Q1. Grid cells are neurons in the medial entorhinal cortex (MEC) that fire at vertices of hexagonal lattices tessellating an environment.

(a) Describe 2 experimentally important aspects of grid cell responses (in addition to the regular hexagonal pattern) which in your view can point to the possible underlying mechanism of grid cells' hexagonal response pattern. (10 points)

(b) Describe the oscillatory-interference model of grid cells. Argue for and against the model taking into account the experimental data that exists in the literature. (10 points)

(c) Since a grid cell fires at the vertices of a hexagonal grid, there would be ambiguity in inferring the position of the animal from the response of one cell (when a grid cell fires, the animal can be in any of the vertices of that grid cell). Do you think that one can infer the position of an animal by looking at response of a population of grid cells? (10 point)

Q2. Suppose that 4 stimuli (A, B, C and D) are presented to an animal with equal probabilities, while a fifth stimulus, E, is presented with twice the probability of the other 4. The table below shows the probability of different spike counts recorded in the experiment in response to each of these stimuli.

stimulus/response	**5 spikes**	**10 spikes**	**15 spikes**	**20 spikes**
stimulus A	3/5	2/5	0	0
stimulus B	2/5	3/5	0	0
stimulus C	1/4	1/4	1/4	1/4
stimulus D	0	0	1/2	1/2
stimulus E	1/2	0	0	1/2

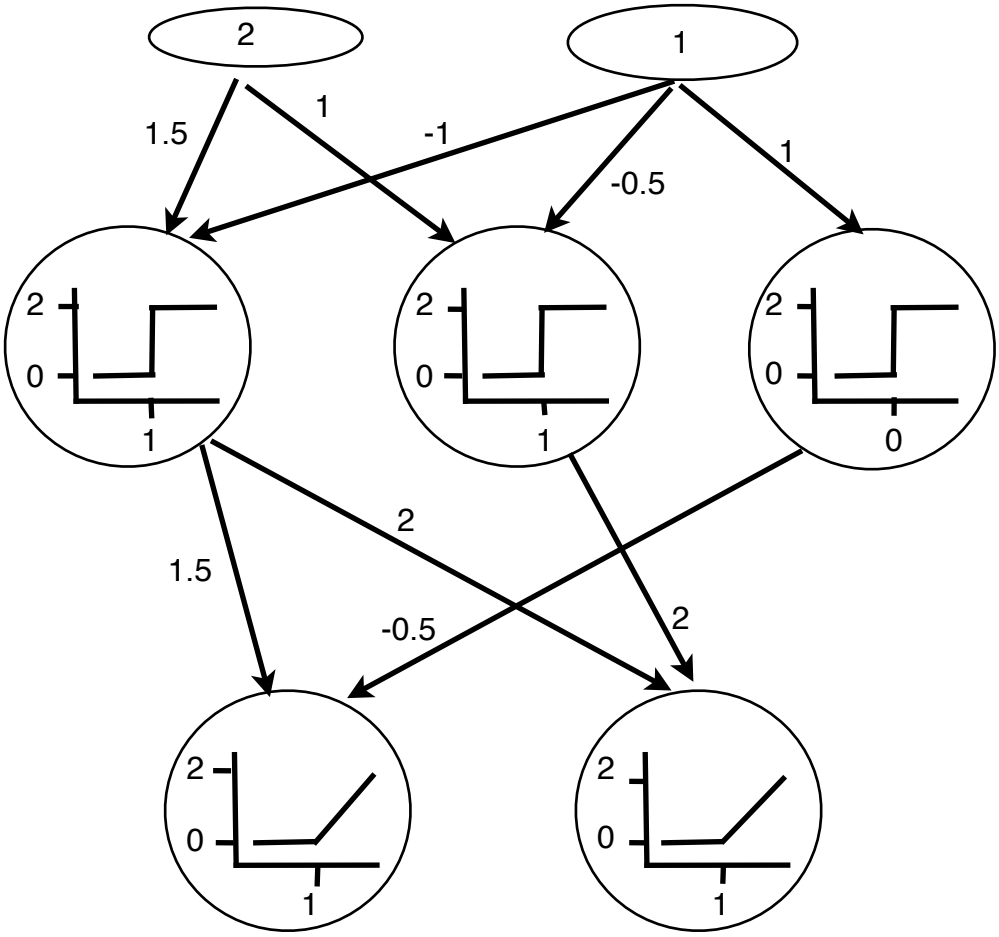
(a) What is the entropy of stimulus set? (5 points)
(b) What is the entropy of the responses? (5 points)
(c) What is the stimulus response mutual information? (10)
(d) Assume that after these measurements, someone shows one of the stimuli to the animal. If 20 spikes are recorded in response to this stimulus, what would be your best guess for which stimulus was presented? (10)

Q3. (a) Describe what noise correlation (5 points) and signal correlation (5 points) mean.
(b) Take a case of positive or negative noise and signal correlations between two cells. Discuss the consequence that these correlations will have on the stimulus-response mutual information. (10 points)

Q4. How does the balance between inhibition and excitation in a recurrent network lead to irregular firing? In addition to the irregular firing, describe another consequence of the inhibition-excitation balance. (10 points)

Q5. Consider the following 3 layer network. The input values shown in ellipses on top of the figure are propagated through the network. The numbers next to each line show the synaptic weights and each neuronal transfer function is shown in a circle. As shown in the figure, neurons in the second layer are all binary neurons with threshold 1 except for the

right most neuron which has a threshold of 0. Neurons in the second layer are threshold-linear neurons with threshold at 1 and a gain of 1.



Calculate input to and the firing rate of each of the 5 neurons. (2 points each)