PURDUE UNIVERSITY | College of Engineering

Engineering Faculty Document No.: 16-24
8/31/2023

TO: The Engineering Faculty

FROM: The Faculty of the Weldon School of Biomedical Engineering

RE: New 200-level course – BME 20200, Thermodynamics of Biomedical Engineering

The Faculty of the Weldon School of Biomedical Engineering has approved the following new 200-level course. This action is now submitted to the Engineering Faculty with a recommendation for approval.

FROM:
BME 29500 Thermodynamics in Biol Sys II
Term offered: Spring
3 credit Lecture
Requisites, Restrictions, and Attributes: Department Permission
Previously offered Spring 2019 thru Spring 2023 with enrollments climbing from 75 to over 150 students per offering.

TO:
BME 20200 Thermodynamics in Biomedical Engineering
Term offered: Spring
3 credit Lecture
Requisites, Restrictions, and Attributes:
Prerequisites: MA 26200 FOR LEVEL UG WITH MIN. GRADE OF D- [MAY BE TAKEN CONCURRENTLY] OR (MA 26500 FOR LEVEL UG WITH MIN. GRADE OF D- [MAY BE TAKEN CONCURRENTLY] AND MA 26600 FOR LEVEL UG WITH MIN. GRADE OF D- [MAY BE TAKEN CONCURRENTLY])
Major Restriction: Biomedical Engineering only

Description: The major objective for this course is to understand and exploit basic principles of thermodynamics as they apply to biological systems and biological processes. Specifically, the course will focus on biological processes across scales: from the nanometer scale of biomolecules, the micrometer scale of cells, the millimeter and meter scales of tissues and organisms, all the way up to the 100+ meter scale for bioprocess equipment and industry-scale production with a focus on dynamic behaviors of systems. The course can be loosely classified into two parts: (i) guiding principles and fundamental equations for thermodynamics in biological and biomedical engineering, and (ii) applications of engineering principles to the study of biological systems.

RATIONALE:

This required core course for all BME sophomores has been taught with a temporary course number (BME 29500) for a number of years and was previously cross-listed with ABE 20200. In coordination with the Department of Agricultural and Biological Engineering we have agreed to separate these courses. We are therefore submitting our BME course for a permanent course number and title. This course is intended to provide students with skills in applying principles of thermodynamics to the study and engineering design of dynamic biomedical systems. Another key course outcome includes the ability to solve multiphysics and multi-scale problems for thermodynamic processes using the computer.

It has been offered for 5 consecutive spring semesters now (2019 to present) with course evaluation averages starting at 3.79 and now at 4.37.

Nan Kong
Professor and Deputy Head
Weldon School of Biomedical Engineering

Link to Curriculog entry: BME - 20200 - Thermo in BME | Curriculog

Course Information

- **Course number and title:** BME20200 Thermodynamics in Biomedical Engineering
- **CRN:**
  - BME20200: 10199
- **Meeting day(s) and time(s)**.
  - Tuesdays, Thursdays 9:00 – 10:15 AM.
- **Instructional Modality**
  - Face-to-Face
- **Course credit hours**
  - 3
- **Prerequisites (if any**)
  - MA 26200 FOR LEVEL UG WITH MIN. GRADE OF D- [MAY BE TAKEN CONCURRENTLY] OR (MA 26500 FOR LEVEL UG WITH MIN. GRADE OF D- [MAY BE TAKEN CONCURRENTLY] AND MA 26600 FOR LEVEL UG WITH MIN. GRADE OF D- [MAY BE TAKEN CONCURRENTLY])

Instructor(s) Contact Information

- **Instructor(s)**
  - Dr. Elsje Pienaar
    epienaar@purdue.edu
    765-494-4682
    MJIS 3074
    Office hours: Tuesdays 10:30 to 11:30 (After class)
  - Email communications are preferred. Emails are read between 9 a.m. and 5 p.m. daily and will be responded to within 48 hours. Please be flexible with these times before deadlines and exams when we get a lot of emails.
  - Please use BME202 as the subject heading in all emails.
- Teaching Assistants
  - Graduate TAs
    - Peter Brumm: pbrumm@purdue.edu
    - Cheng Bi: bi19@purdue.edu
    - Mothieshwar (Mothi) Jayaraman Krishnan, jayara11@purdue.edu
  - Undergraduate tutors
    - Sumantika Sekar: sekars@purdue.edu
    - Siting Zhang: zhan3465@purdue.edu
    - Nikki Kulkarni: kulkar59@purdue.edu
    - Marlee Shepherd: mishephe@purdue.edu
  - TA office hours:
    - BME Resource Center hours with graduate TAs and undergraduate tutors: 7 – 9pm Mondays and Wednesdays in MJIS1097.

Course Description

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How will computation be used in this class? What if I don't know how to code?

This course uses Jupyter Notebooks (in the form of Google Collaboratories), an open-source web application that provides an interactive online environment for computing. What this means is that in each lecture you'll get a link to an online worksheet that will contain the lecture notes as well as the computing exercises for that class period. These documents can be modified by each student to add their own notes, comments, questions and code.

All computing exercises are in python. However, in the first half of the semester all the computing exercises are going to be tightly related to the provided examples. You will be doing things like modifying an example script to change the inputs or to add new variables to a system of equations.

Later in the semester, as you become more familiar with the Jupyter notebook environment, you will be asked to develop models from scratch, but by that point you will have many examples to draw upon. We do not anticipate that python coding will be a source of difficulty in this class but if it is we will provide the resources to help you through this hurdle.

We strongly encourage you to bring a laptop or tablet to this class. If you do not own or a laptop or tablet please let me know and we can make arrangements to facilitate your full class participation/learning.

How will active learning work in this course?

Modeling activities in which you will iteratively develop predictions/hypotheses about how systems work and then compare your predictions to data from computational models. In these exercises you will iteratively refine your understanding of thermodynamics principles and develop intuition about the function of thermodynamics systems.

Class-based research

This course is the product of funded design-based research. We are continuously examining our teaching practices to see how we can provide the most educational value to our students. To support this process we will be observing the classroom and qualitatively examining classroom materials produced in this course. All data and observations from this course will be de-identified to respect student privacy. Consent forms that will allow you to opt-in or opt-out of data collection, will be administered before any classroom observation or materials collection. Your classroom experience and your grade will not be affected in any way. Please contact your instructors with any concerns or questions you might have about this process.

Learning Resources, Technology & Texts

- **Textbook**
  - The fundamental thermodynamic concepts as well as some of the examples are from the textbook "Chemical, Biochemical and Engineering Thermodynamics" by Stanley Sandler 5th Edition.
- **Brightspace learning management system** will be used to communicate course materials and grades. We will use the merged course (BME202) on Brightspace to communicate with everyone.
- **Gradescope** will be used for some assignments and homework.
- **CATME** will be used to assign teams and perform peer evaluations of team members**.**

Learning Outcomes

Successful completion of the course will enable students to meet the following learning objectives:

- Understand basic principles of Mass, Energy, and Entropy balance equations that describe thermodynamic processes (SO 1, 6, 7)
- Apply the following concepts to solve problems in the biological engineering and biomedical engineering disciplines (SO 1, 6, 7)
    - First & Second Law of Thermodynamics
    - Open vs closed systems
    - Balances of mass, heat, work, and entropy/energy flow
    - Reversibility/irreversibility
- Gain knowledge of main factors that determine numerical values of physical chemical properties associated with bioprocesses. (SO 7)
- Solve problems for thermodynamic processes using the computer. (SO 1, 2, 5, 7)

Additionally, students will benefit in the following ways:

- Students will develop the attitudinal dimensions of computational thinking (SO 2)
    - Confidence in dealing with complexity
    - Persistence in working with difficult problems
    - Tolerance for ambiguity
    - The ability to deal with open ended problems
    - The ability to communicate and work with others to achieve a common goal or solution
- Students will gain experience in working with non-linear systems and systems away from equilibrium (SO 1, 6)

Assignments

Your learning will be assessed through a combination of participation, homework, projects, mid-term and final exam spread throughout the academic period. Details on these assignments and exams, including a schedule of due dates, rubrics to guide evaluation, and guidelines on participation and evaluation will be posted on the course website.

- Participation (5%; ongoing). Participation points can be earned by completing and uploading in-class active learning collaboratories to Brightspace, completing surveys and contributing to group discussions.
- Homework (15%).
- Computational Projects (40% three projects throughout the semester).
- Mid-term exam (20%).
- Final exam (20%).

Grading Scale

Grade Ranges

Grade	GPA Value	Range
A+,A	4.0	93-100
A-	3.7	90.0-92.9
B+	3.3	87.0-89.9
B	3.0	83.0-86.9
B-	2.7	80.0-82.9
C+	2.3	77.0-79.9
C	2.0	73.0-76.9
C-	1.7	70.0-72.9
D+	1.3	67.0-69.9
D	1.0	63.0-66.9
D-	0.7	60.0-62.9
F	0.0	<60.0

NOTE: The scale can change per instructor discretion so that a given grade may fall into a lower bin range (i.e. A, A+ could drop down to 83-90) if the instructor deems it necessary. Under no circumstances will the reverse occur.

Attendance Policy

This course follows Purdue's academic regulations regarding attendance, which states that students are expected to be present for every meeting of the classes in which they are enrolled. When conflicts or absences can be anticipated, such as for many University-sponsored activities and religious observations, the student should inform the instructor of the situation as far in advance as possible. For unanticipated or emergency absences when advance notification to the instructor is not possible, the student should contact the instructor as soon as possible by email or phone. When the student is unable to make direct contact with the instructor and is unable to leave word with the instructor's department because of circumstances beyond the student's control, and in cases falling under excused absence regulations, the student or the student's representative should contact or go to the Office of the Dean of Students website to complete appropriate forms for instructor notification. Under academic regulations, excused absences may be granted for cases of grief/bereavement, military service, jury duty, and parenting leave. For details, see the Academic Regulations & Student Conduct section of the University Catalog website.
Guidance on class attendance related to COVID-19 are outlined in the Protect Purdue Pledge for Fall 2021 on the Protect Purdue website.

Regrade Policy

Students have the right to contest any grades throughout the semester. In the event that a student feels an assignment has been inappropriately graded, the student must provide a clear written explanation for the re-grading submission along with the original assignment. Students have **1 week** after the return of a graded assignment to protest a grade; after this time grade disputes will not be accepted. Papers and exams submitted for re-grading will be completely reevaluated (i.e., the entire paper will be re-graded, not only the portion under protest).

Late submission policy

If an assignment is submitted after the deadline, we will still grade the submission if we receive it within 12 hours of the original deadline. Beyond 12 hours, we will still grade the submission, but we will subtract 50% from what your original grade would have been. If you submit your work after the assignment was reviewed in class, or after the solutions are posted, you will not be able to receive any credit for this late submission.

Make-up exams

In the event that you need to miss an exam due to illness or other Purdue excused absences, we can only offer make-up exams if we receive either a Doctor's note or official notification from Purdue prior to the exam.

Academic Guidance in the Event a Student is Quarantined/Isolated

If you must miss class at any point in time during the semester, please reach out to me via email so that we can communicate about how you can maintain your academic progress. If you find yourself too sick to progress in the course, notify your adviser and notify me via email or Brightspace. We will make arrangements based on your particular situation. Please note that, according to Details for Students on Normal Operations for Fall 2021 announced on the Protect Purdue website, "individuals who test positive for COVID-19 are not guaranteed remote access to all course activities, materials, and assignments."

Classroom Guidance Regarding Protect Purdue

Any student who has substantial reason to believe that another person is threatening the safety of others by not complying with Protect Purdue protocols is encouraged to report the behavior to and discuss the next steps with their instructor. Students also have the option of reporting the behavior to the Office of the Student Rights and Responsibilities. See also Purdue University Bill of Student Rights and the Violent Behavior Policy under University Resources in Brightspace.

Academic Integrity

Academic integrity is one of the highest values that Purdue University holds. Individuals are encouraged to alert university officials to potential breaches of this value by either emailing integrity@purdue.edu or by calling 765-494-8778. While information may be submitted anonymously, the more information is submitted the greater the opportunity for the university to investigate the concern. More details are available on our course Brightspace table of contents, under University Policies.

Nondiscrimination Statement

Purdue University is committed to maintaining a community which recognizes and values the inherent worth and dignity of every person; fosters tolerance, sensitivity, understanding, and mutual respect among its members; and encourages each individual to strive to reach his or her potential. In pursuit of its goal of academic excellence, the University seeks to develop and nurture diversity. The University believes that diversity among its many members strengthens the institution, stimulates creativity, promotes the exchange of ideas, and enriches campus life. A hyperlink to Purdue's full Nondiscrimination Policy Statement is included in our course Brightspace under University Policies.

Accessibility

Purdue University is committed to making learning experiences accessible. If you anticipate or experience physical or academic barriers based on disability, you are welcome to let me know so that we can discuss options. You are also encouraged to contact the Disability Resource Center at: drc@purdue.edu or by phone: 765-494-1247.

Mental Health/Wellness Statement

If you find yourself beginning to feel some stress, anxiety and/or feeling slightly overwhelmed, try WellTrack**.** Sign in and find information and tools at your fingertips, available to you at any time.

If you need support and information about options and resources, please contact or see the Office of the Dean of Students. Call 765-494-1747. Hours of operation are M-F, 8 am- 5 pm.

If you find yourself struggling to find a healthy balance between academics, social life, stress, etc. sign up for free one-on-one virtual or in-person sessions with a Purdue Wellness Coach at RecWell. Student coaches can help you navigate through barriers and challenges toward your goals throughout the semester. Sign up is completely free and can be done on BoilerConnect. If you have any questions, please contact Purdue Wellness at evans240@purdue.edu.

If you're struggling and need mental health services: Purdue University is committed to advancing the mental health and well-being of its students. If you or someone you know is feeling overwhelmed, depressed, and/or in need of mental health support, services are available. For help, such individuals should contact Counseling and Psychological Services (CAPS) at 765-494-6995 during and after hours, on weekends and holidays, or by going to the CAPS office on the second floor of the Purdue University Student Health Center (PUSH) during business hours.

Basic Needs Security

Any student who faces challenges securing their food or housing and believes this may affect their performance in the course is urged to contact the Dean of Students for support. There is no appointment needed and Student Support Services is available to serve students 8 a.m.-5 p.m. Monday through Friday. Considering the significant disruptions caused by the current global crisis as it related to COVID-19, students may submit requests for emergency assistance from the Critical Needs Fund

Emergency Preparation

In the event of a major campus emergency, course requirements, deadlines and grading percentages are subject to changes that may be necessitated by a revised semester calendar or other circumstances beyond the instructor's control. Relevant changes to this course will be posted onto the course website or can be obtained by contacting the instructors or TAs via email or phone. You are expected to read your @purdue.edu email on a frequent basis.

Tentative Schedule

* This schedule is subject to change.

Week	Starting	Topics Covered	Activities
1	9-Jan	Syllabus review, Introduction to scientific computing with Python and Google Collaboratories Introduction to thermodynamic fundamentals, Intensive/Extensive properties Fundamental Theorem of Calculus	
2	16-Jan	Differential mass balance analysis of chemical reactions Using stoichiometric equivalents to model the progress of chemical reactions Analytical and Numerical approaches to solve mass balance reactions under dynamic conditions	Homework 1 assigned
3	23-Jan	Mass balance in biological systems	Homework 1 due Project 1 assigned
4	30-Jan	Applying Energy Balance equations to chemical biological and biomedical systems Special focus on understanding heat vs temperature and developing an intuition around the first law of thermodynamics	
5	6-Feb	Guest lecture Dr. Leo Green Introduction to information transfer in biological systems (signal transduction) Models of transcriptional gene regulation (Logic model, Hill Function)	Project 1 due

6	13-Feb	Work Specific Heat Ideal gas law	Toxin project assigned
7	20-Feb	Entropy 2nd law of thermodynamics	
8	27-Feb	Using entropy balance equations in conjunction with mass balance and energy balance equations to solve problems in chemical, biological and biomedical engineering	Toxin project due
9	6-Mar	Exam review, and mid-term exam during class time	Mid-term exam
10	13-Mar	Spring break - no class	Spring break - no class
11	20-Mar	Heat exchange Maximum efficiency Free Energy Parallel and countercurrent flow	
12	27-Mar	Rod problem Fourier approach Steady state Temp distribution Boundary conditions for heat equation	Chemical reactor project assigned
13	3-Apr	Vapor liquid equilibrium and fugacity	
14	10-Apr	Van der waals equations of state Peng-Robinson Equations of State	Reactor project due
15	17-Apr	Mass transport Brownian motion and diffusion reaction and diffusion in biological systems Receptor ligand interactions	
16	24-Apr	Antibody detection project in class work Exam Review	Dead week
Finals Week	1-May		Final exam