Name:

**Instructions:**

1. Put your name on every sheet of paper you hand in for grading, including these exam pages. Please put the exam on top of your solutions and turn in both.
2. This is an open book/notes exam and you may use the computational resources in the lab. However, you may not use the internet and you may not consult with others by any means. You are not allowed to use any communications, electronic or otherwise during the exam. This includes accessing the Internet, using cell phones, tablets, or any other form of information/communications. The honesty policy you signed at the beginning of the course applies.
3. You should **frequently save your files while doing the exam**, in case of computer/software malfunctions. If your computer/programs crashes and you have not saved your programs, there is nothing I can do to help with respect to grading your solutions.
4. Please provide clear, well-presented solutions, clearly indicating the part of the question (A,B,C, etc.) that corresponds to your solutions. If you do not clearly list to which part of the question your solution corresponds, you may lose points.
5. If plots/graphs are requested as part of your solutions, please make sure these are appropriately presented (smooth curves, data points shown, appropriate plot ranges, etc.) or you may lose points. Please supply any relevant programs/spreadsheets, etc. as appropriate to your solution, if partial credit is desired.
6. Please submit any electronic computational programs/files immediately at the end of the exam to [tao@purdue.edu](mailto:tao@purdue.edu). The time stamp on the files must be prior to the end of the exam or they will not be used for grading. Please make sure your last name is at the start of electronic file names and on every sheet submitted. Hard copy printouts of your solutions may be submitted up to an hour

Notes:

1. As with any mass/energy balance equation, checking the dimensions/units is a good way to make sure your equations are consistent.
2. Please be sure your solutions are clearly presented, if partial credit is desired. If I cannot understand how your solutions were developed, it is unlikely that you will receive any partial credit.
3. Please be sure to clearly indicate your solutions with respect to what is being requested in the problem, e.g. solution to Part A: plot of ODE numerical solution

Name:

Topical skin patches are used to slowly deliver drugs to the human body.

Assume a patch is being used to deliver a hormone to the human body. The hormone enters the body by diffusing through the skin. In the blood stream, an enzyme slowly degrades the hormone over time.

Assume that the hormone is only medically effective when its concentration in the body is above C = 0.05 mol/m3. You task is to model this system and determine how long the patch works before it needs replacement.

skin

Cp

Human body

Vb, body volume= 0.05 m3

Cb(t), hormone concentration in body

patch

Data:

Vp, patch volume = 0.00005 m3 (assumed constant) Ap, patch area = 0.01 m2

Cpo, initial hormone concentration in patch = 100 mol/m3

Vb = 0.05 m3 x, skin thickness = 0.0025 m

Cb(0), initial hormone concentration in body = 0 mol/m3

D, diffusivity of skin = 0.000005 m2/hr

Assume that the hormone enters the body by diffusion, i.e. Fick’s 1st law: j=D\*A\*dC/dx=D\*A\*(Cp-Cb)/x (Note: this approximation assumes the skin hormone concentration gradient is always linear)

Assume that the degradation rate of the hormone in the body is enzymatic and the reaction rate can be modeled by the Michelis-Menten rate model, dC/dt = - Vm\*C/(Km+C).

Vm = 1 mol/m3-hr Km = 60 mol/m3

1. (55 points)

Assumption: The concentration of the hormone in the patch is assumed to be constant at Cpo.

1. (20 points) Using the human body as the system, **provide the component mass balance** on the hormone.

2. (30 points) Numerically solve the model and **provide an appropriate plot** of the hormone concentration in the body as a function of time. **Calculate how long it takes (hr)** for the hormone concentration in the body to become medically effective.

4. (5 points) Calculate **how long the patch lasts** (hr), i.e. how long before it needs to be replaced. Explain if this model makes sense.

1. (45 points) The assumption that the patch concentration is constant is not very realistic. In actuality, the hormone concentration in the patch decreases with time. Assume the patch behaves as a lumped parameter system (hormone is uniformly distributed in the patch at all times).
2. (10 points) **Provide the hormone component mass balance for the patch** as the system.
3. (30 points) Incorporating this into the model from part A, numerically solve for the hormone concentration in the body as a function of time and **provide an appropriate plot** of this model.
4. (5 points) Using this model, **determine how long (hr) before the patch must be replaced,**  i.e. the time at which the hormone concentration drops below the effectiveness level. Looking at the solution to your model, explain if it makes sense.