[ESS21]

UNIVERSITY OF BOLTON

SCHOOL OF ENGINEERING

BEng (HONS) BIOMEDICAL ENGINEERING

SEMESTER ONE EXAMINATIONS 2019/20

BIOMEDICAL ENGINEERING MODELLING AND ANALYSIS

MODULE NO: BME 5001

Date: Wednesday 15th January 2020   Time: 10:00 – 12:00

INSTRUCTIONS TO CANDIDATES:

There are SEVEN questions.

Attempt ANY FIVE questions.

Individual marks are shown within the question.

This examination paper carries a total of 100 marks.

This is an open book examination.

Use of Microsoft Excel and Moodle is permitted, but please do NOT open any internet search engines or email.

Answers obtained using Excel must be written in answer booklets. Excel files must be submitted by transferral to an electronic medium (provided).

Q1

The ordinary differential equation (ODE) describing the normal movement z(t) of the tympanic membrane in mm at time t under a 200t mN input load for 3s can be modelled approximately by the equation below:

$$40\,\frac{d^2Z(t)}{dt^2} + 80\frac{dZ(t)}{dt} + 80Z(t) = 200t \qquad \text{mN}$$

Given: $\frac{d^2Z(t)}{dt^2}$, $\frac{dZ(t)}{dt}$, $Z(t)$ all =0 at t =0, use Laplace transforms to derive an expression for Z(t) and sketch how Z(t) varies with time for the first 2 seconds.

(20 marks)

Q2

It can be shown that a simple four degree of freedom surface plate subjected to inline torque loads ($\hat{T}$) can be described by $\hat{T} = K\vec{\Theta}$ where: $\hat{T}$ and $\vec{\Theta}$ are Torque and rotational displacement column vectors respectively and K is the stiffness matrix. Using,

$$\vec{T} = \begin{pmatrix} 8 \\ 5 \\ -4 \\ -3 \end{pmatrix} \text{N} \quad \text{and} \quad K = \begin{bmatrix} 200 & -150 & 0 & 0 \\ -150 & 320 & -240 & 0 \\ 0 & -240 & 440 & -120 \\ 0 & 0 & -120 & 540 \end{bmatrix} \text{Nm/rad}$$

Calculate the displacement vector $\vec{\Theta}$ in degrees.

(20 marks)

Q3

Test data for a piston pressure (P) per horizontal stroke displacement relating to a 500 W vacuum pump is given in the table below:

P(KPa)	**23**	**37**	**87**	**74**	**21**	**6**	**34**	**77**	**89**	**36**	**3**	**11**
Displacement (mm)	**0**	**4**	**8**	**12**	**16**	**20**	**24**	**28**	**32**	**36**	**40**	**44**

Use this information to generate specific coefficients for an approximate Fourier series to represent the data and state the terms a_1 and b_2 in the series. Calculate also the average pressure and over this period from the series coefficients. State why it is not possible to determine terms greater than the third harmonic for this data set.

(20 marks)

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Q4

The pressure (KPa) against angle (deg) for a dialysis pump is shown in Fig.Q4 . The power (W) of the pump can be determined by the integral $C\int_{\Theta 1}^{\Theta 2} P d\Theta$ where P is the pressure in MPa , Θ is the movement in radians and C is a constant with a value of 160.

For this data, determine an estimate of the average Pressure and Power consumption.

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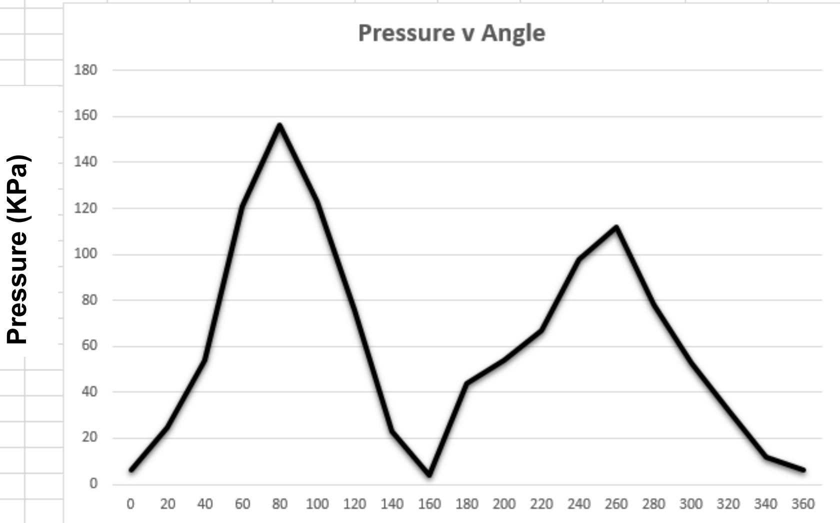
Angle(deg)	Pressure(KPa)
0	6
20	25
40	54
60	121
80	156
100	123
120	76
140	23
160	4
180	44
200	54
220	67
240	98
260	112
280	78
300	53
320	32
340	12
360	6



Movement (deg)

(20 marks)

Q5

The micro strain ε, in μm/m, at a point in a body can be described by the following matrix relative to the global co-ordinate system xyz. Using an appropriate technique determine the Eigen values (λ= principal strains) at this point.

$$|\sigma| = \begin{bmatrix} 2000 & 800 & 200 \\ 800 & -2600 & -400 \\ 200 & -400 & 1800 \end{bmatrix} \mu m/m$$

Determine also the associated Eigen vector for the largest magnitude strain (λ).

(20 marks)

Q6

The displacement x in mm of a compactor which operates at a frequency of 0.2 Hz can be described by the following equation of motion;

$\ddot{x}+0.5\dot{x}+2.5x = 25Fe^{j\omega t}$ when ω is expressed in rad/s.

Determine:

(i) An expression for the relationship between F and *x* neglecting any transient terms,

(10 marks)

(ii) The lag between *x* and F when F is 0.4 N.

(5 marks)

(iii) The steady state displacement *x*.

(5 marks)

Total 20 marks

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Q7

A blood thinning agent is tested on two sets of samples A and B. Set A is untreated and set B is tested with the treatment. The equipment measures the viscosity of a fluid. The lower the value the better the treatment works; the results are shown in table Q7 below.

Table Q7

Set A	Set B
μPa.s	μPa.s
3011	2870
3191	2976
3213	2812
3065	2832
3099	2791
3116	2672
3176	2820
3234	2775
3056	2901

(i) Using this data test the hypothesis that the treatment has no change (H_0) to the one that there is a decrease (H_1). State in your answer the significant value of t and the probability associated with this value.

(15 marks)

(ii) Also estimate the decrease assuming a 99% confidence limit.

(5 marks)

Total 20 marks

END OF QUESTIONS