Syllabus

Version 2020-12-31

# Overview

***Foldable Robotics*** is a course organized around new types of robots being developed in research labs and industry across the country. These devices are designed and built using layered, flat sheets of a wide variety of materials, and folded up to create both form and motion. This class studies these devices from initial prototype and design through implementation and optimization, with a focus on application-specific projects which seek to solve problems of cost, parallelism, complexity, and time with a relatively fast and easy prototyping method.

This class allows students to delve deeper into the analytical problems associated with these devices, in topics such as design, manufacturing, dynamics & simulation, optimization, kinematics & motion, and stiffness analysis.

## Class Basics

**Class:** EGR557 – Foldable Robotics  
**Class Schedule:** Monday/Wednesday, 3:00pm-4:15pm  
**Meeting Location:** Polytechnic Campus, Tech 162  
**Course Number:** [30967](https://webapp4.asu.edu/catalog/course?t=2211&r=30967)  
 **Zoom Link:** <https://asu.zoom.us/j/81969563442?pwd=VWxSaVFRVW5PR25GTjdRWnpmZFdCQT09>  
**Zoom Meeting ID:** 81969563442  
**Zoom Password:** 038986

## Instructor Contact Info

**Instructor:** Daniel M. Aukes  
**E-mail:** [danaukes@asu.edu](mailto://danaukes@asu.edu)  
**Instructor Office:** Tech 152, Polytechnic Campus

## Office Hours

TBD. Will be arranged after week 1. This document will be updated to reflect up-to-date office hours

## Prerequisites

There are no formal prerequisites, but students taking *Foldable Robotics* should be familiar with:

* Programming fundamentals, ideally in a scripted language like Python or Matlab.
* Linear algebra, differential equations, calculus, trigonometry, vectors, etc.
* Working around rapid prototyping machines, and if not, willing to learn.

## Course Objectives

At the end of this course, students will demonstrate proficiency in synthesizing concepts from across a number of engineering domains including robotics, modeling and analysis, optimization, data collection and experimental validation, CAD/CAM design, and manufacturing & rapid prototyping.

## Expected Learning Outcomes

### Design & Bioinspiration

* Identifying and conducting background reading on related research from the fields of biomechanics, robotics, and manufacturing.
* Creating origami-inspired mechanisms like a popup book using manual prototyping tools and techniques.
* Using a graphical design program to create a hinged design
* Using a scripting language to create a hinged design
* Distilling bio-inspired motion into a mechanism design
* Utilizing feedback from simulation and/or experimentation to improve design.

### Kinematics

* Translating a paper design to a set of coordinates and connections.
* Understanding degrees of freedom, constraints.
* Count DOF for simple paper devices.
* Creating constraint equations using vectors.
* Solving nonlinear system of equations with Python
* Plotting and analyzing the motion of foldable mechanisms using kinematic constraint equations.
* Computing numerical force relationships between actuators and end-effectors using the concept of a Jacobian.
* Computing the optimal gear ratio for a motor given jacobian and motor characteristics.

### Dynamics

* Running a parameter-based dynamics simulation.
* Modifying a parameter-based dynamics simulation.
* Creating a parameter-based dynamics simulation.
* Computing the stiffness of a flexible beam using Bernoulli-euler beam theory.
* Computing the stiffness of a composite beam using classical beam theory
* Experimentally determining the stiffness of a beam.
* Using simulations to identify potentially optimal designs.

### Robotics & Mechatronics

* Programming a microcontroller
* Demonstrating motion of an RC Servo Motor
* Integrating sensor signals in a microcontroller
* Collecting data experimentally via sensing
* Displaying experimental data in comparison to a model

### Teamwork and Documentation

* Working in teams to achieve a shared goal
* Presenting work to others via design review presentations
* Responding to and acting on feedback received in public design reviews.
* Writing a final report which documents the design process using all tools learned
* Communicating the essential features of the design and process to the public in outward-facing final videos.
* Documenting each iteration with animations, renderings, photos, and videos in a professional manner
* Retaining all code & design files
* Professionalism in Presentation
  + Homework, reports, and correspondance are clear and well-written.
  + photos/videos are not jerky/blurry do not have cluttered or messy background
  + audio is clean without background noise
  + Videos edited and narrated with a script
  + final project folder is organized according to instructions

### Geometry & Manufacturing

* Extracting and encoding design geometry from/to common file types such as .dxf
* Using constructive solid geometry techniques to construct complex, multi-layer, mechanical designs from design elements such as hinges and holes
* Applying the principles of layer-based process constraints to compute manufacturable laminate mechanisms with CSG
* Demonstrating rapid prototyping techniques using digital equipment like laser cutters, 3D printers, etc.

## ASU Sync

This course uses Sync. ASU Sync is a technology-enhanced approach, designed to meet the dynamic needs of the class. During Sync classes, students learn remotely through live class lectures, discussions, study groups and/or tutoring. You can find out more information about ASU Sync for students here, <https://provost.asu.edu/sync/students> and <https://www.asu.edu/about/fall-2020>.

## Materials, Equipment, and Personal Laptops

**Computers:** It is expected that you can bring a laptop to class to complete in-class programming tasks. You will be expected to install and use the Anaconda distribution of Python. This class is friendly to all operating systems, but I will be using a Windows machine, so that may be easiest. Others have used Ubuntu or OS/X on their own in the past with no problems.

**ASU Sync:**

If attending class in-person, you will need to bring and use earbuds in the classroom; this is essential to reduce interference and cross-talk during breakout sessions.

If attending remotely, you will need the following:

* Reliable home internet for accessing Zoom, Canvas, and other course content.
* A webcam or smartphone with camera for participating in class as well as for data collection.

If you are not able to personally finance the equipment needed to attend class via ASU Sync, ASU has a laptop and WiFi hotspot checkout program available through [ASU Library](https://lib.asu.edu/laptops-and-hotspots).

**Other recommended resources:**

* Adobe Creative Cloud, available to all ASU students for free: <https://uto.asu.edu/adobe-creative-cloud>.
* Microsoft Office ([Microsoft 365](https://myapps.asu.edu/app/microsoft-office-2016-home-usage) is free for all currently-enrolled ASU students)

**Textbook:** There is no textbook. Selected readings from will be provided on blackboard and/or linked to online.

**Materials:** There is no course fee; students will be responsible for obtaining consumable materials used in their project, such as cardboard, adhesive, plastic, etc. We may be able to supply a limited number of motors, sensors, and controllers which can be used for development, but if students wish to keep their robots they will need to purchase their own components.

**Equipment:** Special equipment for making laminate robots is available on the Poly Campus, *though there will be no requirement to use it*. If you do wish to use the tools and equipment you will need to pass all safety training required by the Innovation Hub. See <https://poly.engineering.asu.edu/innovation-hub/> for more information.

## Project

The final project will involve designing a foldable robot using the methods introduced in this class. The project will span the entire semester. Teams of ~4 students will propose a research question they would like to focus on in the realm of foldable robotics. They will survey the state of research on this topic, and craft a project of appropriate scope (with the guidance of the professor) and depth that can be accomplished in the time frame. They will then develop a design workflow, analysis, manufacturing plan, a robot, and validating data that supports the design decisions made.

## Class Schedule

The class schedule can be found on Canvas. It is subject to change, and will be updated regularly. It is your responsibility to keep track of all due dates, which will all be found on canvas.

|  |  |  |
| --- | --- | --- |
| Week | Monday | Wednesday |
| 1 | Introduction | Manufacturing I - Laser Training and Solidworks |
| 2 | Bio-Inspired Robotics I | Project Pitches |
| 3 | Foldable Robotics Background | Python I - tutorial and basics |
| 4 | Kinematics I | Project Presentations II |
| 5 | Kinematics II | Manufacturing II - Computational Solid Geometry |
| 6 | Manufacturing III - Layers & Laminates | Design Workflows I |
| 7 | Design Workflows II | Motor Modeling |
| - | *Spring Break* | *Spring Break* |
| 8 | Manufacturing IV - multilayer designs | Wearable Robotics |
| 9 | Control and Machine Learning | Project Presentations III |
| 10 | Mechatronics I - Arduino & Servos | Mechatronics II: Sensors |
| 11 | Mechatronics III - Arduino Examples | Product Pitches |
| 12 | Stiffness & Beams | Case Study: Dash Robotics |
| 13 | Consulting time | Presentations IV |
| 14 | Dynamics | Python Development |
| 15 | DXF and PDF | Wrap-up & Final Presentations |
| - | *Exam Week* | *Final Project Due* |

# Grading

## Grading Scale

Final points will receive a letter grade according to the following table:

|  |  |
| --- | --- |
| Grade | Range |
| A+ | 97-100.0 |
| A | 93-96.9 |
| A- | 90-92.9 |
| B+ | 87-89.9 |
| B | 83-86.9 |
| B- | 80-82.9 |
| C+ | 77-79.9 |
| C | 70-76.9 |
| D | 60-69.9 |
| E | 0-59.9 |

## Grading Rubric

Some assignments will be graded according to rubric with number values corresponding to a sliding qualitative scale . The following is a general description of what each percentage means in this course:

|  |  |
| --- | --- |
| % | Description |
| 100 | Shows superior effort, quality, mastering of the concepts, and innovation in execution. Documentation is publication-ready. |
| 90 | Exceeds expectations. Demonstrates a complete understanding of the problem, and solution is well executed, documented, and presented. |
| 80 | Above expectations. Minor mistakes are present, but student demonstrates a general understanding of the concepts. Documentation present but perhaps not comprehensive. |
| 70 | Meets expectations. Some effort shown, though there may be flaws in analysis or execution. Documentation is present but lacking in certain areas. |
| 60 | Below expectations. Minimal effort shown. Does not show understanding and may not have thought through their methods. Documentation is lacking substance, clarity, completeness, evidence of effort. |
| 50 | Fails to meet minimum expections. |
| 0 | Not submitted, illegible, not readable, not properly linked |

## Assignments and Assignment Categories

Assignments will be posted to Canvas throughout the semester. It is the student’s responsibility to check periodically for announcements and posted material. Assignments will cover many of the topics presented in class. The goal of assignments is to develop a fundamental understanding of the topics required to create foldable robots, using coding to design, manufacture, and analyze.

Assigned work may be individual in nature, team-based, or an in-class activity. Individual assignments will be graded on an individual basis. The grade for team-based assignments will be shared by all participating members. In-class work generally serves as a starting point for assigned homework, though it may be graded occasionally. Please see the grading rubric section of each assignment for assignment-specific details.

## Readings, Assignments, Examinations, Special Materials, Required Activities

Due to the nature of this class, failing to turn in an assignment on time affects you and your classmates, as each concept builds on the last. It is your responsibility to get in touch with the instructor regarding any questions before assignments are due. Late submissions will lose one letter grade(10%) for every day they are late. **Any sumbission more than four days late will be given a zero.** Additionally, due to the nature of the submission process, **late CATME assignments will not be accepted.**

All assignments must be posted to Canvas by ***11:59 am*** on the day it is due unless otherwise noted.

Assignment submissions must follow the “Assignment Submission Best Practices” document shared alongside this syllabus. It outlines the expectations for well written assignments, reports, and presentations.

## Submitting and Presenting work

Assigned homework will be submitted for grading several different ways. This is always indicated in the “Submission” section of each assignment.

* It may be submitted for grading via Canvas.
* Other work involving external tools (Google Surveys, CATME, etc) will be graded based on submitting to that external tool.
* Some work will be presented in front of the class, and the grade derived from the presentation.
* Other work will be compiled into the design notebook (in the form of a website or report) and graded priodically.

It is the student’s responsibility to pay close attention to each assignment’s submission instructions, as each assignment indicates the method by which the work must be submitted for grading. Failure to submit work in the manner asked for in each assignment will result in a zero.

# How to Succeed in this Course

* Attend all class sessions
* Complete all pre-class preparation assignments and reading
* Complete all post-class follow up assignments and reading
* Participate in office hours
* Check your ASU email regularly
* Log in to the Canvas at least once each week
* Communicate proactively with your instructor
* Create a study schedule so that you don’t fall behind on assignments

# Course Policies

## Attendance & Participation

This class is structured so that it can only be successful with your attendance. Classes will be interactive, and will require you to come with questions, answers, and ideas to discuss. Students should notify me if they will miss class, although this does not excuse them from learning the concepts or turning in their assignments on time.

As this is a Sync-enabled course, however, in-person attendance is not required. It is possible to complete all assigned work remotely.

Thus, attendance *in Zoom* will be required to count your participation. Attendance will be taken each class by taking a snapshot of the Zoom participant list; this may occur more than once per class. Students are expected to sign in to Zoom on time, as important issues are often introduced within the first few minutes of class. Tardies are thus treated as absences. If a student is found to be either absent or inactive on Zoom, they will be counted absent.

*Attending the class in person doesn’t change any of the above requirements. You will still be required to sign in to Zoom to participate and be counted present.*

Accommodations will be made for the following:

* excused absences related to religious observances/practices that are in accord with [ACD 304–04](https://www.asu.edu/aad/manuals/acd/acd304-04.html), “Accommodation for Religious Practices”
* excused absences related to university sanctioned events/activities that are in accord with [ACD 304–02](https://www.asu.edu/aad/manuals/acd/acd304-02.html), “Missed Classes Due to University-Sanctioned Activities”
* Excused absences related to missed class due to military line-of-duty activities that are in accord with [ACD 304–11](https://www.asu.edu/aad/manuals/acd/acd304-11.html), “Missed Class Due to Military Line-of-Duty Activities,” and SSM 201–18, “Accommodating Active Duty Military”

Minus the above exceptions, missing more than **two** classes will result in noticeable penalties to students’ participation grade, in the form of -2% off the student’s final grade per missed class over two.

Please coordinate with your fellow students to make sure someone takes notes during class if you will be unavoidably gone. The participation grade will reflect your contribution to class, office hour sessions, and planned group meetings.

## Classroom Behavior

Until further notified, per ASU policy, faculty, staff, students and visitors, are required to wear face coverings in classrooms, labs, offices and community spaces.

**Professional Communication** in all forms is required. This includes proper dress when attending class remotely and in-person. Please refrain from using any background images in your zoom video feed, though you should consider blacking out your background for privacy and professionalism.

**Cell phones, pagers, and other personal devices** must be turned off during class to avoid causing distractions. The use of recording devices is not permitted during class. Any violent or threatening conduct by an ASU student in this class will be reported to the ASU Police Department and the Office of the Dean of Students.

**Use of laptops in class:** Laptops are strongly suggested for this course. You may use your laptop to take notes, during tutorial sessions, or when giving presentations. Please do not use class time for emails, chats, web browsing, or other non-class related activities.

## Reorganizing a Team

Reorganizing teams is not a desired outcome of a group project but is sometimes necessary if dysfunction rises to a level that it cannot complete the project. One or more teammates or the instructor may initiate the process to split or reorganize a team. Splitting teams does not necessarily work in any members’ best interests, as team-based Team Assignments, which each team member must contribute to, are afterwards spread across fewer people.

However, if the need arises, members must work with the professor to outline the issues which are creating the need to reorganize and the measures which remaining teammates may take to rectify the situation. This can take the form of changes made to communication, workload reallocation, new meeting times, etc. The professor will have the final say in establishing a set of expectations for the team, which must be met within a week. If members fail to live up to these expectations, the team may be split and reorganized by the instructor.

When reorganiztion occurs, each new team will set up their own folders starting with the former team’s work, but new material will be created by the new team, and old material adapted based on the new direction of each new team. Any changes to the project definition due to the split (such as project scope, performance specifications, timeline, etc) will need to be rectified for all future submissions or presentations.

**The instructor has the final say in the establishment and reoganization of teams.**

## Academic Integrity

This class is meant to teach you how to create and use your own design tools for creating folding robots using a variety of published resources, online resources, and classroom content. I encourage you to plumb the depths of what’s available; through this synthesis you might be able to create something unique. However, I expect to be able to tell what is your work and what is someone else’s. For this reason, specific rules for this class are:

* Do your own work for individual assignments and tests.
* Include the your sources of inspiration within assignments and projects. This will help grow the list of cool references, but more importantly, help distinguish inspiration from wholesale plagarism.
* Keep code/text/information you use from outside sources separate from your own original content (through the use of separate folders, for example). Make it explicit what is yours and what is not.
* Include all the licenses or copyright statements as required by the things you reuse. This will make your own code more reuseable for yourself and potentially others in the future.

Students in this class must adhere to ASU’s academic integrity policy, which can be found at <https://provost.asu.edu/academic-integrity/policy>). Students are responsible for reviewing this policy and understanding each of the areas in which academic dishonesty can occur. In addition, all engineering students are expected to adhere to both the ASU Academic Integrity Honor Code and the Fulton Schools of Engineering Honor Code. All academic integrity violations will be reported to the Fulton Schools of Engineering Academic Integrity Office (AIO). The AIO maintains record of all violations and has access to academic integrity violations committed in all other ASU college/schools.

## Copyright

All course content and materials, including lectures (Zoom recorded lectures included), are copyrighted materials and students may not share outside the class, upload to online websites not approved by the instructor, sell, or distribute course content or notes taken during the conduct of the course (see [ACD 304–06](https://www.asu.edu/aad/manuals/acd/acd304-06.html), “Commercial Note Taking Services” and ABOR Policy [5-308 F.14](https://public.azregents.edu/Policy%20Manual/5-308-Student%20Code%20of%20Conduct.pdf) for more information).

You must refrain from uploading to any course shell, discussion board, or website used by the course instructor or other course forum, material that is not the student’s original work, unless the students first comply with all applicable copyright laws; faculty members reserve the right to delete materials on the grounds of suspected copyright infringement.

## Policy against threatening behavior, per the Student Services Manual, [SSM 104–02](https://www.asu.edu/aad/manuals/ssm/ssm104-02.html)

Students, faculty, staff, and other individuals do not have an unqualified right of access to university grounds, property, or services. Interfering with the peaceful conduct of university-related business or activities or remaining on campus grounds after a request to leave may be considered a crime. All incidents and allegations of violent or threatening conduct by an ASU student (whether on- or off-campus) must be reported to the ASU Police Department (ASU PD) and the Office of the Dean of Students.

# Disability Accommodations

Suitable accommodations will be made for students having disabilities. Students needing accommodations must register with the ASU Disabilities Resource Center and provide documentation of that registration to the instructor. Students should communicate the need for an accommodation in sufficient time for it to be properly arranged. See [ACD 304-08](https://www.asu.edu/aad/manuals/acd/acd304-08.html) Classroom and Testing Accommodations for Students with Disabilities.

The Americans with Disabilities Act (ADA) is a federal antidiscrimination statute that provides comprehensive civil rights protection for persons with disabilities. One element of this legislation requires that all qualified students with documented disabilities be guaranteed a learning environment that provides for reasonable accommodation of their disabilities. If you believe you have a disability requiring an accommodation please contact the Disability Resource Center at ASU Polytechnic located in Student Affairs Quad # 4 or call 480-727-1039 / TTY: 480-727-1009. Eligibility and documentation policies are online at: <http://www.asu.edu/studentaffairs/ed/drc/>

## Harassment and Sexual Discrimination

Arizona State University is committed to providing an environment free of discrimination, harassment, or retaliation for the entire university community, including all students, faculty members, staff employees, and guests. ASU expressly prohibits discrimination, harassment, and retaliation by employees, students, contractors, or agents of the university based on any protected status: race, color, religion, sex, national origin, age, disability, veteran status, sexual orientation, gender identity, and genetic information.

Title IX is a federal law that provides that no person be excluded on the basis of sex from participation in, be denied benefits of, or be subjected to discrimination under any education program or activity. Both Title IX and university policy make clear that sexual violence and harassment based on sex is prohibited. An individual who believes they have been subjected to sexual violence or harassed on the basis of sex can seek support, including counseling and academic support, from the university. If you or someone you know has been harassed on the basis of sex or sexually assaulted, you can find information and resources at <https://sexualviolenceprevention.asu.edu/faqs>.

Mandated sexual harassment reporter: As a mandated reporter, I am obligated to report any information I become aware of regarding alleged acts of sexual discrimination, including sexual violence and dating violence. ASU Counseling Services, <https://eoss.asu.edu/counseling>, is available if you wish discuss any concerns confidentially and privately.

# Student Support Services

* ASU Libraries - offers 24/7 access to librarians through “Ask a Librarian” online chat and help by librarians in person at the Reference Desk during most hours the libraries are open. <http://www.asu.edu/lib/>
* Counseling and Consultation – provides confidential mental health and career counseling services for all ASU students. <http://www.asu.edu/studentaffairs/counseling/>
* Learning Resource Center – provides students with academic support services such as tutoring, peer advising, computer assisted instruction, and supplemental instruction. Offers both free and fee-based services. <http://www.asu.edu/vpsa/lrc/>
* Writing Center – provides on-site tutors to help students increase their confidence as writers and improve writing skills free of charge. <http://www.asu.edu/duas/wcenter/>
* Career Services – offers assistance to students in choosing a major, setting career goals, interviewing and job hunting strategies. <http://career.asu.edu/>
* Student Financial Aid Office – offers information and applications for student funding such as grants, loans, scholarships and student employment. <http://www.asu.edu/fa/>
* Student Health and Wellness Center – provides non-emergency medical health care to all ASU students regardless of insurance status. Most visits with a physician or nurse practitioner are free of charge, but fees will be incurred for x-rays, lab results, etc., <http://www.asu.edu/health/>
* Student Recreational Center – offers individual and group fitness opportunities, as well as information on nutrition and wellness, and massages. Use of the general facilities (weights, circuit training and cardio machines) are free, other services (yoga classes, massages) are fee-based. <http://www.asu.edu/src/>
* Student Legal Assistance – provides legal advice and counsel free of charge to all ASU students in areas such as landlord-tenant law, credit reports and collection issues, taxability of scholarships and grants, etc. Notary service is also available at no charge. <http://www.asu.edu/mu/legal/>
* Help Wiki – provides a frequently asked questions resource for technology users at ASU. <http://wiki.asu.edu/help/>
* EMPACT Crisis Hotline – offers free 24-hour support for mental health crises. Call (480) 784-1500 in the Phoenix area, (866) 205-5229 for the toll-free number outside of Phoenix, and (480) 736-4949 for the sexual assault hotline. All services are free and confidential. <http://www.empact-spc.com/>

**Notice:** Any information in this syllabus (other than grading and absence policies) may be subject to change with reasonable advance notice.