Books:

1. Modern Electronic Instrumentation and Measurement Techniques : – A.D. Helfrick and W.D Cooper.
2. A course in Electrical and Electronic Measurements & Instrumentation – A.K. Sawhney
3. A Course in Electronics and Electrical Measurements and Instrumentation – J.B. Gupta.

CHAPTER : 1

INTRODUCTION TO INSTRUMENTATION SYSTEM

1.1 Introduction:

1.1.1 Measurement :- Measurement of a given quantity is the act of comparision betⁿ unknown and ~~pref~~ predefined standard. The result is expressed in numerical value. It is the process by which one can convert physical parameters to meaningful numbers. In the measuring process, the property of an object under consideration is compared to an accepted standard unit. The number of times the unit standard fits into the quantity being measured is the numerical measure. Numerical value is meaningless until followed by a unit. The method of measurement may be direct or indirect.

1.1.2 Instrument :- It is the device which gives the measurement of any particular physical variables applied to it. The assembly of the instruments for measure, update and control the function is called Instrumentation system/Measurement system. Instrument may be mechanical,

PLAN : DATE :

NO :

(the first instrument used by mankind were mechanical in nature eg: strain gauge), electrical (eg: Galvanometer, LVDT, piezo-electrical), electronic (use of semiconductor, response time very small in the range of nano second eg: CRO).

1.1.3 Accuracy : It is the closeness with which an instrument reading approaches the true value of the quantity being measured. So accuracy of a measurement is the conformity to the truth. The accuracy may be specified in terms of inaccuracy or limits of error.

1.1.4 Precision : It is the measure of reproducibility of the measurement i.e. it is the measure of the degree of agreement within a group of measurements.

Precision is composed of 2 characteristics:

(i) Conformity (ii) Significant figures.

Error caused due to the limitation of scale reading is called precision error.

'Precision is necessary but not sufficient cond^n for accuracy'.

1.1.5 Sensitivity : Sensitivity of an instrument is the measure of change in instrument o/p which occurs due to the change in quantity being measured. Thus, sensitivity is the ratio given by:

$$\text{Sensitivity} = \frac{\text{scale deflection}}{\text{value of measurand causing deflection}}$$

$$= \frac{\text{change in o/p}}{\text{change in i/p}}$$

PLAN : DATE :

NO :

1.1.6 Resolution/Discrimination :- ~~It is the~~ If the i/p is slowly increased for some non-zero i/p value, it will be found that o/p doesnot change until a certain ~~Instrument~~ increment is exceeded. This inciement is called Resolution of the Instrument. Thus, the smallest increment in i/p which can be detected with certainty by the instrument is its resolution.

1.1.7 Error :- It is the difference betn measured value & the true value. It shows the deviation of measured value from the true value. Its types are:

Gross Error
Systematic Error
Random error
Probable error
Limiting error

1.2 Components of Instrumentation System:-

Most of the measurement system consists of following functional elements:

(i) Primary Sensing Element
(ii) Variable Conversion Element
(iii) Variable Manipulation Element
(iv) Data transmission element
(v) Data presentation element.

The block diagram of any instrumentation system is as:

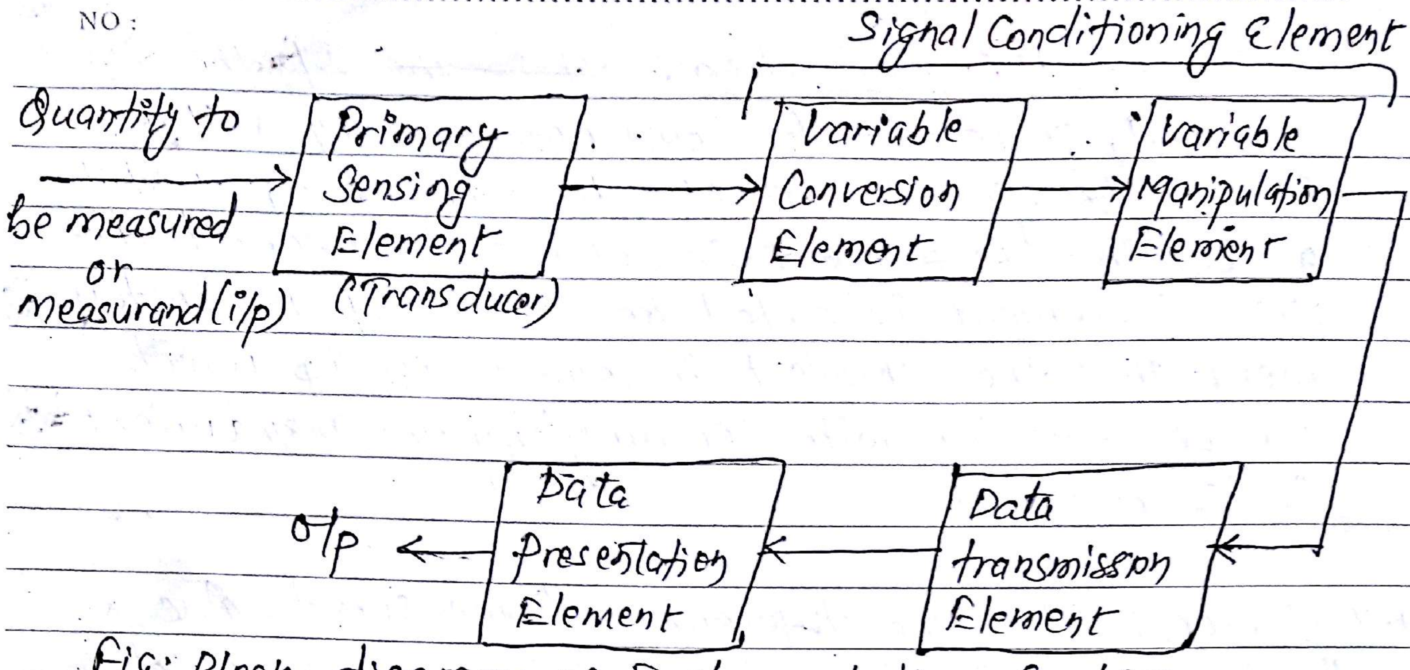


Fig: Block diagram of Instrumentation System.

(i) Primary Sensing Element :- The quantity under measurement makes its first contact with the primary sensing element. ie. the measurand is first detected by the primary sensing element or a transducer. This act is then followed by the conversion of measurand into the electrical form. This is done by a transducer. A transducer, in general, is defined as a device which converts energy from one form to another. But in electrical measurement system, this defination is limited. A transducer is defined as a device which converts the physical quantity into an electrical quantity. The physical quantity to be measured in the first place is sensed and detected by an element which gives the o/p in different analysis form. This signal (o/p) is converted into an electrical signal by a transducer. eg: microphone (which converts ~~eg~~ sound energy into electrical energy). This first stage of measurement system is detector-transducer stage.

(ii) Signal Conditioning Element :-

PLAN : DATE :

NO :

* Variable Conversion Element :- The o/p of a transducer may be an electrical signal of any form. It maybe a voltage, frequency, current or some other electrical parameters. Sometime, this o/p is not suited to the system. For the instrument to perform the desired functions, it may be necessary to convert this o/p to some other suitable form. For eg: Suppose o/p is in analog form and the next stage of system accepts i/p signals only in digital form and therefore an A/D converter will have to be used. The signal conversion from one form to the suitable form is done by variable conversion element.

* Variable Manipulation Element :- The function of this element is to manipulate the signal presented for preserving the original nature of the signal. Manipulation here means only a change in numerical value. for eg: an amplifier serves as a variable manipulation element.

(iii) Data Transmission Element :- The result is to be transmitted from a system to another system. The data transmission is done either thru wire or it may be wireless.
eg: Landline data transmission, RF data transmission.

(iv) Data Presentation Element :- The information about the quantity under measurement has to be conveyed to the person who is handling the instrument for monitoring, control or analysis purpose. The final result or o/p is presented either thru visual devices, indicators or recorders.
eg: X-Y chart recorder, CRO, magnetic recorder, etc.

→ Signal Conditioning & transmission stage is intermediate stage.

→ The last stage ie. Data presentation is terminating stage.

1.3 Types of Signals :-

(i) Continuous time Signal : A continuous time signal is defined as the mathematical continuous function. This function is defined continuously in the time domain. For this signal, the independent variable is time 't'. A continuous time signal is represented by $x(t)$.

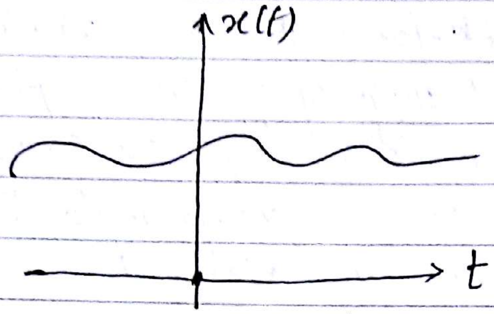
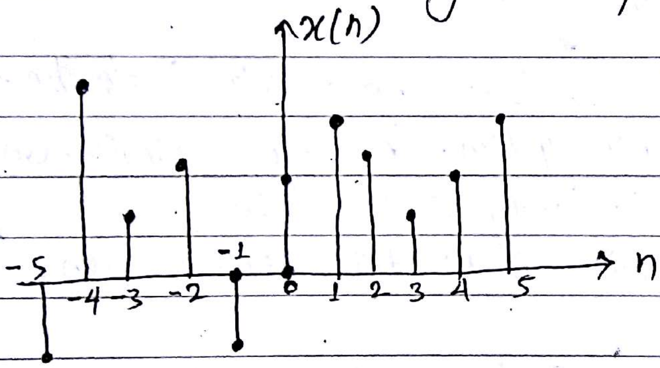


fig: a continuous time signal.

Discrete-time signal: A discrete time signal is defined only at certain time intervals. for discrete-time signal, the amplitude between two time instants is not defined. The independent variable is time 'n'. A discrete-time signal is represented by $x(n)$.



(ii) Deterministic Signal :- Deterministic signals are those signals which can be completely specified in time. The pattern of this type of signal is regular and can be characterized mathematically. The nature and amplitude of such signal at any time can be predicted.

eg: $x(t) = kt$, $x(t) = A\sin\omega t$.

Non-deterministic signal is one whose occurrence is always random in nature. The pattern of such signal is

PLAN :

DATE :

NO :

quite irregular. Non-deterministic signals are called random signals. For eg: thermal noise generated in electric ckts.

(iii) Periodic and Aperiodic Signal :- A periodic signal is that type of signal which has a definite pattern and repeats over a certain period T. For continuous-time signal, it is periodic if

$x(t+T) = x(t)$ for $-\infty < T < \infty$ where T is its period.

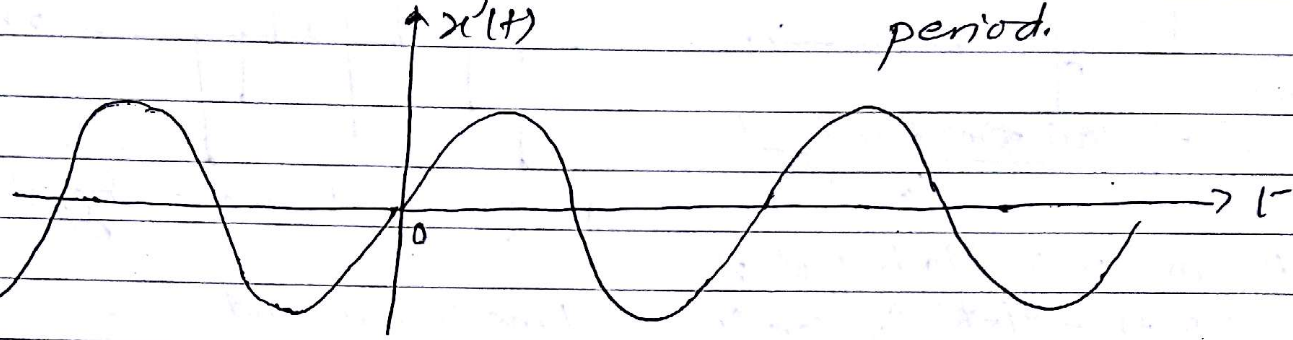


Fig: Continuous time periodic Signal

Similarly, for discrete-time signal, it is periodic if

$x(n+N) = x(n)$ for $-\infty < n < \infty$

where N is the sampling period.

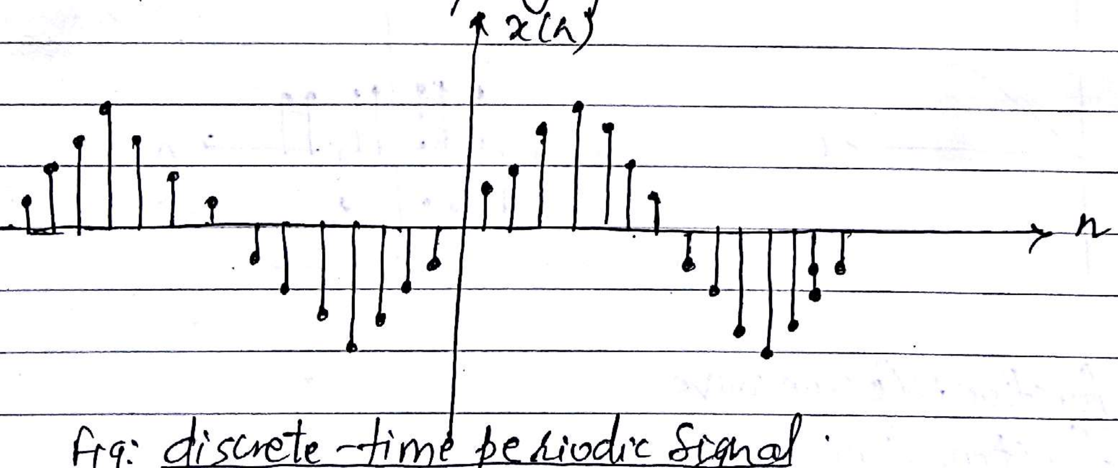
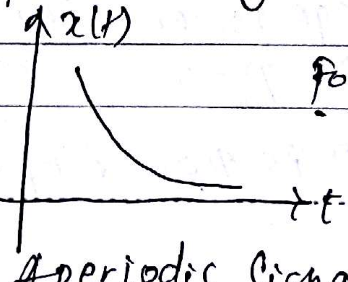


Fig: discrete-time periodic Signal

On the other hand, a signal is said to be aperiodic if it doesnot repeat. Sometimes aperiodic signals are said to have a period equal to infinity.



For eg: $x(t) = e^{-at}$

This is decaying exponential pulse.

Fig: Aperiodic Signal

PLAN : DATE :

NO :

(iv) **Even and odd Signal:-** A signal $x(t)$ or $x(n)$ is said to be even if $x(t) = x(-t)$ for continuous time signal
or $x(n) = x(-n)$ for discrete time signal.

Even signals are identical about the origin and exhibits symmetry in the time domain.

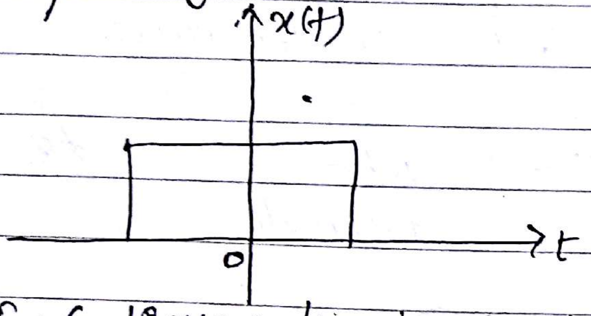


fig: Continuous time even signal

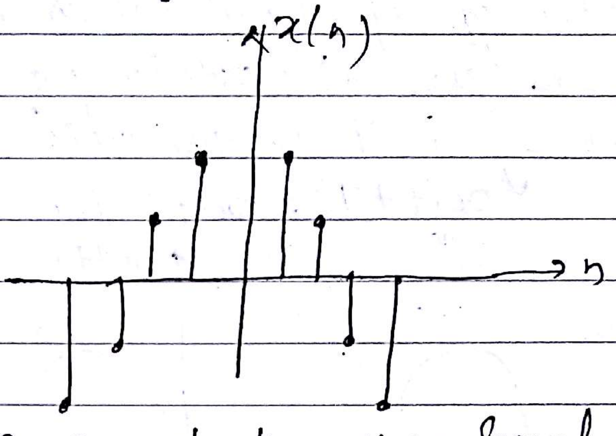
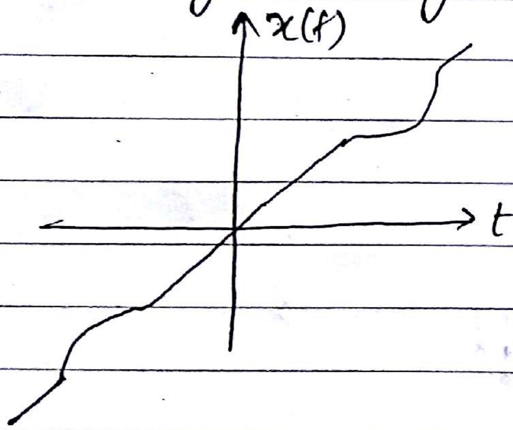
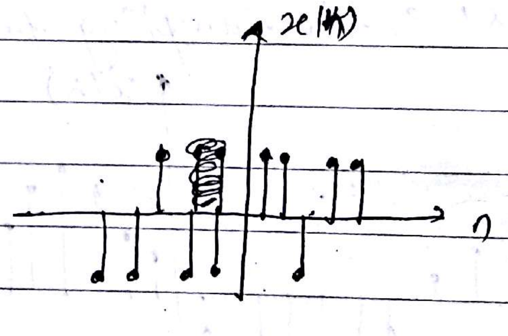


fig: Discrete time even signal

A signal is said to be odd if
$x(t) = -x(-t)$ for continuous time signal and
$x(n) = -x(-n)$ " discrete " "

This type of signal exhibits antisymmetry and is not identical about the origin. Actually, the signal is identical to its negative.

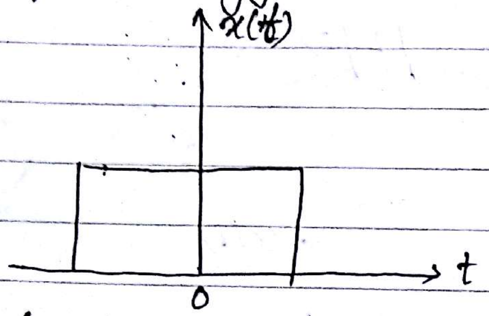




eg: Even function: Cosine wave
Odd function: Sine wave.

(v) **Energy and Power Signal:-** The energy signal is one which has finite energy and zero average power. Hence, $x(t)$ is an energy signal if $0 < E < \infty$ and $P = 0$
where E is energy and P is power of the signal $x(t)$.

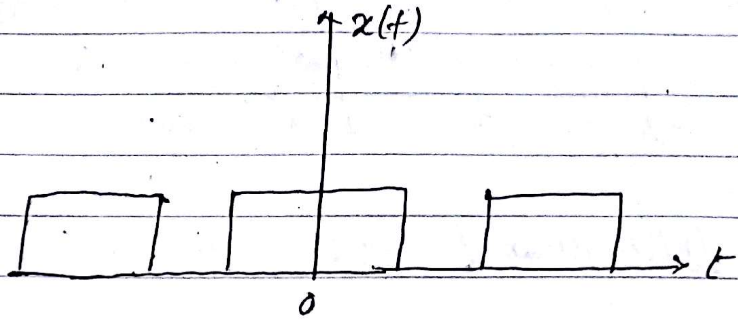
The power signal is one which has finite average power and infinite energy. Hence, $x(t)$ is a power signal if $0<P<\infty$ & $E=\infty$.



(Single rectangular pulse)

Energy Signal

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



(periodic pulse train)

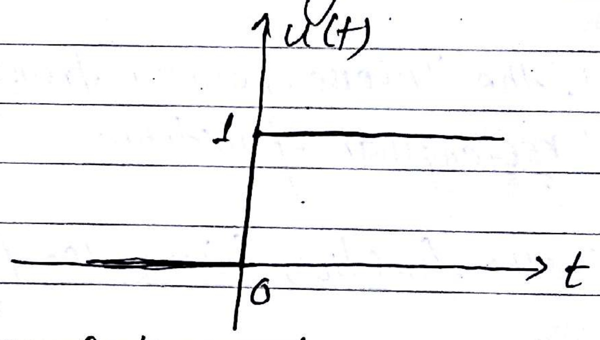
Power Signal

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

(vi) Unit Step Signal :-

A Signal is said to be unit step if

$$u(t)=\begin{cases}0 & \text{for } t<0\\ 1 & \text{for } t\geq 0\end{cases}$$ for continuous time signal



From fig: we could see that the signal exists only for positive side and is zero for negative side.

Fig: Continuous time Unit step function

Similarly, for discrete-time, a signal is unit step if

$$u(n)=\begin{cases}0 & \text{for } n<0\\ 1 & \text{for } n\geq 0\end{cases}$$

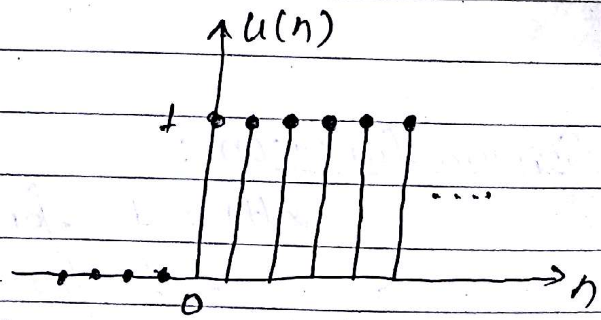


Fig: Discrete time unit-step func^n

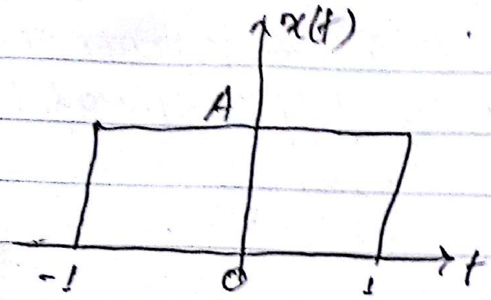
(vii) Rectangular Pulse :

$$x(t)=\begin{cases}A & \text{for } |t|\leq 1\\ 0 & |t|>1\end{cases}$$ for ideal case.

PLAN :

DATE :

NO :

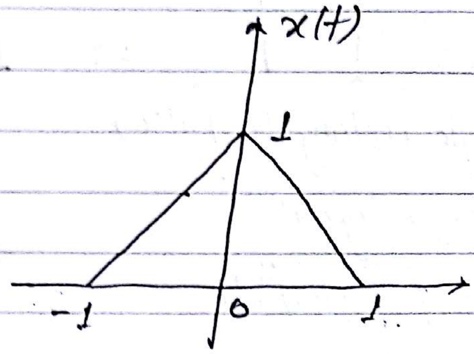


for general case,

$x(t) = A$ for $|t| \leq t_0$

$= 0 \quad |t| > t_0$

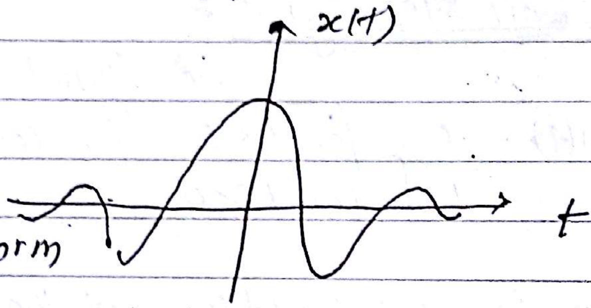
(viii) Triangular Pulse :-



$x(t) = 1 - |t|$ for $|t| < 1$

$= 0$ otherwise.

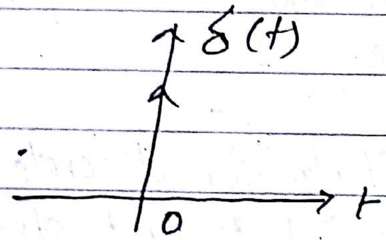
(ix) ~~Sig~~ Sinc Signal :



$$\text{Sinc}(\theta) = \frac{\sin\theta}{\theta}$$

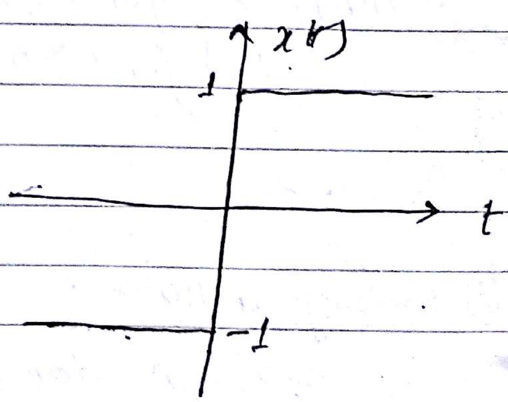
It is the Inverse Fourier transform of rectangular function.

(x) Delta function / Impulse function :-



$\delta(t) = 0$ for $t \neq 0$

(xi) Signum function :



$x(t) = 1$ for $t > 0$

$= -1$ for $t < 0$

$= 0$ for $t = 0$