Instructions. Solve the following three exercises.

1 Inhomogeneous Poisson process

Plot 10 spike trains 1 sec long from a Poisson process with constant rate $\rho = 40$ spk/sec and 10 spike trains 1 sec long from an inhomogeneous Poisson process with time-dependent rate $\rho(t) = \rho_{mean} + \rho_{var} \sin(2\pi f_{var} t)$ with $\rho_{mean} = 40$ spk/sec and $\rho_{var} = 40$ spk/sec and $f_{var} = 10$ Hz. How many spikes do you expect over a 1 sec interval in both cases? Explain. Plot an histogram of the probability density of ISIs obtained over the 10, 1 sec long spike trains in each case. Do you see any differences? Can you explain them?

Hints. Use the integration algorithm explained in the lecture notes and forward Euler with a time step of 0.05 ms. Use the `hist` function to generate an histogram of ISIs with bins of 2 msec centered at 0ms, 2ms, etc... up to 250 msec. Normalize to obtain a probability density and use `bar` to plot the ISIs.

2 Tsodyks-Markram model

a. Plot the steady state release probability value $\langle P_r \rangle_{ss}$ and the postsynaptic rate $f_{post} = \rho \langle P \rangle_{ss}$ of the TM model for $\tau_{rec} = 500$ msec, $p_{rv} = 0.4$ and rates ρ between 0 and 100 Hz.

b. There is a typographical error in the legend of Figure 5.18B of Dayan and Abbott. Can you find it and explain?

c. Reproduce Fig. 5.19 of Abbott and Dayan by integrating the equation for the average instantaneous rate of release given in the lecture notes. Use the same parameters as in the figure, $P_{r0} = 1$, $p_{rv} = 0.4$, $\tau_{rec} = 500$ ms and presynaptic rates as given in the figure.

Hints. Use forward Euler with a time step of 0.05 ms.

3 Integration of synaptic inputs by a leaky integrate and fire neuron

Implement the Matlab code for a leaky-integrate and fire neuron with the following parameters:

1. Resting membrane potential: -70 mV.
2. Time constant: $\tau = 30$ msec.
3. Input resistance: $R = 20$ MΩ.
4. Spiking threshold: -54 mV. Reset at -70 mV after a spike.
5. Refractory period $t_{ref} = 2$ msec. Implement an absolute refractory period (i.e., the membrane potential stays equal to the rest potential during the refractory period and integration of inputs start only *after* the refractory period is over).

a. Compute first the theoretical f-I curve from eq. 9.2 of the lecture notes, then compute the f-I curve numerically by simulating the LIF model and compare the two.

Hints. Use either forward or backward Euler with a time step of 0.01 msec. For simulations, use injected currents between 1 and 111 nA in steps of 5 nA. Re-calibrate the membrane potential so that 0 mV is the resting membrane potential, this will make computations easier. Be sure to adopt a consistent set of electrical units, for example mV, nA and MΩ, μS.