CISC 3250 example exam questions
This gives a sense of the type of questions that can be included. Further math topics covered in the homeworks (but not in this practice set) may appear on the exam as well.

For all computations, you may estimate your answer to the first decimal place – for example, if the correct answer is 0.341, I will accept 0.3 or 0.4 as answers.

What is the approximate ratio of the number of neurons in the primary auditory cortex to the number of neurons or in the cochlea?
   (a) 1:1
   (b) 300:1
   (c) 1:200
   (d) -5:4,020,000
(b)
The more accurate ratio is 30:1, but 300:1 is the closest available option I provided
This observed ratio supports which information representation principle in the brain?
Sparse coding

Beyond studying vision, we can also use fMRI recordings of neural activity to study human emotions. It has been observed when one brain region (let's say the amygdala) shows high activity and another region (let's say the dorsomedial prefrontal cortex) shows low activity, we can predict the subject in the fMRI scanner is a calm person. If, on the other hand, the amygdala and the dorsomedial prefrontal cortex both show high activity, we can predict the subject in the scanner is an aggressive person.

	Amydgala	dmPFC
Calm	High	Low
Aggressive	High	High

1: Presuming there are only two types of activity that can be measured (high or low) for each region, what is the maximum number of personality states (e.g., calm, aggressive, cheery) we can identify with just two brain regions?

2: Let's say we perform another study where we identify 16 personality states using combinations of high and low brain region activity. What is the minimum possible number of brain regions he needs to use to identify these states?

Note: You do not need to have heard anything in the special Invited Lecture to be able to do this problem. Also, I am drastically simplifying Prof. Whalen's research. Assume my description is correct for the sake of doing the problem, but read his papers if you plan to study the neuroscience of emotion in the future!

As we discussed in class, neurons exhibit increasing invariance to location of an object (and other transformations of appearance) as we progress up the hierarchy of the visual object recognition pathway. Let us say the graph to the right shows the normalized firing rates for three neurons in V4 (from left to right, neurons **A**, **B**, and **C**) when a smiley face is shown shifted at differing horizontal distances from the center of vision.

-40   0   40
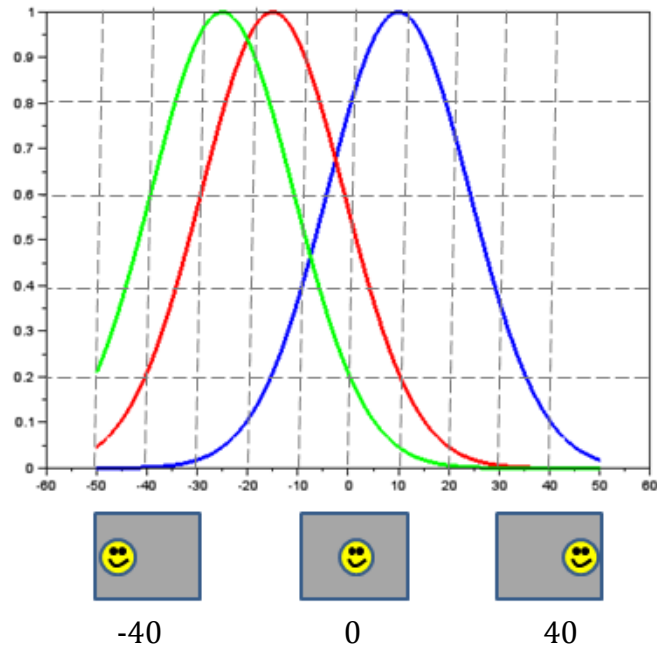
What is the horizontal location of the smiley face (rounded to the nearest 10, e.g., for a displacement of +27 you can answer +30) if the neuron firing rates are each of the following:

Location 1: $\hat{r}_A$=0.5 $\hat{r}_B$=0.9 $\hat{r}_C$=0.4   **-10**
Location 2: $\hat{r}_A$=0.5 $\hat{r}_B$=0.15 $\hat{r}_C$=0

Now, let us consider three new neurons and compute smiley locations using normalized population coding. The favored direction of each neuron is as follows:
Neuron F: 0 degrees from center
Neuron G: -20 degrees from center
Neuron H: 30 degrees from center

The observed normalized firing rating rates are:
Location 1: r_F=.8 r_G=.2 r_H=.6
Location 2: r_F=.1 r_G=.6 r_H=.1

Neurons in the cochlear nucleus tend to be relatively "quiet" (spiking rather little), while neurons in the vestibular nucleus tend to be relatively "hyperactive" (spiking a lot). Let us say the minimum and maximum firing rates for a neuron in each nucleus are:

$r_{min}^{cochlear}$=5 Hz	$r_{max}^{cochlear}$=25 Hz
$r_{min}^{vestibular}$=20 Hz	$r_{max}^{vestibular}$=80 Hz

Convert the following firing rates into normalized firing rates:
$r^{cochlear}$=20 Hz
$r^{cochlear}$=10 Hz
$r^{vestibular}$=20 Hz

$r^{vestibular}$=60 Hz $\frac{60-20}{80} = \frac{40}{80} = \mathbf{0.5}$

Below, we establish a miniature HMAX model, with two layer 1 neurons and one layer 2 neuron (performing the typical layer 1 and layer 2 computations for HMAX). Presume the weights into layer 1 are as specified below and the activation function is as shown to the right. Compute the output from layer 2 given the input values provided.

w_{DA}=2 w_{EA}=0
w_{DB}=-2 w_{EB}=1.5
w_{DC}=1 w_{EC}=-2
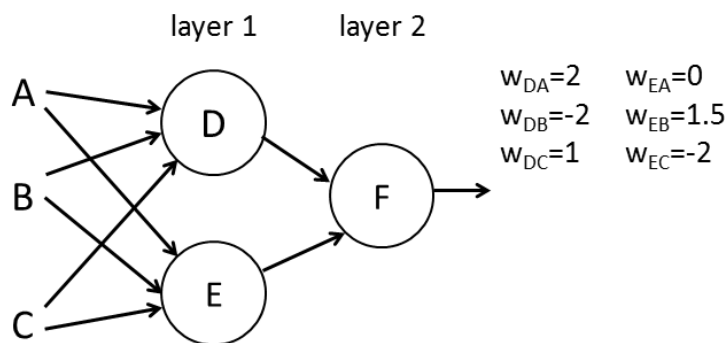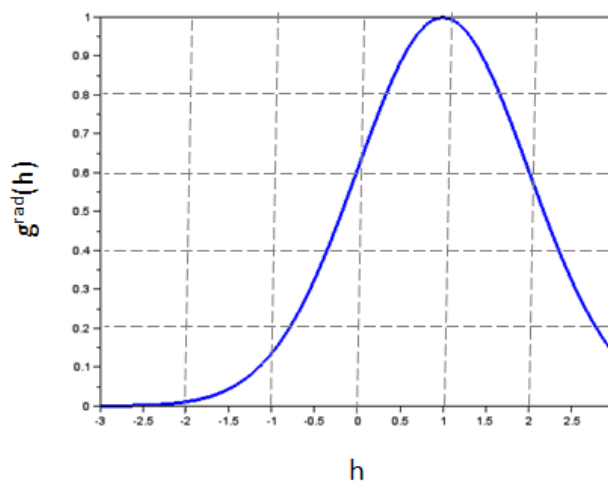
Input 1: r_A=0.5 r_B=1 r_C=0 r_D=g(2 × 0.5 − 2 × 1 + 1 × 0)=g(-1)=0.1
r_E=g(0 × 0.5 + 1.5 × 1 − 2 × 0)=g(1.5)=0.8
r_F=max([0.1 0.8])=**0.8**

Input 2: r_A=1 r_B=0.2 r_C=1

Consider a model neuron whose output is determined solely by the weighted sum of its inputs (no complicated activation function this time). However, each input is modulated by a further attention weight, indicated by the dashed blue lines in the diagram at right. Given the rates for the four inputs A, B, C, and D, compute the output.
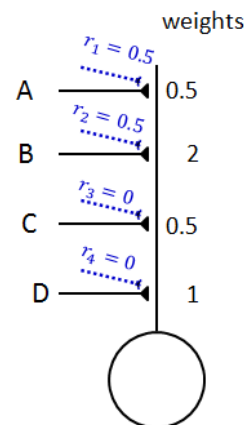
Input 1: r_A=1 r_B=0 r_C=0.5 r_D=0.5
Input 2: r_A=0 r_B=0.1 r_C=1 r_D=1

You are trying to listen to a band in a crowded bar. While listening, you record the responses of 5 neurons. The 5 neurons have distributed firing rates to respond to the instrumental music, the singers, and people talking in the background. The maximum response for each individual sound source (i.e., at loudest volume) is as follows.

Neuron 1	30 Hz	0 Hz	0 Hz
Neuron 2	10 Hz	30 Hz	0 Hz
Neuron 3	0 Hz	20 Hz	0 Hz
Neuron 4	0 Hz	10 Hz	30 Hz
Neuron 5	30 Hz	0 Hz	30 Hz
	Instruments	Singers	Talkers

What is the neural response for:

hearing instruments at maximum volume (1), not hearing the singers (0), and hearing the talkers at half volume (0.5)

hearing instruments at low volume (0.2), hearing the singers fairly loudly (0.8), and not hearing the talkers (0)

If we wish to focus on the singers and ignore the instruments and talkers as much as possible, what multiplying attention weights should we give to each of the 5 neurons?

Include high attention for neurons that fire for singers and 0 attention for neurons that never fire for singers. When neurons fire for both singers and non-singers, include them anyway with a positive attention (so we don't miss anything singing-related).
$a_1=0$ $a_2=1$ $a_3=1$ $a_4=1$ $a_5=0$

An alternate approach would be to give attention only to the neuron that fires only for singers. I would accept this answer too though, in practice, this strategy turns out to be impractical.
$a_1=0$ $a_2=0$ $a_3=1$ $a_4=0$ $a_5=0$

Let us consider the following matrices:

$$A = \begin{bmatrix} 2 & 0 & 1 \\ -2 & 3 & 0 \end{bmatrix} \qquad B = \begin{bmatrix} 0.5 & 1 \\ 2 & -3 \\ 0 & 0.5 \end{bmatrix} \qquad C = \begin{bmatrix} -3 \\ 2 \\ 0 \end{bmatrix}$$

$$D = \begin{bmatrix} 4 & -2 \\ 0 & 5 \end{bmatrix} \qquad E = \begin{bmatrix} 0.5 \\ 0.5 \end{bmatrix}$$

What is AxB

What is AxC

What is DxE $\begin{bmatrix} 4 & -2 \\ 0 & 5 \end{bmatrix} \times \begin{bmatrix} 0.5 \\ 0.5 \end{bmatrix} = \begin{bmatrix} 4 \times 0.5 - 2 \times 0.5 \\ 0 + 5 \times 0.5 \end{bmatrix} = \begin{bmatrix} 1 \\ 2.5 \end{bmatrix}$

Presuming we have two ears attached to a normal-sized human head, compute the angle of the speaker based on the differing arrival times of sound to the left and right ears below:

Left ear: 20.05ms   Right ear: 20.50ms   **-51º**
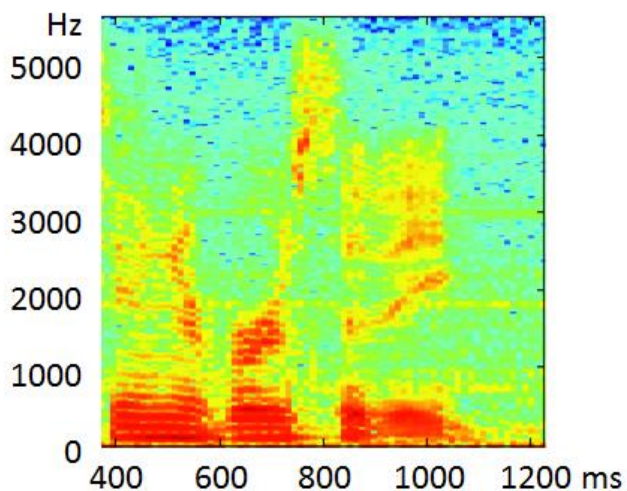
Left ear: 10.34ms   Right ear: 10.26ms

Left ear: 15.25ms   Right ear: 15.00ms

For a normal-sized human head, what is the largest time difference we can expect for sounds coming into the left versus the right ear?
0.58ms from 0.2 m / 343 m/s

Below is the spectrogram for the word "university", consisting of the sounds:
"y" + "oo" + "n" + "ih" + "v" + "er" + "s" + "ih" + "t" + "ee"



The final sound "ee" consists of the formants F1: 500 Hz and F2 2200Hz.

What is the time interval when "ee" is said?

What is the time interval for "s"?
750-800 ms

What are formants F1 and F2 for the "ih" sound?

Let us say we have four 1x20 vectors, recording results from a 20-subject experiment. The vectors are averageSpeed, age, heartRate, accuracy.

averageSpeed vs age

averageSpeed vs heartRate

averageSpeed vs accuracy
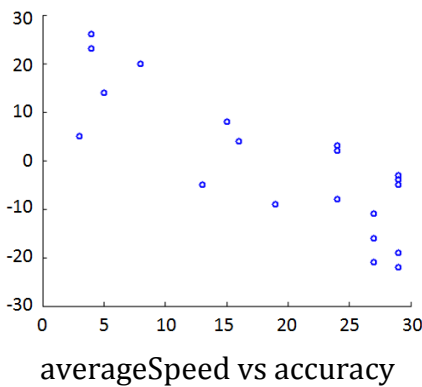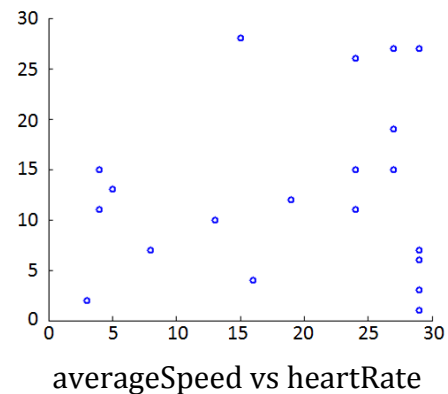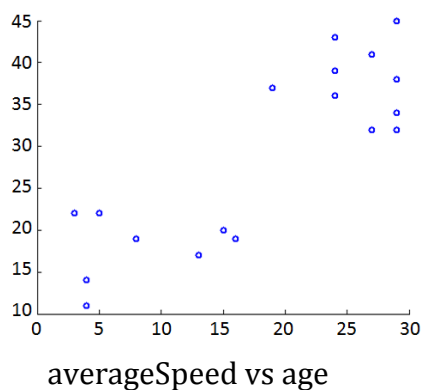
Provide a single Matlab command to draw the plot for averageSpeed vs heartrate

Which of the above three plots would you expect has correlation +0.9

Which of the above three plots would you expect has correlation -0.8
averageSpeed vs accuracy

Which of the above three plots would you expect has correlation +0.1

Provide a single Matlab command to compute the correlation between heartrate and accuracy

Provide the set of subplot commands to produce the 2x2 grid of plots shown above (with the bottom right subplot left empty).

Presume we have a 4 dimensional matrix of brain data called `BrainData` with dimensions 2 x 50 x 60 x 20. The matrix represents the response of a brain at each of 50x60x20 X,Y,Z locations to the picture of a duck (BrainData(1,x,y,z)) or the sound of a duck (BrainData(2,x,y,z)).

Write code to show a slice of brain responses to the sight of the duck, with the slice taken at y=30 .
```
imagesc(squeeze(BrainData(1,:,30,:)))
```

Write code to define a 50x60x20 matrix called `sightOrSound` that represents the difference in neural response for a duck picture versus a duck sound at each voxel. For example, if the brain responded 20 to the picture and 30 to the sound at location 20,45,5 , the corresponding entry in sightOrSound will be -10.

Write code to show the distribution (histogram) of difference values across all the voxels in the matrix `sightOrSound`.