University of California, Berkeley
Department of Mechanical Engineering

Engineering 29: Manufacturing and Design Communication

Spring 2021
Course information

Overview

Welcome to Engineering 29, Spring 2021! This core course in the Mechanical Engineering curriculum introduces three interconnected sets of topics:

- **Manufacturing processes.** We discuss what processes are available, how they work to transform material into the shape needed to make a product, and the advantages and limitations of common processes.
- **Dimensional tolerancing.** No manufacturing process is perfect, and the physical sizes and shapes of manufactured objects inevitably differ slightly from their ideal dimensions. When designing mechanical systems, we need to allow for a realistic amount of dimensional error in manufacturing, and we need to quantify how much deviation is acceptable for the design still to work properly. You will learn how to make and communicate these design decisions.
- **Design communication.** Producing effective and accurate drawings of a mechanical design is a crucial skill for persuading others of the merits of a design, working out how practical it will be to manufacture, and communicating how it is to be manufactured, used, or serviced. Computer-aided design (CAD) software is, of course, now very widely used for this purpose; engineers also frequently draw sketches by hand during the design process and in E29 we will use both CAD and hand drawing.

You will learn and practice this material through a sequence of guided take-home labs and an open-ended final project in which you'll design and prototype a mechanical assembly. Learning is also supported through weekly homeworks and a midterm assignment.

To make it easy to follow the course content during remote learning, the course is organized into modules. If you click on 'Modules' on the left-hand side of the bCourses page, you will see all the lectures, lab, and homework assignments, etc, arranged in a logical order. If you work through these items sequentially while observing the deadlines given, you will be able to stay on track and do well in the class. The modules are:

1. Fundamentals of manufacturing, tolerancing and graphical communication
2. Subtractive manufacturing processes
3. Additive manufacturing processes
4. Forming processes
5. Joining processes
6. Graphical visualization techniques
7. Metrology: measuring manufactured objects
8. Geometric dimensioning and tolerancing
9. The future of manufacturing

Below is further detailed information about how the course is organized and run.

Course staff

Name	**E-mail**	**Office hours** (links require authenticated Berkeley.edu login)
Prof. Hayden Taylor Course instructor	hkt@berkeley.edu	M and W, 5–6pm on https://berkeley.zoom.us/my/hayden.taylor, starting Jan 20th, or by arrangement
Alan Zhang GSI	aszhang@berkeley.edu	Tu and Th, 5–6pm, on https://berkeley.zoom.us/j/96197303250 starting Jan 21st.

Schedule

Below is a summary of the semester's activities. You can also track upcoming assignments using the "Syllabus" link on the left-hand side of the bCourses page. Although lectures will be pre-recorded for asynchronous viewing, I have nominally associated each lecture with a particular day to help you pace your viewing.

Week commencing	Tuesday Lecture	Thursday Lecture	Lab activity	Deadlines (at 11:59pm on date specified)
Jan 18	L1: Course introduction	L2: Fundamentals of tolerancing	No lab	• Jan 22: Start-of-semester and team formation survey
Jan 25	L3: Fundamentals of graphical communication	L4: Subtractive processes: types of subtractive process; mechanics of cutting	Lab 1: Reverse engineering and freehand sketching	• Jan 25: All students signed up for JPS
Feb 1	L5: Cutting-based processes: Turning, milling, drilling, and sawing	L6: Other subtractive processes: e.g. EDM, laser, and abrasive jet	Lab 2: Design for planar component fabrication	• Feb 5: HW1 (Tolerancing)
Feb 8	L7: Additive processes: overview, and extrusion-based processes	L8: Additive processes: powder-based methods. Plus: introduction to teaming and collaborative plan activity	Lab 3: Machine shop and Jacobs virtual tours; toolpath planning	• Feb 8: Lab 1 • Feb 12: HW2 (Subtractive)
Feb 15	L9: Additive processes: liquid-based and others	L10: Forming (polymers): injection molding; extrusion	Project: Concept generation	• Feb 16: Lab 2 • Feb 19: Teaming: collaborative plan
Feb 22	L11: Forming (metals): casting processes	L12: Forming (metals): forging, drawing, and rolling	Lab 4: Injection molding	• Feb 22: Lab 3 • Feb 26: HW3 (Additive)
Mar 1	L13: Joining processes: welding and brazing	L14: Joining processes: fasteners and adhesives	Project: Design Review 1	• Mar 1: Project milestone A (concepts, concept selection and preliminary design) • Mar 5: HW4 (Forming)
Mar 8	L15: Visualization: orthographic projections	L16: Visualization: pictorial views	Lab 5: Welding	• Mar 8: Lab 4 • Mar 12: HW5 (Joining)
Mar 15	L17: Visualization: section views	L18: Visualization: advanced projections	Lab 6: Assemble planar and 3D machined designs	• Mar 15: Teaming: first check-in survey • Mar 18: Midterm
Mar 22	Spring Break			
Mar 29	L19: Metrology: principles, terminology and sampling	L20: Metrology: tools and techniques	Project: Design Review 2	• Mar 29: Lab 5 • Apr 2: HW6 (Visualization)
Apr 5	L21: GD&T: introduction and datums	L22: GD&T: position tolerances	Project: Manufacturing planning and JPS job submission	• Apr 5: Project milestone B (final version of Design Review 2 slides, and 3D CAD for project design) • Apr 9: Teaming: second check-in survey
Apr 12	L23: GD&T: orientation tolerances	L24: GD&T: form and profile tolerances	Lab 7: Dimensional measurements	• Apr 12: Project milestone C (all required project components submitted to JPS for fabrication) • Apr 16: Lab 6
Apr 19	L25: GD&T: runout tolerances	L26: GD&T: examples	Project: Prepare working drawings with GD&T annotations	• Apr 23: HW7 (GD&T)
Apr 26	L27: The future of manufacturing: process technology	L28: The future of manufacturing: design and visualization	Project: Assembly, refinement, and testing	• Apr 26: Lab 7 • Apr 30: HW8 (More GD&T)
May 3	RRR week			• May 7: Project milestone D (project final video and design materials including working drawings) • May 7: Teaming: final survey

Gray-shaded cells in the table above indicate that labs that week will definitely be remote (see campus announcement); for other weeks, whether labs can be optionally in-person will depend on City and campus policies at the time. Access to Jacobs Project Support (JPS) services is expected to be available throughout the semester.

Start-of-semester survey

Please complete the following survey **by Friday January 22nd, 11:59pm** so that the staff can understand your expectations for the class and set up student teams accordingly**:** https://forms.gle/B34evQAMERy5HV5v9 (need to be logged in with your Berkeley.edu Google account).

Lectures

The lectures will be pre-recorded and posted on bCourses. You can access them by going to “Modules” in bCourses, and then clicking on the page associated with the specific lecture that you want to view. The lectures will be posted on or before the dates indicated in the table above.

Labs

Content

Labs will begin in the week of January 25th. There will be seven structured labs, covering the following topics:

1. Reverse engineering and freehand sketching of manufactured objects
2. Mini design challenge: planar components for interlocking assembly
3. Etcheverry Machine Shop and Jacobs Hall virtual tours; toolpath planning for subtractive manufacturing
4. Injection molding
5. Welding
6. Assemble and evaluate objects designed in Labs 2 and 3
7. Dimensional measurements of manufactured components

A detailed guide will be provided for each lab, usually during the weekend before you are scheduled to begin the lab.

Labs 1, 4, 5 and 7 will be done individually – you are free to collaborate informally, but each student will enter their own responses for the lab checkoff in Gradescope.

Labs 2, 3 and 6, meanwhile, will be done in teams of four students that we create based on the preferences and experience you tell us about in the start-of-semester survey. Your outcomes from Labs 2, 3 and 6 will be uploaded on bCourses (one upload per team). Every member of a given team will receive the same score for these three assignments.

Interaction modes: remote or in-person?

The assignments are all designed to be able to be successfully completed remotely, and that appears to be the preference of the majority of enrolled students currently. I know, however, that a significant number of you are keen to have some in-person interaction, and so we secured in-principle approval to use Jacobs Hall 310 for optional in-person labs. Unfortunately, on January 14th Jacobs Hall failed an air handling test, which means that currently that space is not approved for in-person instruction. I am working to find a solution, and will keep you posted on what happens.

Regardless of whether students are able to enter campus buildings, we will be making extensive use of Jacobs Project Support. JPS is a service offered by the Jacobs Institute that fabricates student-designed components to order, for pickup or shipping.

Team formation

We will use the responses to the start-of-semester survey — including preferences by individuals to work together — to create teams of four students with complementary skills. These teams will work together on Labs 2, 3 and 6 as well as on the main semester project.

Lab sections/timing/assistance

There are four weekly lab sections, starting on January 25th, scheduled at the following times:

- Lab 101: W 1–4pm
- Lab 102: W 9am–12pm
- Lab 103: M 9am–12pm
- Lab 104: M 2–5pm

Alan will host each of these lab sections synchronously at the following Zoom link: https://berkeley.zoom.us/j/96197303250. Most weeks, the first 30 mins to 1 hour will be a live introduction to that week's activity, with an opportunity to ask immediate questions. That initial portion will be recorded and posted on bCourses. For the remainder of each 3-hour section, the Zoom link will be left open and Alan will be available to answer questions and give advice as questions arise. You may log in for any of the four sections, regardless of which section you are officially registered in.

Attendance will not be taken at synchronous lab sessions and there will be no advantage in terms of grading to attending synchronously. If you prefer, you can complete the labs in your own time, coordinating as appropriate with your team and seeking help from course staff through office hours, Piazza or e-mail.

The exceptions to this plan will be the two Design Review weeks (March 1 and March 29), when each team will need to attend a ~20-minute slot on Zoom to present and discuss their project with staff and one or more other teams. For any students who are truly unable to attend any of the scheduled labs, we will find a solution.

For Labs 2, 3 and 6 and the project-focused weeks, it will be important to consult with your fellow team members and agree on a plan for working together, which might involve picking a specific section that you will all attend, or working partially or completely asynchronously. These are the types of decisions that engineering teams in industry frequently need to make, and it is not uncommon for teams dispersed across continents and timezones to work effectively together. There are many digital resources to help with this process now, including collaborative editing (even on CAD software), Slack, Zoom, etc. What is crucial is clear communication of expectations and availability.

If we are able to confirm an in-person lab attendance option, any attendance will need to be planned to keep room occupancy within allowed limits.

Assumptions about CAD experience

This class has a *recommended* pre-requisite of E26: Three-dimensional Modeling for Design, or equivalent experience in 3D solid modeling (e.g. Solidworks or Autodesk Fusion 360). In E29 we will build upon core 3D modeling skills by showing, for example, how to annotate working drawings with geometric dimensioning and tolerancing specifications. If you are planning to take E26 concurrently this semester, that will work fine; we have tried to sequence the course schedule so that we make use of these skills only after they have been introduced in E26. If you do not have any solid modeling experience, please indicate that in the start-of-semester survey that will be going out, and we will try to form teams so that every team contains someone with 3D solid modeling experience.

Homeworks

There will be eight homeworks, done on Gradescope, and generally due on Friday nights. We will post the homeworks at least one week before they are due, and aim to provide graded HW within two weeks of the deadline.

Midterm assignment

There will be one midterm, on Gradescope. The scope will be Modules 1–4 (lectures 1–12). It will be live for 48 hours from 8am on Tuesday March 16th until 8am on Thursday March 18th. The midterm will be designed to take about two hours, but you will not be required to complete it in a single sitting and you will not be limited to two hours. You can update your solutions at any point up until the deadline by clicking the "Resubmit" button in Gradescope, editing your answers, and saving them.

Project

The class will include a design, tolerancing and prototyping project in which you will develop a prototype of a mechanical device. The aim is to allow you to apply what you have learned about manufacturing processes and dimensional tolerancing. We will ask your team to address one of the following open-ended briefs:

- Design a device to reduce the risk of transmission of Covid-19
- Design a device to make working/studying from home more efficient, effective or enjoyable
- Design a device to enhance the capabilities of a smartphone
- If there is a different brief that you particularly want to address, your team can propose it.

The emphasis is on mechanical components and the interactions between them, rather than, for example, electronics or software, which are not expected to be a significant element of the project.

There will be four key milestones in the project, interspersed with two design reviews:

- Milestone A (due Mar 1): Concept generation, concept selection and preliminary design
- Design Review 1 (week of March 1)
- Design Review 2 (week of March 29)
- Milestone B (due Apr 5): Final version of Design Review 2 slides, and 3D CAD for project design
- Milestone C (due Apr 12): All required project components submitted to JPS for fabrication
- Milestone D (due May 7): Project final video and design materials including working drawings

The final video will be a five-minute presentation of your project explaining your design process and showing your prototype. More details for the project will be posted around Feb 15th.

Jacobs Project Support (JPS)

Every team will make a physical prototype of their design, thanks to the JPS program. The program is detailed here: https://jacobsinstitute.berkeley.edu/jps/. Essentially, you upload CAD drawings of components you would like to be produced in Jacobs Hall, and Jacobs staff fabricate them, usually within a few days. You can then either pick them up from outside Jacobs Hall or have them shipped to you. There is no charge to register for the program; materials and any shipping are charged at cost to your student account. You are also able to use components from other sources if you wish.

All E29 students need to sign up for the JPS program at this link: https://jacobsaccess.ist.berkeley.edu/jps/signup [link may not be live for a couple more days]. We ask you to register by January 25th.

Teaming activities

We are working with Dr Sara Beckman of the Haas School to provide activities to help your team reflect on its goals, successes, and opportunities for improvements. The aim is to enable your team to function as well as possible. This element of the course will be introduced as part of Lecture 8, and the activities involved are included in the schedule above.

Credit weighting

Credit for the class is apportioned as follows:

- Homeworks (8 assignments, equally weighted): 20%
- Labs (7 labs, equally weighted): 25%
- One take-home midterm assignment: 15%
- Project: 30%
    - Milestone A: Concepts: 25% of project score
    - Milestone B: Design review presentations and slides: 25% of project score
    - Milestone D: Final outcome, including prototype and working drawings: 50% of project score
    - (Note: Milestone C is submitting designs of all required components to JPS for fabrication, which is not itself graded).
- Participation: 10%
    - Completion of start-of-semester survey and four further teaming activities: 50% of participation score (equally weighted across activities). Please note that the credit is for *completion*; your own grade will not be influenced by what other team-mates write in the surveys.
    - Attendance at and meaningful participation in the two project design reviews: 50% of participation score (equally divided between the two reviews).

There is no final exam.

Reference texts

There is no required text and all notes will be provided in the form of lab handouts, lecture notes, and supplementary materials. If interested, here are some books that I can recommend:

Cogorno, Gene R., Geometric Dimensioning and Tolerancing for Mechanical Design, Third Edition, McGraw Hill, 2020.

> This is more detailed than required for the class, but provides comprehensive coverage of GD&T and is available free online to UCB students using the Library proxy:
>
> https://www-accessengineeringlibrary-com.libproxy.berkeley.edu/content/book/9781260453782

Lieu, D.K. and Sorby, S.A., Visualization, Modeling, and Graphics for Engineering Design, Cengage Publishers, 2009. ISBN 978-1-4018-4249-9. Library call number: TA174.L54 2009.

Kalpakjian, S. and Schmid, S., Manufacturing Processes for Engineering Materials, 5th Edition, Prentice Hall, 2008. ISBN 978-0132272711. Library call number: TS183.K34 2008.

Piazza

You can join the course Piazza site here: http://piazza.com/berkeley/spring2021/engin29/home. Access code: 05122018. If you have not used Piazza before, it provides a forum for asking questions about labs and assignments to which instructors and/or students collaboratively construct a response.

Office hours

I encourage you to make use of office hours with any questions you may have about the course material, but also if you want to talk more generally about engineering, career plans, research opportunities, etc.

Academic integrity

We will be adhering to the Berkeley Honor Code (http://asuc.org/honorcode/index.php). If anyone has any questions about the responsibilities they have as part of this Code, or concerns about possible breaches of it, please contact Prof. Taylor.

Late assignments

We do ask that you *try* to complete assignments by the deadlines. We recognize however that this is an especially challenging time for many students, who may have multiple responsibilities and sometimes unpredictable schedules. We will therefore be very accommodating of those who need extra time for assignments. Please try to communicate with Alan or me in advance of the original deadline if for any reason you think you need more time for an assignment. We ask for advance warning (a) as a courtesy, (b) so that we can think of ways to support students as much as possible, and (c) so that we can pause the release of homework solutions for a few days if needed. Please don't be shy about asking for an extension if you need one.

Student Technology Equity Program

The campus operates a free program to provide students with laptops, WiFi hotspots, and other technology to make studying more convenient. I encourage you to take advantage of this scheme if you have any technology needs: https://technology.berkeley.edu/STEP.

Machine shop training

The E29 syllabus provides for students to receive Etcheverry Machine Shop orientation in person. Because of the pandemic, the Shop is currently closed. However, the Shop staff have kindly given an undertaking that students registered for E29 this semester will be entitled to receive their training when the Shop finally reopens (I trust, in the Fall). Obviously there will be a lot of pent-up demand for Shop access when that happens, so please be patient!

Revision history

Date	Revision
Jan 18 2021	Initial version