BAE 560-001/201: AEROSOL SCIENCE & ENGINEERING
Lecture Session: M.W. 10:15am – 11:05am, 143 Weaver Labs
Lab Session: F. 1:30pm – 3:20pm, 125 Weaver Labs

SYLLABUS

Instructor: Dr. Lingjuan Wang-Li; 186 Weaver Labs; Phone: 919-515-6762; Email: Lwang5@ncsu.edu
Prerequisite: MA341 or equivalent
Restrictive Statement: Senior / graduate status or approval of instructor

Instructional Objectives:
This course is designed for graduate and 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; (4) apply air quality models e.g. AERMOD to describe fate and transport of aerosols emitted from different types of sources, and (5) identify and evaluate control techniques for mitigation of particulate matter emissions.

Course Text:

References:
5. Copies of relevant technical papers will be handed out to update materials given in text.

Course Description:
The lecture session of course covers the fundamental principles of mechanical, fluid dynamical, electrical, optical and molecular effects for understanding aerosol properties and modeling aerosol behavior. Subjects to be discussed include:

- **Aerosol fundamentals:** particle size statistics; fluid resistance to aerosol particle motion; diffusion and coagulation of particles; optical characteristics of aerosol; electrical behavior of aerosol; condensation / evaporation; aerosol dispersion; bioaerosol; and health effects

- **Aerosol measurements:** aerosol mass concentration measurements (including source sampling, ambient PM sampling techniques such as TSP, PM10, PM2.5, TEOM, and samplers for work place); particle size distribution (PSD) measurements (including cascade impactor, electrical sensing zone, laser diffraction, microscopy, etc.); aerosol speciation (including organic and inorganic composition analysis)

- **Aerosol emission controls:** case studies for different control technologies in application of particulate matter emission control
General Description of Labs:
In the lab, students will work in teams of two people to complete the lab project. Each team will be responsible for completing the lab as assigned. Tentative hands-on lab experiments and field trips include:

- Ambient temperature, barometric pressure, relative humidity measurements (Psychometrics)
- Pipe air flow rate and pressure drop measurement for stack sampling
- Particle density measurement using AccuPyc 1330 Pycnometer
- PSD measurement techniques – operation of LS13 320 multi-wavelength PSD analyzer
- Bioaerosol sampling: operation of the cascade impactors: viable vs. non-viable samplers
- Ambient aerosol (PM$_{10}$, PM$_{2.5}$, TSP) sampling using gravimetric samplers and TEOM-PM monitors
- PM chemical speciation sampling technique – operation of Partisol2300 PM$_{2.5}$ speciation samplers
- AERMOD – air dispersion modeling practices
- Field trip to EPA’s super ambient air quality monitoring site at Millbrook High school (Raleigh)-managed by NCDENR-Air Quality division
- Field trip to RTI at RTP, EPA’s subcontractor for EPA’s PM$_{2.5}$ chemical speciation network (CSN)

Lab Reports:
The reports, as scientific papers, should have a fairly consistent format that contains the following major sections to help organize information clearly:

- Title
- Abstract – executive summary of the work accomplished
- Introduction – literature review
- Objective(s)
- Material and method
  - Experimental setup
  - Experimental design
  - Experimental procedure
  - Data analysis
- Results and discussions
- Conclusions
- Recommendations for the future work
- References

Lab Grade Determination:
Labs count as 20% of your final grade for this course. You will be graded based on your individual written reports. Each team member will write his or her OWN report for each lab topic. The report will be submitted after the completion of a particular lab project. The exact due date will be determined at least a week before the report is due.

Homework:
Homework will be assigned periodically. 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 maximum grade of 80%.

Examinations:
There will be two exams and the 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.

Grade Determination:
The final grade will not be graded on a curve, and will be determined based upon the following components:
Components | Homework | Lab reports | Exam 1 | Exam 2 | Final
--- | --- | --- | --- | --- | ---
BAE560 | 20% | 20% | 20% | 20% | 20%

Grading: border-line grades may be upgraded based upon attendance, class participation, and evidence of improvements.

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Lab Safety Regulations:
- Do not use any equipment until the instructor has approved of you doing so. If you are ever uncomfortable using equipment or not 100% confident that you know what you are doing, please ask for help from the instructor or TA. There are going to be instances when you will probably be teased or placed under peer pressure to use tools or equipment that you are not sure how to use. Please ignore this and ask the TA or instructor for help. It is better to be an embarrassed 10-fingered person than an accepted nine-fingered person. Keep in mind that some of the tools we will use to construct prototypes may carry unanticipated dangers including electrical shock, poisoning, burns, as well as loss of hearing, eyesight, skin, blood, and other body parts.
- Never work in the lab on physical construction or modification of your prototype alone. Someone else must be in the lab if you are building / testing. This other person can be from another team. You are not permitted to work in the lab on your project except for normal working hours (8-5 weekdays) with permission from the instructor.
- Wear appropriate clothing. Never wear loose fitting clothes when using power equipment as they may become entangles in the machine and cause serious injury. Wear closed toe shoes (no sandals or flip-flops). Wear clothes that you don’t mind getting stained or dirty. Tie-up long hair so it cannot get tangled in equipment.
- Safety in the lab is everyone’s responsibility. You must watch out for your classmates and alert them when they may be doing something unsafely. This is especially true for those of you with experience using equipment. If you see someone doing something unsafe, please try and correct them and if they refuse to change their behavior, report them to the TA or instructor.

Academic Integrity and Honesty: Students are required to comply with the university policy on academic integrity and honesty found in the Code of Student Conduct found at [http://www.ncsu.edu/policies/student_services/student_discipline/POL11.35.1.php](http://www.ncsu.edu/policies/student_services/student_discipline/POL11.35.1.php) & [http://www.ncsu.edu/policies/student_services/student_discipline/POL11.35.1.php](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](http://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.

**Incomplete Grades:** The university policy form incomplete grades can be found at [http://www.fis.ncsu.edu/ncsulegal/41.03-codeof.htm](http://www.fis.ncsu.edu/ncsulegal/41.03-codeof.htm). An IN is not an alternative to an “F”.

**Accommodation for Disabilities:** Reasonable accommodations will be made for students with verifiable disabilities. In order to take advantage of available accommodations, student must register with the Disability Services Office ([http://www.ncsu.edu/dso](http://www.ncsu.edu/dso)) located at 1900 Student Health Center, Campus Box 7509, 515-7653. For more information on NC State's policy on working with students with disabilities, please see the Academic Accommodations for Students with Disabilities Regulation at [http://www.ncsu.edu/policies/academic_affairs/courses_undergrad/REG02.20.1.php](http://www.ncsu.edu/policies/academic_affairs/courses_undergrad/REG02.20.1.php).

**TENTATIVE COURSE TOPICS/ OUTLINE:**

*Part I Aerosol fundamentals: 14 lectures*

1. Introduction (1)
   
   *Overview, definition and properties of gases*

2. Particle size statistics (1)
   
   *Properties of size distribution, number distribution, mass distribution, lognormal distribution*

3. Fluid resistance to aerosol particle motion (3)
   
   *Uniform particle motion, straight-line acceleration, curvilinear particle motion*

4. Diffusion and coagulation of particles (2)
   
   *Brownian motion, diffusion coefficient, diffusive deposition, monodisperse coagulation, polydisperse coagulation*

5. Optical characteristics of aerosols (1)
   
   *Scattering of light, extinction, optical measurement*

6. Electrical behavior of aerosols (1)
   
   *Basic considerations, charging mechanisms, electrical measurement of aerosols*

7. Condensation / evaporation of aerosols (1)
   
   *Thermodynamics, the Kelvin-Helmholtz equation, growth by condensation, evaporation*

8. Filtration of aerosols (1)
   
   *Properties of filters, filtration mechanisms, filter efficiency, pressure drop*

9. Aerosol dispersion modeling (1)
   
   *The Gaussian dispersion model, atmospheric stability classes, plume-rise, maximum downwind ground-level concentration, modeling for point sources, mobile sources, and line sources*

10. Bioaerosols (1)

   *Definition and classification, characteristics, collection and sampling, biological analysis*

11. Health effects (1)
Part II Aerosol measurements: 9 lectures

1. Aerosol mass concentration measurement (2)
   Uncertainty analysis in concentration measurements; airflow control and concentration determination
2. Source sampling (2)
   Principal of Isokinetic sampling; EPA stack samplers
3. Ambient PM sampling (2)
   Sampling efficiency and samplers’ performance; TSP; FRM-PM_{10}; FRM-PM_{2.5}; TEOM-PM monitors
4. Aerosol samplers for workplace (1)
   ACGIH sampling criteria for inhalable, thoracic and respirable fractions; occupational exposure limits; industrial hygiene aerosol samplers
5. Particle size distribution (PSD) measurement (1)
   Aerodynamic separation; electrical sensing zone; laser diffraction; and microscopy
6. Aerosol speciation: chemical and biological compositions (1)
   USEPA PM_{2.5} Chemical Speciation Networks, sampling for analyses of mass, ions, elements, OC/EC

Part III Aerosol controls: 6 lectures

1. Industrial cyclones for PM emission control (1)
   Theory and design considerations
2. PM scrubbers (1)
   Theory and design considerations
3. Electrostatic precipitators (ESP) (1)
   Theory and design considerations
4. Fabric filters – PM bag house design (1)
   Theory and design considerations
5. Case studies (2)

The lab session (14) includes the following hands-on experiments and field trips:

1. Ambient temperature, barometric pressure, relative humidity measurements (Psychometrics) – 1 lab
2. Pipe air flow rate and pressure drop measurements for stack sampling – 1 lab
3. Particle density measurement using AccuPyc 1330 Pycnometer – 1 lab
4. PSD measurement techniques – operation of LS13 320 multi-wavelength PSD analyzer – 1 lab
5. Bioaerosol sampling: operation of the cascade impactors-viable vs. non-viable samplers – 1 lab
6. Ambient PM (PM_{10}, PM_{2.5}, TSP) sampling using gravimetric samplers (FRM) and TEOM-PM monitors – 2 labs
7. PM chemical speciation sampling – operation of Partisol2300 PM_{2.5} speciation samplers – 1 lab
8. AERMOD – air dispersion modeling practices – 2 labs
9. Field trip to EPA’s super ambient air quality monitoring site at Millbrook High school (Raleigh)-managed by NCDENR-Air Quality division – 2 labs
10. Field trip to RTI at RTP, EPA’s subcontractor for EPA’s PM_{2.5} chemical speciation network (CSN) – 2 labs