*Instructor:* Dr. Laura Miller

*Class Meeting Times:* TuTh 2-3:15 pm

*Room:* Wilson Hall 0213

*Office:* 301 Coker Hall

*Email:* Lam9@email.unc.edu

*Office Hours:* Tuesday 3:30-4:30 pm, Thursday 10:30-11:30 am

*Graduate Research Consultant:* Kemal Ozalp, mkoz@live.unc.edu

**Course Description and Goals**

The focus of this first year seminar will be on organisms living within moving fluids. The natural world is replete with examples of animals and plants whose shape influences flow to their benefit. For example, the shape of a maple seed generates lift which allows them to disperse farther. The structure of a pinecone helps it to filter pollen from the air. A falcon’s form during a dive reduces drag and allows it to reach greater speeds.

We will mathematically describe the shape of organisms using 3D computer aided design (CAD). We will use the 3D objects in numerical simulations of flow around an organism. We will also 3D print these objects and place them inside flow tanks for comparison to simulation.

By the end of this course, students should be able to:

* Create 3D physical and mathematical models of organs and organisms.
* Run numerical simulations using COMSOL Multiphysics.
* Explain how the flow around an organism can be important to feeding, nutrient exchange, dispersal, and survivability of organisms.
* Visualize flows experimentally and using numerically generated data.

The goals of this course are not specifically to:

* Teach new mathematical techniques.
* Provide an introduction to numerical analysis.
* Learn the detailed mathematics behind computer-aided design.
* Teach students how to code.

**Prerequisites**

As with all of the first year seminars at UNC, there are no prerequisites for this course. Given the lack of prerequisites, little mathematics background is assumed. Accordingly, this course may not be appropriate for mathematics majors who wish to learn new mathematics. Students are expected to come to class with a sincere interest in learning how mathematics can be used to answer scientific questions, and specifically problems in biological fluid dynamics and biomechanics.

**Reading**

*Required text:* S. Vogel (1994). Life in Moving Fluids: The Physical Biology of Flow. Princeton University Press.

Supplemental material and codes will be provided throughout the semester. All material will be available on sakai.

**Software**

*Students are encouraged to bring a laptop to every class* to participate in interactive simulations of the mathematical models presented. We will use Image J, COMSOL, Autodesk Fusion, and Autodesk Blender for some computer work, and this software is freely available to students at UNC.

**Course Requirements**

Students in this course will be coming from a wide range of backgrounds and interests. The course work and evaluation is designed to allow for flexibility in training and scientific interests.

Homework assignments 30%

Participation 20%

In class 10%

Lab notebooks - 10%

Course project 50%

Proposal 5%

Draft 5%

Final Paper 25%

Presentation 15%

Grades will be assigned using the following scale:

A 92.5 – 100%

A- 90 – 92.4%

B+ 87 .5– 89.9%

B 82.5 – 87.4%

B- 80 – 82.4%

C+ 77 .5– 79.9%

C 72.5 – 77.4%

C- 70 – 72.4%

D 60 – 69.9%

F < 60%

**The final paper will be due during the final exam period. The final presentations will be given the last two days of class**.

Students will be expected to follow the UNC Honor Code, and those who violate the Honor Code will be reported to Honor Court. If you cannot present your project during the regularly scheduled exam time, please let me know as soon as possible to arrange a makeup presentation.

*Homework Assignments*

Students are allowed to work together on the assignments, but rote copying is forbidden. 10% of the total score will be deducted for each day any assignment is late.

*Class projects*

Students will develop their own projects modeling projects during the semester. Students are encouraged to work together, but each student should write their own report. At the end of the semester, students will submit a 10 page report and give a 10 minute presentation to the class. A list of possible projects will be provided, and students will turn in a project proposal the week before fall break. Each student should meet with Dr. Miller during the semester to discuss their projects. A timeline for the projects is given below:

|  |  |
| --- | --- |
| **Due Date**  | **Description**  |
| October 8 | Project proposal.   |
| October 22 | Literature Review |
| October 29 | Draft of Introduction |
| November 5 | Draft of Methods |
| November 12 | Draft of Results |
| November 19 | Draft of Paper + Conclusion – General guidelines: 12 pt Times New Roman font, double spaced, normal 1” margins, 1-2 pages for the introduction, 2-3 pages for the methods, 2-3 pages for the results, 1-2 pages for the summary, 3-5 references.  |
| November 26, December 3   | Presentations – Each student (or group) will give a 10 minute presentation during the last two weeks of class. |
| December 7, noon  | Final Paper – The final paper will be due on the final exam day, upload onto sakai. |

*Tutorials for performing literature searches:* http://library.unc.edu/support/tutorials/

I also encourage you to visit the OUR website to learn about how you might engage in research, scholarship and creative performance while you are at Carolina. http://our.unc.edu

**Policies and Late Assignments**

Homework assignments in late will have points deducted each day (see above). Exceptions will only be made in cases of extreme circumstances or travel related to university activities. Please contact me as soon as possible if such a situation arises. Do not wait until the end of the semester!!

\*Students with medical or learning disabilities: I strongly encourage you to contact me during the first week of the semester to let me know of your situation. I am happy to work with you to accommodate any special needs or requirements.

**Course Schedule**

*Week 1 - Introduction*

August 20 – Introduction to Biological Fluid Dynamics (Vogel Ch. 1-2)

August 22 - Physical parameters

*Week 2 – Dimensionless numbers*

August 27 - Reynolds number

August 29 Makerspace Orientation + more Reynolds number and physical parameters (Murray Hall Makerspace)

*Week 3 – 3D Printing*

September 3 - Makerspace Class on 3D printing (Murray Hall Makerspace)

September 5 - Velocity vectors

Homework: Using thingiverse.com, select an appropriate organism for 3D printing. Use Cura to slice the image and 3D print it at the Makerspace. Turn in your 3D printed object in class on Thursday September 12.

*Week 4 – Visualizing the movement of air and water around organisms*

September 10 - Dye visualization and estimating velocity (Murray Hall Makerspace)

September 12 - Dye visualization II (Murray Hall Makerspace)

*Week 5 – Creating 3D images of organs and organisms*

September 17 - 3D scanning tutorial (with David Romito at Kenan Library)

September 19 - Autodesk Fusion Tutorial (with David Romito at Kenan Library)

Homework: Create an .stl file of an organ or organism using a 3D scanner or Autodesk Fusion.

*Week 6 – Some basics of fluid dynamics and project ideas*

September 24 - Streamlines, pressure, and momentum (Vogel Ch.3-4)

September 26 – How to formulate a course project and an overview of possible projects.

*Week 7 – Computational fluid dynamics in COMSOL*

October 1 - Running a fluid dynamic simulation in COMSOL I

October 3 - Running a fluid dynamic simulation in COMSOL II

*Week 8 – Fluid forces on organisms*

October 8 - Lift and drag (Vogel Ch 5)

October 10 - Tutorial on how to write a research paper

*Week 9 – More skills at the Makerspace*

October 15 - Laser cutter training (Murray Hall Makerspace)

October 17 - Fall break

*Week 10 – Performing an experiment and a numerical experiment*

October 22 - Flow tank demonstrations and practice (Murray Hall Makerspace)

October 24 - Preparing your .stl file for meshing in COMSOL

*Week 11 – How organisms interact with fluids*

October 29 - Shape & drag of sessile and moving organisms (Vogel Ch. 6-7)

October 31 - Velocity gradients and boundary layers (Vogel Ch. 7-8)

*Week 12 – How organisms use vortices*

November 5 - Making and using vortices for locomotion, mixing, and particle capture (Vogel Ch. 10)

November 7 - Strategies for qualitatively and quantitatively describing flows

*Week 13 – Determining the lift and drag acting on models of organisms*

November 12 - Lift and Thrust - gliding, soaring, flapping, undulating in air and water (Vogel Ch. 11-12)

November 14 - Measuring lift and drag in COMSOL

*Week 14 – More ways to use COMSOL and Autodesk for your project*

November 19 - Plotting flow fields in COMSOL

November 21 - Follow up tutorial on Autodesk Fusion

*Week 15 – Student presentations*

November 26 - Student presentations

November 28 - Thanksgiving

*Week 16 – Student presentations*

December 3 - Student presentations