ENGINEERING TRIPOS PART IIA

Thursday 26 April 2012 9 to 10.30

Module 3G5

BIOMATERIALS

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

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

There are no attachments

STATIONERY REQUIREMENTS
Single-sided script paper

SPECIAL REQUIREMENTS
Engineering Data Book
CUED approved calculator allowed

You may not start to read the questions printed on the subsequent pages of this question paper until instructed that you may do so by the Invigilator

Final

1 (a) Describe the differences between bulk and surface erosion with reference to polymeric implants. Consider a 6 mm thick polymeric implant with a characteristic time constant for erosion $\tau_E = 8 \times 10^5$ s and a diffusion coefficient $D = 10^{-8}$ cm^2 s^{-1}. Assuming that the time constant for diffusion τ_D is given by $\pi \langle x \rangle^2 / 4D$, where $\langle x \rangle$ is the mean distance, determine whether this implant would undergo bulk or surface erosion. What are the implications of this result for the use of this particular polymer in a load-bearing tissue engineering application? [40%]

(b) A researcher selects a co-polymer made of poly(lactic acid) and poly(glycolic acid) for a tissue engineering scaffold.

(i) Define the process of hydrolysis. What are the key factors that influence this process? [20%]

(ii) Explain and sketch how the composition of the co-polymer would influence the time-scale of material degradation in the physiological environment. Explain why this time-scale is important in the context of tissue engineering. [20%]

(iii) Draw a schematic plot illustrating the relative changes in the implant's molecular weight, strength, and mass as a function of time, explaining the reason for the different time-scales. [20%]

2 (a) Explain the difference between *ethics* and *morals*. Describe the historical events that gave rise to the modern framework of bioethics. Explain the key governing principles within this modern bioethics framework. [20%]

(b) Define what is meant by nanoparticles. Comment on the ethical issues associated with biomedical nanoparticle use. Give three examples of nanoparticle use in drug delivery applications. [20%]

(c) Drug-loaded, swelling hydrogel nanoparticles release 631 μg of drug after 10 hours, and a total of 3.98 mg of drug after 100 hours. Write down the expression governing the amount of drug released, and explain how this swelling system differs from a solely diffusion-controlled drug release mechanism. [30%]

(d) Consider a drug-loaded, hydrolysable monolithic (non-reservoir) nanoparticle. How would Monte Carlo simulations be used to predict the drug delivery kinetics? [30%]

3 (a) Explain what is measured in an electrocardiogram and how it relates to normal heart physiology. [30%]

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

(i) Describe the types of pacemakers. Explain how a pacemaker restores heart function. [25%]

(ii) Describe the components of a standard pacemaker. List the sources of pacemaker failure. [25%]

(iii) Explain what is meant by fibrosis in the context of pacemaker leads, and how this relates to the normal wound-healing process. [20%]

4 (a) Classify stents on the basis of the method of expansion. In each case, explain briefly the procedure involved and identify the mechanism responsible. [20%]

(b) Define martensitic phase transformations in the context of superelasticity and shape memory effects. Explain the shape memory effect, illustrating your answer with sketches. [40%]

(c) Fig. 1 shows the drug-eluting Bx Velocity stent, premounted onto a stent delivery system.

Fig. 1

(i) Sketch a "unit cell" of the planar (unwrapped) wall structure, which has its sides parallel to the axial and hoop directions, in this unexpanded state. Sketch the same unit cell after full expansion of the stent, assuming that the arrangement of the pair of members forming "vertical loops" in the hoop direction of the stent remains unchanged. [20%]

(ii) Discuss the disadvantages of this stent design. Briefly describe the desirable mechanical and functional characteristics of a stent. [10%]

(iii) Explain the reasons for developing drug-eluting coatings. Briefly describe how drug-eluting coatings function. List their main potential advantages. [10%]

END OF PAPER

ENGINEERING TRIPOS PART IIA, 2012
Module 3G5: Biomaterials

Numerical Answers

1. (a) Critical thickness 1 mm

3. (c) $M_t=100\ t^{0.8}$

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