# DES INV 22 Prototyping & Fabrication (3 units)

This course teaches concepts, skills and methods required to design, prototype, and fabricate physical objects. Each week relevant techniques in 2D and 3D modeling and fabrication are presented along with basic electronics and circuit design. Projects are assigned that cover the weekly course material. Topics include a range of prototyping and fabrication techniques including laser-cutting, 3D modeling and 3D printing, soldering, basic circuits, microcontrollers (Arduino), sensors and actuators, and interface mockups.

Course is open to students in all disciplines, has no pre-requisites, and requires no previous experience. This course may be used to fulfill College of Engineering undergraduate technical elective requirements.

## Enrollment

Because of the hands-on nature of this course, we have a strict capacity limit of 30 students.

## Prerequisites

None. Students of all disciplines are welcome regardless of previous experience.

## Course Information

Instructors: Michael Shiloh and Christopher Myers

Piazza Group (for any course-related questions): If you have a technical question about your homework or project, please ask the class first through this group. For personal class-related issues, use the private messaging feature on Piazza. Do not send individual email.

Maker Pass Fee: This course requires payment of a use fee of $75 for a Jacobs Hall Maker Pass, which covers some materials as well as access to equipment required for the class. Jacobs Institute and a basic electronics kit. There may be additional out-of-pocket expenses for electronics and consumables for your class project.

Lab Hours: The hours for the Jacobs Institute are posted at http://jacobsinstitute.berkeley.edu/jacobs-hall-schedule/.

Textbook: There is no required textbook for this class. There will be readings assigned for many lectures. The readings will be available online.

## Grading
• 40% Homework Assignments
• 40% Class Projects
• 20% Participation (attendance, in-class contributions, on Piazza)

## Schedule

### Week 1
### Topic: Class introduction and working with paper
Introducing Xacto Knife, ruler cutting demo

Readings
- [Introduction](#) of the SparkFun Inventor's Kit for Arduino Experimenter's Guide
- [Experiment 1: Blinking an LED](#) in the SparkFun Inventor's Kit for Arduino Experimenter's Guide
- [Experiment 2: Reading a Potentiometer](#) in the SparkFun Inventor's Kit for Arduino Experimenter's Guide

Assignments
- Create three models of different folded and/or cut paper structures; one has to be able to change shape
- Create your profile on Hackster.io
- Download Arduino IDE and Autodesk Fusion software.
- Complete equipment trainings for Jacobs Hall and/or the Invention Lab
- Purchase supplies and bring to next week's class

### Week 2
### Topic: Introduction to Arduino
Electronics: Installation, problem solving, and introduction to basic Arduino capabilities (digitalRead(), digitalWrite(), analogRead(), analogWrite()). Using a transistor to control a high current load (motor).

Readings
- [Ardunio's Digital Read Serial](#)
- [SparkFun's Switch Basics Tutorial](#)

Assignments
- Use a switch or Photoresistor to control the servo motor in your origami project
- Combine one of your origami/kirigami from last week's homework with the Arduino servo sketch to create something that changes shape (mechanical linkage, accordion, etc.). Feel free to remake your origami/kirigami if you decide that what you have is not conducive to the servo assignment. Servo and origami must be mounted solid to a base and brought to class.

***Week 3***
***Topic: 2D CAD***
Prototyping: Introduction to 2D CAD demo with simple shapes, intro to laser cutter, intro to linkages, physical prototyping

Readings
- N/A

Assignments
- Make a name plate to put on your desk in class.
- Design and laser cut a set of gears and linkages to convert rotary motion into linear motion.
  - Can be hand powered but must have some affordances to actuate it ergonomically and move something.
  - No touching the gear directly, output motion should be highlighted by physical design.

***Week 4***
***Topic: Mechanisms***
Prototyping: mechanisms

Readings
- [Adafruit's Arduino lesson 13: DC Motors](#)
- [SparkFun's Motor overview](#)
- [Adafruit's Arduino lesson 14: Servo motors](#)
- [Adafruit's All About Stepper Motors](#)
- [Adafruit's Stepper Motor lesson](#)
- [Wikipedia's Stepper Motor article](#)

Assignments
- Project #1: Drawing machine
  - Must leave a mark on paper or other surface.
  - You may use any of the sensors and actuators we've learned about.
  - Must be repeatable and operate with only input motion (can not be held in place, supported by hands, pushed or knocked to get started or other physical assistance).

***Week 5***
***Topic: Motors***
Electronics: Introduction to current and Ohm's law, labs (DC motor and transistor, DC motor and H-bridge), presentation of week 4's homework

Readings
- SparkFun's [How to use a Multimeter](#)
- Adafruit's [Multimeter tutorial](#)

Assignments
- Project #1: Drawing machine: hand powered mechanical prototype

- ○ You may use any of the sensors and actuators we've learned about.
- ○ Must be repeatable and operate with only input motion (can not be held in place, supported by hands, pushed or knocked to get started or other physical assistance).

## *Week 6*
## *Topic: Soldering, Perforated breadboard, Arduino Prototyping Shield*
Electronics: Homework presentation of drawing machine, Arduino prototyping shield introduction, Arduino Wire selection, connectors, soldering, wiring management

Readings
- ● N/A

Assignments
- ● N/A

## *Week 7*
## *Topic: Arduino shield examples; Adhesives and Fasteners*
Electronics: show and tell of a variety of shields
Prototyping: adhesives, fasteners

Readings
- ● Adafruit's [Guide to Excellent Soldering](#)

Assignments
- ● Project #1 (Drawing Machine) due
- ● Project #2: Remote controlled vehicle
  - ○ Low fidelity prototype of three chassis designs using laser cut cardboard, 3Dprinted parts, bamboo skewers, straws, etc...
  - ○ Must be actual size and have functionality of final design. i.e. wheels must steer, body must articulate, etc. No electronics, just mechanics.

## *Week 8*
## *Topic: PCB design and creation*
Electronics: PCB layout and Othermill including soldering
Prototyping: Drive by wire/Arduino control

Readings
- ● Fritzing introduction, Othermill tutorial, Bluetooth tutorial
  - ○ [Fritzing Getting Started](#)
  - ○ [Building a Fritzing Circuit](#)
  - ○ [Designing a PCB in Fritzing](#)
  - ○ [Designing an Arduino shield in Fritzing](#)
  - ○ [Introduction to the Othermill](#)
  - ○ Othermill [Hello World](#) project
  - ○ Othermill PCB [Design Considerations](#)
  - ○ [Introducing the Adafruit Bluefruit LE SPI Friend](#)

<u>Assignments</u>
- Project #2: Chassis refinement


***Week 9***
***Topic: Wireless: Bluetooth LE; 3D printing***
Electronics: Arduino-Bluetooth
Prototyping: 3D printing, mechanical prototyping, chassis

<u>Readings</u>
- Chuck Rosenberg's [Robot building tips](#)

<u>Assignments</u>
- Mill and solder your PCB on the Othermill□
- Medium Fidelity chassis, working steering, working motors.
  - We will set up a test track and your vehicle will be graded on how well it performs the required criteria, i.e. does it steer, can it move on its own, climb the ramp?


***Week 10***
Spring Recess


***Week 11***
***Topic: Advanced electronics: Dealing with low frequency and high frequency electrical noise***
Electronics: Review voltage, resistance, and current and the relationship between the three, the difference between ideal conductors and real conductors: resistance, capacitance, inductance, power distribution considerations, low frequency voltage sag, high frequency noise from motors, things to watch out for when you wire up your vehicle

<u>Readings</u>
- Tronixstuff's [Arduino and the SPI Bus](#)
- Sparkfun's [SPI Interface](#)
- Sparkfun's [I2C interface](#)
- Tronixstuff's [Arduino and the I2C Bus](#)

<u>Assignments</u>
- Project #2: a finished fully functional, Bluetooth controlled vehicle
  - working steering, working motors
  - Testing on track, vehicle will be graded on how well it performs the required criteria, i.e. does it steer, can it move on its own, climb the ramp?


***Week 12***
***Topic: Advanced Arduino interfaces***
Electronics: Arduino schematic, pins with special functionality, advanced interfaces

<u>Readings</u>
- Adafruit's [Arduino Processor Interrupts tutorial](#)
- Sparkfun's [Processor Interrupts with Arduino tutorial](#)

- Adafruit's [Timer Interrupts tutorial](#)

<u>Assignments</u>
- N/A

*Week 13*
*Topic:* Arduino timers and interrupts; finishing prototypes
Electronics: Arduino timers and interrupts
Prototyping: fit and finish, coatings and paint, lubrication

<u>Readings</u>
- N/A

<u>Assignments</u>
- Prepare questions for next week

*Week 14*
*Topic: Class choice of topics in electronics*
Electronics: Q&A session about electronics
Prototyping: Review of vehicle designs, failure proofing demos

<u>Readings</u>
- Adafruit's [What's the difference between Arduino, Raspberry Pi, BeagleBoard, etc?](#)
- Browse [Internet of Things Hardware Roundup](#)
- Browse [Make: The Maker's Guide to Boards](#)

<u>Assignments</u>
- Vehicle refinement--incorporate critique feedback to vehicle design

*Week 15*
*Topic: Other microcontrollers; best practices, and the future*
Electronics:  Other microcontrollers
Prototyping: best practices, emerging/future technology

<u>Readings</u>
- N/A

<u>Assignments</u>
- Clean up/refine prototype vehicles for presentations

*Week 16*
RRR Week and Final Presentations