University of Illinois Urbana-Champaign
Department of Aerospace Engineering
AE 598 – Multiphase Flows – Fall 2025

AE 598 – Multiphase Flows – Syllabus

Fabien Evrard & Laura Villafañe Roca

Document last updated on August 24, 2025.

Online platform We will use Canvas for all course-related content, communications, and submissions. You are encouraged to create Discussions in Canvas in order to raise questions about concepts or course assignments. The instructor will moderate discussions and answer questions as timely as possible. For personal communications with the instructor, or to provide feedback on the course, please send a direct message via the Canvas Inbox.

Link to the course homepage: https://canvas.illinois.edu/courses/61487

Course information

Credit	4 hours
Time	12:30 pm – 1:50 pm Tuesday/Thursday
Location	3018 Campus Instructional Facility
Recordings	Available to online students on Mediaspace after each lecture.

Instructor Prof. Fabien Evrard (AE)

Office	Talbot 317
E-mail	fevrard@illinois.edu
Office hours	4–5 pm Tuesdays [zoom link]

Course description From the ejection of regolith during powered spacecraft landing to the atomization of liquid fuel in gas turbine engines, multiphase flows play a central role in aerospace engineering. This course aims to provide students with a fundamental understanding of multiphase flows, e.g., flows laden with solid particles, droplets, and bubbles, or interfacial flows subject to surface tension. For their final project, students will be given the opportunity to formulate their own research project or to choose from a list of suggested topics. This includes potential exposure to computational and experimental approaches used for studying multiphase flows relevant to aerospace engineering applications. The course is suitable for students wanting a theoretical overview of multiphase flows, as well as to gain hands-on experience on the analysis and modeling of multiphase flows.

Learning goals At this end of this course, you will have:

- Gained a fundamental understanding of the behavior of solid particles/droplets/bubbles immersed in a carrier fluid.
- Gained a fundamental understanding of surface tension and the behavior of fluid interfaces.
- Studied the main mechanisms of coupling between multiple fluid and solid phases.
- Been exposed to the theoretical framework used for analysing and modeling multiphase flows.

Prerequisites AE 311 (incompressible flow) or equivalent.

Recommended experience AE 412 (viscous flow & heat transfer), TAM 435 (intermediate fluid mechanics), or equivalents.

Necessary background Tensor calculus, partial differential equations, basic programming.

Recommended textbooks These books cover much of the course material and can be downloaded for free from the university network:

- Crowe, Schwarzkopf, Sommerfeld, Tsuji, *Multiphase Flows with Droplets and Particles*
  ↪ Free download at https://doi.org/10.1201/b11103
- de Gennes, Brochard-Wyart, Quéré, *Capillarity and Wetting Phenomena*
  ↪ Free download at https://doi.org/10.1007/978-0-387-21656-0
- Ishii, Hibiki, *Thermo-Fluid Dynamics of Two-Phase Flow*
  ↪ Free download at https://doi.org/10.1007/978-1-4419-7985-8
- Michaelides, Crowe, Schwarzkopf, *Multiphase Flow Handbook*
  ↪ Free download at https://doi.org/10.1201/9781420040470

Additional textbooks These books provide additional resources on the theory and modeling of multiphase flows, which you may find useful. Some are free to download; the rest is at the Grainger library:

- Clift, Grace, Weber, *Bubbles, Drops, and Particles*
- Prosperetti, Tryggvason, *Computational Methods for Multiphase Flow*
  ↪ Free download at https://doi.org/10.1017/CBO9780511607486
- Subramaniam, Balachandar, *Modeling Approaches and Computational Methods for Particle-Laden Turbulent Flows* ↪ Free download at https://doi.org/10.1016/C2020-0-03264-0
- Tryggvason, Scardovelli, Zaleski, *Direct Numerical Simulations of Gas-Liquid Multiphase Flows*
  ↪ Free download at https://doi.org/10.1017/CBO9780511975264

Assignments This course requires that you submit several Assignments through Canvas:

- 3 homework reports
- final project deliverables

Homeworks will be available on Canvas about one week before the submission deadline. They may include some small coding assignments. Late submission of any assignment will incur a penalty of 10% per day past the submission deadline.

Submissions guidelines will be provided on Canvas for each assignment. Tentative submission deadlines are provided below. They may be subject to changes, which will be announced in class and on Canvas. Therefore, it is your responsibility to regularily check Canvas and look for course announcements.

Tentative assignment submission deadlines:

Homework 1	September 19
Homework 2	October 17
Homework 3	November 14
Project	December 09 (presentation) & December 12 (report)

Midterm exam A closed-book midterm exam will take place between the second and third homework assignment deadlines, during class hours. Specific arrangments will be communicated to online students for them to take this exam. The tentative date for the midterm exam is:

Thursday, October 30, 12:30 pm – 1:50 pm

Grading scheme We will employ the following grading scheme:

Grade repartition:

Homework	35%
Midterm	30%
Project	35%

Grade conversion:

Total	Grade	Total	Grade	Total	Grade	Total	Grade
≥ 98	A+	$[88, 90)$	B+	$[78, 80)$	C+	$[68, 70)$	D+
$[92, 98)$	A	$[82, 88)$	B	$[72, 78)$	C	$[62, 68)$	D
$[90, 92)$	A–	$[80, 82)$	B–	$[70, 72)$	C–	$[60, 62)$	D–
						< 60	F

Outline The outline of the semester is provided below. It may be subject to changes, so you are once again recommended to check Canvas regularly for course announcements.

Week	Date		Module	Content
1	Tuesday	08/26	*Introduction*	Types and examples of multiphase flows
	Thursday	08/28	*Introduction*	Governing equations of multiphase flows
2	Tuesday	09/02	*Rigid particles*	Stokes' drag law
	Thursday	09/04	*Rigid particles*	Extension to finite Reynolds numbers, neighbor effects
3	Tuesday	09/09	*Rigid particles*	Faxén corrections, buoyancy
	Thursday	09/11	*Rigid particles*	Added mass, viscous history, lift forces
4	Tuesday	09/16	*Rigid particles*	BBO and MRG equations
	Thursday	09/18	*Surface tension*	Molecular origin, surface energy, non-dimensional numbers
	Friday	09/19		**Homework 1 due**
5	Tuesday	09/23	*Surface tension*	Young-Laplace law, stability of a planar interface
	Thursday	09/25	*Surface tension*	Capillary vs. gravity waves, Kelvin-Helmholtz instability
6	Tuesday	09/30	*Surface tension*	Rayleigh-Taylor instability, stability of a cylindrical interface
	Thursday	10/02	*Surface tension*	Rayleigh-Plateau instability (inviscid)
7	Tuesday	10/07	*Surface tension*	Rayleigh-Plateau instability (viscous), breakup of a liquid jet
	Thursday	10/09	*Surface tension*	Wetting of surfaces
8	Tuesday	10/14	*Drops & bubbles*	Hadamard-Rybczyński drag law and extensions
	Thursday	10/16	*Drops & bubbles*	Breakup regimes, atomization
	Friday	10/17		**Homework 2 due**
9	Tuesday	10/21	*Drops & bubbles*	Thermocapillary motion, impact of surfactants
	Thursday	10/23	*Turbulence*	Refresher on single-phase turbulence
10	Tuesday	10/28	*Turbulence*	Inertial particles in turbulence
	Thursday	10/30		**Midterm exam**
11	Tuesday	11/04	*Turbulence*	Fluid-fluid interfaces in turbulence
	Thursday	11/06	*Modeling*	Volume-averaged modeling framework for multiphase flows
12	Tuesday	11/11	*Modeling*	Modeling of particle-laden flows
	Thursday	11/13	*Modeling*	Modeling of interfacial flows
	Friday	11/14		**Homework 3 due**
13	Tuesday	11/18	*Final project*	Description of the projects
	Thursday	11/20	*Final project*	Groups work on project
14				**Fall break**
15	Tuesday	12/02	*Final project*	Groups work on project
	Thursday	12/04	*Final project*	Groups work on project
16	Tuesday	12/09		**Final project presentation day**
	Friday	12/12		**Final project report due**

Student code and academic integrity The University of Illinois Urbana-Champaign Student Code will be followed at all times during this course. We invite you to read through Article 1, Part 4: Academic Integrity in particular. Every student is expected to review and abide by this academic integrity policy, and it is your responsibility to read it to avoid putting yourself in a position that may result in you failing this course. If you are ever in doubt about what constitutes plagiarism, cheating, or any other breach of academic integrity in the context of this course, do not hesitate to contact the instructor.

You are expected to produce your own work in all individual assignments. You may collaborate with a peer, but your assignment must be written by you only. Assignments will be checked for plagiarism. If your work closely matches someone else's, it will be flagged and investigated.

Use of Generative AI Technology Generative AI, such as OpenAI ChatGPT, Microsoft Copilot/Bing Chat, Google Gemini, and others, can answer questions and generate text, images, and code. The

appropriate use of generative AI will vary from course to course. Guidelines for using generative AI in this course are as follows:

1. Follow only the specific permitted uses set by your instructor.
2. Document and attribute all AI contributions to your coursework.
3. Take full responsibility for AI contributions, ensuring the accuracy of facts and sources.

Permitted uses of generative AI in this course include:

- Shortening your own text and revising it for spelling and grammar.
- Testing and practicing your knowledge of course topics.
- Conducting basic research on course and assignment topics.

Additional allowed uses and restrictions may apply to specific assignments as specified in that assignment's instructions.

When using generative AI, keep a journal documenting prompts, AI responses, and your usage, or, if possible, share a link to your chat history. Your instructor may ask you to provide this documentation. Refer to the APA style guide for citing generative AI, including the text of your prompt to the AI. Remember, a generative AI conversation in and of itself is not a valid source for facts. Always work to find, verify, and cite the original source of ideas, rather than citing the AI directly. Review the University of Illinois System's Generative AI Guidance for Students. You are responsible for verifying sources and facts and attributing ideas generated by the AI. Generative AI tools sometimes invent facts and sources.

Failure to abide by these guidelines is a violation of academic integrity. We will investigate suspected uses of generative AI that do not follow these guidelines and apply sanctions as outlined in the Illinois Student Code.

Absence policies

Feeling sick before class? If you feel ill or are sick with a potentially contagious illness, you should not attend class and will be considered to have an excused absence. Please contact the instructor via Canvas about making up the work. We will do our best to accomodate such unfortunate instances and make sure you stay on track with the course.

Other health-related issues: Similarily, if you cannot attend class or complete assignments due to health-related issues, including but not limited to feeling ill, caring for a sick family member, or having unexpected child-care obligations, you should inform your instructor and are also encouraged to copy your academic advisor.

Absence letters: Conditions under which an absence letter from the Office of the Dean of Students may be requested are defined in Article 1, Part 5 of the Student Code.

Respect among peers The effectiveness of this course is dependent upon each of us creating a safe and encouraging learning environment that allows for the open exchange of ideas, while also ensuring equitable opportunities and respect for all of us. Everyone is expected to help establish and maintain a environment where students, staff, and faculty can contribute without fear of personal ridicule, or intolerant or offensive language. If you witness or experience racism, discrimination, micro-aggressions, or other offensive behavior, you are encouraged to bring this to the attention of the instructor if you feel comfortable. You can report these behaviors to the Bias Assessment and Response Team (BART). Based on your report, BART members will follow up and reach out to students to make sure they have the support they need to be healthy and safe. If the reported behavior also violates university policy, staff in the Office for Student Conflict Resolution may respond as well and will take appropriate action.

Disability-related accommodations To obtain disability-related academic adjustments and/or auxiliary aids, students with disabilities must contact the course instructor and the Disability Resources and Educational Services (DRES) as soon as possible. To contact DRES, you may:

- Visit 1207 S. Oak St., Champaign
- Call 333-4603
- E-mail disability@illinois.edu
- Go to https://www.disability.illinois.edu

If you are concerned you have a disability-related condition that is impacting your academic progress, there are academic screening appointments available that can help diagnosis a previously undiagnosed disability. You may access these by visiting the DRES website and selecting "Request an Academic Screening" at the bottom of the page.

Family Educational Rights and Privacy Act (FERPA) Any student who has suppressed their directory information pursuant to Family Educational Rights and Privacy Act (FERPA) should self-identify to the instructor to ensure protection of the privacy of their attendance in this course. See https://registrar.illinois.edu/academic-records/ferpa/ for more information on FERPA.

Religious observances Illinois law requires the University to reasonably accommodate its students' religious beliefs, observances, and practices in regard to admissions, class attendance, and the scheduling of examinations and work requirements. You should examine this syllabus at the beginning of the semester for potential conflicts between course deadlines and any of your religious observances. If a conflict exists, you should notify your instructor of the conflict and follow the procedure at https://odos.illinois.edu/community-of-care/resources/students/religious-observances/ to request appropriate accommodations. This should be done in the first two weeks of classes.

Sexual misconduct reporting obligation The University of Illinois is committed to combating sexual misconduct. Faculty and staff members are required to report any instances of sexual misconduct to the University's Title IX Office. In turn, an individual with the Title IX Office will provide information about rights and options, including accommodations, support services, the campus disciplinary process, and law enforcement options.

A list of the designated University employees who, as counselors, confidential advisors, and medical professionals, do not have this reporting responsibility and can maintain confidentiality, can be found here: https://wecare.illinois.edu/resources/students/#confidential.

Other information about resources and reporting is available at https://wecare.illinois.edu/.

Mental health Significant stress, mood changes, excessive worry, substance/alcohol misuse or interferences in eating or sleep can have an impact on academic performance, social development, and emotional wellbeing. The University of Illinois offers a variety of confidential services including individual and group counseling, crisis intervention, psychiatric services, and specialized screenings which are covered through the Student Health Fee. If you or someone you know experiences any of the above mental health concerns, it is strongly encouraged to contact or visit any of the University's resources provided below. Getting help is a smart and courageous thing to do for yourself and for those who care about you.

- Counseling Center (217) 333-3704
- McKinley Health Center (217) 333-2700
- National Suicide Prevention Lifeline (800) 273-8255
- Rosecrance Crisis Line (217) 359-4141 (available 24/7, 365 days a year)

If you are in immediate danger, call 911.

Community of care As members of the Illinois community, we each have a responsibility to express care and concern for one another. If you come across a classmate whose behavior concerns you, whether in regards to their well-being or yours, we encourage you to refer this behavior to the Student Assistance Center (217-333-0050 or http://odos.illinois.edu/community-of-care/referral/). Based on your report, the staff in the Student Assistance Center reaches out to students to make sure they

have the support they need to be healthy and safe. Further, as a Community of Care, we want to support you in your overall wellness. We know that students sometimes face challenges that can impact academic performance (examples include mental health concerns, food insecurity, homelessness, personal emergencies). Should you find that you are managing such a challenge and that it is interfering with your coursework, you are encouraged to contact the Student Assistance Center (SAC) in the Office of the Dean of Students for support and referrals to campus and/or community resources.