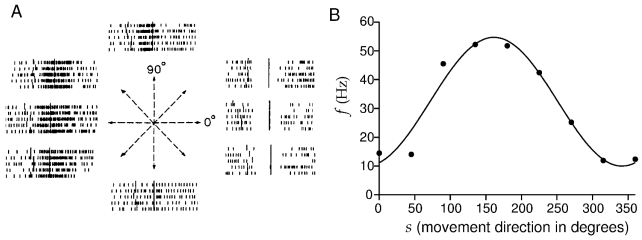
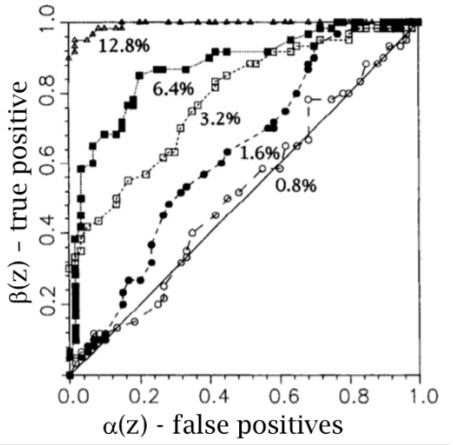
Neuroengineering 2021-2022

# Exam 21 July 2022 – Part I

## Solutions - *Even seats*

**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 long-term synaptic plasticity involves a structural change in the post-synaptic membrane. | T | |
| 6 | The brain operates at the temporal scale of milliseconds. | T | |
| 7 | The synchronicity of the neural activity affects the amplitude of EEG signals. | T | |
| 8 | Scalp EEG is mainly produced by deep (subcortical) regions. | F | *It is mainly produced by cortical regions.* |
| 9 | 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.* |

| | | | |
|---|---|---|---|
| 10. | 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:<br>  <br><br>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.* |
| 11 | In reference to the previous figure (question 10): from the curve I can conclude that this neuron is tuned to be active in correspondence to a given movement direction. | T | |
| 12 | 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 | |
| 13 | In a Poisson spike generator, the program generates a fixed threshold and, at each time step, compares the variable $rest\Delta t$ with the fixed threshold. | F | *The threshold is randomly variable, while* $r_{est}\Delta t$ *is a constant for a given value of s.* |
| 14 | Given the ROC curves in the figure, describing a threshold classification between two conditions (stimuli) at different levels of coherence of the stimulation:<br>  <br><br>The best curve is the one closer to the upper left corner. | T | |
| 15 | 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 | |
| 16 | If $C_{xy}(f)$ is the Ordinary Coherence between *x* and *y*, $C_{xy}(f)=C_{yx}(f)$ . | T | |

| | | | |
|---|---|---|---|
| 17 | 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.* |
| 18 | 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.* |
| 19 | In an undirected graph, I cannot compute the indegree and the outdegree. | T | *In an undirected graph, the concept of "in-degree" and "out-degree" is meaningless.* |
| 20 | Random networks have a smaller Local Efficiency than regular (lattice) networks. | T | |
| 21 | In a graph, the minimum Divisibility is equal to zero. | F | *The minimum Divisibility is equal to 0.5* |
| 22 | Divisibility and Modularity are measures of segregation of a network. | T | |

**Section B**

| | Question | Pts. | Ans. | Explanation |
|---|---|---|---|---|
| 1 | Ag/AgCl electrodes allow recording of extremely slow-changing EEG potentials. | 0.5 | T | True |
| 2 | The advantage of a high CMRR amplifier is that it suppresses common-mode disturbances such as powerline (50 Hz) noise. | 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 | True |
| 4 | The amplitude of the mu rhythm is increased at the beginning of a motor task | 0.5 | F | The mu rhythm desynchronizes (i.e. its amplitude decreases) during the planning and execution of a motor task |
| 5 | Evoked Potentials are deflection of the EEG signal following the presentation of a sensory input. | 0.5 | **T** | True |
| 6 | Movements of the subject's head produces artifacts only in the gamma band. | 0.5 | F | Movement of the subject's head may produce slow artifacts on the EEG recording, whose waveform is closely related to the timecourse of the movement |
| 7 | The potential at the peak of the EP component P20 is lower than the potential at the peak of the N100 component | 0.5 | F | P20 is a positive peak, N100 is a negative peak. The potential of the former is thus higher. |
| 8 | The position of the reference electrode can strongly influence the shape and amplitude of EEG potentials. The profile (i.e. disregarding the actual potential value) of scalp topographies are not influenced. | 0.5 | T | True |
| 9 | Digital processing can remove all significant artifacts, and thus it is not worth using the measurement time to reduce their presence on the raw recording. | 0.5 | F | Digital processing can only reduce artifacts, and may introduce distortions in the useful signal. Whenever possible/convienient artifacts should be avoided at recording time. |
| 10 | Powerline noise is an artifact caused by the capacitive coupling between the power supply conductors and the recording setup including the subject. | 0.5 | T | True |
| 11 | 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 |

| | Question | Pts. | Ans. | Explanation |
|---|---|---|---|---|
| 12 | In an ADC, quantization introduces a noise whose amplitude is proportional to the width of the quantization interval: $\sigma_{quant} = 1/\sqrt{12}\ LSB$ | 0.5 | **T** | True |
| 13 | The Inter-Stimulus Interval (ISI) measures the time interval between the end of a stimulus and the beginning of the following one. | 0.5 | T | True |
| 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 | 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** | True |
| 16 | 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.*] |
| 17 | Given 100 independent and identically distributed random variables with variance equal to 4, the variance of their average is 0.04? | 0.5 | T | $\sigma^2_{avg} = \sigma^2/N$ |
| 18 | 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 |
| 19 | Appropriate application of a high-pass digital filter may prevent saturation by removing high amplitude slow artifacts. | 0.5 | **F** | False, saturation can be prevented only by applying an analog filter before A/D conversion |
| 20 | The sample variance of a signal is given by $s_X^2 = \frac{1}{N-1}\sum_i (x_i - \bar{X})^2$, where the sum extends on the $N$ samples of the signal $X$ | 0.5 | **T** | True |
| 21 | The P300 ERP generated by attending a target stimulus is exploited to build virtual keyboards based on a BCI | 0.5 | **T** | True |
| 22 | 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 |
| | **Total points** | **11** | | |