# Neuroengineering 2022-2023
## Exam 14 June 2023 – Part I

**How to submit your answers.**

Type your answers in the Exam.net editor.

Write the answers in the same sequence as the questions. Use a separate line for each question. Start the line with the question number. Use dashes ('-') to indicate skipped answers. For example:

```
Section A
1. True
2. A
3. B and D
4. ---
5. 500 ms
...
Section B
1. ...
```

In the exceptional case that one or more of your answers require specific assumptions that were omitted in the question, you can add short comments at the end of each section. Start the optional comment with the number of the question it refers to. For example:

```
...

Comments
7. I assumed that the sinewave frequency is lower than the Nyquist frequency.
```

The total score will be computed summing the contribution of each answer, whose maximum partial score is shown on the right of each question, according to the following rules:

- correct and complete answer will contribute the maximum score
- partially correct or incomplete answers will contribute a fraction of the maximum score
- missing answers will not contribute
- wrong answers to the closed-ended questions (T/F, multiple choice, etc) will contribute with a negative score equal to –(max/N), where N is the number of possible choices.

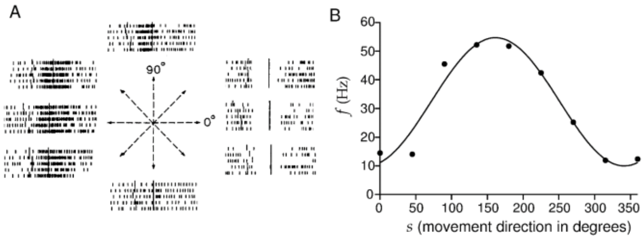
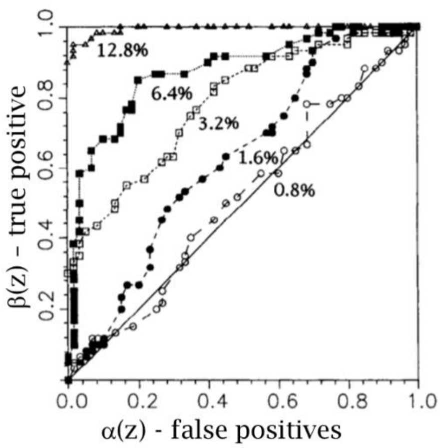
For instance:

- a correct T/F answer contributes 0.5 points,
- a missing T/F answer contributes 0 points
- a wrong T/F answer contributes -0.25 points.

The maximum total score for part I is 26.

**Section A**

| | Question | Points (correct) | Points (wrong) |
|---|---|---|---|
| 1 | The voltage-gated $K^+$ channel inactivation state is responsible for the absolute refractory period. | 0.5 | -0.25 |
| 2 | The voltage-gated $Na^+$ channel is responsible for the repolarization phase of the action potential. | 0.5 | -0.25 |
| 3 | Temporal and spatial summation can occur simultaneously. | 0.5 | -0.25 |
| 4 | The firing rate influences the amplitude of the resulting action potential in the post-synaptic cell. | 0.5 | -0.25 |
| 5 | The frontal lobe houses the primary visual function. | 0.5 | -0.25 |
| 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. | 0.5 | -0.25 |
| 7 | The long-term synaptic plasticity involves a structural change in the post-synaptic membrane. | 0.5 | -0.25 |
| 8 | The brain operates at the temporal scale of milliseconds. | 0.5 | -0.25 |
| 9 | The neurons' spatial orientation affects the amplitude of EEG signals | 0.5 | -0.25 |
| 10 | The synchronicity of the neural activity affects the amplitude of EEG signals. | 0.5 | -0.25 |
| 11 | Scalp EEG is mainly produced by deep (subcortical) regions. | 0.5 | -0.25 |
| 12 | The electrical variation of the membrane potential that mainly contributes to EEG is the action potential. | 0.5 | -0.25 |

<table>
<tr><td>13</td><td>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.</td><td>0.5</td><td>-0.25</td></tr>
<tr><td>14</td><td>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.</td><td>0.5</td><td>-0.25</td></tr>
<tr><td>15</td><td>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.</td><td>0.5</td><td>-0.25</td></tr>
<tr><td>16</td><td>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>The best curve is the one closer to the upper left corner.</td><td>0.5</td><td>-0.25</td></tr>
<tr><td>17</td><td>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.</td><td>0.5</td><td>-0.25</td></tr>
</table>

| | | | |
|---|---|---|---|
| 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. | 0.5 | -0.25 |
| 19 | If $C_{xy}(f)$ is the Ordinary Coherence between $x$ and $y$, $C_{xy}(f)=C_{yx}(f)$ . | 0.5 | -0.25 |
| 20 | Given the Granger Index $G_{xy}$ between two time series $x$ and $y$, a negative value of $G_{x\rightarrow y}$ means an inverse precedence between the two time series. | 0.5 | -0.25 |
| 21 | In the event of data paucity, the Partial Directed Coherence (PDC) is the most accurate estimator of causality in the statistical sense. | 0.5 | -0.25 |
| 22 | In an undirected graph, I cannot compute the indegree and the outdegree. | 0.5 | -0.25 |
| 23 | Random networks have a smaller Local Efficiency than regular (lattice) networks. | 0.5 | -0.25 |
| 24 | In a graph, the minimum Divisibility is equal to zero. | 0.5 | -0.25 |
| 25 | Divisibility and Modularity are measures of segregation of a network. | 0.5 | -0.25 |
| 26 | Modularity belongs to the interval [0, 1] | 0.5 | -0.25 |

**Section B**

| | Question | Pts. |
|---|---|---|
| 1 | The frequency of oscillation of the beta rhythm is around 10 Hz | 0.5 |
| 2 | The oscillations of mu rhythm are more “arc-shaped”, rather than resembling a regular sinewave | 0.5 |
| 3 | The advantage of a high CMRR amplifier is that it suppresses common-mode disturbances such as powerline (50 Hz) noise. | 0.5 |
| 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 |
| 5 | Contact impedance of the electrodes can be measured using a direct (non-alternating) current. | 0.5 |
| 6 | The EEG electrode F8 is located to the left of electrode F7 | 0.5 |
| 7 | An eyeblink produces an artifact which often interferes with the analysis of the beta band of the EEG. | 0.5 |
| 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 |
| 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 |
| 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 |
| 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 |
| 12 | Evoked brain activity is phase-locked to the stimulus to which it is a response. | 0.5 |
| 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 |
| 14 | In Analog to Digital Conversion, the Nyquist frequency equals half of the sampling frequency. | 0.5 |
| 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 |
| 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 |
| 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 |
| 18 | The frequency spectrum of white noise is flat, i.e. it has the same power at any frequency. | 0.5 |
| 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 |
| 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 $\Delta f$ is higher than required. | 0.5 |
| 21 | The Butterworth filter is a design method in the family of FIR | 0.5 |
| 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 |
| 23 | The “waxing and waning” of the alpha rhythm is a change of amplitude occurring about 10 times a second. | 0.5 |

| | Question | Pts. |
|---|---|---|
| 24 | The SOA is always greater than the ISI | 0.5 |
| 25 | When aliasing occurs in ADC, a sinusoidal component with frequency $f_0 = 0.7\ f_s$ is reconstructed as a sinusoidal component at $f_1 = 0.2\ f_s$<br>($f_s$ is the sampling frequency) | 0.5 |
| 26 | The probability distribution of the average of $N$ independent and identically distributed random variables approaches zero for $N \to \infty$ | 0.5 |
| | **Total points** | **13** |