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BioE 110

Biomedical Physiology for Engineers

Midterm Exam I

Spring 2013

Name	
SID	

Write your name on the top of each page!
If you need extra space, use the back of the sheet.
No laptops or electronic communications devices allowed.

SCORE (for instructors only)

Question 1:		/20
Question 2:		/20
Question 3:		/20
Question 4:		/30
Question 5:		/30
Question 6:		/30
TOTAL		/150

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Potentially useful constants and conversions

$R = 8.31\ J\ K^{-1}\ mol^{-1} = 0.0821\ L\ atm\ K^{-1}\ mol^{-1}$

$F = 96\ 485\ C\ mol^{-1}$

$N_A = 6.022 \times 10^{23}\ mol^{-1}$

$k_B = 1.38 \times 10^{-23}\ J\ K^{-1}$

1 atm = 101.325 kPa

1 atm = 760 mmHg

1 cP = 1 mPa s

$1000\ L = 1\ m^3$

ln x = 2.303 log x

Elementary charge (*e*) = 1.6×10^{-19} C

For a sphere of radius R:

Volume = $4/3 * \pi R^3$

Surface area = $4 * \pi R^2$

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1. Consider a 25ºC chamber consisting of two 1L solutions of mannose (MW 180 g/mol) separated by a semipermeable membrane. Assume that mannose has a reflection coefficient across this membrane of 0.75 and is 100% soluble under these conditions. **(20 total)**

A. If the osmotic pressure gradient across the membrane is 167 kPa, and the more dilute of the two solutions has a concentration of 10 mM, how much mannose (in g) must have been dissolved in the other solution? Neglect any concentration changes associated with mannose diffusing across the membrane. **(10)**

B. If the effective resistance to flow across the membrane is 83.5 kPa-s/ml, what is the flow rate of water across the membrane at steady state (in ml/s)? **(10)**

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2. Consider a newly discovered microorganism and the transport of hypothetical ions A^+, B^{+2}, C^-, and D^-. The table below lists the intracellular and extracellular concentrations of each ion, as well as each ion's relative conductance. The temperature is 37ºC. **(20 total)**

Ion	Intracellular conc. (mEq)	Extracellular conc. (mEq)	Relative conductances
A^+	50	5	1
B^{+2}	0.01	1	1.5
C^-	unknown	unknown	2.5
D^-	60	60	0.0001

A. Calculate the values of the equilibrium potential for A^+ and B^{+2} (in mV). **(10)**

B. If the overall membrane potential at steady state is -40 mV, estimate the value of the equilibrium potential of C^- (in mV)$^-$. **(10)**

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3. Consider a spherical lipid vesicle of membrane thickness 10^{-9} m and diameter 10^{-6} m that encapsulates a 100 mM solution of glucose (molecular diameter ~10^{-9} m, MW 180 g/mol) and is placed in a 25°C bath containing 2 mM glucose. Ignore any effects of osmotic pressure/flow. **(20 total)**

A. If the partition coefficient of glucose across the lipid membrane is 0.0015 and the solution has a viscosity of 0.001 $N*s/m^2$, calculate the steady-state flow rate of glucose across the membrane (in mol/s). **(10)**

B. Suppose glucose was replaced inside and outside the vesicle by the same concentrations (100 mM and 2 mM) of a second molecule Y whose diffusion coefficient is twice that of glucose but whose partition coefficient is one-third that of glucose. What would be the steady-state flow rate of this molecule across the membrane? **(10)**

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4. A 35-year old woman comes to your clinic for a routine checkup. Her vital signs are as follows: T=37 ºC, HR=72 beats/min, BP 125/65 mmHg. **(30 total)**

A. What are this woman's pulse pressure and mean arterial pressure (in mmHg)? **(10)**

B. If this woman has a left ventricular end-diastolic volume of 103 mL and an ejection fraction of 60%, what is her cardiac output? **(10)**

C. Sketch a representative pressure-volume loop for this patient's left ventricle (don't worry about the actual numbers). Superimposed on this PV loop, draw a new PV loop as a dashed line showing how the PV loop would eventually change if the patient took a positive inotropic agent (e.g. digitalis). Be especially clear what happens to the height, width, and position of the PV loop, and if one or more of these quantities change, explain why in a few words. **(10)**

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5. Consider a small artery of diameter 1.5 cm that simultaneously branches into three arterioles with diameters of 0.5 cm, 0.75 cm, and 1 cm. **(30 total)**

A. If the blood flow through the small artery is 50 ml/min, at what velocity does blood flow through that artery? **(10)**

B. What is the flow rate (ml/min) of blood through the largest of the three arterioles? **(15)**

C. Suppose one of the arterioles eventually branches into a set of capillaries. Consider one of these capillaries: If the oncotic pressures in the capillary and interstitial space are 28 mmHg and 5 mmHg respectively, the hydrostatic pressures in the capillary and interstitial space are 3 mmHg and 32 mmHg respectively, and the flow rate of fluid across the capillary wall is 2.5 ml/min, what is the hydraulic conductance (in ml/min-mmHg)? **(10)**

D. Suppose you do an experiment in which you tie off the small artery at both ends, inject defined volumes of saline solution, and measure the resulting pressure difference across the arterial wall. You find that when the total volume of saline solution in the artery is 50 ml, the transmural pressure is 10 mmHg, and when you inject an additional 25 ml of solution, the pressure increases to 260 mmHg. What is the compliance of the artery (in ml/mmHg)? **(10)**

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6. Answer the following questions in 1-2 sentences, unless otherwise specified. **(30 total)**

A. Rank conduction speed through these three structures in order from fastest to slowest (no explanation needed): atrial intranodal tracts, atriventricular node, Purkinje fibers. **(5)**

B. During phase 4 (rest) or a ventricular action potential, the inward sodium and calcium currents are large enough to balance the outward potassium current, even though the conductance of the membrane to sodium and calcium are much, much smaller than the potassium conductance. How is this possible? **(5)**

C. Which segment of the EKG would you expect to be most affected by a lesion that delays conduction through the atrioventricular node? **(5)**

D. Carotid sinus massage is often a simple yet effective way of ending episodes of supraventricular tachycardia. Why? **(5)**

E. Left ventricular hypertrophy is often observed as a compensatory mechanism to chronic systemic hypertension. Use Laplace's law to explain this finding. **(5)**

F. When a neuron in the body fires an action potential, why does it only travel in one direction? Your answer should specify a molecular mechanism **(5)**

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