Version AEM/2

EGT2
ENGINEERING TRIPOS PART IIA

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23 April 2018 9.30 to 11.10

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

10 minutes reading time is allowed for this paper at the start of the exam.

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

1 (a) Collagen is the main structural protein in the extracellular space of the various connective tissues in animal bodies.

(i) List three processing methods which can enable engineering control of collagen structures and properties. [25%]

(ii) Give two examples of tissue engineering applications of collagen. In each case, briefly explain how the processing method would determine the associated application. [25%]

(b) Following the implantation of a biomaterial, describe in detail the cascade of events that result in normal localised tissue healing and wound repair. [50%]

2 (a) (i) Describe in detail what is meant by a *medical device*. Where appropriate, include examples in your description. [10%]

(ii) Explain what is meant by the term *bioethics*. [10%]

(iii) The Nuremberg code established ten guidelines for human experimentation, the first of which states that "The voluntary consent of the human subject is absolutely essential". Explain what is meant by *consent* in this context. [10%]

(b) (i) Explain what is meant by the term *standards* in terms of medical device manufacturing. Include a brief description of the role of standards in your answer. [20%]

(ii) New European medical device regulations were adopted in 2017. Briefly describe any four changes resulting from these new regulations and note why they were introduced. [20%]

(c) You have designed a new hypodermic needle system made up of a stainless steel needle with a coating that prevents bleeding after removal. The needle is attached by adhesive to the polypropylene hub, as shown in Fig. 1. You have also decided that steam sterilisation is the most economical sterilisation technique when you start production, based on capital expenditure and expected volumes.

Describe how you would confirm this is an appropriate and effective sterilisation technique for your product. Include in your description, any tests that you would order for validation and how you would determine the precise time and temperature to use. [30%]

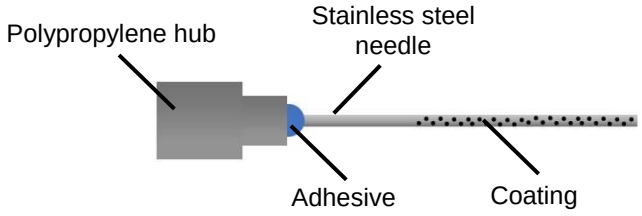

Figure 1

3. Polymer systems play important roles for drug delivery applications.

(a) State three main functions of polymers when used for drug delivery systems. For each function, briefly explain the purpose of the polymer system. [30%]

(b) One type of diffusion-controlled delivery device is based on monolithic device systems, with the drug encapsulated within a slab of thickness δ. Two limiting cases can be identified for such a device type: $C_0 < C_s$ and $C_0 > C_s$, where C_0 is the drug concentration in the carrier at time $t = 0$, and C_s is the solubility of drug in the carrier.

(i) For the case of $C_0 < C_s$, using a concentration versus distance diagram, sketch how the drug concentration within the slab varies with distance at different times. State the conditions under which such a sketch is valid. [15%]

(ii) For the case of $C_0 > C_s$, the drug concentration profile of a monolithic patch, with high drug loading, in contact with a perfect sink, can be modelled as shown in Fig.2. Assuming the surface in contact acts as a perfect sink, the drug concentration sinks to zero at the edge of the polymer ($x = 0$). None of the suspended phase dissolves until the environmental concentration drops below C_s and hence there is a sharp discontinuity in concentration a finite distance h from the perfect sink at time t. The discontinuity then moves a distance Δh in a small time step. Using Fig.2 and applying Fick's *first* law (page 8 of the Materials Data Book) to the region of 0 to *h*, show that the classic solution for drug release per unit area m_d, of a patch with high drug loading, is given by

$$m_d = [D\, C_s\, (2\, C_0 - C_s)]^{1/2} t^{1/2}$$

where *D* is diffusion constant and *t* is time. [40%]

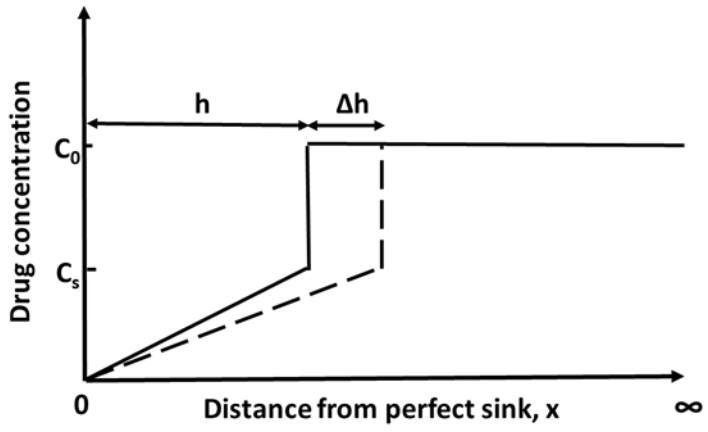

Figure 2

(c) List two other types of polymer-based controlled release systems in addition to the diffusion-controlled system above. For each type, name an example material system. [15%]

4 (a) Define *superelasticity*. Identify the temperature range over which the superelastic effect is possible. Using a hoop force versus stent diameter diagram, explain how the superelastic effect is utilised in stents. Hence, state the changes in structure during the different stages of stent deployment. [35%]

(b) Explain the concept of "training" involved in *shape memory* materials. Hence explain how you would "train" a material to have a preferred shape. Suggest which effect, the superelastic or the shape memory, you would consider more suitable for a cardiovascular stent. Give reasons for your choice. [20%]

(c) Figure 3 shows the predicted dependence of the Young's modulus along the long axis of a stent (axial Young's modulus) on the strut orientation angle θ for two stent designs: (i) a single-angle ply and (ii) a ±θ angle ply. Suggest which stent design would be more suitable for a stent and identify the optimum range of strut orientation angles. Explain your reasoning. Explain the importance of the axial Young's modulus for preventing Neointimal Hyperplasia. [30%]

(d) Briefly describe other mechanical characteristics of a balloon expandable stent. [15%]

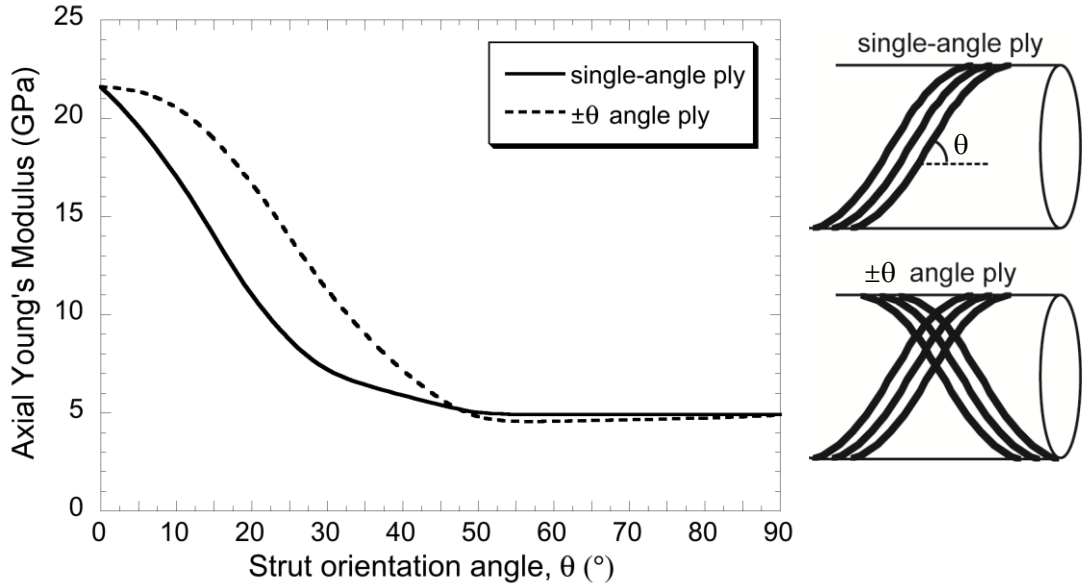

Figure 3

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