
SEMESTER 2b ASSESSMENT PAPER 2024/2025

ADVANCED MECHANICAL MEASUREMENT

DURATION – 2 hours

This paper contains five questions.

Answer **ALL** questions.

An outline marking scheme is shown in brackets to the right of each question.

Only University approved calculators may be used.

Q1.

A sensor outputs an analog voltage signal $x(t)$, with frequency components ranging from 0 to 2 kHz and amplitude range $[-1V, 1V]$. This signal needs to be digitized for further processing by a microcontroller, which involves three steps: **sampling**, **quantization**, and **encoding**.

Please, answer the following questions:

- 1.1) If uniform quantization is used with 5-bit binary representation for each sampled value, how many quantization levels are there? (0.5 points)
- 1.2) What is the quantization interval (resolution) in volts? (0.5 points)
- 1.3) If one sample value is $x = 0.5V$, to which quantization level (starting from 0) will it be assigned? (0.5 points)
- 1.4) Using unsigned binary encoding, represent the quantized level obtained in the previous question as a 5-bit binary code. (0.5 points)

[Total: 2 points]

Q2.

A radar system transmits a coded pulse $s[n] = [1, 1, 2, 3]$ and receives a delayed/noisy signal $y[n] = [0, 1, 2, -1, 2, 0]$.

Please, answer the following questions:

2.1) Compute the auto-correlation $R_{ss}[k]$; (1 point)

2.2) Compute the unbiased cross-correlation $R_{sy}[k]$. (1 point)

[Total: 2 points]

Q3.

A music synthesizer generates a signal containing a 330 Hz tone and its 800 Hz harmonic. The signal is sampled at $f_s=8$ kHz. A 10ms duration of the signal is analyzed using DFT.

Please, answer the following questions:

- 3.1) What is the Nyquist frequency? Can the system capture both 330Hz and 800Hz without aliasing? (0.5 points)
- 3.2) Calculate the number of samples used in the DFT and calculate the frequency resolution of the DFT for the 10ms signal; (0.5 points)
- 3.3) Identify which frequency bin corresponds to 330Hz and 800Hz; (0.5 points)
- 3.4) Is there spectral leakage when performing DFT? If yes, which measures can be taken to mitigate it? (0.5 points)

[Total: 2 points]

Q4.

Given two real-valued discrete-time signals $x[n]$ and $y[n]$ of length $N=4$, with time-domain values $x[n] = \{1, -1, 2, 0\}$ and $y[n] = \{0, 2, 1, -1\}$.

Please, answer the following questions:

4.1) Calculate the discrete Fourier transforms (DFT) $X[k]$ and $Y[k]$ of $x[n]$

and $y[n]$; (0.5 points)

4.2) Assuming $y[n]$ is the response of a linear time-invariant (LTI) system to $x[n]$, estimate the system's frequency response function $H[k]$; (0.5 points)

4.3) Compute the auto-power spectrum $S_{xx}[k]$ of $x[n]$; (0.5 points)

4.4) Compute the cross-power spectrum $S_{xy}[k]$ of $x[n]$ and $y[n]$. (0.5 points)

[Total: 2 points]

Q5.

You should measure the vibration modes of a diving board to be installed on a public swimming pool. Testing of the FRF shall be performed on the laboratory.

Please, answer the following questions:

5.1) Sketch measurement chain (setup, sensors type/position and actuators) and intended excitation technique to measure first two vibration modes; *(1 point)*

5.2) Swimmers complain about large vibration of the board during diving. Possible disturbances were found to be the swimming pool water pumps and the compressors of the conditioning units. Define a possible setup and technique to allow disturbance characterization. *(1 point)*

[Total: 2 points]