CE 597/EEE 595: Indoor Air Quality

Spring 2016

Lectures: M, W, F: 12:30-13:20 - HAMP 1113

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Office Hours: M, F: 13:30-15:00 or by appointment.

Prerequisites: Graduate standing with an undergraduate degree in engineering or consent of instructor. Qualified undergraduate students may enroll with consent of instructor.

Course Objectives

By taking this course you will be able to:

1. Mechanistically evaluate pollutant transport dynamics in buildings through application of material-balance models.
2. Apply fundamental principles of aerosol physics to characterize the behavior of indoor aerosols from several nanometers to tens of micrometers in size.
3. Evaluate human exposure to indoor aerosols and analyze the effectiveness of engineering control strategies for indoor air pollution.
4. Read and critically analyze papers in the technical literature on indoor air quality and aerosols.
5. Gain additional insight regarding specific topics related to indoor air quality and aerosols through a rigorous course project.
6. Prepare and review written and oral technical communication.

Textbook - Required

Hinds, W.C. (1999). *Aerosol Technology: Properties, Behavior, and Measurement of Airborne Particles*, 2nd Edition. Wiley.

Additional References

Friedlander, S.K. (2000). *Smoke, Dust, and Haze: Fundamentals of Aerosol Dynamics*, 2nd Edition. Oxford [Online access available through Purdue Libraries].

Kulkarni, P., Baron, P.A., and Willeke, K. (Eds.) (2011). *Aerosol Measurement: Principles, Techniques, and Applications*, 3rd Edition. Wiley [Online access available through Purdue Libraries].

Seinfeld, J.H. and Pandis, S.N. (2006). *Atmospheric Chemistry & Physics: From Air Pollution to Climate Change*, 2nd Edition. Wiley.

Nazaroff, W.W. and Alvarez-Cohen, L. (2001). *Environmental Engineering Science*. Wiley.

Grading
The overall course grade will be weighted as follows:
Homework Assignments: 30%
Take-Home Exam: 25%
Course Project: 40%
Participation: 5%

Attendance
Regular attendance and participation are essential and expected. If you are unable to attend a lecture due to illness, personal or family emergency, or observance of a holiday, please contact me via e-mail.

Readings
Readings specified in the course outline are an integral component to the course and are required. There will be periodic in-class discussions on the assigned journal papers.

Homework Assignments
Homework will be assigned in-class approximately four times over the course of the semester. All assignments are due at the beginning of class for the assigned day. Homework assignments should be completed individually. Students may submit their assignment in the form of an electronic PDF (prepared in Microsoft Word or LaTeX, filename: LastName_FirstName_HW_No.pdf) or a hardcopy (handwriting should be neat, legible, and organized and papers should be stapled in the upper lefthand corner). Students are encouraged to use MATLAB and Microsoft Excel to complete their assignments.

Take-Home Exam
There will be one 24-hour take-home exam in this course, tentatively scheduled for March 9, 2016.

Course Project
Students will work in teams to investigate any one of several topics relevant to the course. Students will be able to choose from a list of topics provided by the instructor, or may propose their own topic (with permission from the instructor). The project will include several deliverables to be submitted throughout the semester. Students are expected to complete a rigorous study of the topic (including a review of existing literature), prepare a final written report of the findings in the form of a 10 to 12 page conference/journal paper, and give an oral presentation to classmates during the last week of the semester. Students are expected to integrate course material to complete the course project and to demonstrate a firm understanding of project materials as reflected in the final written report and oral presentation.

Academic Dishonesty
Purdue prohibits "dishonesty in connection with any University activity. Cheating, plagiarism, or knowingly furnishing false information to the University are examples of dishonesty" [Part 5, Section III-B-2-a, University Regulations]. Furthermore, the University Senate has stipulated that "the commitment of acts of cheating, lying, and deceit in any of their diverse forms (such as the use of substitutes for taking examinations, the use of illegal cribs, plagiarism, and copying during examinations) is dishonest and must not be tolerated. Moreover, knowingly to aid and abet, directly

or indirectly, other parties in committing dishonest acts is in itself dishonest" [University Senate Document 72-18, December 15, 1972].

Grief Absence Policy for Students
Purdue University recognizes that a time of bereavement is very difficult for a student. The University therefore provides the following rights to students facing the loss of a family member through the Grief Absence Policy for Students (GAPS). GAPS Policy: Students will be excused for funeral leave and given the opportunity to earn equivalent credit and to demonstrate evidence of meeting the learning outcomes for missing assignments or assessments in the event of the death of a member of the student's family.

Students with Disabilities
If you have a disability that requires special academic accommodation, please make an appointment to speak with me during the first week of the semester in order to discuss any adjustments. It is the student's responsibility to notify the Disability Resource Center `http://www.purdue.edu/drc` of an impairment/condition that may require accommodations and/or classroom modifications.

Emergencies
In the event of a major campus emergency, course requirements, deadlines, and grading percentages are subject to changes that may be necessitated by a revised semester calendar or other circumstances beyond the instructor's control. Relevant changes to this course will be posted on Blackboard or can be obtained by contacting me via e-mail.

Nondiscrimination
Purdue University is committed to maintaining a community which recognizes and values the inherent worth and dignity of every person; fosters tolerance, sensitivity, understanding, and mutual respect among its members; and encourages each individual to strive to reach his or her own potential. In pursuit of its goal of academic excellence, the University seeks to develop and nurture diversity. The University believes that diversity among its many members strengthens the institution, stimulates creativity, promotes the exchange of ideas, and enriches campus life.

Purdue University prohibits discrimination against any member of the University community on the basis of race, religion, color, sex, age, national origin or ancestry, genetic information, marital status, parental status, sexual orientation, gender identity and expression, disability, or status as a veteran. The University will conduct its programs, services and activities consistent with applicable federal, state and local laws, regulations and orders and in conformance with the procedures and limitations as set forth in Executive Memorandum No. D-1, which provides specific contractual rights and remedies. Any student who believes they have been discriminated against may visit `http://www.purdue.edu/report-hate` to submit a complaint to the Office of Institutional Equity. Information may be reported anonymously.

Note: This syllabus is subject to change. Current version: February 22, 2016.

Tentative Course Outline [*Updated: February 22, 2016*]

Lectures	Days	Topics Covered	Reading*	Assignments
1-3	Jan.11,13,15	Course introduction & project overview, indoor aerosols & gases, the material-balance principle	Corsi (2015)	
4-5	Jan.20,22	Material-balance models for buildings	Nazaroff (2013a)	
6-8	Jan.25,27,29	Material-balance models for buildings	Nazaroff (2013b)	Jan.27: HW1 assigned
9-11	Feb.1,3,5	Aerosol physics: particle size distributions	S&P Ch.8	
12-14	Feb.8,10,12	Aerosol physics: properties of gases, rectilinear particle motion	Hinds Ch.2,3	Feb.8: HW1 due
15-17	Feb.15,17,19	Aerosol physics: rectilinear particle motion	Hinds Ch.5, S&P Ch.9	Feb.15: project justification due & HW2 assigned
18-20	Feb.22,24,26	Aerosol physics: Inertial impaction, brownian motion & diffusion	Hinds Ch.7	
21-23	Feb.29, Mar.2,4	Aerosol physics: adhesion, resuspension, nucleation, condensation	Qian & Ferro (2008)	Feb.29: HW2 due, HW3 assigned
24-26	Mar.7,9,11	Aerosol physics: coagulation, indoor aerosol modeling		Mar.7: HW3 due, Mar.9: Take-home exam (48 h)
Spring Vacation: Mar.14-18				
27-29	Mar.21,23,25	Filtration & air cleaning	Stephens & Siegel (2012)	Mar.21: analysis plan due
30-32	Mar.28,30, Apr.1	Inhalation exposure to aerosols	Bhangar et al. (2011), Koivisto et al. (2012)	Mar.28: project lit. review due
33-35	Apr.4,6,8	Aerosol measurement techniques	K,B&W Ch.17	
36-38	Apr.11,13,15	Bioaerosols & occupational workplace aerosols	Ege et al. (2011), Yamamoto et al. (2015)	
39-41	Apr.18,20,22	Indoor combustion, biomass stoves, low-cost particle sensors	Zhang & Smith (2007)	Apr.18: draft of project report due, peer-review assigned. Apr.22: peer-review due
42-44	Apr.25,27,29	Course project presentations		Apr.29: final project report due

*Copies of journal papers and chapters from Seinfeld & Pandis (S&P) and Kulkarni, Baron & Willeke (K,B&W) will be posted to Blackboard.

Journal Paper Readings

Corsi, R.L. (2015). Connect or Stagnate: the Future of Indoor Air Sciences. *Indoor Air*, 25:231-234 (Editorial).

Nazaroff, W.W. (2013a). Four Principles for Achieving Good Indoor Air Quality. *Indoor Air*, 23:353-356 (Editorial).

Nazaroff, W.W. (2013b). Exploring the Consequences of Climate Change for Indoor Air Quality. *Environmental Research Letters*, 8:015022.

Qian, J. and Ferro, A.R. (2008). Resuspension of Dust Particles in a Chamber and Associated Environmental Factors. *Aerosol Science & Technology*, 42:566-578.

Stephens, B. and Siegel, J.A. (2012). Comparison of Test Methods for Determining the Particle Removal Efficiency of Filters in Residential and Light-Commercial Central HVAC Systems. *Aerosol Science & Technology*, 46:504-513.

Bhangar, S., Mullen, N.A., Hering, S.V., Kreisberg, N.M., and Nazaroff, W.W. (2011). Ultrafine Particle Concentrations and Exposures in Seven Residences in Northern California. *Indoor Air*, 21:132-144.

Koivisto, A.J., Aromaa, M., Mäkelä, J.M., Pasanen, P., Hussein, T., and Hämeri, K. (2012). Concept To Estimate Regional Inhalation Dose of Industrially Synthesized Nanoparticles. *ACS Nano*, 6(2):1195-1203.

Ege, M.J., Mayer, M., Normand, A.C., Genuneit, J., Cookson, W.O., Braun-Fahrländer, C., Heederik, D., Piarroux, R., von Mutius, E., for the GABRIELA Transregio 22 Study Group. (2011). Exposure to Environmental Microorganisms and Childhood Asthma. *The New England Journal of Medicine*, 364(8):701-709.

Yamamoto, N., Hospodsky, D., Dannemiller, K.C., Nazaroff, W.W., and Peccia, J. (2015). Indoor Emissions as a Primary Source of Airborne Allergenic Fungal Particles in Classrooms. *Environmental Science & Technology*, 49:5098-5106.

Zhang, J. and Smith, K.R. (2007). Household Air Pollution from Coal and Biomass Fuels in China: Measurements, Health Impacts, and Interventions. *Environmental Health Perspectives*, 115(6):848-855.