Name: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Date:\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**BIEN 401/501**

**PRACTICE**

**EXAM 1**

*Honor Statement:* On my honor, I promise that I have not received any outside assistance on this exam (I didn’t look at another student’s paper, I didn’t view any unauthorized written materials, I didn’t talk or listen to another student).

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The last page of the exam contains useful equations. When the exam starts you may rip off the last page for easy access. When the exam concludes, please stuff the torn page back into your exam packet before submitting your exam. If you used any additional papers for scratch work, please stuff these in your exam packet as well.

**Concept Questions (1-10)**

**(3 points each)** Circle the correct answer choice for each of the following questions.

Study concepts including vocabulary terms, cause and effect relations, and other concepts. Questions will appear as multiple choice or true-false.

**Computational Questions (11-19)**

For each question, you must show your work to get credit (partial and/or full). Be sure to answer all parts if a question has multiple parts.

1. **(10 points)** The wall shear stress (with SI units of Pa) for flow in a narrow annular gap between a fixed cylinder and a rotating cylinder is a function of density , dynamic viscosity , angular velocity (which has SI units of 1/s), outer radius , and gap width . Determine the number of dimensionless numbers that can be formed. Write out the dimensionless numbers that can be formed using and as your repeating variables.
2. **(10 points)** At 50oC, liquid A has a vapor pressure of 268 mmHg. At 50oC, liquid B has a vapor pressure of 236.2 mmHg. For a liquid at 50oC composed of A and B, with A having a mole fraction of 0.25, determine **(A)** the vapor pressure and **(B)** the composition of a vapor bubble in equilibrium with the liquid.
3. **(10 points)** Consider a microchannel used for cell culturing. Within the layer of cells. a specific protein is produced in a uniform and constant rate, At the bottom of the channel () there exists a solid wall. At the top of the channel (), the protein reacts with a surface coating in a reaction that occurs so quickly that the concentration of the protein can be assumed 0 at this surface. Assume no convection takes place and that the system operates under steady state conditions. Determine the concentration profile for the range . State any assumptions and boundary conditions.
4. **(10 points)** A 75 -thick cellulose membrane has a molecular weight cutoff of 100 kDa. The membrane has a surface area of 5 cm2 and a porosity of 40%. The pores are quite tortuous and have a tortuosity factor of 2.2. For plasma with a viscosity of 1.2 cP, determine **(A)** the hydraulic conductance of the membrane. If the membrane was stacked with a 50 -thick membrane with hydraulic conductance of 0.5 mL hr-1 atm-1 cm-2 (effectively two membranes arranged in series), what would be the overall hydraulic conductance (hint: it is called hydraulic *conductance* for a reason).
5. **(10 points)** A cell culture solution is used to create a therapeutic protein. The solution is fed through a membrane separator at a feed rate of 100 mL/hr. The feed has a cell mass concentration of 20 g/L, a therapeutic protein concentration of 8 g/L, and other (unwanted) proteins with an initial concentration of 10 g/L. The membrane has pore sizes that allow the some of the proteins to pass, but not the cells. The retentate (the solution that doesn’t pass through the filter) is discovered to have a cell mass concentration of 36 g/L and a therapeutic protein concentration of 2 g/L. The filtrate (the solution that does pass through the membrane) has a measured total protein (therapeutic + unwanted) concentration of 28 g/L. Assuming all solutions have a constant density (of 1 g/mL), determine (**A**) the flow rate of the filtrate, (**B**) the efficiency of the separator (which can be calculated by taking the total mass of therapeutic protein in the filtrate and dividing it by the therapeutic protein mass in the feed stream).

1. **(15 points)** A 3D cell mass can be modeled as a sphere with radius . The medium around the cell mass is well-mixed such that the concentration of a specific drug is constant at . The drug diffuses into the cell mass and has a constant diffusivity . It was determined through earlier tests that cells metabolize the drug in a manner that can be characterized as a zero-order reaction (i.e., the reaction rate is constant). **(A)** Assuming steady-state operation, simplify and solve the overall mass balance expression, listing all assumptions and boundary conditions, to determine the concentration profile for the range . **(B)** Derive the expression for the drug transfer rate into the cell mass it its surface (i.e., at ).
2. **(15 points)** A membrane with a nominal molecular weight cutoff (NMWCO) of 80 kDa is used to separate two aqueous (water) solutions, A and B. Solution A contains a large protein with molecular weight 200 kDa and a concentration of 20 mg/mL; solution B contains small solute molecules with an average molecular weight of 800 Da and a concentration of 35 mg/L. The solutions are both at 25oC. The membrane contains straight pores and has a porosity of 35% and a thickness of 50 . Assume the hydrodynamic of both solutions A and B to be 1 atm. Determine **(A)** the diameter of the pores in the membrane (hint: the cutoff value assumes that spherical molecules with a MW equal or greater than the NMWCO are too big to pass), **(B)** the hydraulic conductance of the membrane, and **(C)** the filtrate flux (in cm/s) through the membrane.

**END OF EXAM**

**Answer Key**

11.

12A.

12 B.

13.

14A.

14B.

15A.

15B.

16.

16A.

16B.

17A.

17B.

17C.