

I. 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. In addition to sterilization by (a) ionizing radiation, the effective techniques include use of (b) dry heat, (c) wet heat, autoclaving, (d) ethylene oxide, (e) chemicals, glutaraldehyde, and (f) filtration. What are the details of these techniques that correctly answer the questions below? :

- A. For each technique (a), (b), (c), (d), (e), (f) named above, what are the types of materials that can be safely and effectively sterilized by each method, what are the benefits and problems with that method, and what are two such specific materials that can be sterilized by that method?

(a) ionizing radiation

(b) dry heat

(c) wet heat, autoclaving

(d) ethylene oxide

(e) chemicals, glutaraldehyde

(f) filtration

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

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

C. Polyethylene (PE) and Polypropylene (PP) are two very similar and common biomaterials utilized in many medical devices, but only one of these materials is safely and effectively sterilized by ionizing radiation. Which of these two polymers, PE or PP, is not routinely sterilized by ionizing radiation and Why Not?

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?

D. Draw a graph showing the nonlinear relationship observed for the Strengths of Adhesion of flowing blood component deposits on materials of increasing Critical Surface Tensions placed in contact with that flowing blood. Label the Critical Surface Tension zone associated with lowest degree of deposit retention, where the materials exhibit the greatest thromboresistance or "blood compatibility".

E. Draw a schematic diagram of the earliest deposits retained on every material's surface immediately (within 5 minutes) after its first exposure to flowing whole blood, and label the blood components and thicknesses of those features called the "conditioning film" and the "primary film". [examples of components to consider: fibrinogen, albumin, gamma globulin, red blood cells, white blood cells, platelets, chylomicra, others?]

II. Cardiovascular Biomechanics

1. Describe the human cardiovascular system including its anatomy (how it is organized) and function (How it works. Physiology. Function of each components). Your presentation must have an easy-to-follow logic. Details of vessels through different organs (other than the heart and lungs) can be omitted.

2. 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?

3. Describe blood rheology. What factors affect the viscous behavior of blood? Under what conditions can you treat blood approximately as a Newtonian fluid and why? How would you model it as a non-Newtonian fluid? In what kind of situations you must consider the formed elements?

4. For a fluid flowing through a circular tube, use the simplest approach to derive a relationship between the pressure gradient and the wall shear stress. Then assume (a) Newtonian fluid, (b) Power Law fluid and derive an expression of the flow rate in terms of pressure gradient.

5. Mechanics of blood vessel:
- a. Illustrate the stress-strain relationship for steel, dry bone, skin and blood vessel. What factors make the mechanical study of soft biological tissues more complex than non-biological materials?
 - b. How do the structural components of the blood vessel wall contribute to its material behavior (especially the nonlinear behavior)?
 - c. Draw a uniaxial loading-unloading curve for a typical artery. Explain its shape and why so is.
 - d. A popular approach to nonlinear elasticity of arteries is to use the "incremental law". How would you set up an experimental test to obtain the incremental modulus of a rabbit mesentery at a defined pressure loading?

6. Unsteady blood flow:
- a. What issues and complications are involved in pulsatile flow that you do not have to worry about when dealing with a steady flow?
 - b. What assumptions are made so that you can obtain the Moen-Kortweg relationship for pressure wave speed in vessels?
 - c. What assumptions are made so that you can obtain the Womersley solution of the Navier-Stokes equations?
 - d. From a physical mechanistic point of view, show the equivalence of the Womersley number (or stokes number) and the Reynolds number.
 - e. What happens to the flow velocity profile with increasing Womersley number? And why?

7. Explain how you would model the blood flow in:
 - a. Coronary artery
 - b. Carotid artery
 - c. Aorta
 - d. Cerebral aneurysm
 - e. Microvasculature with sickle cells

Justify your strategies and assumptions. Since model appropriateness depends on the objective (the questions that needs to be address by modeling), you may want to define a question that is of health significance for each case, and then present your approach.