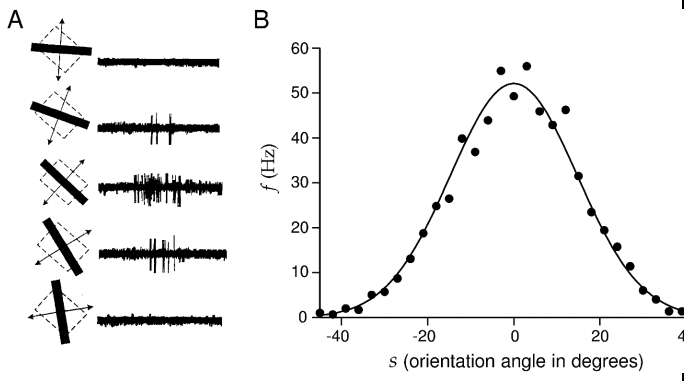
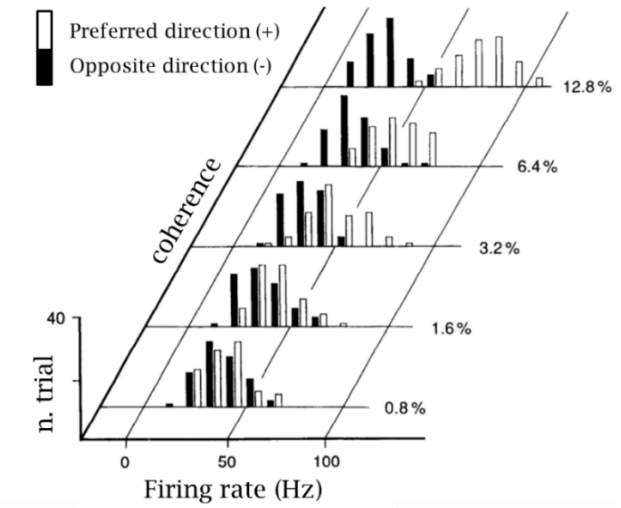
Neuroengineering 2022-2023

Exam 28 March 2024 – Part I
Solutions

Section A

1	The voltage-gated Na^+ channel opening is responsible for the repolarization phase of the action potential.	F	*It is responsible for the depolarization phase.*
2	The voltage-gated K^+ channel is responsible for the absolute refractory period.	F	*It is responsible for the relative refractory period.*
3	The part of the pyramidal neuron that acts as a current dipole is the dendritic tree.	T	
4	The firing rate influences the temporal summation of the PSPs.	T	
5	Each brain lobe contains several Brodmann areas.	T	
6	Axonal sprouting and pruning are part of the mechanisms behind brain plasticity.	T	
7	The synchronicity of the neural activity in a region affects the amplitude of the EEG signals it produces.	T	
8	The distance between the neurons and the electrodes does not affect the amplitude of the EEG signals they produce.	F	*Attenuation and blur increase with distance.*
9	To record *in vivo* measures of the membrane potential over the axon of a neural cell, you will use intracellular recordings.	F	*Intracellular recordings are more difficult to be performed in vivo, and on thin structures like the axon. To this purpose, extracellular recordings are more appropriate.*
10	Potentials recorded by electrodes which are at a close distance on the scalp are mutually independent.	F	*Due to the volume conduction, there's a strong correlation between scalp potentials recorded at a close spatial distance.*

11	Given the following tuning curve, reporting the firing rate of a neuron of the primary visual cortex (B) in response to the orientation angle of a visual stimulus (A):  If the measured firing rate is 20 Hz, I can infer a univocal orientation angle that produced that response.	F	*There are two possible orientations that produce a 20 Hz firing rate (-20 and 20 degrees).*
12	In reference to the previous figure: from the curve I can conclude that there is a preferred stimulus orientation for which this neuron is designed to respond.	T	
13	In reference to the previous figure: there are stimulus orientation angles to which this neuron is “blind” (i.e., it doesn’t show any response).	T	
14	Given the firing rate distribution in the figure, obtained for a neuron of the primary visual cortex in response to the motion direction of dots on the screen in two possible directions (+ and -) and with different levels of coherence between the dots:  Discriminability *d’* is higher when the coherence level is equal to 0.8% than when it is equal to 6.4%.	F	*Discriminability is higher when the two distributions are less overlapping, e.g. when the coherence level is equal to 6.4% with respect to 0.8%.*

15	In reference to the previous figure: the distribution (-) is less affected by the coherence level than the distribution (+).	T	
16	In reference to the previous figure: there is an optimal value *z* that can be used as a threshold for classification at all coherence levels	F	*The optimal value of the threshold z depends on the two distributions; therefore it is different for different coherence levels.*
17	The Granger Causality Index G_{xy} is a multivariate estimator of brain connectivity.	F	*It is pairwise (bivariate).*
18	The normalized $PDC_{xy}(f)$ between two time series *x* and *y* $\in[0, \infty]$.	F	*The normalized PDC* $\in$ *[0, 1].*
19	The Ordinary Coherence between two time series *x* and *y* is a function of the frequency.	T	
20	In a graph, the distance *d(i,j)* between two nodes is given by the average length of the paths that link them.	F	*It corresponds to the shortest (oriented) path between the nodes.*
21	In a graph, the Global Efficiency $\in[0, 1]$.	T	
22	A regular network has fewer nodes than a random network.	F	*We can define regular and random networks of any dimension (number of nodes).*
23	Random networks have a smaller Local Efficiency than regular (lattice) networks.	T	
24	In a graph, the minimum Divisibility is equal to zero.	F	*According to the most used normalization, the minimum Divisibility is equal to 0.5. More generally, even with different choices of the term k, D can never be equal to zero.*
25	Divisibility and Modularity are measures of integration of a network.	F	*They are directly proportional to the network segregation given the classes on which they are computed.*
26	Modularity belongs to the interval [0, 1]	F	*Modularity can be negative.*

Section B

	Question	**Pts.**	Ans.	Explanation
1	The proper (visual) alpha rhythm is generated in the frontal lobe of the cerebral cortex.	0.5	F	The primary visual area is located in the occipital cortex
2	The delta and theta frequency bands identify frequencies lower than those in the alpha band	0.5	T	TRUE
3	Event-Related Desynchronization/ Synchronization (ERD/S) quantify the amount of coupling between signals on two EEG channels.	0.5	F	ERD/S quantify changes of the power of EEG relative to a baseline period
4	Ag/AgCl electrodes allow recording of extremely slow-changing EEG potentials.	0.5	T	TRUE
5	The CMRR of a bipolar amplifier measures how much higher is the gain of the potential difference between the input electrodes with respect to the gain of their average with respect to the electrical ground.	0.5	T	TRUE
6	The measurement of a single EEG signal requires four electrodes – two as input to the differential amplifier, one connected to the reference electrode and one to provide the ground potential.	0.5	F	Only 3 electrodes are needed. Either the recording is bipolar and the reference electrode is not needed, or it is monopolar and one of the first two electrodes mentioned in the question is superfluous.
7	If the electrodes' contact impedance is not much lower than the amplifier's input impedance the amplitude of the measured potential is closer to zero than the actual value.	0.5	T	True. In fact, the series of the electrode impedance and input impedance act as a voltage divider. Only if the former is much lower than the latter, the voltage at the amplifier's input is approximately equal to the actual biological potential.
8	In the electrode labels of the International 10-20 System, odd numbers designate electrodes on the right side of the head	0.5	F	False, the opposite is true
9	A sudden upwards movement of the eyes generates a positive deflection of EEG potentials (EOG) on the Fz channel.	0.5	T	TRUE
10	The heart activity can contaminate an EEG recording because a ballistocardiographic artifact is indirectly generated by the pulse of a blood vessel causing movements of a nearby electrode.	0.5	T	TRUE
11	Notch filters effectively remove powerline noise because they reject all signals above their corner frequency.	0.5	F	Notch filters selectively reject the narrow frequency band affected by the artifact

	Question	**Pts.**	Ans.	Explanation
12	Synchronized averaging of N EEG trials produces N values each corresponding to the average value of the potential in each trial.	0.5	F	The number of samples of the waveform obtained by synchronized averaging is independent of the number N of trials (it equals the number of samples in each trial).
13	The SOA is always greater than the ISI	0.5	T	The SOA equals the ISI plus the duration of the stimulus
14	Brain activity in response to a stimulus can be non-phase-locked, meaning that they show variable latency (jitter) at each repetition. This activity is called induced.	0.5	T	TRUE
15	Induced activity is often examined by analyzing the envelope of the EEG in a relevant frequency band, i.e. by rectifying or squaring the pass-band filtered trials before averaging them.	0.5	T	TRUE
16	The reconstruction of an analog signal from its sampled version is equivalent to the sum a set of a set of sinc() functions, one for each sample.	0.5	T	TRUE
17	When aliasing occurs in ADC, a sinusoidal component with frequency $f_0 = 0.7f_s$ is reconstructed as a sinusoidal component at $f_1 = 0.2f_s$ (f_s is the sampling frequency)	0.5	F	$f_1 = f_s - f_0 = 0.3f_s$
18	Aliasing can be prevented by applying a digital low-pass filter with cutoff frequency lower than the Nyquist frequency.	0.5	F	Aliasing must be prevented by applying an analog filter before ADC. Digital filters can only be applied after the signal is sampled, and thus aliasing has occurred. No digital filter can remove it at that point.
19	Quantization divides the input range of the ADC into (approximately) 2^{NBITS} intervals, where NBITS is the number of bits of the ADC.	0.5	T	A NBITS Analog to digital converter has 2^{NBITS} possible levels, thus the input range is divided into $2^{NBITS} - 1$ intervals
20	The RMS is the average of the squared value of the samples of a signal	0.5	F	The RMS is the *square root of* the average of the squared value of the samples of a signal
21	It is more likely that samples of zero mean a gaussian noise will have amplitude in [-0.5,+0.5] rather than [0.5,1.5]	0.5	T	The Gaussian probability distribution peaks at 0, thus probability is higher in an interval centered in 0 (when both intervals have the same width).

	Question	**Pts.**	Ans.	Explanation
22	The probability distribution of the average of N independent and identically distributed random variables approaches zero for $N \to \infty$	0.5	F	The pdf of the average approaches a (non-zero) Gaussian distribution
23	Spectral analysis is well suited at identifying narrowband useful signals in (approximately) white noise, because a peak in the spectrum may still be detected even when the low signal-to-noise ratio (SNR) prevents the signal's waveform to be recognized among the noise samples.	0.5	T	TRUE
24	The output of FIR filters is the linear combination of samples of the input. The output of IIR filters combines both samples of the input and past samples of the output.	0.5	T	TRUE
25	An IIR filter can be designed to have "linear phase", so that they do not introduce time-domain distortions in the waveform of the output signal.	0.5	F	IIR filters cannot be designed to have liner phase
26	The amplitude of a P300 event related potential be voluntarily modulated through the exercise of motor imagery, to build a cursor control based on a BCI.	0.5	F	Through motor imagery an individual can learn to modulate sensorimotor rhythms, not ERPs
	Total points	**13**		