BMED 3300 – Biotransport A/B/E/F
Spring 2015 - Syllabus

Lectures: (A/B/E/F) M W 10:05-10:55 am Instructional Center 105 (Building 55)
(E/F: Ethier) F 10:05-10:55 am Whitaker 1214
(A/B: Kemp) F 10:05-10:55 am Whitaker 1232

Recitation sections:
(A) W 12:05-12:55 pm, Whitaker 1214
(B) W 9:05-9:55 am, ES&T 1105
(E) W 2:05-2:55 pm, Whitaker 1232
(F) W 1:05-1:55 pm, Whitaker 1214

Instructors: Prof C. Ross Ethier, Ph.D.
ross.ethier@bme.gatech.edu
Office: 2306 IBB
Office hour: Wednesdays 12-1

Prof. Melissa Kemp, Ph.D.
melissa.kemp@bme.gatech.edu
Office: 1314 IBB
Office hour: Wednesdays 3-4

TAs: (E/F): Ms. Akia Parks
aparks14@gatech.edu

(A/B): Mr. Chad Glen
glenc@gatech.edu
TA office hours will be announced during the first recitation.

Undergraduate TAs: Sara Khalek, Jackson Hair

Purpose: The overall purpose of this course is to introduce students to the fundamentals of momentum, heat and mass transfer and to teach their application to biotransport problems.

Objectives: At the end of the course students should be able to:

1. Understand the physical factors governing the transport of momentum, heat and mass, and how these factors operate in biological systems.
2. Understand the basis of conservation laws underlying momentum, heat and mass transfer, and be able to apply these laws through control volume and/or differential balances.
3. Quantify the transport of one or more of momentum, heat and mass by using:
    a. Basic equations of fluid mechanics (mass conservation, Bernoulli, generalized Bernoulli, simplified forms of the Navier-Stokes equation)
    b. Basic equations of heat and mass transfer (convection-diffusion equation).
    c. Additional differential equations with appropriate boundary conditions.
4. Describe fluid flow (pressure drops, velocities, velocity profiles, shear stresses, shear rates) for various biological systems, particularly for flow through conduits.
5. Determine concentrations at a particular point or concentration profiles (both with and without reactions), and determine mass fluxes.

6. Determine convective mass and heat transfer coefficients using appropriate approaches.
7. Distinguish between modes of heat transfer or mass transfer, explain analogies between heat, mass and momentum transfer and apply the correct equations to describe each mode.

Web Page: https://t-square.gatech.edu; look for the **BMED-3300-A,B,E,F** page

** Note: the individual sections have been combined into **1 T-Square course page**.
Class notes, homework, homework solutions, etc. are to be printed out from the web page. This site will be used to send important announcements to the class; therefore you must verify that you are enlisted in the membership.

Piazza website. This term we will be using Piazza for class discussion. The system is highly effective at getting you help fast and efficiently from classmates, the TA, and instructors. Rather than emailing questions to the teaching staff, we encourage you to post your questions on Piazza. If you have any problems or feedback for the developers, email team@piazza.com. You will need to sign up for participation by going to: **piazza.com/gatech/spring2015/bmed3300abef** .

Tegrity lectures. Tegrity is software that allows lectures (including screencasts) to be created and posted to the web. A number of Tegrity lectures have been created for BMED3300, covering basic mathematical topics such as: vector calculus (dot product, gradient operator [∇f], divergence operator [$\nabla \cdot \boldsymbol{f}$]), elementary solution techniques for first order linear differential equations, the meaning of the substantive derivative, and how to compute mass flow rate and volume flow rate using surface integrals. If you do not thoroughly know this material already **you need to watch these lectures** (they are each 10-15 minutes long). You can log in to Tegrity via the link on the tool tabs on the T-square web page, or via **https://gatech.tegrity.com/TegrityUtils/Login.aspx** .

Textbook: **Required:** *Fundamentals of Momentum, Heat and Mass Transfer, 5th Edition* , JR Welty, CE Wicks, RE Wilson and G Rorrer, Wiley, New York, NY (2008). Due to very minor changes associated with the latest 6th edition (and you are welcome to buy the more expensive book), we will continue to refer to the 5th in class communication.

Detailed class notes will be available to download from T-square.

Suggested: *Transport Phenomena in Biological Systems*, G.A. Truskey, F. Yuan, D.F. Katz, 2nd ed. Pearson Prentice Hall Bioengineering, Upper Saddle River, NJ (2009)

Very important: The term tests and final exam will be open book and will contain questions that require access to tables, graphs and/or formulas from the required textbook. To ensure the integrity of exams, students are not allowed to use computers or other electronic devices (except for calculators – see below) during exams. Therefore, if you purchase an e-version of the Welty text you will have to print out relevant sections for use during exams. If purchasing a digital copy enter the following number on the Wiley website for your access code: ISBN9780470475164

Prerequisites: BMED 2210* and MATH 2403 (* Minimum grade of C required.)

Students enrolled in this course must have satisfactorily completed all of the prerequisite courses before registering for BMED 3300.

Lectures: Lectures on Mondays and Wednesdays will be delivered in the standard manner. Friday sessions will be a little different: for a substantial fraction of the allotted time, we will work homework problems in a "flipped" format. Note the different classrooms (Whitaker 1214

and 1232) used on Fridays for this class. Short mini-lectures on difficult topics will be posted on the T-square web site so that students can refer to them during term as needed. Exception: the first and last Fridays of term, we will have a regular lecture in the regular classroom.

Recitations: There will be special recitations during the first week of class (January 7, 2015). These will focus on math concepts that you need to master to pass BMED3300. Past experience shows that most students need this refresher. Please don't miss this material and then be mathematically "underwater" for the rest of the term.

The content of recitations is largely dependent on student demand. The TAs will be available to provide guidance on homework problems and preparation for exams. (Note that homework problems will not be worked to completion by the TA.) If no questions are forthcoming from students, the TA's may shorten the scheduled recitation period.

Honor Code: Students are expected to abide by the GT Honor Code (www.honor.gatech.edu) at all times. The objective of the honor code is "to prevent any students from gaining an unfair advantage over other students through academic misconduct". Starting with the first offense, any potential violations of the honor code will be immediately reported to the Dean of Students to be reviewed. To preserve the integrity of the classroom and the instructor-student relationship, Profs Ethier & Kemp cannot use personal discretion in instances of potential honor code violations – ***consider this the first and only warning***.

Examples of honor code violations include:

- Looking at another individual's solutions during a quiz, test or exam.
- Communicating with other students during a quiz, test or exam.
- Claiming other students' work as your own.
- Using notes of any kind during closed-book, in-class quizzes
- Making untrue claims/statements (of any sort) to the instructors regarding use of electronic resources (T-square, Matlab, your personal laptop crashing, etc.)

For any questions involving these or any other Academic Honor Code issues, please consult your instructor or visit www.honor.gatech.edu.

Grading:

Midterm tests (see below)	30% total
Matlab assignments (see below)	15% total
Quizzes (see below)	20% total
Final Exam	35% (comprehensive)

Please note that students' final grades will be based solely on the marking algorithm outlined above. Regrettably, to do otherwise would be arbitrary and unfair; accordingly, requests from students to be allowed to submit supplemental material after the end of term to increase their grades will neither be entertained nor responded to. Similarly, requests to arbitrarily increase student grades so that "I can get into medical school"/"I can graduate next term"/"I don't have to pay any more tuition"/"I really feel like I know the material but my tests do not reflect that" will neither be entertained nor responded to.

Important note about grading: This is a difficult course, possibly the hardest in the BME undergraduate program at Tech. Notably, the concepts are difficult to master. To examine students' understanding of these concepts, exam questions are somewhat open-ended and test a range of concepts, from simple to difficult. Additionally, exams and quizzes require students to work relatively quickly. Both of these features are by design: real-life biomedical engineering problems are usually open-ended and "messy", and the ability to problem solve

in a timely fashion is critical. Some students do not like this aspect of the Ethier/Kemp sections of BMED3300. If you are one such student, you should change sections now.

Related to the above, it is hard to know how students will perform on open-ended problems. Thus, we do not have a hard target for class averages on exams/quizzes and sometimes they turn out to be lower than typical in other GT courses, e.g. the final exam in one Fall 2014 section had an average of 43% (interestingly, in that same section the lowest and highest final exam scores were 0% and 100%, respectively). To account for this, we curve the raw exam/quiz scores. Some students become discouraged because they receive low numerical scores on the exams/quizzes. Please remember that due to the nature of the curving process, it is the distribution of raw scores with respect to the class average that is the major determinant of grades, not the absolute value of your raw score. If you feel discouraged by receiving low numerical raw scores irrespective of the class average, you should change sections now.

Homework: Over the course of the term, at least 8 problem sets will be assigned. They will not be marked. Note that term test and final exam problems will be similar to those set in problem sets, and students cannot realistically expect to pass the course without completing the problem sets. To quote a student from the Spring 2013 session, "Success in this class is highly correlated with effort put in on the homework as well as class attendance." Problem set solutions will be posted on T-square. Homework assignments will be unified across all sections.

Quizzes: There will be 4 in-class quizzes (see class schedule). **Unlike the terms tests and the final exam, the quizzes will be closed book.** Each quiz will be 15 minutes in duration and will be based on material taken directly from the preceding problem sets; specifically, Quiz n (n=1…4) will cover material from Problem Sets 2n-1 and 2n. Students who have completed and understood the relevant problem sets can expect to score extremely well on the quizzes. No make-up quizzes will be offered. The overall Quizzes grade will be the arithmetic average of grades from the four quizzes, i.e. each quiz will be worth 5%.

Matlab Problems: Although the majority of the class will focus on analytically solving transport problems, there will be three graded assignments requiring Matlab programming that count toward 15% of your grade (5% each). The two-page documents must be submitted electronically to T-square by the due date and time as specified on T-square. The assignments will be unified across all sections and will require implementation of numerical methods for biotransport problems. You are expected to turn in independent work for this assignment.

Term Tests: See the class schedule for the dates of term tests. Each term test will consist of 2 questions and be 50 minutes in duration. No make-up term tests will be given. All questions will be mandatory and the overall Term Test grade will be the arithmetic average of grades from the two tests, i.e. each test is worth 20%.

Final Exam: The final exam date and time are scheduled by the Registrar's office and therefore are not flexible (see http://www.registrar.gatech.edu/students/exams.php). The final exam for BMED3300 for this semester is scheduled for all sections on **Monday April 27, 11:30am – 2:20pm** (Period 2).

No request to take the final exam at an alternative time or date will be allowed for any reason. Y**ou must attend your assigned final time for taking the exam.**

Absence policy: *Planned absences*: We expect that all students will attend every quiz, every term test and the final exam at the scheduled times; therefore, except for approved Institute activities, permission to miss a scheduled quiz/test/exam will only be given in extremely unusual

circumstances. This does not include activities such as "leaving early for Thanksgiving/Spring break", "there is a really interesting meeting/conference I want to attend", etc. As stated in the Georgia Tech regulations, "students should discuss planned absences with their instructors as soon as possible after the beginning of an academic term." We require that all planned absences be supported by documentation in advance of the planned absence. Therefore, planned absence from a quiz, term test and/or exam without prior discussion with the instructor and his/her approval will automatically result in a mark of zero for that quiz/term test/exam, with no exceptions.

Unplanned absences: If a student is unavoidably absent from one or more quizzes, terms tests or the final exam, he/she must notify the professor for their assigned section as soon as practically possible. The reason for the absence must be communicated and documentary evidence provided, e.g. a doctor's note in case of illness. Failure to provide suitable documentary evidence and/or timely notification will automatically result in a mark of zero for that quiz/term test/exam, with no exceptions.

Open book: The final exam and the term tests are "open book". This means that students may use any printed or written material during the exam, including but not limited to textbook(s), formula sheets, reference books, handwritten and/or printed class notes, previous years' exams, problem sets, problem set solutions, etc. However, to preserve the integrity of the exam, students may not use computers, tablets, e-readers, cell phones or any other electronic device (with the exception of calculators – see below) during the exam. Prohibited electronic devices must be packed away into bags during exams and be unavailable to students during the course of the exam.

You may expect that solution of some or all exam problems will require charts, tables and/or formulas from the textbook. Students are therefore strongly advised to bring a hard copy of the textbook or a printout of relevant sections from the e-textbook to exams with them.

Regrades: Regrade requests must **be submitted within one week after** graded materials are originally returned. The item to be regraded must be accompanied by an appropriately detailed written statement from the student explicitly identifying the reason(s) for the requested regrade. Please be aware that, except for trivial error of addition, all regrade requests will result in the complete remarking of the item, and thus the regrade can result in the overall mark for the item in question decreasing, increasing or staying the same.

Units: Units matter in real life[*]. Thus, for all answers that require units, half the marks for the answer are awarded for the numerical value and half are for the correct units. (Tragically, simply putting down the correct units does not give half the marks; the correct numerical value is required for full marks.)

Miscellaneous:

Stopping work. All students are required to finish working once time has been called by the instructor or TA during any quiz, term test and/or exam. Failure to comply with instructions to finish working will result in a penalty being assigned at the discretion of the instructor, up to and including a grade of zero in egregious cases.

Calculators. Students must use silent, non-communicating calculators during exams. Programmable/graphing calculators are allowed. However, calculators on cell phones or similar handheld devices may not be used at any time during exams. Further, calculators that can do symbolic mathematics (e.g. differentiation) are not allowed. Each student is responsible for bringing

[*] If you don't believe this, see http://en.wikipedia.org/wiki/Gimli_Glider & http://en.wikipedia.org/wiki/Mars_Surveyor_'98_program

a calculator to every exam; calculators may not be borrowed from the professor or TA and they may not be shared.

Email etiquette. Georgia Tech is a professional environment and all members of the campus community are expected to act accordingly. This extends to the use of email. Email inquiries to the instructor or TA should be addressed either "Dear Prof __", "Dear Mr __" or "Dear Ms __" (as appropriate), and signed with a student's first and last name in order to receive a response. This includes Piazza posts where students expect to receive a response from the instructors.

Cell phones. Cell phones must be silenced during all lectures, recitations, quizzes, tests and exams. Students are expected to avoid texting and messaging during lecture. Failure to comply with this policy may result in removal from the classroom.

Student privacy policy. Based upon the Family Educational Rights and Privacy Act (FERPA) (http://www.ed.gov/policy/gen/guid/fpco/ferpa/index.html), student grades and performance in the class can not legally be discussed with anyone other than the student; this includes parents.

Return of graded work. All graded materials will be handed back through the recitations prior to the final exam. Graded materials will not be available after the final exam.

BMED 3300 A,B,E,F: Biotransport Spring 2015 – Course Schedule

Day	Date	Topic	Instructor	Welty et al. Section(s)	Notable deadlines
Mon	Jan 5	***Course overview*** ***Unit I: Introduction*** What is biotransport? Generate ideas model (GIM).	CRE/MLK	1.1-1.4	
Wed	Jan 7	Units. Stresses. Fluid properties. Continuum concept. Fluid kinematics. Eulerian/Lagrangian. Steady/unsteady. Streamlines.	CRE	1.1-1.4	
Fri	Jan 9	***Unit II: Control Volume Approach*** Systems vs. Control Volumes. Fluxes.	CRE	3.1-3.4	
Mon	Jan 12	Reynolds Transport Theorem.	CRE	3.5, 4.1	
Wed	Jan 14	Control volume form of mass conservation.	MLK	4.2, 4.3	
Fri	Jan 16	Flipped session	MLK/CRE		
Mon	Jan 19	**Martin Luther King Day holiday – no class**			
Wed	Jan 21	Control volume form of momentum equation. Examples: momentum transport to cart, artificial ventricle.	CRE	5.1, 5.2	
Fri	Jan 23	Flipped session	MLK/CRE		
Mon	Jan 26	***Unit III: Differential Approach to Fluid Flow*** Fluid statics. Buoyancy. Fluid rheology.	CRE	2.1/4, 7.1/2/4	**Quiz 1**
Wed	Jan 28	Derivation of continuity equation. Example: flow in diverging duct.	CRE	9.1	
Fri	Jan 30	Flipped session	MLK/CRE		
Mon	Feb 2	Navier-Stokes equations. Navier-Stokes equations example: Poiseuille flow.	CRE	9.2, 8.1	
Wed	Feb 4	Example: Flow in the tear film.	CRE	8.2	
Fri	Feb 6	Flipped session	MLK/CRE		
Mon	Feb 9	Derivation of Euler-n, Euler-s and Bernoulli equations.	CRE	9.3	
Wed	Feb 11	Bernoulli and Euler equation examples: flow through a stenosis, flow in a curved vessel.	CRE	11.1, 11.3-5	**Matlab problem 1 due**
Fri	Feb 13	Flipped session	MLK/CRE		
Mon	Feb 16	***TERM TEST 1***	CRE		
Wed	Feb 18	***Unit IV: Dimensional Analysis and Real Flows*** Dimensions. Buckingham Pi theorem. Similitude. Model design.	CRE	12.3-12.5	
Fri	Feb 20	Flipped session	MLK		
Mon	Feb 23	What is a boundary layer? Laminar boundary layer equations & Blasius sol'n. Skin friction coefficient. Turbulent boundary layers.	CRE	12.8, 12.13-15	**Quiz 2**
Wed	Feb 25	Drag, lift, drag coefficient and lift coefficient. Example: peregrine falcon.	CRE	12.2	
Fri	Feb 27	Flipped session	MLK/CRE		**DROP DATE**
Mon	Mar 2	***Unit V: Diffusive Mass Transfer*** Introduction. Concentrations and mass fluxes. Brownian motion.	MLK	24.1	
Wed	Mar 4	The diffusion coefficient. Fick's first and second law.	MLK	24.1, 25.1-25.4	
Fri	Mar 6	Flipped session	MLK/CRE		
Mon	Mar 9	Steady-state diffusion in 1D.	MLK	26.1	
Wed	Mar 11	Steady-state diffusion in 1D - continued.	MLK	26.1	
Fri	Mar 13	Flipped session	MLK/CRE		**Matlab problem 2 due**
Mar 16-20		**Spring break – no class**			
Mon	Mar 23	Membrane transport. Permeability. Example: Overton's rules for cells.	MLK	Assigned notes	**Quiz 3**
Wed	Mar 25	Steady state diffusion with reactions.	MLK	26.1	
Fri	Mar 27	Flipped session	MLK/CRE		

Mon	Mar 30	***TERM TEST 2***	MLK		
Wed	Apr 1	Convective mass transfer.	MLK	15.1-5, 16.1-4, 17.1-2	
Fri	Apr 3	**Good Friday holiday – no class**			
Mon	Apr 6	Convective mass transfer in ducts – biological examples.	MLK	18.1, 27.1-2, 30.7	
Wed	Apr 8	Unsteady diffusion – error functions.	MLK	18.2, 27.4	
Fri	Apr 10	Flipped session	MLK/CRE		
Mon	Apr 13	Unsteady diffusion – charts.	MLK	Assigned notes	**Quiz 4**
Mon	Apr 15	***Unit VI: Heat Transfer and Convective Mass Transfer*** Conductive heat transfer, convection, radiation.	MLK	19.1-3,	
Fri	Apr 17	Flipped session	MLK/CRE		**Matlab problem 3 due**
Mon	Apr 20	Multimode heat transfer. Concentration/thermal boundary layer.	MLK	24.3,28.1-4	
Wed	Apr 22	Heat and mass exchangers. Example: hemodialysis.	MLK	22.1-2	
Fri	Apr 24	Analogy between heat, mass and momentum transfer. Overview of final exam.	CRE	19.6, 28.6-8	
Mon	Apr 27	**FINAL EXAM ALL SECTIONS:** 11:30am – 2:20pm (Period 2)			

Note that some topics will take somewhat less than one lecture to cover; others will require somewhat more than one lecture. The lecture schedule shown above is therefore approximate.