Department of Mechanical Engineering
University of California, Berkeley

Engineering 27 – Introduction to Manufacturing and Tolerancing

Course information
Fall 2015

Prof. Hayden Taylor (hkt@berkeley.edu)
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Welcome

Welcome to the second-ever offering of Engineering 27, and the first iteration of this class to use the new facilities of Jacobs Hall. This class is being rolled out as part of Berkeley's new Design and Manufacturing curriculum. The importance of manufacturing to the US and to the global economy means that we are increasing 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 think we are being quite ambitious in the content of the labs and homeworks, and we need your help to calibrate expectations appropriately. Therefore 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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Telephone:	510 642-4901
Office:	6159 Etcheverry Hall
Office hours:	Mondays 11am–12.30pm, Wednesdays 2–3.30pm, and by arrangement, all in 6159 Etcheverry.
Graduate Student Instructor	**Sonia Travaglini**
E-mail:	travaglini@berkeley.edu
Office hours:	Tuesdays in Jacobs Hall; exact timing and location to be confirmed.
Graduate Student Instructor	**Brian Salazar**
E-mail:	brian10salazar@berkeley.edu
Office hours:	Wednesdays 6–7.30pm in 210 Jacobs

Class and lab schedule

Week #	Week commencing (Monday)	Lecture	Laboratory	Lab location	Assignments due
1	8/31	**Introduction.** The economic importance of manufacturing. Manufacturing process "taxonomy". Lab and project introduction and logistics. Safety. Reverse engineering.	Lab 1: Reverse-engineering of manufactured products	Hesse 33	
2	9/7	Labor day – no lecture	Lab 2: Reverse-engineering of a model Stirling engine	Hesse 33	• Mon 9/7, 5pm: Jacobs Hall safety training due online. • Fri 9/11, 5pm: Lab 1 report including team compositions.
3	9/14	**Subtractive processes.** Introduction to drilling, milling, turning, tapping, and water-jet cutting. Metal cutting principles and analysis.	Lab 3: Machine shop tour	Etcheverry 1166 (Student Machine Shop)	• Fri 9/18, 5pm: Lab 2 report.
4	9/21	**Additive processes.** Stereolithography; fused deposition modeling; selective laser sintering/melting; inkjet-based processes; laminar fabrication; hybrid subtractive–additive processes.	Lab 4: Flywheel re-design for waterjet	Jacobs 210	• Wed 9/23, 11:59pm: HW1 (Subtractive).
5	9/28		Lab 5: Dimensional measurements of components	Jacobs 210	• Fri 10/2, 5pm: Lab 4 rationale summary and CAD file.
6	10/5	**Tolerancing basics.** Introduction to process variability and surface quality concepts. Types of fit: clearance, interference and transition. Relationship of fit to process capabilities.	Lab 6: Design for additive manufacturing	Jacobs 210	• Wed 10/7, 11:59pm: HW2 (Additive). • Fri 10/9, 5pm: Lab 5 report.
7	10/12	**Metrology principles and methods.** Manual metrology tools including calipers, micrometers, and hole gages. Coordinate measuring machines. Stereo vision systems. Optical interferometry.	Field trip (details to follow)		• Wed 10/14, 11:59pm: HW3 (Tolerancing).

Week #	Week commencing (Monday)	Lecture	Laboratory	Lab location	Assignments due
8	10/19	**Geometric dimensioning and tolerancing (GD&T).** Motivation and principles. Datum and datum simulator concepts. Form, profile, orientation, location and runout tolerances.	Lab 7: Additive manufacturing data preparation	Jacobs 210	• Sun 10/25, 5pm: Midterm peer evaluations • Fri 10/23, 5pm: Lab 6: written report
9	10/26		Lab 8: Additive manufacturing print run	Jacobs 210	• Wed 10/28, 11:59pm: Take-home midterm assignment due on bCourses. • Fri 10/30, 5pm: Lab 7: written report and design data
10	11/2		Lab 9: Injection molding demonstration and dimensional measurement of produced components	Hesse 70	• Wed 11/4, 11:59pm: HW4 (Metrology).
11	11/9	**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 10: Welding demonstration	Hesse 70	• Thu 11/12, 11:59pm: HW5 (GD&T).
12	11/16		Lab 11: Project assembly and testing	Jacobs 210	• Wed 11/18, 11:59pm: HW6 (Casting & Molding) • Fri 11/20, 5pm: Lab 9 report
13	11/23	**Joining processes.** Survey of welding processes including oxyacetylene, submerged arc, MIG, TIG, and electrical resistance welding.	Happy Thanksgiving: no labs on Nov 24 or 27		
14	11/30		Lab 12: Project assembly and testing	Jacobs 210	• Wed 12/2, 11:59pm: HW7 (Welding)
15	12/7	RRR week.			• Fri 12/11, 5pm: Lab 11&12 report and final peer evaluations
16	12/14	Finals week.	Final takes place Thursday December 17, 3–6pm		

Lectures

Lectures will take place on Mondays 2–3pm, in 105 North Gate. 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 August 31.

Scheduling

There are four lab sections:

- *Tuesdays* 10am–12pm and 2–4pm (GSI: Sonia Travaglini)
- *Fridays* 10am–12pm and 2–4pm (GSI: Brian Salazar)

We have opened as much space as necessary to allow all waitlisted students into their lab section of choice. If you need to change sections, please contact the GSI(s) of your current section and of the section into which you would like to switch.

Please note that while, in the Berkeley scheduling system, three hours are allocated to each lab section per week, lab sessions will actually last two hours and the morning sections will begin at 10am, not 9am.

Lab groups

We ask you to form teams of 5–6 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 ask you to list the names of your team members in your Lab 1 report, which is due by 5pm on Friday, September 11th. This information is important as it will be needed for us to organize the Machine Shop tours in the following week.

Pre-lab preparation

Each lab session will have an associated handout which will be posted on bCourses approximately one week before the lab session begins. Please download this handout, *read it through carefully before your scheduled lab session*, and *complete any pre-lab questions* on paper. Your pre-lab answers will be handed to the GSI when you arrive at the 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

Each lab session will have a worksheet that will describe certain tasks you have to complete and questions that are to be discussed with your lab-mates and then answered.

For many labs, a short written report will be required. We are designing these tasks and questions to be completed within each two-hour lab. 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, of 5pm on the Friday of the week *after* the lab session takes place. We ask you to upload lab reports to bCourses. A scan of a (legible) handwritten report is absolutely fine. We aim to grade reports within two weeks of submission.

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.

For Lab 1, we ask every person to upload a copy of their group's report by the deadline on 9/11. The GSIs will then create teams within bCourses so that for future reports, only one upload per team will be needed.

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 30% of the total class grade (see "Grading" below), and will be made up as follows:

Report topic	**Proportion of lab grade**
Lab 1 (Consumer product reverse engineering)	10%
Lab 2 (Stirling engine reverse engineering)	10%
Lab 4 (Redesign of Stirling engine flywheel)	10%
Lab 5 (Dimensional measurements and variability)	15%
Labs 6&7 (Design and data preparation for additive manufacturing)	20%
Lab 9 (Injection molding dimensional variability analysis)	15%
Labs 11/12 (Testing and evaluation of modified Stirling engine)	20%
Total	**100%**

Peer evaluations will be done anonymously and online twice during the term, with due dates of 10/16 and 12/11. The purpose of these brief evaluations is to check that all students are contributing substantially to the team reports. The staff will discreetly address any cases where a student appears to be significantly under-contributing to their team.

Drop-in lab

The Hesse lab staff have kindly arranged for Hesse 33 to be available for drop-in use by E27 students 8am–5pm Monday–Friday. The manufactured products and Stirling engines used in the labs will be made available in the drop-in lab, in case students wish to check details or dimensions for any of their assignments. When Jacobs opens we will attempt to make similar arrangements there.

Safety

Please print, carefully read, and sign the document "Instructional Laboratory and Student Shop Safety Guidelines" that is posted on bCourses, bring it to the first laboratory session you attend, and hand it to your GSI.

Also, we need you to complete online safety training for Jacobs Hall by 9/7: https://bcourses.berkeley.edu/enroll/TY4ETA (requires CalNet authorization).

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. 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 2470/2480 Bancroft Way, or from Ace Hardware at 2145 University Ave (near the intersection with Oxford St).
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. It is preferable if you upload your homework solutions in Word or PDF format to bCourses (a scan of handwritten work is absolutely fine). Alternatively, you can place written homework in the labeled mailbox on the third floor of Etcheverry (please remember to put your name and "E27" at the top of the first page). If you turn in your homework on paper, we strongly advise you to keep a scan or photo of your work.

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 Thursday 12/17/15, 3–6pm. This will be a cumulative exam that will test material from throughout the class.

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.

- *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 http://50.30.47.15/ebook/IPE/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.

  For more in-depth coverage of manufacturing processes.

Grading

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

- Homeworks: 20%
- Take-home midterm (week 8): 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 completion of prelabs and peer evaluations, the peer evaluation scores that you received, and feedback from GSIs based on interactions in class, office hours and lab sessions.

Academic integrity

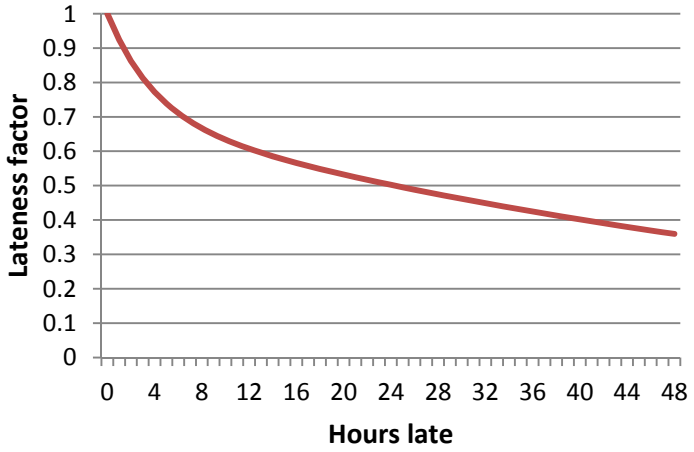
We will be adhering to the Berkeley Honor Code (http://asuc.org/honorcode/index.php). If anyone has any questions about the responsibilities they have as part of this Code, please contact the course instructor.

Lateness and illness policy

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 the GSI to arrange an alternative time to complete the relevant lab work, homework, or assessment once you have recovered. The fact that Hesse 33 has open 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.

For written assignments turned in after the deadline with no legitimate excuse, the score for that assignment will be multiplied by the following lateness factor: $L = 0.3e^{-t/4} + 0.7e^{-t/72}$ where t is the number of hours late.



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 inaugural 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 last year 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. This project is in progress and we have begun testing some of the new online training materials. If you would like to help in this process by beta-testing our lathe training materials, please let me know.

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 training. Please check with the Shop staff if you think you have a need for training and access.

Software

Before Lab 9 (week of 11/2) 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/simulation-moldflow-adviser-ultimate

In case your team is not able to install the program in advance of Lab 9, one or more computers will be made available for use in lab with the software pre-installed.

We are grateful to Autodesk for contributing financial support — through their Design for Autodesk program — for materials needed in this class. As you may know, most Autodesk software is available free of charge to students. Below is a message from Autodesk in which you might be interested:

“Students can earn a $250 Visa gift card by completing a 15+ component CAD model in Autodesk Fusion 360 (our newest CAD solution which is fully-integrated, allows for organic modeling, and is cloud-based – it also runs on Mac!). The full version of Fusion 360 is completely free for students and educators and can be downloaded here.

Here are some additional Fusion 360 learning materials …:

Design Academy: Fusion 360 [and] Youtube: Fusion 360”