Department of Mechanical Engineering
University of California, Berkeley

Engineering 27 – Introduction to Manufacturing and Tolerancing

Course information
Spring 2019

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Updated: February 26, 2019

Welcome

Welcome to Engineering 27. This class is part of Berkeley's core undergraduate Design and Manufacturing curriculum. The current resurgence of manufacturing in the U.S. — and its enormous continued economic importance both here and in many other parts of the world — mean that we have increased the emphasis placed on manufacturing in our lower-division curriculum, and this class is one result of that shift.

To make this class a success, we need your full engagement. We encourage you to send us your thoughts, comments and suggestions about the class regularly. You can make suggestions by e-mail, in office hours, or by sending the instructors a message through bCourses. Taking the time to tell us what we can do to improve will help enhance your experience and that of students who will take the class in the future.

Staff

Course instructor

Prof. Hayden Taylor
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Office hours[1]: Wed 3–5pm, Thurs 3.30–4.30pm, and by arrangement, all in 6159 Etcheverry.

Graduate Student Instructors:

Brian Salazar
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Zack Yun
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Office hours: Tues 1–3pm, Hesse 'fishbowl' GSI office

[1] My regular office hours for the semester will begin on Jan 23 and end on May 9. On some occasions I may need to reschedule, in which case I'll make a bCourses announcement.

Class and lab schedule

Wk #	Week commencing	Lecture (Wednesday)	Laboratory	Lab location	Assignments due
1	1/21	**Introduction.** The economic importance of manufacturing. Overview of manufacturing processes. Lab and project introduction and logistics. Safety. Reverse engineering.	No lab this week		• Fri 1/25, 11:59pm: Complete start-of-semester survey. • Fri 1/25, 11:59pm: Jacobs Hall General Workshop Safety training and Maker Pass registration and payment.
2	1/28	**Tolerancing basics.** Introduction to process variability and surface quality concepts. Types of fit: clearance, interference and transition. Relationship of fit to process capabilities.	Lab 1: Reverse-engineering of manufactured products	Jacobs 210/220	
3	2/4	**Additive processes.** Stereolithography; fused deposition modeling; selective laser sintering/melting; inkjet-based processes; laminar fabrication; hybrid subtractive–additive processes.	Lab 2: Flywheel redesign for planar manufacture	Jacobs 210/220	• Mon 2/4, 11:59pm: team compositions created in bCourses.
4	2/11		Lab 3: Machine shop and Jacobs facilities tour and OMAX training	Meet in Jacobs 210/220; head from there	• Mon 2/11, 11:59pm: Lab 1 report. • Wed 2/13, 11:59pm: HW1 (Tolerancing). • Fri 2/15, 11:59pm: one team-member completed each of laser cutter and waterjet training
5	2/18	**Subtractive processes.** Introduction to drilling, milling, turning, tapping, and water-jet cutting. Metal cutting principles and analysis.	This week is open lab time for developing Design and Tolerancing project concepts. Monday 2/18 is a class holiday; GSIs will be available in the lab on other lab days. Attendance is at your team's discretion this week.		• **Tues 2/19**, 11:59pm: Lab 2 rationale summary and CAD file.
6	2/25		Lab 4: Brainstorming for Design and Tolerancing project	Jacobs 210/220	• **Sun 3/3, 11:59pm**: LSI and pulse surveys

Week #	Week commencing	Lecture (Wednesday)	Laboratory	Lab location	Assignments due
7	3/4	**Metrology principles and methods.** Manual metrology tools including calipers, micrometers, and hole gages. Coordinate measuring machines. Stereo vision systems. Optical interferometry.	Lab 5: Design and Tolerancing project: component development and manufacturing process selection	Jacobs 210/220	• Wed 3/6, 11:59pm: HW2 (Additive processes).
8	3/11	**Geometric dimensioning and tolerancing (GD&T).** Motivation and principles. Datum and datum simulator concepts. Form, profile, orientation, location and runout tolerances.	Lab 6: Dimensional measurements, 3D scanning and variability modeling	Jacobs 210/220	• Mon 3/11, 11:59pm: Project concept generation and selection • Wed 3/13, 11:59pm: HW3 (Subtractive processes).
9	3/18		Lab 7: Design and Tolerancing project: design reviews, manufacturing planning and tolerancing specification	Jacobs 210/220	• Fri 3/22, 11:59pm: at least one team-member to have completed Type A 3D printer training.
10	3/25	**Spring break**			
11	4/1	**Geometric dimensioning and tolerancing (GD&T)** *continued*.	Lab 8: Injection molding	**Meet in Hesse 33**	• Fri 4/5, 11:59pm: mid-term teaming pulse surveys • Fri 4/5, 11:59pm: Take-home midterm assignment
12	4/8	**Forming processes.** Overview of casting, molding, sintering, forging and bending processes. Descriptions of sand, die, and investment casting. Principles of injection and compression molding.	Lab 9: Welding demonstration	**Meet in Hesse 33**	• Mon 4/8, 11:59pm: Lab 6 report. • Wed 4/10 11:59pm: HW4 (Metrology).
13	4/15		Lab 10: Stirling engine: redesigned flywheel testing	Jacobs 210/220	• Mon 4/15, 11:59pm: Lab 8 report. • Fri 4/19, 11:59pm: Five-slide project design summary.

Week #	Week commencing	Lecture (Wednesday)	Laboratory	Lab location	Assignments due
14	4/22	**Joining processes.** Survey of welding processes including oxyacetylene, submerged arc, MIG, TIG, and electrical resistance welding.	Free lab time for Design and Tolerancing project prototype production	Jacobs	• Wed 4/24, 11:59pm: HW5 (GD&T).
15	4/29				• Wed 5/3, 11:59pm: HW6 (Forming and joining).
16	5/6	RRR week.	Design and Tolerancing project demonstrations at Jacobs Showcase: Jacobs 310, Thursday May 9, in two sessions: 9.45am–11.30am (for those in Brian's lab sections) and 11.45am–1.30pm (for Zack's sections). Full team participation required.	Jacobs	• Final project prototype and slideshow due at Jacobs Showcase and on bCourses by Fri 5/10, 11:59pm • Sun 5/12, 11:59pm: final teaming surveys
17	5/13	Finals week.	Final takes place Tuesday May 14, 8–11am		

Lectures

Lectures will take place on Wednesdays 1–2pm, in 50 Birge Hall. Lectures will be recorded and will be available to watch/listen on Cal Central: https://calcentral.berkeley.edu. If you are registered for E27, the class will appear under "My Classes" and the videos under "Course Captures" on the right hand side of the E27 class page. In case of any technical issues in accessing the recordings, please contact Educational Technology Services via the web form at https://www.ets.berkeley.edu/request-support-or-give-feedback-calnet.

Laboratories

Locations

Week-by-week locations for lab sessions are detailed in the schedule above. Labs begin in the week of **January 28**.

Sections

There will be five lab sections, each led by the GSI indicated:

- Mondays 9–11am, Jacobs 220 (Brian)
- Mondays 1–3pm, Jacobs 210 (Zack)
- Wednesdays 9–11am, Jacobs 220 (Brian)
- Wednesdays 3–5pm, Jacobs 220 (Zack)
- Thursdays 9–11am, Jacobs 210 (Brian)

If you need to change sections or need to find space in a specific section in order to take the class, please contact one of the GSIs.

Although, in the scheduling system, the labs are noted as being three hours long, we have designed the labs to take two hours, and we only require attendance during one of the weekly two-hour periods noted above. However, we do have the room for a full third hour in each case, so you are welcome to stay and continue working with your team if desired.

Jacobs Hall Maker Pass

We will make extensive use of Jacobs Hall, for which a Maker Pass is required. The Jacobs Hall Maker Pass fee is $75 for the semester. Payment can be made online or by check and details are at: http://jacobsinstitute.berkeley.edu/our-space/makerpass/get-maker-pass/. Fee waivers are available to students with financial need and requestable via this form: https://goo.gl/forms/vnSLqAd8b1yDp24d2.

Lab groups

We ask you to form teams of 3–5 people which will last for the whole semester and in which you will work during all the laboratory sessions. Feel free to identify potential group members in advance of the first lab session; in addition, the first 15 minutes of the first lab session will be allocated to finding team members.

We recommend that you try to form teams with at least one person who has a good working knowledge of a 3D CAD package such as Solidworks or Fusion 360, and at least one person who knows some Matlab.

We ask that you use bCourses to create a group containing your team-members under the tab "Lab teams (self-organize here)" tab in the "People" section of the class site. Please do this by the end of Monday 2/4 and give your team a name of your choice; after that, we will freeze the groups' composition so that you can use them to upload assignments as a team. If you need to change teams after 2/4, please contact your GSI.

Pre-lab preparation

Each lab session will have an associated handout which will be posted on bCourses before the lab session begins. Please download this handout, and *read it through carefully before your scheduled lab session*. Please also bring along the lab handout, either in printed form or on a screen that you can view while working.

Lab deliverables

Most lab sessions will have certain tasks you have to complete and questions that are to be discussed with your lab-mates and then answered. For some labs, a short written report will be required. You will work with your team-mates to do the practical work, discuss the questions, and produce a **joint report** from your team.

Knowing that some teams will want a little extra time to put the finishing touches to their lab reports, we are setting a deadline for submission of the report, when required, that falls a little over a week after the lab session takes place. We ask you to upload lab reports to bCourses as a group submission. A scan of a (legible) handwritten report is absolutely fine.

Each group report needs to feature all team-members' names on the first page and to include a short paragraph listing the contributions of each team-member. All team members must have an opportunity to review the report's contents before the report is uploaded.

We will create team groups within bCourses based on the team compositions supplied by February 4, so that only one copy of each report will need to be uploaded per team.

In case of any concerns or disagreements about the content of a lab report that your team has prepared, please discuss them with your team in the first instance, and then contact your GSI if they cannot be resolved.

Your final score for lab deliverables will constitute 35% of the total class grade (see "Grading" below), and will be made up as follows:

Report topic	**Proportion of class grade**
Lab 1 (Consumer product reverse engineering)	4%
Lab 2 (Redesign of Stirling engine flywheel)	4%
Labs 4, 5&7 (Project motivation, design, and process selection)	10%
Lab 6 (Dimensional measurements and variability)	4%
Lab 8 (Injection molding dimensional variability analysis)	3%
Final project slideshow and project prototype	10%
Total	**35%**

Drop-in lab opportunities

The manufactured products that you will analyze in Lab 1, including the Stirling engines, will be made available in Jacobs for use outside of the scheduled lab hours, in case you wish to check details or dimensions for any of your assignments. Generally we will store these items on the shelves in Jacobs 210. If you cannot find them please contact your GSI.

Safety and training

Please carefully read and sign the document "Instructional Laboratory and Student Shop Safety Guidelines" that is posted on bCourses under Files -> Labs, and hand it to your GSI. You can print it in advance, but copies will also be available in lab for you to sign.

Also, we need you to complete General Workshop Safety Training for Jacobs Hall by 1/25: https://bcourses.berkeley.edu/enroll/TY4ETA (requires CalNet authorization).

Please note that by 1/25 only the GWS training is required. There is a subsequent deadline on 2/15 for at least one team-member to be trained on the laser cutters and one team-member on the OMAX waterjet cutter (including the hands-on training). There is also a deadline on 3/22 for at least one team-member to have been trained on the Type A 3D printers (including the hands-on training).

There are two key things to be aware of for any lab session that takes place anywhere in Hesse, in Jacobs, or in Etcheverry 1166:

1. Please ensure that you have safety glasses by 2/11 (for the Machine Shop tour). You are required to bring your own safety glasses and wear them whenever indicated by signs or by staff. These can be purchased, for example, from the Cal Student Store at 2495 Bancroft Way, or from Ace Hardware at 2020 Milvia St, Berkeley.

2. No shorts/skirts or open-toe footwear are allowed in the labs. Legs and toes must be covered to protect them.

Safety guidelines will require us to send you home to change if you do not follow these guidelines. In exceptional circumstances, the Hesse lab staff may be able to supply safety glasses to students who are able to pay using a CARS account, but this will need to be arranged in advance of the lab because there will not be time to supply glasses at the start of a lab session.

Homeworks

Homeworks will be due by 11:59pm on the Wednesday of the week they are due. Homework questions will be released on bCourses at least one week, and usually longer, before the due date. Your responses will be due on bCourses in the format indicated in the homework assignment. Solutions will be posted a few days after the deadline and well in advance of exams. We aim to return graded homework within two weeks of submission.

Final exam

The final exam is scheduled to take place on Tuesday 5/14/18, 8–11am. This will be a cumulative exam that will test material from throughout the class.

Field trips

We will be organizing a number of optional field trips to visit local manufacturing companies. More details on how to sign up for them will be made available soon.

Reference books

There is no required course text book and all the material you need to succeed in E27 will be included in the lecture slides, homeworks, laboratory handouts and in additional materials that will be posted on bCourses.

Books for possible supplementary reading include:

- *Visualization, Modeling and Graphics for Engineering Design* by D. Lieu and S. Sorby, Delmar Cengage Publishing, ISBN 978-1-4018-4249-9. Library call number: TA174.L54 2009 (there are several copies available on one-week loan).
  This text has very thorough coverage of tolerancing in Chapter 16. Please note that there are abridged versions of the book that do not cover tolerancing.

  For more in-depth coverage of manufacturing processes, see:

- *Fundamentals of Modern Manufacturing: Materials, Processes, and Systems*, by M.P. Groover, Wiley. ISBN 978-1-1182-3146-3. Library call number: TS183.G78 2013.

  Concise coverage of manufacturing processes. There is a PDF version online at https://futureingscientist.files.wordpress.com/2014/01/fundamentals-of-modern-manufacturing-4th-edition-by-mikell-p-groover.pdf.

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

Grading

Students will receive a letter grade for this course, composed in the following way:

- Homeworks: 20%
- Take-home midterm (week 10): 10%
- Final exam: 25%
- Laboratory and project reports: 35%
- Active and constructive participation in labs*: 10%

* In establishing the participation score, we will take into account the reliable and timely completion of any prelabs and the Learning Styles Inventory and teaming surveys that will be sent to you several days before they are due. For the initial and mid-term surveys (due 3/3 and 4/5 respectively), you will receive credit for *completing* the surveys but your grade will *not* be dependent on the scores you receive from team-mates. For the *final* survey (due 5/12), however, your grade may be influenced by how your team-mates rate your contribution. The idea is to encourage frank and constructive mid-term feedback to be given, enabling 'course-correction' by team members, but still to motivate engagement in team-work as the projects near completion. Your participation score can also be positively influenced by any constructive interactions with the teaching staff about class material, *e.g*. in class, office hours and lab sessions.

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, please contact the course instructor.

Lateness and illness

Laboratory sessions are an integral part of this class and are considered compulsory. However, if you fall ill we would prefer you to rest so that you can get better as soon as possible. If you fall ill or experience exceptional circumstances, please contact your GSI to arrange an alternative time to complete the relevant lab work, homework, or assessment once you have recovered. The fact that Jacobs is open long hours will help people to make up lab work. We will *not* be requiring written excuses from medical personnel.

For labs to run smoothly we encourage you to make every effort to arrive promptly at the start of your lab session, and certainly no later than 10 minutes after its scheduled start time.

We do ask that you try to complete assignments by the deadlines. We will be accommodating of occasional slightly late assignment completion, but may penalize frequent or egregious lateness. Please make sure you communicate with your GSI if for any reason you think you need more time for an assignment.

A note about the Student Machine Shop and training

Student Machine Shop orientation is not part of the E27 syllabus.

We appreciate that many students would like to become trained in the Machine Shop. As you are probably aware, demand for access to the shop is extremely high and is growing — the Shop currently trains ~400 people/year. The Shop staff is currently working at full capacity. As a result, when we were planning the first offerings of E27 we agreed not to include automatic Shop training in the syllabus.

In response to the strong demand for Shop access, I secured a grant from Berkeley's Center for Teaching and Learning to begin to move some of the safety/orientation training online and thus hopefully increase the number of people it is possible to train to use the shop. Training materials for lathe turning, resulting from this project, will form part of the homework on subtractive manufacturing.

In any case, the full range of Jacobs Hall facilities (http://jacobsinstitute.berkeley.edu/our-space/labs-and-equipment/) is now in operation and available to you as an E27 student. This includes state-of-the-art additive processes, laser and abrasive-jet cutting, metal-working, wood-working, and a small-scale bench-top milling capability. So we think that for the purposes of the E27 Design and Tolerancing project, you will have access to ample facilities.

Moreover, many students are, in any case, involved in a wide range of extra-curricular, class project and research activities that qualify them to sign up for Machine Shop training. Please check with the Shop staff if you think you have a need for training and access.

Software

Before Lab 8 (week of 4/1) it would help if at least one member of your team could download and install the free program Simulation Moldflow Adviser Ultimate, from:

http://www.autodesk.com/education/free-software/moldflow-adviser-ultimate

The software will also be installed in the Jacobs CAD labs for you to use. If you need instructions for installing the student version of Solidworks, these can be found under Files>Software in bCourses. Alternatively, Inventor and Fusion 360 are available free to students via the Autodesk website.