Version-YYSH3

EGT2
ENGINEERING TRIPOS PART IIA

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Tuesday 6 May 2014 9.30 to 11

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**Module 3G5**

**BIOMATERIALS**

*Answer not more than **three** questions.*

*All questions carry the same number of marks.*

*The **approximate** percentage of marks allocated to each part of a question is indicated in the right margin.*

*Write your candidate number **not** your name on the cover sheet.*

**STATIONERY REQUIREMENTS**
Single-sided script paper

**SPECIAL REQUIREMENTS TO BE SUPPLIED FOR THIS EXAM**
CUED approved calculator allowed
Engineering Data Book

**You may not start to read the questions printed on the subsequent pages of this question paper until instructed to do so.**

1 (a) Describe the differences between bulk and surface erosion with reference to polymeric implants. Give three different criteria that illustrate whether an implant will erode by a bulk or surface mechanism, clearly defining all terms and describing the physical meaning of the parameters. [45%]

(b) Two polymer samples, A and B, have the molecular weight distributions shown in Table 1. Define the following terms and compute each parameter for both samples:

(i) number average molecular weight;

(ii) weight average molecular weight;

(iii) molecular weight polydispersity index. [25%]

(c) Identify the likely mechanisms of polymerization suggested by the molecular weight distribution data for samples A and B in (b), and explain how they differ. [15%]

(d) Describe the effect of a polymer's average molecular weight on:

(i) elastic modulus;

(ii) strength;

(iii) melt viscosity. [15%]

| Chain molecular weight (g/mol) | Number of chains, polymer A | Number of chains, polymer B |
|---|---|---|
| 500 | 840 | 6050 |
| 1500 | 620 | 3320 |
| 2500 | 730 | 1820 |
| 3500 | 9200 | 1205 |

Table 1. Molecular weight distribution for polymer samples A and B.

2 (a) Describe the electrical signalling in a healthy heart and how it corresponds to the PQRST signature on an electrocardiogram. [30%]

(b) Pacemakers are common electrical implants used in patients with pathological heart rhythms.

(i) Describe the components of a normal functioning pacemaker, and explain how a pacemaker restores heart function. [15%]

(ii) Describe galvanic corrosion and explain why this is important in pacemaker failure, including how biological entities influence corrosion. [15%]

(c) Describe the normal process of wound healing. Explain the mechanism of fibrosis in the normal wound-healing process, and elaborate how it can lead to the malfunctioning of a pacemaker lead. [40%]

3 (a) Sketch a graph describing the amount of drug in the body as a function of time for a controlled-release drug delivery scheme with a constant drug infusion rate. Clearly label any asymptotic limits. Compare this approach with traditional methods of drug delivery. [30%]

(b) The Higuchi (1961) solution gives the cumulative amount of drug released as a function of time as:

$$M_t = A\sqrt{(2C_0 - C_s)C_s Dt}$$

Define all terms in this expression. Describe the key assumptions on which the use of this expression relies. Explain how this solution can be extended to describe the kinetics of swelling-controlled (hydrogel) drug delivery systems. [30%]

(c) Nanoparticles are increasingly being used in drug delivery.

(i) Describe basic types of nanoparticles and give examples of how they are used in drug delivery. [10%]

(ii) Describe the common techniques used to characterize nanoparticles and the challenges associated with characterizing basic aspects of nanoparticle structure, such as size. [20%]

(iii) How do nanoparticle based drug delivery schemes fit into the existing legal and regulatory structure for medical devices? [10%]

4 (a) To which class of materials does bone belong and why? Bone responds to loading. Explain what this means, and outline some of the consequences of this behaviour in the context of the "Mechanostat" theory. [30%]

(b) Briefly describe the criteria for selecting materials for a total hip replacement. In your answer you should consider mechanical, chemical, biological and processing requirements. Sketch and label the components used in a total hip replacement. List the material(s) used in each of the components. When different classes of materials are used, explain the reason(s) for their use. [30%]

(c) Coatings are often used on the stems of cementless prostheses.

(i) When referring to bone attachment, what is the difference between a plasma-sprayed and a wire / fibre mesh coating? [5%]

(ii) A hydroxyapatite coating of 40 μm thickness is deposited by plasma spraying at a temperature of 550°C onto a 2 mm thick Ti-6Al-4V substrate. Assuming that all of the strain is accommodated in the coating, estimate the associated in-plane stress in the coating. Discuss the magnitude of the stress calculated. Comment on whether the stress obtained in practice is different from what you have calculated and why.
($E_{HA}$= 165 GPa, $\nu_{HA}$=0.3, $\alpha_{HA}=13\times10^{-6}\,K^{-1}$.) [25%]

(iii) A highly porous material is made by bonding together an isotropic assembly of short stainless steel fibres of radius 50 μm. It can be shown, using a simple beam-bending model, that Young's modulus $E$ of such a material is given by

$$E = \frac{9E_f f}{32\left(\frac{L}{D}\right)^2}$$

where $E_f$ is Young's modulus of the fibre material, $f$ is the fibre volume fraction, $D$ is the fibre diameter and $L$ is the average length of fibre segments between joints. The porosity of this material is measured to be 85% and the value of $L$ is estimated to be 0.5 mm. Explain whether the stem of the prosthesis can be made entirely of this material. Explain why the Young's modulus of the stem is of particular importance.
(The Young's modulus of (cortical) bone is 10-25 GPa.) [10%]

**END OF PAPER**

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