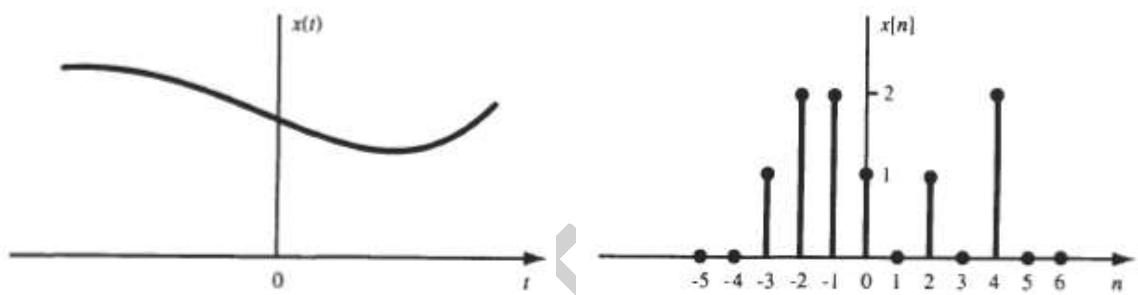
Chapter – 1 Introduction of Signal and System

1.1 SIGNALS AND CLASSIFICATION OF SIGNALS

A signal is a function representing a physical quantity or variable, and typically it contains information. Mathematically, a signal is represented as a function of an independent variable t. Usually t represents time. Thus, a signal is denoted by x(t).

A. Continuous-Time and Discrete-Time Signals:

A signal x(t) is a continuous-time signal if t is a continuous variable. If t is a discrete variable, that is, x(t) is defined at discrete times, then x(t) is a discrete-time signal. Continuous time signal is represented by x(t) and discrete time signal is represented by x[n].



(a) (b)

Fig. 1-1 Graphical representation **of** (a) continuous-time and ***(b)*** discrete-time signals.

We can also explicitly list the values of the sequence. For example, the sequence shown in Fig. l-l(b) can be written as

$x[n] = \{\ldots, 0,0,1,2,2,\underset{\uparrow}{1},0,1,0,2,0,0, \ldots\}$ We use the arrow to denote the n = 0 term.

If arrow is not indicated then the first term corresponds to the n= 0 and x[n] will be zero for n<0.

B. Analog and Digital Signals:

If a continuous-time signal x(t) can take on any value from $-\infty$ to $+\infty$ then the continuous-time signal x(t) is called an analog signal. If a signal x(t) can take on only a finite number of distinct values, then we call this signal a digital signal.

C. Deterministic and Random Signals:

Deterministic signals are those signals whose values are completely specified for any given time. Thus, a deterministic signal can be modeled by a known function of time *t*. ***Random*** signals are those signals that take random values at any given time and must be characterized statistically.

D. Even and Odd Signals:

A signal x(t) or x[n] is referred to as an ***even*** signal if

$$x(-t) = x(t)$$
$$x[-n] = x[n]$$

A signal x(t) or x[n] is referred to as an ***odd*** signal if

$$x(-t) = -x(t)$$
$$x[-n] = -x[n]$$

Any signal x(t) or x[n] can be expressed as a sum of two signals, one of which is even and one of which is odd. That is,

$$x(t) = x_e(t) + x_o(t)$$
$$x[n] = x_e[n] + x_o[n]$$

Where
$$x_e(t) = \frac{1}{2}\{x(t) + x(-t)\}$$
$$x_o(t) = \frac{1}{2}\{x(t) - x(-t)\}$$

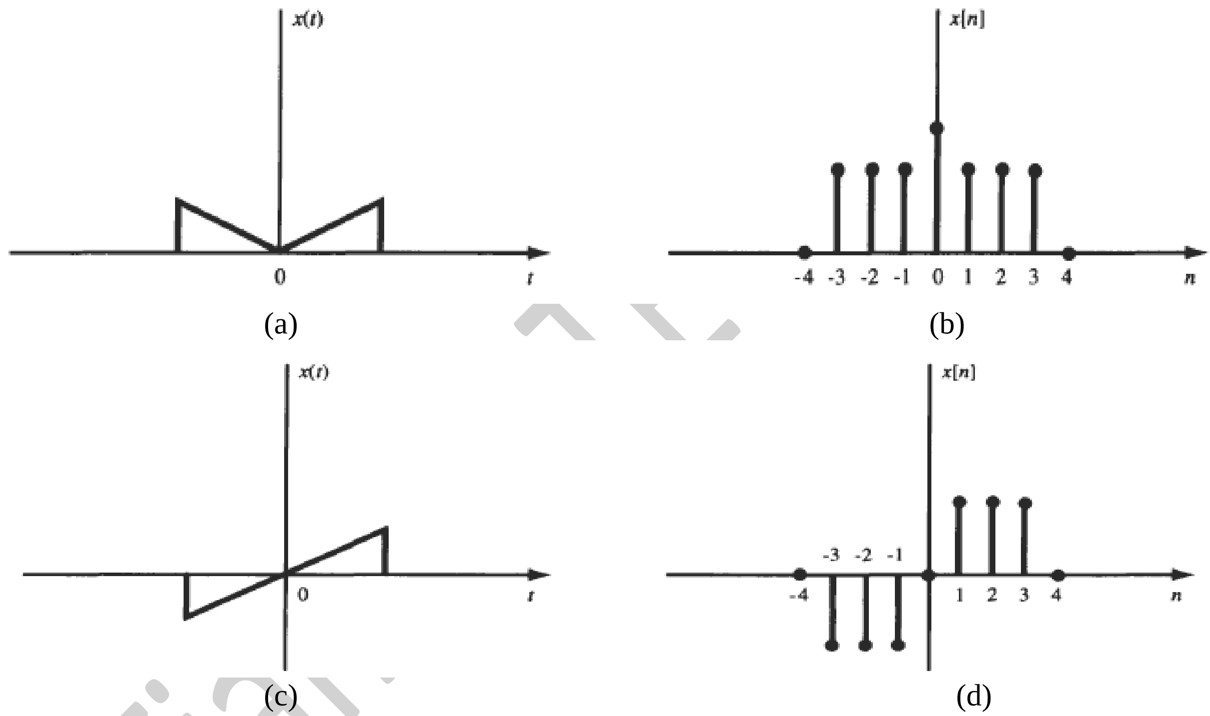


Fig. 1-2 Examples of even signals (a and *b*) and odd signals *(c* and *d)*

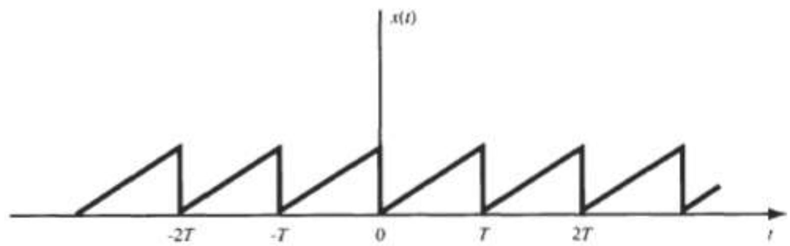
E. Periodic and Non-periodic Signals:

A continuous-time signal x(t) is said to be periodic with period T if there is a positive nonzero value of T for which

$x(t + T) = x(t)$ for all ***t***

This definition doesn't hold for the DC signal. For a DC signal x(t) the fundamental period is undefined since x(t) is periodic for any choice of T.

Any continuous-time signal which is not periodic is called a non-periodic (or a-periodic) signal.



A sequence (discrete-time signal) x[n] is periodic with period N if there is a positive integer N for which

x[n +N] =x[n]   all n

Any sequence which is not periodic is called a nonperiodic (or aperiodic sequence).

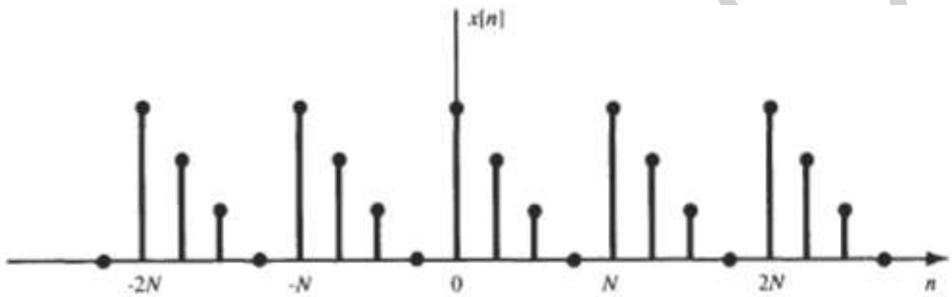


Fig. 1-3 Examples of periodic signals.

F. **Energy and Power Signals:**

For a continuous-time signal x(t), the normalized energy content E of x(t) is defined as

$$E = \int_{-\infty}^{\infty} |x(t)|^2 dt$$

The normalized average power P of x(t) is defined as

$$P = \lim_{n\to\infty} \frac{1}{T}\int_{-T/2}^{T/2} |x(t)|^2 dt$$

Similarly, for a discrete-time signal x[n], the normalized energy content ***E*** of x[n] is defined as

$$E = \sum_{n=-\infty}^{\infty} |x[n]|^2$$

The normalized average power P of x[n] is defined as

$$P = \frac{1}{2N+1}\sum_{n=-N}^{N} |x[n]|^2$$

Important notes:-

1. x(t) (or x[n]) is said to be an energy signal (or sequence) if and only if $0 < E < \infty$, and so $P = 0$.

2. x(t) (or x[n]) is said to be a power signal (or sequence) if and only if $0 < P < \infty$, thus implying that $E = \infty$.

3. Signals that satisfy neither property are referred to as neither energy signals nor power signals.

1.2. Basic signals

A. Unit Step Function:

The discrete-time version of the unit-step function is defined by