ME 537 FLUID MECHANICS OF AEROSOLS
FALL 20204

INSTRUCTOR: Goodarz Ahmadi, Room 267 CAMP (325-268-2322)
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Office Hours: Monday and Wednesday 12:30 - 3:30 pm.

TEXT: None. Lecture notes are available on the web.

TA: Roy King (CAMP 292) Office hours: Friday 3:00-5:00 pm.

Course Description

Review of viscous flow theory. Creeping flows around a sphere. Drag and lift forces acting on particles. Introduction to aerosols. Diffusion of aerosols in laminar flows. Brownian motion and Langevin equation. Mass diffusion in pipe and boundary layer flows. Effects of electrostatics, van der Waals, and other surface forces. Computational aspects of aerosol dispersion in laminar flows. Particle adhesion and particle removal from surfaces. Coagulation of aerosols due to Brownian movements. Experimental techniques for particle adhesion measurements. Cleanroom equipment. Applications to micro-contamination control, xerography, and surface cleaning in microelectronic and imaging industries. Aerosol transport and deposition in environmental and biomedical applications.

Delivery Method

The course is offered in blended mode, both in-person in the class, as well as online (synchronous). The lectures are captured by Echo360 and are made available to students on Moodle.

COURSE WEB SITE:

https://webspace.clarkson.edu/projects/crcd/public_html/me537/index.php
https://sites.clarkson.edu/gahmadi/courses/me537/

Course Objectives

1. To provide a fundamental understanding of aerosol transport and removal in laminar flows.
2. To provide a fundamental understanding of particle adhesion and removal from surfaces
3. To provide a fundamental understanding of computational modeling of particle resuspension in laminar flows.
4. To provide a fundamental understanding of the industrial, environmental, and biomedical applications of aerosols.

Course Learning Outcomes

Objective 1:

- Students will be able to formulate and solve aerosol transport and deposition in laminar flows.

Objective 2:

- Students will be able to analyze the adhesion and removal of micro- and nanoparticles to surfaces.

Objective 3:

- Students will demonstrate a fundamental understanding of computational fluid mechanics and particle trajectory analysis procedures.
- Students will demonstrate using the ANSYS-Fluent Code for solving aerosol transport in laminar flows.

- Students will become familiar with the experimental procedure for particle adhesion and removal analysis.

Objective 4:

- Students will understand the micro-contamination problems in microelectronic and imaging industries.
- Students will understand the basics of surface cleaning, including ultrasonic cleaning.
- Students will demonstrate the application of aerosol transport and dispersion in at least one industrial, environmental, or biomedical application.

COURSE OUTLINE

Course Schedule & Graded Activities

Dates	Module Title	Learning Materials (readings, videos, etc.)	Activities
Week 1	**I. REVIEW OF VISCOUS FLOWS**	– Navier-Stokes Equation – Simple Flows – Creeping Flows – Drag on Spherical Particles	Homework
Weeks 2-4	**II. AEROSOLS**	– Introduction to Aerosols – Hydrodynamic Forces (Drag, Lift) – Brownian Motions – Convective Diffusion – Aerosol Kinetics – Particle Deposition Mechanisms – Gravitational Sedimentation – Aerosol Coagulation	Homework
Weeks 5-6	**III. PARTICLE ADHESION**	– JKR and other Adhesion Models – Particle Removal – Effects of Charge and Humidity	Homework
Weeks 7-9	**IV. COMPUTATIONAL FLUID MECHANICS**	– Finite Difference and Finite Volume Methods – Introduction to CFD – Introduction to ANSYS-Fluent Code	Computer Projects Exam-1
Weeks 10-12	**V. SIMULATION METHODS**	– Laminar Flow Simulation – Spherical Particles in Laminar Flows – Brownian Motion of Nanoparticles – Spherical Particles Resuspension	Computer Projects
Weeks 13	**VI. EXPERIMENTAL TECHNIQUES**	– Particle Adhesion Measurement – Particle Removal – Surface Cleaning – Laser Surface Scanner	Homework
Weeks 14-16	**VII. APPLICATIONS**	– Micro-contamination Control – Surface Cleaning – Clean Room and Process Equipment – Ultrasonic and Megasonic Cleaning – Aerosol Transport and Deposition in Environments	Homework

COURSE TOPICS

I. REVIEW OF VISCOUS FLOWS
- Navier-Stokes Equation
- Simple Flows
- Creeping Flows
- Drag on Spherical Particles

II. AEROSOLS
- Introduction to Aerosols
- Hydrodynamic Forces (Drag, Lift)
- Brownian Motions
- Convective Diffusion
- Aerosol Kinetics
- Particle Deposition Mechanisms
- Gravitational Sedimentation
- Aerosol Coagulation

III. PARTICLE ADHESION
- JKR and other Adhesion Models
- Particle Removal
- Effects of Charge and Humidity

IV. REVIEW OF COMPUTATIONAL FLUID MECHANICS
- Finite Difference and Finite Volume Methods
- Introduction to Fluent Code

V. SIMULATION METHODS
- Laminar Flow Simulation
- Spherical Particles in Laminar Flows
- Brownian Motion of Nanoparticles
- Spherical Particles Resuspension

VI. EXPERIMENTAL TECHNIQUES
- Particle Adhesion Measurement
- Particle Removal
- Surface Cleaning
- Laser Surface Scanner

VII. APPLICATIONS
- Micro-contamination Control
- Surface Cleaning
- Clean Room and Process Equipment
- Ultrasonic and Megasonic Cleaning
- Aerosol Transport and Deposition in Environments

EVALUATION METHOD

Exam 1 (October 11, 2024, CAMP 268, 3:00-4:15 pm) 25%
Final Exam (Final Exam week) 35%
Computational Projects 30%
Homework 10%

Grading

Grade Ranges

Graduate Letter Grades

Course Average	Grade	Quality Points
97+	A+	4.0
93-96	A	4.0
90-92	A-	3.667
87-89	B+	3.334
84-86	B	3.0
80-83	B-	2.667
76-79	C+	2.334
70-75	C	2.0
<70	F	0

Course Policies

Etiquette Expectations & Learner Interaction

Educational institutions promote the advancement of knowledge through positive and constructive debate--both inside and outside the classroom. Please visit and follow: Netiquette and Electronic Learner Interaction Guidelines.

Institutional Policies & Regulations

Academic Integrity

Students are expected to abide by the standards of academic honesty, as described in the Clarkson Regulations. The work or words of others must be properly cited. Please refer to Clarkson Library's Guide to Plagiarism and Citing Sources.

Students with Disabilities Policy

Clarkson University welcomes inquiries and applications from individuals who have disabilities. Information relating to disabling conditions is not a determining factor in admission decisions. The University strives to make all facilities and programs accessible to students with disabilities by providing appropriate academic adjustments and other appropriate modifications (accommodations), as necessary. Timely notification of any need for accommodations due to a disability is encouraged so that the Office of Accommodative Services (OAS) may provide for students in an efficient manner.

For more information or other appropriate campus referrals, contact:

Director of Accommodative Services
Clarkson University
P.O. Box 5645
Potsdam, NY 13699-5635
Phone: 315-268-7643
Fax: 315-268-2400
Email: oas@clarkson.edu
Office of Accessibility Services Website

Instructor Participation

During this course, as your instructor, you can expect me to

- Respond to emails and voicemails within 1 day
- Grade activities and assessments within 3 days
- Be an active participant on the discussion board

Academic Freedom

The fundamental aspects of academic freedom at Clarkson University include both the freedom to teach and the freedom to learn. Students are encouraged to exercise this freedom responsibly, embracing opportunities for open discussion, inquiry, and expression in the classroom. Professors evaluate student performance based solely on academic criteria, fostering a fair and supportive learning environment. To maintain a respectful and safe community, the University prohibits actions that violate the law, defame individuals, pose genuine threats, infringe on privacy or confidentiality, contravene the Equal Opportunity, Harassment, and Nondiscrimination Policy, or involve unwelcome activity in the classroom. The professor determines if classroom behavior is inappropriate and may address the issue directly or refer it to the appropriate official with authority to be addressed.

REFERENCES

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3. J. Happel and H. Brenner, Low Reynolds Number Hydrodynamics, Martinus Nijhoff (1983).
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6. F. White, Viscous Flow, McGraw Hill (1974).
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