# Neuroprothetik Exercise 3
# Mathematical Basics 2

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## 1 Implementations in Matlab or Python

Implement the following methods as functions in Python or Matlab:

- Forward (Explicit) Euler

- Heun Method

- Exponential Euler

## 2 Solve Functions

Solve the differential equation $\frac{dV}{dt} = 1 - V - t$ where $V(t = -4.5) = V_0 = -4$ with the solvers implemented above. Vary the stepsize (1s, 0.5s, 0.1s, 0.012) and plot the results and answer the following questions.

- Interpret the impact of changing the stepsize.

- Why not just use a very small stepsize.

## 3 The Leaky Integrate and Fire Neuron

Implement a model of the leaky integrate and fire neuron with the following parameters

$$V_{n+1} = \begin{cases} V_n + \frac{\Delta t}{C_m}(-g_{leak}(V_n - V_{rest}) + I_{input}(t_n)) & V_n < V_{thr} \\ V_{spike} & V_n = V_{thr} \\ V_{rest} & V_n = V_{spike} \end{cases}$$

- $g_{leak} = 100\,\mu S$

- $V_{rest} = -60\,mV$

- $V_{thr} = -20\,\text{mV}$

- $V_{spike} = 20\,\text{mV}$

And simulate the cell for $50\,\text{ms}$ ($\Delta t = 25\,\mu\text{s}$ should be sufficient) with the following current inputs:

- constant $10\,\mu\text{A}$

- constant $20\,\mu\text{A}$

- rectified 50Hz sinus with $10\,\mu\text{A}$ amplitude

- rectified 50Hz sinus with $30\,\mu\text{A}$ amplitude

Plot the results and interpret what you see.

# 4 Solution

Here you can see how the resulting plots should look like. This is just to give you an idea if your results are valid.
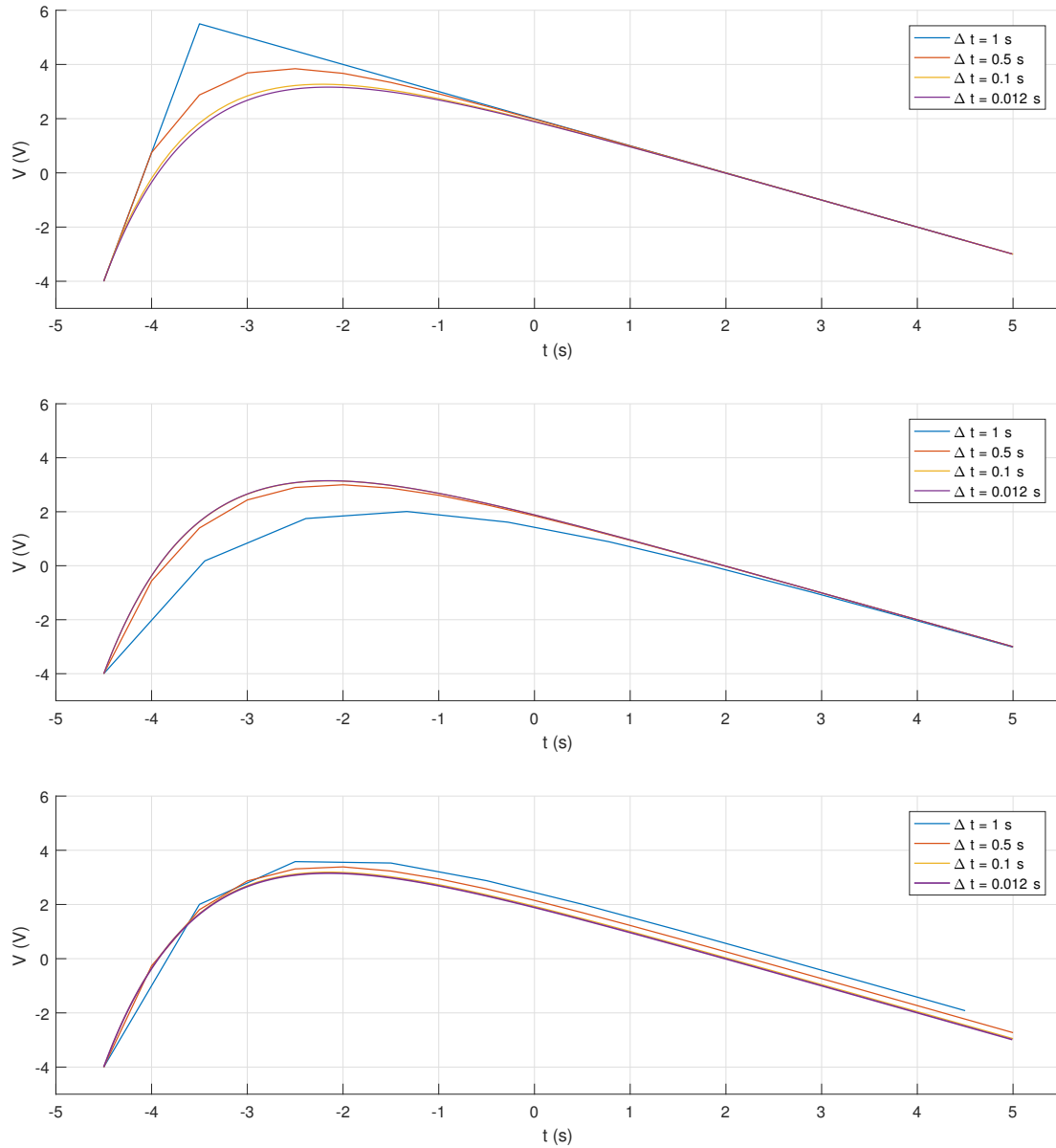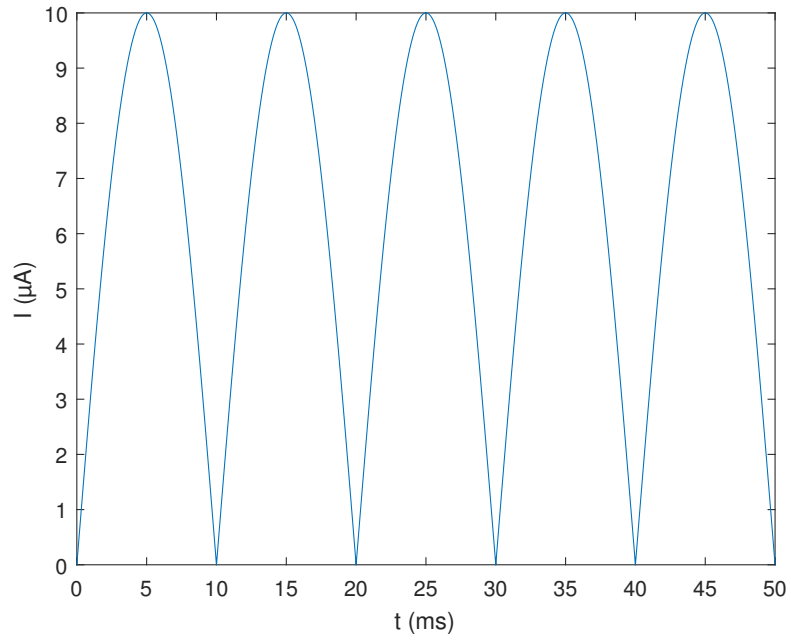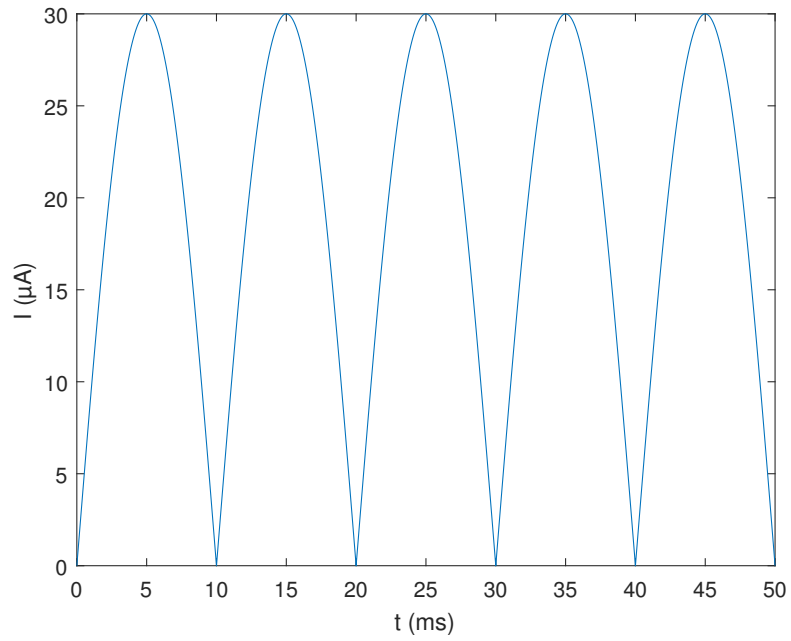


Figure 1: Approximations of the given differential eqution in 2 with different methods and different stepsizes. Top: Forward-Euler-Method. Middle: Heun-Method. Bottom: Exponential-Euler Method. The different colors resemble the given timesteps visible in the legend.

(a) Rectified Sine-Input with an amplitude of $10\,\mu A$ for the model visible in figure 3c



(b) Rectified Sine-Input with an amplitude of $30\,\mu A$ for the model visible in figure 3d

Figure 2: Current Inputs for LIF-Models visible in figures 3c and 3d

(a) Constant current input of $10\,\mu A$

(b) Constant current input of $20\,\mu A$

(c) Rectified Sine-Input with an amplitude of $10\,\mu A$, input signal visible in figure 2a

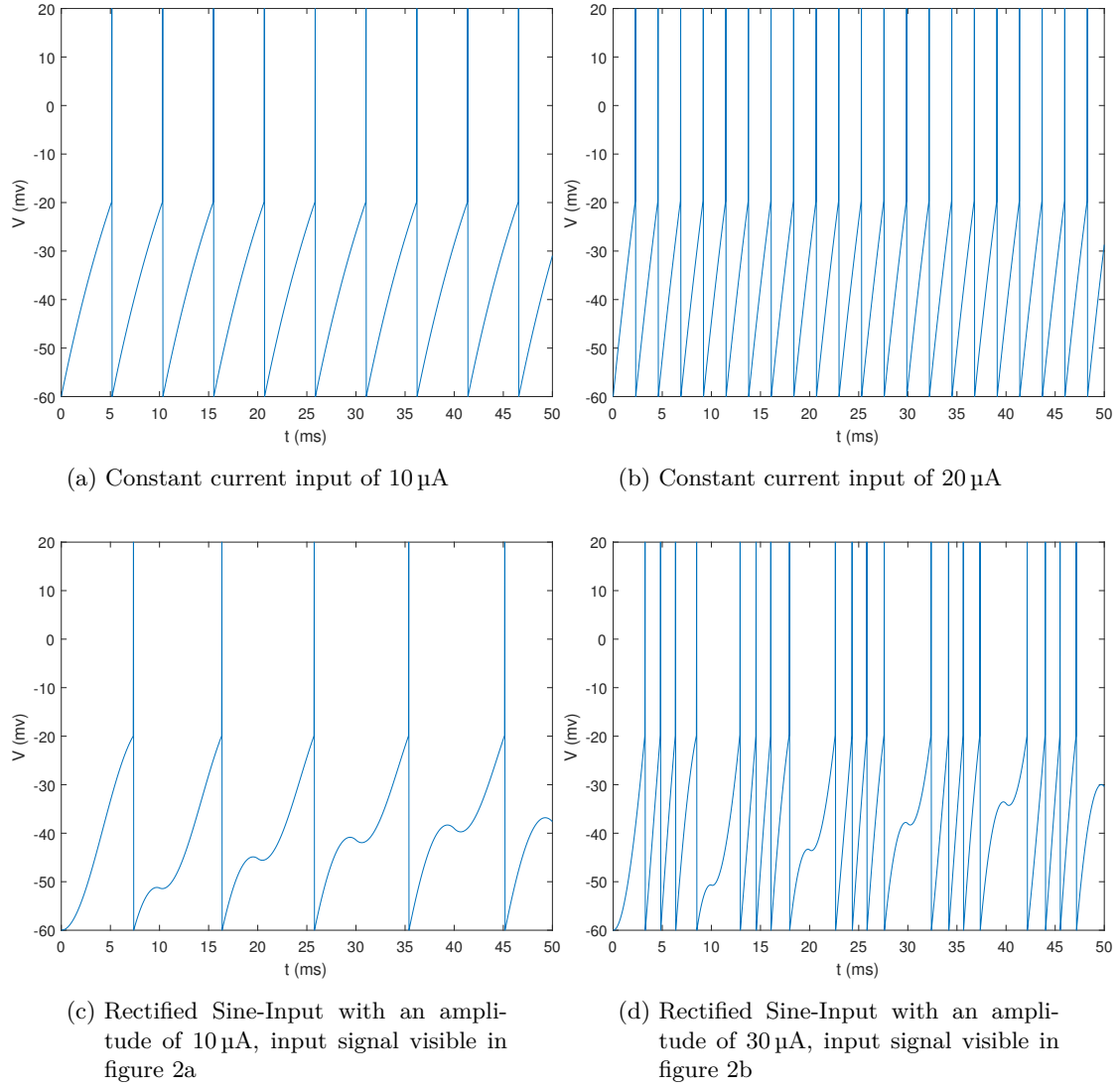(d) Rectified Sine-Input with an amplitude of $30\,\mu A$, input signal visible in figure 2b

Figure 3: Results for the LIF-Model for different current inputs.