

University of Calgary  
Schulich School of Engineering  
Department of Electrical and Computer Engineering

ENEL 563 Biomedical Signal Analysis  
Midterm Exam

Tuesday, 28 February 2012, ICT 422  
9:30 – 10:45 a.m. (75 minutes)  
Total Marks: 20

**Instructions:**

1. This is a closed-book, closed-notes exam.
2. Calculators and electronic devices of any kind are not allowed.
3. Answer all (four) questions.
4. In case of problems requiring numerical or algebraic manipulation, show all steps clearly.
5. In case of problems requiring algorithms, provide the reason or logic for each step.
6. Specify units or dimensions when appropriate.
7. In drawing plots of signals, spectra, etc., label the axes clearly.

**Question 1:** Draw a schematic representation of Einthoven's triangle showing the directions (polarities) of leads I, II, and III of the electrocardiographic (ECG) signal.

Rearrange the vectors and derive the relationship between the three leads I, II, and III using vector arithmetic.

(4 marks)

**Question 2:** Consider the contraction of a muscle at a low level of effort. Suppose that two motor units (MUs) are active. Assume that one of the MUs has a biphasic action potential and is firing at the rate of 10 pulses per second (pps). Assume that the other MU has a triphasic action potential and is firing at the rate of 12 pps.

For a duration of 0.5 second, draw a schematic sketch of the motor unit action potential trains for the two MUs individually and separately. Draw a schematic sketch of the overall or combined electromyographic (EMG) signal of the muscle. (Assume that the action potentials do not overlap.) Mark the time axis clearly in your drawings.

(4 marks)

**Question 3:** You are given a set of  $M$  signals,  $x_k(n)$ ,  $k = 1, 2, \dots, M$ , each with  $N$  samples,  $n = 0, 1, 2, \dots, N - 1$ . The index  $n$  represents sampled time and the index  $k$  represents the  $k^{\text{th}}$  signal in the set.

a) Explain the differences between ensemble averages and temporal averages.

Give equations to define the following:

b) the ensemble mean at an instant of time  $n = n_1$ ;

c) the temporal mean of the  $k^{\text{th}}$  signal computed over the period  $n = n_1$  to  $n = n_2$ ; and

d) the average signal or template,  $\bar{x}(n)$ ,  $n = 0, 1, 2, \dots, N - 1$ , computed over the set of signals.

(6 marks)

**Question 4:** You are given two processes that generate two signals,  $x$  and  $y$ , with the probability density functions (PDFs)  $p_x(x)$  and  $p_y(y)$ , respectively. The joint PDF between the two processes is  $p_{x,y}(x, y)$ .

a) Write an expression to define the mean of the signal  $x$ .

b) Write an expression to define the variance of the signal  $x$ .

c) Write an expression to define the covariance between the two signals  $x$  and  $y$ .

d) Write an expression to define the normalized correlation coefficient between the two signals.

e) Give interpretations of the variance and normalized correlation coefficient and indicate practical use or applications of these measures.

(6 marks)

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