NAME: SID:

BioE 10

Introduction to Biomedicine for Engineers

Midterm Exam II

Fall 2010

Name	
SID	

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)

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

NAME: **SID:**

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 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 μm^2. (10)

B. Suppose the concentration of Na+ in your culture medium is 145 mM and the concentration of Na+ in the cell is 10 mM. Calculate the Nernst potential (in mV) for Na+ under these conditions. Assume T = 37 C, and recall that R = 8.31 J/K-mol and F = 96485 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 <u>importing</u> X into the cell that involves Na^+/K^+ ATPase and a Na^+/X co-transporter, and if energy is required to make this process work, identify the source of that energy (a drawing may help). (5)

A. Cell area: 10000 um^2 = 0.0001 cm^2
# cells that can fit in 75 cm^2 total area: 75/0.0001 = 750000
N = Noe^kt
100000 = 50000 e^(k*20)
K = ln(2)/td = ln(2)/20 = 0.0347

750000 = 50000 e ^(0.0347*t)
T = 78 hrs

B. E = (RT/zF) * ln ([ion outside cell]/[ion inside cell])
= ((8.314 J/K mol) * (273+37)K)/(1*96485 C/mol) * ln(0.145M/0.010M)
= 0.0714 J/C = 0.0714 V

C. If you have higher concentration of X on the inside and lower concentration on X on the outside and you want to send the X from outside to inside against the concentration gradient, use Na+/K+ ATPase using ATP as energy source to drive Na+ out of the cell, so as the concentration of Na+ increases outside, it can come back in using the Na+/X co-transporter, with which the X comes back in.

NAME: **SID:**

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)

A. PKA + cAMP ← → PKA-cAMP (Kr backward and Kf forward)

Kd = [PKA][cAMP]/[PKA-cAMP] = Kr/Kf
Ka = 1/Kd
R = [cAMP]/(Kd + [cAMP])

Need to include final equation of: r/[L] = 1/Kd - r/Kd

Plot should include r/[L] on y axis (1/mM) and r on x axis; slope = -1/kd

B.

Kd = 50nM
R = [cAMP]/(Kd + [cAMP])
0.75 = x/(50+x) → 0.75 * (50 + x) = x → 37.50 + 0.75x = x → 150
[cAMP] = 150 nM.

NAME: **SID:**

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 stain of 0 and 70%, and at a strain of 55% you measure a stress of 40 MPa (40 x 10^6 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 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)

a)

$$\sigma = E\epsilon$$

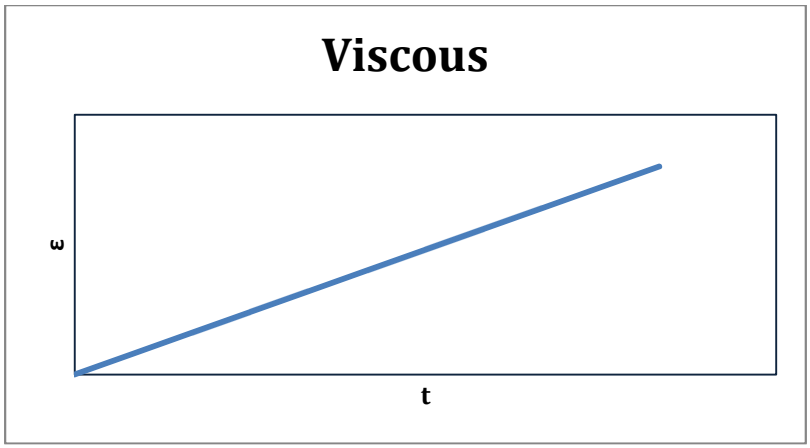
$$40\ MPa = E \times 0.55$$
$$E = 72.7\ MPa$$

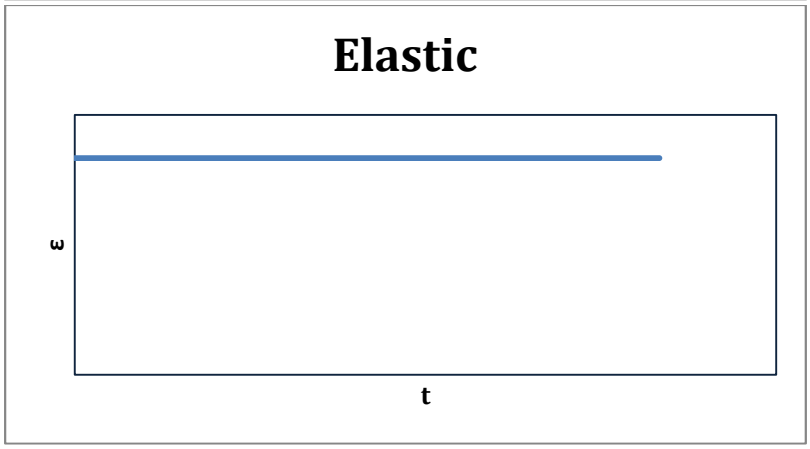
b)

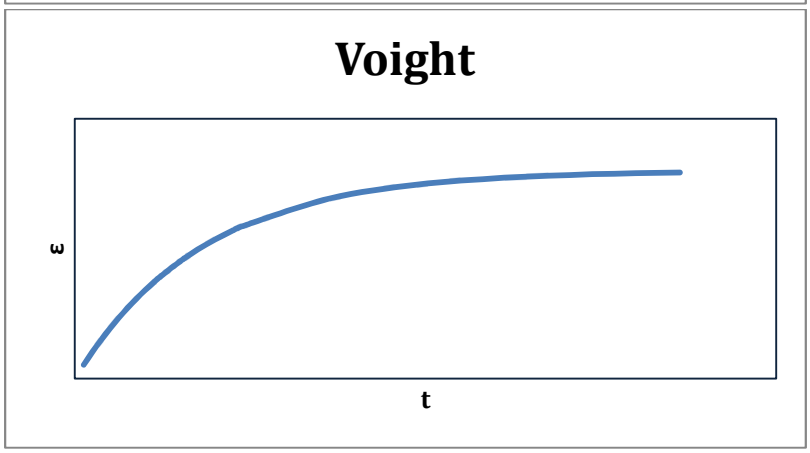
$$\sigma = \frac{F}{A} = \frac{100kg \times \frac{9.8m}{s^2}}{1cm^2 \times \left(\frac{1m}{100cm}\right)^2} = 9.8 \times 10^6 Pa$$
$$\epsilon = \frac{\sigma}{E} = \frac{9.8 \times 10^6 Pa}{72.7 \times 10^6} = 0.135 = \frac{\Delta l}{l_0} = \frac{\Delta l}{100cm}$$
$$\Delta l = 13.5cm$$
$$l_f = l_0 + \Delta l = 100cm + 13.5cm = 113.5cm$$

c)

NAME: SID:

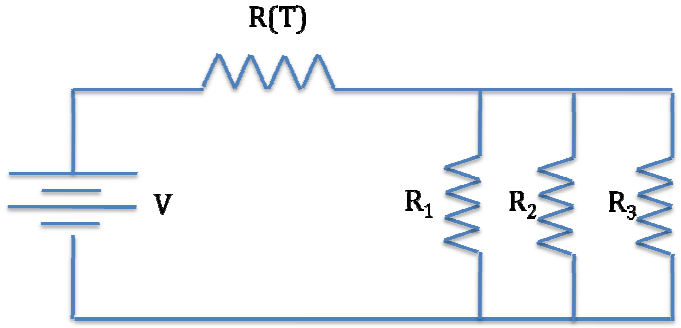






NAME: SID:

4. Consider the following circuit:



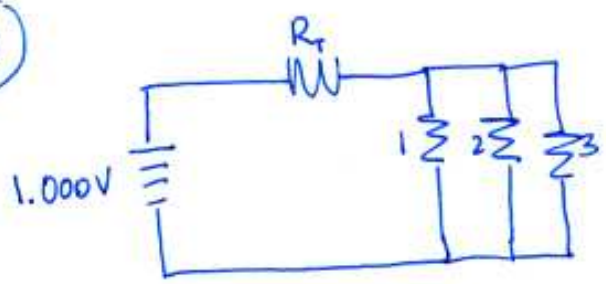
A. Suppose V = 1.000 V, R_1 = 1.000 kOhm, R_2 = 2.000 kOhm, R_3 = 3.000 kOhm, and R(T) is a thermistor that obeys the following equation: R (kOhm) = exp[100.0*(1/T – 1/300.0)] where T is temperature in Kelvin. Derive an equation that describes the <u>total</u> current in the circuit as a function of temperature. (15)

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

NAME: SID:

Problem 4

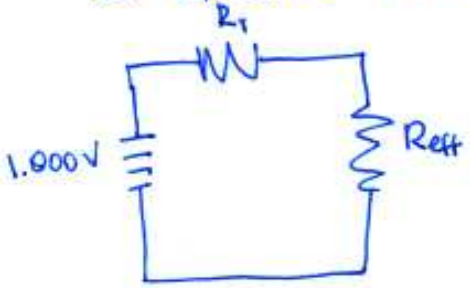
(a)



$R_1 = 1.000\ k\Omega$
$R_2 = 2.000\ k\Omega$
$R_3 = 3.000\ k\Omega$
$R(T) = e^{100(\frac{1}{T} - \frac{1}{300})}$

$$\frac{1}{R_{eff}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} = \frac{1}{1} + \frac{1}{2} + \frac{1}{3} = 0.5455\ k\Omega$$

So effective circuit =



$$R_{total} = R_T + R_{eff}$$

$$R_{total} = e^{100(\frac{1}{T} - \frac{1}{300})} + 0.5455 \ (\text{in } k\Omega)$$

$$V = IR \rightarrow I_{total} = \frac{V_{total}}{R_{total}} = \frac{1.000 \ (\text{in volts})}{e^{100(\frac{1}{T} - \frac{1}{300})} + 0.5456 \ (\text{in } k\Omega)}$$

can convert to same units so ratio will yield amps: $(\frac{kV}{k\Omega} = A)$

$$I_{total} \ (\text{in amps}) = \frac{0.001\ kV}{e^{100(\frac{1}{T} - \frac{1}{300})} + 0.5455\ k\Omega}$$

(B)

37°C → $\frac{K}{310}$
39°C → 312

$$I_{tot,310} = \frac{0.001\ kV}{e^{100(\frac{1}{310} - \frac{1}{300})} + 0.5455} = 0.0006515\ A$$

$$I_{tot,312} = \frac{0.001\ kV}{e^{100(\frac{1}{312} - \frac{1}{300})} + 0.5455} = 0.0006524\ A$$

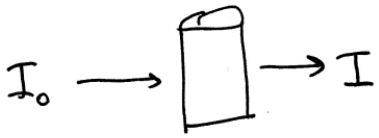
$$\Delta I = 0.0006524\ A - 0.0006515\ A$$
$$= 652.4\ \mu A - 651.5\ \mu A = \boxed{0.9\ \mu A}$$

NAME: SID:

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 μM). Assume the extinction coefficient (ε) of lysozyme in solution is 40,000 cm^{-1} M^{-1}. (10)

(5)

Intensity of light emerging from sample is 75% of intensity of light entering sample



$I = 0.75 I_0$

So $\frac{I_0}{I} = \frac{1}{0.75} = 1.33$ (inverse transmittance)

A_λ = absorbance = $\log\left(\frac{I_0}{I}\right) = \log(1.33) = 0.124$

$A_\lambda = \varepsilon C \ell$ where $\varepsilon = \frac{40,000}{cm \cdot M}$ + $\ell = 1\,cm$

$0.124 = \frac{40,000}{cm \cdot M} \cdot C \cdot 1\,\cancel{cm}$

$C = 0.000003\,M$

$\boxed{C = 3\,\mu M}$

NAME: **SID:**

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)

a) The Seebeck effect is a flow of current brought on by a difference of temperature between two metals. Thermocouples have two different metals fused together to create two junctions. The difference in temperature of these two junctions creates the current and is used to measure temperature because the change in voltage is proportional to temperature.
b) Korotkoff sounds are noises made by turbulent blow of blood through the brachial artery between the systolic and diastolic pressures while taking a blood pressure reading.
c) In a double reciprocal plot, most of the data is bunched together and later values can skew the slope of the line drastically. A Scatchard plot allows for the data to be more dispersed and provides a more accurate slope.
d) A piezoelectric material generates different voltages when strain is applied. A pyroelectric material's potential is altered at different temperatures.
e) Yield stress occurs when plastic deformation takes place. Failure stress occurs when the material fails, or breaks.
f) Paracrine signaling is when a ligand diffuses from one cell to another while endocrine signaling is when a ligand travels through the vasculature.

NAME: SID: