Name: **Student ID number:**

Question 1

a. Give two general properties of tasks in which deep learning approaches are often effective, but other AI approaches are not. (1 point)

b. Give a specific example of a data source to which artificial DCNNs are applied, which has:
   i) 1 dimension
   ii) 2 dimensions
   iii) 3 dimensions (3 points)

c. i) Describe the ReLU thresholding operation commonly used in artificial DCNNs, in terms of its inputs and outputs (1 point)
   ii) What is the main theoretical motivation for including a thresholding operation (1 point)

d. i) Describe the (max) pooling operation commonly used in artificial DCNNs (1 point)
   ii) What is the main theoretical motivation for including a pooling operation (1 point)

e. i) Describe the normalisation operation commonly used in artificial DCNNs (1 point)
   ii) What is the main theoretical motivation for including a normalisation operation (1 point)

ANSWERS

a. Difficult to describe using formal mathematical rules

   Easy/intuitive/automatic for humans (0.5 points each)

b. I) Language processing / time series processing
   ii) Image processing
   iii) Medical image processing (1 each)

c. I) Set negative outputs to zero (0.5) and make positive outputs proportional/equal to inputs (0.5)
   ii) Introduces a nonlinearity (1)

d. I) Downsample the input (0.5) by taking the maximum activation over small groups of inputs (0.5)
   ii) Reduces computational load introduced by increasing numbers of feature maps (1)

e. I) Subtract the mean activation of a group of units (0.5) then divide by the standard deviation (0.5)
   ii) Forces independent and identically distributions in different groups of units (or feature maps (1)
   OR Avoids response level drifting up from repeated thresholding
   OR Forces even split between active and inactive units
   OR Weights different feature maps similarly

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Question 2

a. How are different inputs to a biological neuron integrated to determine the neuron's firing rate? (3 points)

b. i) How does the sharing of connection weights differ between biological neural networks and most artificial DCNNs? (1 point)

ii) Give three reasons why this difference occurs, considering the properties of both biological and artificial networks. (3 points)

c. i) Describe one spatial analysis of visual position information (i.e. a spatial filter) in the retina.

ii)Describe one non-spatial analysis of visual feature information in the retina. (3 points total for both parts)

a¶ Synaptic inputs lead to excitatory **and inhibitory** post-synaptic potentials (1)
A single EPSP is too small to activate voltage gated sodium channels (1)
When several EPSPs arrive in a short time, they add together (1)
Only when this summed PSP reaches the threshold for sodium channel activation does the neuron fire (1)

b¶ I) Weights are shared in artificial networks, not in biological networks (1)
ii) Biological filters use distinct, independent synapses (1)
Orientation pinwheel organisation emerges when weights are independent (1)
Artificial networks use a matrix multiplication (1)
A large matrix multiplication is fast (1)
Fewer weights need to be learned/better constrained network (1)

c¶ I) Description of surround suppression (1) by nearby photoreceptors (1)
ii) Description of colour opponency (1) comparing the activity of different cone types (1) to determine ratio of activity (1). Specific example of comparison operations also get 1 point.
(Max 3 for both parts)

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Question 3

d. Kay et al. (2008) built 'receptive field' models of the responses of each point in an fMRI scan (voxel) to natural images. This allowed them to determine which image was shown from the resulting brain activity. For each voxel, they summarise its response preference (tuning) using three parameters, which closely follow the image parameters that determine whether a neuron in V1 will respond. What are these three parameters? (3 points)

a. In Yamins and colleagues' paper "Performance-optimized hierarchical models predict neural responses in higher visual cortex", they test the performance of various models, biological neurons, and human observers on object recognition tasks of increasing complexity.
   i) How did they change task complexity? (1 point)
   ii) How did the object recognition performance of different models, different biological neurons and human observers change with task complexity? (4 points)

b. Why does a network that includes recurrent lateral or feedback connections require models to run over several time points/cycles? (2 points)

Answers:

a. Position / 'space' (1)
   Orientation (1)
   Spatial frequency (1)
   Contrast (1) (a valid answer, though not what we want)
   (Max 3)

b. I) Changed the amount of view variation
   ii) All performed well in low variation tasks (1)
   Humans, deep models and IT neurons stayed strong as variation increased (2)
   V4 neurons (1) and simple models dropped performance with increasing variation (1)
   (Max 4)

c. Feedback and lateral connections come from units that are not initially responsive (1)
   Information from the current level must feed into other levels (1)
   Then feed back to influence the current level (1)