PY 107: Physics of Food/Cooking

Fall 2019
Prof. Karl Ludwig
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Lecture: M,W 4:30-6:15 pm SCI 117
Office Hours: TBA **All office hours held in PRB 459.**
Teaching Assistants: TBA

Lab and Discussion PRB 459
Section B1: Tuesday 6:30-9:15 pm
Section C1: Thursday 12:30-3:15 pm
Section D1: Friday 2:30-5:15 pm
Section E1: Wednesday 6:30-9:15 pm

Course Website: Blackboard Learn. https://learn.bu.edu
PY107 A1 Physics of Food/Cooking (Fall 2018)

Text Books: REQUIRED

1) Science & Cooking: A Companion to the Harvard Course
   by Michael P. Brenner, Pia M. Sörensen and David A. Weitz
   (Order online from Amazon) Kindle Edition (~ $10)

2) The Kitchen as Laboratory
   Edited by César Vega, Job Ubbink and Erik van der Linden
   Publisher: Columbia University Press
   Available as a Kindle Edition on Amazon (~ $10), in paperback or in hardcover
   ISBN-10: 9780231153454
   ISBN-13: 978-0231153454

A free college physics text book to get more details about specific points covered in the course:
http://cnx.org/contents/031da8d3-b525-429c-80cf-6c8ed997733a@8.8:1
This is part of https://openstaxcollege.org/books free college level course books.

Recommended**, not required** (available in our lab):
On Food and Cooking, Rev 04 – Harold McGee (Simon+Schuster)
Modernist Cuisine at Home - Nathan Myhrvold, Maxime Bilet (The Cooking Lab, 2012)
The Science of Good Cooking – The Editors of America's Test Kitchen and G. Crosby
The Food Lab – J. Kenji López-Alt (W.W. Norton & Co.)

Calculator: A scientific calculator will be needed for worksheet, lab, homework and exam calculations. You will not be allowed to use a calculator on your cell phone for the exams.

Homework: Weekly homework assignments posted on course website with due date.

Exams: There will be two in-class exams. Exam 1 will be on Oct. 15 and Exam 2 will be on Dec. 11. Exams will consist of both short-answer (multiple choice, fill-in-the-blank, true/false) questions and quantitative problems to be solved. Problems will be taken from practice exams that will be made available to you, from homework problems and from lecture and discussion worksheets.

Final Project (done in a team): Develop or examine a cooking recipe to illustrate the underlying science. Execute the project in one lab session, make a Powerpoint presentation, and submit an individual final report to the course Blackboard website.

Grade Weights:

Attendance Worksheets	2%
Homework + Discussion	18%
Labs	20%
Final Project	10%
Exam 1	25%
Exam 2	25%

Overall Course Curve (I reserve the right to assign higher grades):

93-100	A
90-93	A-
86-90	B+
83-86	B
80-83	B-
76-80	C+
73-76	C
70-73	C-
60-70	D
< 60	F

Guest Chef Lectures: Chefs from the BU community (including faculty from the Culinary Arts and Gastronomy program at MET college) will demonstrate cooking methods relevant to the scientific concepts taught in this course. The instructor will help interpret the methods and /or recipes and relate it to the material covered in lectures/ labs.

PY 107 Lecture Topics

Topic 1: Introduction to course
- Why use cooking to teach science?
- Composition of foods (weight, volume, moles—density)
- Units, significant figures and scientific notation
- Archimedes' Principle
- Components of Food (Carbohydrates, proteins, fats)
- Analyze a recipe: Classic Pound cake / Nestle Toll House Cookies
- Demos: Foods and density-Rainbow shots, Compare density of ice cream brands

Topic 2: Food Molecules
- Molecular interactions and covalent bonds,
- Electrostatic interactions-pH and ions
- Energy from food (Calorie values of foods)

Demo: Ricotta cheese by changing pH of milk—electrostatic interactions.

Topic 3: Energy, Heat and Temperature—

Temperature and kinetic energy
Heat and First Law of Thermodynamics
Specific Heat
Demos: Specific heat of oil versus water
Calories by burning a chip

Topic 4: Phase Transitions- Introduction

Latent Heat
Entropy
Phase diagram of water, and other familiar substances.
Solubility and freezing point depression and boiling point elevation
Demo: Cooking with liquid nitrogen
Demo: Pressure Cooking
Demo: Transitions of CO_2 /dry ice

Topic 5: Phase transitions in food/cooking

Supercooling, Nucleation and crystallization
Phase diagram and microscopic structure of chocolate
Entropy of mixing
Protein denaturation
Phase transitions in cooking eggs/meat
Demos: Chocolate / Sous Vide cooking—eggs

Topic 6: Elasticity

Relationship between elasticity and force.
Stress, strain, Hooke's Law, Young's modulus and shear modulus.
Microscopic Origins. $G \sim kT/ l^3$.
Applications to food texture, taste and mouth-feel. Elasticity of dough
Demo: Elasticity of strudel dough.

Topic 7: Viscosity and Viscoelasticity

Viscosity
Polymers as thickeners, starch
Applications to candy making—viscosity of sugar syrup
Demos: Viscosity changes in making sauces and fruit jelly candies.

Topic 8: Gelation and Spherification

Physics of gelation
Solution to gel transition, Gel swelling and collapse
Gelation of proteins, carbohydrates, hydrocolloids
Osmosis, Fick's Law of diffusion
Spherification
Demos: Spherification, gelatin desserts.

Topic 9: Emulsions and Foams

What are emulsions and foams
Surface energy, Laplace Pressure, surfactants
Demos: Carbonated Drinks, Whipped Cream, Mayonnaise, Dessert Foam

Topic 10: Heat Transfer, Heat diffusion

Heat conduction, convection, radiation
Relation between time and temperature for cooking
Heat, Entropy and Second Law
Demos: Heat diffusion in cooking a steak.

Topic 11: Browning Reactions

Topic 12: Baking and Fermentation

Baking powder vs baking soda
Yeast

A detailed lecture, lab and homework schedule is provided below.

Labs and Discussion Sections: (will be held weekly in PRB 459)

During those weeks when there is no lab activity, you are required to attend for a discussion and quiz which will typically last for about 1.5 hour.

Students will conduct physics labs using food ingredients and table-top cooking equipment. Students will work in teams of three. **You must come prepared by reading the lab instructions posted on the course website and doing the pre-lab worksheets. A written lab report (pdf or doc file) with data, calculations and photos will be required to be submitted.** Guidelines for writing the report will be provided.

YOU MUST DO ALL Labs to pass the course.
If you miss a lab **due to illness** contact **both the lab TF and Prof. Ludwig** by **email** as soon as you can so we can make arrangements. If at all possible we will try to have you do the lab with one of the other sections in the scheduled week.

Relation to the BU Hub:

This course will address the Hub areas of *Scientific Inquiry I* (Social and Scientific Inquiry), *Quantitative Reasoning I* (Quantitative Reasoning) and *Critical Thinking* (Intellectual Tool Kit).

Scientific Inquiry I

Outcome 1 – Students will learn how basic principles of physics along with molecular biophysics concepts apply to questions related to food and cooking. They will learn about molecular composition of food, and how molecular interactions are involved in getting energy from food. They will examine the essential role of temperature and phase transitions in cooking and see how the laws of thermodynamics apply to cooking. They will relate physical properties like elasticity, viscosity to mouthfeel and texture. Understanding of these concepts will be tested in homework, lecture quizzes, exams, and in lab.

Quantitative Reasoning I

Outcome 1 – Students will demonstrate their understanding of core concepts and theoretical tools by quantitative reasoning using basic mathematics. Lectures will regularly include derivations of simple equations and solving quantitative problems so the students can learn these methods and apply them in homework problems and exams. Students will work on simple numerical problems in more or less daily classroom quizzes which provide an opportunity for them to test their preconceptions with predictions based on basic science.

Outcome 2 – Students will be given problems which they will model mathematically and manipulate via linear equations to obtain values of physical quantities. They will analyze data to obtain averages and standard deviations and present data in tables and graphs. They will use logarithms and exponentials and scientific notation for numbers. They will learn the importance of units and to convert between different units. They will calculate exact numerical values as well as order of magnitude estimates.

Outcome 3 -- Students will learn to communicate quantitative information visually as well as numerically. This will be evaluated in quizzes, exams, homework and laboratory reports.

Outcome 4 – In applying quantitative analysis of a situation, one is limited by the accuracy of the model, particularly due to the assumptions that enter into it, and by the quality of the data being interpreted. This is particularly true in a subject as complex as foods and cooking, in which equations used at the level of this course are highly simplified. Limitations of simplified equations will be examined in the lectures, in doing homework problems and in labs where students' measurements directly reflect deviations from the simple models used. Students will be asked to reflect on the accuracy of their data and where errors and hidden assumptions could enter. They will learn that a subject such as food and cooking involves considerable complexity so that quantitative methods can be guides and provide useful estimates, but cannot easily capture the details exactly. Understanding of these points will be tested in homeworks, exams and laboratory reports.

Critical Thinking

Outcome 1 – The difference between deductive and inductive reasoning will be explicitly discussed and students will experience both. Core physical laws will provide the basis of deductive approaches, with students learning to accurately translate everyday experiences of food and cooking into the concepts used in natural sciences. Having made the connection between their experience and the concepts used in the natural sciences, students will apply existing laws and make deductive predictions in homework and exam problems, and in the lab. Conceptual questions form an integral part of homework and exams. In the lab, students will also find areas in which the simple physical laws they have discussed in lecture don't work well. Through experiment, they will see patterns that then allow them to create new hypotheses to better explain their results, i.e. practice induction. In food, particularly, there is always the temptation to focus on what a student "likes" or "dislikes". Students will learn to identify an outcome in terms of agreed-upon criteria in terms of texture, elasticity, color, etc. and focus on the processes causing a particular outcome versus their subjective taste. Understanding of these points will be addressed in lectures, discussions, homeworks, exams and laboratory reports.

Outcome 2 – Students will learn to argue from physical principles and laws, while also considering the assumptions which go into those laws and determine their validity or invalidity in a given situation. This will often take the form of deriving relationships between physical quantities for a given situation. Students must also consider whether they have included all relevant effects, or at least the dominant ones. An important part of this is learning to clearly state assumptions about the dominant mechanisms operating in a given situation. This logical approach enables them to test the validity of an argument within a given starting picture. Again, understanding of these points will be addressed in lectures, discussions, homeworks, exams and laboratory reports.

PY 107 Schedule

Homework to be handed in on assigned date **by 5 pm** in box labeled PY 107
near SCI 121 (near the stairwell)

(BSW = Brenner, Sörenson & Weitz: *Science & Cooking*;
KAL = *The Kitchen as Laboratory*)

Week of	Lecture Topic	Reading BSW	Reading KAL	Lab/ Discussion	HW Assigned	HW Due Date
9/2 (only class is on 9/4)	*Introduction, Density, Archimedes principle*	Chapter 1	Forward, pages 1-6	No Lab/Disc	***HW 0*** Math Review	Due in your first disc/lab section
9/9	*Food molecules, moles, pH, milk*	Chapter 1		DISC lab safety, math review	***HW 1*** Density, moles	Monday 9/16
9/16	*Molecular interactions, energy, calories*	Chapter 2		**LAB 1** *pH, cheese*	***HW 2*** Molecules calories, pH	Monday 9/23
9/23	*Heat, Temperature, specific heat*	Chapter 2		DISC ***QUIZ*** based on HW 1, 2 SPECIAL TOPIC Knives	***HW 3*** Heat, temperature	Monday 9/30
9/30	*Phase Transitions*	Chapter 3	Chapter 1,17	**LAB 2** *Phase diagrams, ice cream*	***HW 4*** Latent heat, phases	Monday 10/7
10/7	*Chocolate, Elasticity*	Chapters Choco-late, 4	Chapters 10,24	DISC ***QUIZ*** based on HW 3,4 SPECIAL TOPIC Eggs	Exam review problems	NOT to be turned in
10/14 (Note: T,W classes this week)	**EXAM 1; Tuesday, Oct. 15 in class 4:30-6:00pm**					
	Diffusion	Chapter 5	Chapter 12		***HW 5*** Elasticity	Monday 10/21
10/21	*Gelation, Spherification*	Chapter 5	Chapters 4,6	**LAB 3** *Elasticity of gel and cake*	***HW 6*** Gelation, Spheri-fication	Monday 10/28
10/28	*Viscosity, Viscoelasticity*	Chapter 7	Chapters 18,19,20	**LAB 4**	***HW 7*** Viscosity	Monday 11/4

				Viscosity, Spheri-fication		
11/4	*Emulsions, Foams, Colloids*	Chapter 8	Chapters 14, 15, 16	DISC **QUIZ** based on HW 6 SPECIAL TOPIC Sous Vide PROJECT PLANNING	***HW 8*** Project Proposal	Monday 11/11
11/11	*Heat Transfer*	Chapter 6	Chapter 22	**LAB 5** *Heat Transfer/ Emulsion*	***HW 9*** Emulsion, Foams	Monday 11/18
11/18	*Heat Transfer*	Chapter 6		**PROJECT EXECUTION LAB**	***HW 10*** Heat Transfer	Monday 12/2
11/25	*Maillard Reaction* **Thanksgiving Recess**	Chapter 6	Chapter 13	No discussion/labs and no assignments		
12/2	*Baking Fermentation Food Safety & Preservation*	Chapters 9,10	Chapters 3,28	**PROJECT PRESENTATIONS** during your scheduled lab period		
12/9	*Final Exam Review Final Remarks*			No discussion/labs and no assignments		
	Exam 2; Wednesday, Dec. 11 in class 4:30-6:00pm					