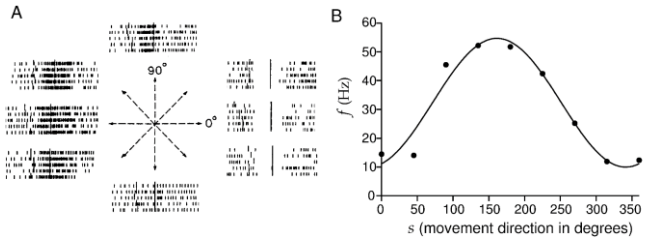
Neuroengineering 2022-2023

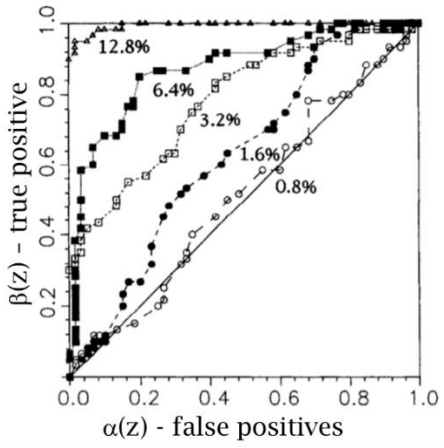
Exam 14 June 2023 – Part I

Solutions

Section A

	Question	Ans.	Explanation
1	The voltage-gated K^+ channel inactivation state is responsible for the absolute refractory period.	F	*The voltage-gated Na^+ inactivation state is responsible for the absolute refractory period. K^+ voltage-gated channel does not go through any inactivation state.*
2	The voltage-gated Na^+ channel is responsible for the repolarization phase of the action potential.	F	*The repolarization phase of the action potential is due to the opening of the voltage-gated K^+ channel.*
3	Temporal and spatial summation can occur simultaneously.	T	
4	The firing rate influences the amplitude of the resulting action potential in the post-synaptic cell.	F	*It can affect the temporal summation and therefore the amplitude of the post-synaptic potentials, not of the action potential.*
5	The frontal lobe houses the primary visual function.	F	*The primary visual cortex is located in the occipital lobe.*
6	In the brain primary motor cortex (Penfield homunculus) the extension of the cortical region which controls a specific body region is proportional to that body region's volume.	F	*The extension of the cortical region which controls a specific body region is proportional to the number of motor nerves, not to the body region's volume.*
7	The long-term synaptic plasticity involves a structural change in the post-synaptic membrane.	T	
8	The brain operates at the temporal scale of milliseconds.	T	
9	The neurons' spatial orientation affects the amplitude of EEG signals	T	
10	The synchronicity of the neural activity affects the amplitude of EEG signals.	T	

11	Scalp EEG is mainly produced by deep (subcortical) regions.	F	*It is mainly produced by cortical regions.*
12	The electrical variation of the membrane potential that mainly contributes to EEG is the action potential.	F	*The synchronous variations of post-synaptic potentials (and their extracellular counterpart) are the main contributors to EEG signals.*
13	The tuning curve in the figure shows (panel A) the spike trains obtained - for different trials - from a neuron of the primary motor cortex in correspondence to an arm movement, and (panel B) the firing rate *f* of the same neuron as a function of the angle *s* of the same movement direction:  When the firing rate is 55 Hz, I can infer which movement direction produced that response.	T	*Yes, because there's a unique value of s that can produce a neuronal response with that firing rate.*
14	In reference to the previous figure (question 10): from the curve I can conclude that this neuron is tuned to be more active in correspondence to a specific movement direction.	T	
15	In reference to the previous figure (question 10): the firing rate *f* in panel B was computed as the average of the neural response function across trials.	T	

16	Given the ROC curves in the figure, describing a threshold classification between two conditions (stimuli) at different levels of coherence of the stimulation:  The best curve is the one closer to the upper left corner.	T	
17	In reference to the previous figure (question 14): the Area Under the Curve (AUC) for each level of coherence is proportional to the discriminability of the two conditions.	T	
18	In reference to the previous figure: by considering only the true positives and false positives, and neglecting the true negatives and false negatives, we miss part of the results of the classification.	F	True negatives and false negatives are related to false positives and true positives, respectively. Therefore, we are not neglecting any result of the classification.
19	If $C_{xy}(f)$ is the Ordinary Coherence between *x* and *y*, $C_{xy}(f)=C_{yx}(f)$.	T	
20	Given the Granger Index G_{xy} between two time series *x* and *y*, a negative value of $G_{x\to y}$ means an inverse precedence between the two time series.	F	*A negative value of $G_{x\to y}$ means that the residual of the bivariate model is higher than in the simple model, which is probably due to an incorrect modeling.*
21	In the event of data paucity, the Partial Directed Coherence (PDC) is the most accurate estimator of causality in the statistical sense.	F	*When we have a limited amount of data, PDC returns inaccurate results due to the low ratio between data samples and model parameters.*

22	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.*
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 segregation of a network.	T	
26	Modularity belongs to the interval [0, 1]	F	Modularity can be negative.

Section B

	Question	Pts.	Ans.	Explanation
1	The frequency of oscillation of the beta rhythm is around 10 Hz	0.5	F	The minimum conventional oscillation frequency of the beta rhythm is 14 Hz
2	The oscillations of mu rhythm are more “arc-shaped”, rather than resembling a regular sinewave	0.5	T	
3	The advantage of a high CMRR amplifier is that it suppresses common-mode disturbances such as powerline (50 Hz) noise.	0.5	T	
4	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	
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	Powerline noise is accentuated by asymmetries in the recording electrode pairs, such as impedances and cable path, because asymmetries prevent the noise to be rejected by the amplifier’s common-mode rejection capabilities.	0.5	T	
9	Notch filters effectively remove powerline noise because they selectively reject the narrow band affected by the artifact, preserving almost entirely the useful signal.	0.5	T	

	Question	Pts.	Ans.	Explanation
10	The potential at the peak of the EP component P20 is higher than the potential at the peak of the N100 component	0.5	T	
11	One can never remove one of the channels from the raw EEG recording prior to analysis. Rather all epochs contaminated from artifacts will be rejected.	0.5	F	Artifact rejection should aim at minimizing the amount of data discarded. If removing a whole channels prevents discarding a large number of trials, this option should be considered.
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 relative changes of the power of the EEG rhythm in a predefined frequency range, relative to a baseline period.	0.5	T	
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	The frequency spectrum of white noise is flat, i.e. it has the same power at any frequency.	0.5	T	
19	The Central Limit Theorem (CLT) states that the average of N independent identically distributed signals tends to zero for $N \to \infty$.	0.5	F	This is only true if the mean of the signals is zero itself
20	The method of the averaged periodogram to estimate the spectrum of a stochastic signal is applied when a lower variability of the PSD estimate at each frequency sample is desirable, while the spectral resolution Δf is higher than required.	0.5	T	
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

	Question	Pts.	Ans.	Explanation
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	
23	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.
24	The SOA is always greater than the ISI	0.5	T	The SOA equals the ISI plus the duration of the stimulus
25	When aliasing occurs in ADC, a sinusoidal component with frequency $f_0 = 0.7\ f_s$ is reconstructed as a sinusoidal component at $f_1 = 0.2\ f_s$ (f_s is the sampling frequency)	0.5	F	$f_1 = f_s - f_0 = 0.3\ f_s$
26	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
	Total points	**13**		