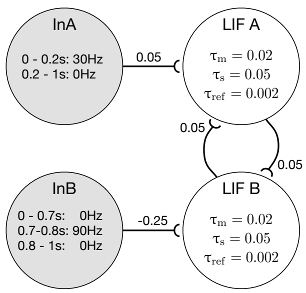
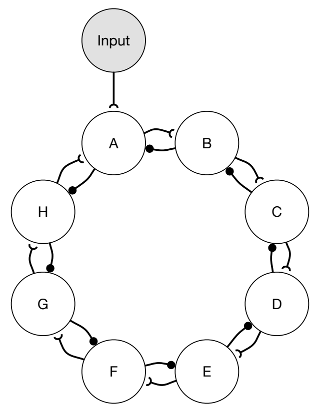
Experiments with Networks of LIF Neurons

For these questions, you will build and simulate various neural networks. To help you, the notebook `as01.ipynb` has code to get you started. In particular, it implements a `Neuron` base class, from which the classes `InputNeuron` and `LIFNeuron` are derived. There is also a `Synapse` class, for connecting neurons, and a `SpikingNetwork` class for putting neurons and connections together into a functioning network. You can see each class' documentation for more information, or see the sample code in this week's Exercises.

For all these simulations, you should use a time step of 1 ms (0.001 s).



(a) Two LIF



(b) Ring Oscillator

Figure 1: Network Models

Question 1: Two LIF Neurons

[4 marks]

a) Build the network with **two** `LIFNeuron`s as shown in Fig. 1a, each projecting its output to the other. That is, neuron `A` is connected to neuron `B` with a weight of 0.05, and `B` is connected to `A` with a weight of 0.05.

   Add an input neuron, called `InA`, and connect it to neuron `A` with a weight of 0.05. Have neuron `InA` fire at 30 Hz for 0.2 seconds at the start, and then go silent. You can create that input neuron using

```
InA = InputNeuron( GenerateSpikeTrain([30], [0.2]) )
```

   Add another input neuron, called `InB`, that connects to neuron `B`. Neuron `InB` should be silent, except fire at 90 Hz starting at 0.7 s and ending at 0.8 s. Connect `InB` to neuron `B` with a weight of -0.25.

b) Simulate the network for at least 1 second, and produce a spike-raster plot for the four neurons in the network.

c) Consider the interaction between neurons `A` and `B`. Which situation is this interaction most similar to?

   (a) A ball rolling down a hill, gaining speed and momentum.

   (b) Audio feedback from holding a microphone too close to its loudspeaker.

   (c) A guitar string vibrating when plucked.

   Justify your answer by pointing out the similarities. Place your answer in the markdown block in the notebook.

Question 2: Ring Oscillator

[5 marks]

a) Create a network with 8 LIF neurons; for the sake of this question, let's label them `A` through `H`. For all 8 neurons, use `Tau_m` = 50 ms, and `Tau_s` = 100 ms. Connect `A` to `B` with a weight of 0.2. Likewise, connect `B` to `C` with a weight of 0.2, etc., until you finally close the loop by connecting `H` to `A` with a weight of 0.2. This is the excitatory ring.

b) Now, add inhibitory connections between the same pairs of neurons, but running in the opposite direction around the ring. That is, connect `B` to `A` with a weight of -0.4, and `A` to `H` with a weight of -0.4, etc.

c) Add an input neuron to stimulate any one of the ring neurons (with a weight of 0.2). This input neuron should have a firing rate of 25 Hz for the first 0.3 seconds, and then go dormant. This full network is shown in Fig. 1b

d) Simulate the network for at least 4 seconds, and produce a spike-raster plot of all 9 neurons in the network. If all is working, you should see each neuron in the ring exhibit a "burst" of spikes in sequence. This excitation travels like a wave around the ring. If this is not what you are seeing, play with `Tau_m`, `Tau_s`, and the connection weights until you see this wave of activation travel around the ring.

e) How long does it take the wave of activity to go around the ring? Try to estimate the period accurately as possible and explain how you computed it. Place your answer in a markdown cell in the notebook.