Subject

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Unit - 1

Signal -

A function of one or more independent variables which contains some information

eg :- Radio Signal, T.V. Signal etc.

One Dimensional Signal -

When function depends on a single variable.

eg :- Speech signal whose amplitude varies with time.

Multi Dimensional Signal -

When functions depends on two or more variables.

eg :- image as it is a 2-dimensional signal with horizontal and vertical co-ordinates.

Classification of Signals -

Based upon their nature and characteristics in the time domain, S/g is classified as

1) Continuous - time S/g

2) Discrete - time S/g.

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1) Continuous time Signal :- (Analog signal)

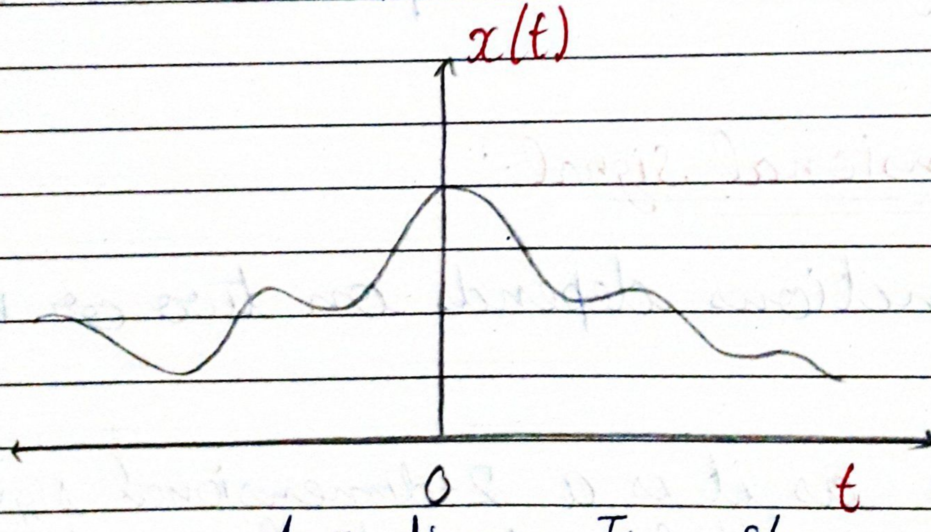
A s/g of continuous amplitude and time.

* This s/g will have certain value at every instant of time.

* It is represented by $\boxed{x(t)}$

where $x \rightarrow$ represent shape of s/g

$t \rightarrow$ represent time. It is the Independent Variable.

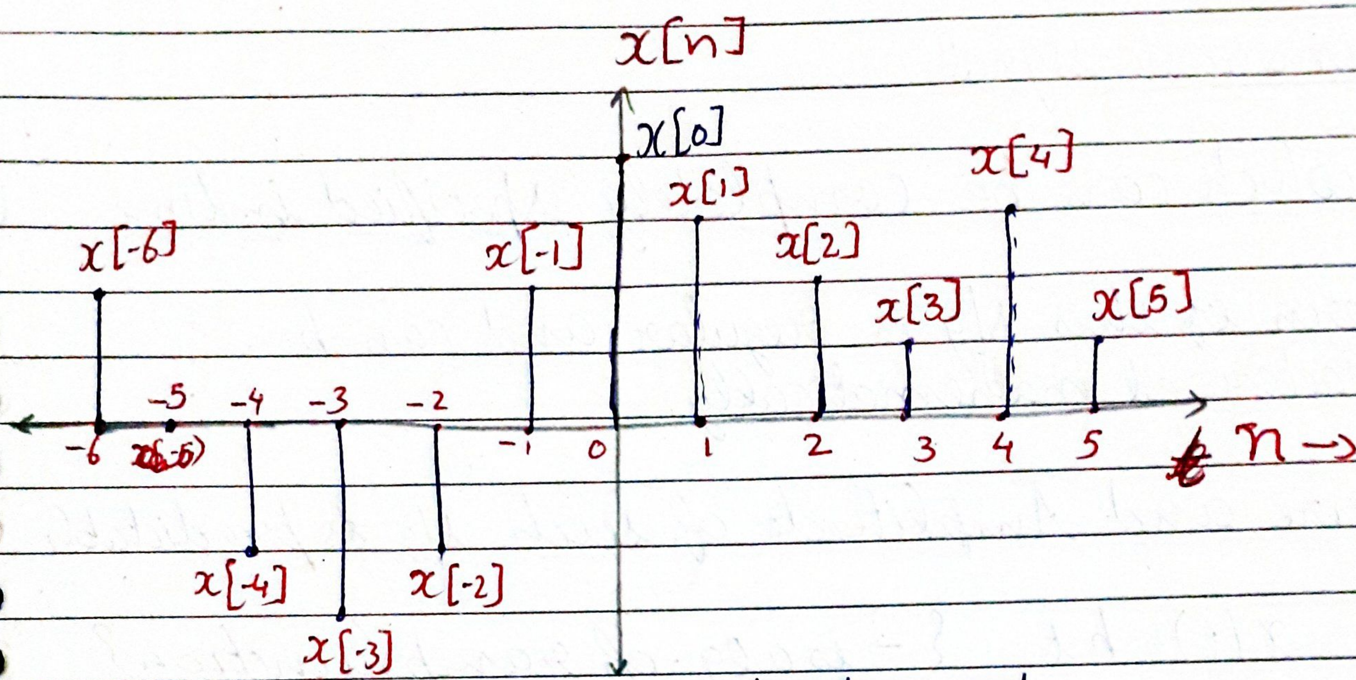


A continuous Time S/g.

2) Discrete time Signals :-

A s/g which represent only at discrete instant of time. (it has values at only certain intervals).

* It is represented by $\boxed{x[n]}$ square bracket independent variable



A discrete time s/g.

* Further both continuous time s/g and discrete time s/g can be classified as:-

1) Deterministic and non-deterministic (random) signal.

2) Periodic and non-periodic s/g.

3) Even and odd s/g.

4) Energy and Power s/g

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1) Deterministic and Non-Deterministic

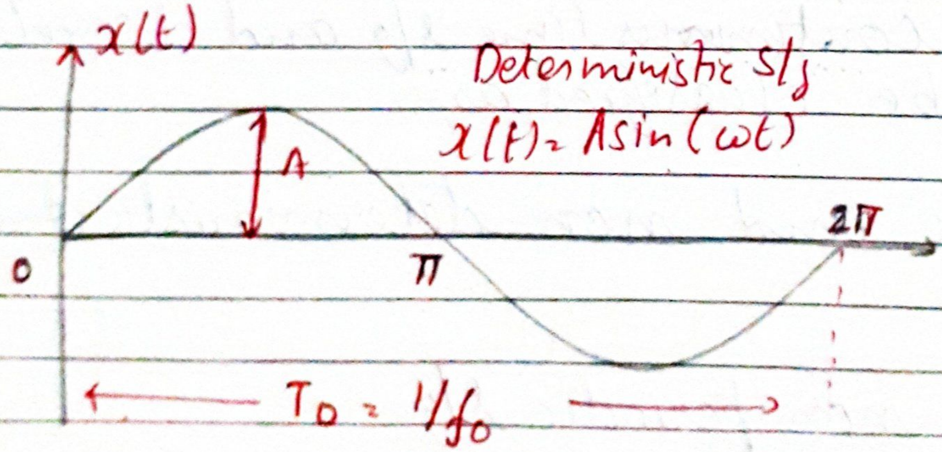
Deterministic signal:-

s/g which can be completely specified in time.

* Pattern of this s/g is regular and can be characterized mathematically.
* Nature and Amplitude of such s/g is predictable

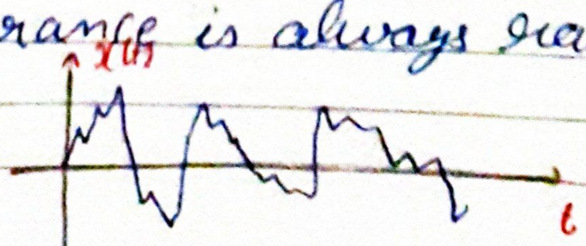
eg:- $x(t) = bt$ { → is a eq. of ramp function }

$x(t) = a \sin \omega t$ { → sinusoidal s/g with Amp A }



Random s/g :- (Non Deterministic s/g) :-

A s/g whose occurance is always random in nature.



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2) Periodic and Non Periodic S/g :-

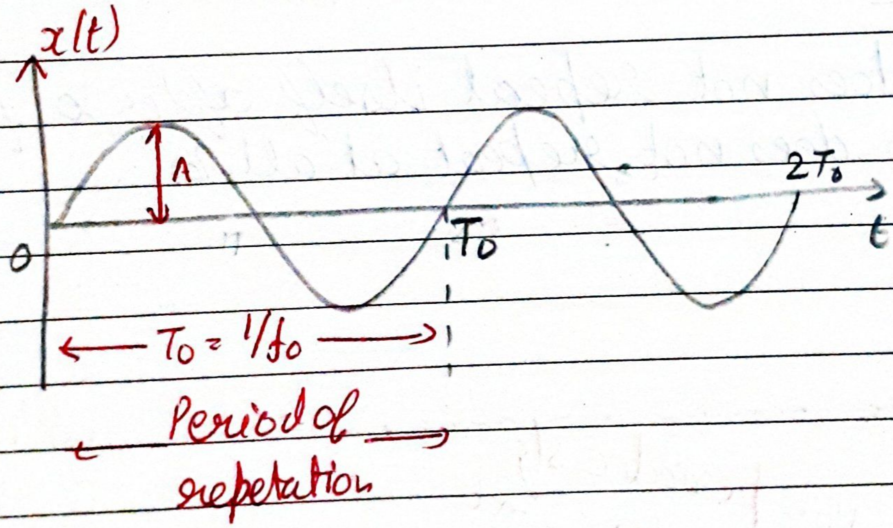
1) Periodic s/g :- (continous s/g)

A s/g which repeat itself after a fixed time period.

Mathematically,

$$\boxed{x(t) = x(t + T_0)}$$ → condition of Periodicity

where T_0 = Period of s/g $x(t)$



Periodic s/g.

Periodic s/g (Discrete s/g)

Mathematically,

$$\boxed{x[n] = x[n + N]}$$ → condition of Periodicity.

where N → period of s/g.

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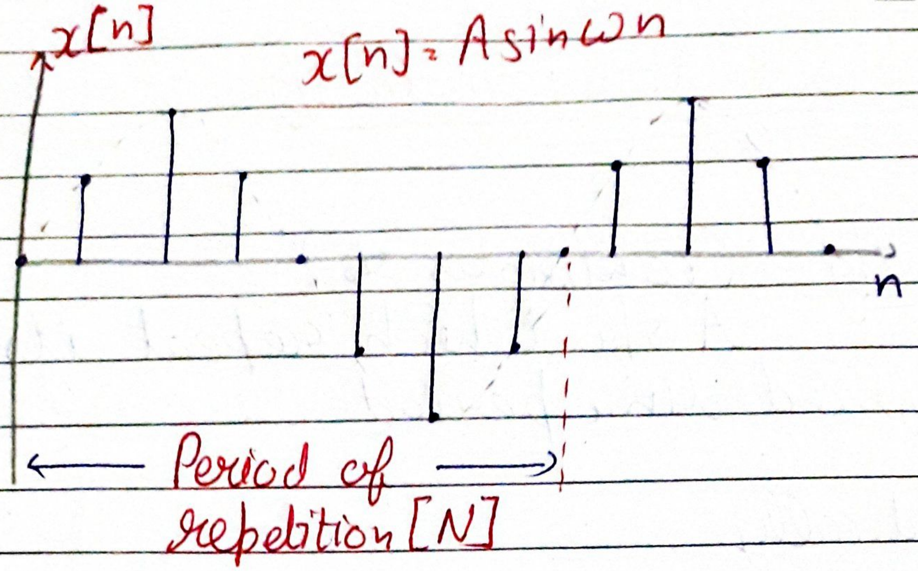
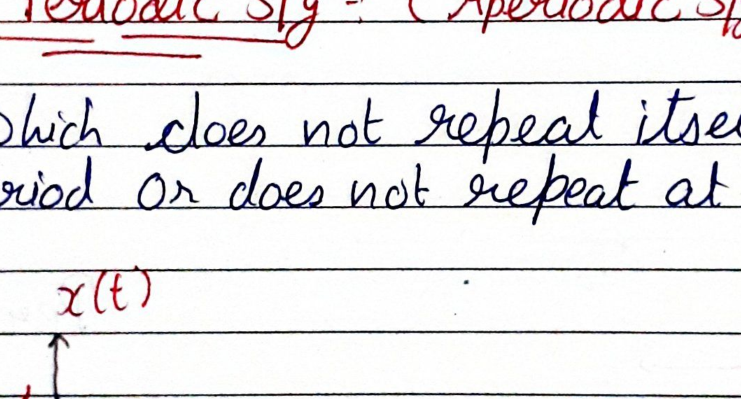


Discrete time periodic s/g.

2) Non - Periodic s/g :- (Aperiodic s/g)

A s/g which does not repeat itself after a fixed time period or does not repeat at all.



Mathematically (condition for Non periodic s/g)

$$\boxed{\begin{array}{l} x(t) \neq x(t+T_0) \rightarrow \text{for CT s/g} \\ x[n] \neq x[n+N] \rightarrow \text{for DT s/g.} \end{array}}$$

Q Condition for periodicity of a discrete-time s/g :-

Sol. A discrete time sinusoidal s/g is periodic only if its frequency f_0 is rational.

ie. $f_0 \rightarrow$ should be in form of ratio of two integers.

Proof :-

Let for D.T. s/g condition of periodicity is given by

$$x[n+N] = x[n] \quad -①$$

Let $x[n]$ be a cosine wave.

$$\therefore x[n] = A\cos[2\pi f_0 n + \theta] \quad -②$$

where $A \rightarrow$ Amplitude
$\theta \rightarrow$ Phase shift

Now replace n by $[n+N]$ in eq ②, we get

$$x[n+N] = A\cos[2\pi f_0 (n+N) + \theta] \quad -③$$

comparing eq ①, ② & ③, we get

$$A\cos[2\pi f_0 n + \theta] = A\cos[2\pi f_0 (n+N) + \theta]$$

$$A\cos[2\pi f_0 n + \theta] = A\cos[2\pi f_0 n + 2\pi f_0 N + \theta] \quad -④$$

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Let us consider K (an integer). If we have to satisfy the above eq.

$$2\pi f_0 N = 2\pi K$$

$$\therefore \boxed{f_0 = \frac{K}{N}} \rightarrow \text{integer}$$

f

Periodicity condition for $x[n] = x_1[n] + x_2[n]$

Let $x_1[n]$ & $x_2[n]$ are both periodic discrete s/g. sequence.
Let f_1 & f_2 be the corresponding frequency.

$\therefore$ Acc. to condition of periodicity

$$f_1 = \frac{K_1}{N_1} \quad \& \quad f_2 = \frac{K_2}{N_2}$$

$\therefore$ resultant s/g $x[n]$ is periodic if $\frac{N_1}{N_2}$ is ratio of two integers.

* Period of $x(n)$ will be least common multiple of N_1 & N_2

Formula for fundamental angular freq.

* $\boxed{\Omega = \frac{2\pi}{N}}$ $N \rightarrow$ no. of samples in one cycle.

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Numerical

1) Prove that the sine wave is a periodic s/g.

Sol. Let us consider a sine wave $x(t)$ which is mathematically represented as

$$x(t) = A \sin \omega_0 t$$

Condition for periodicity:

$$x(t+T_0) = A \sin \omega_0 (t + T_0)$$

$$= A \sin(\omega_0 t + \omega_0 T_0) \quad \text{--- (1)}$$

As, we know $\omega_0 = 2\pi f_0$

and $T_0 = \frac{1}{f_0}$

$$\therefore \omega_0 T_0 = 2\pi \cancel{f_0} \times \frac{1}{\cancel{f_0}}$$

$$\boxed{\omega_0 T_0 = 2\pi}$$

Subt. the value of $\omega_0 T_0$ in eq (1)

$$x(t+T_0) = A \sin[\omega_0 t + 2\pi] \qquad \{\sin(A+B) = \sin A \cos B + \cos A \sin B\}$$

$$= A\{\sin(\omega_0 t)\cos 2\pi + \cos(\omega_0 t)\sin 2\pi\}$$

$$x(t+T_0) = A\{\sin \omega_0 t\} \qquad \left\{\begin{matrix}\cos 2\pi = 1 \\ \sin 2\pi = 0\end{matrix}\right\}$$

Hence sine wave is a periodic s/g.

2) Prove that the exponential signal is a non-periodic s/g.

Sol. Let $x(t) = e^{-\alpha t}$ be the exponential s/g. — ①

Let $t = (t + T_0)$

Sub. the value of t in equation of exponential s/g.

$$x(t+T_0) = e^{-\alpha(t+T_0)} = e^{-\alpha t} \cdot e^{-\alpha T_0}$$

but $T_0 = \infty$

$$e^{-\alpha T_0} = e^{-\infty} = 0$$

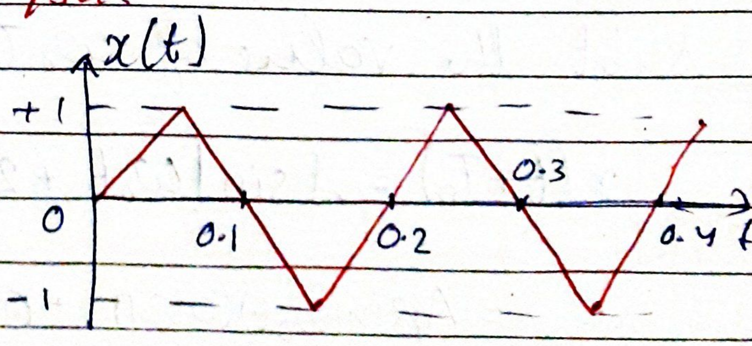
$$x(t+T_0) = e^{-\alpha t} \cdot 0 = 0 \quad — ②$$

comparing eq ① & ②

$$x(t) \neq x(t+T_0)$$

Hence exponential s/g is not a periodic s/g.

3) What is the fundamental freq of the waveform shown below in Hz & rad/sec.



Sol.

If we see the diagram clearly.

One cycle = 0.2 sec

$T_0 = 0.2$ sec

Subject

Frequency $(F_0) = \frac{1}{T_0} = \frac{1}{0.2} = \boxed{5 Hz}$

Frequency in rad/sec $\omega_0 = 2\pi f_0$

$= 2 \times 3.14 \times 5$

$= 31.4$ rad/sec

4) Determine whether the following discrete-time s/g are periodic or not. If periodic determine fundamental period.

1) $\cos(0.01\pi n)$

Sol. Let $x[n] = \cos[0.01\pi n]$ — (1)

Sol. comparing with standard eq. $x[n] = \cos 2\pi f n$ — (2)

$2\pi f \cdot n = 0.01\pi n$

$f = \frac{0.01}{2} = \frac{1}{200} = \frac{K}{N}$

$\because f$ is expressed in the ratio of two integers with $k = 1$ & $N = 200$,

Hence s/g is periodic with $N = 200$.

2) $x(n) = \cancel{\cos 3\pi n}\ \sin 3n$

comparing with standard eq. $x[n] = \sin 2\pi f n$

$2\pi f n = 3n$, $\Rightarrow f = \frac{K}{N} = \frac{3}{2\pi}$ which is not an integer

3) Even (Symmetrical) or Odd (Antisymmetrical) s/g

Symmetrical Signal (continuous Time)

A s/g $x(t)$ is said to be symmetrical or even if it satisfies the condition.

$$x(t) = x(-t)$$

where $x(t)$ = value of s/g for +ve(t).

$x(-t)$ = value of s/g for -ve(t).

Asymmetrical s/g (continuous Time)

A s/g $x(t)$ is said to be antisymmetrical or odd if it satisfies the condition.

$$x(t) = -x(-t)$$

Even Discrete Time s/g :-

$$x[n] = x[-n]$$

Odd Discrete Time s/g :

$$x[n] = -x[-n]$$

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Decomposing a s/g into Even and Odd parts

Let $x(t)$ be the s/g which is expressed in even & odd part.

$$x(t) = x_e(t) + x_o(t) \quad -(1)$$

where $x_e(t)$ = Even component of s/g $x(t)$

$x_o(t)$ = Odd component of s/g $x(t)$

put $t = -t$ in eq (1)

$$x(-t) = x_e(-t) + x_o(-t) \quad -(2)$$

Expression for even part $x_e(t)$

$$x_e(t) = x_e(-t) \quad \{\text{for even s/g}\}$$

$$x_o(-t) = -x_o(t) \quad \{\text{for odd s/g}\}$$

Sub. the above value in eq. (2)

$$x(-t) = x_e(t) - x_o(t) \quad -(3)$$

adding eq (1) & (3) we get -

$$x(t) + x(-t) = 2x_e(t)$$

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

Expression for the odd part $x_o(t)$

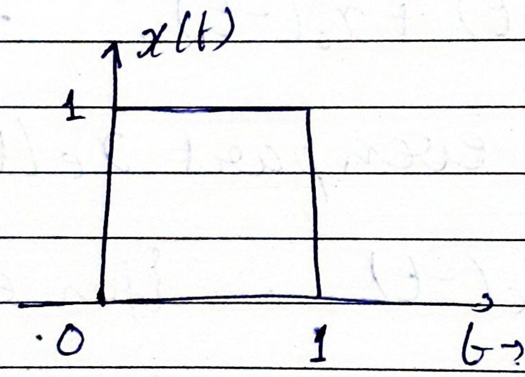
Subtracting eq ③ from eq ①.

$$x(t) - x(-t) = 2x_o(t)$$

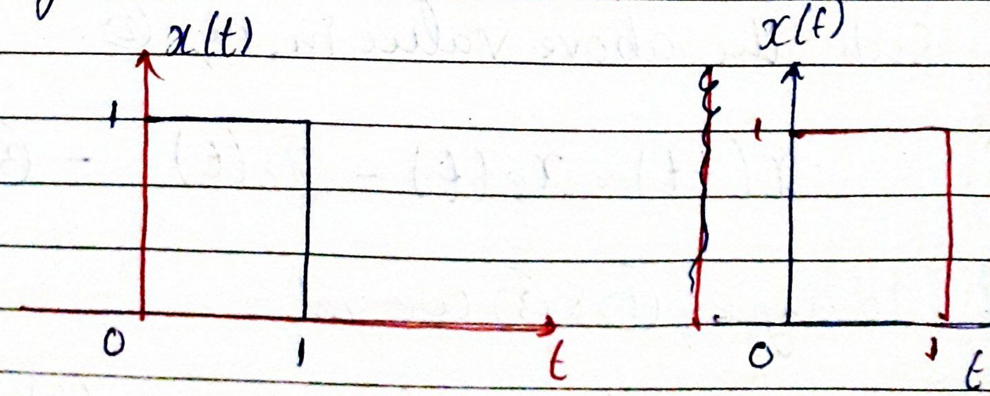
$$\boxed{x_o(t) = \frac{1}{2}\left[x(t) - x(-t)\right]}$$

—— x —— x —— x ——

Q. Draw even & odd part of x(t)



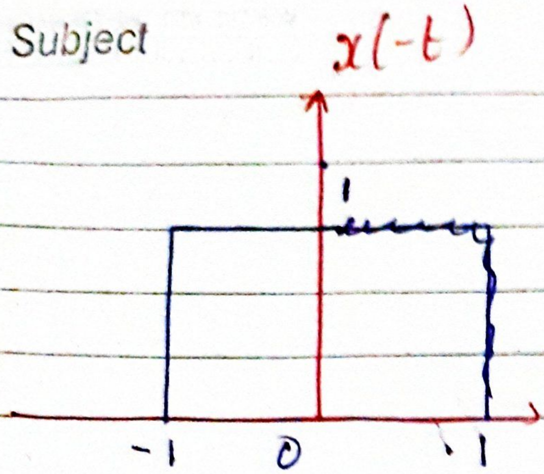
Sol. Step 1 :- Draw s/g $x(t)$



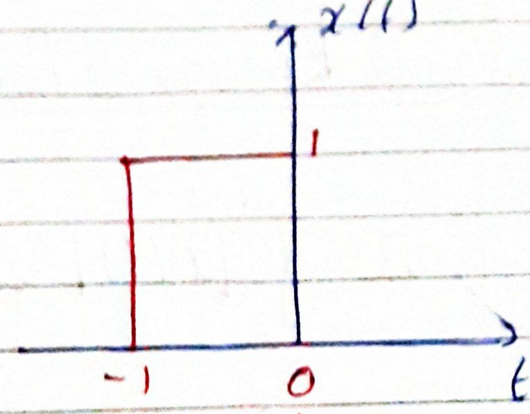
(a) (b)

Step 2 :-

Draw the folded version (mirror image) $x(-t)$.

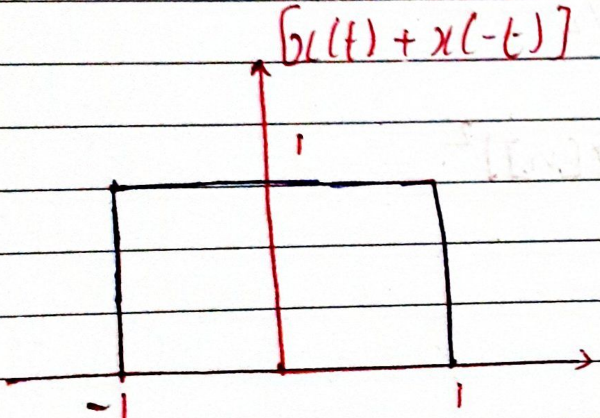


(c)

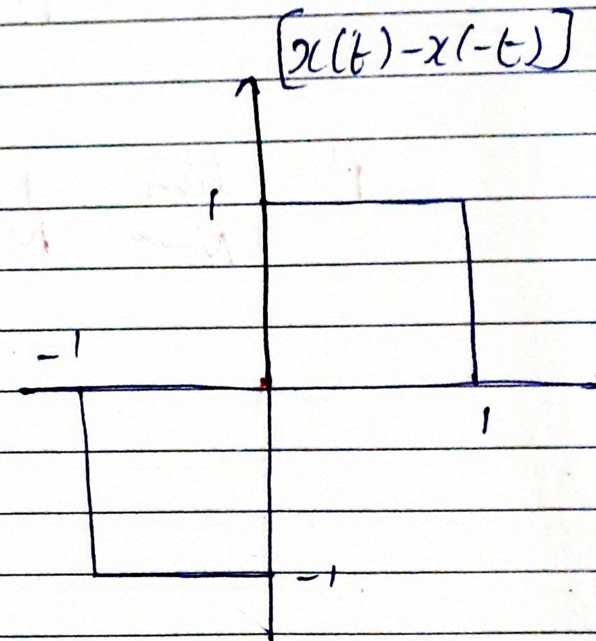


(d)

<u>step 3</u> :- Next, we add $x(t)$ and $x(-t)$ or subtract $x(-t)$ from $x(t)$

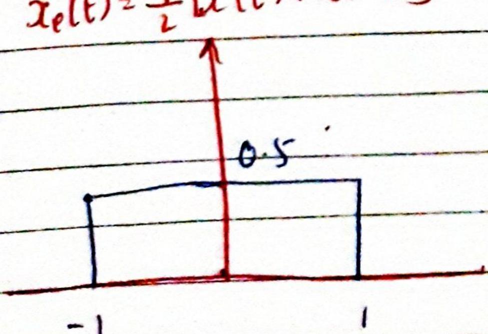


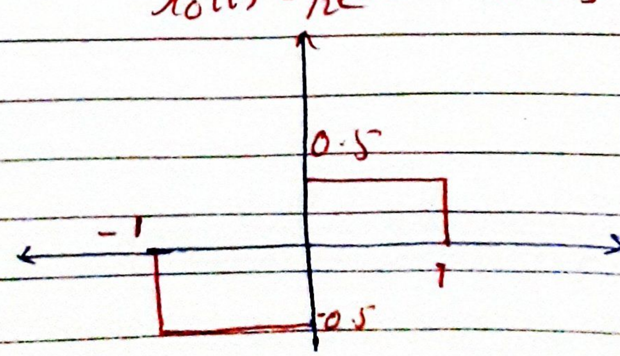
(e)



(d)

<u>step 4</u> :- divide the addition & sub. by 2 to get $x_e(t)$ & $x_o(t)$





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4) Signal Energy & Power

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

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

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

$$P = \lim_{N \to \infty} \frac{1}{N} \cdot \sum_{n=-N/2}^{N/2} |x[n]|^2$$

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Energy and Power Signals.

Energy Signal:-

which has finite energy and zero average power.

If $\boxed{0 < E < \infty \ \& \ P = 0}$ — ①

then $x(t)$ is an energy Signal.

where E is energy
P is Power.

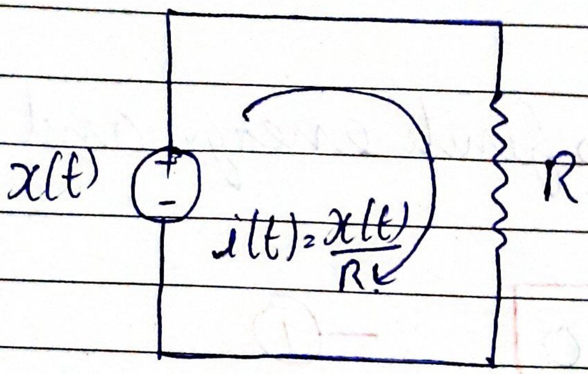
Power Signal:-

which has finite average power and infinite energy.

If $\boxed{0 < P < \infty \text{ and } E = \infty}$ — ②

* if a s/g $x(t)$ does not satisfy any of the above two condition, then it is neither energy s/g nor a power s/g.

Derivation for Energy S/g :-



Let $x(t)$ be the voltage applied across a $(R)\,\Omega$ resistor.
Let $i(t)$ be the current

$$i(t) = \frac{x(t)}{R}$$

Let $p(t)$ be the instantaneous power, which is given by

$$p(t) = v(t) \cdot i(t) \quad \text{--- (1)}$$

Sub. $v(t) = x(t)$ & $i(t) = \frac{x(t)}{R}$ in eq (1), we get

$$p(t) = x(t) \cdot \frac{x(t)}{R} = \frac{x^2(t)}{R}$$

As we know that the total energy dissipated is the integral of the instantaneous power.

$$\therefore \text{Energy dissipated} = \int_{-\infty}^{\infty} \frac{x^2(t)}{R}\, dt$$

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put $R = 1$

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

For real s/g, Energy is

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

For a complex s/g, Energy is

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

$\rightarrow$ for continuous time s/g.

$$\boxed{E = \sum_{n=-\infty}^{\infty} |x(n)|^2}$$

$\rightarrow$ for discrete time s/g.

IIly

For a real s/g, Average Power P

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

For a complex valued s/g, Average Power P is

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

$\rightarrow$ for continuous time s/g

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For discrete time s/g.

$$\boxed{P = \lim_{N\to\infty} \frac{1}{N} \sum_{n=-N/2}^{N/2} |x[n]|^2}$$

Multichannel and Multidimensional s/g :-

Multichannel s/g :-

s/g which are generated by multiple sources or multiple sensors.
The resultant s/g is the vector sum of s/g from all channels. eg → ECG s/g.

$$x(t) = \begin{bmatrix} x_1(t) \\ x_2(t) \\ x_3(t) \end{bmatrix}$$

Multidimensional s/g :-

If a s/g is a function of single independent variable, the s/g is called $\boxed{\text{one-dimensional s/g}}$

If a s/g is a function of multi (many) independent variables, it is called $\boxed{\text{multidimensional s/g}}$.

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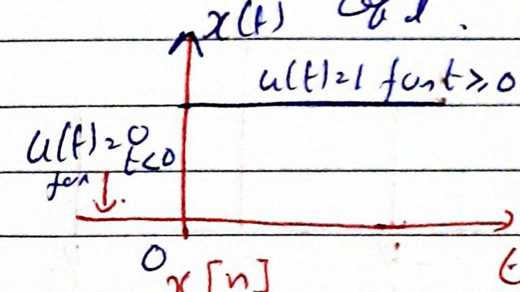
Standard S/g :-

① Unit Step S/g :- has constant amp. of 1 for 0 or +ve value of t.

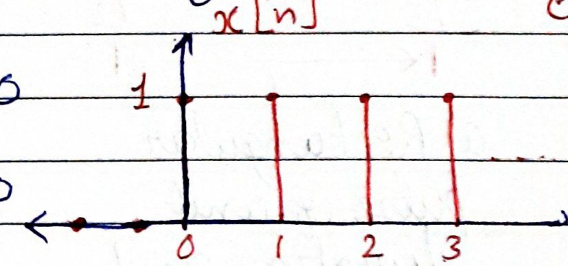
$$u(t) = \begin{cases} 1 & \text{for } t \geq 0 \\ 0 & \text{for } t < 0 \end{cases}$$

(continous Unit step S/g)



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

(discrete continous Unit step S/g)

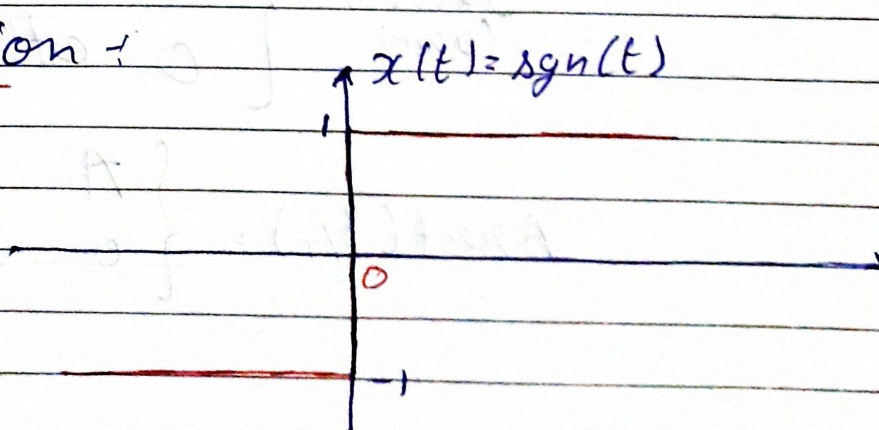


$$u[n] = \{\underset{\uparrow}{1}, 1, 1, 1, \ldots\}$$

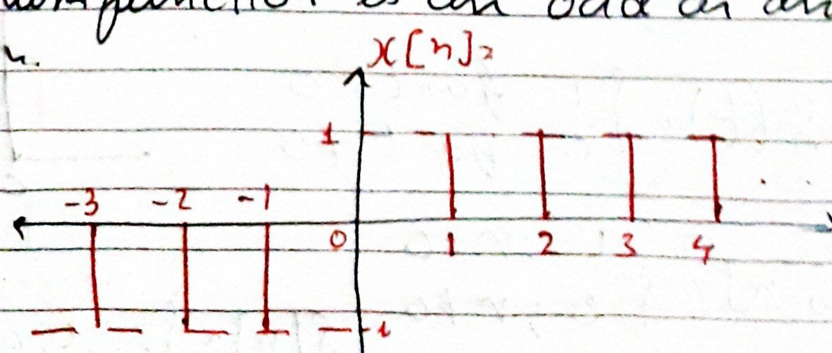
(arrow shows the starting n = 0.)

② Signum Function :-

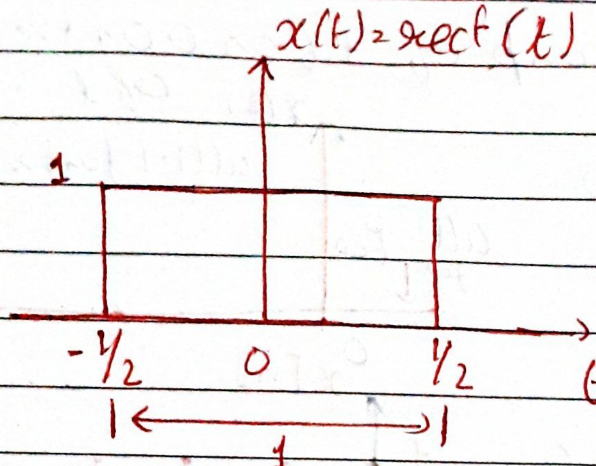
$$sgn(t) = \begin{cases} +1 & \text{for } t > 0 \\ -1 & \text{for } t < 0 \end{cases}$$

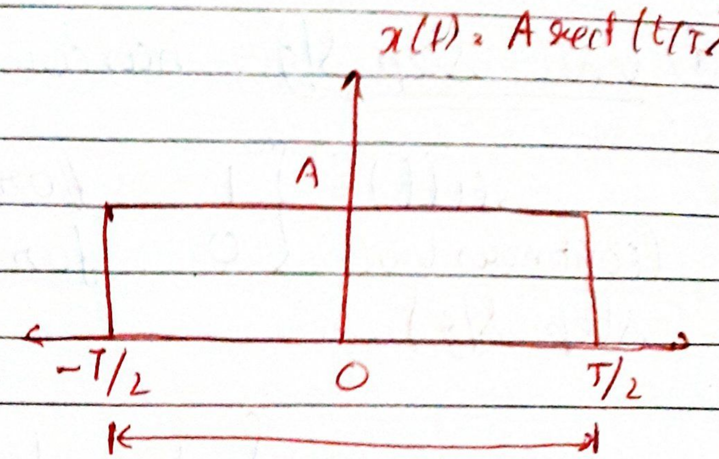


* This signum function is an odd or antisymmetric function.



③ Rectangular Pulse.





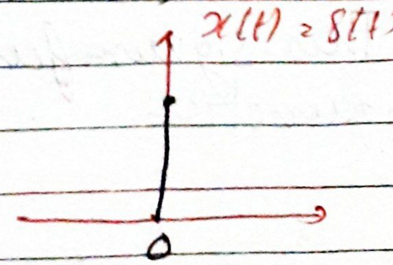
a) Rectangular pulse of unit duration and unit amplitude

b) Rectangular pulse of duration T and amp A.

$$\underset{(unit)}{rect(t)} = \begin{cases} 1 & \text{for } -1/2 \le t \le 1/2 \\ 0 & \text{otherwise} \end{cases}$$

$$A\, rect(t/T) = \begin{cases} A & \text{for } -T/2 \le t \le T/2 \\ 0 & \text{otherwise} \end{cases}$$

④ Delta or Unit Impulse function $\delta(t)$



$$\delta(t) = \begin{cases} 1 & \text{for } t = 0 \\ 0 & \text{for } t \neq 0 \end{cases}$$

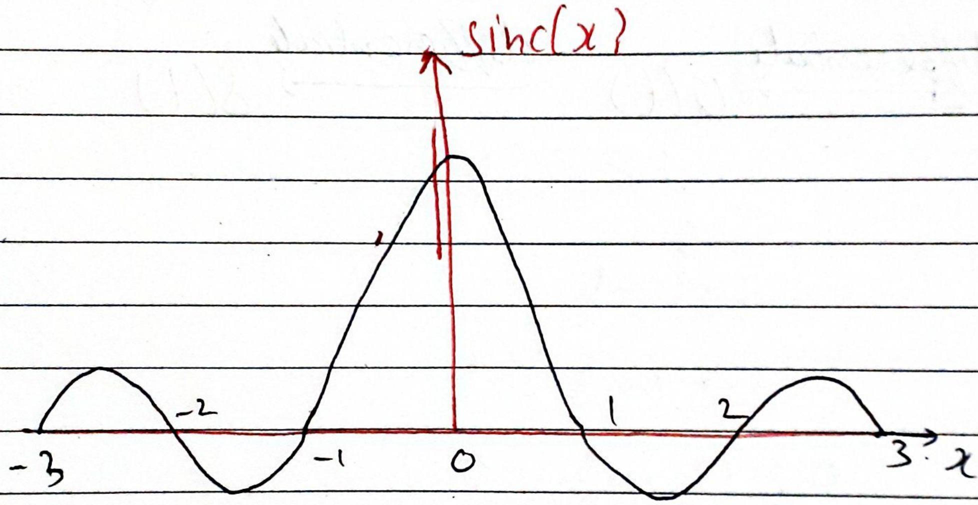
$$\delta[n] = \begin{cases} 1 & ; n = 0 \\ 0 & ; n \neq 0 \end{cases}$$

$$\delta[n] = \{\ldots 0, 0, 0, \underset{\uparrow}{1}, 0, 0, 0\}$$

(3) Sinc Function

$$\mathrm{sinc}(x) = \frac{\sin(\pi x)}{(\pi x)} \quad \text{for } x = 0$$

$$\mathrm{sinc}(x) = \begin{cases} 1 & \text{at } x = 0 \\ 0 & \text{at } x = \pm 1, \pm 2, \pm 3 \ldots \end{cases}$$



Relationship between Step, Ram & Delta Function

1) Unit step and unit ramp function:-

$$\frac{d}{dt} r(t) = u(t) \quad \text{or} \quad \int u(t)\,dt = r(t)$$

2) Unit step and delta function:-

$$\frac{d}{dt} u(t) = \delta(t) \quad \text{or} \quad \int \delta(t)\,dt = u(t)$$

Rel: Unit ramp and delta function

$$r(t) = \iint \delta(t)\,dt \quad \text{or} \quad \frac{d^2}{dt^2} r(t) = \delta(t)$$

$$\delta(t) \xrightarrow{\text{integrate}} u(t) \xrightarrow{\text{integrate}} r(t)$$

$$r(t) \xrightarrow{\text{differentiate}} u(t) \xrightarrow{\text{differentiate}} \delta(t)$$

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1) Prove the following :-

a) $\delta(n) = u(n) - u(n-1)$

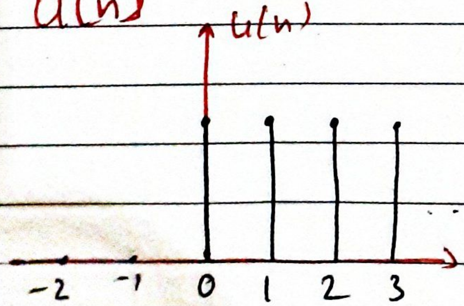
Sol:- As we know

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

$$u(n-1) = \begin{cases} 1 & \text{for } n \geq 1 \\ 0 & \text{for } n < 1 \end{cases} \quad -(2)$$

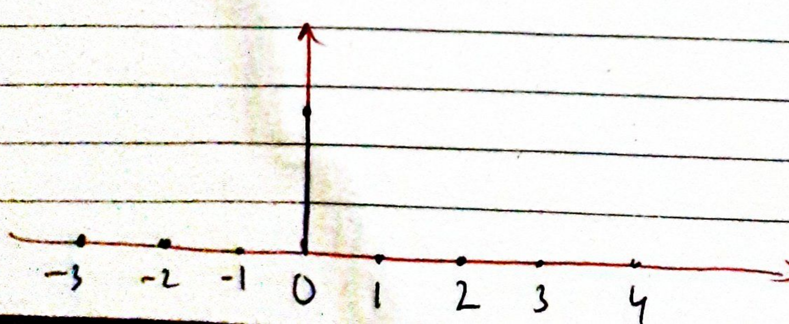
$$u(n) - u(n-1) = \begin{cases} 0 & \text{for } n \geq 1 \text{ i.e. } n > 0 \\ 1 & \text{for } n = 0 \\ 0 & \text{for } n < 0 \end{cases}$$

$u[n]$



$u[n-1]$

$u[n] - u[n-1] = \delta[n]$



$\therefore u[n] - u[n-1] = \delta[n]$

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2) ~~$x(t) = rect\left(\frac{t}{T_0}\right)$~~

*

Steps: {General steps for determination of energy or Power s/g}

1) Check whether s/g is periodic or nonperiodic. If periodic and has infinite duration, then it is power s/g. Calculate power.

2) If s/g is periodic and of finite duration, then it is energy s/g and calculate energy directly.

3) If s/g is not periodic, it is energy s/g. calculate energy directly.

2) $u(n) = \sum_{K=-\infty}^{n} \delta(K)$

As we know $\delta(K) = \begin{cases} 0 & \text{for } n<0 \\ 1 & \text{for } n \geq 0 \end{cases}$

If we see the eq. the R.H.S of eq. is an unit sample seq. $u(n)$.

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Q. Determine whether the following s/g are energy s/g or power s/g. Calculate their energy or power

1) $x[n] = \cancel{\cos}\left(\frac{1}{2}\right)^n u[n]$

we can not compare it with the standard eq. to calculate ~~f~~ f.

Hence it is not a periodic s/g.

$$E = \sum_{n=-\infty}^{\infty} |x(n)|^2 = \sum_{n=0}^{\infty} \left[\left(\frac{1}{2}\right)^n\right]^2 = \sum_{n=0}^{\infty} (1/4)^n$$

$$\sum_{n=0}^{\infty} a^n = \frac{1}{1-a} \qquad |\alpha| < 1$$

$$= \frac{1}{1 - \frac{1}{4}} = \frac{4}{3}$$

Operations -

1) Transformation in Independent Variable of s/s

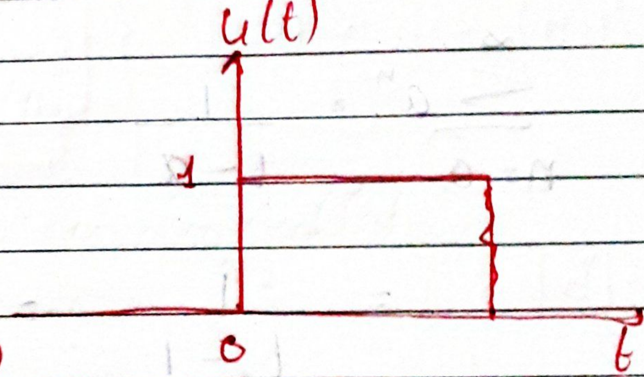
a) Delay / Advancing

b) Time Folding

c) Time Scaling.

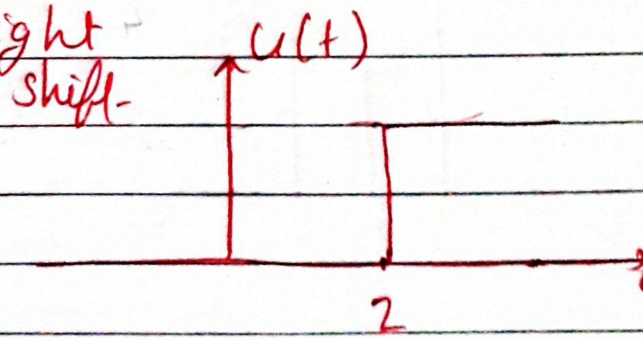
a) Time Delay / Advancing -

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



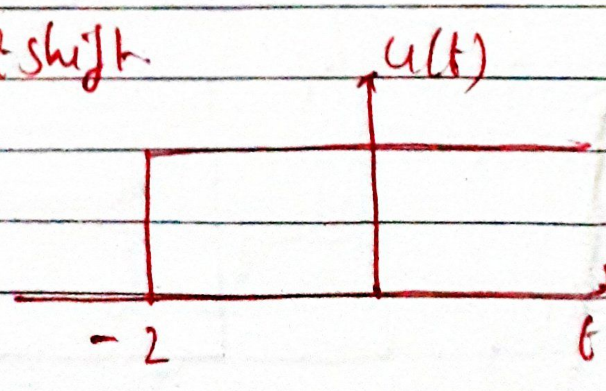
Unit step function delayed by 2 → right shift

$$u(t-2) = \begin{cases} 1 & \text{for } t \geq 2 \\ 0 & \text{for } t < 2 \end{cases}$$



Unit step function advances by 2. → left shift

$$u(t+2) = \begin{cases} 1 & \text{for } t \geq -2 \\ 0 & \text{for } t < -2 \end{cases}$$

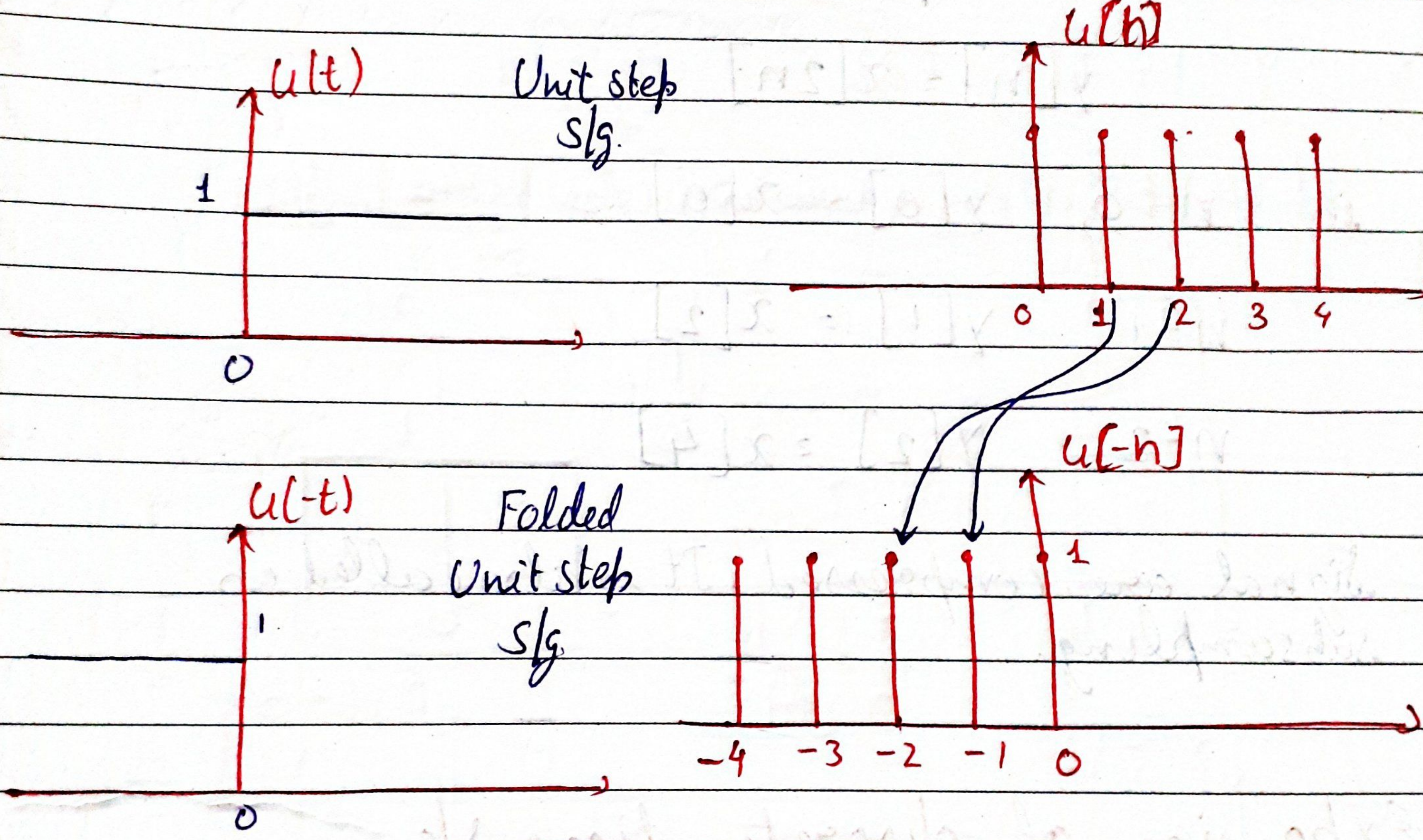


b) Time folding:-

* It is used in convolution.

Let $x(t)$ is a s/g.
Time folded s/g is obtained by replacing (t) with ($-t$)

$y(t) = x(-t)$ $\qquad$ $y[n] = x[-n]$



Time folding operation on unit step s/g.

c) Time Scaling:-

It is divided into two parts.

a) Time compression:- Time axis is compressed.

$y(t) = x(2t)$

$y(t)$ will be compressed in time

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b) Time expansion:- Time axis is expanded.

$y(t) = x(t/2)$ y(t) will be expanded in time

Compression of Discrete-time s/g:-

Let $x[n]$ be the pulse, then

$$y[n] = x[2n]$$

ie. $n = 0,$ $y[0] = x[0]$

$n = 1$ $y[1] = x[2]$

$n = 2$ $y[2] = x[4]$

Signal are compressed. It is also called as subsampling.

Expansion of discrete-time s/g:-

$$y[n] = x\left[\frac{n}{2}\right]$$

$$y[0] = x[0]$$

$$y[2] = x\left[\frac{2}{2}\right] = x[1]$$

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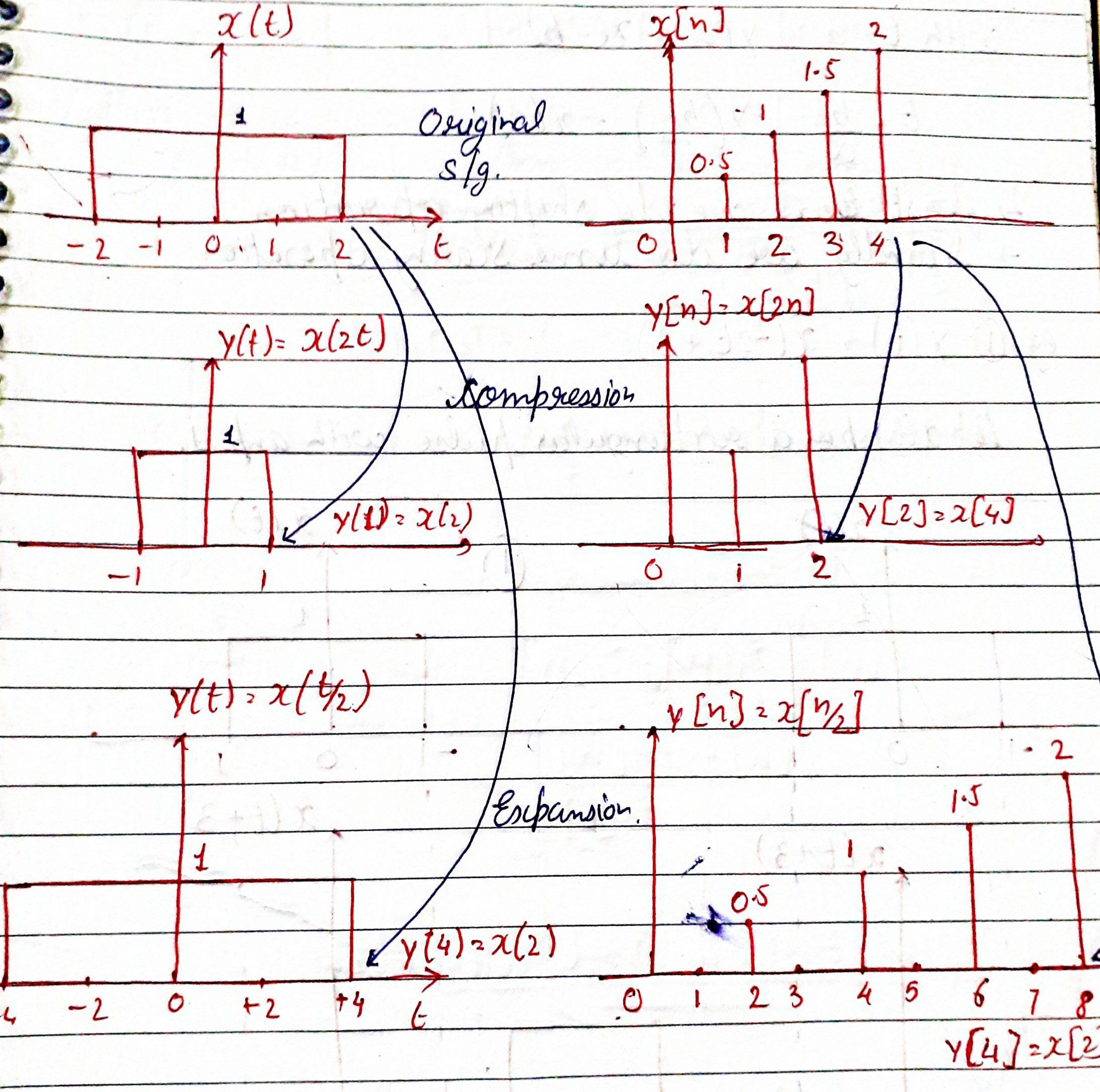
Continuous-time s/g

Discrete-time s/g



$y(t) = x(at - b)$

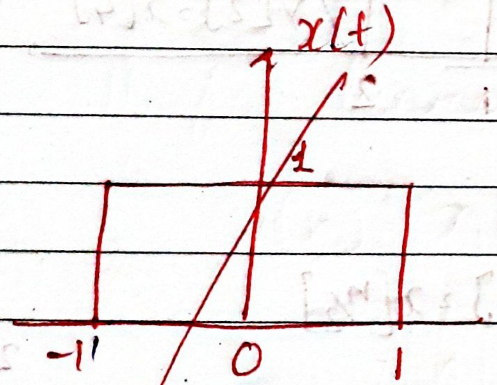
with $t = 0$, $\quad y(0) = x(-b)$

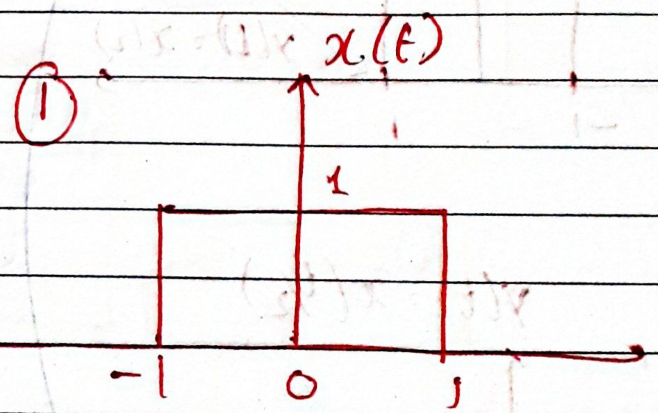
$t = \frac{b}{a} \quad y(b/a) = x(0)$

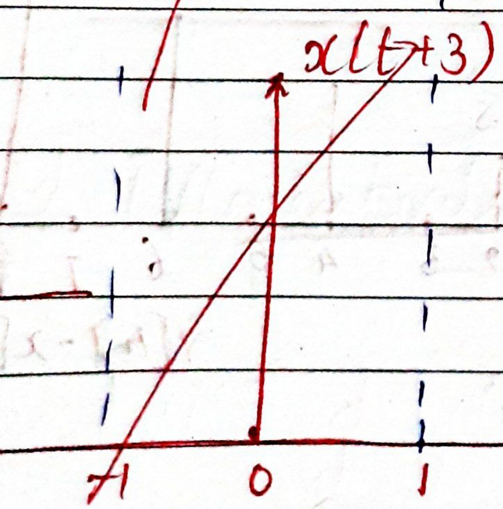
→ first ~~time~~ we do shifting operation
→ secondly we do time scaling operation

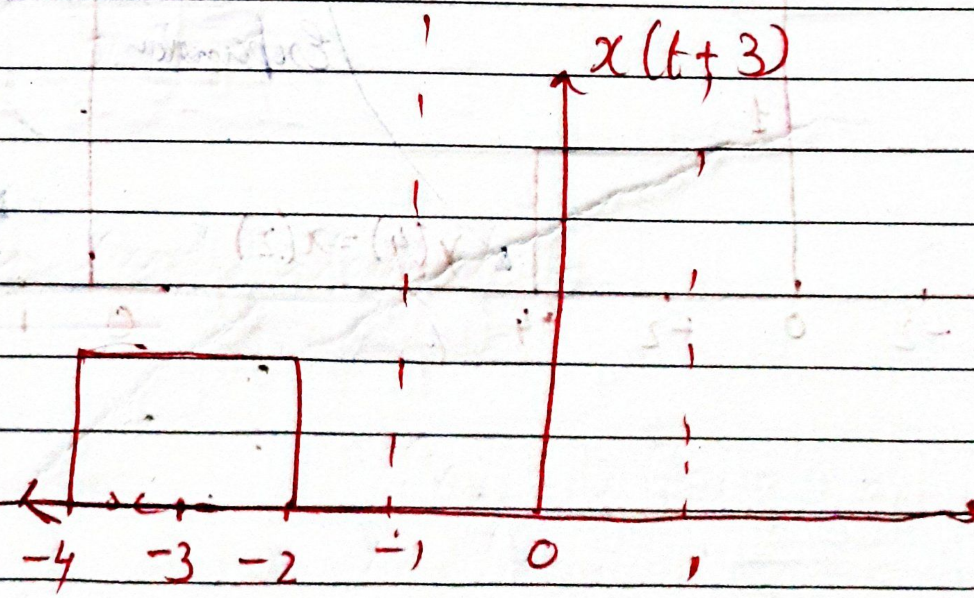
eg-① $y(t) = x(-2t + 3)$

Let $x(t)$ be a rectangular pulse with amp 1.



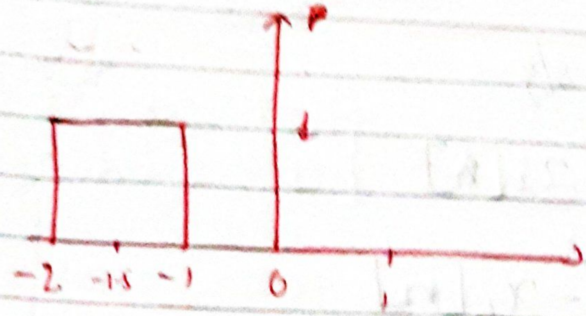






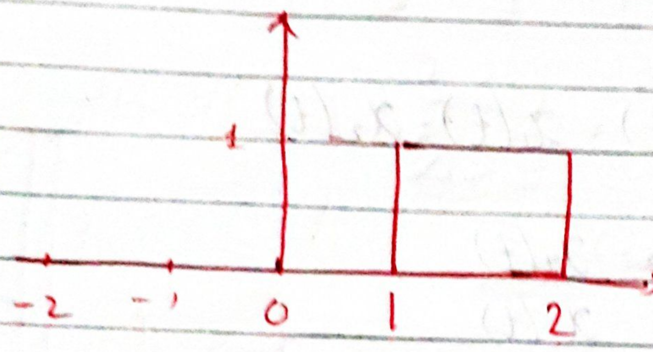
$x(2t)$

$x(2t+3)$ (time shifting)



$x(-2t+3)$

folded waveform



2) Transformation on Amplitude of the s/g :-

a) Amplitude scaling :- Amplitude can be changed.

b) Addition & subtraction :-

Let $x_1(t)$ & $x_2(t)$ be two continuous time s/g.
Let $y(t)$ be the ~~o/p~~ resultant s/g.

$y(t) = x_1(t) + x_2(t)$ → for addition

$||^y$ $y(t) = x_1(t) - x_2(t)$ → for subtraction lly for discrete time s/g.

$$y[n] = x_1[n] + x_2[n]$$

$$y[n] = x_1[n] - x_2[n]$$

c) Multiplication and Division:-

For Multiplication

$$y(t) = x_1(t) \cdot x_2(t)$$

For division $y(t) = \dfrac{x_1(t)}{x_2(t)}$

lly for discrete time s/g.

$$y[n] = x_1[n] \cdot x_2[n]$$

$$y[n] = \frac{x_1[n]}{x_2[n]}$$

d) Differentiation and Integration.

$y(t) = \dfrac{d}{dt} x(t)$

$y[n] = x[n] - x[n-1]$

(as direct diff doesn't exist for discrete s/g.)

$y(t) = \int_{-\infty}^{t} x(\tau) d\tau$

$y[n] = \sum_{k=-\infty}^{n} x[n]$

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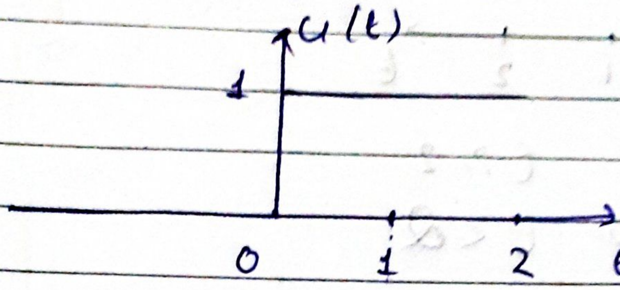
Numerical

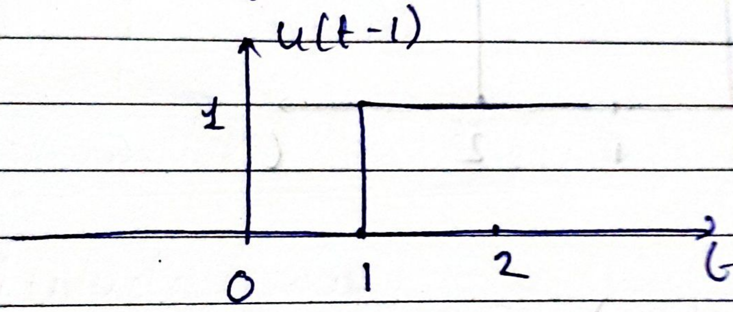
1) Draw the waveform for following step function

a) $f_1(t) = 2u(t-1)$

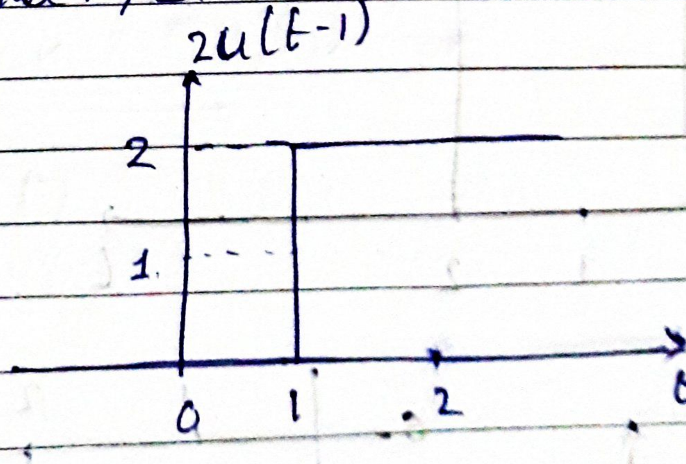
① Draw waveform of $u(t) = \begin{cases} 1 & t \geq 0 \\ 0 & t < 0 \end{cases}$



② Draw waveform of $u(t-1) = \begin{cases} 1 & t \geq 1 \\ 0 & t < 1 \end{cases}$

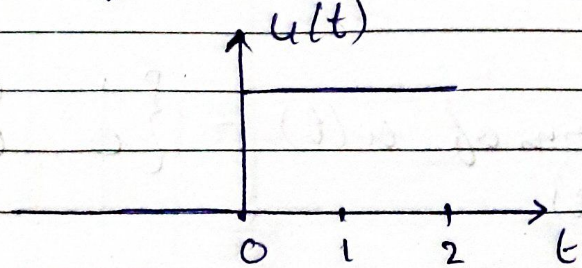


③ Draw waveform of $2u(t-1)$ in this the amp is multiplide by 2.

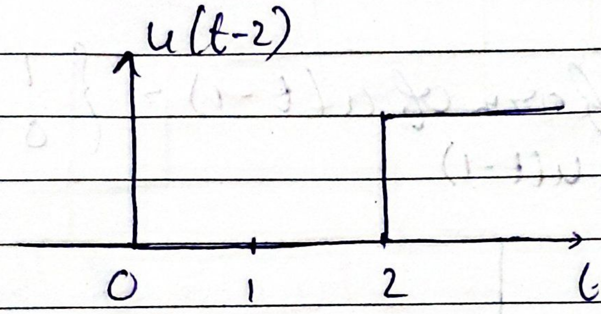


b) $f_2(t) = -2u(t-2)$

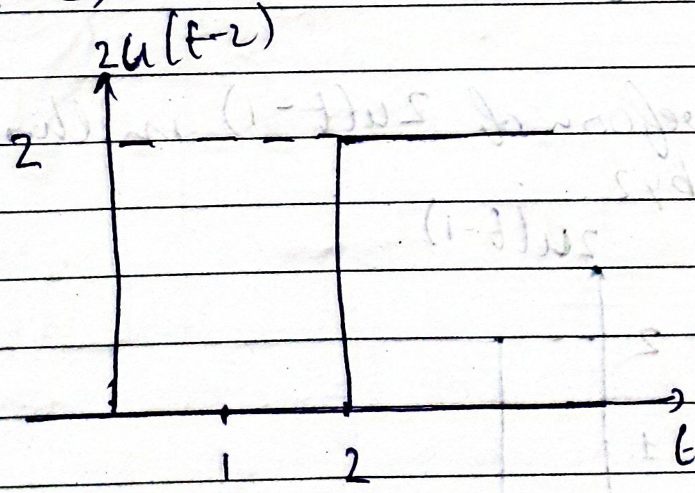
① Draw waveform of $u(t) = \begin{cases} 1 & t \geq 0 \\ 0 & t < 0 \end{cases}$



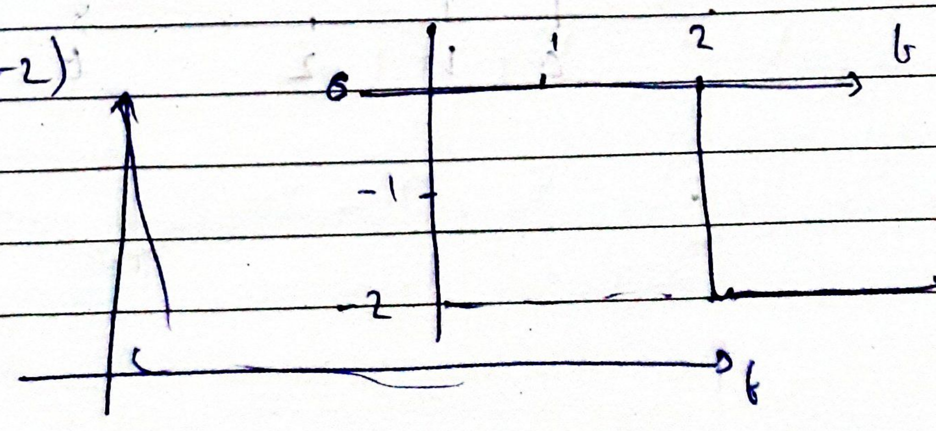
② Draw $u(t-2) = \begin{cases} 1 & t \geq 2 \\ 0 & t < 2 \end{cases}$



③ Draw $2u(t-2)$



Draw $-2u(t-2)$



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System and Classification of System :-

System :- a mathematical model of a physical process that relates the i/p (or excitation) s/g to the o/p (or response) s/g.

a) System with Memory and without Memory :-

A system is Memoryless if o/p at any time depends on only the i/p at the same time. eg:- Resistor.

$$\boxed{y(t) = x(t)}$$

A system is with Memory if o/p at any time depend on future values of i/p or o/p.

eg :- accumulator or summer and delay.

$$\boxed{y[n] = \sum_{k=-\infty}^{n} x[k]}$$ → for accumulator or summer

$$\boxed{y[n] = x[n-1]}$$ → for delay.

b) Causal and Noncausal System

Causal :- if o/p $y(t)$ at $t = t_0$ depends on only the i/p $x(t)$ for $t \le t_0$.

or

if o/p of a system depends (w.r.t to time) on only the present / past values of i/p.

Noncausal :- If the o/p depends on future values

eg →

$$y(t) = x(t+1)$$

Q. Prove whether $y[n] = x[-n]$ is causal or non causal system.

Sol :- Let us consider

$$y[n] = x[-n]$$

at $n = n_0$, $y[n_0] = x[-n_0]$ → this is past value

at $n = -4$, $y[-4] = x[4]$

Present value future value

Hence for this case the o/p $y[-4]$ depends on future value $x[4]$.

Hence we can conclude that the above system is non causal.

c) Linear and Nonlinear system :-

A system is said to be linear if it satisfy two properties.

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1) Additivity :-

i.e. the response to $x_1(t) + x_2(t)$ is $y_1(t) + y_2(t)$

2) Homogeneity (Scaling)

i.e. response to $a\,x_1(t)$ is $a\,y_1(t)$

or

$$\boxed{\begin{array}{l} a x_1(t) + b x_2(t) \longrightarrow a y_1(t) + b y_2(t) \\ a x_1[n] + b x_2[n] \longrightarrow a y_1[n] + b y_2[n] \end{array}}$$

* a zero i/p yields a zero o/p.

d) Time Invariant and Time Varying System

Time Invariant :- if a time shift (delay or advance) in the i/p s/g causes the same time shift in the o/p s/g.

$$\left.\begin{array}{l} a\,x(t-\tau) = a\,y(t-\tau) \\ a\,x[n-k] = a\,y[n-k] \end{array}\right] \quad — \ (1)$$

Time Varying System :- If a system does not satisfy the eq (1) ~~given in~~ then it is called time varying system.

* If a system is linear and time invariant, then it is called linear time invariant (LTI) system.

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e) Stable System :-

A system is bounded-i/p/bounded-o/p (BIBO) stable if for any bounded i/p x defined by

$$|x| \leq K_1$$

the corresponding o/p y is also bounded.

$$|y| \leq K_2$$

where K_1 & K_2 are finite real constant.