



SIE 481/581 Design for Additive Manufacturing
Time & Location: M&W 12-1:15PM, Harvill Bldg, Rm 111

Hannah Budinoff, Ph.D.
Assistant Professor, Department of Systems and Industrial Engineering
Office: ENGR 129; hdb@arizona.edu
Office Hours: 11-11:50 AM Mondays

Course Description

This course is an introduction to the engineering design process with a focus on understanding constraints and opportunities associated with additive manufacturing (AM). Students will gain an understanding of how to exploit AM to manufacture parts with complex geometry, while also considering economic viability and manufacturability. Opportunities and constraints associated with various AM technologies, from fused-filament fabrication (often called 3D printing) to metal AM processes, will be surveyed. The course will culminate in a hands-on design project where students will use design-for-additive-manufacturing (DfAM) frameworks and tools to design a novel product. This course aims to promote creativity and critical thinking, which are necessary to effectively use AM technology in the context of product design.

Course Objectives

During this course, students will develop an understanding of manufacturing processes constraints and learn to identify opportunities associated with additive manufacturing. Students will apply their knowledge of manufacturing processes, materials, and computer-aided design tools to design and manufacture a new part or product using additive manufacturing processes.

Expected Learning Outcomes

By taking this course, both undergraduate and graduate students will possess the capability to:

- Explain the engineering design process and discuss how systematic methodologies and strategies can promote improved design outcomes
 - Identify and quantify economic, geometric, and material property constraints associated with parts made using AM technologies
 - Discuss and analyze opportunities to exploit geometric freedoms enabled by AM technologies
 - Apply DfAM methodologies and tools to develop solutions to practical design problems
- For graduate students, additional assignments will be given for advanced learning outcomes:
- Explain interactions between part geometry, material, quality, and AM process constraints
 - Investigate and report on emerging applications and technologies related to AM

Course Prerequisites or Co-requisites

SIE majors: Advanced Standing; SIE 383 / Other ENGR majors: Advanced Standing; (AME 211 OR BE 221) AND (AME 324A OR MSE 370)). Advanced standing is required before taking this course. For Advanced Standing of undergraduate students, please visit the webpage for detail information to obtain the advanced standing:
<http://sie.engr.arizona.edu/advanced-standing>.

Absence and class participation policies

Student attendance and active participation in class discussions and team projects is required.

- **In-person/live online students:** You are expected to attend class in person for each class, unless prior arrangements have been made with the instructor to attend remotely. You will complete a short activity during lecture to earn participation points. The lowest three scoring participation activities will be dropped at the end of the semester.
- **Online asynchronous students:** You are expected to engage in the class each week either by joining Zoom during class time or watching the recorded lectures each week. To earn the class participation points, you will need to watch >90% of the video and complete any assigned in-class activity prior to 8AM AZ time on Monday the following week of class. The lowest three scoring participation activities will be dropped at the end of the semester.
- **Religious Reasons:** The UA policy regarding absences for any sincerely held religious belief, observance or practice will be accommodated where reasonable,
<http://policy.arizona.edu/human-resources/religious-accommodation-policy>.
- **Pre-Approved Absences:** Absences pre-approved by the UA Dean of Students (or Dean Designee) will be honored. See: <https://deanofstudents.arizona.edu/absences>

Course Structure

The format of the course is a combination of lecture, in-class discussion, out of class assignments, and group projects. All students will participate in a semester-long project in small groups. Each team will use design-for-additive-manufacturing frameworks and tools to design a novel product of their choosing. The deliverables for this project include two progress reports, two presentations, a final report, and a 3D printed prototype of your team's design. **Graduate students** will be required to report and present on a relevant research topic. Graduate students will also be required to contribute more to the team design project, with fewer students assigned to each team with graduate students.

Grading Scale and Policies:

Tasks	Weight (%)	
	Undergraduate	Graduate
Online reading quizzes	10	10
Exam 1	7	7
Exam 2	7	7
Exam 3	7	7
Individual Design Assignments	24	24
Team Design Project	30	30
In-class activities	15	5
MS Research Project	—	10

Total	100	100
--------------	-----	-----

Late individual design assignments will be subject to a 50% penalty and can only be submitted up to one week late. All students will receive one “free” late homework without penalty. Plan on only using this free late assignment for when you really need it, due to illness or unexpected emergency.

No late submissions are allowed for any course submissions other than homework. The lowest three quiz and the lowest three participation activities will be dropped for each student at the end of the semester.

Percentage	Letter Grade
90% – 100%	A
80% – 89%	B
70% – 79%	C
60% – 69%	D
<60%	E

AI Policy

In this course, GenAI tools may be used for **some** coursework.

You may use AI for:

- Identifying resources (e.g., finding papers for research project)
- Copyediting of written text
- Outlines of design reports or presentations
- Brainstorming design ideas

You may NOT use AI for:

- Completing reading quizzes
- Exams
- Completing individual design challenges
- Writing design reports or presentations from scratch

If you are in doubt as to whether you are misusing AI tools or want to discuss AI usage in this course, please contact me.

AI support must be acknowledged per assignment expectations so as not to violate the [Code of Academic Integrity](#).

How to write an acknowledgement statement:

I acknowledge the use of *[insert name of AI system(s)]* to *[describe specific use of generative artificial intelligence]*. Prompts used included *[share link or copy-and-paste prompt]*.

See [UA Libraries Guide: How to Cite AI](#).

Scheduled Topics/Activities:

Date	Module	Details
Aug. 24 M	Module 1: AM Processes + Engineering Design	Course introduction + What is AM? Why DfAM? Course structure, grading, expectations, overview of additive manufacturing and the role of design for additive manufacturing. Introduce Reading/Online Quizzes.
Aug. 26 W	Module 1	AM processes I: Polymer and liquid-based processes. Material extrusion, vat photopolymerization, and material jetting. Compare process capabilities, materials, geometric limitations, and typical applications.

Aug. 31 M	Module 1	AM processes II: Powder- and energy-based processes. Powder bed fusion, binder jetting, directed energy deposition, and sheet processes. Compare process capabilities and design implications. Introduce the semester-long team design project, including project goals, deliverables, and team formation. Team Project: project kickoff.
Sept. 2 W	Module 1	Engineering design process. Problem definition, requirements, functional decomposition, concept development, evaluation, and iteration. Introduce Individual Design Assignment 1.
Sept. 7 M	—	No class — Labor Day.
Sept. 9 W	Module 1	Function analysis + requirements. Translating customer needs into engineering requirements, functional decomposition, constraints, and measurable design criteria.
Sept. 14 M	Module 1	Concept generation + geometric modeling. Concept generation strategies, morphological approaches, concept evaluation, and translating concepts into preliminary CAD.
Sept. 16 W	Module 1	From traditional design to DfAM. What changes when AM becomes the manufacturing process? Introduce DfAM principles and the relationship between design decisions and AM capabilities. Individual Design Assignment 1 due. Introduce Individual Design Assignment 2 and the team-project requirements/proposal.
Sept. 21 M	Module 2: DfAM Conceptualization & Exploitation	DfAM frameworks + design decision-making. Introduce structured DfAM frameworks and methods for identifying opportunities for AM. Apply a DfAM worksheet to an existing product.
Sept. 23 W		Exam 1 + Introduce Individual Design Assignment 2 + Introduce MS project
Sept. 28 M	Module 2	AM design heuristics. Design rules and heuristics for identifying AM opportunities, including geometric freedom, internal features, complexity, and functional integration. Application exercise using example products.
Sept. 30 W	Module 2	Integrated DfAM + AM candidacy. Evaluate when AM is an appropriate manufacturing process and when it is not. Integrate functional, economic, geometric, and manufacturing considerations. Team Project: project proposal due.
Oct. 5 M	Module 2	Part consolidation. Identify opportunities to combine components into fewer parts. Discuss assembly reduction, interfaces, fasteners, and functional integration. Apply part-consolidation strategies to example products.
Oct. 7 W	Module 2	Complexity + multifunctional design. Explore how AM changes the relationship between geometric complexity and manufacturing difficulty. Discuss multifunctional structures and integrating multiple functions into a single component.
Oct. 12 M	Module 2	Customization, biomimicry + integrated functionality. Mass customization, patient-/user-specific design, biomimetic

		structures, and multifunctional products. Individual Design Assignment 2 due.
Oct. 14 W	Module 2	Lattices + advanced geometric opportunities. Introduction to lattice structures, cellular materials, lightweighting, graded structures, and other geometries enabled by AM. Application/design activity.
Oct. 19 M		Team project preliminary design review. Teams present their problem definition, requirements, concepts, selected concept, and preliminary DfAM rationale. Instructor/team feedback and design critique. Team Project: preliminary design review milestone.
Oct. 21 W	Module 3: Manufacturing Constraints and Design Guidelines	General AM design constraints. Transition from exploiting AM freedom to understanding manufacturing limitations. Discuss minimum features, unsupported geometry, overhangs, tolerances, surface finish, process variability, and design-for-quality. Introduce Individual Design Assignment 3.
Oct. 26 M	Module 3	Polymer AM design guidelines. Process-specific design considerations for material extrusion and other polymer AM processes. Feature size, wall thickness, orientation, anisotropy, bridging, support structures, and tolerances.
Oct. 28 W	Module 3	Exam 2 + lecture
Nov. 2 M	Module 3	Metal AM design guidelines. Powder bed fusion and other metal AM considerations, including overhangs, supports, thermal effects, residual stress, feature limitations, and post-processing.
Nov. 4 W	Module 3	Build orientation, supports, accuracy + quality. Orientation as a design decision; tradeoffs among supports, surface quality, build time, mechanical properties, and manufacturability. Individual Design Assignment 3 due.
Nov. 9 M	Module 5: Computational DfAM	Optimization fundamentals + topology optimization. Optimization concepts, objective functions, constraints, design spaces, and topology optimization. Discuss how optimization changes the engineering design process. Introduce Individual Design Assignment 4.
Nov. 11 W	—	No class.
Nov. 16 M	Module 5	Topology optimization for AM. Integrating topology optimization with AM constraints, including minimum feature sizes, overhangs, supports, build orientation, and post-processing. Evaluate optimized designs critically rather than treating optimization as an automatic design solution.
Nov. 18 W	Module 5	Lattice design + simulation. Computational generation of lattices, mechanical performance, simulation, and tradeoffs among weight, performance, manufacturability, and complexity. Team Project: progress report/design evaluation due.

Nov. 23 M		Exam 3. Advanced computational DfAM . Critical evaluation of computationally generated designs, including topology optimization, lattices, simulation, and computational design limitations. Individual Design Assignment 4 due.
Nov. 25 W	Module 6: Emerging DfAM + Design Synthesis	Asynchronous class. Graduate Research Project presentations/discussions begin.
Nov. 30 M	Module 6	Data-driven and ML-based DfAM + emerging research. Applications of machine learning and data-driven methods to design, manufacturability, process selection, and performance prediction. Graduate Research Project: remaining presentations/discussions. Team project final preparation and design critique.
Dec. 2 W	Module 6	Emerging DfAM: digital materials + multi-material AM. Digital materials, voxel-based design, multi-material structures, fiber reinforcement, and other emerging approaches. Connect emerging technologies to the DfAM principles developed throughout the semester.
Dec. 7 M	Module 6	Final team presentations + design showcase. Teams present their final AM product/design, prototype, design process, DfAM decisions, manufacturing considerations, analysis, and final justification. Team Project: final presentation and prototype/design due. Individual contribution/peer evaluation completed.
Dec. 9 W	Module 6	Final team presentations + design showcase continued. Individual contribution/peer evaluation completed.

Final project

There is no final exam in this course. The final project report and presentation will be due in the last week of class. The UA's policy on final exams is available at:

<https://registrar.arizona.edu/faculty-staff-resources/room-class-scheduling/schedule-classes/final-exams>

Required Texts or Readings:

There are several free required textbooks available on D2L free for all students. Weekly readings will be assigned. See Course Content > Course Textbook for details.

Required Materials:

Access to a basic fused-filament fabrication 3D printer is highly recommended due to the hands-on nature of this course. Your instructor will help you identify appropriate 3D printers available for student use on campus or in your local community during the first week of class. (There are a wide variety of makerspaces and organizations that offer 3D printing, including CATalyst, the University of Arizona's library 3D printing service, some UPS stores, Xerocraft, and many public libraries. Low-cost 3D printers are also widely available for purchase.)

We will use CAD, CAM, and CAE software as part of this course. The software packages we will use are free to UArizona students. Instructions for downloading and using the relevant software will be provided in class.

University IT Support:

For course videos and online support: support@engr.arizona.edu

Course Drop Policy: The UA's policy concerning Class Attendance, Participation, and Administrative Drops is available at:
<http://catalog.arizona.edu/policy/class-attendance-participation-and-administrative-drop>

Threatening Behavior Policy

The UA Threatening Behavior by Students Policy prohibits threats of physical harm to any member of the University community, including to oneself. See
<http://policy.arizona.edu/education-and-student-affairs/threatening-behavior-students>.

Accessibility and Accommodations

Our goal in this classroom is that learning experiences be as accessible as possible. If you anticipate or experience physical or academic barriers based on disability, please let me know immediately so that we can discuss options. You are also welcomed to contact the Disability Resource Center (520-621-3268) to establish reasonable accommodations. For additional information on the Disability Resource Center and reasonable accommodations, please visit <http://drc.arizona.edu>.

If you have reasonable accommodations, please plan to meet with me by appointment or during office hours to discuss accommodations and how my course requirements and activities may impact your ability to fully participate.

Please be aware that the accessible table and chairs in this room should remain available for students who find that standard classroom seating is not usable.

Code of Academic Integrity

Students are encouraged to share intellectual views and discuss freely the principles and applications of course materials. However, graded work/exercises must be the product of independent effort unless otherwise instructed. Students are expected to adhere to the UA Code of Academic Integrity as described in the UA General Catalog. See:
<http://deanofstudents.arizona.edu/academic-integrity/students/academic-integrity>.

The University Libraries have some excellent tips for avoiding plagiarism, available at <http://new.library.arizona.edu/research/citing/plagiarism>.

*Selling notes and/or other course materials to other students or to a third party for resale is **not** permitted without the instructor's express written consent.* Violations to this and other course rules are subject to the Code of Academic Integrity and may result in course sanctions. Additionally, students who use D2L or UA e-mail to sell or buy these copyrighted materials are subject to Code of Conduct Violations for misuse of student e-mail addresses. This conduct may also constitute copyright infringement.

Classroom behavior policy

To foster a positive learning environment, the use of cell phones or mobile devices during class is not allowed.

Additional Resources for Students

UA Academic policies and procedures are available at
<http://catalog.arizona.edu/policies>

Student Assistance and Advocacy information is available at
<http://deanofstudents.arizona.edu/student-assistance/students/student-assistance>

Confidentiality of Student Records

<http://www.registrar.arizona.edu/personal-information/family-educational-rights-and-privacy-act-1974-ferpa?topic=ferpa>

Subject to Change Statement

Information contained in the course syllabus, other than the grade and absence policy, may be subject to change with advance notice, as deemed appropriate by the instructor.

UA Nondiscrimination and Anti-Harassment Policy:

The University is committed to creating and maintaining an environment free of discrimination, see: <http://policy.arizona.edu/human-resources/nondiscrimination-%20and-anti-harassment-policy>. Our classroom is a place where everyone is encouraged to express well-formed opinions and their reasons for those opinions. We also want to create a tolerant and open environment where such opinions can be expressed without resorting to bullying or discrimination of others. UA Academic policies and procedures are available at <http://catalog.arizona.edu/policies>. Student Assistance and Advocacy information is available at <http://deanofstudents.arizona.edu/student-assistance/students/student-assistance>