About the Instructor

Glen Whitney <whitney@math.harvard.edu> (p) 5-9063 will hold office hours (Science Center 506) during the Fall 2018 term on Mondays 3-4 pm and Fridays 10-11 am. Dr. Whitney has a varied background in mathematical logic, quantitative finance, and non-associative algebra, but currently primarily pursues public mathematics outreach with a goal of improving general perceptions about mathematics. You can see a selection of recent work at Studio Infinity. In addition, Dr. Whitney is the editor of the Playground, a quarterly problem column in the MAA undergraduate magazine, Math Horizons.

About the Course Assistant

Laura Pierson <lpierson@college.harvard.edu> will hold a review session Wednesdays 1:30 - 2:20 in SC 411 and an office hour Thursdays at 6:15PM in SC 310 starting Sep 12/13.

About the Class

The goals for the class include not only developing a repertoire of mathematical ideas that lend themselves to physical expression and a toolkit of methods for realizing those expressions, but learning strategies for extending the range of ideas accessible in these ways, and for using the objects built to engage diverse audiences and communicate with them concerning the underlying mathematical topics. To do this, we will embark together on several cycles of exploring a mathematical topic, modeling (in software) related structures that we could build, and constructing one or more chosen designs, using a variety of production techniques. These activities will occur both in and out of class, so come to class ready to ask questions and discuss the math ideas we'll be investigating, ready to manipulate software models as we create them (to this end, everyone for whom it is convenient to bring a laptop to class should generally do so), and ready to build our designs to create physical models.

Outline of Topics

These are the planned topics for our successive cycles of exploration and building. How many of the topics we actually rotate through will depend on how in-depth (and therefore how time-consuming) our explorations on any given topic become. It is also possible that additional topics will arise from ideas that come up in class. In any case, we will be sure to include computer-controlled cutting and 3D printing among the production techniques covered.

1. Face-to-face polyhedra
   In our first abbreviated cycle, to illustrate and become familiar with the process, we will build a pre-selected model in connection with an exploration of what structures are possible when regular polyhedra are connected to each other face-to-face.
2. Pythagorean Theorem
   In the first full cycle, we will begin with a topic presumably familiar at some level to all participants: the Pythagorean Theorem. However, we will explore it in greater depth and breadth than usual. We will use dynamic geometry software (Geogebra, CaRMetal, Cinderella, and/or Geometry Expressions) to model various aspects of the Theorem that we have explored. Finally, we will construct mechanical linkages illustrating one or more of these models we designed, using simple materials such as cardboard and brass paper fasteners.
3. Three-dimensional integer lattice
   Modeling: Voxel Builder; Fabrication: face-to-face attachment of cubes.
4. Other configurations of cubes
   Modeling: three-dimensional dynamic geometry software (Geogebra, CaRMetal, and/or vZome); Fabrication: box and hinge construction.
5. Symmetry and point groups
   Modeling: SymmetriSketch; Fabrication: computer-controlled cutting.
6. Classification of transitive polyhedra
   Modeling: polyhedron-building software (polyhedronisme and/or Poly); Fabrication: paper nets.
7. Frameworks and rigidity
   Modeling: Numerical computation software (SageMath, Gnu Octave, and/or NumPy); Fabrication: strut and hub construction.
8. Curves
   In the final topic area for the course, we will touch on some or all of: coordinate systems on the sphere, parametric curves, point groups acting on curves, and zero sets of polynomials in two and three real variables. Modeling: Three-dimensional modeling software (OpenSCAD and/or Surfer); Fabrication: 3D printing.

Course Requirements

Weekly assignments

There will be weekly assignments due at class time each Friday, starting Sep 14. These will be roughly evenly divided among writing explanations and solutions to questions and problems related to our mathematical discussions, modeling mathematical structures in software, and prepping designs, plans, and/or materials for in-class building sessions and/or creating finished products using facilities available on campus (we'll cover what's available later on). In addition, there will be optional challenge problems at a higher level of difficulty in each area; turning in quality work on any of these will reduce the weight of the other areas and the other categories of assignments below.

Major assignments

There will be three more major projects, two during the semester and one final project.

1. **Seeing Math**. If the goal is to help others understand the value and ubiquity of mathematics, we must ourselves become adept at perceiving math in the world around us and understanding its significance. To that end, you will write a blog post with pictures and/or video that illuminates a mathematical idea underlying, explaining, or enhancing something you observe in the natural or built environment. Your blog will include writing about a specific mathematical question or problem inspired by that observation, and its solution. This assignment will be due Wednesday, October 3, by the time of the review session.
2. **Making Math**. Conversely, we seek to take other mathematical ideas and bring them into the real world. In this project, you will take either a mathematical problem or its solution, and create from it a physical construction which reveals how and why that problem or solution is beautiful or engaging or both. This project allows you to explore any topic area and/or any (reasonable) fabrication approach of particular interest to you, not limited by and in greater depth than the weekly assignments. This assignment will be due Wednesday, November 7, at the review session.
3. **Doing Math**. Ultimately we want to bring the joy and relevance of mathematics to a wider audience. For this project, you will create a mathematics exhibit, which should be as hands-on/interactive as possible. You will present your exhibit in a session open to all members of the Harvard community at the regularly-scheduled time that a final examination for this course would take place. In addition, all exhibits (with your approval) will be presented at the Cambridge Science Festival in April, and you will be welcome to attend and present what you've done to an even wider audience.

Submission and grading

All non-physical work may be submitted electronically; all software modeling assignments must, of course, be submitted electronically. Weekly assignments will receive numerical points and the major assignments will receive letter grades. Your final grade will be based 35% on the weekly assignments, 25% on the final project, 15% on each of the other major assignments, and 10% on asking and answering thoughtfully in our discussions and contributing to our in-class modeling and and building efforts. Quality work turned in on the challenge problems will reduce the weights on the other categories proportionally.

Collaboration and Use of Outside Materials

You may at any time discuss any assignments or work for the class with any other student in the class, or seek help from the course assistant or the instructor. Those activities don't have to be acknowledged. However, *every* submission of work (weekly assignments and major assignments) should have accompanying "Acknowledgments and Sources" in which you give credit to any other people you had substantive discussions with, and *any* written materials from *any* source (library, internet, comic-book store, etc.) that you used in preparing the assignment. You are welcome to use any such sources or materials, but failure to credit them is a failure of academic honesty.

Because the weekly assignments are expository and/or exploratory in nature, the final work you hand in on them must be your own; it is unacceptable to hand in a copy or superficially edited version of either another student's work or of text you find from any other source. For the major assignments, you are welcome to either work on your own or to submit a joint project with **one** other student. If you choose to do a joint project, then both collaborators should also each separately submit their own brief reports on the collaboration: two or three paragraphs (unless you have more to say) describing what you thought each person contributed to the collaboration, and how it was productive and/or challenging. You are welcome to take on the same, different, or no collaborators variously on the three major assignments.