T-3

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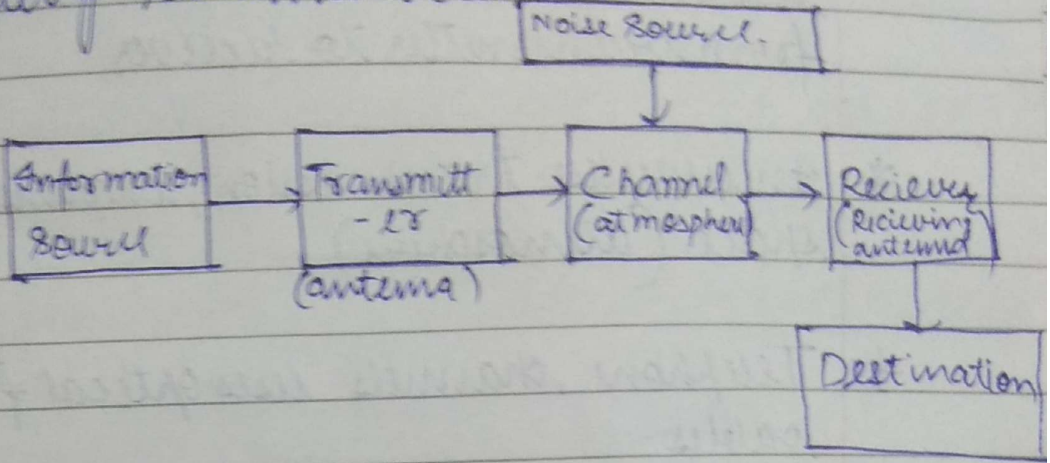
COMMUNICATION SYSTEM

Analog communication:-



TRANSMITTER:-

* converts electrical signal into form that is suitable for transmission through physical channel.
  e.g → in TV & Radio Broadcast.

* It translate signal into appropriat frequency range, so that signal transmitted by multiple radio stations do not interfere.

* It modulates signal to be transmitted during modulation technique like.
  → Amplitude modulation (AM)
  → Frequency modulation (FM)
  → or Phase " (PM)

* Other functions performed by transmitter are amplification of modulated signal, radiation of signal by means of transmitting antenna.

CHANNEL:—

* Communication channel is the physical medium that is used to send signal from transmitter to reciever.

* In wireless transmission, channel is free space (atmosphere)

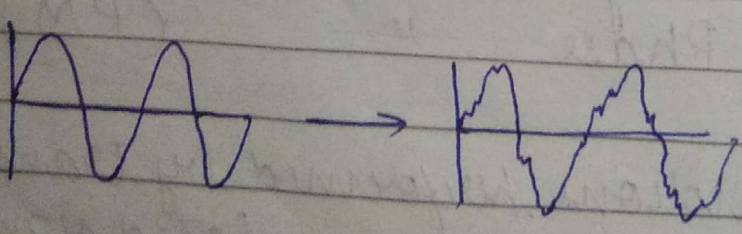
* Telephone channels uses optical fibre cables.

* Signal is degraded due to man made noise, atmosphere noise & thermal noise.

* Automobile ignition noise is man made noise.
Electrical lightening due to thunderstorm. is atmospheric noise.

Imp

* Noise generated at front end of reciever where signal amplification is performed is <u>thermal noise</u>.



NOISE EFFECT ON SIGNAL

RECIEVER:-

* Function of reciever is to recover the message signal contained in recieved signal.

* It also demodulates modulated signal send by transmitter.

* It also performs function of signal filtering & noise suppression.

MODULATION:-

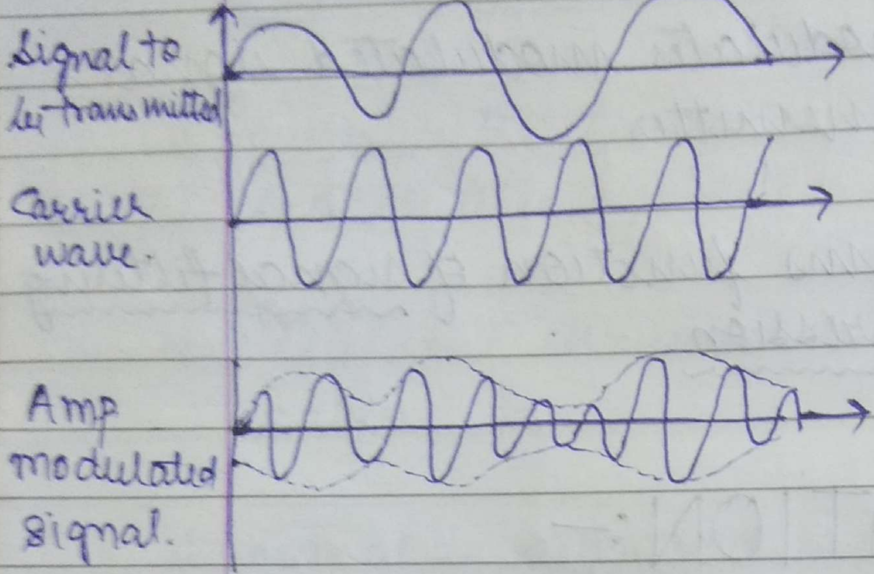
It is the process of varying one or more properties of carrier signal with a modulating signal that contains information to be transmitted.

3 Types of analog modulation:-

1. AM (Amplitude modulation)
2. FM (Frequency ")
3. PM (Phase ")

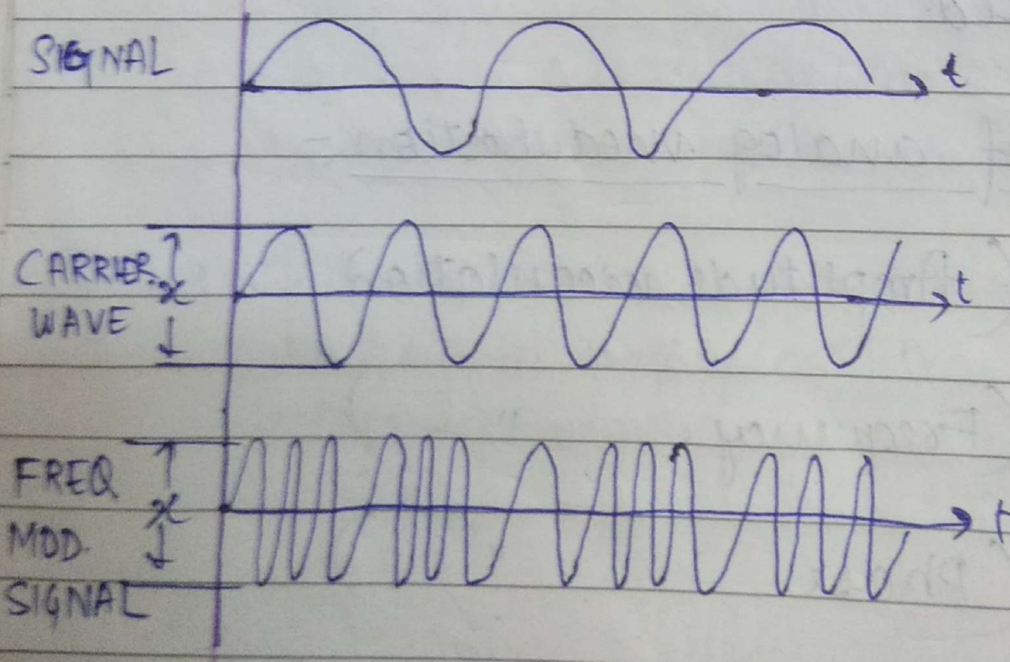
1. AM:—

Amplitude of carrier signal is varied in proportion to waveform being transmitted.



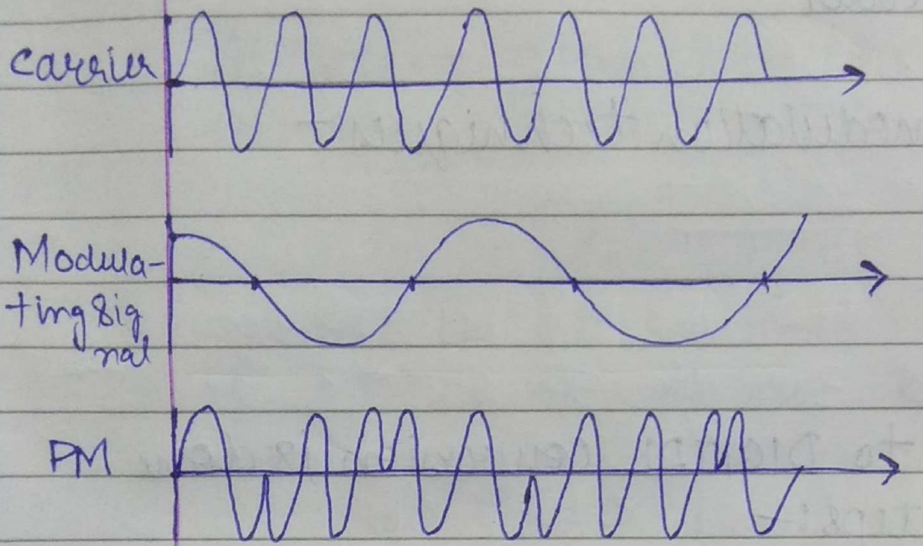
frequency remains same only the amp is changed according to the signal.

2. Frequency Mod.:—



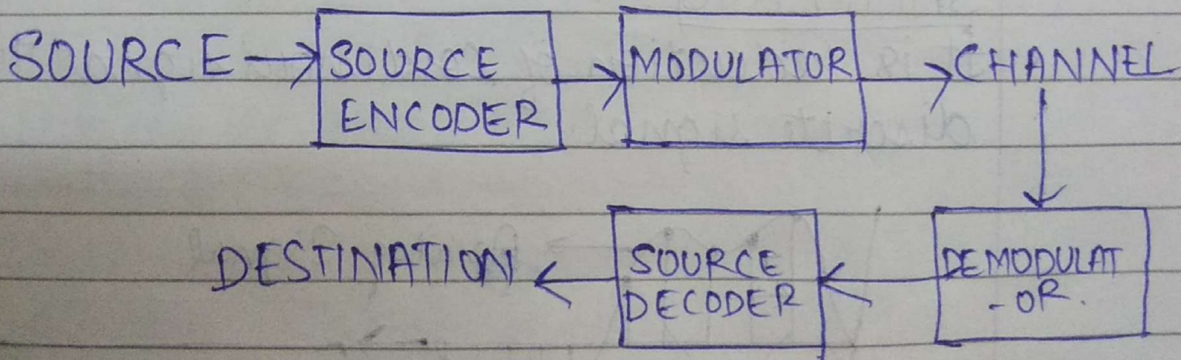
3. Phase modulation:-

PM is a modulation pattern that encodes information as variations in instantaneous phase of carrier wave



[occurs when mod. signals changes its phase]

DIGITAL COMMUNICATION:-



* Source → represents message to be transmitted which includes speech, videa, image or text data.
* Information has been acquired in analog form, it must be converted into digital form.

* This analog to digital conversion is done by source encoder block.
* Modulator process binary information for transmission over channel.
* AT reciever side, data is demodulated & then connected into analog form by source decoder.

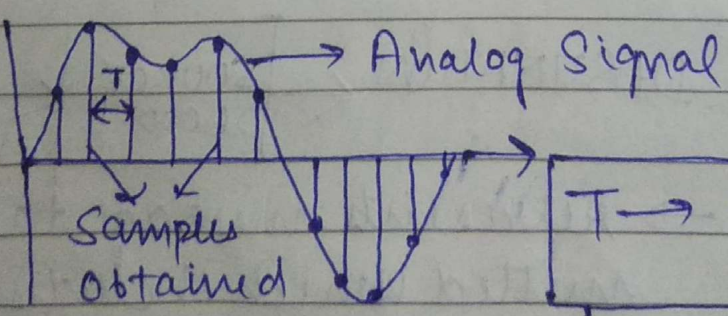
Digital modulation techniques:-
- ASK
- FSK
- PSK

ANALOG to DIGITAL conversion is done in 2 steps:-

Step1 ⟶ Sampling
Step2 ⟶ Quantization.
[Done by Encoder]

SAMPLING:-

• It is reduction of continous signal to discrete signal.

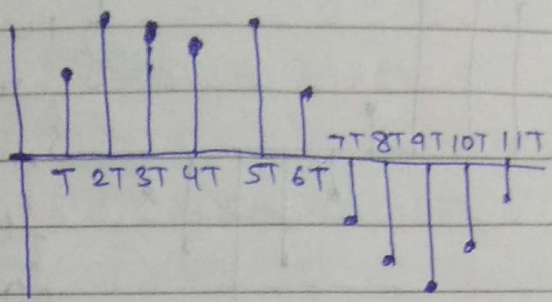


T → Sampling Period

Samples are separated by T

Less the T more will be the Bandwidth.

Samples obtained:-



Sampling frequency f_s is no. of samples obtained in 1 sec.

$$\boxed{f_s = \frac{1}{T}}$$

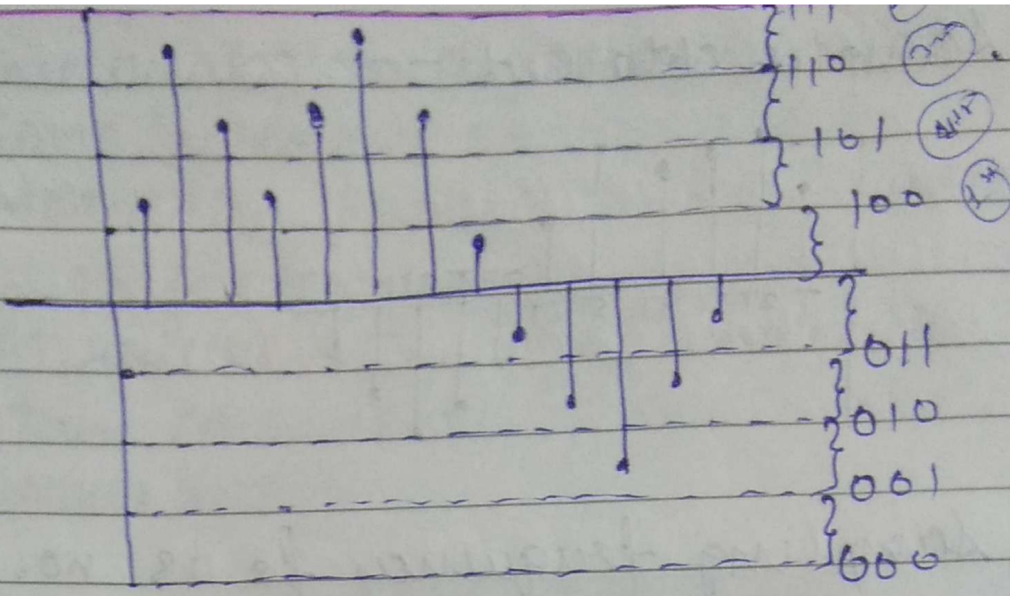
if $T = 0.5 \Rightarrow$ 2 samples in 1 sec

$$\boxed{f_s = \frac{1}{0.5} = 2}$$

QUANTIZATION:-

* It is the process of mapping a large set of input values to smaller set.
* Difference b/w I/P value & quantized value is called quantization error.
* Device that performs quantization is called Quantizer.

3 BIT QUANTIZER

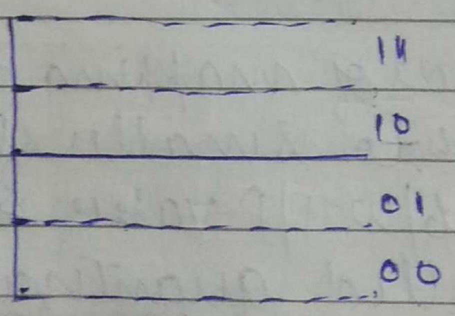


Quantized value:-

100	111	110	101	110	111	110	100	011
1st	2nd	3rd	4th	5th	6th	7th	8th	9th

010	001	010	011
10th	11th	12th	13th

2 BIT Quantizer:-



* More bit of quantizer then more accuracy (less the quantization error)

DISADVANTAGES of Digital Communication:—

1. Quantization error.
2. High Power consumption:—
→ Analog signal needs to be converted into digital signal at transmitter end & vice versa at reciever end which requires extra circuitary & more power consumption.

3. Infinite Bandwidth:—

$$BW \propto \frac{1}{\text{Time period of Pulses}}$$

In order to have fast switching, time period of pulses should be reduced ∴ Higher BW is needed.

4. Difficult transmission as compared to analog communication.

ADVANTAGES of Digital Communication over analog comm.:—

* More secure data.
* More immunity to noise
* Digital information can be easily saved & retrieved.
* Cheaper than analog comm.

SNR (Signal to Noise Ratio):-

Ratio of Signal Power to Noise Power.

$$(SNR)_{dB} = 10 \log \frac{(\text{SIGNAL POWER})}{(\text{NOISE POWER})}$$

$$P \propto (AMP)^2$$

$$(SNR)_{dB} = 20 \log \frac{S}{N}$$

S → Signal Amp.
N → Noise Amp.

BER (Bit Error Rate):-

* Ratio of no. of bit errors to total no. of bits transferred.

e.g →

BITS transmitted:-
1001001101

BITS Recieved:-
1011000001

BER = $\frac{3}{10}$ = 0.3 or 30%

NEED OF MODULATION:-

1. To separate signal from different transmitters.
(Using FM, each signal is modulated at different frequency)

2. To reduce size of antenna

$$\text{Height of Antenna} \propto \frac{1}{\text{frequency}}$$

At higher freq. (using FM), height of antenna would decrease. [Generally in MHz]

3. To transmit information to long distances.

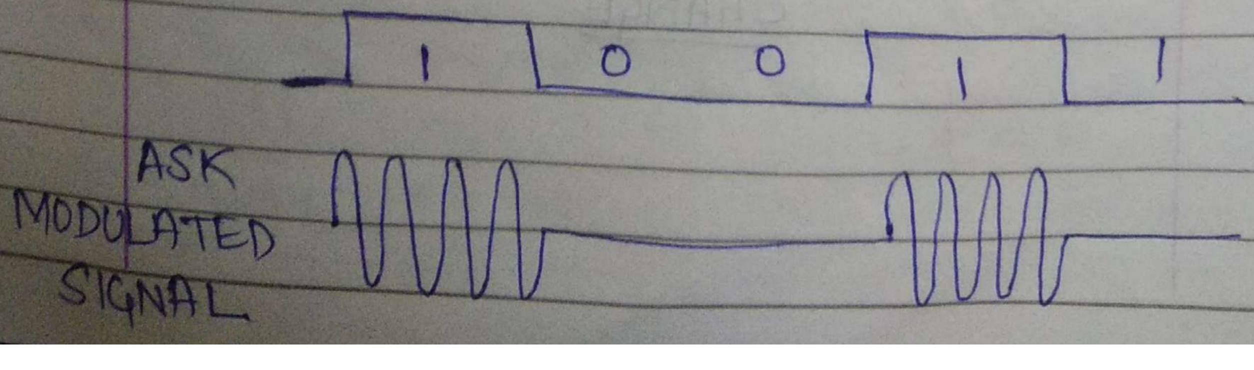
4. To have effective power radiated by Antenna ($\underline{\underline{P \propto f}}$)

DIGITAL MODULATION TECHNIQUES :-

1. Amplitude Shift Keying (ASK)
2. Frequency " " (FSK)
3. Phase " " (PSK)

1. ASK :-

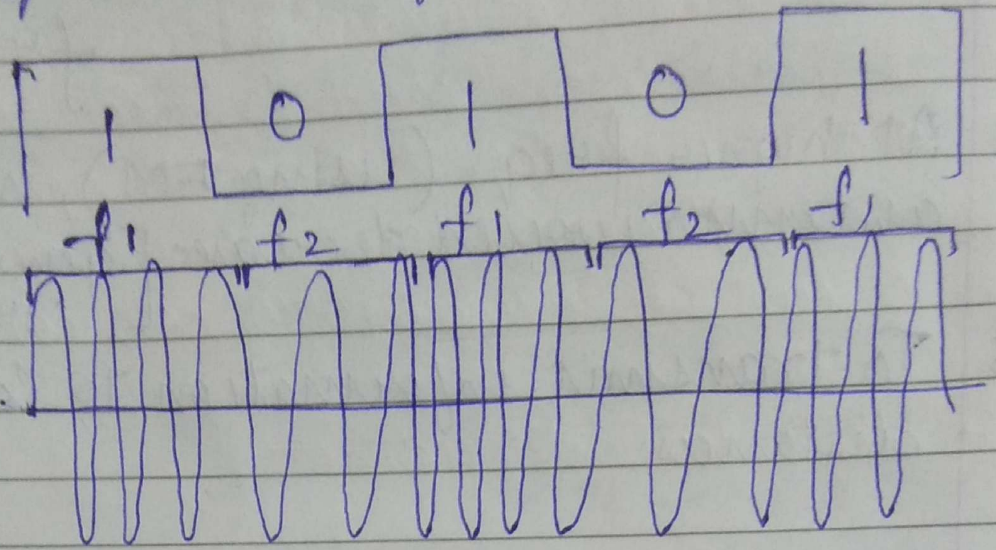
In ASK, Binary '1' is represented by sending a fixed amplitude carrier wave of fixed freq.



2. FSK:-

Use pair of discrete frequency f_1 & f_2 to represent binary '1' & '0'.

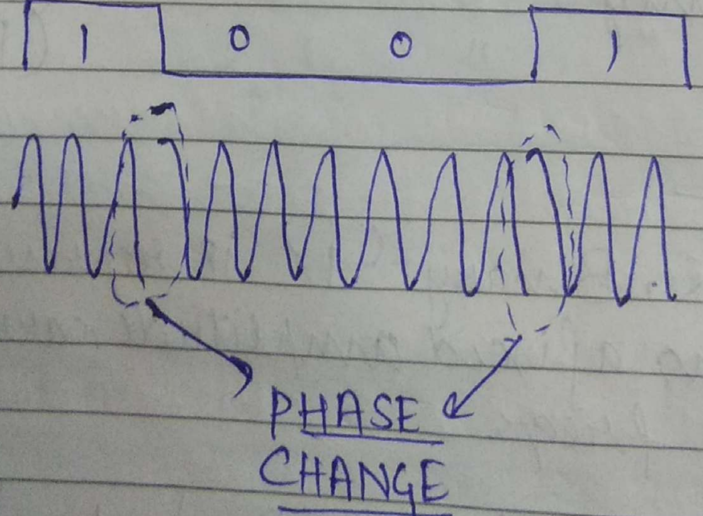
FSK.



$\boxed{f_1 > f_2}$

3. PSK:-

It is digital modulation technique that conveys data by changing phase of signal.



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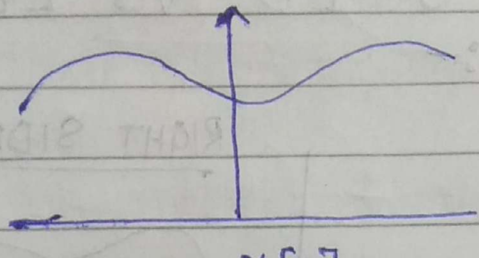
SIGNALS & SYSTEMS :-

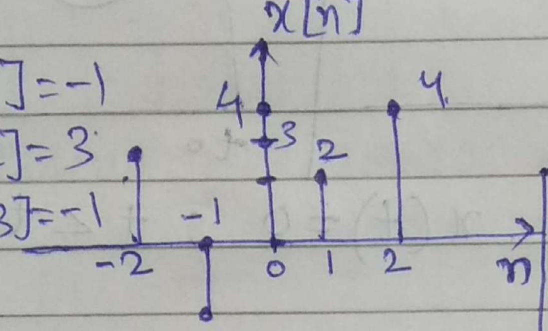
CLASSIFICATION OF SIGNALS:-

1. Continous time & discrete time signals.



CONTINOUS TIME (CT)

$x[-1] = -1$
$x[-2] = 3$
$x[-3] = -1$



DISCRETE TIME

$x[0] = 4$
$x[1] = 2$
$x[2] = 4$

Defined on discrete intervals of time.

2. Finite & ∞ Duration signal.

$$x(n) = \begin{cases} 2n & -1 < n < 1 \\ 0 & \text{else} \end{cases}$$

$$x(t) = \begin{cases} 4 & t \geq 0 \\ 0 & t < 0 \end{cases}$$

$\Downarrow$

FINITE SIGNAL

∞ Duration:-

$x(t) = 4t$ for all t.
$x[n] = 4n$ " " n.

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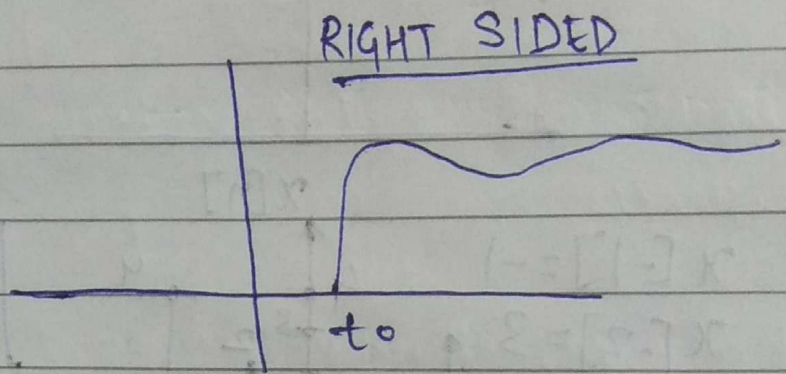
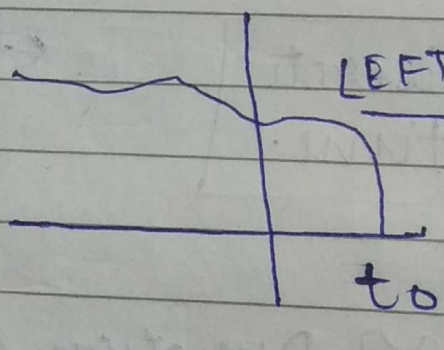
3. RIGHT SIDED VS LEFT SIDED SIGNAL:-



$x(t) = 0 \; ; \; t < t_0$



$x(t) = 0 \; ; \; t > t_0$

4. ANALOG VS DIGITAL SIGNAL:-

ANALOG SIGNAL:-
whose amplitude can take any value in continous range.

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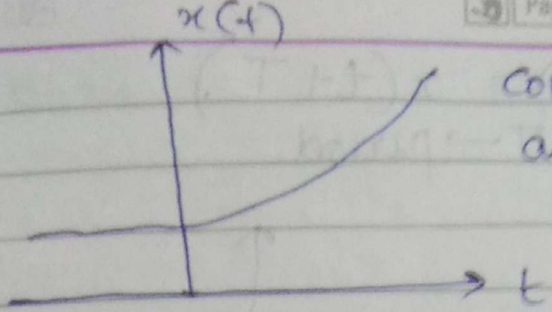
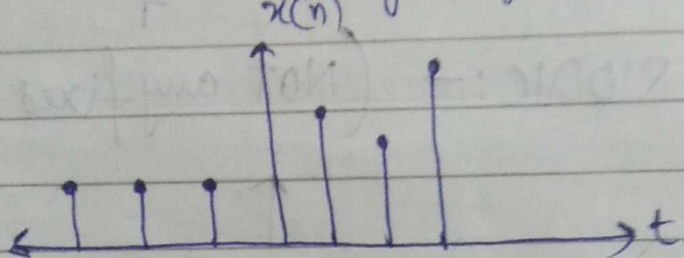


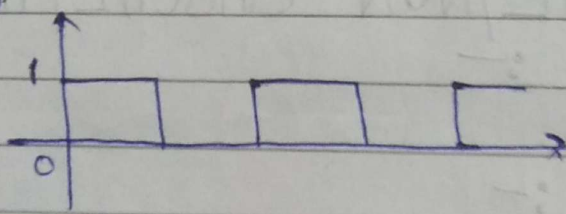
Continous time analog signal:—

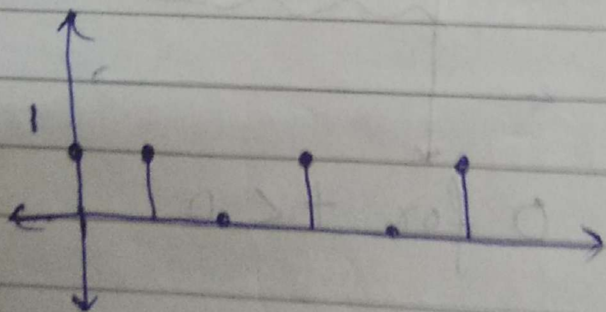


Discrete time analog signal

DIGITAL SIGNAL:—

Whose amplitude can take only finite no. of values





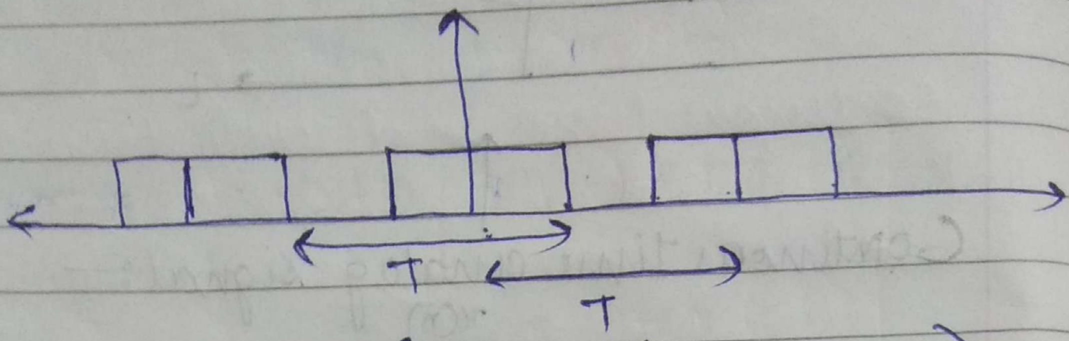
5 PERIODIC VS APERIODIC SIGNAL:—

PERIODIC:—

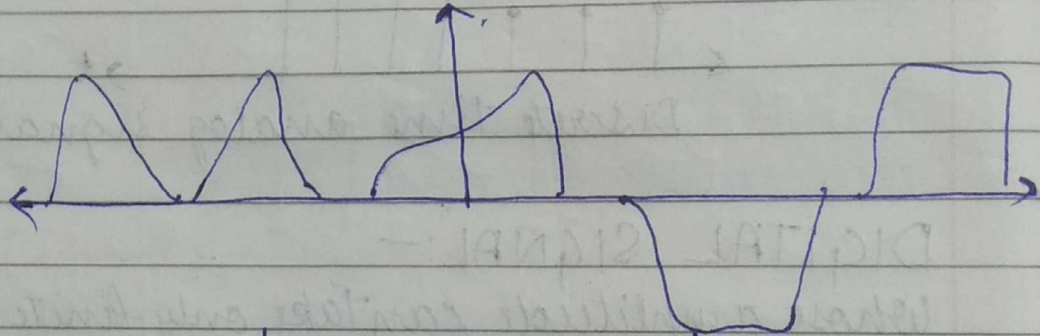
Repeats its value after fixed time.

$x(t) = x(t+T)$

$T \rightarrow$ period

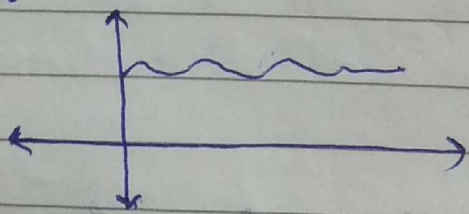


APERIODIC :- (Not any fixed pattern)



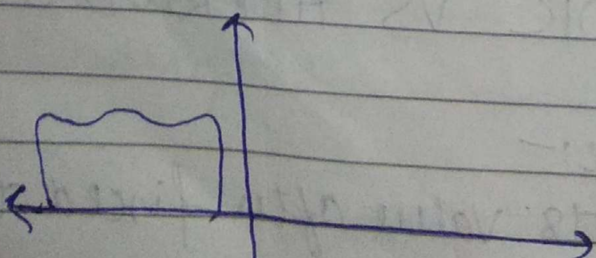
6. CASUAL / NON CASUAL / ANTI CASUAL SIGNAL :-

CASUAL :-



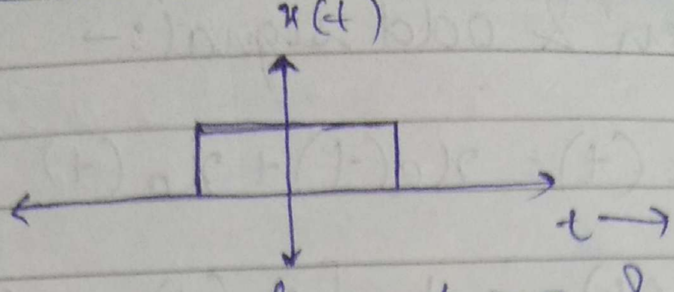
0 for $t < 0$

ANTI CASUAL :-



0 for $t > 0$

NON CASUAL:-

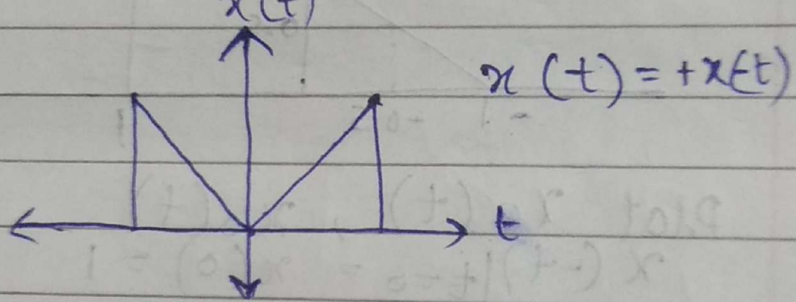


FINITE VALUE for $t > 0$ & $t < 0$

7. EVEN VS ODD SIGNAL:-

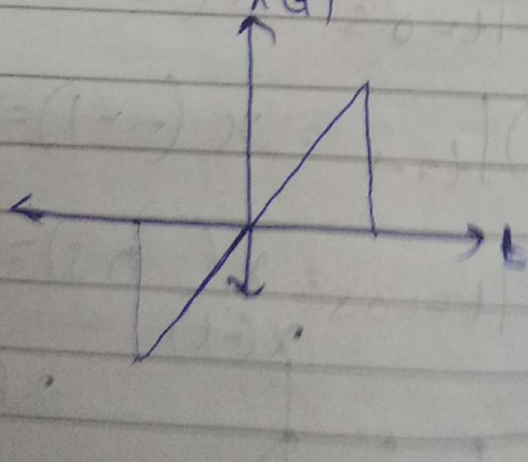
Even Signal:-

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



Odd Signal:-

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



* Any signal can be represented in terms of Even & odd signal:—

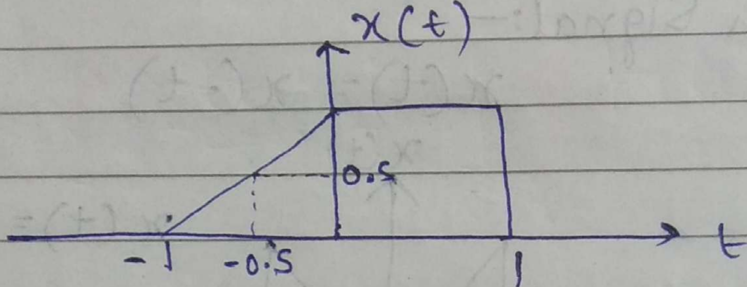
$$x(t) = x_e(t) + x_o(t)$$

Even comp. of $x(t)$ $\rightarrow$ $x_e(t) = \frac{1}{2}\left[x(t) + x(-t)\right]$

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

$\hookrightarrow$ Odd component of $x(t)$

Q.



Plot $x_e(t)$, $x_o(t)$

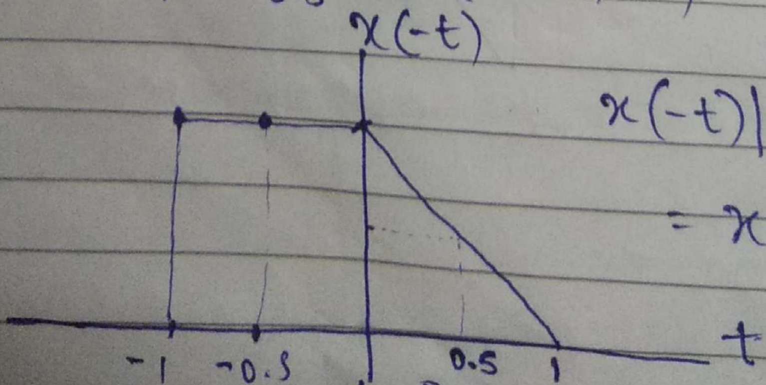
$x(-t)|_{t=0} = x(0) = 1$

$x(-t)|_{t=1} = x(-1) = 0$

$x(-t)|_{t=0.5} = x(-0.5) = 0.5$

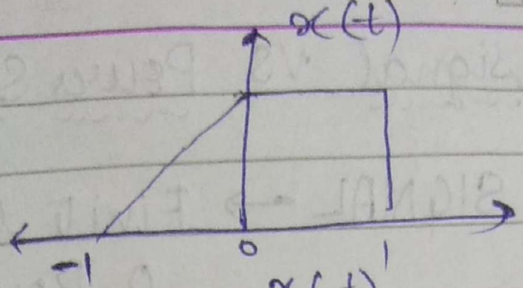
$x(-t)|_{t=-1} = x(--1) = x(1) = 1$

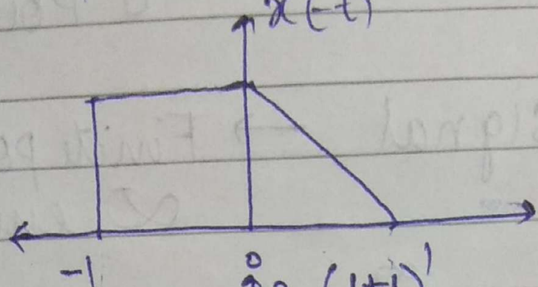
$x(-t)|_{t=-0.5} = x(0.5) = 1$

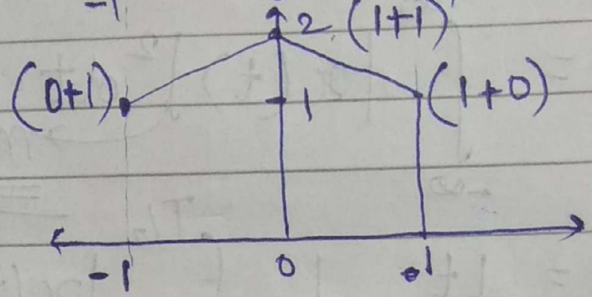


$x(-t)|_{1.1}$

$= x(1.1) = 0$

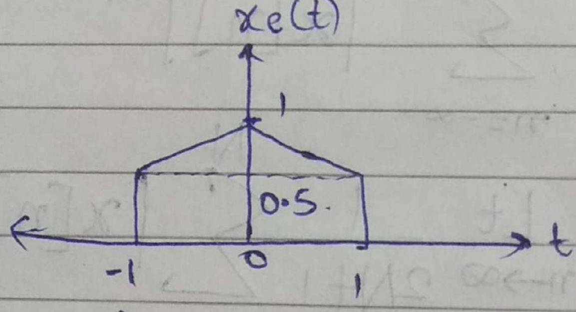




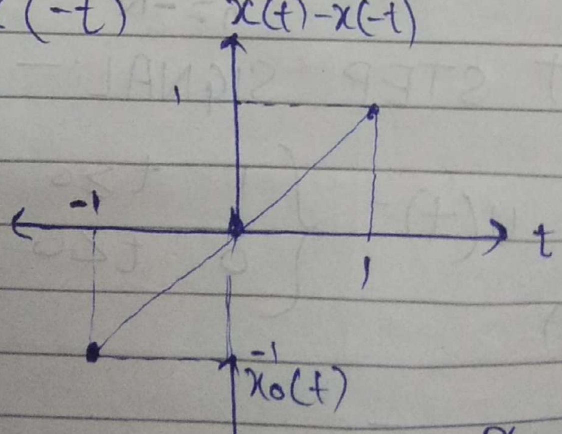


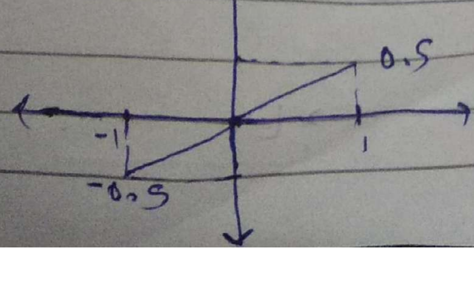
$x(t)+x(-t)$

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



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





$$x_o(t) = \frac{x(t) - x(-t)}{2}$$

8. Energy Signal VS Power Signal :-

ENERGY SIGNAL → Finite energy & 0 Power.

Power Signal → Finite power & ∞ energy.

For continous time signal.

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

magnitude

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

For discrete time signal.

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

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

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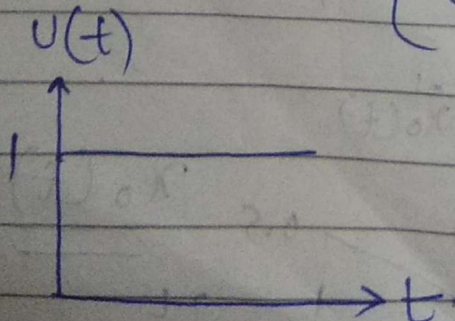
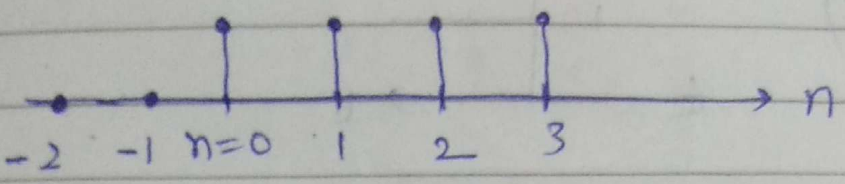
9. UNIT STEP SIGNAL :-

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



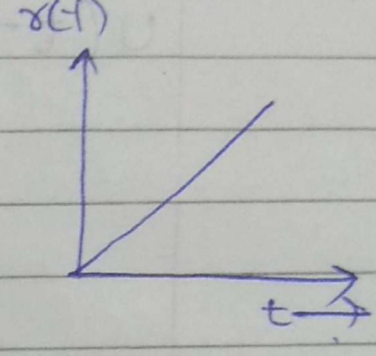
for discrete time intervals :-

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

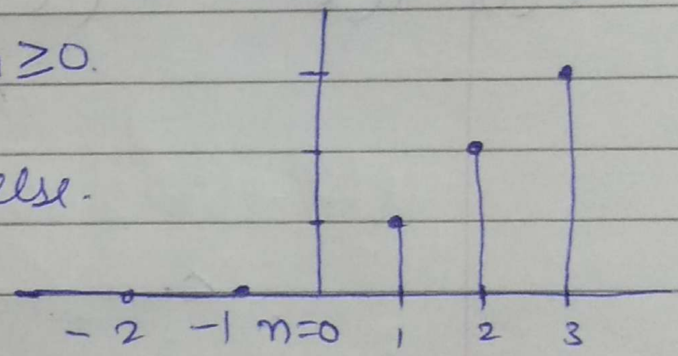


10. UNIT RAMP:-

$$r(t) = \begin{cases} t & t \geq 0 \\ 0 & \text{else.} \end{cases}$$

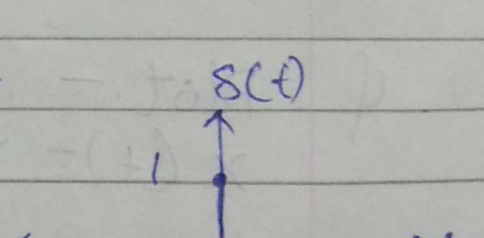


$$r[n] = \begin{cases} n & n \geq 0. \\ 0 & \text{else.} \end{cases}$$

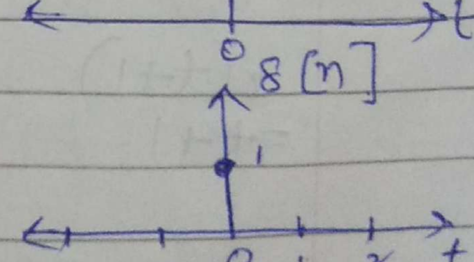


11. UNIT IMPULSE:-

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



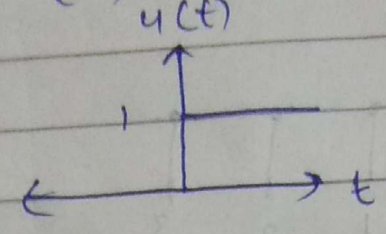
$$\delta(n) = \begin{cases} 1 & n = 0 \\ 0 & \text{else} \end{cases}$$



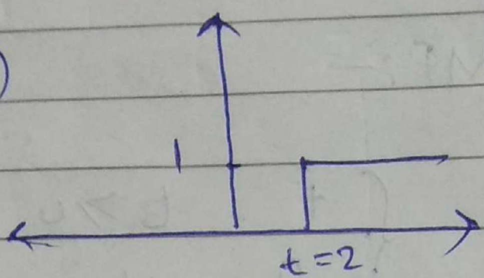
Q. Plot

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

$u(t)$



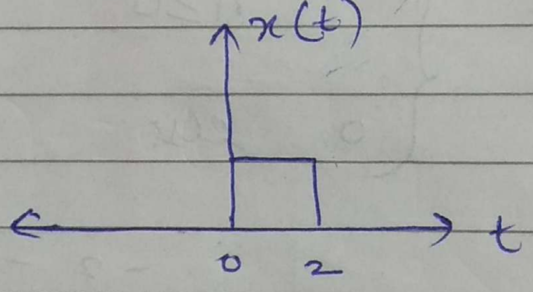
$u(t-2)$



$\left| u(t-2) \right|_{t=2}$

$= u(0) = 1$

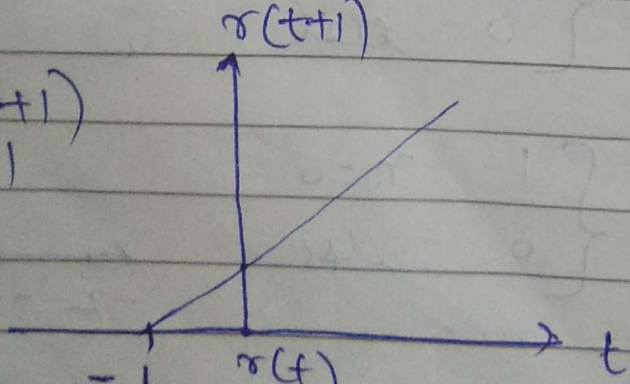
$x(t) = u(t) - u(t-2)$ [Subtracting the corresponding values]

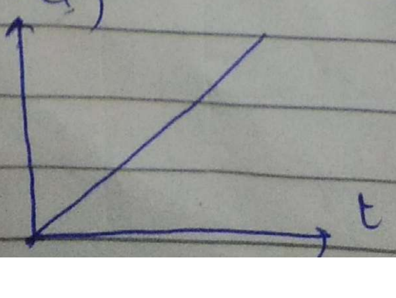


Q Plot —

$x(t) = r(t+1) - r(t) + r(t-2)$

$r(t+1)$
$= t+1$





$t+1-t = \boxed{1}$ $t+1-t$

$r(t+1) = t+1$

$r(t) = t$

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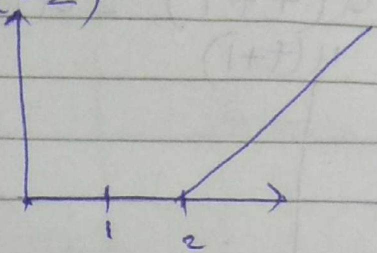
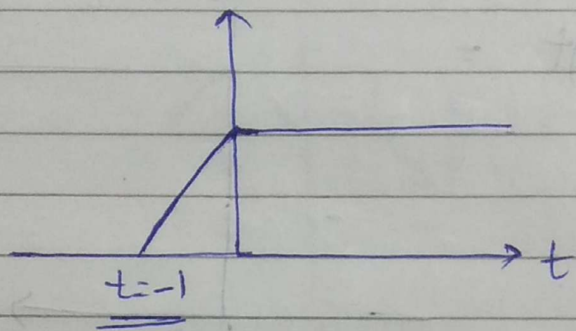
$r(t-2)$

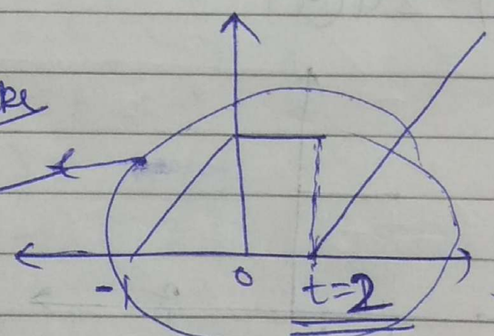


$r(t+1) - r(t) = 1$



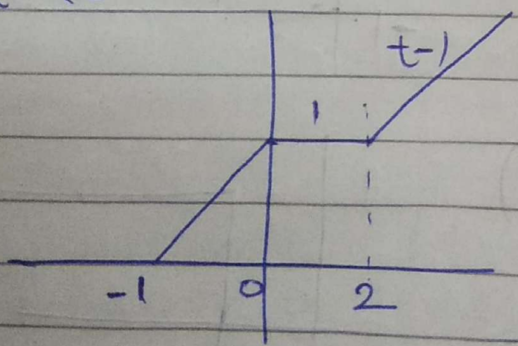
$1+t-2 = t-1$

Dont Do like this.



Not Correct

for $t<0$



for $t<2$

Same as above

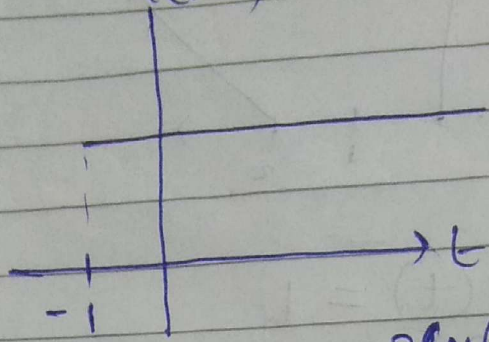
for $t>2$

$t-2+1$

$t-1$

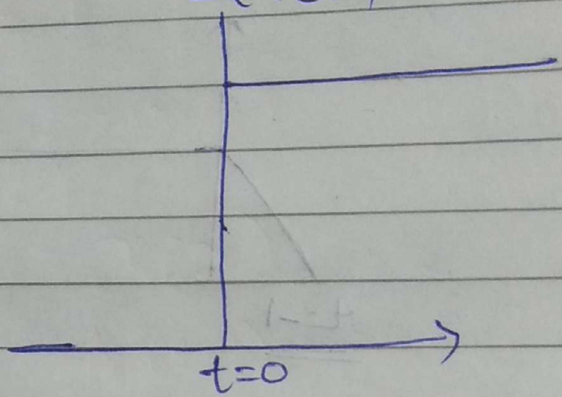
Q. $x(t) = u(t+1) - 2u(t) + u(t-2)$

$u(t+1)$

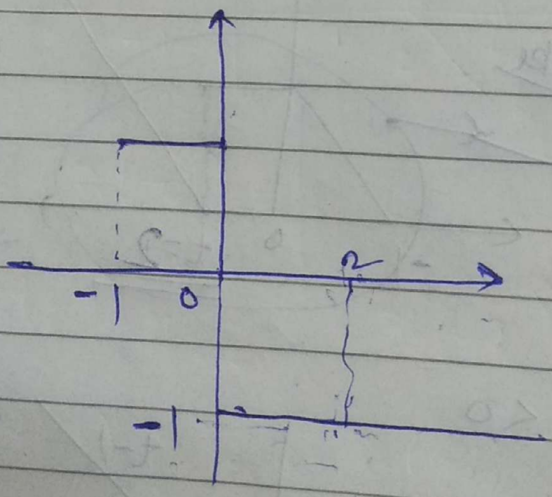


$2u(t)$

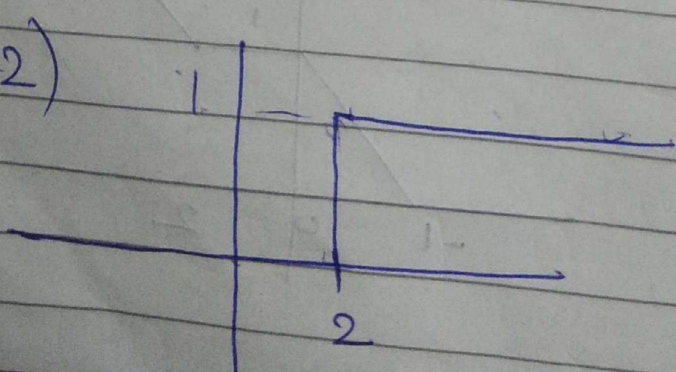
$2(u)t$ =



$u(t+1) - 2u(t)$



$u(t-2)$



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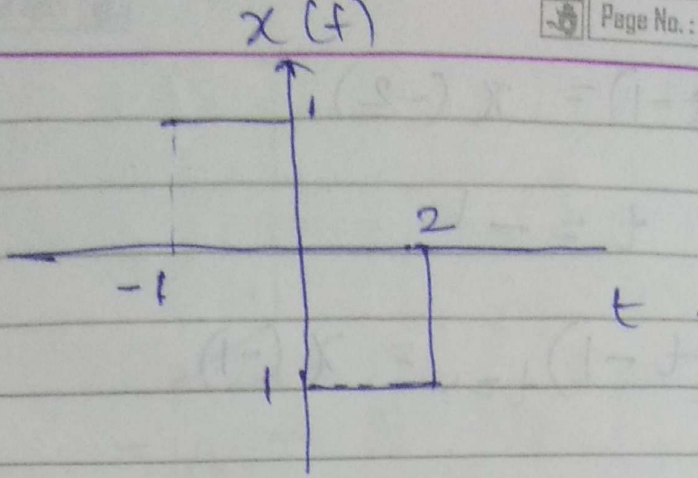
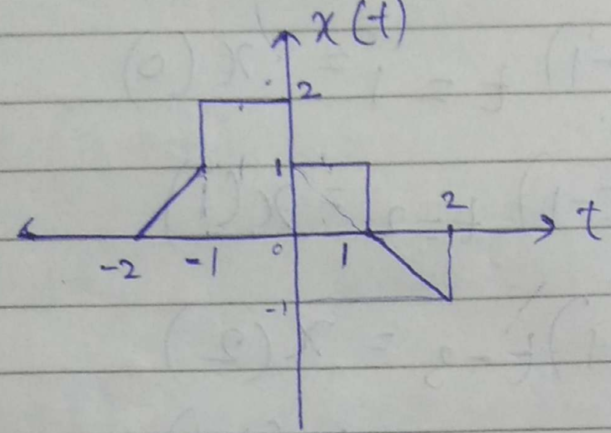


Q.



Plot :-

$x(t-1)$, $x(3t-1)$, $-3x(2+t)$,

$x(t)\left[\delta\left(t+\frac{1}{2}\right)-\delta\left(t-\frac{1}{2}\right)\right]$

for $-2<t<-1$

$x(t) = r(t+2)$

$\boxed{x(t-1) = r(t+1)}$

for $-1<t<0$

$x(t) = u(t+1) - u(t)$

$\boxed{x(t-1) = u(t) - u(t-1)}$

for $0<t<1$

$x(t) = u(t) - u(t-1)$

$\boxed{x(t-1) = u(t-1) - u(t-2)}$

for $1<t<2$.

$x(t) = 1-t$ $\quad x(t-1) = 1-(t-1) = \underline{\underline{2-t}}$

$x(t-1) = x(-2)$

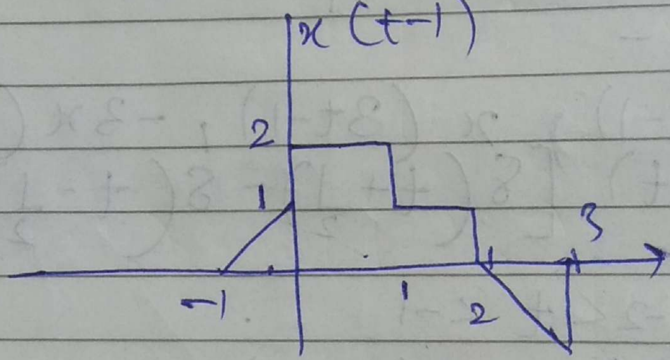
$t = -1$

$x(t-1)_{t=0} = x(-1)$

$x(t-1)_{t=1} = x(0)$

$x(t-1)_{t=2} = x(1)$

$x(t-1)_{t=3} = x(2)$



for $x(3t-1)$

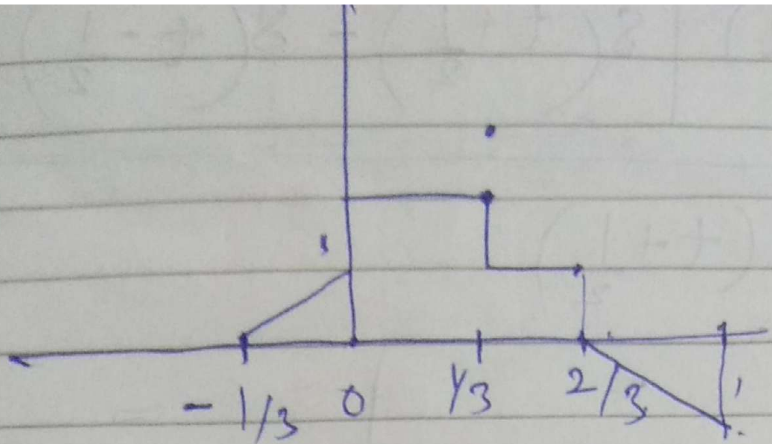
$x(3t-1)_{t=-1/3} = x(-2)$

$x(3t-1)_{t=0} = x(-1)$

$x(3t-1)_{t=1/3} = x(0)$

$x(3t-1)_{t=2/3} = x(1)$

$x(3t-1)_{t=1} = x(2)$



Q $-3x(2+t)$

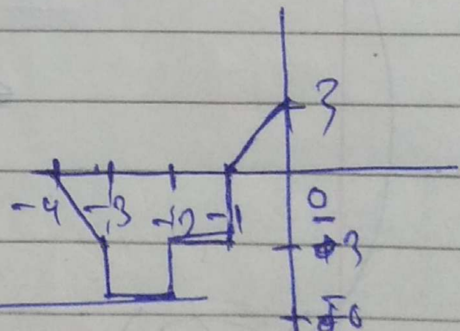
$-3x(2+t)_{t=-4} = -3x(-2) = 0$

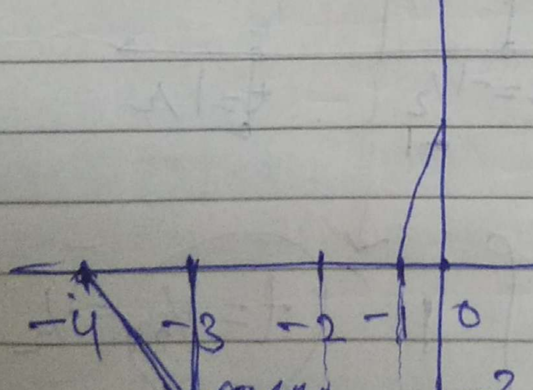
$-3x(2+t)_{t=-3} = -3x(-1) = -3$

$-3x(2+t)_{t=-2} = -3x(0) = -6$

$-3x(2+t)_{t=-1} = -3x(1) = 0.$

$-3x(2+t)_{t=0} = -3x(2) = +3.$



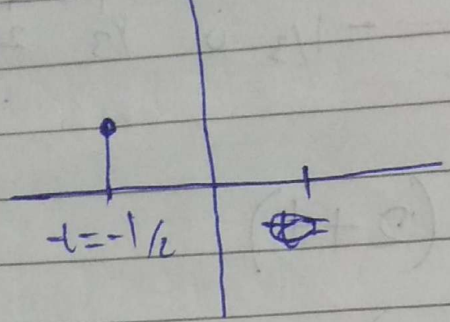


* We can plot first $x(2+t)$ then multiply the graph by -3

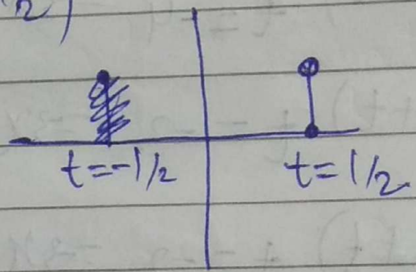
$$x(t)\left[\delta\left(t+\frac{1}{2}\right) - \delta\left(t-\frac{1}{2}\right)\right]$$

$$\delta\left(t+\frac{1}{2}\right)$$

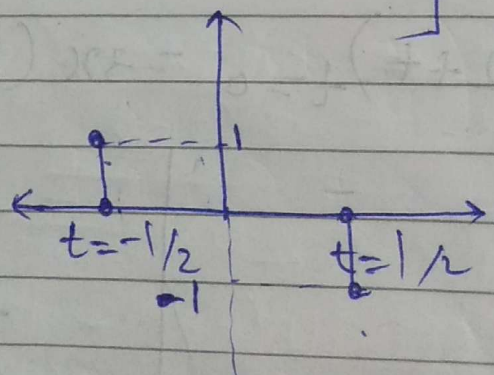
=



$$\delta\left(t-1/2\right)$$

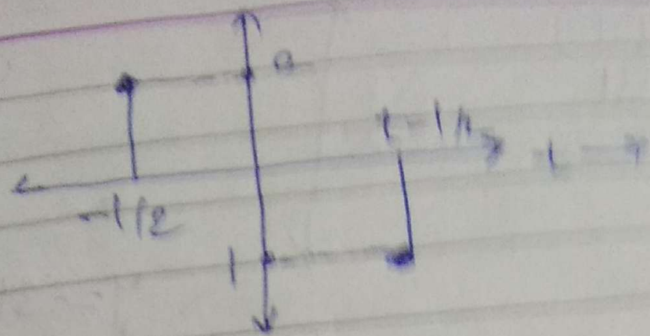


$$\left[\delta\left(t+1/2\right) - \delta\left(t-1/2\right)\right]$$



$$x(t) = \begin{cases} 1 & t = 1/2, -1/2 \\ 0 \quad -1 & t = \text{else} \end{cases}$$

$$x(t)[\quad] = \begin{cases} & t = 1/2, -1/2 \\ 0 & t = \text{else} \end{cases}$$



Q. find even & odd parts of :

a) $g(t) = 2t^2 - 3t + 6$

a) $x_e(t) = \frac{1}{2}\left[g(t) + g(-t)\right]$

$$= \frac{1}{2}\left[2t^2 - \cancel{3t} + 6 + 2t^2 + \cancel{3t} + 6\right]$$

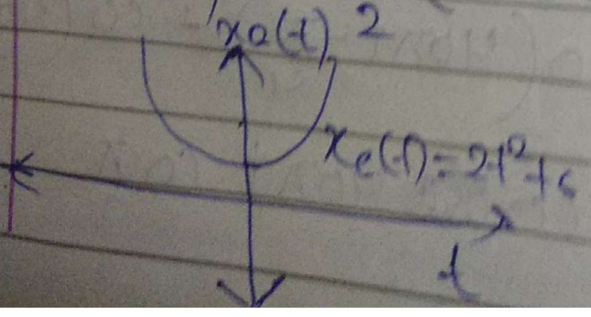
$$= \frac{1}{2}\left[4t^2 + 12\right]$$

$$= 2t^2 + 6$$

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

$$= \frac{1}{2}\left[2t^2 - 3t + 6 - 2t^2 - 3t - 6\right]$$

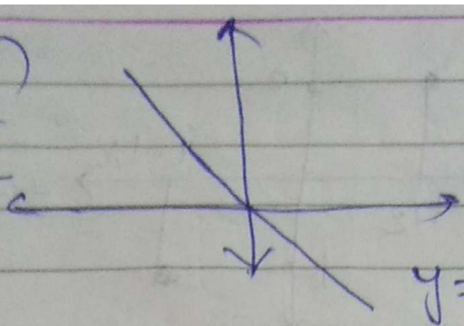
$x_o(t) = \frac{1}{2}(-6t) = \underline{-3t}$



$\underline{x_e(t) = 2t^2 + 6}$

$x_o(-t)$
$= -3t$

$y = -3t$



$y = -3t$

(b) $x(t) = \text{sinc}\, t$

$$x_e(t) = \left[\frac{\text{sinc}\, t + \text{sinc}(-t)}{2}\right]$$

$$= \frac{\frac{\sin t}{t} + \frac{\sin t}{t}}{2}$$

$$= \text{sinc}\, t = \frac{\sin t}{t}$$

$x_o(t) = 0$

c) $g(t) = 2\cos\left(40\pi t - \frac{\pi}{4}\right)$

$$g_e(t) = \frac{1}{2}\left[g_e(t) + g_o(-t)\right]$$

$$= \frac{1}{2}\left[20\cos\left(40\pi t - \frac{\pi}{4}\right) + 20\cos\left(-40\pi t - \frac{\pi}{4}\right)\right.$$

$$= 10\left[\cos\left(40\pi t - \frac{\pi}{4}\right) + \cos\left(40\pi t + \frac{\pi}{4}\right)\right.$$

$$= 10 \times 2\cos 40\pi t \cos\frac{\pi}{4}$$

$$= 10\sqrt{2}\cos 40\pi t$$

$g_o(t) = \frac{20}{2}\left[\cos\left(40\pi t - \frac{\pi}{4}\right) - \cos\left(40\pi t + \frac{\pi}{4}\right)\right]$

$= 10\left[2\sin 40\pi t \sin\frac{\pi}{4}\right]$

$= \underline{10\sqrt{2}\sin 40\pi t}$

e^{-j2t}

Q. Find Power & Energy:

a) $x(t) = e^{-j2t}\, u(t)$

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

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

$E = \int_{0}^{\infty} 1\, dt$

$$\boxed{\begin{array}{c} E = \infty \\ 0 < P < \infty \end{array}}$$

$E = [t]_0^{\infty} = \underline{\underline{\infty}}$

Value of Power is finite, hence it is power ~~Sinkex~~ signal

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

$P = \lim_{T\to\infty} \frac{1}{T}\int_{0}^{T/2} 1\, dt = \lim_{T\to\infty} \frac{1}{\cancel{T}} \times \cancel{T}/2 = 1/2$

b) $x(t) = \begin{cases} t & 0 \leq t \leq 1 \\ 2+t & 1 \leq t \leq 2 \\ 0 & \text{else} \end{cases}$

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

$$E = \int_0^1 |t|^2 \, dt + \int_1^2 |2+t|^2 \, dt$$

$$E = \int_0^1 [t^2] \, dt + \int_1^2 (4+t^2+4t) \, dt$$

$$E = \left[\frac{t^3}{3}\right]_0^1 + \left[\frac{t^3}{3} + 2t^2 + 4t\right]_1^2$$

$$E = \cancel{\frac{1}{3}} + \frac{8}{3} + \cancel{4} + 8 - \cancel{\frac{1}{3}} - 1 - \cancel{4}$$

$$E = 7 + \frac{8}{3}$$

$$\boxed{E = \frac{28}{3}}$$

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

$$= \lim_{T \to \infty} \frac{1}{T} \left[\int_0^1 \left(t^2 \right) dt \right.$$

$$+ \int_1^2 \left(4 + t^2 + 4t \right) dt$$

$$\boxed{+ \int_2^{T/2} \left(t^2 + 4 + t^2 + 4t \right) dt}$$

$$= \lim_{t \to \infty} \frac{1}{T} \left[L \right.$$

$$= \underline{\underline{0}}$$

Q. $x(t) = \cos\left(\underline{4t + \frac{\pi}{3}} \right)$

$$E = \int_{-\infty}^{\infty} \left| \cos\left(\underline{4t} + \frac{\pi}{3} \right) \right|^2 dt$$

$$E = \int_{-\infty}^{\infty} \left(\cos\left(4t + \frac{\pi}{3} \right) \right)^2 dt$$

$$E = \int_{-\infty}^{\infty} \left(\frac{1 + \cos\left(8t + \frac{2\pi}{3}\right)}{2} \right) dt$$

$$E = \frac{1}{2} \left(t + \frac{\sin\left(8t + \frac{2\pi}{3}\right)}{8} \right)_{-\infty}^{\infty}$$

$$E = \frac{1}{2} \left[\underline{\underline{\infty}} + [\quad] \right)$$

$$\boxed{E = \infty}$$

Dont

Do like this

$$P = \lim_{T \to \infty} \frac{1}{T} \int_{-T/2}^{T/2} \left(\frac{1 + \cos\left(8t + \frac{2\pi}{3}\right)}{2} \right) dt$$

$$P = \lim_{T \to \infty} \frac{1}{T} \left[t + \frac{\sin\left(8t + \frac{2\pi}{3}\right)}{2} \right]_{-T/2}^{T/2}$$

$$\frac{1}{T} \left[T + \frac{\sin\left(4T + \frac{2\pi}{3}\right)}{2} - \frac{\sin\left(-4T\right)}{2} \right]$$

* limit is $-\infty$, to ∞

$$= 1 + \frac{\sin\left(4T + \frac{2\pi}{3}\right)}{2T} \frac{\left(4T + \frac{2\pi}{3}\right)}{\left(4T + \frac{2\pi}{3}\right)}$$

$$= \cancel{\left[1 + (2 - 0) + (2) = \underline{5} \right]}$$

$$\frac{-\sin\left(-4t+\frac{2\pi}{3}\right)}{2\cancel{t}\left(-4t+\frac{2\pi}{3}\right)} \quad \left(-4t+\frac{2\pi}{3}\right)$$

$$= 1$$

(c) $\omega t = 4t$

$\omega = 4$

$2\pi \cancel{f} = 4$

$\frac{2\pi}{T} = 4$

$$\boxed{T = \frac{2\pi}{4} = \frac{\pi}{2}}$$

$$P = \frac{1}{\pi/2}\,\frac{1}{2}\int_{-\pi/4}^{\pi/4}\left(1+\cos\left(8t+\frac{2\pi}{3}\right)\right)$$

$$P = \frac{1}{4}\int_{-\pi/4}^{\pi/4} + \frac{1}{4}\left[0\right]$$

$$P = \frac{1}{\pi}\left[\frac{\pi}{4} - \left(-\frac{\pi}{4}\right)\right] + \frac{1}{\pi}(0)$$

$$\boxed{P = 1/2}$$

Left margin: $T/2$, $-T/2$, $\sin$, $-4t+\frac{2\pi}{3}$, 2

20/9/18

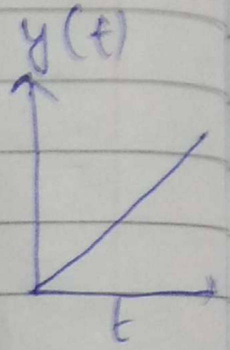
Deterministic Vs Random Signal:-

* Deterministic signal is a signal in which each value of signal is FIXED. & can be determined by mathematical expression.

* Random signal has lot of uncertainty & its future value can't be protected.

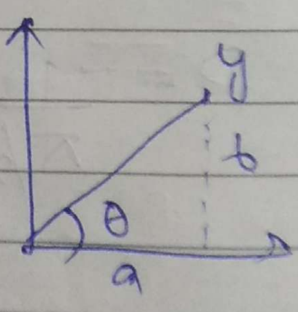
REAL VS COMPLEX SIGNALS:-

Real signal e.g → $y(t) = t$



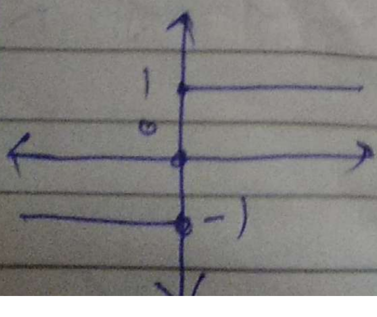
Complex signal e.g. $y = a + jb$

$\theta = \tan^{-1}\left(\frac{b}{a}\right)$



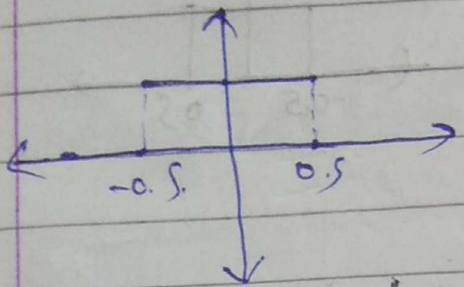
SIGNUM FUNC^n OR SIGN FUNC^n:-

$$\mathrm{Sgn}(x) = \begin{cases} -1 ; & x < 0 \\ 0 ; & x = 0 \\ 1 ; & x > 1 \end{cases}$$

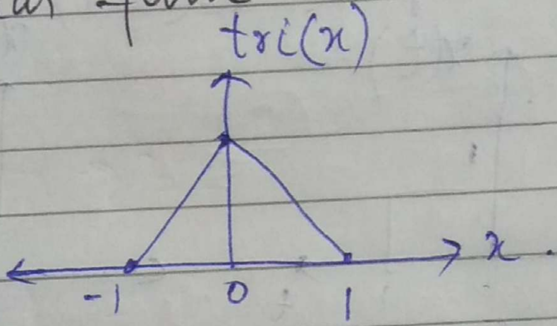


Rectangular func^n:-

$$rect(t) = \pi(t) = \begin{cases} 0 & |t| > 1/2 \\ 1/2 & |t| = 1/2 \\ 1 & |t| < 1/2 \end{cases}$$



Triangular func^n:-

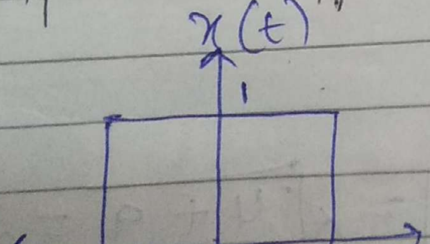


Sinc func^n:-

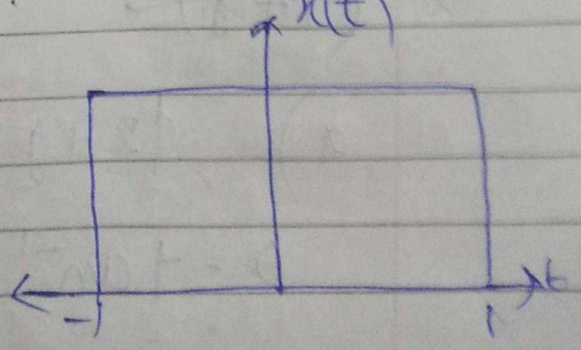
$$sinc(x) = \frac{\sin x}{x}$$

OPERATIONS ON SIGNAL:-

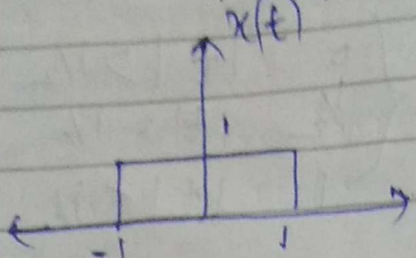
1. Amplitude Scaling:-

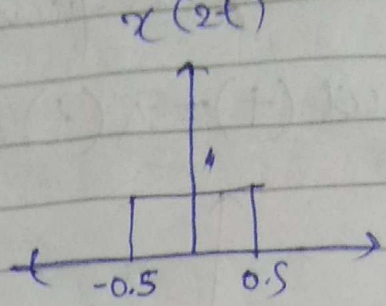


eg. $2x(t)$



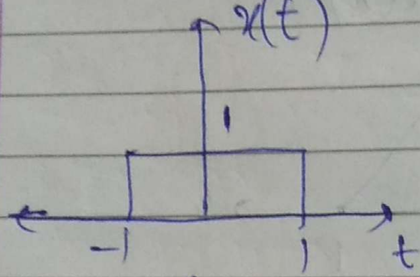
2. Time ~~shifting~~ scaling :—

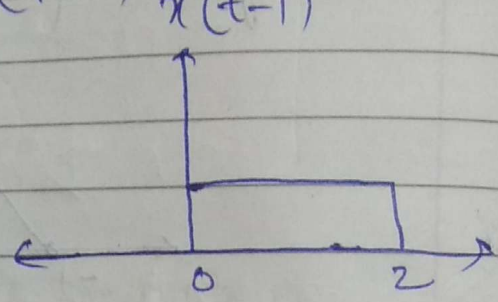




3. Time shifting :—

e.g → $x(t-1)$





$$x(t-1)\Big|_{t=0} = x(-1)$$

$$x(t-1)\Big|_{t=2} = x(1)$$

Q. Express in polar form :—

a) $2 + j3$

b) $(1+j)e^{j\pi/3}$

a) $|2+j3| = \sqrt{4+9} = \sqrt{13}$

$\theta = \tan^{-1}\left(\frac{3}{2}\right)$

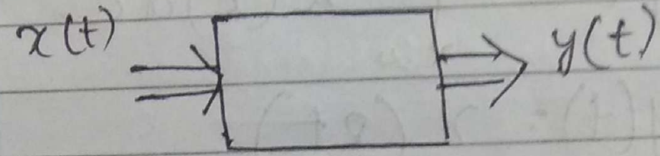
$= \sqrt{13}\, e^{j\tan^{-1}(3/2)}$

e) $(1+j)$

$$= \sqrt{2}\, e^{j\pi/4}$$

$$= \sqrt{2} e^{j\pi/4} e^{j\pi/3} = \sqrt{2} e^{j\frac{7\pi}{12}}.$$

SYSTEM:-



PROPERTIES:-

1. MEMORY:-
A system has memory if its output depends on past values of input; else it is memoryless.

2. STABLE:-
If output is bounded (finite) due to bounded input, it is stable.

3. CAUSAL:-
Casual if output doesn't depends on future value of input, otherwise it is non casual.

4. LINEARLITY:-
Linear if output $= ay_1 + by_2$ due to input $= ax_1 + bx_2$.

5. TIME INVARIANCE:-

If output due to delayed input $x(t-t_0)$ is equal to $y(t-t_0)$ else it is it is time invariant else it is time variant.

Q. a) $y(t) = x(t+2) - x(t-2)$
b) $y(t) = \sin[x(t)]$
c) $y(t) = \int_{-\infty}^{t} x(\tau)\,d\tau$.
d) $y(t) = x\left(\frac{2t}{5}\right)$

} Tell properties

MEMORY
a) HAS memory (depending on $\underline{t-2}$)
b) memoryless
c) memory ($\int_{-\infty}^{t}$ $(-\infty, t)$)
d) ~~memoryless~~
→ memory ($t=2$, $y(2) = x(0.8)$ depending on previous input)

CAUSAL:-
a) NON CAUSAL. $\boxed{x(t+2)}$
b) CASUAL
c) CASUAL
d) NON CASUAL.
$y(t=-2)$
$y(-2) = x(-0.8)$

Casual

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Page No. :

TIME INVARIANCE :-

a) $y(t) = \underbrace{x(t+2-t_0) - x(-t-2-t_0)}$

o/p At $t = t-t_0)$ ①

$y(t-t_0) = \underbrace{x(t-t_0+2) - x(t-t_0-2)}$ ②

① & ② are same hence it is time invariant

b) $y(t) = \sin x(t)$

$y(t) = \sin x(t-t_0)$

$y(t-t_0) = \sin x(t-t_0)$

time invariant.

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

$y(t) = \int_{-\infty}^{t-t_0} x(\tau) d\tau$

$y(t-t_0) = \int_{-\infty}^{t-t_0} x(\tau)\, d\tau$

Time invariant.

d) O/P due to delayed I/P

$$= x\left(\frac{2t}{5} - t_0\right) \quad \text{--- } ①$$

$$y(t-t_0) = x\left(\frac{2}{5}(t-t_0)\right) \quad \text{--- } ②$$

$① \neq ②$

Hence time variant.

STABILITY:-

a) Stable [Finite Output]
b) Stable
c) Unstable [Infinite Output as $\int_{-\infty}^{\infty}$ will give ∞ value
d) Stable

LINEARITY:-

a) $ax_1(t+2) - ax_1(t-2) + bx_2(t+2) - bx_2(t-2)$

$y(t) = ay_1 + by_2$
(LINEAR)

b $y(t) = \sin(ax_1 + bx_2)$
$\neq ay_1 + by_2$
(NON Linear)

Date :
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c) $y(t) = \int_{-\infty}^{t} ax_1 + bx_2 \, d\tau$.

$y(t) = \int_{-\infty}^{t} ax_1 \, d\tau + \int_{-\infty}^{t} bx_2 \, d\tau$

$y(t) = a y_1 + b y_2$.

Hence Linear

d) $y(t) = x\left(\frac{2t}{5}\right)$.

$y(t) = ax_1 + bx_2$.

$y(t) = ay_1 + by_2$

(LINEAR)

TRANSFORMER:

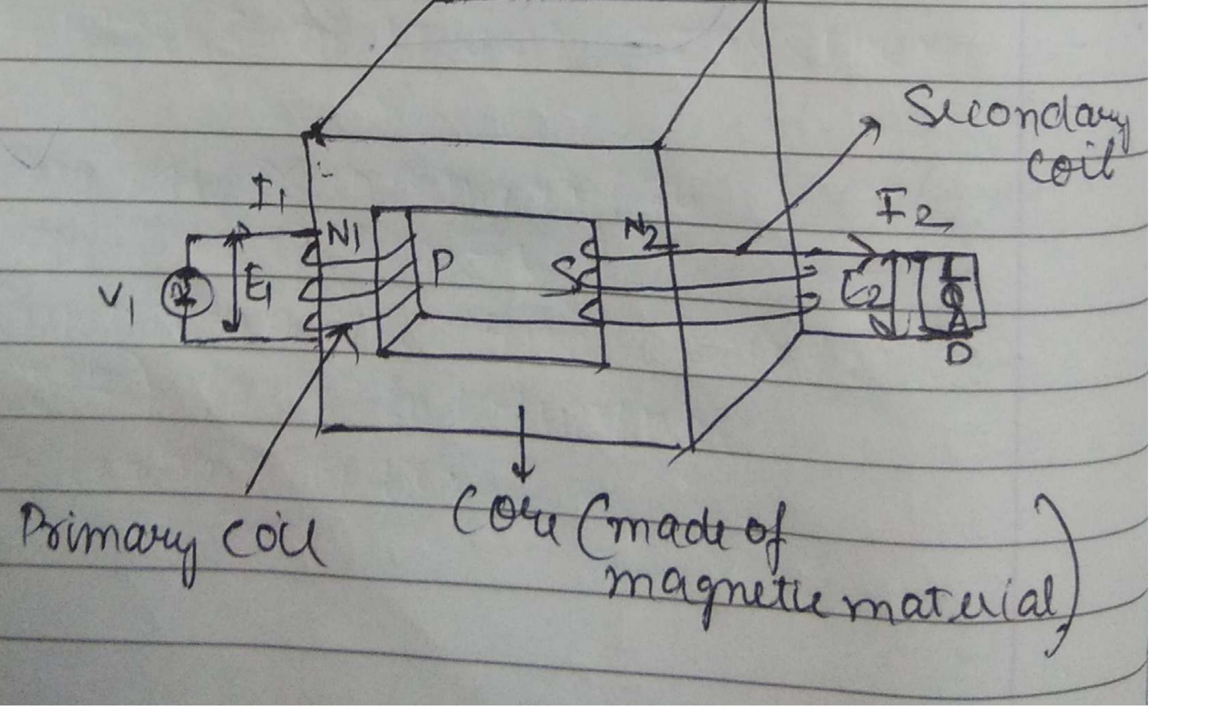
* Transformer transfers electric energy from one circuit to other through magnetic coupling.

* It raises or lowers voltage with corresponding decrease or increase in current.

* Product of voltage & current (Power) remains same in primary & secondary coil.

* It has two windings insulated from each other & wound on core made of magnetic material.

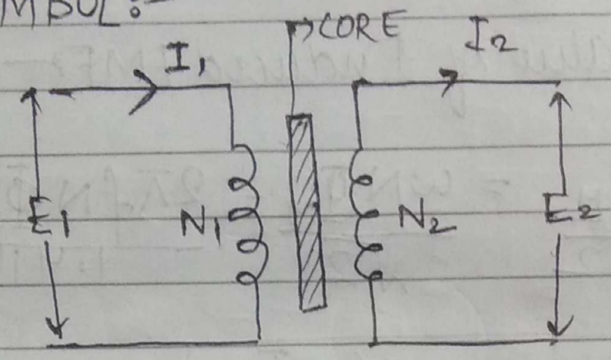
PRINCIPLE OF OPERATION:-



* It operates on principle of mutual induction b/w two cores.

* When current in one coil is changed, then an EMF is induced in secondary coil.

SYMBOL:-



$E_1 \rightarrow$ EMF in primary
$E_2 \rightarrow$ " " secondary
$I_1 \rightarrow$ Current in primary
$I_2 \rightarrow$ " " secondary

EMF EQUATION :-

Due to sinusoidally varying voltage applied to primary coil (V_1), magnetic flux setup in core is:

$$\Phi = \Phi_M \sin(\omega t) = \Phi_M \sin(2\pi f t)$$

Resulting induced EMF in winding of N turns-

$$e = -N \frac{d\Phi}{dt}$$

$$= -N \frac{d}{dt}(\Phi_M \sin \omega t).$$

$$e = -N\Phi_M \, \omega \cos \omega t$$

$$= N\omega \Phi_M \sin\left(\omega t - \frac{\pi}{2}\right)$$

Peak Value of Induced EMF

$$E_M = \omega N \Phi_M$$

RMS Value of Induced EMF:-

$$E = \frac{E_M}{\sqrt{2}} = \frac{\omega N \Phi_M}{\sqrt{2}} = \frac{2\pi f N \Phi_M}{1.414}$$

$$\boxed{E = 4.44 \, f N \Phi_M}$$

This eq^n is known as EMF eq^n of transformer.

FEATURES OF IDEAL TRANSFORMER:-

→ Core has ∞ permeability.
→ Core has 0 losses
→ Resistance of winding is zero hence no (I^2R) losses in windings.
→ No Leakage flux.

STEP UP TRANSFORMER:-

$I_1 > I_2$ $E_2 > E_1$ $\boxed{K>1}$

Tranformer Ratio(K)

$$\left[K = \frac{N_2}{N_1} = \frac{E_2}{E_1} = \frac{I_1}{I_2} \right]$$

STEP DOWN TRANSFORMER:-

$E_1 < E_2$, $I_2 > I_1$

$N_1 > N_2$

$K < 1$

Q. 50Hz transformer has 30 Primary turns & 350 sec turns net cross sectional area of core is 250 cm². If primary coil is connected to 230V, 50 Hz supply find:

a) PEAK Value of flux density in core
b) Voltage induced in secondary coil.
c) Primary coil current if current in secondary coil is 100A.

a) $\phi_1 = \frac{250}{100 \times 100} \times$

$E = 4.44 f N \Phi_M$

$\Phi_M = \frac{E}{4.44 f N} = 0.0345 Wb$

$B_M = \frac{\Phi_M}{A} = \frac{0.0345}{250 \times 10^{-4}} = \underline{1.38 T}$

b) $\frac{N_2}{N_1} = \frac{E_2}{E_1}$

$\frac{350}{30} = \frac{E_2}{230}$

$E_2 = \frac{35\cancel{0}}{3\cancel{0}} \times 230$

$\boxed{E_2 = \cancel{1610 V}}$ 2683.33

23
7
1610

$\frac{35 \times 230}{3}$

c) $\cancel{\frac{I_1}{I_2} = \frac{350}{50}}$

$\cancel{I_2 = \frac{100 \times 80}{350}}$

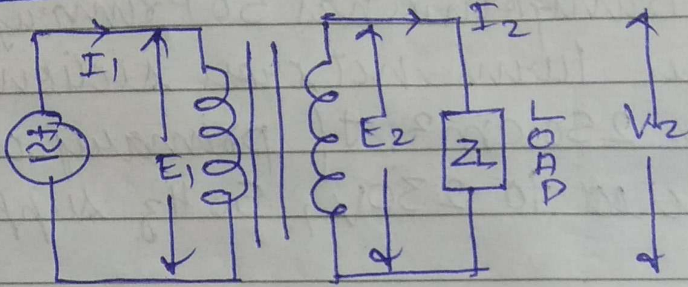
$\cancel{I_2 = \frac{100}{7}}$

$\frac{I_1}{I_2} = \frac{350}{30}$

$I_1 = \frac{350 \times 100}{30}$

$\boxed{I_1 = \cancel{700A}\ \frac{3500}{3} A}$

IMPEDENCE TRANSFORMATION:-

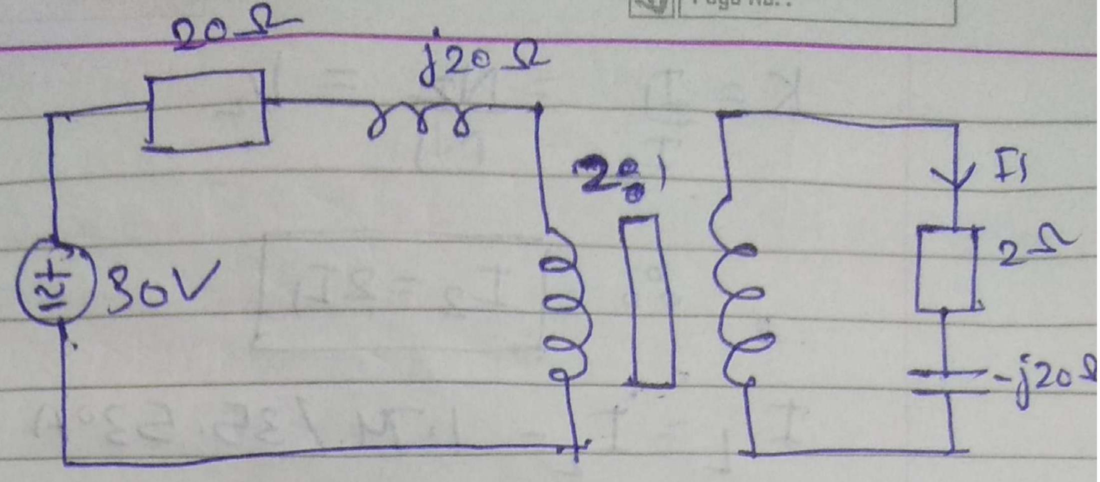


$$Z_{eq} = \frac{V_1}{I_1} = \frac{V_1 \times V_2 I_2}{I_1 \times V_2 I_2}$$

$$Z_{eq} = \frac{1}{K} \times \frac{1}{K} \times Z_L$$

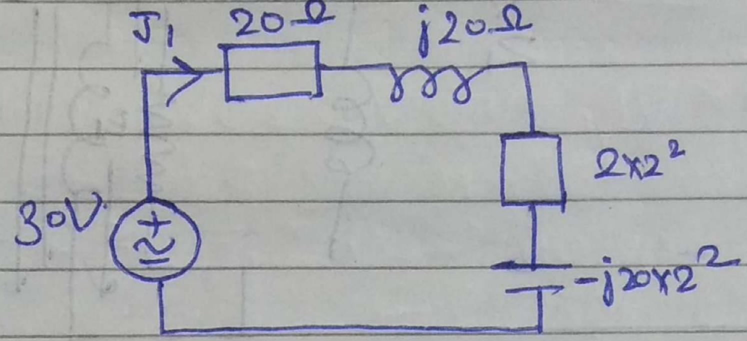
$$\boxed{Z_{eq} = \frac{Z_L}{K^2}}$$

Q



Find I_L.

Transforming LOAD Imp. into primary.



$$I_1 = \frac{30}{20+j20+4(2-j20)}$$

$$I_1 = \frac{30}{28-j60} \times \frac{28+j60}{28+j60}$$

$$= a+jb$$

$$= \sqrt{a^2+b^2} \angle \tan^{-1}\frac{b}{a}$$

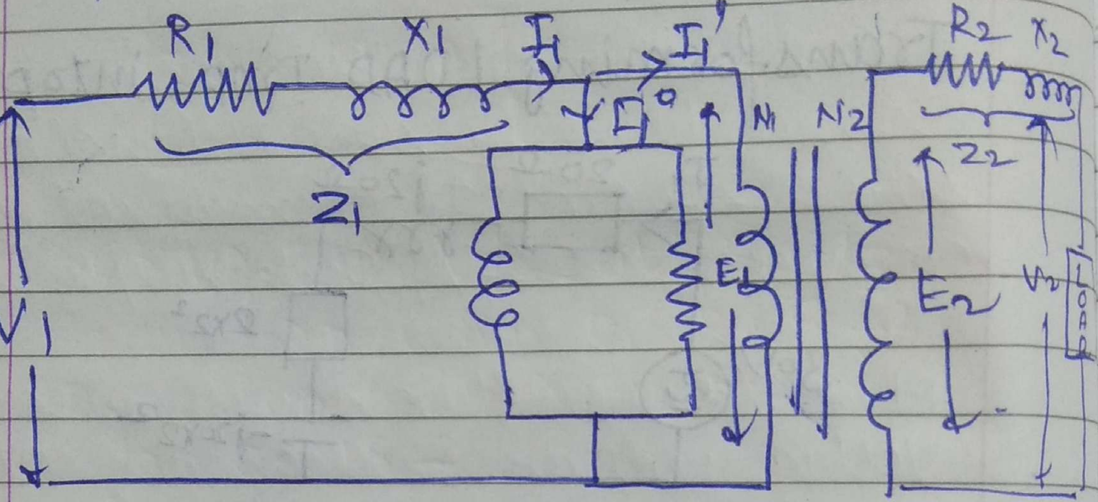
$$\boxed{I_1 = 0.872 \angle 35.53^\circ \text{ A}}$$

$$K = \frac{I_1}{I_2} = \frac{N_2}{N_1} = 1/2$$

$$\therefore \boxed{I_2 = 2I_1}$$

$$I_L = I_2 = 1.74 \angle 35.53° A$$

EQUIVALENT CKT OF TRANSFORMER



Some leakage flux is present in both primary & secondary side. This gives rise to leakage reactance X_1 & X_2.

$R_1 \rightarrow$ resistance of PRIM. coil.
$R_2 \rightarrow$ " " SEC. coil.

$I_1 \longrightarrow$ PRIMARY CURRENT

$I_2 \rightarrow$ SECONDARY CURRENT.

$I_0 \rightarrow$ NO LOAD COMPONENT OF PRIM CURRENT

$I_1' \rightarrow$ LOAD COMPONENT OF PRIM CURRENT

$I_M \rightarrow$ Magnetizint Component

$I_W \rightarrow$ Working component or loss component.

$$R_0 = \frac{E_1}{I_W}$$

$$X_0 = \frac{E_1}{I_M}$$

Q. 230 V / 110 W, 50 Hz TRANSFORMER takes i/p of 350 Volt amperes at no load core loss is 110W. Find

i) No load power factor

ii) Loss component of no load current

iii) Magnetizing " " " " ".

$$V_1 I_0 = 350$$

$$\therefore I_0 = \frac{350}{230} = 1.52A$$

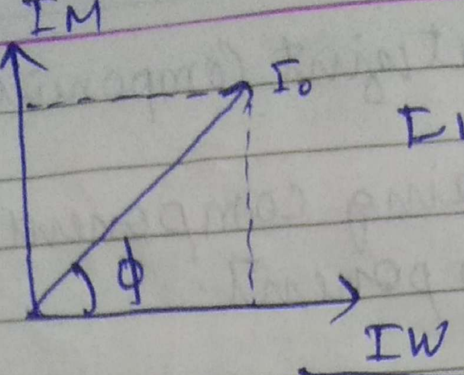
$$P = V_1 I_0 \cos\phi$$

$\cos\phi$ = power factor (PF)

$$\therefore PF = \frac{P}{V_1 I_0}$$

$$PF = \frac{110}{350} = 0.314$$

ii)



$I_W = I_0 \cos\phi$
$= 1.52 \times 0.314$
$= 0.478 A$

$I_M = \sqrt{I_0^2 - I_W^2}$

$= \sqrt{(1.52)^2 - (0.478)^2}$

$\boxed{I_M = 1.44 A}$

Q. 50 KVA, 4400 V/220V, 50 Hz transformer has $R_1 = 3.45\,\Omega$, $R_2 = 0.009\,\Omega$, $X_1 = 5.2\,\Omega$, $X_2 = 0.015\,\Omega$
Find

a) Re as referred to primary
b) " " " " secondary
c) Xe " " " primary
d) " " " " secondary.
e) Ze " " " primary.
f) " " " " secondary.
g) Total copper loss

$I_1 = \frac{50,000}{4400} = 11.36 A$

$I_2 = \frac{50,000}{220} = 227.27 A$

$$K = \frac{V_2}{V_1} = \frac{220}{4400} = 0.05$$

a) $Re_1 = R_1 + \frac{R_2}{K^2}$

b) $Re_2 = K^2 R_1 + R_2$

c) $Xe_1 = X_1 + \frac{X_2}{K^2}$

d) $Xe_2 = K^2 X_1 + X_2$.

e) $Ze_1 = \sqrt{Re_1^2 + Xe_1^2}$

f) $Ze_2 = \sqrt{Re_2^2 + Xe_2^2}$

g) $I_1^2 R_1 + I_2^2 R_2 = 909\,W$.