[ENG05]

UNIVERSITY OF BOLTON

SCHOOL OF ENGINEERING

BEng (HONS) BIOMEDICAL ENGINEERING

SEMESTER ONE EXAMINATIONS 2018/19

BIOMEDICAL ENGINEERING MODELLING AND ANALYSIS

MODULE NO: BME 5001

Date: Wednesday 16th January 2019 Time: 10:00 – 12:00

INSTRUCTIONS TO CANDIDATES:

Attempt any 5 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).

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Q1

A musculoskeletal system is described by the ordinary differential equation (ODE) below where the movement *y*(*t*) of the muscle in mm at time t under a 50 N ramp load can be modelled approximately by the equation below:

$$25\frac{d^2y(t)}{dt^2} + 5\frac{dy(t)}{dt} + 10\,y(t) = 50t \text{ N}$$

Given: $\frac{d^2y(t)}{dt^2}$, $\frac{dy(t)}{dt}$, $y(t)$ all =0 at t =0, use Laplace transforms to derive an expression for y(t) and sketch how y(t) varies with time for the first 3 seconds.

(20 marks)

Q2

It can be shown that a four degree of freedom operating table subjected to inline hydraulic forces ($\hat{F}$) can be described by $\hat{F} = K\vec{u}$ where: $\hat{F}$ and $\vec{u}$ are force and displacement column vectors respectively and K is the stiffness matrix. Using,

$$\vec{F} = \begin{pmatrix} 1800 \\ 800 \\ -600 \\ 450 \end{pmatrix} \text{N} \quad \text{and} \quad K = \begin{bmatrix} 80 & -45 & 0 & 0 \\ -45 & 64 & -48 & 0 \\ 0 & -48 & 84 & -48 \\ 0 & 0 & -48 & 64 \end{bmatrix} \text{kN/m}$$

Calculate the displacement vector $\vec{u}$ in mm.

(20 marks)

Q3

Test data for the motor torque per angle relating to an 800 W surgical robot arm is given in the table below:

T (Nm)	**35**	**58**	**97**	**63**	**55**	**97**	**122**	**167**	**188**	**213**	**145**	**71**
Angle (Deg)	**0**	**30**	**60**	**90**	**120**	**150**	**180**	**210**	**240**	**270**	**300**	**330**

Use this information to generate specific coefficients for an approximate Fourier series to represent the data and calculate the terms a_3 and b_1 in the series. Calculate also the average torque and speed 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 energy used in heating up a chilled organ can be determined from the integral

$$\frac{v}{50}\int_{t1}^{t2} Idt$$

where I is the current in amps, t is the time in hours and v is 220 volts.

The monitored data is given below in Fig Q4, for this data determine an estimate of the energy used.

Also estimate the time at peak power consumption.

Time (mins)	Current (mA)
0	12
25	35
50	79
75	236
100	445
125	276
150	134
175	66
200	89
225	237
250	345
275	678
300	789
325	511
350	453
375	556
400	233
425	112
450	22

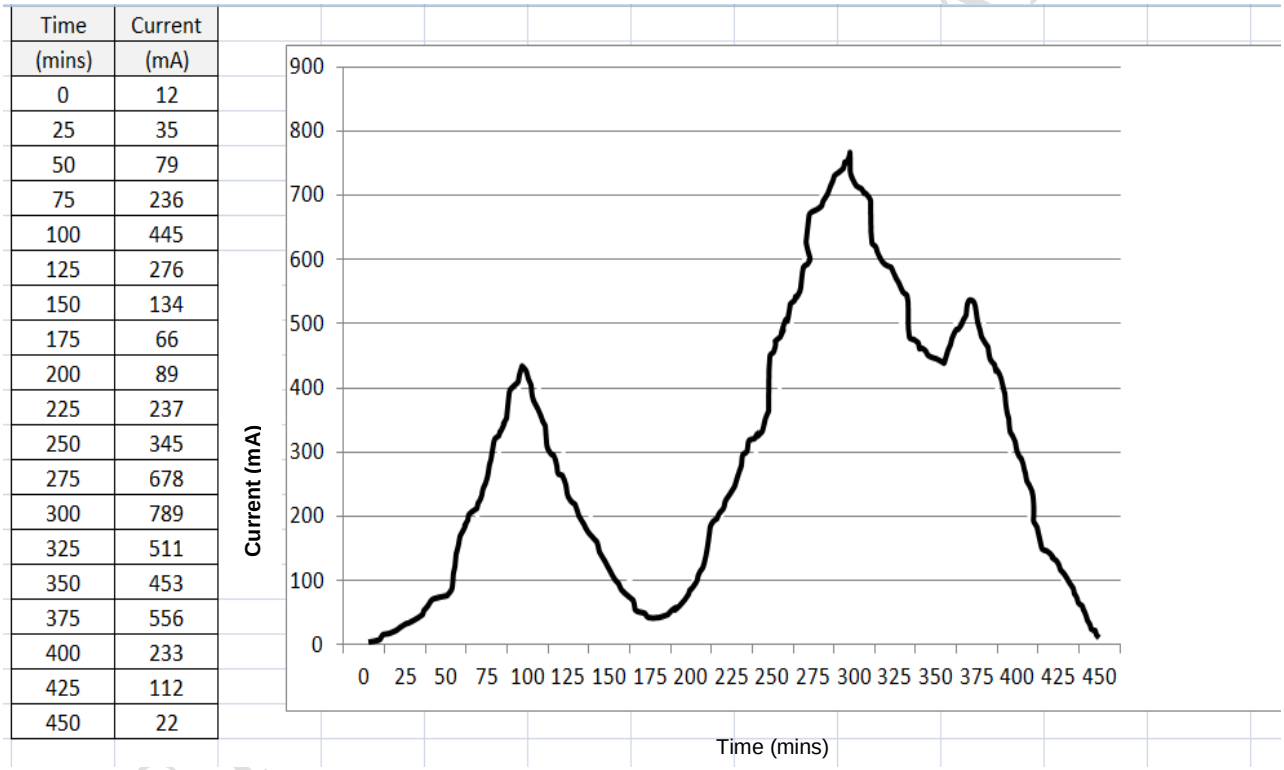

Fig Q4 Current used over time period

(20 marks)

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Q5

The stress σ, in MPa, 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 stresses) at this point.

$$|\sigma| = \begin{bmatrix} 125 & 65 & 55 \\ 65 & -90 & 25 \\ 55 & 25 & 105 \end{bmatrix} \text{MPa}$$

Determine also the associated Eigen vector for the minimum principal stress (smallest λ).

(20 marks)

Q6

Part of a small dentist waste pump system operates at a frequency ω of 1.6 rad/s. If the equation of motion describing the attachment is given by;

$0.8\ddot{Z} + 0.64\dot{Z} + 3.2Z = Fe^{j\omega t}$ mN

Where: Z is the vertical displacement in mm and F is the waste force.

For this model:

(i) Derive an expression for the relationship between F and Z neglecting any transient terms,

(10 marks)

(ii) Calculate the lag between Z and F when F is 0.16 N.

(5 marks)

(iii) Calculate also the steady state displacement Z.

(5 marks)

Total 20 marks

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Q7

A new surface treatment, method 2, for a medical insert is currently under trial. The treatment involves a coating on the surface. The smaller the thickness, the better the method. Table Q7 shows the first set of results for a set of inserts.

Table Q7

Method 1	Method 2
Coating thickness (μm)	Coating thickness (μm)
516	503
521	507
512	509
545	511
514	504
518	506
509	508
528	509
519	505

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

(12 marks)

(ii) Also estimate the potential decrease assuming a 99% confidence limit. Does Method 2 satisfy this level? State your reason

(8 marks)

Total 20 marks

END OF QUESTIONS