

Department of Mechanical Engineering
University of California, Berkeley

Engineering 27 – Introduction to Manufacturing and Tolerancing

Course information

Spring 2016

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

Welcome to Engineering 27. This class is part of Berkeley's new Design and Manufacturing curriculum. The current resurgence of manufacturing in the US — and its enormous continued economic importance in many other parts of the world — mean 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

E-mail:

Telephone:

Office:

Office hours:

Prof. Hayden Taylor

hkt@berkeley.edu

510 642-4901

6159 Etcheverry Hall

Mondays 1.30–3pm, Wednesdays 4–5.30pm, and by arrangement, all in 6159 Etcheverry.

Graduate Student Instructor

E-mail:

Office hours:

Brian Salazar

brian10salazar@berkeley.edu

TBD

Class and lab schedule

Week #	Week commencing (Monday)	Lecture (Wednesday)	Laboratory	Lab location	Assignments due
1	1/18	Introduction. The economic importance of manufacturing. Manufacturing process “taxonomy”. Lab and project introduction and logistics. Safety. Reverse engineering.			<ul style="list-style-type: none"> • Fri 1/22, 5pm: Jacobs Hall General Workshop Safety training and Maker Pass registration and payment • Fri 1/22, 5pm: Complete background questionnaire
2	1/25	Subtractive processes. Introduction to drilling, milling, turning, tapping, and water-jet cutting. Metal cutting principles and analysis.	Lab 1: Reverse-engineering of manufactured products	Jacobs	<ul style="list-style-type: none"> • Fri 1/29, 5pm: Team compositions due by e-mail to Brian
3	2/1		Lab 2: Reverse-engineering of a model Stirling engine	Jacobs	<ul style="list-style-type: none"> • Fri 2/5, 5pm: Lab 1 report
4	2/8	Tolerancing basics. Introduction to process variability and surface quality concepts. Types of fit: clearance, interference and transition. Relationship of fit to process capabilities.	Lab 3: Machine shop tour	Etcheverry 1166 (Student Machine Shop)	<ul style="list-style-type: none"> • Wed 2/10, 11:59pm: HW1 (Subtractive). • Fri 2/12, 5pm: Lab 2 report
5	2/15	Metrology principles and methods. Manual metrology tools including calipers, micrometers, and hole gages. Coordinate measuring machines. Stereo vision systems. Optical interferometry.	Lab 4: Flywheel re-design for waterjet	Jacobs	<ul style="list-style-type: none"> • Wed 2/17, 11:59pm: HW2 (Tolerancing). • Fri 2/19, 5pm: at least one team-member to have completed Type A 3D printer training
6	2/22	Additive processes. Stereolithography; fused deposition modeling; selective laser sintering/melting; inkjet-based processes; laminar fabrication; hybrid subtractive–additive processes.	Lab 5: Dimensional measurements of components	Jacobs	<ul style="list-style-type: none"> • Wed 2/24, 11:59pm: HW3 (Metrology). • Fri 2/26, 5pm: Lab 4 rationale summary and CAD file.

Week #	Week commencing (Monday)	Lecture (Wednesday)	Laboratory	Lab location	Assignments due
7	2/29	Additive processes <i>continued</i>	Field trip (details to follow)		<ul style="list-style-type: none"> Fri 3/4, 5pm: Lab 5 report.
8	3/7	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 6: Design for additive manufacturing	Jacobs	<ul style="list-style-type: none"> Wed 3/9, 11:59pm: HW4 (Additive processes). Sun 3/13, 5pm: Midterm peer evaluations/team assessment
9	3/14		Lab 7: Additive manufacturing data preparation	Jacobs	<ul style="list-style-type: none"> Wed 3/16, 11:59pm: Take-home midterm assignment due on bCourses. Fri 3/18, 5pm: Lab 6: written report
10	3/21	Spring break			
11	3/28	Joining processes. Survey of welding processes including oxyacetylene, submerged arc, MIG, TIG, and electrical resistance welding.	Lab 8: Additive manufacturing design and print	Jacobs	<ul style="list-style-type: none"> Fri 4/1, 5pm: Lab 7: written report and design data
12	4/4		Lab 9: Injection molding demonstration and dimensional measurement of produced components	Meet in Hesse 33	<ul style="list-style-type: none"> Wed 4/6, 11:59pm: HW5 (Casting & Molding)
13	4/11	Geometric dimensioning and tolerancing (GD&T). Motivation and principles. Datum and datum simulator concepts. Form, profile, orientation, location and runout tolerances.	Lab 10: Welding demonstration	Meet in Hesse 33	<ul style="list-style-type: none"> Fri 4/15, 5pm: Lab 9 report
14	4/18		Lab 11: Stirling engine re-assembly and testing	Jacobs	<ul style="list-style-type: none"> Wed 4/20, 11:59pm: HW6 (Welding)
15	4/25		Lab 12: Additive manufacturing project testing	Jacobs	<ul style="list-style-type: none"> Wed 4/27, 11:59pm: HW7 (GD&T) Fri 4/29, 5pm: Lab 11 report

Week #	Week commencing (Monday)	Lecture (Wednesday)	Laboratory	Lab location	Assignments due
16	5/2	RRR week. Review session during the regular W 1–2pm slot.			<ul style="list-style-type: none"> • Fri 5/6, 5pm: Additive manufacturing final report (incorporating Labs 8 & 12) • Fri 5/6, 5pm: Final peer evaluations and reflections
17	5/9	Finals week.	Final takes place Tuesday May 10, 8–11am		

Lectures

Lectures will take place on Wednesdays 1–2pm, in 3106 Etcheverry. 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 25.

Scheduling

There are three lab sections. For the weeks in which the labs are noted in the schedule as taking place in Jacobs, the exact studio location is as follows:

- *Tuesdays* 9–11am, 310 Jacobs
- *Tuesdays* 1–3pm, 210 Jacobs
- *Wednesdays* 9–11am, 310 Jacobs

If you need to change sections, please contact the GSI, Brian Salazar.

Jacobs Hall Maker Pass

Many of the lab sessions will take place in Jacobs Hall, for which a Maker Pass is required. Starting this semester, the Jacobs Hall Maker Pass fee is \$75 for the semester, payable by credit card at <https://www.regonline.com/jacobshallmakerpassspring2016>, or by check made out to “UC Regents,” brought to 234 Jacobs Hall. Fee waivers are available to students with financial need and requestable via this form: <http://goo.gl/forms/VemqltXS5e>. For more information on fee payment, contact Aleta Martinez at aleta@berkeley.edu.

Lab groups

We ask you to form teams of 3–4 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 that one member of your team e-mails the GSI, Brian Salazar, with the names of your team-members, as well as a name for your team, by 5pm on Friday, January 29th.**

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.

We will create team groups within bCourses based on the names supplied on Friday January 29th, 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 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%
Lab 11 (Testing and evaluation of modified Stirling engine)	10%
Lab 12 (Testing of additively manufactured structure)	10%
Total	100%

Peer and team evaluations

Peer evaluations and team assessments will be done anonymously and online twice during the term, with due dates of 3/13 and 5/6. The purpose of these brief evaluations is to check that all students are contributing substantially to the team reports, to provide an opportunity for your team to reflect on how it is functioning and to identify any ways in which team functioning might be improved.

Drop-in lab opportunities

The manufactured products that you will analyze in Lab 1 and the Stirling engines used in several of the labs 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 the GSI, Brian.

Safety

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

Also, we need you to complete General Workshop Safety Training for Jacobs Hall by 1/22: <https://bcourses.berkeley.edu/enroll/TY4ETA> (requires CalNet authorization).

Please note that by 1/22 only the GWS training is required; there is a subsequent deadline on 2/19 for at least one team-member to be 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 2/8. 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. Please upload your homework solutions in Word or PDF format to bCourses (a scan of handwritten work is absolutely fine). If you use a camera to photograph handwritten work, please make sure you convert it to PDF or paste it into a Word document before uploading, because pure image files like JPG or TIF are hard for the reader to annotate. 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 5/10/16, 8–11am. 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](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 any positive interactions with the teaching staff about class material, e.g. in class, office hours and lab sessions.

Academic integrity

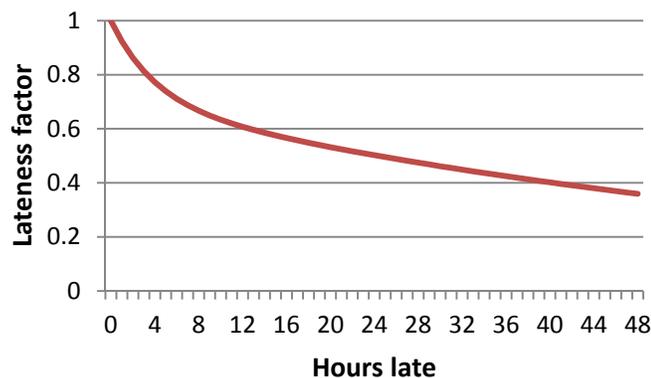
We will be adhering to the Berkeley Honor Code (<http://asuc.org/honorcode/index.php>). If anyone has any questions about the responsibilities they have as part of this Code, please contact the course instructor.

Lateness and illness 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 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.

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 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 4/4) 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 Jacobs with the software pre-installed.