Prof. Lydia L. Sohn
Course Proposal, Mechanical Engineering
2/21/2020, Revised 7/10/2020

ME 126 / 226L: The Science and Engineering of Cooking (4 units)

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Lectures T/Th 1:30-3:00pm

Description

This course will discuss concepts from the physical sciences and engineering (e.g. heat and mass transfer, phase transitions, fluid mechanics, etc.) that serve as a foundation for everyday cooking and haute cuisine. The course will integrate the expertise of visiting chefs from the Bay Area (and beyond) who will serve as guest lecturers and present their cooking techniques. These unique opportunities will be complemented by lectures that investigate in-depth the science and engineering that underlie these techniques. Demonstrations and guest lectures by food science leaders/technologists will also be featured. Working in teams of 3-4, students will perform "edible" labs that focus on the particular topic introduced by the chef or food scientist of the week. Homework will reinforce the topics. For undergraduates, two midterms will test the understanding of these topics. For graduate students, two midterm papers will be required to demonstrate a working understanding of course material. A final written project and presentation will be in lieu of a final exam.

At the end of the course, students will be able to explain how a range of cooking techniques and recipes work, in terms of the physical and chemical transformations of the food.

Campus permitting, invited Chefs will give public lectures on their techniques the same week that they present to the class.

Prerequisites

At a minimum: Physics 7a and Chemistry 1a. An introduction to thermodynamics (ME109) and to materials (ME108) is strongly recommended.

Textbook

Primary: On Food and Cooking: The Science and Lore of the Kitchen, Harold McGee, Scribner, 2004 (2nd Edition)
Suggested: The Food Lab: Better Home Cooking Through Science, Kenji Lopez, W. W. Norton & Company, 2015

Additional textbooks covering the scientific and engineering aspects of cooking will be put on reserve.

Course Objectives

The purpose of this course is to:

- apply fundamental science and engineering concepts that are at the heart of cooking and the new wave of modernist cuisine occurring in the culinary field
- enhance skills in design, prototyping, testing, and analysis through hands-on laboratory exercises, as cooking is fundamentally an experimental science
- apply the principles of engineering and physics to adapt or scale recipes to meet "design challenges" and predict results of such modifications
- learn interdisciplinary skillsets from a broad spectrum of specialties

Desired Course Outcomes

Overall, students will learn and develop critical thinking skills for how to approach and quantitatively solve interdisciplinary problems. They will be able to explain the science behind a range of cooking techniques, and how that science contributes to a successful recipe, in terms of the physical and chemical transformations of the food. In greater detail, they will be able to explain practical applications of heat and mass transfer, flow characteristics of fluid, electromagnetic radiation, and material properties of foods as they are heated and cooled. Although cooking is an activity that most people have witnessed or participated in, this course will dissect the physical phenomena underlying common techniques. The course will give concrete examples of the principles discussed in engineering classes (e.g. heat and mass transfer), allowing students to make intuitive connections between coursework and their everyday lives. Furthermore, students will apply the appropriate engineering concepts to solve realistic engineering problems that occur daily in everyone's life. Students will learn to propose and develop a project, perform project management, and develop communication skills through oral presentations and within the context of team dynamics.

Topics Covered
Energy, Temperature, Heat, Phase transitions, Elasticity, Diffusion, Heat transfer, Fluid Mechanics, Viscosity, Enzymatic reactions, and Emulsions

Class/Laboratory Schedule
Three hours of lectures and 1 hour of discussion per week. 2-hour laboratory experiments per week. Accommodations will be made for those students who have specific food allergies (no experiments will involve tree nuts or peanuts).

Contribution of the Course to Meeting Professional Components
Students are required to work in teams and to write a professional report detailing their background literature search, design process, experimental testing, data analysis, and design process. Students are required to provide an in-depth oral presentation to the class.

Relationship of the Course to ABET Program Outcomes
- an ability to apply knowledge of mathematics, science, and engineering
- an ability to design and conduct experiments, as well as to analyze and interpret data
- an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability
- an ability to function within multi-disciplinary teams
- an ability to identify, formulate, and solve engineering problems
- an understanding of professional and ethical responsibility
- an ability to communicate effectively
- the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context
- a recognition of the need for, and an ability to engage in life-long learning
- an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice

Assessment of Student Progress toward Course Objectives
Students will be assessed with homework, lab worksheets (which have questions on experiments, results, and data analysis), midterm exams, and a final project (which will include a project proposal, progress reports, a final report, and final presentation).

Course Syllabus (Tentative) and Grading

Grading

Class Component	% Toward Final Grade	Additional Information
Homework	15%	Homework will consist of quantitative problem sets applying physical science and engineering concepts (e.g. thermodynamics, fluid mechanics, phase change, etc.) to the solution of cooking-based problems. Graduate students: Computational modeling will be used to supplement assignments.
Lab Worksheet	20%	Undergraduates: Worksheets will have questions on experiments, results, and data analysis. Graduate students: In depth lab reports will be required. Reports will include a description of the experiment, experimental results, and statistical analyses. Quantitative discussion of results based on principles covered in weekly lectures must be applied.
Midterm Exam	2 x 20%	Undergraduates: two exams to test concepts and labs to date Graduate students: In lieu of midterm exams, two in-depth midterm papers on different cooking phenomena investigated in the edible labs will be required.
Final Project	25%	Final project proposal, progress reports, final report, and final presentation are required. Final projects are expected to involve recipe development Graduate students: Final projects are expected to mathematical modeling of cooking phenomena (e.g. genetic diversity of sourdough)

Syllabus (Tentative)

Week	Topic	Reading	Lab
1	**Components of Food & Historical Background** Introduction, Food components, moles, etc.	McGee, Chapter 15: "The Four Basic Food Molecules" (p. 793-809) and Appendix A: "A Chemistry Primer—Atoms, Molecules, and Energy" (p. 811-817)	No Lab
2	**Energy, Temperature, and Heat** Energy, calorimetry, molecular bonds, heating and temperature	McGee, Chapter 14: "Cooking Methods and Utensil Materials" (p. 777-787)	Introduction to various modern tools (sous vide), inductive heating, calibration
3	**Phase Transitions** Phase behavior macroscopically and microscopically, temperature, pressure, phase diagrams, violations to phase diagrams	McGee, Chapter 2: "Eggs" (p. 69-87) Supplemental Handouts	Phase transitions of sugar and eggs
4	**Enzymatic Reactions and Fermentation** Chemical processes in microbes, fermentation, yeast	Reese et al., Influences of Ingredients and bakers on the Bacteria and Fungi in Sourdough Starters and Bread, mSphere (2020) De Vuyst et al., Microbial Ecology and Process Technology of Sourdough Fermentation, Adv. Appl. Microbiol (2017)	Microbial communities of sourdoughs
5	**Elasticity** Mouthfeel, texture, molecular origins of elasticity, gels, steak, tofu, flan	Sakai et al., Increasing Elasticity through Changes in the Secondary Structure of Gelatin by Gelation in a Microsized Lipid Space, ACS Central Science (2018) Cheng et al., The Viscoelastic Properties of Soybean Curd (Tofu) as Affected by Soymilk Concentration and Type of Coagulant, Int'l J. Food Science Tech. (2004)	Snap and texture of candy
6	**Undergraduates: Midterm 1** **Graduate Students: Paper 1 Due**		
7	**Diffusion** Gelation, diffusion, cross-linking, polymers, spherification, random walk	Zhou et al., "Understanding diffusion theory and Fick's law through food and cooking," Advances in Physiology Education	Spherification
8	**Heat Transfer** Heat transfer, transition temperature, diffusion of heat, baking a cake	McGee, Chapter 15: "Cereal Doughs and Batters", p. 517-564 Olszewski, From baking a cake to solving the diffusion equation, American Journal of Physics (2006)	Cooking with Heat

9	**Viscosity** Viscosity, molecular origin, role of temperature, thickeners and food additives	McGee, Chapter 11: "Sauces" p. 582-637	Measuring viscosity of different thickeners (guar gum, xanthum gum, corn starch)
10	**Emulsions and Foams Desserts** Emulsions, surfactants, elasticity of elastic materials, mayonnaise, culinary foams	McGee, Chapter 11: "Sauces", p. 582-639 Godefroidt et al., Ingredient functionality during foam-type cake making: a review, Comprehensive Review in Food Science (2019)	Creation of various foams and mayonnaise, measurement of the foam physical properties
11	**Dessert** Science of candy, chocolate, crystallization	McGee, Chapter 12: "Sugars, Chocolate, and Confectionery" (p. 647-712) Pirouzian et al., Pre-crystallization process in chocolate: Mechanism, importance, and novel aspects, Food Chemistry (2020)	Tempering of chocolate, investigation of the different crystal formation of chocolate
12	**Undergraduates: Midterm 2** **Graduate students: Paper 2 Due**		
13	**New Directions in the Culinary World** What engineering methods and instrumentation not known to the culinary world might elevate recipes and food preparation? What are the dreams of chefs—"If I had XXX, then I could imagine making…"	Supplemental Handouts	
14	**Final Project Presentations**		
15	**Final Project Presentations**		