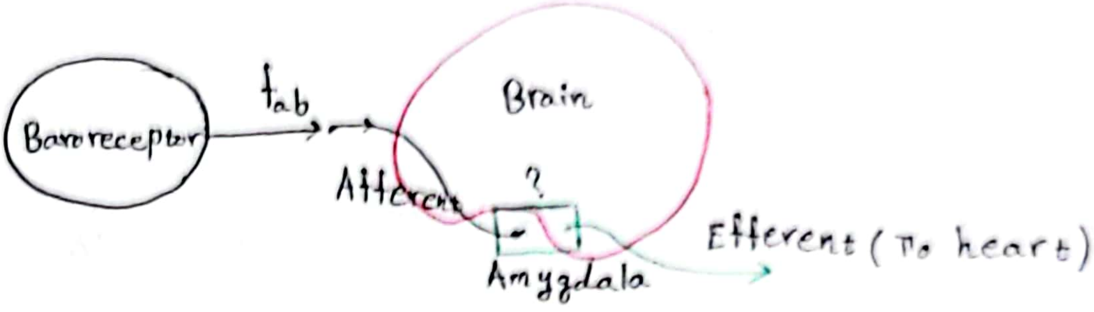
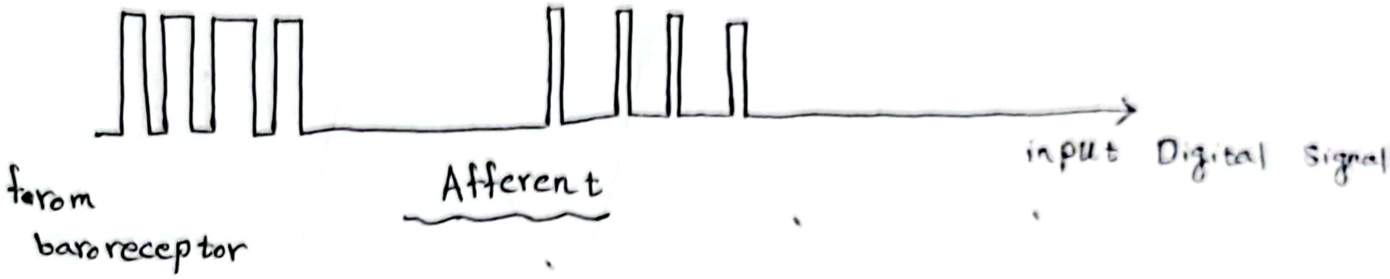
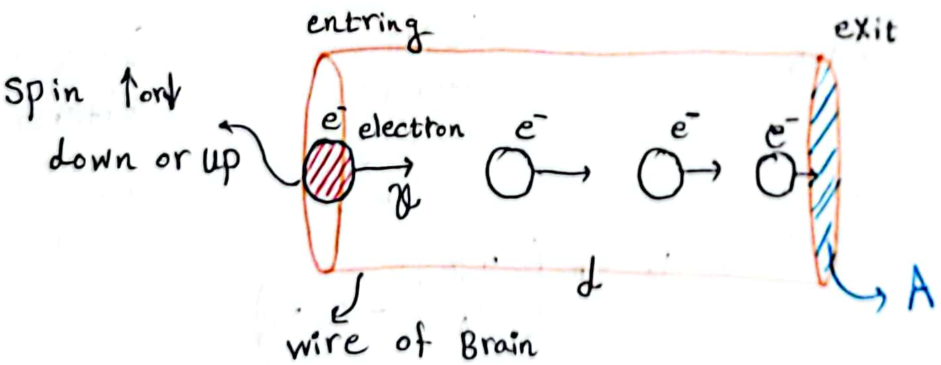




first Method: Drift movement of electrons in the neural lines:



$Q = neAd$

$t = \tau = \frac{d}{v}$

v: speed of electron

n: number of charges e per unit Volume

$I = \frac{Q}{\tau} = neAv$

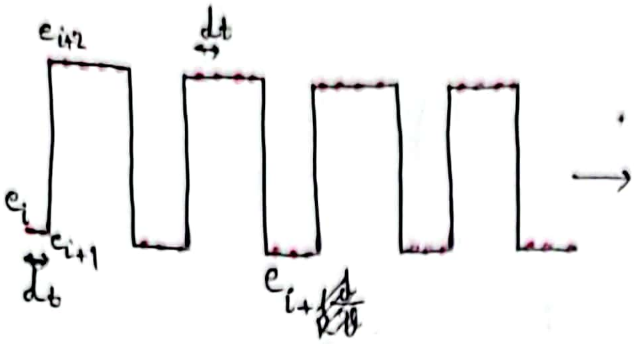
I: current

A: cross section area

τ: transfer time (delay of information)

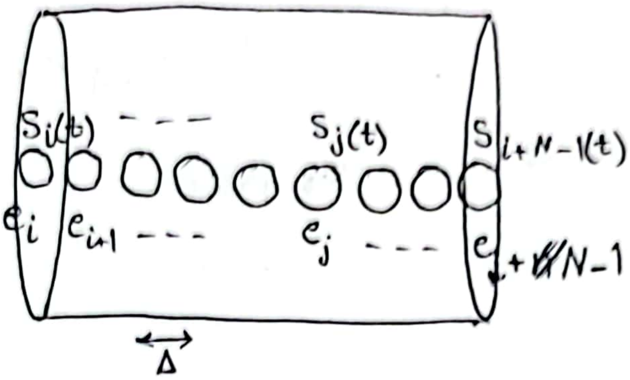
Q: total mobile charge in length d of wire

time step of solving $= dt$



$$S_{e_i} = \begin{cases} 1 \rightarrow \text{up} \\ 0 \rightarrow \text{down} \end{cases}$$

spin of ith electron



$$\Delta = \frac{d}{N}$$

Number of electrons in wire

$$\Delta = v\,dt \quad , \quad N = \frac{d}{v\,dt}$$

So we need to define delay function!

$$S(i+N-1) = ? \qquad S_i(t) = S_{i+N-1}(t + N\,dt)$$

$$\boxed{S_{i+N-1}(t) = S_i(t - N\,dt)}$$ → if speed is uniform and constant.

oops! ← ✗

Second Method: Wave Equation

we can convert the Digital signal to sin wave with equation of:

$$y(t,x) = D \sin\left(x \times \frac{2\pi}{\lambda} - \omega t + \phi_0\right)$$

λ

$$\lambda = v T = \frac{v}{f_{ab}}$$

$$\left\{ \begin{array}{l} \text{period} = T = \dfrac{1}{f_{ab}} \\ \omega = \dfrac{2\pi}{T} = 2\pi f_{ab} \end{array} \right.$$

wire

length of imagine: l

Afferent wave — Efferent wave

$\mapsto x=0$ — $\mapsto x=l$

$\rightsquigarrow$

$$y(t,l) = D \sin\left(\frac{2\pi}{\lambda} l - \omega t + \phi_0\right)$$

$$= D \sin\left(\frac{2\pi}{v} f_{ab} l - 2\pi f_{ab} t + \phi_0\right)$$

$$= D \sin\left(\underbrace{2\pi f_{ab}\left(\frac{l}{v} - t\right) + \phi_0}_{\phi_{final}(t)}\right)$$

$$\rightarrow \Delta\phi = \phi_{final} - \phi_{input} = 2\pi f_{ab}\left(\underbrace{\frac{l}{v}}_{\tau} \cancel{- t} \cancel{+ t}\right)$$

$$\rightsquigarrow \Delta\phi = 2\pi f_{ab} \times \tau \rightsquigarrow \text{Delay}$$

$\sim\!\!\!\to$ $y_{final} = \underset{=1}{D} \sin\left(\phi_{input} + 2\pi f_{ab} \tau\right)$

$\to$ $$\text{exit port} = \begin{cases} +1 \to \text{if } y_{final} > 0 \\ 0 \to \text{if } y_{final} < 0 \end{cases}$$

$\underbrace{\tau, f_{ab}, t, \phi_0}_{\text{inputs}}$, $\underbrace{\text{exit port}}_{\text{output}}$

if output and input's frequncy are same, output Digital wave can be model as shown simulat