Question 1 (26 marks)

(a) (1 mark) A time-of-flight displacement sensor works by:

(i) Detecting the shift in frequency of the reflected signal
(ii) Detecting a change in the amplitude of the reflected signal
(iii) Measuring the time it takes for the reflected signal to return from the target
(iv) Detecting the optical interference between the incident and reflected waves

(b) (4 marks) True or false

(i) Piezoelectric sensors can be used to measure acceleration
(ii) Strain gauges are a type of non-contact sensor
(iii) Piezoelectric sensors are not sensitive to temperature changes
(iv) Strain gauges operate by detecting changes in electrical resistance

(c) (1 mark) What is meant by a bi-polar data acquisition system?

(i) The system works well both in the north and south poles
(ii) The system can measure both negative and positive voltage
(iii) The system can only measure fluctuating signals
(iv) The system can measure negative or positive voltages

(d) (1 mark) A record of background noise in a room was sampled at 44 kHz for 75 seconds. Into how many sub-records would you divide the 75-second record in order to obtain a random spectral error of 20%

(i) 5 (ii) 25 (iii) 15 (iv) 75

(e) (1 mark) Using your answer from question (d) what would the frequency resolution of the spectrum be?

(i) 0.2 seconds (ii) 0.5 Hz
(iii) 1/3 Hz (iv) 1/3 seconds

(f) (1 mark) If a record is sampled at 4096 Hz what is the Nyquist frequency?

(i) 4096 Hz (ii) 2048 Hz
(iii) 1024 Hz (iv) 2048 seconds

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Question 1 continues:
(g) (6 marks) True or false

(i) A 12-bit analogue-to-digital converter provides smaller resolution than a 10-bit converter
(ii) Harmonic signals can be accurately sampled at a frequency less than twice the signals frequency
(iii) There is no relationship between the length of a record and the frequency resolution of its spectrum
(iv) A triangular wave can be represented by a Fourier series
(v) The Fourier transform of a real signal produces complex numbers
(vi) The Fourier transform cannot be applied to transient signals

(h) (6 marks) A thermocouple, initially at zero °C, is suddenly immersed it in a hot liquid. After 10 seconds the indicated temperature \( T_i \) by the thermocouple is 90% of the temperature of the hot liquid. The time constant, \( \tau \), of the thermocouple is:

(i) 4.34 seconds
(ii) 3.43 seconds
(iii) 3.43 °C
(iv) 0.434 seconds

Recall:

\[
T_i = T_{\text{max}} - \Delta T \exp \left( -\frac{t}{\tau} \right)
\]

(i) (5 marks) There are at least 10 ways the plot of maximum daily wave height and wind speed shown in Figure 1.1 can be improved. Name five.

Question 2 (26 marks)
During the evaluation of a new cushioning material, a 3 kg dead weight is allowed to fall freely on a cushion sample. The acceleration (in m/s²) of the dead weight during the impact was digitally sampled at 10,000 samples per second and is shown in Figure 2.1 as well as stored on disk in ascii format (impact.txt).

(a) (12 marks) Assuming that the drop height is not known and that the impact is elastic, use Matlab® to estimate the coefficient of restitution between the dead weight and the cushioning material.

**Make sure to record your program in the answer book.**

(b) (6 marks) If the drop height was known to be 0.45 metres, estimate the coefficient of restitution between the dead weight and the cushioning material.

(c) (6 marks) Give an explanation for any difference in the results.

(d) (2 marks) What would be the effect on the coefficient of restitution if the drop height was increased to 0.50 metres then decreased to 0.40 metres?
Question 3 (9 marks).

(a) (15 marks) As the engineer responsible for monitoring the health of a nuclear reactor, you ask three trainee engineers under your charge to independently measure and analyse the random vibrations from a critical section of the plant. You receive three Probability Density Functions as shown in Figure 3.1. Sketch a section of the original record for each case and describe the anomaly (if any) in each case.

(b) (6 marks) In order to install a more reliable automated machine condition monitoring system, you have been supplied the performance curves (Figure 3.2) for three anti-aliasing low-pass filters by an engineering instrumentation manufacturer. Determine the drop-off rate of each filter in terms of dB/decade.
Question 4 (27 marks)

File ‘wave.txt’ is an ASCII file containing a record of ocean wave profile data, in metres, acquired with a sampling frequency of 64 Hz, as shown in Figure 4.1.

(a) (24 marks) Using spectral averaging compute the PSD of the signal and sketch the PSD for the frequency range from 0 to 5 Hz. Use FFT size of 1024 points. On the graph in Figure 4.2 indicate the maximum value of the PSD and the corresponding frequency.

(b) (3 marks) Determine the spectral resolution and PSD random error.

Make sure to record your program in the answer book.
Solution Q4

a) and b)