**UNIVERSITY OF BRISTOL**

**May / June 2019 Examination Period**

**FACULTY OF ENGINEERING**

**Third Year / M Level Examination for the Degree of**
**Bachelor of Science / Master of Engineering / Masters of Science**

# COMS 30127 / COMSM 2127
# Computational Neuroscience

**TIME ALLOWED:**
**2 hours**

This paper contains *two* parts.
The first section contains *15* short questions.
Each question is worth *two marks* and all should be attempted.
The second section contains *three* long questions.
Each long question is worth *20 marks*.
The best *two* long question answers will be used for assessment.
The maximum for this paper is *70 marks*.

**Other Instructions:**

**Calculators must have the Faculty of Engineering Seal of Approval.**

**TURN OVER ONLY WHEN TOLD TO START WRITING**

# Section A: short questions - answer all questions

**Q1**. A substantial part of Henry Molaison's hippocampus was removed in an attempt to cure his epilepsy. What were the consequences of this damage to Henry Molaison? Henry Molaison was known as patient H.M.

**Q2**. What is the difference between *in vivo* and *in vitro* electrophysiology?

**Q3**. Why is the fourth order Runge-Kutta approximation better than the Euler approximation when solving differential equation?

**Q4**. Solve the differential equation

$$\frac{df}{dt} = 1 - f$$

with $f(0)$=-1.

**Q5**. The hippocampus is important for encoding declarative memories (memories we can verbalise about). Name the two main subtypes of declarative memories.

**Q6**. What assumption does the idea of "rate coding" rely on?

**Q7**. What does "retinotopy" refer to in the visual regions of the brain?

**Q8**. The left and right hemispheres of the brain respond to different aspects of the visual field. What part of the visual field does the brain's right hemisphere respond to?

**Q9**. There are several types of topographic map superimposed in visual cortex. Name two of the types.

**Q10**. For a spike train with spike times $\{t_1, t_2, \dots, t_n\}$ evoked by stimulus $s(t)$ define the spike triggered average.

**Q11**. Briefly describe the synaptic theory of working memory.

**Q12**. Give the equations for the basic pairwise STDP model.

**Q13**. Explain what is meant by detailed excitation-inhibition balance.

**Q14**. What causes the imbalance of ion concentrations across the neuron membrane?

**Q15**. According to the Hodgkin-Huxley equation the conductance of the potassium gate is proportional to $n^4$ where

$$\frac{dn}{dt} = \alpha(1 - n) - \beta n$$

What is the usual interpretation of $\alpha$ and $\beta$? Show how the equation can be rewritten in the form

$$\tau\frac{dn}{dt} = n_\infty - n$$

## Section B: long questions - answer two questions

**Q1**. This question is about the leaky integrate-and-fire neuron.

(a) The voltage in the integrate-and-fire neuron satisfies:

$$\tau_m \frac{dV}{dt} = E_L - V + RI$$

However this is not the whole model; what must be added to give the integrate and fire model? *[3 marks]*

(b) How is the membrane time constant $\tau_m$ related to the electrical properties of the cell membrane? *[3 marks]*

(c) Sketch a plot of the absolute impedance of the subthreshold voltage of the integrate-and-fire neuron. *[4 marks]*

(d) Derive a formula for the interspike interval for this neuron when there is a constant current large enough to cause spiking. *[7 marks]*

(e) There are a few common extensions to the integrate-and-fire model used to make it more realistic. Name one example of such an extension. *[3 marks]*

**Q2**. This question is part about inhibitory plasticity and part about Hopfield networks.

(a) Give the learning rule used by Vogels et al. Science 2011 to achieve excitation-inhibitory balance in recurrent networks. *[3 marks]*

(b) Give the expression to which the weight converges for the above rule and explain its meaning. *[7 marks]*

(c) What aspect of the Hopfield network learning rule might be described as Hebbian? *[3 marks]*

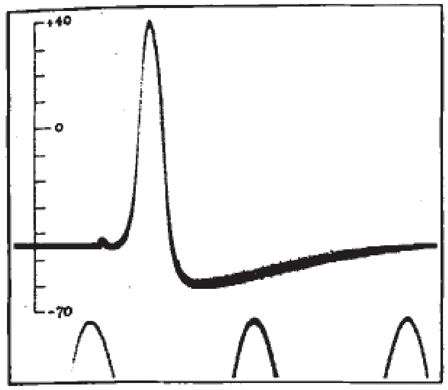
(d) Imagine a Hopfield network with three neurons, and two patterns to store: (-1,1,-1) and (1,1,-1). Compute the synaptic weights between the three neurons: $w_{12}$, $w_{13}$ and $w_{23}$. *[4 marks]*

(e) Assume the neurons have a threshold value $\theta = 1/2$. If the same network were initialised in state (-1,-1,-1), and you did a synchronous update on all the neurons' states, what would the network state be at the next timestep? *[3 marks]*

**Q3**. This question is about models of spiking neurons.

(a) The figure shows a recording made by Hodgkin and Huxley of an action potential.

(cont.)




What ion flow accounts for the upswing and downswing in the voltage. *[4 marks]*

(b) Write down the Hodgkin-Huxley equation for the voltage; include the relationship between the conductances and the gating variables $n$, $m$ and $h$; there is no need to include equations for the gating variables. Take care to define the various constants. *[6 marks]*

(c) Sketch the asymptotic values of $n$, $m$ and $h$ and describe the role they play in forming the spike. *[5 marks]*

(d) What assumptions are made to roughly derive the Morris-Lecar model from the Hodgkin-Huxley one. *[5 marks]*



**END OF PAPER**