BMED3310 Syllabus

[Biotransport, AO1/A, and 3]

[Summer and 2026]

Instructor Information

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General Course Information

Description

The overall objective of this course is to introduce you to the fundamentals of momentum, heat and mass transfer for their application to biotransport problems.

Course Learning Outcomes

Specifically at the end of the course students will be able to:

1. Formulate differential equations that represent the physical situation of biomedical problems involving mass, momentum or heat transfer (or combinations of these) and determine appropriate boundary conditions.
2. Apply conservation laws of fluid flow to describe the system (pressure drops, velocities, velocity profiles, shear stresses, shear rates) for various geometries, particularly for flow through conduits.
3. Distinguish between modes of heat transfer or mass transfer, explain analogies between hear and mass transfer and apply the correct equations to describe each mode.
4. Apply differential mass balances to determine concentrations at a particular point or concentration profiles with and without (biochemical) reactions, and to determine mass fluxes.
5. Determine convective mass transfer coefficients using appropriate analogies for the geometric situation.

Required Course Materials

Recommended: Fundamentals of Momentum, Heat, and Mass Transfer, J.R. Welty, C.E. Wicks, R.E. Wilson, G. Rorrer, 5th ed, John Wiley & Sons, Inc., New York, NY, 2008.

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.

Grading Policy:

Calculation of course grade. A weighted average grade will be calculated as follows:

Exam 1	30%
Exam 2	30%
Exam 3	30%
Participation/Attendance	10%

The minimum grades that will be assigned for a given course average are:

>83%	A
>74%-83%	B
>65%-74%	C
60%-65%	D
<60%	F

Assignment

Homework will be posted on the website. Homework will not be graded. It is your responsibility to complete the homework. Homework solutions will be posted on the course website within one week after being handed out.

Description of Graded Components

There will be three exams. Everyone must take all of the exams. No make–up exams will be given. The exam will be at the end of three models on mass transfer, convective mass transfer and fluid mechanics and heat transfer. Each exam is worth 30% of the final grade.

Participation grade will be based on student attendance and participation in lectures and recitations

Course Policies

Attendance and/or Participation

Lectures: Attendance at lectures is required in person and attendance will be taken each lecture.

Problem Solving Session (PSS): The "flipped classroom" recitation format will be used in recitations. Students will form groups of 4-5 students who will work together on solving homework problems. TAs and instructor will be present to answer questions and assist with problem solving. Attendance at recitations is required in person and will be noted at each session..

Canvas: We will use canvas for official announcements, direct communication, sharing assignment files, quiz files, test files, sharing supplementary materials, posting and submission of all graded assignments, grade reporting, and sharing of links to instructional videos. Please make sure you check the Canvas website and familiarize yourself with all its features.

Log in to https://t-square.gatech.edu/portal using GTID. Class notes, homework and homework solutions are to be printed out from the web page.

Academic Integrity

Georgia Tech aims to cultivate a community based on trust, academic integrity, and honor. Students are expected to act according to the highest ethical standards. Review Georgia Tech's Honor Code and the student Code of Conduct.

Any student suspected of cheating or plagiarism on a quiz, exam, or assignment will be reported to the Office of Student Integrity, who will investigate the incident and identify the appropriate penalty for violations.

Core IMPACTS

Core IMPACTS is the University System of Georgia's General Education curriculum. If you are teaching a course that counts towards Core IMPACTS, you should include a syllabus statement about the Core area and associated career competencies. This resource developed by the Center for Excellence in Teaching and Learning and Online Education at Georgia State University includes template syllabus statements for each of the Core IMPACTS areas that you may adapt for your course.

Accommodations for Students with Disabilities

If you are a student with learning needs that require special accommodation, contact the Office of Disability Services (404-894-2563) as soon as possible to make an appointment to discuss your special needs and to obtain an accommodations letter. Please also e-mail me as soon as possible in order to set up a time to discuss your learning needs.

Student-Faculty Expectations Agreement

At Georgia Tech, we believe that it is important to strive for an atmosphere of mutual respect, acknowledgement, and responsibility between faculty members and the student body. The Student-Faculty Expectations articulate some basic expectations that you can have of me and that I have of you. In the end, simple respect for knowledge, hard work, and cordial interactions will help build the environment we seek. Therefore, I encourage you to remain committed to the ideals of Georgia Tech while in this class.

Course Expectations, Policies, and Resources

We are committed to creating an inclusive and supportive classroom

It is our intent for this class that all of us (students, teaching assistants, and instructors) feel respected and connected as a community of learners. In this class, we place a great deal of emphasis on working together. Cognitive science shows that people learn best when they interact with each other, building on each others' ideas. So, we've set things up so that you will almost always be interacting with someone else – your partner, your tablemates, and the instructors. Working with others can be challenging but we must learn how to do so effectively because it is an essential skill for today's engineer. This is because engineering teams composed of individuals with diverse backgrounds, skills, and perspectives are better able to identify new opportunities to create value and to solve problems efficiently and creatively. Diverse teams achieve these benefits only if they know how to work well together, to operate inclusively, and to authentically value their teammates varied skills, perspectives, and prior experiences.

In this course we will practice how to work and learn together. We need each of you to be comfortable sharing with each other, with your teaching assistants (TAs) and professor, what you don't know and what you are not sure about. Be patient with each other and always work to help each other learn. This is not a race. It is not the number of problems we solve together that matters. Rather, it is the quality of our learning that matters. We are likely to learn more by moving slowly and deliberately through a single problem than by racing through several problems without taking the time to reflect on what we've learned and what we're struggling to understand. Civil discourse, reasoned thought, sustained discussion, and constructive engagement without silencing or otherwise disrespecting others is expected of everyone in this class. This is important because if you do not feel respected or connected you may find it difficult to be at your best. Your problem-solving and productivity may suffer, and you may end up learning less. We can't let that happen. Let's work together to create a course climate that will enable everyone to realize their full potential.

Pre- &/or Co-Requisites

BMED 2210 (Minimum grade of C required) and MATH 2551 (or MATH 2401) and MATH 2552 (or MATH 2403)

Extensions, Late Assignments, & Re-Scheduled/Missed Exams

In Case of Difficulties: Please contact Dr. Babensee or Dr. Singh **AS SOON AS POSSIBLE** if you cannot complete an assignment or take an exam on time. We are willing to make reasonable accommodations, especially for things such as approved institute activities, emergencies, mental or physical health issues or religious observances. **The key here is that you need to communicate with us.** Without any communication and/or approval, assignments **will be accepted up to 48 hours after their due date,** but 25% of the points will be deducted each day. Assignments more than 48 hours late without communication get a 0.

Campus Resources for Students

Undergraduate Student Academic Success Resources:

- Academic Support: Academic Success and Advising (a unit in the Office of Undergraduate Education & Student Success) provides free support for your courses. Students can attend scheduled supplemental review (PLUS) sessions, stop by Drop-In Tutoring, or schedule a one-on-one appointment through Knack. To explore what options work best for you, please visit us online at success.gatech.edu/tutoring, email us at tutoring@gatech.edu, or come see us at Clough Undergraduate Learning Commons, Suite 283.

Student Well-Being:

At Georgia Tech, we are concerned about your overall physical, social, and mental well-being. A comprehensive list of wellness related resources has been compiled and maintained by the Office of the Vice President for Student Engagement and Well-being (student-resource-guide (gatech.edu)

Course Outline

MASS TRANSFER (Lecture #)

1. Fundamental Molecular Mass Transfer (1-2)

Concentrations, mass and molar velocities, fluxes
Fick's law, Diffusivity *(Simple mass transfer across a cell membrane or a polymeric membrane e.g., drug delivery)*
Rate equations for mass transfer in a binary mixture
Membrane permeability, molecular/pore diameter, partition coefficient, solute molecular weight (*Capillary wall permeability, polymeric membrane permeability)*
Convection mass transfer definition, mass transfer coefficient

2. Differential Equations of Mass Transfer (3-8)

Differential species mass balances – control volume, equation of continuity
Special forms of the continuity equation – Fick's second law, Laplace equation
Common boundary conditions
Shell Mass balances
Steps for modeling processes involving molecular diffusion (*Oxygen transport within an engineered tissue bundle, Mass transfer controlled by external diffusion resistance for solute evaporation from a supersaturated spherical droplet – flux)*
Diffusion with chemical reaction *[Respiration in a spherical cell – homogeneous reaction at a constant rate, Life Support For a Spherical Organism: First-Order Kinetics for Respiration (Thiele modulus)*, *O_2 transport in multicellular spheroid – critical aggregate size so no necrosis at core, Absorption of a species from a gas into a liquid in which a homogeneous first order chemical reaction occurs-rectangular coordinates, Immobilized biofilm for waste water treatment-rectangular coordinates, Cylindrical Coordinates with Constant Consumption Within Cylinder, Oxygen transport within an engineered tissue bundle revisited, Cylindrical Coordinates with First Order Consumption Within Cylinder*]
Diffusional resistances in series (*Rate controlling membrane in drug delivery*)

3. Convective Mass Transfer (9-12)

Dimensionless parameters – Schmidt number, Prandtl number, Lewis number
Concentration boundary layer analysis – Exact analysis and approximate analysis
Mass, Energy, and Momentum Analogies – Prandtl and von Karman analogies, Chilton-Colburn analogy
Leveque region, Fully developed region, mass transfer coefficients, effect of shear rate (Flow past a reactive wall – Blood Coagulation on Biomaterials – Thrombin Generation)
Transport of Solute Between a Capillary and the Surrounding Tissue – Krogh Tissue Cylinder, overall mass transfer coefficient
Solute Transport in a Vascularized Bed

Membrane processes, fluid side mass transfer coefficient with a permeable membrane, overall mass transfer coefficient (Hemodialysis)

MOMENTUM TRANSFER (Lecture #)

4. Fundamental Fluid Mechanics (13-15)

Fluid properties – point, system, element
Velocity and acceleration of fluid elements
Shear stress vs. shear rate, viscosity, wall shear stress, wall shear rate
Newtonian and Non-Newtonian fluids (*Water vs. Blood*) – Blood rheology, Casson equation, Fahraeus Effect, Fahraeus-Linquist Effect – explanations, Marginal zone theory
Steady Flow in a circular pipe: velocity profiles
Steady Flow in a circular pipe: Hagen-Poiseuille Equation, Rabinowitsch equation

5. Principles of Fluid Flow (16-19)

Macroscopic Mechanical Energy Balance
Bernoulli Equation and applications (*Pressure Drop through a nozzle: stenotic vessel*), friction losses – friction factor, friction loss (fittings, expansions, and contractions) and pump work
Hydraulic networks – pipes in series and pipes in parallel
Flow past immersed bodies – wall drag and form drag and drag coefficients

HEAT TRANSFER (Lecture #)

6. Fundamental Heat Transfer (20)

Conductive heat transfer, thermal conductivity, resistances (*conduction through a composite slab, conduction through a hollow cylinder, conduction in a hollow sphere*)
Convection heat transfer
Radiative heat transfer
Combined mechanisms of heat transfer, resistances in series, overall heat transfer coefficient (*composite slab with film resistances*)

7. Differential Equations of Heat Transfer (21)

Differential Equation for Heat Transfer
Bioheat equation
Special Forms of The Differential Energy Equation - Fournier field equation, Poisson equation, Laplace equation
Common boundary conditions
Conduction in Systems With Heat Sources - One-Dimensional Conduction With Internal Generation of Energy, planar wall, cylinder
Heat Transfer with phase change

8. Convective Heat Transfer (22)

Dimensionless parameters – Prandtl number, Nusselt number, Rayleigh number, Grashof number, Stanton number

Convective heat transfer coefficient correlations – Natural and forced convection, laminar flow, turbulent flow, different geometries

9. Transient Heat Transfer (23)

Lumped parameter analysis (low conduction resistance compared with convection)
(thermocouple response time)
Transient conduction charts, 2D an 3D transport *(cooling of a heart)*
Heat transfer into a semi-infinite medium *(skin burn injury)*