THE PHYSICS OF SHAPES
FROM NATURE TO THE HAND

Baudouin Saintyves (bsaint@saic.edu)

COURSE DESCRIPTION

Curious about the links between sand riddles in the desert, shape-shifting robots, skyscrapers, and the cracks on an old painting? This class examines the physics behind shape formation, both in nature and in the work of humans. We will question the distinction between those who observe natural systems and those who create as engineers, designers and artists. Through concrete interdisciplinary examples, emphasizing classical concepts of physics, as well as advances in engineering, biology, architecture and more, we will explore the surprising forms that discovery & invention can take. Formal lectures will give the student a conceptual and methodological background necessary for a scientific implementation, while hands-on “kitchen” labs will confront them to the medium. They will put into practice this knowledge in producing their own scientific project, within their craft. Seminars by renown international speakers will expose the student to current experts and cutting-edge interdisciplinary research and open their own prospective.

LEARNING GOALS

The goal of this class will be:

- To introduce the scientific method
- To introduce a culture of physics closely related to your everyday experience in your surroundings and in your practice, and to inspire you in your own work.
- To integrate physical thinking into the design process.
- To build skills in designing interdisciplinary projects that involve science.

GRADING

- Seminar report (15%, 4 assignments):
- Home Labs report (15%, 3 assignments)
- Final project (50%, 5 assignments)
- Participation, attendance, and Q&A (10%)
- Lecture quizzes (10%, 6 best grades)
We are all going through a challenging time with a pandemic that disconnect us from social interactions. Online classes are a way for students to keep learning and to not disrupt their growth. On another hand, as you might have experienced, it is difficult to engage and maintain focus in an online setting as we use to do in person. For this reason, I wish to promote a proactive/interactive class environment where the human presence can be felt the most possible in the virtual place. This requires an effort from both our sides.

On my side, I have designed a class that take advantage of the online situation by inviting speakers from all over the world to give seminars, and by preparing labs that you can do at home mostly with kitchen and household kind of supplies. I have also built for the lectures an online teaching setup that helps reproducing a more in person feel. It consists in:

- A camera filming me standing up behind a transparent lightboard that allows me to write and project teaching material or to play videos.
- A projector that displays on a large wall in front of me all the student cameras for the interaction with you.
- A multi-camera broadcasting system to do live science demos.

On your side, I will ask you to turn on your camera throughout all the classes, and maintain engagement as much as you can, by refraining any extra class activities such as texting, phone calls, web wandering or project works that belong to other classes. This is very important to maintain interactivity, especially in class conversations where good collective feedbacks will lead to better projects, including yours. For this matter, student will have to have their camera on to be counted as attending. Some of you might have specific reasonable reasons for not wanting to be visible during classes, or at specific moments. Please email me in advance to discuss the matter.

Please contact me, preferably in advance, if you will be missing a class. Please arrive to class ON TIME. This is crucial. Arriving late disrupts the daily schedule and group discussion + work in a major way.

If you think you will miss multiple classes/parts of class due to illness, and/or feel too ill to participate, please contact Health Services (312.499.4288) to discuss their situation and, if necessary, may ask Health Services to send an Extended Absence Notification. For an extended absence due to other circumstances, contact Academic Advising (312.629.6800).

If you have any questions or are unsure of anything, first check the syllabus and Canvas course announcements and if you can’t find the answer, ask me!

If there is anything you would like to talk to me about otherwise, please just let me know. Right now I have no set office hours, but am happy to set them up. Otherwise, simply reach out by email and we can certainly find time to talk.
1 **YOUR RESPONSIBILITIES**

Taking this course involves coming to class regularly and on time. You need to come to class prepared, turn assignments in complete + on time, and actively engage with course. Keeping track of your academic progress is your own responsibility, as is maintaining respectful behavior towards all people in the class. Even if you are absent assignments are still due and you will need to find a way to turn them in on time.

2 **MY RESPONSIBILITIES**

As instructors, we are likewise responsible for coming to class on time & prepared, being accessible, for returning your assignments in a timely manner, and helping maintain a positive learning atmosphere throughout the course.

3 **COURSE COMMUNITY CONDUCT (ONLINE AND OTHERWISE)**

*We live in a global culture of surveillance.*

For this reason:

- **No one in the course should record audio or video of the class meetings without consent** in advance from all active participants. Any recorded materials should not be shared without permission, and in principle not beyond the class community.

*We live in a global culture of media saturation and constant distraction.*

For this reason:

- **Refrain from texting, checking email, surfing the web and other multi-tasking not related to the class. The course is a vehicle for study and Remote learning is like driving a car, maybe consider the screen a windshield – keep your attention focused for turns, red lights, green lights, surprise attractions, storm clouds, rainbows, pedestrians, roadside stands.**

Please refer to school policy at the end of this document for further information regarding academic honesty, devices policy and student support.
**Schedule (subject to change)**

**Week slot:** Thursday 1:30pm – 4:30pm

Classes consists in lectures (~1h), home labs (~1h30), seminars with Q&A (1h30) and class conversations revolving around student projects. Every class slot has a 10 min pause. Starting from October, at least 30 min per week is allocated to discuss updates of few chosen projects with all the class. All projects will be discussed at least twice within these time slots before final presentation.

<table>
<thead>
<tr>
<th>Date</th>
<th>Topic</th>
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<tbody>
<tr>
<td>September 2</td>
<td>Introduction / Lecture 1</td>
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<td>September 9</td>
<td>Lecture 2 / Philip Ball (rec)</td>
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<td>September 16</td>
<td>Severine Atis (live) / Home lab 1</td>
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<tr>
<td>September 23</td>
<td>Lecture 3 (Methodology) / project conversations (2h)</td>
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<td>September 30</td>
<td>Project proposal presentation</td>
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<td>October 7</td>
<td>Steve Pavlovsky (live? rec? TBC) / Home lab 2 / Writing 1 / project updates (30min)</td>
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<td>October 14</td>
<td>Lecture 4 / Gizem Gumuskaya (live) / project updates (30min)</td>
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<td>October 21</td>
<td>Lecture 5 / Home lab 3 / project updates (30min)</td>
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<td>October 28</td>
<td>Lecture 6 / Heinrich Jaeger (rec) / project updates (30min)</td>
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<td>November 4</td>
<td>Lecture 7 / project updates (2h)</td>
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<td>November 11</td>
<td>Lecture 8 / project updates (2h) / Writing 2</td>
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<td>November 18</td>
<td>Lecture 9 / Frederic Lecheneault (rec) / project updates (30min) / due date Home lab 4</td>
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<td>December 2</td>
<td>Project presentation</td>
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<tr>
<td>December 16</td>
<td>Project presentation / Writing 3</td>
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Live seminars are public, and questions are open to anyone in the audience, but class students will be given priority. The full list of speakers for the public lectures is still to be confirmed and will be updated in a new version of the class syllabus.
SYLLABUS

1. **Introduction (Day 1)**
   - Student intro in 1-2min
   - Description of the class
   - Home labs Instructions
   - Project examples from previous semester.

2. **What is a shape and why are we studying it? (Lecture 1)**
   - What is a shape, a form, a pattern? Features and scales.
   - Overview of real example, highlighting features similitudes across scales and systems.
   - Patterns in art and science *(Seminar Philip Ball)*
   - Physics in performance: Liquid light shows *(Seminar Steve Pavlovsky)* and new media art *(demo and seminar Baudouin Saintyves)*

3. **Patterns in liquids (lecture 2-3)**
   - Scaling approaches
   - Surface tension and principle of minimization
   - Concept of force balance: Surface tension and gravity in the shape of a droplet.
   - Laplace pressure
   - Soap films and surfactant
   - Diffusion and advection
   - Marangoni flow,
   - Mixing
   - Convection patterns: Rayleigh-Besnard instability
   - Reaction-Diffusion patterns *(Seminar Severine Atis)*
   - Turbulence and chaotic flows *(Seminar Severine Atis)*

4. **Methodology (lecture 4)**
   - The scientific approach
   - Lab notebook and documentation
   - Measuring
   - Project preparation

5. **From flow to branching and fractals (lecture 5-6)**
   - Viscous fingering instability
   - Diffusion limited aggregation: a minimal branching model
   - Fractal patterns: when nature is scale invariant
   - Universality
   - Crystallization and dendritic growth
   - Characterization of fractal patterns: the fractal exponent
   - Self-similarity and self-affinity

6. **Shapes in solids: Toward metamaterials (lecture 7)**
   - Elasticity
   - Bending and buckling
- Fractures
- Drying patterns
- Wrinkling patterns
- Elasto-capillarity: when liquid deform (small) solids
- Metamaterials: Designing materials properties
- Auxetic materials
- Origamis (*Seminar Frederic Lechenault*)
- Yarn and knits (*Seminar Frederic Lechenault*)

7. **From granular matter to social systems, biology, architecture, and robotics (lecture 8)**
   - Not quite liquid, not quite solid
   - The jamming transition (*Seminar Heinrich Jaeger*)
   - Arches and force network
   - Granular matter in biology
   - From granular matter to social systems: Birds, fish, pedestrians
   - Granular builder: termites and ants
   - From granular matter to collective robotics
   - Bio-architecture and bio-robotics (*Seminar Gizem Gumuskaya*)
   - Reconfigurable architecture (*Seminar Heinrich Jaeger*)

8. **Waves in fluids and grains (lecture 9)**
   - Faraday instability
   - Vibrating droplet
   - Walking droplet
   - Chladni plates
   - Sand ripples
PROJECT

In the class project, students will be pushed to pose a scientific question within their practice, that they will explore experimentally or through literature review. In such setup they will experience the process of motivating and putting into practice scientific thinking in a given context. They will learn to implement scientific methodology, experimental protocols, while informing their own practice.

Project advancement, from finding a problem to implementing it, will be discussed during interactive class conversations all the semester until the final presentation. Students are expected to participate and help their peer with feedbacks. Engagement of individual students with class conversations will be considered in their final participation and attendance grade. There will be 5 project assignments corresponding to “milestones” in the project development (% of project grading in parenthesis):

1) **Project proposal presentation (5% for attendance):** Students present concisely an idea or more they have in mind with slides and documents (5-10min). They receive feedback from the teacher and other students. Potential collaborations between students might emerge.

2) **Writing 1 (15%):** Students write a formal one page project proposal based on the feedback of their proposal presentation the week before. Upon review of the document, I give my approval with or without modification to pursue in the direction proposed.

3) **Writing 2 (25%):** Students write a report of their first systematic experimental observations. For people doing literature review, they write a detailed plan of their final documentation.

4) **Final presentation (25%):** Students present their final project in 15min + 15min Q&A from all the audience. Presentations can eventually takes the form of a performance but must be accompanied with a document that the attendance can read to present more explicitly the student’s approach and the knowledge used.

5) **Writing 3 (25%):** Students write their final documentation integrating their slides, writing 1, writing 2, and adding an introduction, new eventual results, a discussion/conclusion, and potential future perspectives.

HOME LABS (4 SESSIONS)

- Lab 1 – Soap Bubbles.  
  *Concepts explored: Area minimization, surfactant, surface tension, colors and wavelengths*

- Lab 2 - Liquid light show : Fluid choreographies with water, alcohol and food dyes.  
  *Concepts explored: surface tension, Marangoni instability, chaos, convection.*

- Lab 3 – Branching patterns and fractals: Fingering instabilities in fluids (glycerol and paint), drying patterns, cracks in food wrap.  
  *Concepts explored: Fractals, viscosity, surface tension, flow instability, cracks*

- Lab 4 - Field work: Exploring shapes and patterns in your surroundings.
**IMPORTANT DATES**

- **Classes begin:** September 2
- **Add/drop deadline:** September 9
- **Project proposal writing assignment:** October 7
- **Last day to withdraw:** ?
- **Project presentations start:** December 2
- **Critique week (no class):** December 6-10
- **Last day of classes:** December 16

**SCHOOL POLICY**

1. **ACADEMIC HONESTY (FROM THE SAIC STUDENT HANDBOOK) —**
   “Academic misconduct includes both plagiarism and cheating, and may consist of: the submission of the work of another as one’s own; unauthorized assistance on a test or assignment; submission of the same work for more than one class without the knowledge and consent of all instructors; or the failure to properly cite texts or ideas from other sources. Academic integrity is expected in all coursework, including online learning. It is assumed that the person receiving the credit for the course is the person completing the work.” Please refer to:

   Plagiarism: How to Recognize It and Avoid It and the Flaxman Library’s “When to give credit.”

   Academic integrity is expected in all coursework, including online learning. It is assumed that the person receiving the credit for the course is the person completing the work. Make yourself completely familiar with these guidelines, as you will be held accountable to them!

2. **ACCOMMODATIONS FOR STUDENTS WITH DISABILITIES**
   SAIC is committed to full compliance with all laws regarding equal opportunities for students with disabilities. Students with known or suspected disabilities, such as a Reading/Writing Disorder, ADD/ADHD, and/or a mental health condition who think they would benefit from assistance or accommodations should first contact the Disability and Learning Resource Center (DLRC) to schedule a virtual appointment. DLRC staff will review your disability documentation and work with you to determine reasonable accommodations. They will then provide you and your instructors with a letter outlining the approved accommodations via email. You must request accommodations for each course before any accommodations will be implemented. You should contact the DLRC as early in the semester as possible. The DLRC can be reached via phone at 312.499.4278 or email at dlrc@saic.edu.
3 STUDENT SUPPORT
The Office of Students Affairs at SAIC is here to support all students with resources to aid in their success inside and outside of the classroom. If you have difficulty affording groceries or accessing food everyday, and/or do not have a safe and stable place to live, please contact the Office of Student Affairs - (312) 629-6800; studenthelp@saic.edu during business hours. If you contact them after hours, someone will respond the next business day.

The SAIC Wellness Center, which includes Counseling Services, Health Services and the Disability and Learning Resource Center, is also here to support students' mental health, health and accessibility needs. You may contact them at:

- Counseling Services: counselingservices@saic.edu and 312-499-4271 (press 1 to speak to a counselor after hours)
- Health Services: healthservices@saic.edu and 312-499-4288/877.924.7758
- Disability and Learning Resource Center: dlrc@saic.edu and 312-499-4278

In case of an emergency, please contact SAIC Campus Security, 24 hours a day, by visiting any campus security desk or calling 312.899.1230.

4 WRITING CENTER
Tutors are available for VIRTUAL APPOINTMENTS to help all currently enrolled degree-seeking students with their brainstorming, writing, and editing. Tutors can assist with artist statements, application materials, essays, presentation texts, thesis drafts, proposals, and creative projects.
To sign up for an appointment, please visit our website:
https://www.saic.edu/academics/writing-center
Here you’ll find information about tutors and directions about how to schedule an appointment through our new appointment system, EAB Navigate. Once your appointment is set, you’ll receive a confirmation with a Zoom link, which you’ll use to meet with your tutor online. To prepare for your appointment, please have your writing ready to share with your tutor in a Google Doc and click on your Zoom link in your confirmation email at the scheduled time.

Hours
Monday – Thursday: 8 AM - 8 PM (CST)
Friday: 8 AM - 6 PM (CST)
Please email us with any questions!
wcenter@saic.edu

Writing Center - Lakeview Building, 116 S. Michigan Ave., 10th Floor: writingcenter@saic.edu
312.499.4138
Schedule appointments in advance: http://www.saic.edu/academics/academicresources/writingcenter/

5 DIGITAL DEVICES
DIGITAL DEVICES in class (LAPTOPS, PHONES, TABLETS, etc.)
The student use of various digital devices in Modified In-Person classes, such as laptops, phones, tablets, etc. should be limited only to appropriate use given the format
of the class. Use of digital devices in class to do non-class related work will not be allowed or tolerated. Similarly, use of digital devices in class during screenings will not be allowed or tolerated. If a student has a software or hardware related problem please visit the CRIT Helpdesk on the 9th floor of the 112 S. Michigan (Maclean) Building for assistance addressing these issues.