PhD Qualifier Examination - Bioengineering

1. Bioengineering/Examination of Biomedical Materials

Four-Part Question [1]. All types of materials and devices suitable for implantation into the human body must be treated to assure they are sterile. Sterilization is usually by (a) ionizing radiation, (b) dry heat, (c) wet heat, autoclaving, (d) ethylene oxide, (e) chemicals, such as glutaraldehyde, and (f) filtration. Regarding these techniques, correctly answer the questions below :

A. For each technique (a), (b), (c), (d), (e), (f), a potentially implantable Biomaterial is named that CAN NOT by suitably sterilized by that method. Write the reason for this failure, after each material named below:

(a) ionizing radiation

polypropylene sutures

(b) dry heat

polyethylene acetabular cups

(c) wet heat, autoclaving

polyglycolic acid sutures

(d) ethylene oxide

living tissue on polymer scaffold

(e) chemicals(glutaraldehyde is one example)

fluorescently-tagged proteins

(f) filtration

crosslinked hydrogels

B. For approval by the US Food and Drug Administration (FDA), the dose of ionizing radiation that must be applied to assure sterilization is {circle all the correct answers}

2.5 MegaRads = 25 kiloGrays? or 2.5 MilliRads? or 25 Grays?

Delivered by ***(circle correct answers above and below)***

Gamma irradiation? or Laser beam? or X-Ray beam? or Electron beam?

C. What are the common features of metal, metal alloy, ceramic, and glass that make them ***all intrinsically high-surface-energy materials***?

D. Tissue Engineering is a major current theme in Bioengineering research/development. What is a "tissue engineered" biomedical device, and how would you assure that it is safely and effectively sterilized without killing the living tissue components of that device?

2. Bioengineering/Cardiovascular Biomechanics

1. Vascular system:
   a. Describe the structure of the vascular network.
   b. Draw a graph of the mean pressure change along vascular segments from left ventricle to pulmonary vein. Clearly mark the vascular segments. Comment on where the maximal pressure drop occurs and why.
   c. How does the total flow rate change along the various vascular segments? How about the flow velocity and total vascular cross-sectional area? Use graphs to help providing clear answers to these questions.
   d. How does the anatomy and mechanical properties of the arteries vary along the various segments?

2. Hemodynamics and atheroscelrosis
   a. What kinds of flow have been implicated as promoting the genesis of atherosclerosis? Where does atherosclerosis most frequently form? Why?
   b. What cells mediate the vascular response in atherogenesis? How?
   c. What kinds of hemodynamics might be relevant in vulnerable plaque rupture? Through what possible mechanism?
   d. Propose a method to monitor and detect vulnerable plaque in patients.

3. Propose a method to model the aortic wall mechanics for a patient with an abdominal aortic aneurysm. The purpose is to predict the risk of rupture. Be specific about how you would obtain the materials property. Please present your proposal scholarly.

4. In an experiment where you pressurize (loading) and un-pressurize (unloading) an artery. Sketch a typical loading-unloading curve you would expect, with Extension as X-axis and Force as Y-axis, and explain the nonlinear phenomena, and how the arterial wall components involvement contribute these phenomena.

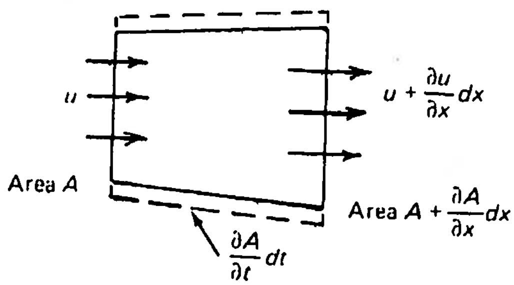
5. The Moen-Koertweg relationship describes the wave propagation in cylindrical blood vessels. The speed of pressure wave transmission depends upon the wall elastic properties and interaction between the wall and the blood contained within. Many simplifications and idealizations are evoked in order to derive this relationship.

a. List major assumptions about the vessel tube, the bluid, wave amplitude, etc.)

b. Apply mass and momentum balances to a control volume enclosed by the vessel wall of a differential length *dx* (see diagram below). Show that under appropriate assumptions, these will give rise to the two following partial differential equations with respect to time (t) and axial location (x). Hint: the balance: inflow value – outflow value=value change in the volume within time (dt)+external forces (for momentum only).

$$\frac{\partial A}{\partial t}+\frac{\partial (uA)}{\partial x}=0$$

$$\frac{\partial u}{\partial t}+u\frac{\partial u}{\partial x}=-\frac{1}{\rho}\frac{\partial P}{\partial x}$$



Now you have 3 unknown dependent parameters but only two equations. In order to close the equations, let's assume a rather simplistic linear pressure-diameter relationship:

$$2a_i = 2a_{i0} + \alpha p_i \quad \text{or} \quad da_i = \frac{\alpha}{2} dp_i \quad \text{......... Eq. 3}$$

Where a_i is the inner radius of the tube, , and $p_i(x,t)$ is transmural pressure in the tube.

c. Consider small disturbances in an initially stationary blood-filled tube, linearize the PDEs from b. and derive the following linear wave equations: (6 pts)

$$\frac{\partial^2 p_i}{\partial x^2}-\frac{1}{c^2}\frac{\partial^2 p_i}{\partial t^2}=0\ ,\ \frac{\partial^2 u}{\partial x^2}-\frac{1}{c^2}\frac{\partial^2 u_i}{\partial t^2}=0 \quad \text{.......... Eq. 4}$$

where wave speed $c=\sqrt{\frac{a_i}{\rho\alpha}}$ .... Eq. 5

d. In a thin-walled elastic tube of thickness *h* and Young's modulus *E*, express the wave speed in terms of these parameters.

e. In an experiment on an exposed abdominal aorta of a dog, the pulse wave speed is determined to be 1.5 m/s. The wall thickness of the artery was measured to be 5% of the diameter. Estimate the Young's modulus for the aorta.