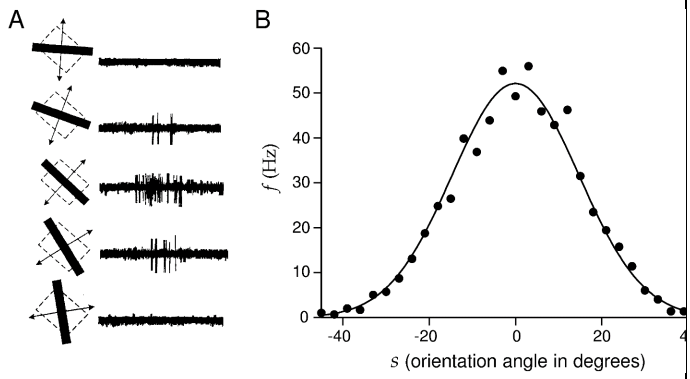
Neuroengineering 2022-2023

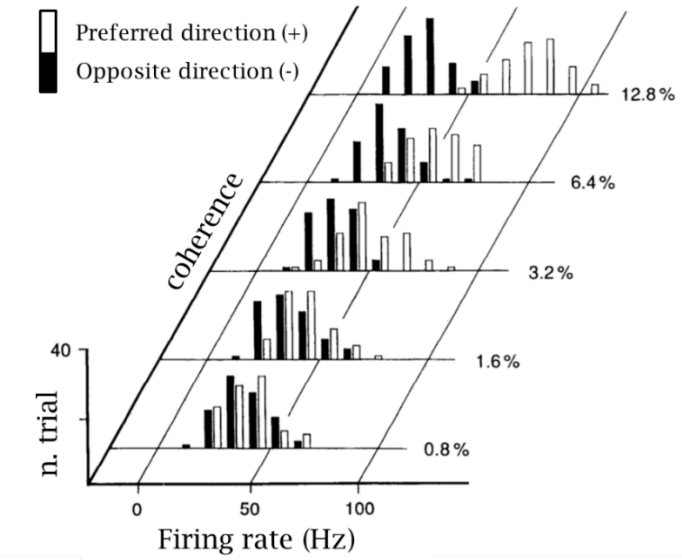
Exam 12 September 2023 – Part I

Solutions

Section A

	Question	Ans.	Explanation
1	The voltage-gated Na^+ channel opening is responsible for the depolarization phase of the action potential.	T	
2	The voltage-gated K^+ channel is responsible for the relative refractory period.	T	
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 “waxing and waning” of the alpha rhythm is a change of amplitude occurring about 10 times a second.	0.5	F	The oscillation of the alpha rhythm occurs approximately 10 times a second. On the other hand, “waxing and waning” describes the amplitude modulation of the rhythm, which occurs about an order of magnitude more slowly.
2	The CMRR is usually expressed in decibel (dB) and high values characterizes better amplifiers.	0.5	T	True
3	The difference of contact impedances of electrodes should be small compared to the input difference of the differential amplifier, otherwise the resulting unbalance compromises its common-mode rejection capability.	0.5	T	
4	An artifact is a potential difference due to sources outside the brain.	0.5	T	
5	Contact impedance of the electrodes can be measured using a direct (non-alternating) current.	0.5	F	Contact impedance is frequency dependent and must be measured with an alternating current in the same frequency range as the EEG.
6	The EEG electrode F8 is located to the left of electrode F7	0.5	F	In the International 10-20 System, labels with odd/even numbers are located over the left/right hemisphere
7	An eyeblink produces an artifact which often interferes with the analysis of the beta band of the EEG.	0.5	F	An eyeblink artifact is a slow wave lasting several tens of a second (i.e. well below 10 Hz)
8	Sweating can affect the EEG, causing an increase of contact impedance and an increase of powerline noise	0.5	F	Sweating causes a slow changing and high amplitude artifact (below 0.5 Hz, up to a few mV)
9	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
10	The alpha rhythm is said to be synchronized when the amplitude of its oscillations increase.	0.5	T	

	Question	Pts.	Ans.	Explanation
11	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).
12	Evoked brain activity is phase-locked to the stimulus to which it is a response.	0.5	T	
13	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
14	In Analog to Digital Conversion, the Nyquist frequency equals half of the sampling frequency.	0.5	T	
15	Appropriate application of an analog filter (i.e. before the analog signal is converted) may prevent saturation by removing high amplitude artifacts in specific frequency bands.	0.5	T	
16	Quantization divides the input range of the ADC into (approximately) $NBITS$ intervals, where NBITS is the number of bits of the ADC.	0.5	F	Quantization divides the input range of the ADC into (approximately) 2^{NBITS} intervals
17	The RMS and the standard deviation of a zero-mean signal have the same value (assume that the number of samples $N \to \infty$).	0.5	T	
18	In a gaussian noise, the probability density that a sample has a given amplitude value follows the normal distribution with zero mean.	0.5	T	A gaussian noise has normal distribution of amplitude of the samples. [*A white noise has a flat spectrum.*]
19	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
20	The spectral leakage phenomenon is observed, for instance, when comparing the spectrum of a signal with the spectrum of a short section of the same signal.	0.5	T	True
21	The Butterworth filter is a design method in the family of FIR	0.5	F	The Butterworth filter is an Infinite Impulse Response (IIR) filter
22	The amplitude of sensorimotor rhythms can be voluntarily modulated through the exercise of motor imagery, to build a cursor control based on a BCI.	0.5	T	True
23	EEG electrodes made of gold allow recording of extremely slow-changing potentials.	0.5	F	Gold electrodes are *polarizable*, thus the opposite is true

	Question	Pts.	Ans.	Explanation
24	The advantage of a high CMRR amplifier is that it suppresses common-mode disturbances such as powerline (50 Hz) noise.	0.5	T	True
25	The amplitude of the electromyogram (EMG) originated from muscles never exceed $10\ \mu V$.	0.5	F	EMG can be hundred times higher than EEG, and exceed 1 mV
26	The amplitude of ERPs is measured with respect to a baseline epoch (usually preceding the stimulus), in which the amplitude is assumed to be zero.	0.5	T	True
	Total points	**13**		