ENGINEERING TRIPOS PART IIB

Wednesday 1 May 2013 9.30 to 11.00

Module 4G6

CELLULAR AND MOLECULAR BIOMECHANICS

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.*

Attachments:
3C7 datasheet(s) (2 pages).

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

vsd02

1 Consider the linear three element muscle model sketched in Fig. 1. The model comprises a dashpot, a spring and an active force generating element. The dashpot has a force F versus velocity v relation $F = \eta v$, while the spring is assumed to be linear with a spring constant k. The muscle is held under isometric conditions and at time $t = 0^-$ all elements of the model are unstressed. At time $t = 0^+$ the force generating element is activated such that it exerts a constant contractile force T_0 for all times $t > 0$.

(a) Derive the governing differential equation for response of the model in terms of the change in length x of the spring element. [20%]

(b) Determine the force T versus time t response of the muscle for all times $t > 0$. [30%]

(c) Sketch the T versus time t response derived in part (b) and discuss whether the model is appropriate for predicting the isometric response of a muscle. [20%]

(d) An alternative muscle model is the same as that sketched in Fig. 1 but with the positions of the spring and dashpot interchanged. Derive the force T versus time t response for this alternative model for a muscle under isometric conditions and hence discuss which of the two models is more appropriate. [30%]

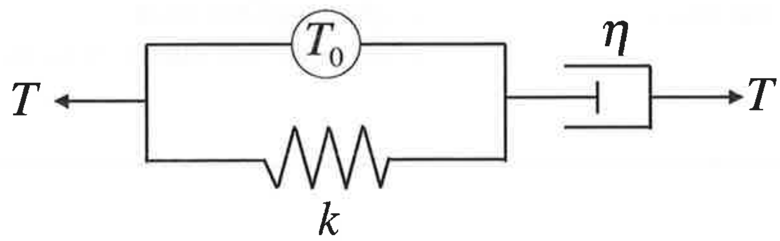

Fig. 1

2 (a) Briefly describe the mechanism of glucose transport across the cell membrane. [15%]

(b) In the context of your answer in part (a) discuss how insulin affects the transport glucose across the cell membrane. [20%]

(c) Sketch the flux rate of glucose across the cell membrane as a function of the external glucose concentration. [20%]

(d) Almost immediately upon entering a cell, glucose is phosphorylated in the first step of glycosis. How does this rapid and nearly unidirectional reaction affect the flux rate of glucose across the membrane? Discuss your answer in the context of the sketch in part (c). [30%]

(e) How is the flux rate of glucose across the cell membrane affected by the concentration of ATP? [15%]

(TURN OVER

3 Account for the following observations:

(a) A highly concentrated solution of sugar or salt is able to kill bacteria but not affect a plant leaf. [25%]

(b) Skin comprises a network of collagen fibres, yet its modulus is several orders of magnitude lower than that for collagen. [25%]

(c) The cell membrane of red blood cells is highly compliant despite the fact that it is a fully triangulated network. [25%]

(d) Ion pumps are essential for the survival of animal cells but not needed in plant cells. [25%]

4 A sketch of the idealised cross-section of wood is shown in Fig. 2. The prismatic (tubular) structure comprises struts of uniform thickness t and length either ℓ or 2ℓ as shown.

(a) Calculate the relative density $\bar{\rho}$ of wood terms of t and l. [10%]

(b) The cell walls are composed of a material that is rigid, ideally plastic with a yield strength σ_Y.

(i) Determine the macroscopic yield strength of wood Σ_{3Y} in the x_3 – direction in terms of $\bar{\rho}$ and σ_Y. [30%]

(ii) Now calculate the macroscopic yield strength Σ_{1Y} in the x_1-direction, assuming that all nodes become plastic hinges at collapse. Again express Σ_{1Y} in terms of $\bar{\rho}$ and σ_Y. [40%]

(c) Explain why balsa wood is much more anisotropic than oak. [20%]

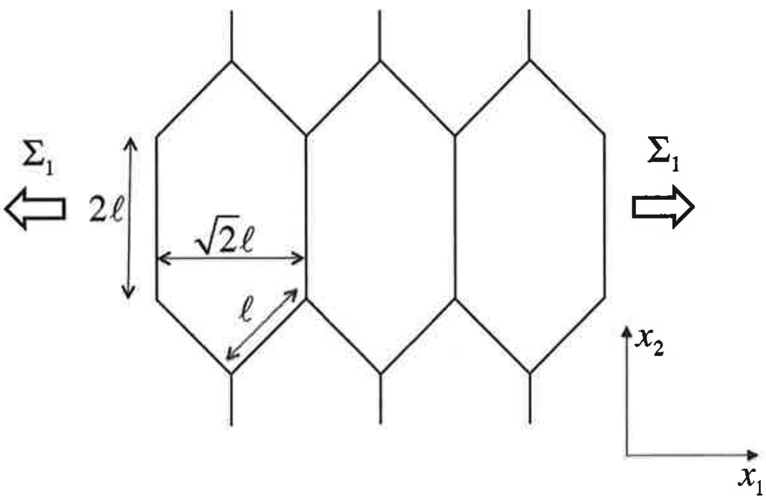

Fig. 2

END OF PAPER