University of California, Berkeley • Department of Mechanical Engineering

Engineering 29: Manufacturing and Design Communication

Spring 2022 • Course information

Overview

Welcome to Engineering 29, Spring 2022! 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 structured 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, 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 Berkeley.edu login)
Prof. Hayden Taylor Course instructor	hkt@berkeley.edu	Thursdays 5–6pm in 6159 Etcheverry, Fridays 1–2pm on this link, or by arrangement
Sara Shonkwiler GSI	sara_shonkwiler@berkeley.edu	Starting Jan 25: Tu 1–2pm (in person, Hesse "fishbowl"); Th 1–2pm (Zoom: https://berkeley.zoom.us/j/96161805386)
Alondra Perez GSI	alondraperez@berkeley.edu	Starting Jan 25: M 5–6pm (in-person, Hesse "fishbowl"); W 5–6pm (on Zoom)

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.

Week commencing	Tuesday Lecture	Thursday Lecture	Lab activity	Deadlines (at 11:59pm on date specified)
Jan 17	L1: Course introduction	L2: Fundamentals of tolerancing	No lab	• Jan 21: Start-of-semester and team formation survey
Jan 24	L3: Fundamentals of graphical communication	L4: Subtractive processes: types of subtractive process; mechanics of cutting	Lab 1: Reverse engineering and freehand sketching (Zoom link)	• Jan 28: Sign up for Machine Shop Training, Jacobs Project Support and a Jacobs Maker Pass
Jan 31	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 4: HW1 (Tolerancing)
Feb 7	L7: Additive processes: overview, and extrusion-based processes	L8: Additive processes: powder-based methods. Plus: introduction to teaming and collaborative plan activity	Lab 3: Design for material cutting and toolpath planning	• Feb 8: Lab 1 • Feb 11: HW2 (Subtractive)
Feb 14	L9: Additive processes: liquid-based and others	L10: Forming (polymers): injection molding; extrusion	Project: Concept generation	• Feb 15: Lab 2 • Feb 18: Teaming: collaborative plan
Feb 21	L11: Forming (metals): casting processes	L12: Forming (metals): forging, drawing, and rolling	Lab 4: Injection molding	• Feb 22: Lab 3 • Feb 25: HW3 (Additive)
Feb 28	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 4: HW4 (Forming)
Mar 7	L15: Visualization: orthographic projections	L16: Visualization: pictorial views	Lab 5: Welding	• Mar 8: Lab 4 • Mar 11: HW5 (Joining)
Mar 14	L17: Visualization: section views	L18: Visualization: advanced projections	Lab 6: Assemble planar and 3D machined designs	• Mar 15: Teaming: first check-in survey • Mar 17: Midterm take-home assignment
Mar 21	Spring Break			
Mar 28	L19: Metrology: principles, terminology and sampling	L20: Metrology: tools and techniques	Project: Design Review 2 (Plus: optional widget remake in Machine Shop)	• Mar 29: Lab 5 • Apr 1: HW6 (Visualization)
Apr 4	L21: GD&T: introduction and datums	L22: GD&T: position tolerances	Project: Manufacturing planning and JPS job submission (Plus: optional widget remake in Machine Shop)	• Apr 5: Project milestone B (final version of Design Review 2 slides, and 3D CAD for project design) • Apr 8: Teaming: second check-in survey
Apr 11	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 15: Lab 6
Apr 18	L25: GD&T: runout tolerances	L26: The future of manufacturing	Project: Prepare working drawings with GD&T annotations	• Apr 22: HW7 (GD&T)
Apr 25	Buffer time or guest lecture	Buffer time or guest lecture	Project: Assembly, refinement, and testing	• Apr 26: Lab 7 • Apr 29: HW8 (More GD&T)
May 2	RRR week: Jacobs Design Showcase			• May 6: Project milestone D (project final video and design materials including working drawings) • May 6: Teaming: final survey

Start-of-semester survey

Please complete the following survey **by Friday January 21st, 11:59pm** so that the staff can understand your expectations for the class and set up student teams accordingly: https://forms.gle/ejz4hWBc8jXrHZSbA (need to be logged in with your Berkeley.edu Google account).

Lectures

For the first two weeks of class, the lectures (TuTh 11–12.30) will be live on Zoom: https://berkeley.zoom.us/j/96023196406. After that, lectures will be in HMMB 390. Recordings of all lectures will be posted on bCourses and 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. They will also be accessible via the "Media Gallery" in bCourses.

Labs

Content

Labs will begin **in the week of January 24** (with Lab 1 being remote; see below). 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.

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 or five 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 five weekly lab sections, starting **in the week of January 24th**, scheduled at the following times:

- Lab 101: Tu 2–5pm (Alondra)
- Lab 102: W 9am–12pm (Sara)
- Lab 103: W 2–5pm (Sara)
- Lab 104: F 9am–12pm (Sara)
- Lab 105: Th 2–5pm (Alondra)

The first lab will be operated remotely via Zoom (https://berkeley.zoom.us/j/95025831327) and subsequent labs will be in person in Jacobs 10c. If you need to switch sections please e-mail the GSI(s) for your current and desired sections explaining your situation.

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 15th until 8am on Thursday March 17th. 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. Examples of previous years’ midterm assignments will be provided.

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 mechanical device to enhance the capabilities of a smartphone
- Design a mechanical device to reduce the risk of transmission of the omicron or future variants of Covid-19
- Design a mechanical device to facilitate “hybrid” events (e.g. parties, family gatherings, lectures, meetings, study sessions, etc) where some people gather in-person and others join via electronic means
- 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 February 28)
- Design Review 2 (week of March 28)
- Milestone B (due Apr 5): Final version of Design Review 2 slides, and 3D CAD for project design
- Milestone C (due Apr 12): Any components that you will request JPS to fabricate for you need to be submitted to JPS for fabrication
- Milestone D (due May 6): 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. In-person participation at the Jacobs Design Showcase during RRR week will also be expected. More details for the project will be posted early in the semester.

Jacobs Maker Pass

All students in E29 are asked to obtain a Maker Pass so that they can participate fully in the prototyping of their project and lab designs, and take advantage of the opportunity to receive training on the various tools in Jacobs. Please register via this link by January 28th. The fee is $100 for the semester, but fee waivers are available based on financial need and this is determined during the sign-up process.

Jacobs Project Support (JPS)

You also have the option to have components fabricated for you by Jacobs Hall staff using the Jacobs Project Support service: 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 pick them up from Jacobs Hall. 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 *in addition to signing up for a Maker Pass*: https://jacobsaccess.ist.berkeley.edu/jps/signup. We ask you to register by January 28th.

Machine shop training

The E29 syllabus provides for students to receive Etcheverry Machine Shop orientation. The orientation includes an online preliminary training, followed by a one-day in-person training with Machine Shop staff where you practice making an object ("widget") using a lathe, mill and other tools. Please register for Machine Shop training using the online form here by January 28th. The Machine Shop staff will then be in touch with you to provide more details on how to schedule and complete the training. When you complete the form please select the "ME class project" option for your affiliation.

We believe that learning is best reinforced by practice, so during the two weeks after Spring Break we plan to offer timeslots when students who have completed their Machine Shop orientation can sign up to make a second copy of their widget.

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 any 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

This term we will be using Piazza for class discussion. Piazza provides a forum for asking questions about course material and activities to which instructors and/or students collaboratively construct a response. I encourage you strongly to direct questions through Piazza as it usually the quickest way to get your questions answered. You can join the course Piazza site here: https://piazza.com/berkeley/spring2022/engin29. Access code: 06172016.

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 still a 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 the GSIs 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.

Revision history

Date	Revision
Jan 15 2022	Initial version
Jan 18 2022	Fixed hyperlinks
Jan 23 2022	Updated GSI OH information