MSE/BioE C118 - Biological Performance of Materials

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Exam 1: October 19, 2004 **Closed Book Exam**
Please answer all of the questions clearly and box your final answer. Useful equations, data, and physical constants appear at the end of the exam.

NAME:_____

ID NUMBER:_____

Prob. 1	Prob. 2	Prob. 3	Prob. 4	Total
Max = 25	Max = 25	Max = 25	Max = 25	Max = 100

Extra Credit (2 pts.)
What medical procedure and type of implant did Vice President Dick Cheney receive in 2001?

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1. You are asked to develop a coating for a sensor to measure blood glucose levels. You perform a water contact angle study on the existing coating for the sensor and determine $\theta_{ADV}^{H_2O} \sim 100°$. You decide to develop a coating based on one of the three modifications discussed in the Prime and Whitesides (Science, 1991) paper. (25 pts.)

a. What were the three coatings addressed in the paper and what existing or native materials were they intended to model?

b. You perform a water contact angle study on the *new* coatings for the device and determine $\theta_{ADV}^{H_2O}$ is in the range between ~ 30° and 35°. What additional techniques would you perform to characterize the material and surface? Be sure to include the principle of the technique, what the technique measures, and its limitations.

You decide to implant your material with each of the aforementioned coatings into the muscle of a well-established animal model to evaluate their biological performance. Describe the development of the interfacial hierarchy over time existing between the implant and the host tissue.

d. What type of long-term interactions can occur between the implant and the body?

e. One coating shows poor biological performance as determine by chronic inflammation and fibrous tissue encapsulation. Examination of proteins bound to the materials surface indicates that they were responsible for the poor performance. How could the bound proteins influence the biological performance? Which coating would be most likely to have caused this response? Which coating would you choose for the sensor?

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2. You are asked to evaluate two semi-crystalline biodegradable copolymers as potential fracture fixation plates. You are concerned about dimensional change in the plate as a function of loading, and decide to conduct a creep experiment. Address the response of a Voigt-Kelvin element in a typical creep experiment.

a. Write an expression for the differential equation for the Voigt-Kelvin element, then solve this equation using appropriate boundary conditions to generate an equation expressing the time dependence of strain for the creep experiment.

b. Sketch a creep curve, indicate which component (i.e., spring or dashpot) contributes to the features of the curve, and demonstrate the effect of increasing crystallinity on the curve.

c. Based on the response of the Voigt-Kelvin element, sketch the effect of removing the stress after equilibrium has been reached

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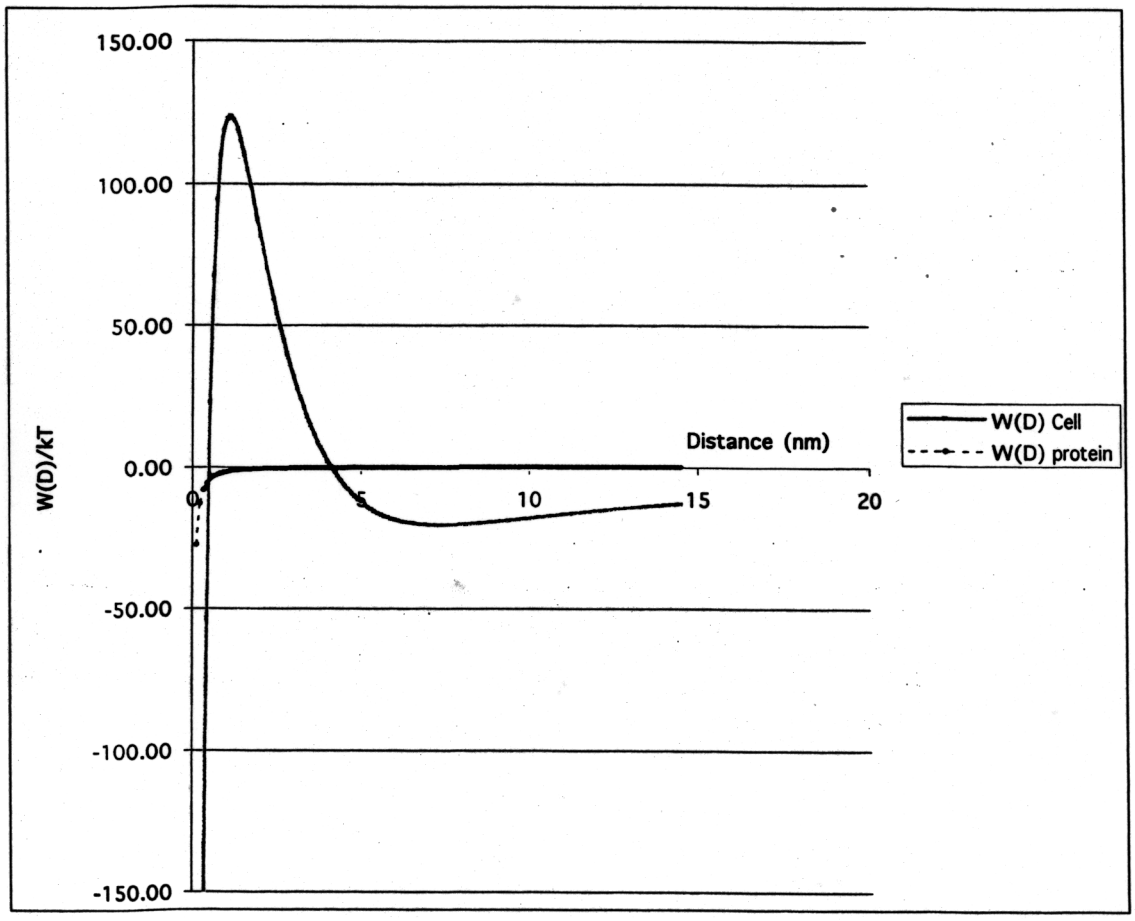
3. As a first approximation to understanding the biological performance of a new polymer, you use DLVO theory to approximate the interaction free energy as a function of distance between the polymer and either proteins, cells or bacteria. (25 pts.)



The curves were generated using the following parameters: polymer surface potential of -8 mV; surface potential of -10 mV for the cell; surface potential of -10 mV for the protein; a 1:1 electrolyte with a concentration of 0.2M and a Debye length (κ^{-1}) of 1.48 nm; at body temperature (37 °C). The diameter of the cell was 10 μM and the protein 30 nm.

a. Explain how you would calculate the total interaction free energy W(D) curve for both a protein and a cell approaching the polymer surface? Show which equations you would use.

b. Based on this graph and DLVO theory, describe initial events occurring at the surface after exposure to a solution containing both proteins and cells. What would allow the cell to overcome the energy barrier at the 2° minimum to approach direct contact with the surface?

c. What parameters could you manipulate to alter the DLVO curve and minimize platelet interaction with the surface? Be sure to draw new total interaction free energy curves demonstrating the influence of your perturbation.

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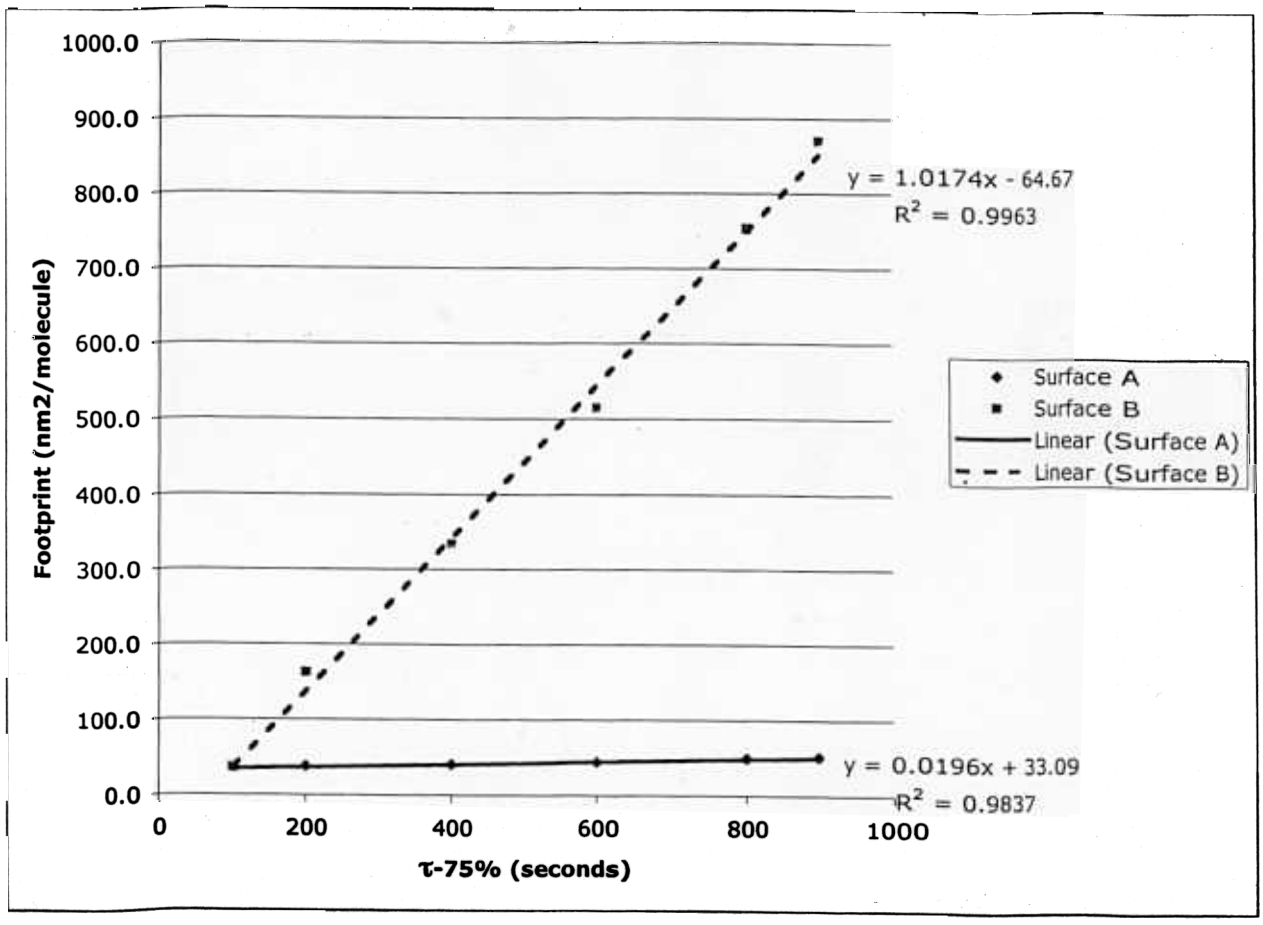
4. You are asked to evaluate a new polymer as a non-thrombogenic (i.e., non-protein adsorbing) coating for an intravascular stent. To evaluate the polymer you begin by making a contact angle measurement and find $\theta_{ADV}^{H_2O}$ is approximately 90°. Next you decide to conduct a protein adsorption experiment and assess the spreading rate of the protein. (25 pts.)

a. Why would you conduct a protein adsorption experiment? What are the three key aspects of protein adsorption that would affect the biological performance of the stent coating?

b. You conduct a fibrinogen adsorption experiment and generate the data given below. How would you perform this experiment and what would you measure? Hint: draw a typical protein adsorption kinetics curve and identify appropriate regions of the curve that can be used to calculate the data for the figure below.



c. You decide to conduct a protein adsorption experiment where you increase the concentration of protein successively after the surface excess (mol/area) has reached equilibrium. For each surface, draw "direct" versus "successive" protein adsorption isotherms.

d. Which polymer coating would you choose and why?