ME 637 PARTICLE TRANSPORT, DEPOSITION AND REMOVAL-II
Spring 2021

INSTRUCTOR: Goodarz Ahmadi, Room 267 CAMP (325-268-2322)
gahmadi@clarkson.edu
Office Hours: Monday and Wednesday 12:30 - 3:30 pm
(Due to COVID-19, all meetings will be by appointment on Zoom
https://clarkson.zoom.us/j/761986404)

TEXT: None. Lectures notes are available on the web.
http://webspace.clarkson.edu/projects/crcd/

TA: Almir Tricic tricica@clarkson.edu Office hours by appointment

Course Description

Review of viscous flow theory. Creeping flows around a sphere. Introduction to turbulent flows and turbulent modeling. Algebraic, one and several equation models. Drag, lift, virtual mass and Basset forces acting on particles. Wall effects and nonspherical particles. Aerosol transport and dispersion in turbulent flows. Turbulent diffusion and wall deposition of aerosols. Particle charging mechanisms and electrostatics forces. Thermophoretic and electrophoretic effects. Introduction to colloids and electrokinetic phenomena. Computational aspects of aerosol dispersion and deposition in turbulent flows. Sublayer model approach. Approximate simulation of turbulence and turbulence transport. DNS simulation methods. Nonspherical particle transport in turbulent flows. Coagulation of aerosols due to shear and turbulence. Experimental techniques for turbulent flow measurements. Hot-wire anemometry, Isokinetic sampling. Particle concentration and velocity measurements with Phase-Doppler, and PIV. Applications to microcontamination control, air pollution, combustor, spray and particle deposition in human lung. Clean room equipment, xerography, and surface cleaning in microelectronic and imaging industries.

Delivery Method

The course is offered in blended mode, both in-person in the class, as well as online (asynchronous). The lectures will be captured Echo 360 and will be made available to students on Moodle.

COURSE WEB SITE:

https://webspace.clarkson.edu/projects/crcd/public_html/me637/index.php
https://sites.clarkson.edu/gahmadi/courses/me637/

Course Objectives

1. To provide a fundamental understanding of aerosol/particle transport and removal in turbulent flows.
2. To provide a fundamental understanding of the computational modeling of dilute two-phase flows.
3. To provide a fundamental understanding of the industrial applications of dilute multiphase gas-solid turbulent flows.
4. To familiarize the students with the modern experimental techniques in aerosol transport and deposition.
5. 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 turbulent flows.

Objective 2:

- Students will be able to formulate and analyze charged particle transport and deposition.

Objective 3:

- Students will be able to perform computational fluid dynamics and particle trajectory analysis in turbulent flows.
- Students will demonstrate using the ANSYS-Fluent Code for solving particle transport in turbulent flows.
- The student will be able to perform an experimental study of aerosol transport and deposition processes.

Objective 4:

- Students will be able to analyze the industrial gas cleaning and separation processes.
- Students will demonstrate the application of aerosol transport and dispersion in industrial, environmental, or biomedical applications in pollution transport and respiratory deposition

COURSE OUTLINE

Course Schedule & Graded Activities

Dates	Module Title	Learning Materials (readings, videos, etc.)	Activities
Week 1-2	**I. REVIEW OF VISCOUS FLOWS**	− Navier-Stokes Equation − Simple Flows − Creeping Flows − Drag on Spherical Particles	Homework
Weeks 2-3	**II. REVIEW OF COMPUTATIONAL FLUID MECHANICS**	− Finite Difference and Finite Volume Methods − Introduction to ANSYS-Fluent Code	Homework
Weeks 4-8 Break Days Feb. 12,17,18	**III. REVIEW OF TURBULENCE MODELING**	− Algebraic Models − Two-Equation Models − Stress Transport Model − Rate-Dependent Models − PDF Models	Homework
Weeks 9-10 Break Days Mar. 9,10	**IV. AEROSOLS**	− Review of Drag, Lift, Virtual Mass and Basset Forces, BBO Equation − Review of Nonspherical Particles − Review of Brownian Motions − Review of Particle Deposition Mechanisms − Aerosol Transport in Turbulent Flows − Wall Deposition in Turbulent Flows	Computer Projects

		– Inertia Impaction – Particle Charging Mechanisms – Electrostatic Forces – Thermophoretic Forces – Aerosol Coagulation – Coagulation by Turbulence and Shear Fields	
Exam 1	**Mar. 12 (Friday) 11:30-12:45**	**Exam 1, CAMP 177 or 268 (Friday) 11:30-12:45**	**Exam 1**
Weeks 11 Break Days Mar. 22,25	**V. COLLOIDS**	– Introduction to Colloids – Double Layer Forces – Electrokinetic Phenomena	Computer Projects
Weeks 12-15 Break Day Apr. 13	**VI. SIMULATION METHODS**	– Sublayer Model of Turbulence – Particle Deposition on Smooth and Rough Wall – Sublayer Simulation of Charged Particle – Approximate Simulation of Instantaneous Turbulent Flows – DNS and Large Eddy Simulation of Turbulence – Particle Transport and Deposition in Turbulent Flows – Brownian Motion of Nano-particles in Turbulent Flows – Nonspherical Particle Transport in Turbulent Flows	Homework
Weeks 15 Break Day Apr. 23	**VII. EXPERIMENTAL TECHNIQUES**	– Turbulent Flow Measurement (Hot-Wire, PIV, Laser-Doppler) – Particle Concentration and Velocity Measurements (Phase-Doppler, PIV) – Particle Production – Aerosol Sampling Techniques and Aerosol Instrumentation – Advanced Surface Cleaning Techniques (laser, cryogenic, ultrasonic)	Homework
Weeks 16	**VIII. APPLICATIONS**	– Microcontamination Control and Clean Room Operation – Xerography – Indoor Air Quality – Computational Methods for Indoor Air – Lung Deposition and Inhalation Drug Delivery – Filtration Processes and Gas Cleaning – Combustors and Boilers – Spray formation	
Final Exam		**Final Exam week**	**Final Exam**

COURSE TOPICS

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

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

III. REVIEW OF TURBULENCE MODELING
- Algebraic Models
- Two-Equation Models
- Stress Transport Model
- Rate-Dependent Models
- PDF Models

IV. AEROSOLS
- Review of Drag, Lift, Virtual Mass and Basset Forces, BBO Equation
- Review of Nonspherical Particles
- Review of Brownian Motions
- Review of Particle Deposition Mechanisms
- Aerosol Transport in Turbulent Flows
- Wall Deposition in Turbulent Flows
- Inertia Impaction
- Particle Charging Mechanisms
- Electrostatic Forces
- Thermophoretic Forces
- Aerosol Coagulation
- Coagulation by Turbulence and Shear Fields

V. COLLOIDS
- Introduction to Colloids
- Double Layer Forces
- Electrokinetic Phenomena

VI. SIMULATION METHODS
- Sublayer Model of Turbulence
- Particle Deposition on Smooth and Rough Wall
- Sublayer Simulation of Charged Particle
- Approximate Simulation of Instantaneous Turbulent Flows
- DNS and Large Eddy Simulation of Turbulence
- Particle Transport and Deposition in Turbulent Flows
- Brownian Motion of Nano-particles in Turbulent Flows
- Nonspherical Particle Transport in Turbulent Flows

VII. EXPERIMENTAL TECHNIQUES
- Turbulent Flow Measurement (Hot-Wire, PIV, Laser-Doppler)
- Particle Concentration and Velocity Measurements (Phase-Doppler, PIV)
- Particle Production

- Aerosol Sampling Techniques and Aerosol Instrumentation
- Advanced Surface Cleaning Techniques (laser, cryogenic, ultrasonic)

VIII. APPLICATIONS

- Microcontamination Control and Clean Room Operation
- Xerography
- Indoor Air Quality
- Computational Methods for Indoor Air
- Lung Deposition and Inhalation Drug Delivery
- Filtration Processes and Gas Cleaning
- Combustors and Boilers
- Spray formation

EVALUATION METHOD

Exam 1 (March 8, CAMP 268, (11:30-12:45) 25%
Final Exam (Final Exam week) 35%
Computational Projects and Lab 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

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

REFERENCES

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- M.R. Spina and W.W. Nazaroff, Particle deposition from turbulent flow: Review of published research and its applicability to ventilation ducts in commercial buildings, http://repositories.cdlib.org/lbnl/LBNL-51432/