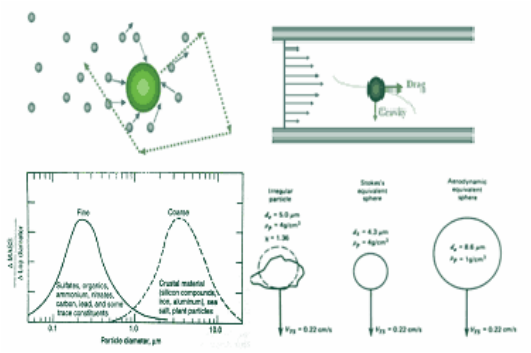
BAE 590B-003: AEROSOL MECHANICS

Department of Biological and Agricultural Engineering

Syllabus – Spring 2006

M.W.F. 10:15 – 11:05, 125 Weaver Labs



Instructor Information:

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Office Hours:

Tuesday 1:30 pm – 3:00 pm, or by appointment

***Prerequisite**: Senior / Graduate status or approval of instructor*

Instructional Objectives:

This course is designed for graduate or senior undergraduate students who have a desire to work in the area of air quality. Upon completion of this course, students will be able to (1) identify the governing mechanism(s) for aerosol behavior under different circumstances; (2) evaluate various aerosol measurement techniques and analyze their limitations; (3) design particulate matter (aerosol) sampling systems for source emission determination; ambient air monitoring; workplace air quality monitoring; and laboratory experiments; and (4) apply aerosol fundamentals in control of particulate matter (aerosol) emission.

Course Text:

Hinds, W.C. *Aerosol Technology: Properties, Behavior, and Measurement of Airborne Particles, 2nd edition.* John Wiley & Sons, New York, 1999. ISBN0471194107. $95.95 (new), $77.98 (used).

References:

1. Zhang, Y. *Indoor Air Quality Engineering.* CRC press, Florida, 2005. ISBN1566706742.
2. Baron, P.A. and K. Willeke. *Aerosol Measurement: Principles, Techniques, and Applications, 2nd edition.* John Wiley & Sons, New York, 2001. ISBN0471356360.
3. Cooper, C.D. and F.C. Alley. *Air Pollution Control – A Design Approach, 3rd edition*. Waveland Press, Inc. prospect heights, Illinois, 2002. ISBN1577662180.
4. Seinfeld J.H. and S.N. Pandis. *Atmospheric Chemistry and Physics: from Air Pollution to Climate Change*. Wiley Interscience, 1997. ISBN 0-471-17816-0.
5. Copies of relevant technical papers will be handed out to update materials given in text.

Course Description:

The class focuses on aerosol technology. It covers the fundamental principles of mechanical, fluid dynamical, electrical, optical and molecular effects for understanding aerosol properties and modeling aerosol behavior. The applications include aerosol sampling (source, ambient, and workplace) and aerosol emission control.

Homework:

Homework will be assigned periodically (approximately 10 assignments in total). It will be collected at the beginning of the class on the due date. Late homework will be accepted up to 5:00pm on the due day, but it will receive a grade of 80% of what the actual score was.

Examinations:

There will be two exams – one midterm and one final. The exams will be closed book, closed notes; however, students are allowed to bring a formula sheet to the exam.

Missed exams will be a **zero**, except for University Excused Absences. In order to take a makeup exam, students have to inform instructor about the absence **before** the exam unless there is an unexpected accident.

Term Project:

There will be a term project, which represents 25% of the grade for this course. The project topic is of the student's choosing. Each student should have a topic selected upon instructor's approval by February 3. Each student is expected to give a 15 – 20 minutes oral presentation on their term project research on April 24 and 26. The final paper is due on April 28, and should be written in the style of a paper to be submitted to a major refereed journal for publication.

Grade Determination:

The final grade will not be graded on a curve, and will be determined based upon the following components:

(1) Homework: 25%; (2) Midterm: 25%; (3) Final: 25%; (4) Term project: 25%

A^+	98-100	B^+	87-89	C^+	77-79	D^+	67-69
A	95-97	B	84-86	C	74-76	D	64-66
A^-	90-94	B^-	80-83	C^-	70-73	D^-	60-63

Academic Integrity:

The Code of Student Conduct at North Carolina State University sets out a code of ethics and personal dignity. Students should refer to this code and value honesty and integrity. The code could be found at http://www.ncsu.edu/policies/student_services/student_discipline/POL11.35.1.php.

It is permissible in this course to discuss the interpretation of the problem statement, share ideas or approaches for solving the problem, and explain the concepts involved in the problem. Any other aid is not permissible and considered as a violation of the academic integrity policy. No academic misconduct will be tolerated in this course.

Attendance:

Students are expected to attend class on time. In case of absence, the student must provide documentation substantiating the reason for the absence that is satisfactory to the instructor, within one week of the last date of the absence. For illness, documentation should include a note from a doctor or clinic. For further information, students should refer to the University attendance policy at www.ncsu.edu/provost/academic_regulations/attend/reg.htm.

Students with University Excused Absences will be allowed to makeup missing exam and late homework without any penalty. However, it is the student's responsibility to identify the materials covered during the absence and to contact instructor for scheduling makeup exam.

Students with Disabilities:

Reasonable accommodations will be made for students with verifiable disabilities. In order to take advantage of available accommodations, students must register with Disability Services for Students at 1900 Student Health Center, Campus Box 7509, 515-7653.
http://www.ncsu.edu/provost/offices/affirm_action/dss/

Tentative Course Outline:

Part I: Aerosol Fundamentals

1. Introduction: overview and definitions (*Hinds, Ch.1*,)
    a. Overview and definitions
2. Properties of gases (Hinds, *Ch.2; Zhang, Ch.5; Cooper &Alley, Ch.10*)
3. Particle size statistics (*Hinds, Ch.4; Zhang, Ch.3*)
    a. Properties of size distribution
    b. Number distribution
    c. Mass distribution
    d. The log-normal distribution
4. Particle mechanics – 1 (*Hinds, Ch.3; Zhang, Ch.4*)
    a. Uniform particle motion
5. Particle mechanics – 2 (*Hinds, Ch.5*)
    a. Straight-line acceleration and curvilinear particle motion
6. Diffusion and coagulation of aerosols – 1 (*Hinds, Ch.7, Ch.12; Zhang, Ch.6*)
    a. Brownian motion
    b. Diffusion coefficient
    c. Diffusive deposition
7. Diffusion and coagulation of aerosols – 2
    a. Monodisperse coagulation
    b. Polydisperse coagulation
    c. Kinematical coagulation
8. Filtration of aerosols (*Hinds, Ch.9; Zhang, Ch.10*)
    a. Properties of filters
    b. Filtration mechanisms
    c. Filter efficiency
    d. Pressure drop
9. Optical characteristics of aerosols (*Hinds, Ch.16*)
    a. Scattering of light
    b. Extinction
    c. Optical measurement
10. Electrical behavior of aerosols (*Hinds, Ch.15; Zhang, Ch.12*)
    a. Basic considerations
    b. Charging mechanisms
    c. Electrical measurement of aerosols
11. Condensation and evaporation (*Hinds, Ch.13*)
    a. Thermodynamics
    b. The Kelvin-Helmhoz equation
    c. Growth by condensation
    d. Evaporation
12. Atmospheric aerosols – 1 (*Seinfeld, Ch.7*; *Hinds, Ch.14; Handout*)
    a. Introduction and background (**Dr. Zhang**, MEA–NCSU)
13. Atmospheric aerosols – 2 (*Seinfeld, Ch.9, 13; Handout*)
    a. Formation of secondary aerosols (**Dr. Aneja,** MEA–NCSU)
14. Bioaerosols (*Hinds, Ch.19; Baron & Willeke, Ch.24*)
    a. Definition and classification
    b. Characteristics
    c. Collection and sampling
15. Health effect of aerosols

Part II: Aerosol Measurement

16. Measurement uncertainty analysis (*Handout*)
    a. Basic concepts
    b. Uncertainty analysis
17. Flow measurement and control (*Hinds, Ch.2, Ch.10; Zhang, Ch.8*)
18. Measurement of pressure and energy consumption (*Handout*)
19. Determination of air density and PM mass concentration (*Handout*)
20. Aerosol measurement techniques – 1: sampling and transport of aerosols (*Hinds, Ch.10 Zhang, Ch.8; Baron, Ch.10*)
    a. Air sampler and sampling efficiency
    b. Isokinetic sampling
21. Aerosol measurement techniques – 2: inertial, gravitational and centrifugal techniques 1 (*Hinds, Ch.5; Zhang, Ch. 7; and Baron, Ch. 10*)
    a. Conventional impactors
    b. Virtual impactors
22. Aerosol measurement techniques – 3: inertial, gravitational and centrifugal techniques 2
    a. Low Reynolds sampling cyclone
23. Aerosol measurement techniques – 4: dynamic mass measurement (*Barons Ch.14*)
    a. Tapered element oscillating microbalance method (TEOM)
24. Aerosol measurement techniques – 5: direct reading technique (*Baron, Ch.17*)
    a. Aerodynamic particle sizer
25. Aerosol measurement techniques – 6: electrical measurement of aerosols (*Hinds, Ch.15*)
    a. Coulter Counter Multisizer
26. Aerosol measurement techniques – 7: PSD measurement by laser diffraction (*Handout*)
27. Aerosol measurement techniques – 8: diffusion denuders (**Dr. Robarge**, SSC–NCSU)
28. Aerosol measurement techniques – 9: chemical analysis methods for atmospheric aerosol component (*Baron, Ch.11; Seinfeld Ch.7.3*)
29. Application of aerosol measurement techniques – 1: ambient air sampling 1 (*Handout*)
    a. NAAQS
    b. Sampling system components and size selective inlets
    c. TSP samplers (high-volume and low volume)
30. Application of aerosol measurement techniques – 2: ambient air sampling 2 (*Handout*)
    a. FRM PM_{10} samplers
    b. FRM $PM_{2.5}$ samplers
    c. PM coarse sampling
31. Application of aerosol measurement techniques – 3: fugitive dust sampling 1 (*Barons, Ch.28 and handout*)
    a. Factors affecting dust emission
    b. Emission calculation procedure
32. Application of aerosol measurement techniques – 4: fugitive dust sampling 2
    a. Emission modeling
33. Application of aerosol measurement techniques – 5: aerosol measurement in the workplace (*Baron, Ch.25 and handout*)
    a. ACGIH sampling criteria for inhalable, thoracic and respirable fractions
    b. Occupational exposure limits
    c. Industrial hygiene aerosol samplers
34. Application of aerosol measurement techniques – 6: indoor aerosols (*Baron, Ch.29*)
    a. Measurement strategies
    b. Sampling and analysis methods
    c. Sampling of PM emission from building

Part III: Aerosol Emission Control

35. Electrostatic precipitators – ESP (**Dr. Frey**, CE–NCSU)
    a. Theory and design considerations (*Zhang, Ch.12*; *Cooper & Alley, Ch.5*)
36. Aerodynamic air cleaner – 1 (*Zhang, Ch.11; Cooper & Alley, Ch.4*)
    a. Case study 1 – design of a cyclone abatement system for cotton gins (theory and design considerations)
37. Aerodynamic air cleaner – 2 (*Zhang, Ch.11)*
    a. Case study 2 – design of a uniflow cyclone for AFO buildings (theory and design considerations)
38. Particulate scrubbers (*Cooper & Alley, Ch.3*)
    a. Theory and design considerations
39. PM bag filter (*Cooper & Alley, Ch.6; Zhang, Ch.10*)
    a. Case study 3 - design of a bag house system for grain elevators (theory and design considerations)

Tentative Lecture Schedule & Topics:

Week	Class	Date	Topics	Assignments	Reading
1	1	01-09-06	Introduction: overview & definitions		Hinds, Ch.1
	2	01-11-06	Properties of gases		Hinds, Ch.2; Zhang, Ch.5
	3	01-13-06	Particle size statistics	HW #1	Hinds, Ch.4
2		01-16-06	No class, holiday		
	4	01-18-06	Particle mechanics – 1	HW #2	Hinds, Ch.3
	5	01-20-06	Particle mechanics – 2		Hinds, Ch.5
3	6	01-23-06	Diffusion and coagulation of aerosols – 1	HW #3	Hinds, Ch.7
	7	01-25-06	Diffusion and coagulation of aerosols – 2		Hinds, Ch.12
	8	01-27-06	Filtration of aerosols		Hinds, Ch.9
4	9	01-30-06	Optical characteristics of aerosols	HW #4	Hinds, Ch.16
	10	02-01-06	Electrical behavior of aerosols		Hinds, Ch.15
	11	02-03-06	Condensation and evaporation	Term paper topic due	Hinds, Ch.13
5	12	02-06-06	Atmospheric aerosols – 1 (**Dr. Zhang**, MEA)		Seinfeld, Ch.7 Handouts
	13	02-08-06	Atmospheric aerosols – 2 (**Dr. Aneja**, MEA)		Seinfeld, Ch.7, 13 Handouts
	14	02-10-06	Bioaerosols		Hinds, Ch.19
6	15	02-13-06	Health effect of aerosols		Handouts
	16	02-15-06	Measurement uncertainty analysis	HW #5	Handouts
	17	02-17-06	Flow measurement and control		Hinds, Ch.2; Zhang, Ch.8
7	18	02-20-06	Measurement of pressure		Hinds, Ch.2
	19	02-22-06	Determination of air density and concentration	HW #6	Handouts
	20	02-24-06	Aerosol measurement techniques – 1		Hinds, Ch.10; Zhang, Ch.8; Baron, Ch.10
8	21	02-27-06	Aerosol measurement techniques – 2		Hinds, Ch.5; Zhang, Ch.7; Baron, Ch.10
	22	03-01-06	Aerosol measurement techniques – 3	Term paper abstract due	Handouts
		03-03-06	**Midterm Exam** (closed book, closed notes)		
9		03-06-06	No class, spring break		
		03-08-06	No class, spring break		
		03-10-06	No class, spring break		
10	23	03-13-06	Aerosol measurement techniques – 4	HW #7	Baron, Ch.14
	24	03-15-06	Aerosol measurement techniques – 5		Baron, Ch.17
	25	03-17-06	Aerosol measurement techniques – 6		Hinds, Ch.15
11	26	03-20-06	Aerosol measurement techniques – 7		Handouts
	27	03-22-06	Aerosol measurement techniques – 8 (**Dr. Robarge** SSC, NCSU)		Zhang, Ch.6; Baron, Ch.19 Handouts

	28	03-24-06	Aerosol measurement techniques – 9		Baron, Ch.11; Seinfeld, Ch.7.3
12	29	03-27-06	Application of aerosol measurement tech. – 1	HW #8	Handouts
	30	03-29-06	Application of aerosol measurement tech. – 2		Handouts
	31	03-31-06	Application of aerosol measurement tech. – 3		Baron, Ch.28
13	32	04-03-06	Application of aerosol measurement tech. – 4		Handouts
	33	04-05-06	Application of aerosol measurement tech. – 5		Baron, Ch.25 and Handouts
	34	04-07-06	Application of aerosol measurement tech. – 6		Baron, Ch.29 Handouts
14	35	04-10-16	Electrostatic precipitators (**Dr. Frey**, CE–NCSU)		Cooper Ch. 5; Zhang Ch.12
	36	04-12-06	Aerodynamic air cleaner – case 1	HW #9	Cooper Ch. 4; Zhang, Ch.11
		04-14-06	No class, spring holiday		
15	37	04-17-06	Aerodynamic air cleaner – case 2		Zhang, Ch.11
	38	04-19-06	PM scrubbers	HW #10	Cooper & Alley Ch. 3
	39	04-21-06	PM bag filter – case 3		Cooper & Alley Ch. 6
16	40	04-24-06	Term project presentations		
	41	04-26-06	Term project presentations		
	42	04-28-06	Dead week	Term paper due	
		05-03-06	**8:00 am - 11:00 am** **Final Exam (closed book, closed notes)**		