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**BioE 10**  
**Introduction to Biomedicine for Engineers**  
**Midterm Exam II**  
**Fall 2010**

<b>Name</b>	
<b>SID</b>	

**Write your name and SID on the top of each page!**  
**If you need extra space, use the back of the sheet.**  
**No computers or electronic communications devices allowed.**  
**Two double-sided sheets of notes allowed.**  
**Please limit all responses to “short answer” questions to 1-2 sentences.**  
**Exam must be written in ink to be eligible for a regrade.**

**SCORE (for instructors only)**

<b>Question 1:</b>		<b>/25</b>
<b>Question 2:</b>		<b>/15</b>
<b>Question 3:</b>		<b>/30</b>
<b>Question 4:</b>		<b>/25</b>
<b>Question 5:</b>		<b>/10</b>
<b>Question 6:</b>		<b>/30</b>
<b>TOTAL</b>		<b>/135</b>

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1. Suppose you are working at a tissue engineering startup company, and your job involves culturing vascular endothelial cells with the ultimate goal of seeding these cells into polymer scaffolds to create vascular grafts.

A. Suppose you seed 50,000 cells into a tissue culture flask with a surface area of  $75 \text{ cm}^2$ . How many hours will it take for the culture to reach confluence (i.e., grow to a continuous monolayer of cells)? Assume that the doubling time of the cell is 20 hours and that a single cell occupies a surface area of  $10,000 \text{ } \mu\text{m}^2$ . (10)

B. Suppose the concentration of  $\text{Na}^+$  in your culture medium is 145 mM and the concentration of  $\text{Na}^+$  in the cell is 10 mM. Calculate the Nernst potential (in mV) for  $\text{Na}^+$  under these conditions. Assume  $T = 37 \text{ C}$ , and recall that  $R = 8.31 \text{ J/K}\cdot\text{mol}$  and  $F = 96485 \text{ C/mol}$ . (10)

C. Consider a hypothetical solute X, and suppose the intracellular concentration of X is much higher than the extracellular concentration of X. Describe a strategy for importing X into the cell that involves  $\text{Na}^+/\text{K}^+$  ATPase and a  $\text{Na}^+/\text{X}$  co-transporter, and if energy is required to make this process work, identify the source of that energy (a drawing may help). (5)

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2. The small-molecule second messenger cyclic adenosine monophosphate (cAMP) plays a central role in several signal transduction pathways. Perhaps the best known function of cAMP is to bind and activate protein kinase A (PKA), which can phosphorylate proteins and trigger a variety of cellular effects.

A. Suppose you conduct an equilibrium dialysis experiment that yields the fraction of bound PKA ( $r$ ) as a function of cAMP concentration. Describe how you could extract the dissociation constant ( $K_d$ ) from these data using Scatchard analysis. Your answer should include both an equation (which you do not need to derive) and a plot in which the value of  $K_d$  is related to the slope of the plot. (5)

B. Suppose the  $K_d$  for the binding interaction between cAMP and PKA is 50 nM. What concentration of cAMP would you need to have in solution to occupy 75% of the binding sites on PKA? (10)

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3. Imagine you are performing mechanical testing on a polymeric biomaterial under consideration for use in a new type of catheter.

A. Suppose you perform a controlled strain measurement on this material (i.e., systematically increase strain, measure resulting stress). If the material displays linearly elastic behavior between a strain of 0 and 70%, and at a strain of 55% you measure a stress of 40 MPa ( $40 \times 10^6 \text{ N/m}^2$ ), what is the Young's modulus of the material? (10)

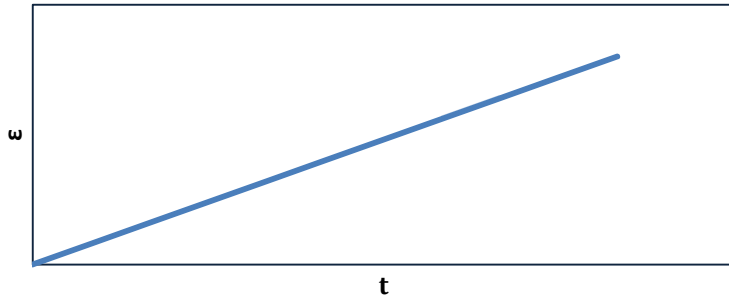
B. Now suppose you cut a strip of the material that is 100 cm in length and has a cross-sectional area of  $1 \text{ cm}^2$ , and you hang a 100 kg weight from it. Using your answer in A, calculate the length of the material after you hang the weight. (10)

C. Now consider a completely different material, and suppose you conduct a creep test in which you apply an instantaneous, constant stress (step stress) and measure the resulting strain of the material. Sketch the strain response as a function of time for a (1) purely viscous material, (2) purely elastic material, and (3) a Voigt-model viscoelastic material (spring and dashpot in parallel). In all cases, indicate the time at which the step stress was applied, e.g. with an arrow. (10)

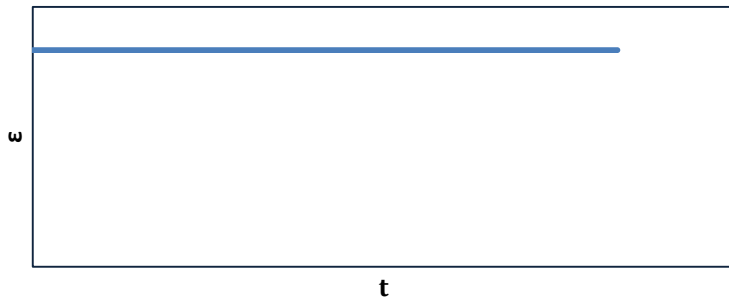
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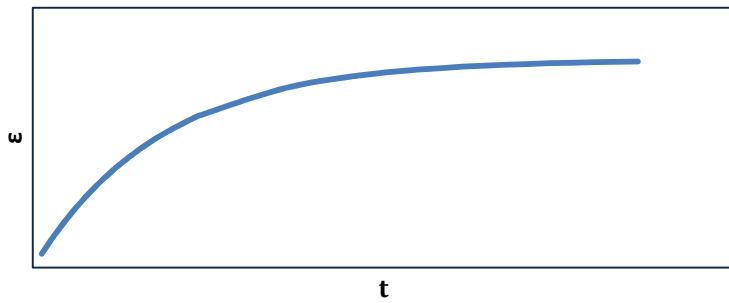
### Viscous



### Elastic



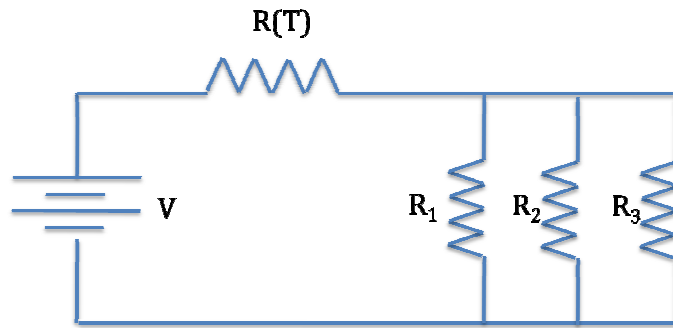
### Voight



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4. Consider the following circuit:



A. Suppose  $V = 1.000 \text{ V}$ ,  $R_1 = 1.000 \text{ k}\Omega$ ,  $R_2 = 2.000 \text{ k}\Omega$ ,  $R_3 = 3.000 \text{ k}\Omega$ , and  $R(T)$  is a thermistor that obeys the following equation:  $R \text{ (k}\Omega) = \exp[100.0 \cdot (1/T - 1/300.0)]$  where  $T$  is temperature in Kelvin. Derive an equation that describes the total current in the circuit as a function of temperature. (15)

B. Using your answer in A, how much of a current change (in  $\mu\text{A}$ ) would be associated with an increase in body temperature from  $37 \text{ C}$  to  $39 \text{ C}$ ? In order to avoid significant rounding errors, carry 4 significant figures throughout your calculation. (10)

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5. Suppose you are interested in measuring the concentration of a solution of the protein lysozyme by spectrophotometry. If the intensity of light at the detector that emerges from the sample is 75% of the intensity of light that enters the sample, and the cuvette has an optical path length of 1 cm, calculate the concentration of lysozyme in solution (in  $\mu\text{M}$ ). Assume the extinction coefficient ( $\epsilon$ ) of lysozyme in solution is  $40,000 \text{ cm}^{-1} \text{ M}^{-1}$ . (10)



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6. Answer the following questions in 2 sentences or less:

A. What is the Seebeck effect and how can it be exploited to measure temperature? (5)

B. What are Korotkoff sounds? (5)

C. Why is the Scatchard plot considered superior to the much simpler double-reciprocal plot ( $1/r$  vs  $1/[L]$ ) as a means of linearizing and extracting  $K_d$  values from binding data? (5)

D. What is the difference between a piezoelectric material and a pyroelectric material? (5)

E. What is the difference between a yield stress and a failure stress? (5)

F. What is the difference between paracrine and endocrine signaling? (5)

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