

# MATH 194.2: MATHEMATICS & ORIGAMI

## *Fall 2012 Course Syllabus*

Last updated: September 18, 2012

Origami has seen a tremendous renaissance in recent years. New techniques have unlocked new possibilities for the humble square of paper. At the same time, the connections between origami and mathematical thought have proven to be remarkably rich. Origami artists and hobbyists are able to connect with mathematicians and computer scientists to forge a vibrant community of folders.

In this course, we will use origami (paper-folding) to explore topics in mathematics such as trisecting angles, solving cubic equations, and creating 3-dimensional polyhedra. In the process, we will also see how mathematics has revolutionized origami over the past 50 years.

### **Course details**

**Time:** Thursday 12:45 – 2:20pm

**Place:** PPHAC 212

**Instructor:** Kevin Hartshorn

**Office:** PPHAC 215

**Hours:** MW 2:30-4:00pm, Th 10:00-11:30am,  
*or by appointment*

**e-mail:** hartshorn@math.moravian.edu

## COURSE GOALS

This course is designed to introduce you to the world of origami and to begin thinking about creation of origami designs as a mathematical endeavor. Through our work, I hope that we'll be able to make progress toward the following goals.

1. Develop precision and accuracy in folding paper and creating origami models.
2. Be able to develop models from written directions, through “reverse engineering,” and through individual experimentation.
3. Analyze an origami structure with a mind toward geometric structure, symmetry, and relations to other origami figures.
4. Develop a deeper understanding and appreciation of geometric topics (e.g.: Hamiltonian paths, Euler’s Formula, angles for regular polygons, etc.).

There will be no exams in this course. Instead, you will demonstrate your progress toward these goals through class discussion, homework assignments, and reflective writing.

## MATERIALS FOR CLASS

Students are responsible for bringing materials to class. Each student should purchase the following materials for use during the course:

- (a) 6” origami paper – the bookstore is stocked with paper recommended for the course
- (b) Pencils – either mechanical pencils or wood pencils with a portable sharpener.
- (c) Eraser – the little nub on the back of your pencil is not enough. Buy a pink eraser.
- (d) Ruler – at least 12 inches (18 inches is even better), marked with both inches and centimeters
- (e) Journal – a small diary-type journal will be sufficient for most of our work. There will be regular in-class writing and questions for you to explore at home.
- (f) Paper – you should have 8.5 by 11 inch loose-leaf paper, either lined or blank. Do not submit work that has been ripped out of a spiral notebook.

These materials should be brought to class each day. Note that you are to bring your journal *and* additional paper (both origami paper and writing paper) every day.

## OUTLINE OF TOPICS FOR THE COURSE

The schedule below indicates my initial plans for this course. Note that it is subject to change based on the direction of our discussion.

<b>8/30/12</b>	Introduction, map coloring	
<b>9/6/12</b>	Haga's Origamics (part 1)	
<b>9/13/12</b>	Origami geometry and subdividing paper	
<b>9/20/12</b>	Origami "bases"	
<b>9/27/12</b>	Flat-folding questions	
<b>10/4/12</b>	Haga's Origamics (part 2)	Model demos 1
<b>10/11/12</b>	Constructing regular polygons	
<b>10/18/12</b>	Building sonobe models (part 1)	
<b>10/25/12</b>	Buckyballs and tori	Final model/topic selection
<b>11/1/12</b>	Origami tessellations	Model demos 2
<b>11/8/12</b>	Topics in modern origami (*)	
<b>11/15/12</b>	Topics in modern origami (*)	
<b>11/22/12</b>	<i>Thanksgiving!</i>	
<b>11/29/12</b>	Topics in modern origami (*)	
<b>12/6/12</b>	Final presentations and discussion	Final model and paper due

(\*) There are several ideas in modern origami that we may discuss. In the class before fall break (October 4), we will select what topics to explore. Some possibilities are:

Origami design (circle packing and TreeMaker)	Unfolding polyhedra	Fold-and-one-cut algorithm
Map folding problems	Folding polygons to polyhedra	Rigid foldability
	Constructing pop-up cards	Flat foldability

## ASSESSMENT

Your grade will be based on attendance, active reading, work on problem sets, creative projects, original analysis, and several exams. How these various activities are weighted in the final grade will be up to you, subject to the following constraints.

10%	Attendance and active participation
35%	Homework assignments
15%	Writing and journal entries
40%	Projects (10% for each small project, 20% for large project)

For this class, you can translate percentage grades to letter grades by this rough guide: 85% or above is an A (+ or -), 70 – 85% is a B (+ or -), 60 – 70% is a C (+ or -) and 50 – 60% is a D (+ or -). As I assess your work, I keep the following criteria<sup>1</sup> in mind:

**A** = 4.00 points; **A-** = 3.67 points. These grades are given for achievement of the highest caliber. They reflect independent work, original thinking, and the ability to acquire and effectively use knowledge.

**B+** = 3.33 points; **B** = 3.00 points; **B-** = 2.67 points. These grades are given for higher-than-average achievement. Evidence of independent work and original thinking is expected.

**C+** = 2.33 points; **C** = 2.00 points; **C-** = 1.67 points. These grades are given when the student has devoted a reasonable amount of time, effort, and attention to the work of the course and has satisfied the following criteria: familiarity with the content of the course, familiarity with the methods of study of the course, and active participation in the work of the class.

**D+** = 1.33 points. **D** = 1.00 point; **D-** = 0.67 point. These grades are given for work below the standard expected by the College. They indicate work that in one or more important aspects falls below the average expected of students for graduation. The work is, however, sufficient to be credited for graduation, if balanced by superior work in other courses.

**F** = 0 points. This indicates failure.

Remember that the final assignment of grades will be based on my judgement as professor of the course.

## ATTENDANCE AND PARTICIPATION

Our class has only 14 meeting times. Each time we meet is vital to our progress. Missing a class meeting, *regardless whether the absence is excused or unexcused*, will result in a 5 point deduction in your overall course grade.

You are expected to come to each class prepared for the day's activities. Your participation grade is based not on merely showing up to class, but to your contribution to the overall learning experience. At the end of each day, you will write a short reflection on the day's activities, self-reporting your contribution for the day, according to the following rubric.

1. Students getting a 1 often seem on the margins of the class and may have a negative effect on the participation of others. They often don't participate because they haven't read the material or done the homework. Alternatively, they may be actually disruptive, radiating negative energy via hostile or bored body language, or be overtly rude.
2. A student receiving a 2 participates in discussion, but in a problematic way. Such students may talk too much, make rambling or tangential contributions, continually interrupt the instructor with digressive questions, bluff their way when unprepared, or otherwise dominate discussions, not acknowledging cues of annoyance from instructor or students. Students in this category often profit from a conference with the instructor. Alternatively, students receiving a 2 may come to class prepared, but do not voluntarily contribute to discussions and gives only minimal answers when called upon. Nevertheless these students show interest in the discussion, listen attentively, and take notes. Students in this category may be shy or introverted. The instructor may choose to give such students a 3 if they participate fully in small group discussions or if they make progress in overcoming shyness as the course progresses.
3. Comes to class prepared and makes thoughtful comments when called upon, contributes occasionally without prompting; shows interest in and respect for others' views; participates actively in small groups. A 3 score may also be appropriate to an active participant whose contributions are less developed or cogent than those of a 4 but still advance the conversation.
4. A student receiving a 4 comes to class prepared; contributes readily to the conversation but doesn't dominate it; makes thoughtful contributions that advance the conversation; shows interest in and respect for others' views; participates actively in small groups.

If I have cause to disagree with your self-reported score, you will receive an e-mail within 24 hours of class, inviting you further discuss your work for the day.

## HOMEWORK

There will be homework assigned every meeting. I will typically expect each homework assignment to take 2 to 3 hours to complete. Homework is due in class, late work will be subject to a penalty. It is your responsibility to get your homework to me, even if you are unable to attend class.

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<sup>1</sup> from <http://www.moravian.edu/studentLife/handbook/academic/academic.html>

All homework will be assessed on a 5 point scale (see “Assessment” above for a translation to a letter-grading scale). Most homework will be one of the following types:

- *Complete an activity that was started in class* – such assignments will be assessed at the beginning of class based on evidence of work and reflection. We will then discuss the results in class.
- *Problems based on our class activities* – these will be collected and graded for accuracy. Full credit will only be given to answers that demonstrate the thought process.
- *Paper folding assignments* – these will be assessed based on completeness, accuracy, and neatness. Remember that precision is a vital component to origami work, and sloppy folding can make it difficult or impossible to complete the final figure.

## ACADEMIC HONESTY

Homework problems and assignments are meant to be completed on your own, or in conjunction with a classmate. You are *not* to use outside resources (books, web searches, etc) in completing homework assignments. The goal of these assignments is not to reach the best possible answer, but to develop your own thinking and problem-solving skills.

You are welcome to work with classmates on problems. You are also welcome to stop by my office for help.

Assignments that do allow use of on-line resources will be made clear.

## WRITING AND JOURNAL ENTRIES

You will be asked to keep a journal of your thoughts and reflections on the course. Be sure to bring your journal to class every day, as there will be both in-class and take-home journaling assignments.

In class, you will use your journal for reflections based on the origami activities as well as end-of-class summaries.

At home, you will be asked to take time every day to explore ideas in origami. At the end of each class, I will provide some guidelines for your journaling. Journaling will be graded based on evidence of genuine thought and effort. Genuine effort should provide the equivalent of 1 to 2 pages of 8.5x11 paper every day (if your journal is smaller, this will require more pages). Thus between class periods, I will expect roughly 3 to 4 pages of writing.

## PROJECTS

There are three projects you will be asked to complete for the course: two smaller demonstrations and one larger model/analysis.

### **The mini-projects**

Each person will create and analyze an origami model. The choice for the model is completely up to you, and you are welcome to use any design instructions that you find on-line or through other written resources. In addition, you need to provide a mathematical analysis of the model. This analysis will be a two to three page essay. Details on the project will be provided in a separate handout.

### **The large-scale project**

On the last day of class, everyone will have to have completed some large-scale project with mathematical analysis. This project may be a single-sheet project or a modular project. Your grade for this project will be based on the degree of difficulty, the quality of work in creating the model, the quality of your mathematical analysis, and the writing quality of your written analysis. Details on this project will be provided in the second week of class.

## Resources

As you plan your choices for the two projects, I recommend taking advantage of the following resources

- On-line resources
  - Robert Lang's web site: <http://www.langorigami.com/>
  - Jim Plank's origami page: <http://www.cs.utk.edu/~plank/plank/pics/origami/origami.html>
  - Gurmeet Singh Manku's blog: <http://gurmeetsingh.wordpress.com/origami/>
  - The British Origami Society: <http://britishorigami.info/>
  - Tom Hull's origami page: <http://kahuna.merrimack.edu/~thull/OrigamiMath.html>  
Tom Hull provides several other links at <http://kahuna.merrimack.edu/~thull/omfiles/mathlinks.html>
  - Eric Anderson's page: <http://www.paperfolding.com/>
  - There are many flickr pages for origami, including this group pool for sonobe designs: <http://www.flickr.com/groups/sonobe/>
- Books (these are available in the Math/CS reading room, PPHAC 238)
  - *Marvelous Modular Origami*, by Meenakshi Mukerji
  - *Unit Polyhedron Origami*, by Tomoko Fuse
  - *Multidimensional Transformations: Unit Origami*, by Tomoko Fuse
  - *Joyful Origami Boxes*, by Tomoko Fuse
  - *Polyhedron Origami for Beginners*, by Miyuki Kawamura
  - *Origami Design Secrets*, by Robert Lang
  - *Genuine Origami*, by Jun Maekawa
  - *Origami Tessellations*, by Eric Gjerde
  - *Essential Origami*, by Steve and Megumi Biddle
  - *Shapes, Space, and Symmetry*, by Alan Holden

## OTHER ITEMS OF NOTE

- Everyone is expected to adhere to Moravian College's Academic Honesty policy, as described in the Student Handbook (<http://www.moravian.edu/studentLife/handbook/academic/academic2.html>).
- Students who wish to request accommodations in this class for a disability should contact Elaine Mara, assistant director of learning services for academic and disability support at 1307 Main Street, or by calling 610-861-1510. Accommodations cannot be provided until authorization is received from the Academic Support Center.
- If you have any questions, concerns, or comments about the course, please feel free to contact me in my office or by e-mail.
- This syllabus is subject to change, and changes will be noted in class.