Engineering Faculty Document No. 76-18
March 16, 2018

**TO:** The Faculty of the College of Engineering

**FROM:** The Faculty of the School of Biomedical Engineering

**RE:** New Undergraduate Course, BME 45600, Mathematical Models and Methods in Physiology

The Faculty of the School of Biomedical Engineering has approved the following new course. This action is now submitted to the Engineering Faculty with a recommendation for approval.

**BME 45600 Mathematical Models and Methods in Physiology**
Term offered: Fall, Cr. 3
Prerequisite: BME 25600

**Description:** Teaches principles of mathematical modeling applied to the excitable tissues, including peripheral nerves, brain, muscle, and heart. Using small group, problem based learning, students solve challenging problems involving coupled differential equations, finite element analysis, simulated annealing, and other numerical methods in order to model consequences of assumptions about how excitable tissues work or interact with implanted devices. Creation of custom computer code is required. Written problem descriptions provided by the instructor are extensive and detailed, serving as a "guide on the side" to student groups, while requiring key discoveries to be made by students themselves. Background information for each problem is presented in lectures. Problems are related to topics such as the function of the cochlea, the genesis of the electrocardiogram, and deep brain stimulation for the treatment of Parkinson's disease.

**Reason:** This course provides undergraduate students opportunities to sharpen and refine their ability to apply mathematical techniques to problems in biology and medicine in a realistic way consistent with known anatomy and physiology. The course meets an identified need in the BME curriculum for upper level elective courses in medically related applications of mathematical modeling. This course provides advanced-level opportunities to integrate knowledge of physical sciences, mathematics, and life sciences, putting relevant concepts and techniques into practice.

This course has been offered seven times previously as a BME special topics with a regular enrollment of more than 20 upper-class students.

George R. Wodicka

George R. Wodicka,
Dane A. Miller Head and Professor
Weldon School of Biomedical Engineering

# BME 495 Mathematical Models and Methods in Physiology
# Fall 2015

**Class time: Mondays 3:30-5:20**
**Location: MJIS 1083**

**Course Instructor:**
Dr. Charles F. Babbs (babbs@purdue.edu)

**Volunteer Teaching Assistant:**
Matt Pharris (mpharris@purdue.edu)

**Course Description:** This course is more like a job and less like a typical college course. It uses real-world engineering problems to introduce advanced analytical tools and concepts relevant to biomedical engineering design. Each topic is briefly introduced, and students work in small teams to investigate physical mechanisms involving human anatomy and physiology using mathematical models and methods. Group work is done during scheduled class periods and other times by arrangement. Topics include brain concussions and protective helmets, origin of the electrocardiogram and bi-ventricular pacing, and deep brain stimulation for Parkinson's disease. Mathematical methods include coupled linear and nonlinear differential equations, finite element analysis, and simulated annealing. Creation of custom computer code is required. Students prepare extensive and detailed written technical reports. A midterm and a final examination encourage individual accountability and understanding.

**Learning outcomes:** Students will learn and practice the following engineering skills: Reviewing anatomy of a selected body organ or system, conducting research on a disease process using the Internet, pronouncing medical terms correctly, creating a biomechanical model of a body organ or tissue, preparing research progress notes in the form of power point slides; making spontaneous informal oral presentations of research progress, describing the function of a body organ system in terms of algebra, calculus, and/or governing differential equations, evaluating constants in mathematical models on the basis standard normal physiology and routine medical observations, solving second order, linear differential equations by the method of undetermined coefficients, programming in MATLAB or a suitable computational engine including the use of arrays and subroutines; debugging computer code; testing the validity of numerical methods such as Newton-Raphson, validating mathematical models by comparison with known analytical solutions, solving systems of coupled linear or nonlinear differential equations using numerical methods such as simple Euler or Runge-Kutta, solving systems of simultaneous equations using tools such as simulated annealing, Gauss-Seidel, Gauss-Jordan, creating graphs and charts of results, reconciling theoretical calculations with experimental observations, discussing the strengths and limitations of a particular mathematical model, preparing a bibliography for a technical report, writing, revising, an proofreading detailed technical reports, working in teams in both face-to-face and online environments to enhance productivity and eliminate errors.

**Class Attendance:** Attendance is required for introductory sessions. Attendance is required also at work sessions during regular class time (3:30 to 5 p.m. Mondays), during which spontaneous oral progress reports may be requested by the staff. Some additional team meetings and work sessions will likely be needed as "homework", and can be scheduled by arrangement within each group. Online collaboration using Google documents is recommended (see docs.google.com).

**Course Format:** Class sessions are designed to be interactive and task oriented with a minimal number of formal lectures. Groups are required to meet and work on assignments during class time when there is no lecture. To investigate topics students will use the first floor laboratories, small group study rooms, Internet access, and electronic document support. Groups are required to keep current research progress notes in the form of Microsoft Word documents or Power Point slides. Faculty and staff may request spontaneous oral progress reports at any time during scheduled class sessions. Faculty and staff will be available to address questions and give encouragement as well as to hear oral progress reports. The written problem statements provided to students on Blackboard are exceedingly detailed and supplied with adequate hints so that students can do challenging, advanced work while avoiding false starts and blind alleys. These written problem statements include instruction and guidance on relevant mathematical methods.

**Campus Emergency Response Procedures:**

- Fire Alarm – Evacuate the building using the exits on the east side of RM 1087 or 1083 MJIS. Only gather personal items if it does not jeopardize your safety. Assist those who need help, if possible. Proceed to the front lawn of the Burton Morgan Building. Report to a course instructor your name before leaving the emergency assembly area.
- All hazards warning (examples of hazards: tornado (severe weather)/hazardous materials release/civil unrest/directed by police personnel) – When you hear the all hazards alarm immediately seek shelter. Continue to a safe location (typically the lowest level of the building in an area without windows).
- To report an emergency, call 911. To obtain updates regarding an ongoing emergency, sign up for Purdue Alert text messages, view www.purdue.edu/ea.
- There are nearly 300 Emergency Telephones outdoors across campus and in parking garages that connect directly to the PUPD. If you feel threatened or need help, push the button and you will be connected immediately.
- If we hear a fire alarm during class we will immediately suspend class, evacuate the building, and proceed outdoors. Do not use the elevator.
- If we are notified during class of a Shelter in Place requirement for a tornado warning, we will suspend class and shelter in the basement.
- If we are notified during class of a Shelter in Place requirement for a hazardous materials release, or a civil disturbance, including a shooting or other use of weapons, we will suspend class and shelter in the classroom, shutting the door and turning off the lights.

- Please review the Emergency Preparedness website for additional information. http://www.purdue.edu/ehps/emergency_preparedness/index.html

**Campus Emergency Policy:** In the event of a campus wide emergency the class outline and course requirements may be subject to change. The course instructor will provide information in regards to changes in the course requirements or course schedule as a result of a campus wide emergency.

| | COURSE OUTCOME | Relationship to BME program outcomes |
|---|---|---|
| I | Effectively communicate skills in oral and written form, both individually and as part of a team. | 6, 7 |
| III | Generate and justify solutions to a medical and/or biological problems that addresses customer needs and realistic constraints | 1, 3 |

**Students with Disabilities:** Any student who feels s/he may need an accommodation based on the impact of a disability should contact the instructor privately to discuss specific needs. Please contact the Disability Resource Center in room 830 Young Hall for more information on reasonable accommodations for students with documented disabilities.

**Academic Conduct:** Students are expected to behave in a professional and ethical manner in all aspects of this course. Plagiarism, cheating, or other acts of academic dishonesty will not be tolerated. Any infractions whatsoever will result in immediate expulsion from the course and a failing grade for the semester. Instances of plagiarism or cheating will also be reported to the Dean of Students Office to be recorded on your permanent academic record. If an individual behaves in any other manner that is unprofessional or unethical during the semester, the course instructor(s) reserves the right to fail the student for that as well. For more information, see the Purdue University Student Conduct Code at: http://www.purdue.edu/odos/adminstration/codeconduct.htm.

**Strength of Diversity:** In this course, each voice in the classroom has something of value to contribute. Please take care to respect the different experiences, beliefs and values expressed by students and staff involved in this course. We support Purdue's commitment to diversity, and welcome individuals of all ages, backgrounds, citizenships, disabilities, education, ethnicities, family statuses, genders, gender identities, geographical locations, languages, military experience, political views, races, religions, sexual orientations, socioeconomic statuses, and work experiences.

## Course Assessment

**Grade Composition and Grading Scale (subject to change with notice):**

- 3 group-based, written technical reports, 60% (grade penalties for lateness)
- 1 individual midterm exam, 15%
- Comprehensive individual final exam, 25%

| | |
|---|---|
| 90-100% | A |
| 80-89% | B |
| 70-79% | C |
| 60-69% | D |
| 00-59% | F |

**Make-up exams:** Given at the discretion of the instructor; format may be different from regular exams. Advance notice, when possible, is highly recommended. Students must adhere to Purdue policy as outlined: http://www.purdue.edu/usp/acad_policies/attendance.shtml

**Problem work groups:**

- Modified random assignment of group members (see attached list)
- Practice "teaming", including face-to-face and online collaboration
- Work product is a detailed and complete technical report (see style guide)
- Individual grades on technical reports determined from overall report grade and individual grade correction factors based on peer evaluations (see below)

**Group dynamics**

Teamwork is essential in biomedical engineering. All members of each report writing group are expected to contribute evenly. Rotate roles to enhance the learning experience (lead author, code writer, Power Point maestro, etc.) Encourage quieter members to speak up. Encourage more dominant personalities to listen. Work through minor personal and interpersonal issues with respectful, open communication. If major personal or interpersonal problems arise, contact the instructors early-on.

**Peer evaluation**

To minimize problems with loafing or freeloading by individual members and to mimic the real-world situation in which a person's reputation at work matters, a peer evaluation system will be used in this course. Educational research has shown that having multiple peer evaluations reduces social loafing and increases students' satisfaction with group members' contribution and also the perceived fairness of the project grades (Aggarwal, 2008). The simple, survey-based system that we will use in this course is the most effective and fair yet devised (Zhang and Ohland, 2009). After each technical report is turned in, group members will receive and E-mail with a link to a short survey in which they rate the contributions of all group members, including themselves to the overall success of the project. Individual grades, $G_i$, will be calculated from the group grade, $G_g$, as

$$G_i = G_g \cdot \left[ 0.5 + 0.5 \frac{\text{average individual rating}}{\text{average rating for entire group}} \right].$$

Game theory analysis shows that the best strategy for self and peer evaluations under this system is to tell the truth—that is, people who try to fake out the system tend to get worse grades (Tu and Lu, 2005).

## Schedule for 2015

| **Week (date)** | **Topic / Event** |
|---|---|
| Week 1<br>Aug 24 | Course introduction<br>***Background Lecture:*** Bio-impedance<br>Begin Problem 1: The impedance stethoscope<br>Study and review of vital signs |
| Week 2<br>Aug 31 | Small group work |
| Week 3<br>Sept 7 | Labor Day -- No class<br>Small group work |
| Week 4<br>Sept 14 | Small group work |
| Week 5<br>Sept 21 | Small group work |
| Week 6<br>Sept 28 | **Problem 1 report due**<br>***Background lecture:*** Systemic arterial hypertension<br>Begin Problem 2: Accuracy of blood pressure readings<br>Study and review of cardiovascular physiology |
| Week 7<br>Oct 5 | Small group work |
| October Break<br>Oct 12 | No class |
| Week 8<br>Oct 19 | **Midterm exam (one hour)**<br><br>Small group work |
| Week 9<br>Oct 26 | Small group work |
| Week 10<br>Nov 2 | Small group work |
| Week 11<br>Nov 9 | **Problem 2 report due**<br>***Background lecture:*** Pulmonary hypertension<br>Begin Problem 3: Measuring pulmonary artery pressure with microbubbles<br>Study and review of spring-mass-damper mechanics |
| Week 12<br>Nov 16 | Small group work |
| Week 14<br>Nov 23 | Small group work |
| Week 15<br>Nov 30 | Small group work |
| Week 16<br>Dec 7 | **Problem 3 report due** |
| TBA | **Final Exam** |

**Style guide for technical reports**

Reports should be submitted in the style of Biomedical Engineering Online (featuring and emphasizing the mathematical methods). For a sample of the formatting style go to http://www.biomedical-engineering-online.com/content, or see the sample article posted on Blackboard.

Reports should include the following elements:

- Title
- Authors names
- Structured abstract with Background, Methods, Results, and Conclusions
- Background section including description of relevant anatomy, physiology, disease process, objective of the present research
- Methods section including theory, approach, diagrams of models, derivation and solution of equations in proper mathematical style, numerical methods, methods for estimation of parameter values, tables showing parameter values used with references if appropriate
  **For full credit show detailed steps of mathematical derivations**
- Results section including validation of methods, numerical results, presented in Figures and legends as well as Tables in line with the text, positioned for easy reading and accompanied by brief prose descriptions of the results, which never "speak for themselves"
- Discussion including major general principles discovered, limitations of the models and methods, reasons why the limitations can be discounted in this case (otherwise it would have been stupid to proceed)
- Conclusions regarding the biological or medical significance of the results
- References at the end in style of BME Online
- Appendices, such as computer code, when indicated.

# BME 495 Fall 2015 Problem Work Groups

| Group # | Name 1 | Name 2 | Name 3 | Name 4 |
|---|---|---|---|---|
| 1 | | | | |
| 2 | | | | |
| 3 | | | | |
| 4 | | | | |
| 5 | | | | |
| 6 | | | | |