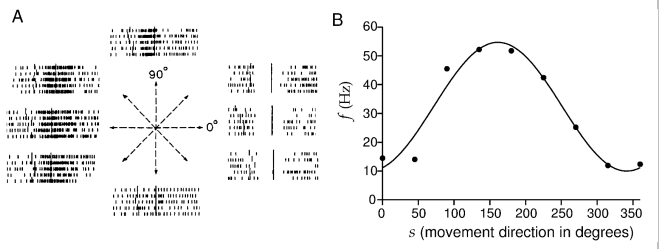
Neuroengineering 2023-2024

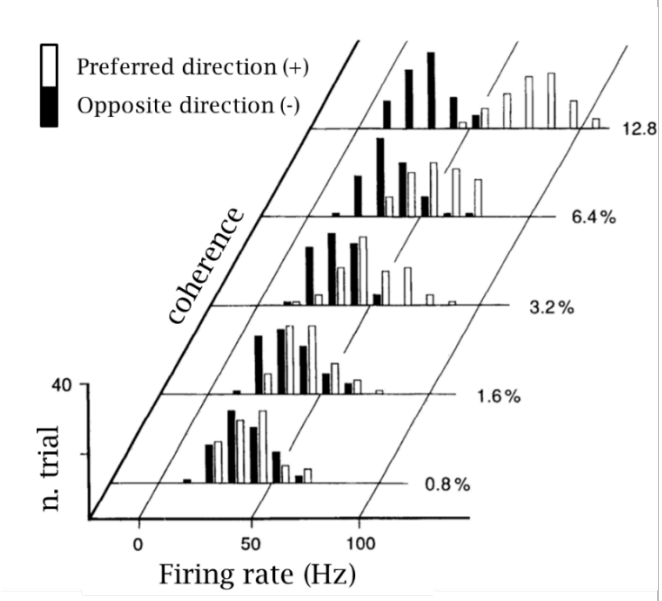
Exam 10 January 2025 – Part I

Solutions

Section A

#	Question	Ans.	Explanation
1	In the Nernst equation for the electrochemical equilibrium there is a term referred to diffusional forces and a term referred to electrical forces.	T	
2	Given that at a certain temperature *T* the Cl- equilibrium potential is equal to -80 mV, and the membrane potential is equal to -70 mV, the Cl- net current will be a depolarizing one.	F	*If the ion equilibrium potential is more negative than the membrane potential, the ion net current will be a hyperpolarizing one.*
3	The temporal summation of PSPs does not depend on the temporal distance between subsequent action potentials in the presynaptic cell.	F	*The temporal summation occurs when the presynaptic neuron fires multiple times in close succession.*
4	A hyperpolarization with respect to the resting membrane potential can cause the generation of an action potential.	F	*The generation of an action potential is caused by a depolarization of the neuronal membrane.*
5	The motor homunculus is located in the frontal lobe.	T	
6	The short-term synaptic plasticity can involve a structural change in the post-synaptic membrane.	F	*Structural changes in the post-synaptic membrane occur with long-term plasticity.*
7	To measure the membrane potential over the soma of a neural cell *in vitro*, the correct procedure is to record extracellular measures.	F	*To measure the membrane potential we need intracellular recordings, that can be more easily performed in vitro and on large portions of the cell, like the soma.*
8	In a cortical pyramidal neuron, thalamo-cortical synapses are located in the apical portion of its dendritic tree.	F	*They are located in the basal part of the dendritic tree.*
9	Radially symmetric neurons produce a closed field and therefore do not significantly contribute to scalp EEG.	T	

#	Question	Ans.	Explanation
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, showing the spike trains obtained - for different trials - from a neuron of the primary motor cortex in correspondence to an arm movement (panel A), and the firing rate *f* of the same neuron as a function of the angle *s* of the same movement direction (panel B):  The maximum neural response is obtained for a movement direction with an angle of 350 degrees.	F	*The maximum neural response is obtained for a movement direction with an angle of 150 degrees.*
12	In reference to the previous figure: from the curve, I can conclude that this neuron is tuned to be more active in correspondence to a specific movement direction.	T	
13	In reference to the previous figure: the firing rate *f* in panel B was computed as the average of the neural response function across trials.	T	

#	Question	Ans.	Explanation
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 6.4% than when it is equal to 12.8%.	F	*Discriminability is higher when the two distributions are less overlapped, i.e. when the coherence level is equal to 12.8% rather than to 6.4%.*
15	In reference to the previous figure: the histogram obtained for the preferred direction (+) is less affected by the coherence level than the distribution (-).	F	*On the contrary, it is the one affected by the coherence level.*
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	If a time series is not Fourier-transformable, it is impossible to compute its PSD.	F	*The PSD can be computed by means of the Wiener-Khinchin Theorem even if the time series is not Fourier-transformable.*
18	A necessary condition for a linear autoregressive (AR) model is that the time series to be modeled is wide-sense stationary.	T	
19	PDC is a spectral, bivariate (pairwise) method.	F	*It is a spectral, multivariate method.*

#	Question	Ans.	Explanation
20	The use of Ordinary Coherence can mitigate the problem of the common source.	F	Being a pairwise method, the Ordinary Coherence cannot mitigate nor solve the problem of the common source.
21	A negative value of the Granger Index $G_{x \to y}$ should never occur if the two AR models that are compared to compute the index are correct.	T	
22	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.*
23	In a graph, the Global Efficiency $\in [0, 1]$.	T	
24	In an undirected graph, I cannot compute the indegree and the outdegree.	T	*The concept of "in-degree" and "out-degree" is based on directionality.*

Section B

#	Question	Ans.	Explanation
1	The purpose a filter is to allow desired spectral component of a signal to pass almost unaltered, while attenuating undesired spectral components	T	TRUE
2	The DFT of a signal represents the amplitude A_i and initial phases ϕ_i of sinewave components of the signal at frequencies f_i ranging from $0Hz$ (included) to the sampling frequency (excluded).	T	TRUE
3	In ERP analysis, the EEG continuous recording must be segmented into epochs (trials) of fixed duration, each aligned to a repetition of the event	T	TRUE
4	A negative peak in a ERP recorded on a specific subject with a latency of $108ms$ may still be named N100, if it matches the physiological phenomenon of the nominal N100 component.	T	TRUE
5	In an ERP, the response to a stimulus has a reduced amplitude when the SOA is too short.	T	TRUE
6	Despite being more expensive, gold electrodes should be preferred to Ag/AgCl electrodes since they allow recording of extremely slow-changing EEG potentials.	F	Gold electrodes are polarizable, thus the opposite is true
7	EEG electrodes whose first letter of the label is “C” (e.g. “Cz”) are located on the central region of the head, i.e. the region between the left and the right hemisphere	F	The central region is above the central sulcus which divides the frontal and parietal lobes. The mesial region is above the interhemispheric scissure, and it is designated by a trailing “z” in EEG labels
8	Ensuring a contact impedance below 5 kis not relevant when the input impedance of the EEG amplifier is below 50 k	F	The opposite is true: the input impedance of the EEG amplifier must be several orders of magnitude higher than the contact impedance
9	The artifact generated by eye movements can reach amplitudes up to $5\mu V$ in the EEG recordings	F	EOG artifacts can be two orders of magnitude higher than that.
10	The Central Limit Theorem (CLT) states that the average of N zero-mean independent identically distributed signals approaches zero for $N \to \infty$.	T	TRUE

#	Question	Ans.	Explanation
11	The measurement of two monopolar EEG channels requires four electrodes – two collecting the potentials fed to the non-inverting input of the differential amplifier, one providing the reference potential and one providing the ground potential.	T	TRUE
12	In analog-to-digital conversion, each spectral component of the analog signal should have frequency below the Nyquist frequency	T	TRUE
13	The heart activity is likely to contaminate an EEG recording if the reference electrode is not placed on the head.	T	TRUE
14	The alpha rhythm can be observed by filtering the spontaneous EEG signal using a narrowband filter, with cutoff frequencies at 14 and 30 Hz (approximately)	F	With these cutoff frequencies we would observe the beta rhythm
15	The synchronized average of N trials containing only spontaneous EEG whose variance {var}*{trial}=^2 is a signal whose variance {var}*{avg}=^2/N	T	TRUE
16	The proper (visual) alpha rhythm is modulated (synchronized, desynchronized) by opening and closing the eyes. This phenomenon is best observed on the frontal EEG channels.	F	Only the first half of the statement is true. The primary visual area is located in the occipital cortex, thus the occipital (and parietal) channels are most sensitive.
17	In an ADC, quantization introduces a noise whose amplitude is proportional to the width of the quantization interval (V_{LSB}): $\sigma_{quant} = \frac{1}{\sqrt{12}} \cdot V_{LSB}$	T	TRUE
18	As a preliminary step to EEG data analysis, one or more channels can be removed from the dataset if they are extensively contaminated by artifacts	T	TRUE
19	A BCI system may replace functions that are physiologically subserved by nerves and muscles, by directly measuring brain activity and converting it to an artificial output.	T	TRUE
20	The CMRR of a bipolar amplifier measures the ratio between the gain of their average with respect to the electrical ground and the gain of the potential difference between the input electrodes.	F	Numerator and denominator are swapped

#	Question	Ans.	Explanation
21	The frequency response of a filter in the stopband should be plotted in a graph whose vertical axis has a logarithmic scale (i.e. the gain is expressed in dB).	T	TRUE
22	Evoked potential is synonymous of Event-Related Potentials	F	Event related potentials include evoke potentials, as well as EEG responses to motor or cognitive events.
23	The RMS is the square root of the average of the squared value of the samples of a signal	T	0
24	Aliasing occurs when an analog signal is sampled using a limited input range of the ADC.	F	Aliasing occurs when an analog signal is sampled outside the conditions set by the Shannon's theorem. Clipping (saturation) occurs when the input range of the ADC is smaller than the amplitude of the input analog signal.