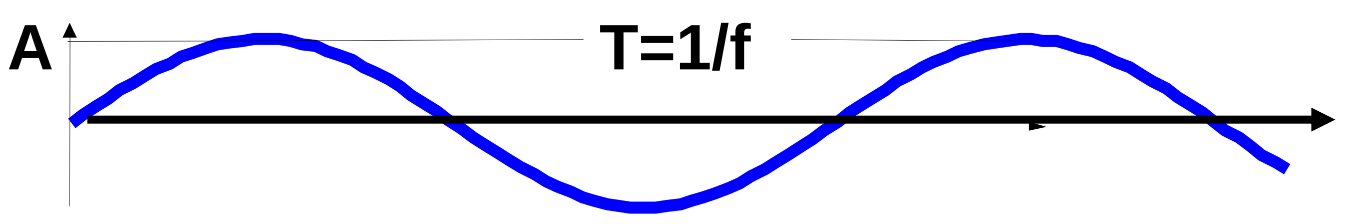
- Any signal can be classified as simple or composite.
- A simple signal is the sine wave. It cannot be decomposed into simpler signals.
- A composite signal is composed of multiple sine waves.

Continuous Time Sinusoidal Signals

- A simple harmonic oscillation is mathematically described as

$$x(t) = A*\cos*(w*t + \theta)$$

- This signal is completely characterized by three parameters: A = amplitude, $w = 2\pi f$ = frequency in rad/s, and θ = phase in radians.



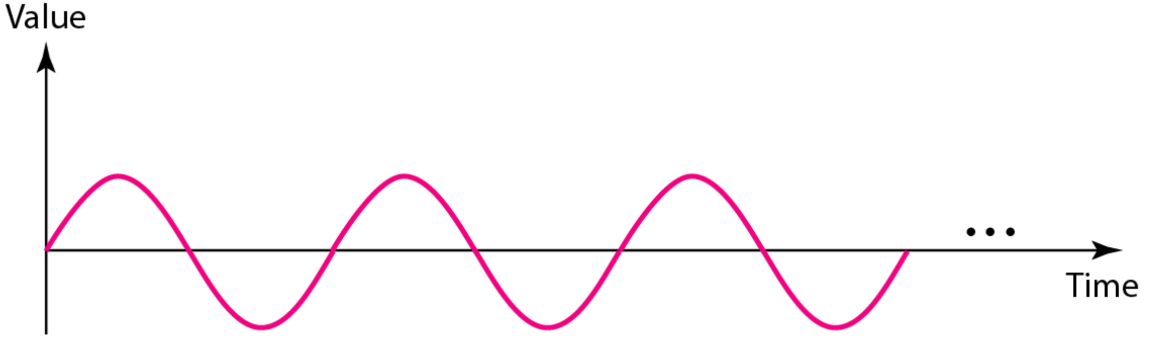
Periodic and Non-periodic Signals

- A signal x(t) is called periodic in time if there exists a constant $T_0 > 0$ such that

$$\boxed{x(t) = x(t + T_0) \quad \text{for} \quad -\infty < t < \infty}$$

- Where t denotes time and T_0 is the period of $x(t)$.

- A sine wave is an example of a periodic signal:



Description of Sine Wave

- A sine wave can be described using the following formula

$$\boxed{x(t) = A\sin(2\pi ft + \theta)}$$

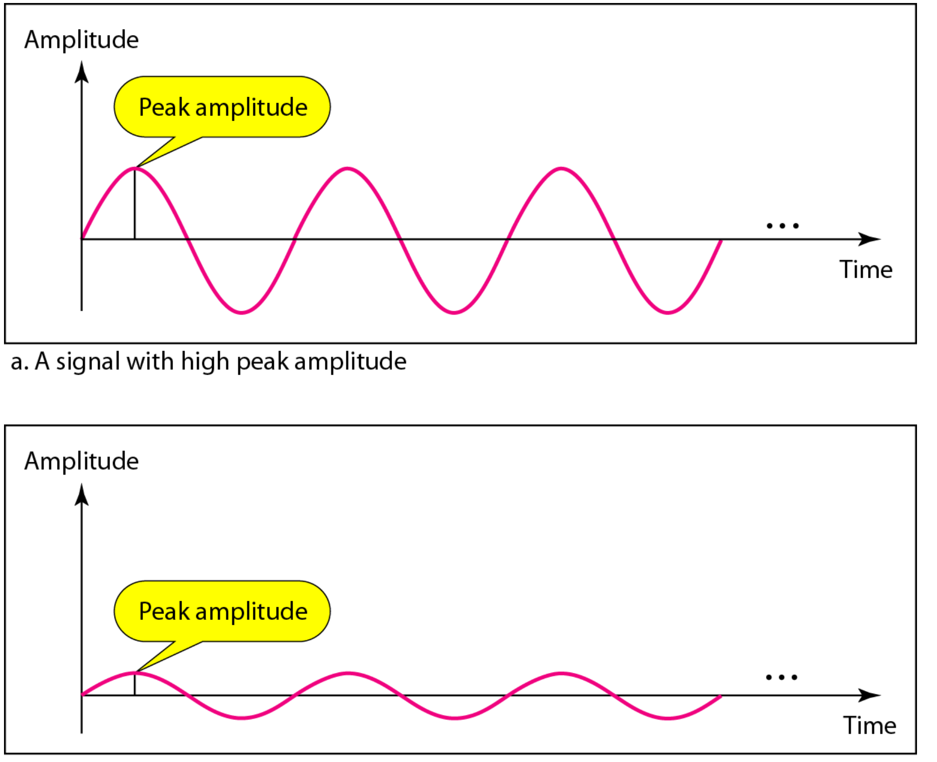
- Where
  - Amplitude
  - Frequency
  - Phase

Amplitude

- A signal is absolute of its high intensity.
- It is proportional to the energy it carries

$$x(t) = A\sin(2\pi ft + \theta)$$

$$\begin{aligned} A &: \text{amplitude} \\ f &: \text{frequency} \\ \theta &: \text{phase shift} \end{aligned}$$



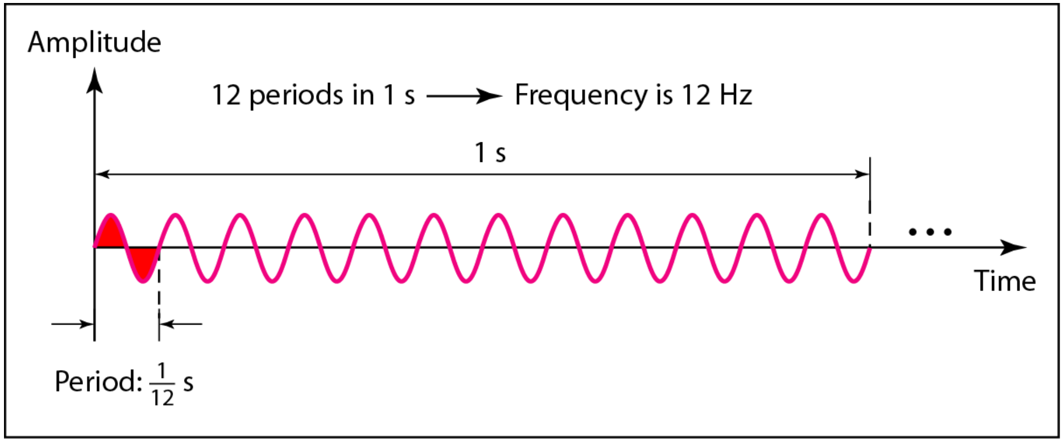
a. A signal with high peak amplitude
b. A signal with low peak amplitude

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

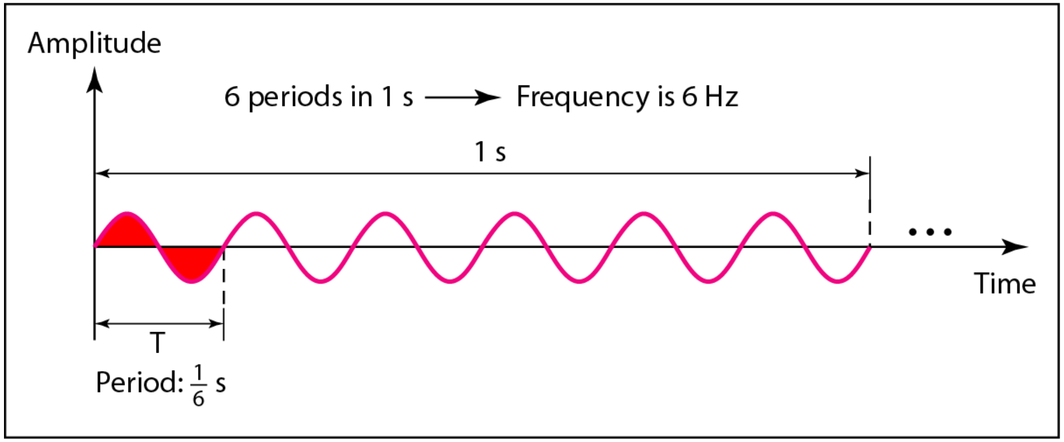
Frequency

- Period is the amount of time taken by the signal to complete its one cycle (second)
- Frequency is the number of cycles per second (Hz).

The 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

Frequency

- Frequency expresses how quick the signal is changing with time.
  - Fast change means high frequency.
  - Slow change means low frequency.
- If a signal does not change at all, its frequency is *zero*.
- If a signal changes instantaneously (contains edges), its frequency is *infinite*.

Frequency and Period

Frequency and period are the inverse of each other.

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

Table 3.1 ***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

Example 3.1

The power we use at home has a frequency of 50 Hz. The period of this sine wave can be determined as follows:

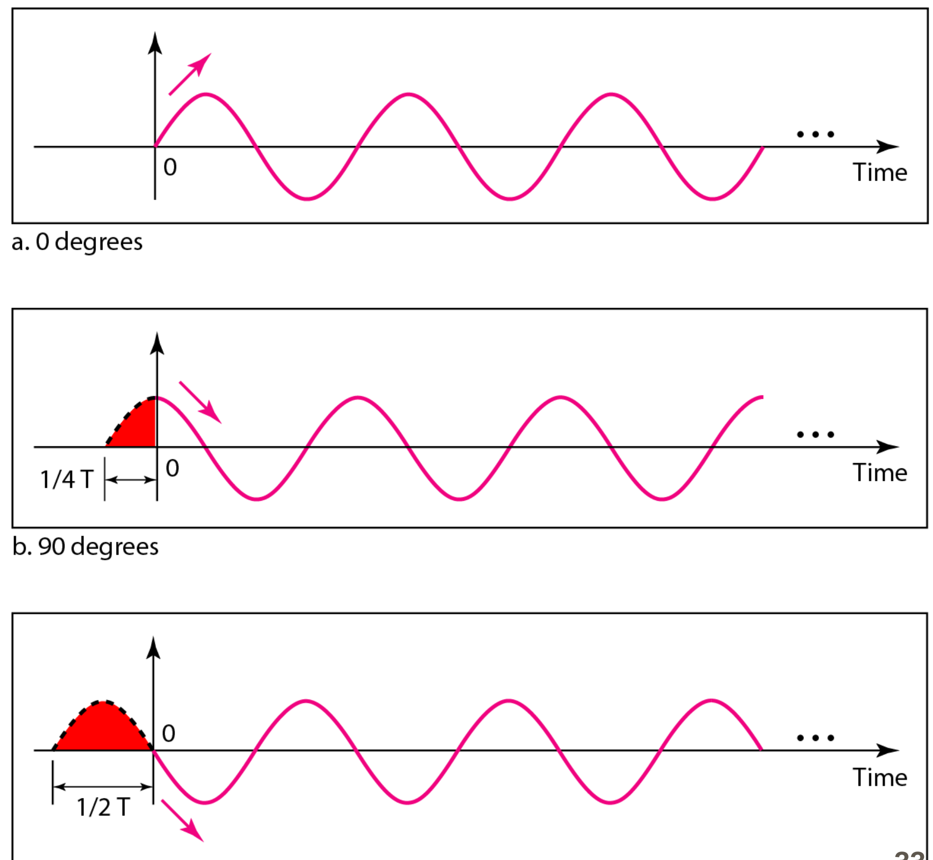
Solution

$$T = \frac{1}{f} = \frac{1}{50} = 0.02\,s = 0.02 \times 10^{3}\,ms = 20\,ms$$

Phase

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

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



a. 0 degrees

b. 90 degrees

c. 180 degrees

Example 3.3

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

Solution

We know that 1 complete cycle is 360°. Therefore, 1/6 cycle is

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

Thank You