MODELLING OF EXCITATION AND FIRING IN SIMPLE NEURAL NETWORKS

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ABSTRACT

In the project, the aim is to understand how and under what conditions a neuron can be fired or excited. For that matter, by using NEURON simulation program and Python programming language, a neural network will be designed and be tested with several signals for stimulation purposes. After that, in order to understand further, the concept of firing and excitation of a neuron will be investigated by applying external stimulations in a simulation environment. At the end, how external stimulation techniques could be used to fire or excite a neuron will be answered.

THE ELECTRICAL CIRCUIT MODEL

$$\delta I = C_m \frac{dV}{dt} + G_{Na} * m^3 * h * (V - E_{Na}) + G_K * n^4 * (V - E_K) + G_{Cl} * (V - E_{Cl}) \; + I_{app}$$

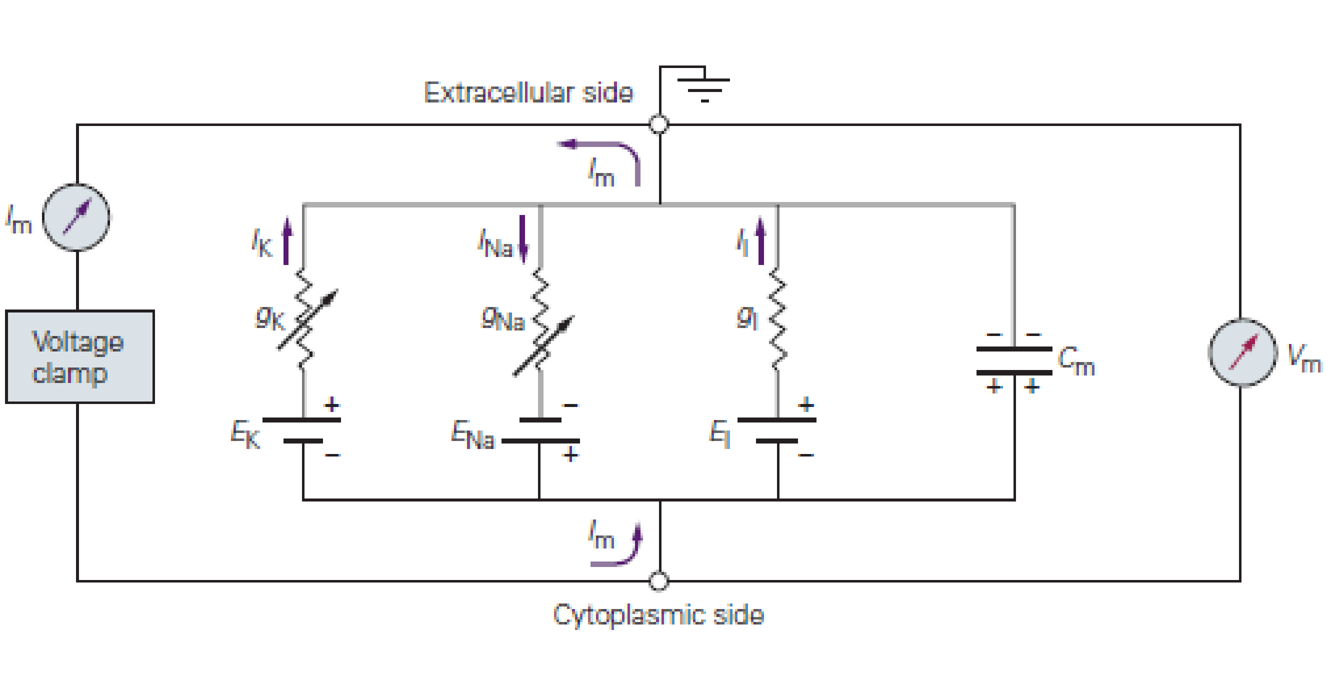


Figure 1: Electrical model

THE MATHEMATICAL MODEL

x	E_x [mV]	G_x [mS/cm²]
Na	55	40
K	-77	35
CL	-65	0.3

Table 1: Electrical potential and conductivity of voltage gated ion channels [3]

x	α_x (u/mV) [ms^{-1}]	β_x (u/mV) [ms^{-1}]
n	$0.01\,(V + 10) / [-1 + e^{(V+10)/10}]$	$0.125\, e^{V/80}$
m	$0.1\,(V + 25) / [-1 + e^{(V+25)/10}]$	$4\, e^{V/18}$
h	$1 / [1 + e^{(V+30)/10}]$	$1 / [1 + e^{(V+30)/10}]$

Table 2: Coefficient equation for m, n, and h [4]

$$\frac{dn}{dt} = \alpha_n * (1 - n) - \beta_n * n$$

$$\frac{dm}{dt} = \alpha_m * (1 - m) - \beta_m * m$$

$$\frac{dh}{dt} = \alpha_h * (1 - h) - \beta_h * h$$

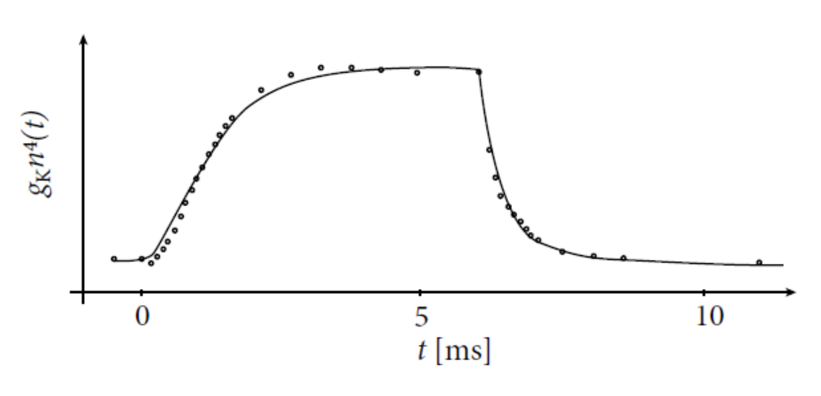
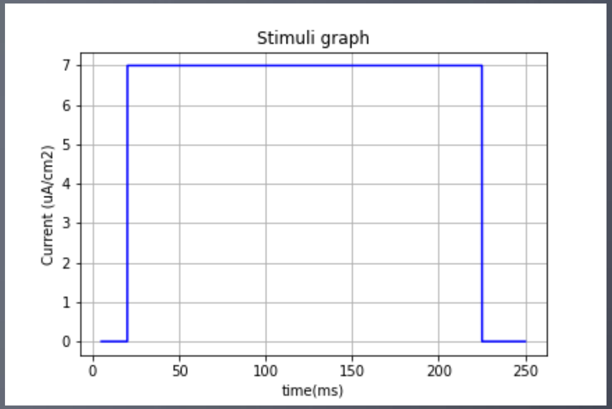
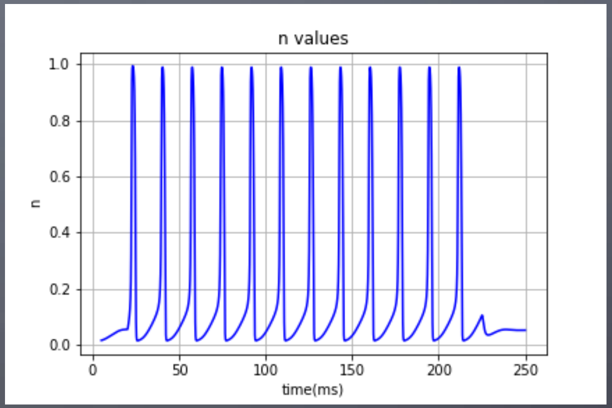


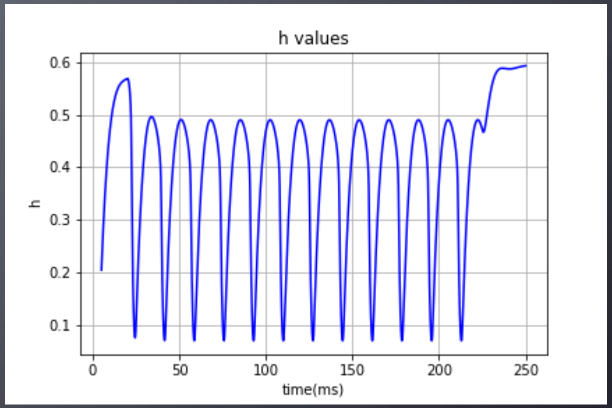
Figure 2: Voltage gated potassium channel graph

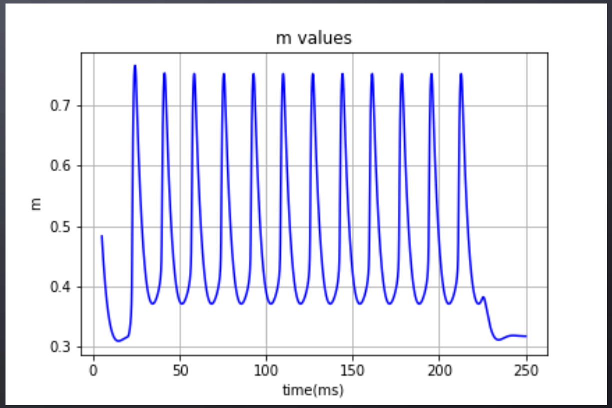
CONDUCTIVITY OF ION CHANNELS

The conductivity of ion channels in an axon change according to the membrane potential of the axon, and this change in conductivity can affect the ability of the axon to transmit electrical signals. By controlling the opening and closing of ion channels in response to changes in the membrane potential, neurons can regulate the flow of ions into and out of the cell, allowing them to generate and transmit electrical signals [1].









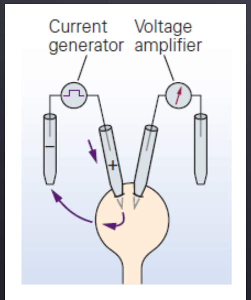
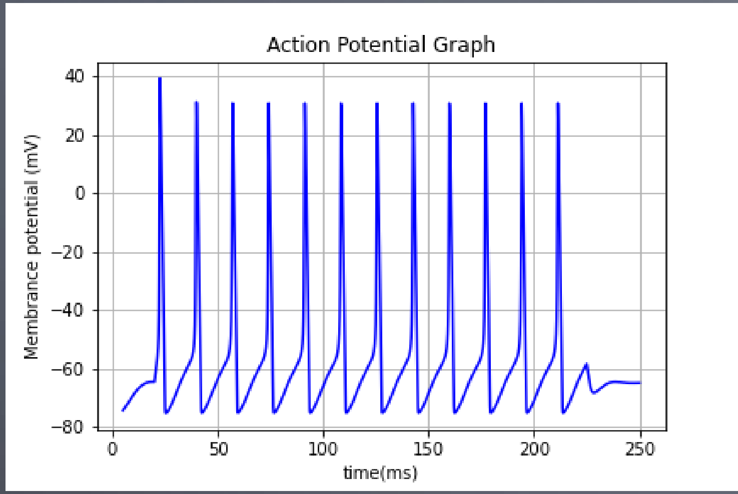
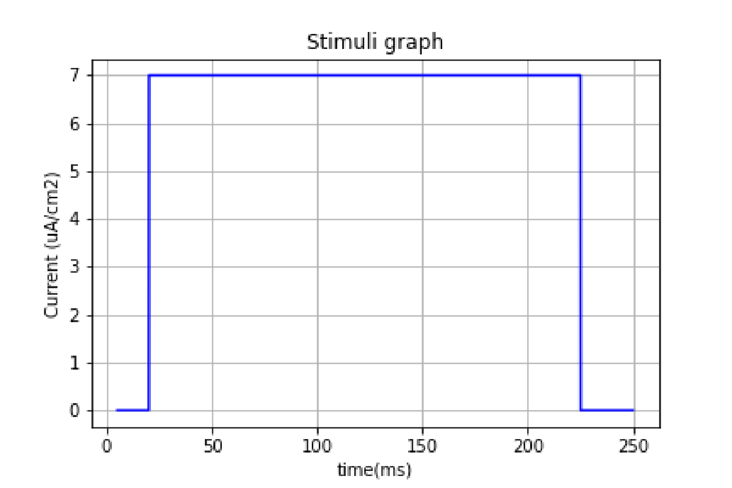
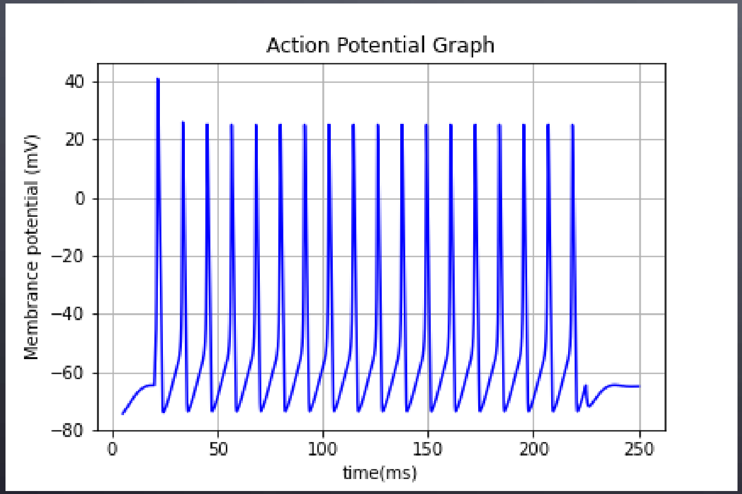


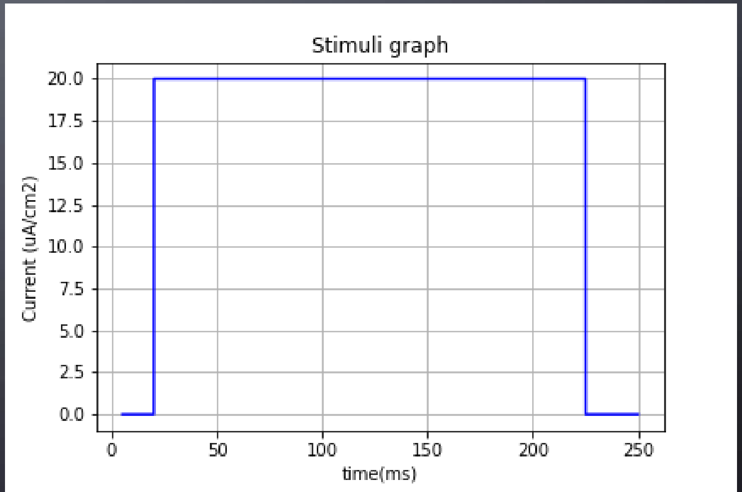
Figure 3: Microglass for current source and microelectrode for action potential recording

VARIOUS STIMULI AND ITS CORRESPODING ACTION POTENTIALS









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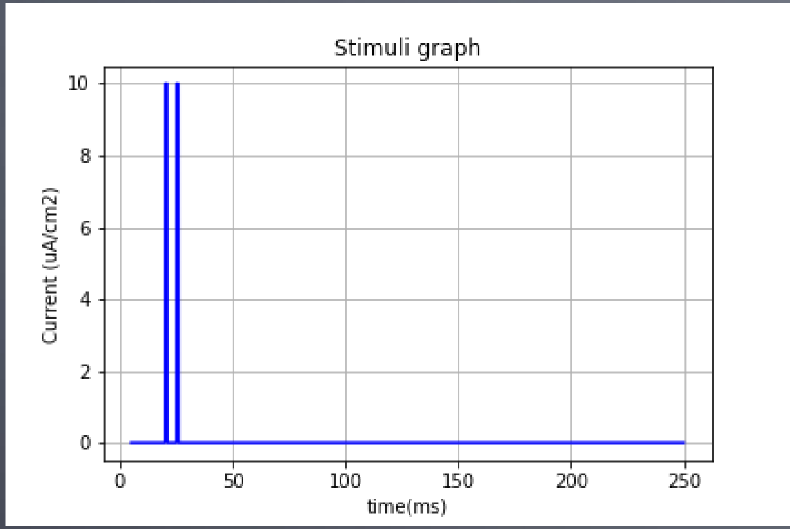

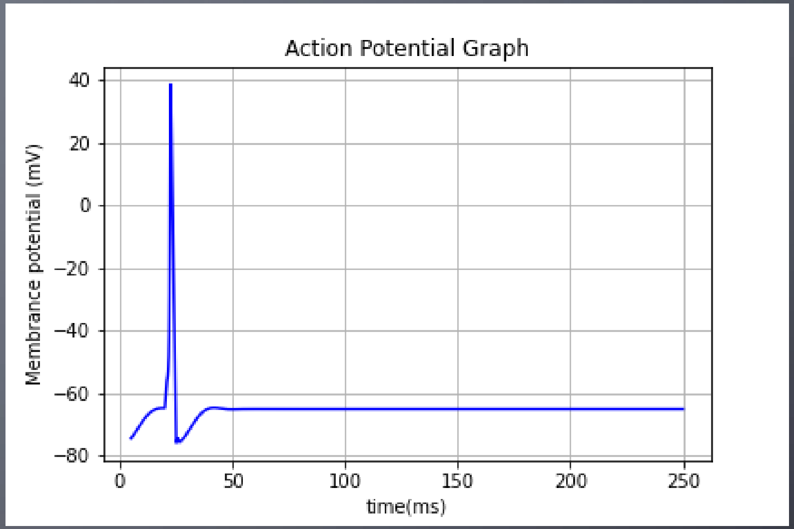

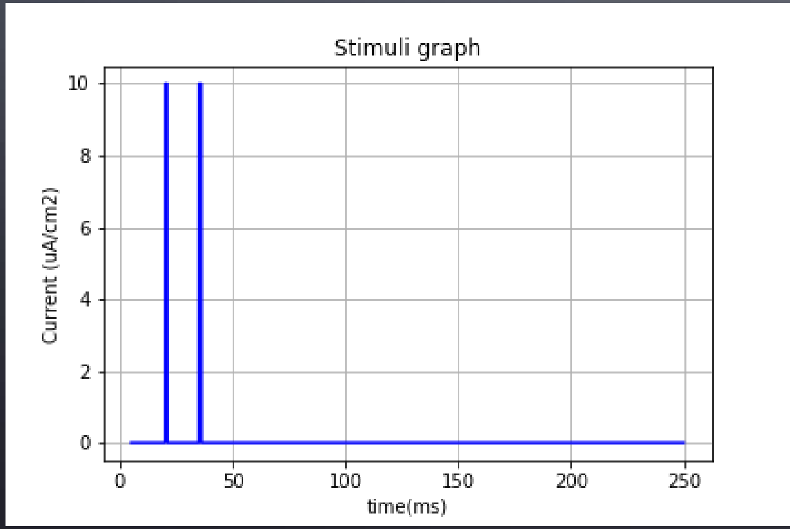

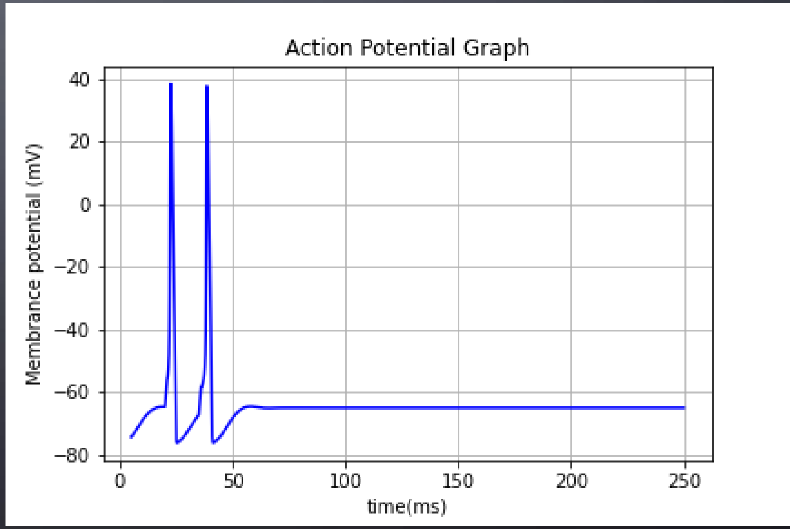

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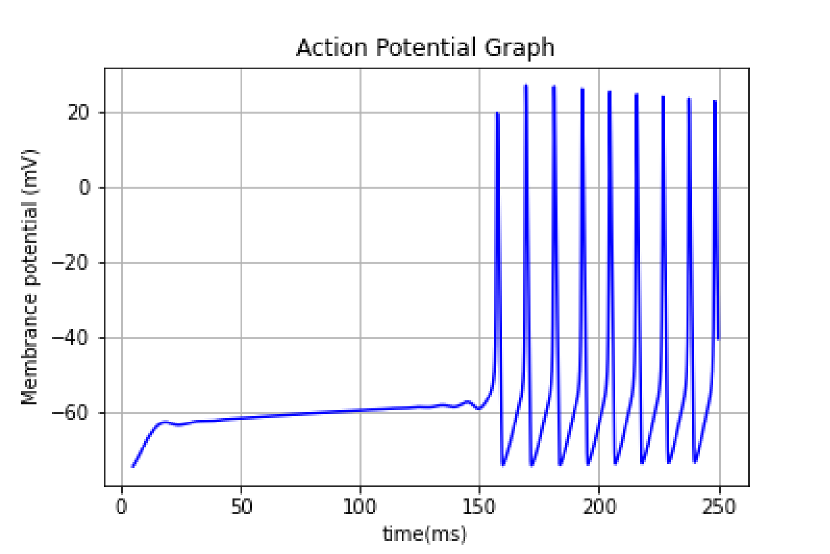
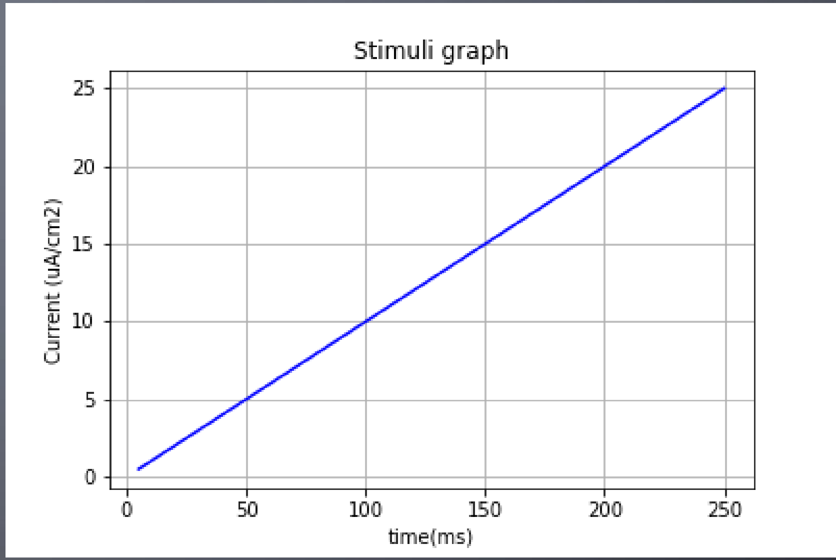
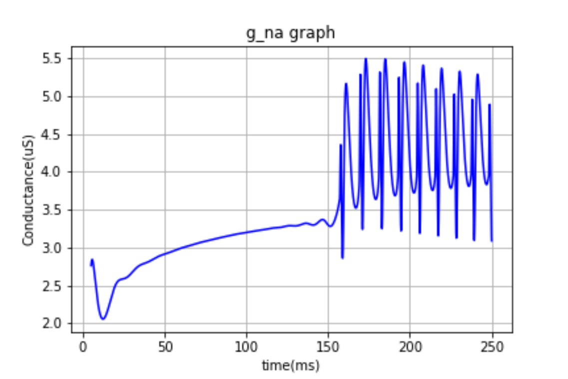
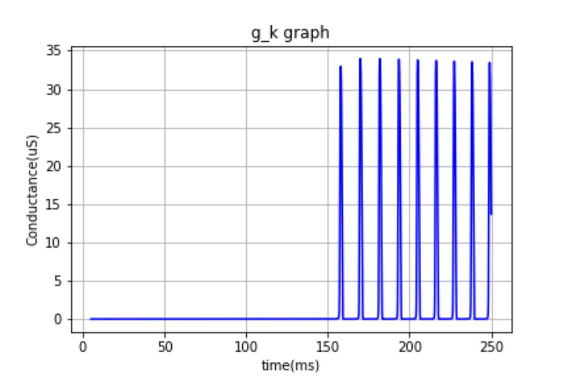








PHYSICAL MODEL

$D = \epsilon_0 \epsilon_r \boldsymbol{E}$

$J_c = \sigma \boldsymbol{E}$

$\nabla \boldsymbol{J} = Q_{j,v}$

$\boldsymbol{J} = \sigma \boldsymbol{E} + \boldsymbol{J_e}$

$\boldsymbol{E} = -\nabla V$

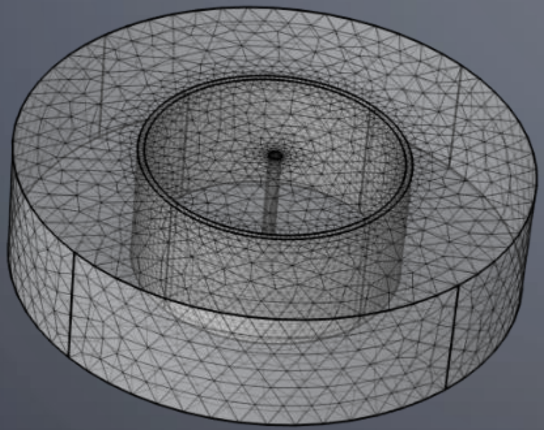


Figure 4: Physical model for axoplasm, membrane and extracellular area of an axon

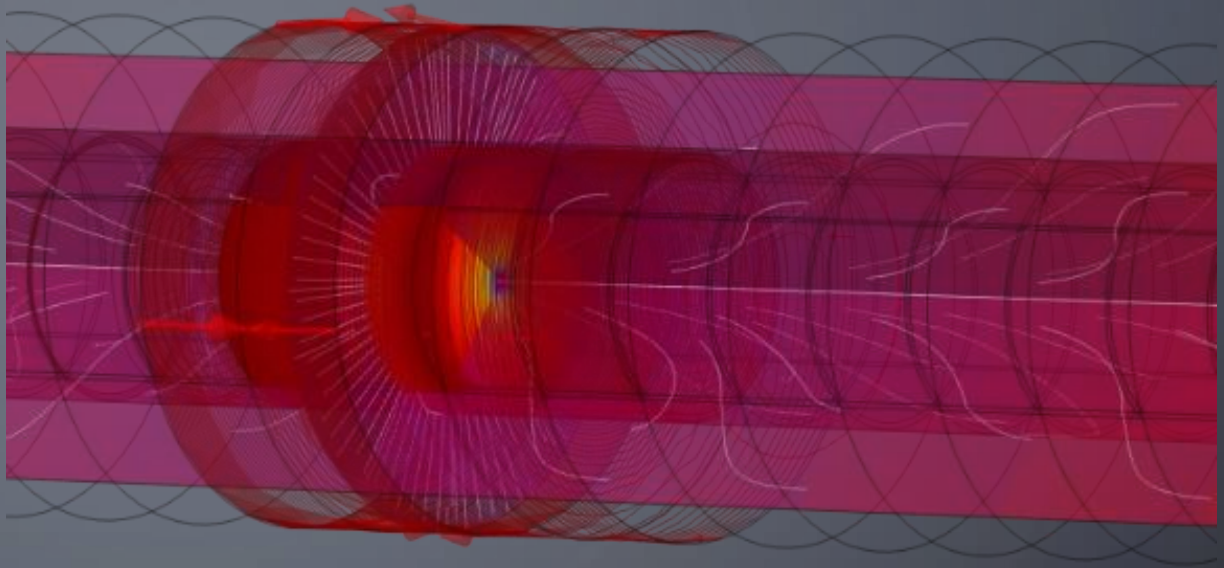
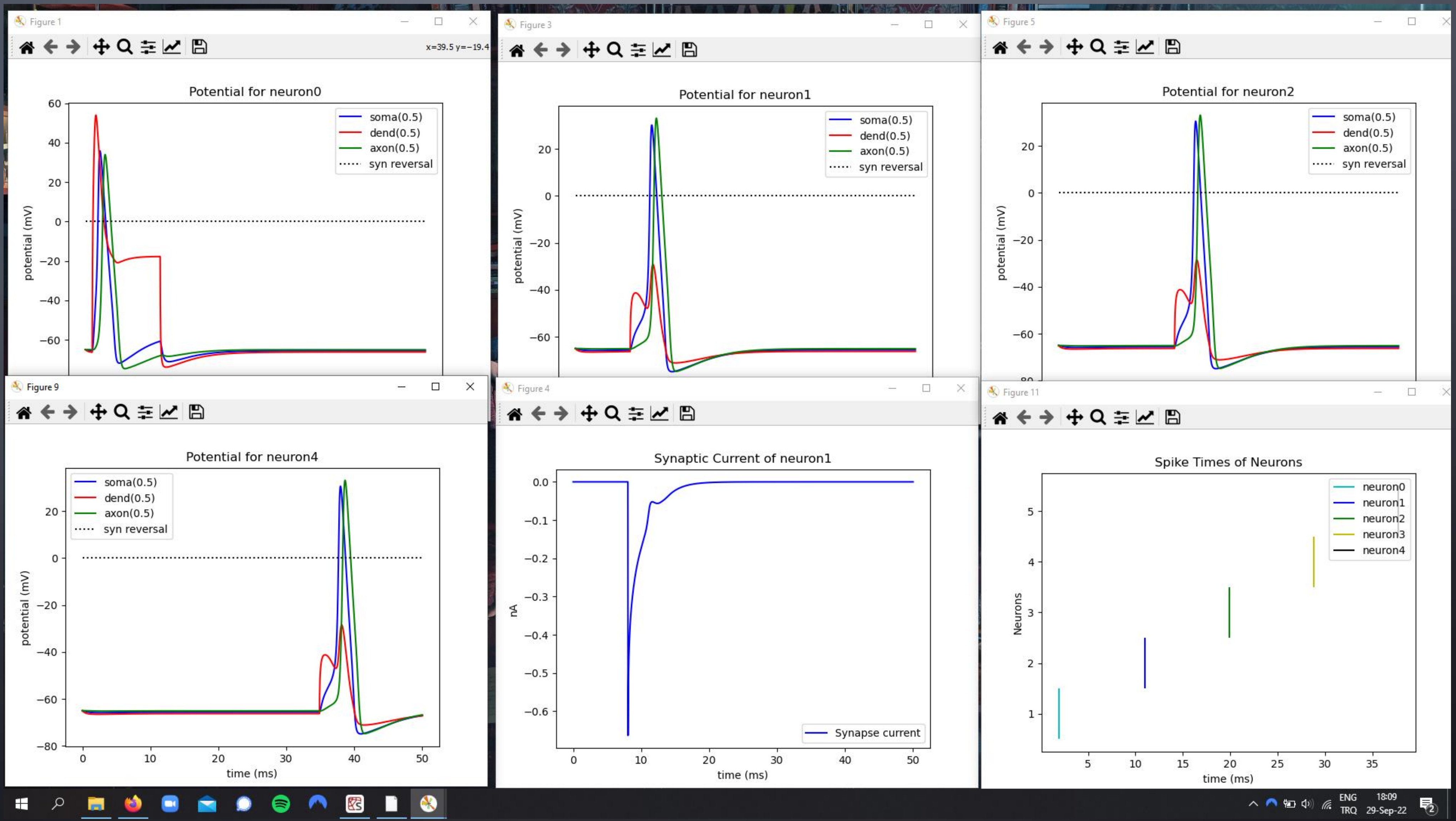


Figure 10: A physical axon model with stimuli

Figure 11: Physical model for axon and **E** field

FURTHER RESEARCH



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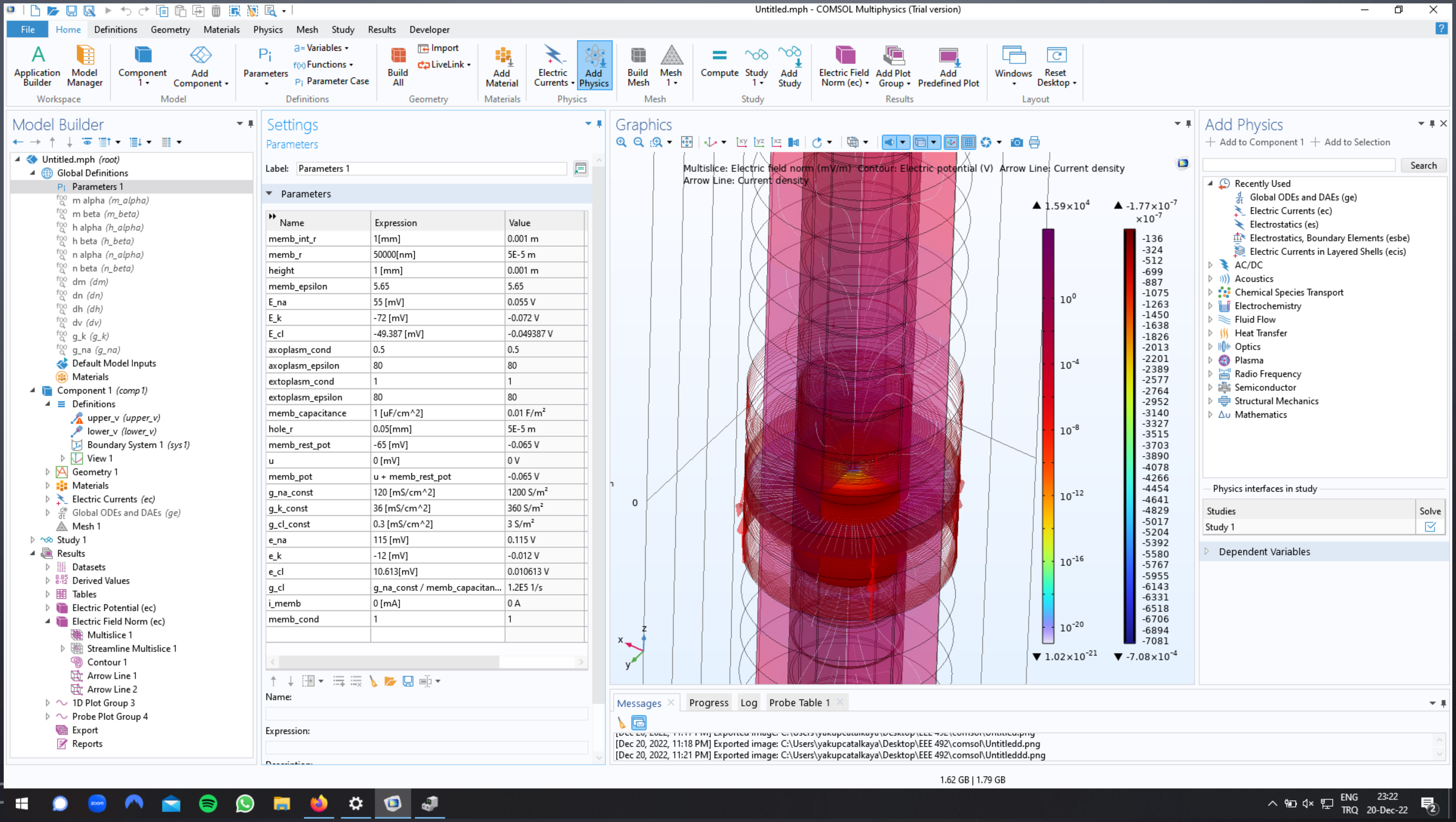

THANKS FOR LISTENING …

References

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