

## Homework 2

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### Problem 1

#### Problem Statement

For this problem, I simulated the regular spiking neuron using the Izhikevich model with varying currents, and recorded plots for voltage vs. time and spike rate vs. current.

#### Results

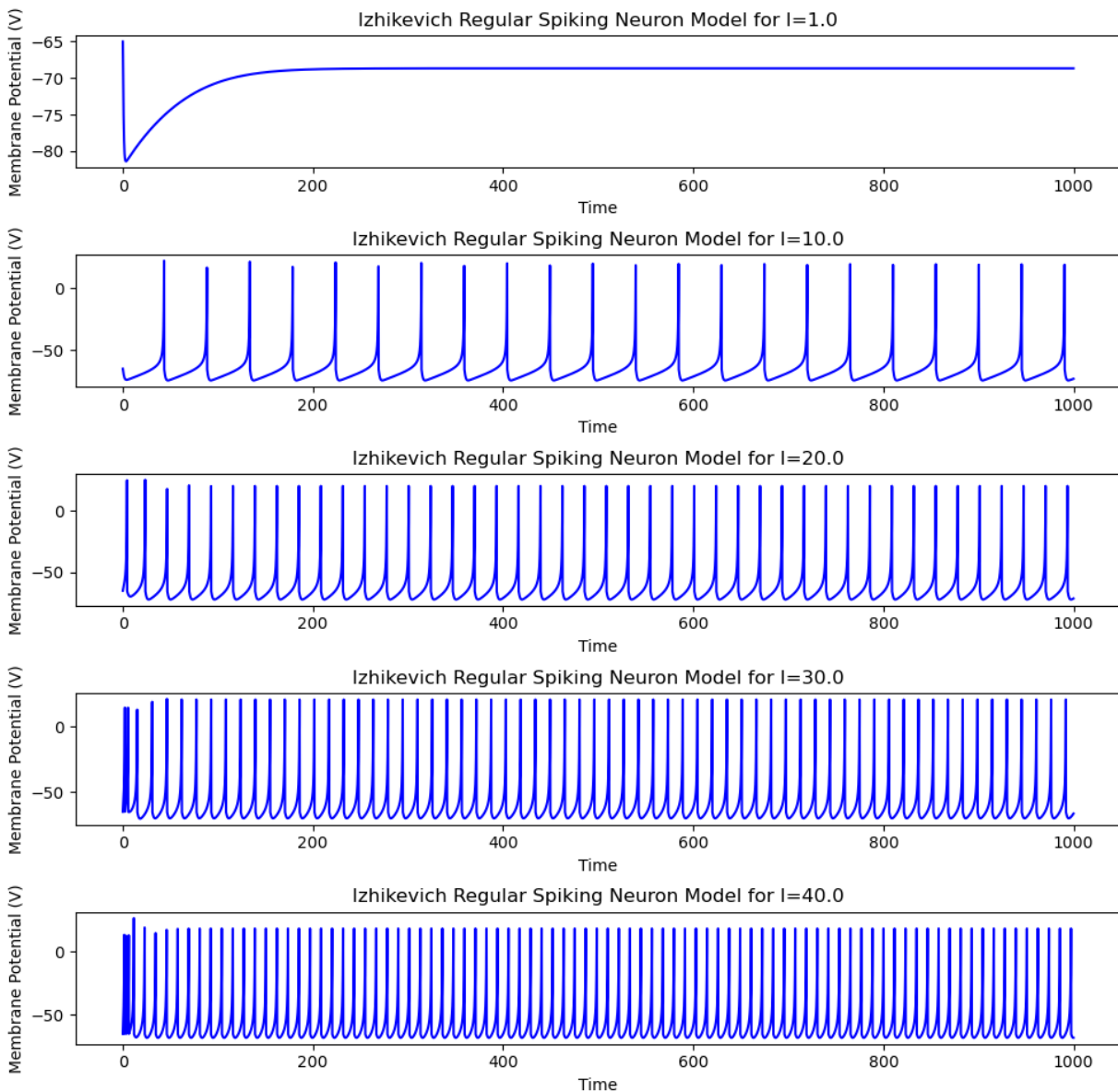


Figure 1.1. The plots of membrane potential as a function of time and input current for several simulations of the regular spiking neuron.

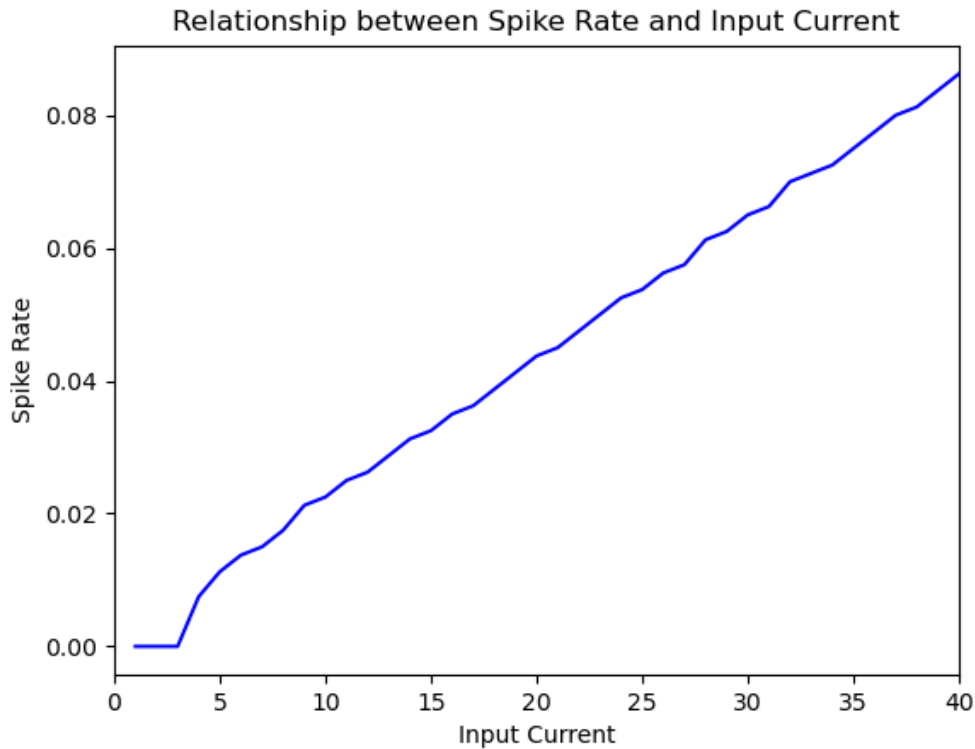


Figure 1.2. Plot of mean firing rate as a function of input current. The relationship is relatively linear.

## Discussion

The relationship between input current and the number of spikes recorded in the simulation appears to be somewhat linear. For the regular spiking neuron, the threshold to start producing spikes seems to be between 3 and 4 current units, as in Figure 1.2, the rate of spikes is zero between 1-3 current units. In addition, the regular spiking neuron will initially have a higher frequency of spikes before dropping to a more constant level. This is demonstrated in Figure 1.1, where the simulations for 30 and 40 current units show a cluster of spikes. It appears that given only the output, the fast spiking rate at the beginning could be used to tell when a high input current started being applied, and the spiking rate roughly shows the level of excitation of the neuron.

## Problem 2

### Problem Statement

For this problem, I simulated the fast spiking neuron using the Izhikevich model with varying currents, and recorded plots for voltage vs. time and spike rate vs. current. In addition, I compare the spike rate vs. current between the fast spiking neuron model and the regular spiking neuron model.

### Results

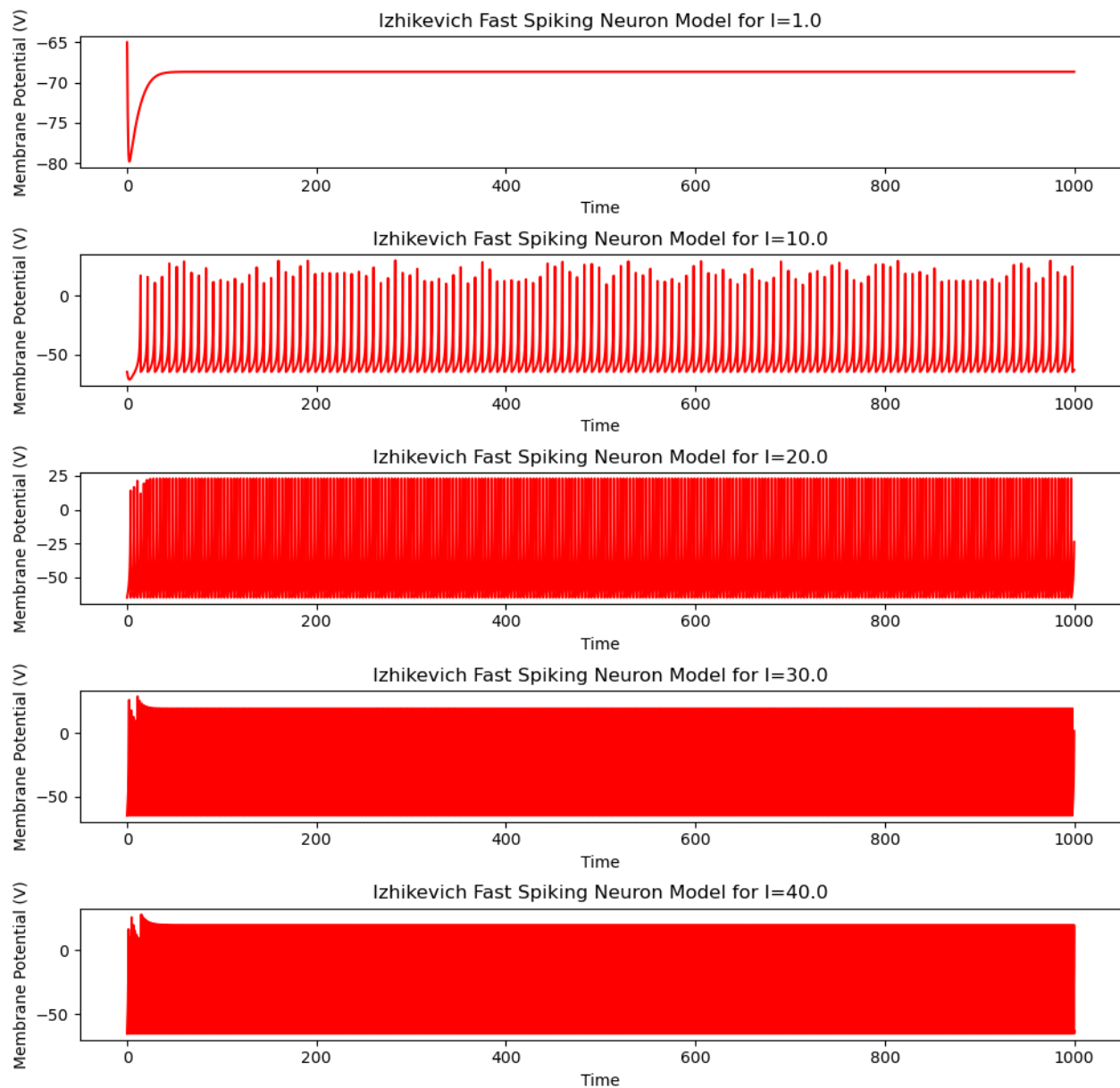


Figure 2.1. The plots of membrane potential as a function of time and input current for several simulations of the fast spiking neuron. The frequency of spikes is much higher than the regular spiking model.

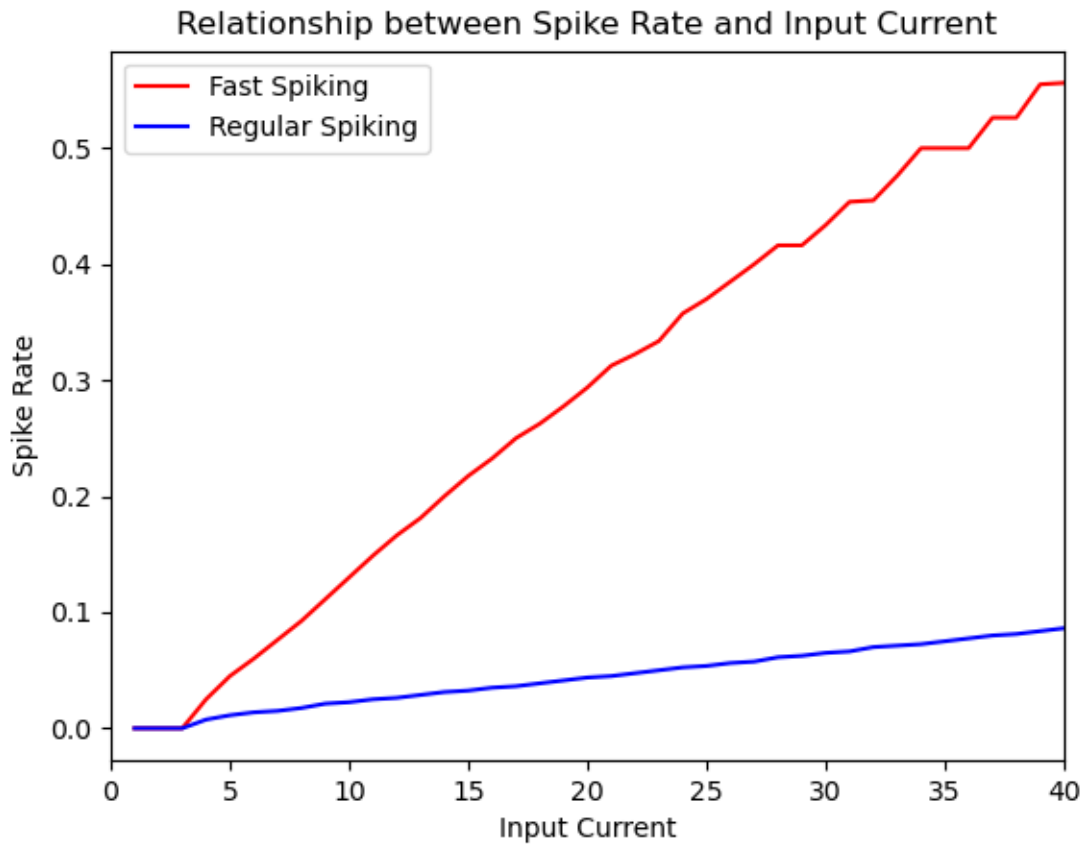


Figure 2.2. A comparison of mean spike rate as a function of input current between fast spiking and regular spiking neuron models. They both share a relatively linear relationship with current, although the fast spiking neuron's mean spike rate grows much faster.

## Discussion

The fast spiking neuron model has similar behavior to the regular spiking neuron model: 1-3 volts is insufficient to cause a spike during the simulation time, and the spikes at the beginning of the simulation appear to be more clustered together than the rest of the simulation, which can be seen in Figure 2.1. The mean spike rate of the fast spiking neuron appears to have more variability, which presents as the line being more jagged than the line for the regular spiking mean spike rate in Figure 2.2.

## Problem 3

### Methods

I used ChatGPT 3.5. My prompt was “generate the code for simulating a regular spiking Izhikevich neuron that runs for 1000 time-steps with inputs of  $I$  from 0 to 40 in steps of 1, then plots the spiking rate vs.  $I$  using the last 800 time-steps to calculate the spiking rate”, and I used this prompt because I summarized the Problem 3 requirements as a command.

### Result

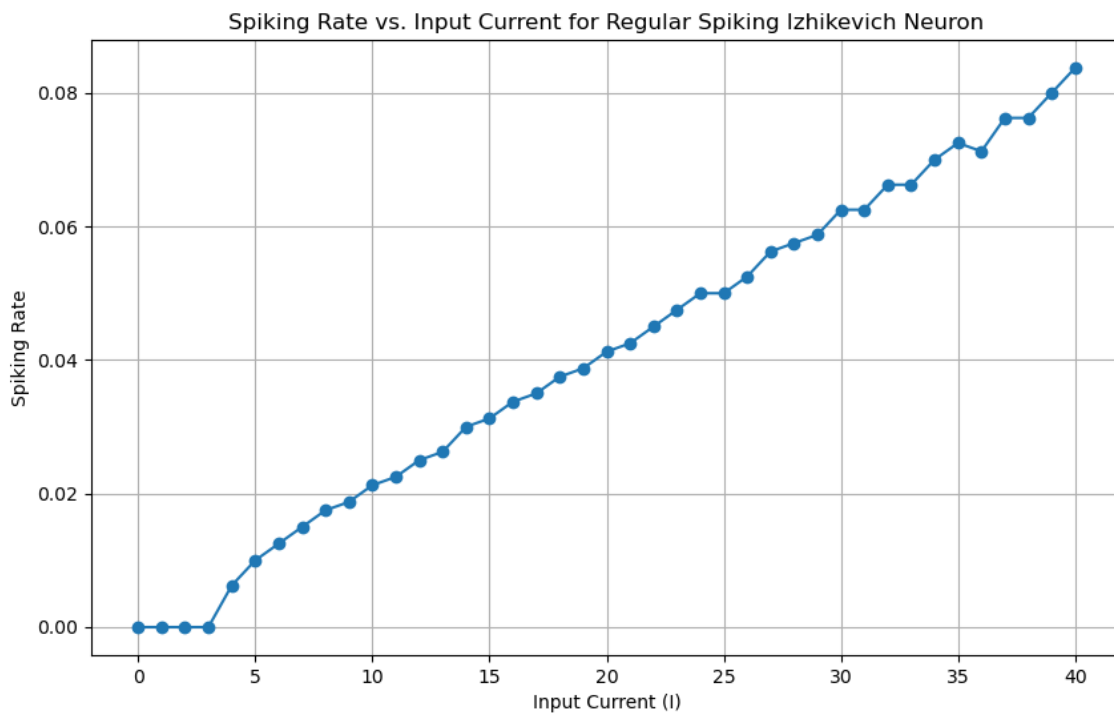


Figure 3.1. The plot of mean spike rate vs. input current created using ChatGPT-generated code.

### Discussion

The code ran successfully without any modifications, although required a minor modification. The spike rate was incorrectly calculated because it used spikes from all 1000 time-steps and then divided by 800. I think “last 800 time-steps to calculate the spiking rate” did not explicitly state to only use spikes from the last 800 time-steps. As a result, each non-zero data point was slightly inflated. I fixed it by only incrementing the spike count if  $t > 200$ .

After fixing the error, the plot produced as shown in Figure 3.1 is nearly if not identical to Figure 1.2 outside of aesthetic choices.

# Transcript



generate the code for simulating a regular spiking Izhikevich neuron that runs for 1000 time-steps with inputs of  $I$  from 0 to 40 in steps of 1, then plots the spiking rate vs.  $I$  using the last 800 time-steps to calculate the spiking rate



To simulate a regular spiking Izhikevich neuron and plot the spiking rate vs. input current ( $I$ ), you can use Python with libraries such as NumPy and Matplotlib. Here's a code example that accomplishes this task:



python

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```
import numpy as np
import matplotlib.pyplot as plt

# Define the Izhikevich neuron parameters
a = 0.02
b = 0.2
c = -65
d = 8

# Simulation parameters
total_time_steps = 1000
input_range = np.arange(0, 41, 1)
spike_rates = []

# Define the Izhikevich neuron simulation function
def izhikevich_neuron_simulation(I, total_time_steps):
    v = -65 # Initial membrane potential
```

```

u = b * v # Initial recovery variable

spike_count = 0 # Counter for spikes

for t in range(total_time_steps):
    if v >= 30: # Spike condition
        spike_count += 1
        v = c
        u += d

    # Update membrane potential and recovery variable
    dv = (0.04 * v**2 + 5 * v + 140 - u + I) # Membrane potential change
    du = a * (b * v - u) # Recovery variable change
    v += dv
    u += du

# Calculate spiking rate
spiking_rate = spike_count / (total_time_steps - 200) # Use the last 800
return spiking_rate

# Simulate and collect spiking rates for different input currents
for I in input_range:
    spiking_rate = izhikevich_neuron_simulation(I, total_time_steps)
    spike_rates.append(spiking_rate)

# Plot spiking rate vs. input current
plt.figure(figsize=(10, 6))
plt.plot(input_range, spike_rates, marker='o', linestyle='-')
plt.xlabel('Input Current (I)')
plt.ylabel('Spiking Rate')
plt.title('Spiking Rate vs. Input Current for Regular Spiking Izhikevich Neuron')
plt.grid(True)

plt.show()

```

In this code:

1. We define the parameters for the regular spiking Izhikevich neuron (a, b, c, and d).
2. We set the simulation parameters, including the total number of time steps and the range of input currents (I) from 0 to 40 in steps of 1.
3. The `izhikevich_neuron_simulation` function simulates the neuron's behavior for a given input current (I) and calculates the spiking rate using the last 800 time steps (discarding the first 200 time steps).
4. We loop through the input current range, simulate the neuron for each I value, and collect the spiking rates.
5. Finally, we plot the spiking rate vs. input current using Matplotlib.

Make sure you have NumPy and Matplotlib installed in your Python environment to run this code.