UNIVERSITY OF OREGON

Syllabus: Passive Cooling Seminar
ENVS / ARCH 493M / 593M
4 credits **Spring 2019**

Course description

Air conditioning in America has risen from a luxury to a perceived necessity in the past fifty years. Non-residential buildings that once relied on awnings, shades, and operable windows for cooling have been retrofitted to the extent that three-quarters of those built before 1964 now have mechanical cooling; in 2013, only 9% of new homes were built *without* air conditioning. As a result, space cooling in the U.S. now consumes an estimated 6 quadrillion Btu of energy each year, at a cost of $62 billion, and emits over 340 million metric tons of CO_2. At the same time, the pressure to design buildings with smaller carbon footprints is rising, promoting new interest in passive cooling designs. Diverse strategies, including shading, cross ventilation, stack ventilation, wind catchers, passive cool towers, night-flush cooling of thermal mass, green roofs, earth tubes, and courtyards have now been well-studied in numerous climates. In this course, students will gain the tools and experiences to estimate the passive cooling performance of each strategy under specific climatic conditions through field, laboratory, and computational exercises. This course has a service learning component: small-group term projects will develop passive cooling strategies for projects of interest to a community partner, including existing or planned buildings, incorporating spatial, experiential, and quantitative components. One field trip to an off-site location may be required.

Prerequisite: ARCH 491 / 591: Environmental Control Systems I or equivalent, or permission of the instructor.

Contact information

Instructor: Alexandra Rempel, Assistant Professor, Environmental Studies Program, arempel@uoregon.edu
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Lab: Volcanology 117

Materials

1. Readings, available on Canvas
2. Field instruments, available in class and for check-out; students are responsible for care and return
3. Sketchbook with graph paper such as the Leuchtterm1917 available at the UO bookstore

Website

Assignments, announcements, and grades will be posted on Canvas.

Field work

One day of each week will be devoted to laboratory exercises, several of which involve outdoor work. Please prepare for rain and cool temperatures.

Term projects

Term projects will involve the thermal analysis of an existing or planned space and an integrated proposal for its redesign, involving shading, natural ventilation, evaporative cooling, thermal mass sizing, and radiative cooling, as well as thermal comfort considerations. Projects will be presented during the course's scheduled exam time in Week 11.

Passive icebox competition

The final laboratory exercise of the term will be a competition to build the Iciest Box, as evaluated by interior surface and air temperatures over a 48h period, outdoors; peer evaluations and external judging will be included.

Content

Week	Topics	Reading
1a. Call to Action	Cooling energy use; history of a/c and refrigeration adoption; intro to passive cooling; review of unit conversions; review of graph interpretation	
1b. Lab: Invisible Life of Buildings	Quiz: Units conversions, graph interpretation, reading Exercise: Measure and diagram air temperatures, humidity, air velocity, surface temps in and around campus non-a/c buildings (Deady, Gerlinger, Campbell, Volcanology, Hendricks)	*The Moral History of Air-Conditioning* (Cashman); *How Bad is Your A/C for the Planet?* (Schlossberg)
2a. Heat and Humidity	Solar radiation, climates, cooling season severity and patterns, CDD, TMY3 and other weather files, Climate Consultant, DView, internal gains; vernacular responses	*Understanding Weather & Climate* (Aguado & Burt): Ch. 3: Energy and Temperature *Sun, Wind & Light* (Brown & DeKay): Estimating Heat Gains
2b. Lab: Too. Darn. Hot.	Quiz: Climate formation, CDD calcs, internal heat gains Exercise: Using weather files and field measurements, estimate and graph hourly and daily heat gains from people, lighting, equipment, and solar radiation in a designated space.	
	Saturday: likely date for field trip to term project site(s)	
3a. Thermal Comfort	Operative temperatures; Clo; Met; air velocity; standard and adaptive comfort zones; optional alternative exercise for ARCH4/594 veterans	*ASHRAE 55: Thermal Environmental Conditions for Human Occupancy*
3b. Lab: Thermal Delights	Quiz: Interpreting and applying thermal comfort graphs Exercise: Discover, discuss, measure, and draw thermally delightful spaces from a cooling perspective.	*Thermal Delight* (Heschong), Preface and Ch. 2: Delight
4a. Shading	Solar geometry; sunpaths; quantifying hourly heat gain from solar radiation; optical properties of glass; exterior vs. interior shading positions; visible transmittance and reflectance; shading needs vs. sun angles; solar vs. thermal year; operability and schedules; precedents	*Heating, Cooling, Lighting* (Lechner): Solar Geometry *Design for the Solar Year* (Lechner) *Sun, Wind, & Light* (Brown & DeKay): Shading
4b. Lab: Shading Devices	Quiz: Solar geometry, glass properties, shading for the thermal year Exercise: Construct a tennis-ball heliodon from a kit of parts; diagram and prepare to model an exterior *operable* shading device	
5a. Exam 1	Challenging multiple choice involving hand calculations and graph use; closed-notes; no phones; individual	
5b. Lab: Shading Device Testing	Pinup and peer review of operable shading devices	

6a. Natural Ventilation	Natural and forced convection; wind patterns; cooling by bulk airflow; ASHRAE HOF graphs; single-sided, cross, and stack ventilation configurations and sizing; sample calculations of hourly heat removal to inform scheduling; precedents: tropical dwellings	*Sun, Wind, & Light* (Brown & DeKay): Natural Ventilation *Green Studio Handbook* (Kwok & Grondzik): Natural Ventilation
6b. Lab: Natural Ventilation + Comfort	<u>Quiz:</u> Convection calculations and aperture sizing for natural ventilation <u>Exercise:</u> Using WRPlotView and SAMSON wind data, design a natural ventilation scheme and hourly schedule for a site of interest and estimate hourly adaptive comfort; alternate hour, configure a space on campus for maximum air velocity	
7a. Thermal Mass	Thermal properties of materials: conductivity, density, heat capacity, emissivity; example hourly calculations emphasizing time-dependence of cooling; precedents: courtyards, desert dwellings	*Green Studio Handbook* (Kwok & Grondzik): Night Ventilation of Mass
7b. Heavy, but not Metal	<u>Quiz:</u> Thermal properties of materials <u>Exercise:</u> Prediction of thermal mass ability to lower peak temperatures in a heated chamber over multiple cycles of natural ventilation; demonstration of thermal mass + natural ventilation simulation in EnergyPlus	
8a. Evaporative Cooling	Water as a polar molecule; latent heat of vaporization; psychrometry; wet-bulb depression; direct, indirect, and intrinsic evaporative cooling; porosity and hygroscopicity	*Green Studio Handbook* (Kwok & Grondzik): Cool Towers *Sun, Wind, & Light* (Brown & DeKay): Evaporative Cooling *Adobe and Latent Heat* (Morony) *Courtyards* (Reynolds)
8b. Lab: Letting off Steam	<u>Quiz:</u> Evaporative cooling <u>Exercise:</u> Measurement of surface temperatures over time, under heat lamps, of diverse moist materials + controls to show relationships among heat delivery, evaporation, and cooling	
9a. Radiative Cooling	Radiative heat transfer; view angle calculations; night sky temperatures and emissivities; precedents: courtyards, flat roofs, roof ponds; exam review	
9b. Exam 2	Challenging multiple choice involving hand calculations and graph use; closed-notes; no phones; individual	
10a. Lab: Building the Iciest Box	<u>Exercise:</u> Strategy and construction session; site introduction; competition guidelines; instrumentation	
10b. Lab: Ice Box Judging	<u>Exercise:</u> Peer review; judging; awards	
11. Exam Week	Term project presentations	

Learning outcomes (All students)

By the end of the course, students will be able to:

1. **Gather climate, microclimate, and indoor data** for a building using weather files and field instruments, and use this information to quantify the extent, severity, and character of its cooling needs.
2. **Explain the relative effectiveness** of passive cooling strategies in a given situation with respect to underlying heat transfer, climate, and microclimate phenomena in words and with graphed data.
3. **Select effective passive cooling strategies**, and assign priorities to them, based on climatic and internal heat gain information.
4. **Quantify** seasonal cooling benefits and abilities to create comfortable conditions by each strategy individually, subject to identified assumptions.
5. **Propose a plausible passive cooling system** for a project of immediate value, including performance estimates, in a coherent oral presentation supported by compelling graphs, drawings, and diagrams.

Additional learning outcomes (Graduate students)

By the end of the course, graduate students will also be able to:

1. **Propose a field protocol** for the investigation of an existing building to prepare for design of passive cooling measures.
2. **Evaluate the integrated performance of multiple passive cooling systems** operating simultaneously.

Expected student workload

- Undergraduate: A typical week will include 30 pages of reading and studying of central concepts (3h), a laboratory report (3h), two class meetings of 2h each (4h), and work on a project or presentation (2h), for an average weekly workload of 12h. Depending on student allocation of project work, weekly workloads may vary.
- Graduate: A typical week will include 30 pages of reading and studying of central concepts (3h), a more extensive laboratory report (4h), two class meetings of 2h each (4h), and work on a more extensive project or presentation (5h), for an average weekly workload of 16h. Depending on student allocation of project work, weekly workloads may vary. Graduate assignments will be longer and project requirements will be greater than those for undergraduates, in compliance with University guidelines.

Evaluation

Accomplishment will be evaluated on the basis of class participation, a competition, and a term project, as follows. All grades will be recorded in Canvas. Grade appeals should be made in writing to the instructor.

Class participation:	10%
Weekly collaborative quizzes:	10%
Weekly laboratory reports:	30%
Exams (2):	30%
Final project & presentation:	20%

Letter grades reflect the following:

A: Demonstrates an excellent, thorough, nuanced understanding or accomplishment. Discussion comments and questions are thoughtful and constructive, reflecting careful study of the reading assignments. Group work is active, constructive, collaborative, and shows initiative and resourcefulness. Written work is comprehensive, clear, concise, thoughtful, accurate, and free of grammatical and spelling errors; computational work is complete and accurate; visual work is complete, well-organized, and accessible.

B: Demonstrates a good understanding or accomplishment. Discussion comments and questions are constructive, reflecting good attention to the reading assignments and solid comprehension. Group work is active, constructive, and collaborative, but shows limited initiative and resourcefulness. Written work contains good but not exemplary content, is difficult to follow in places, and/or contains a small number of grammatical and spelling errors; computational work is generally good with minor errors; visual work is complete and of good quality but may be mildly disorganized and/or difficult to interpret in places.

C: Demonstrates an adequate understanding or accomplishment. Discussion contributions are few in number, contain limited constructive content, and/or reflect inattention to reading assignments. Group work is attempted, but shows low energy or effort to collaborate with group members, and/or creates unusual levels of conflict. Written work is incomplete and/or superficial, difficult to follow, and/or contains numerous grammatical and spelling errors; computational work is conceptually adequate but contains significant errors; visual work is mostly complete but with shallow content and/or careless presentation.

D: Demonstrates inferior understanding or accomplishment. Discussion contributions are rare, with minimal content. Behavior in class disrupts others' learning. Group work is inferior, incomplete, or disruptive. Written work contains just enough content to pass, is thoroughly difficult to follow, and/or contains egregious grammatical and spelling errors; computational work is incomplete and contains mis-applied concepts and/or significant errors; visual work is incomplete as well as limited in content and/or presented carelessly.

F: Demonstrates unsatisfactory understanding or accomplishment. Preparation for and/or participation in class is absent. Assignments are missing.

Students taking this course Pass / No Credit, must earn a C- to pass as an undergraduate or B- to pass as a graduate student. Grades of Incomplete will only be given for documented, excusable (e.g. medical) situations.

Equity and inclusion

- Equity: Many students in this course have overcome, or are currently overcoming, significant barriers to their education. To ensure that this course is fully accessible to all students, the instructor will respond promptly to requests for additional resources or other accommodation.
- Inclusion: The diversity that students bring to this course is a resource, benefit, and strength. Our collective goal must therefore be to create a classroom environment in which everyone feels welcome and encouraged to share their ideas and perspectives, and to engage in constructive debate, without fear of disparaging or hostile remarks. Mistakes may be made, but the instructor will prevent any such pattern from developing in the class. In addition, any student who feels marginalized or dismissed is urged to speak with her directly so that an effective solution can be developed as soon as possible.

Classroom participation

Students are expected to attend all classes, having carefully read and studied the assignments, and to participate fully discussions and group work, without distracting themselves or others. "Full participation" means devoting one's *full* attention to class: listening attentively, taking notes, asking questions, making thoughtful comments, and working with classmates to complete in-class work. *Texting, emailing, tweeting, snapchatting, instagramming, online shopping, etc. are strictly prohibited*; violations will constitute unsatisfactory class participation.

Illness

Students who are sneezing, coughing, or otherwise clearly ill should stay home to speed recovery and avoid infecting others. The first two absences for illness will be excused with notification by the morning of class; a doctor's note will be required to excuse further absences. Other absences (for example, involving academic or university athletic trips) may be excused with documentation.

Late and missing work policy

Studying the reading carefully for discussion, completing laboratory reports on time, and arriving at class prepared are central to the learning process for this course. Quizzes may not be made up, but will be excused with valid documentation (e.g. written notification of illness before class; academic or university trips). Late laboratory reports will be penalized 1% per hour late.

Important: Missed exam policy. If a student misses an exam for a documented emergency (severe illness, funeral, etc.), the other exam will count double. For planned university business, official documentation must be provided at least one week before the exam, and the student must arrange to take the exam in advance. If a student misses both exams, a cumulative make-up exam will be given on the last day of Exam Week. Unfortunately, personal events (e.g. weddings, graduations, work trips), even if planned, cannot be excused.

Academic integrity

Mutualistic collaboration, which supports the learning of all students involved, is welcome: students are encouraged to discuss reading, field work, and projects outside of class. Full collaboration is, in fact, expected in group work and projects. Parasitic collaboration, however, in which one person (the parasite) represents the work of another (the host) as his/her own, or allows the host to complete the majority of the work while the parasite contributes little, grievously damages the learning process of the parasite and risks harming the host as well. Any activity that *diminishes* the learning of *any* student involved is strictly prohibited. Activities that violate personal and institutional academic integrity include:

1. Fraud: The alteration of documents or data with the intent to deceive groupmates or the instructor.
2. Copying: Creating a submission for a graded exercise by reproducing another student's work.
3. Fabrication: Falsification or invention of information.
4. Plagiarism: Representing the work of another as one's own by omitting acknowledgement or reference.
5. Sabotage: Destruction of another's work.

If academic dishonesty is suspected, the instructor will meet with the student(s) involved to review the evidence and allow student(s) the opportunity to explain. If the instructor concludes that a violation occurred, penalties will be assessed as follows:

1. First or minor violation: Written warning and requirement to re-do the assignment in question.
2. Second or significant violation: A grade of "F" or zero on the assignment in question and requirement to complete a substantial research paper on academic integrity.
3. Third or major violation: Failing grade for the course and referral to the Dean of Students, including the instructor's written summary of events and copies of supporting documentation.

Please refer to the University of Oregon Academic Integrity website (integrity.uoregon.edu) for further details.

Archiving

At the conclusion of the course, students will be required to submit their work digitally for archiving.

Bibliography

1. Aguado, E., Burt, J.E. and James, E.B., 2014. *Understanding weather and climate*. 7th Edition, Pearson.
2. ASHRAE, ASHRAE/ANSI Standard 55-2017. *Thermal environmental conditions for human occupancy*. American Society of Heating, Refrigerating, and Air-Conditioning Engineers: Atlanta, GA.
3. Brown, G.Z. and DeKay, M. 2000. *Sun, wind, & light: Architectural design strategies*. 2nd Ed. John Wiley & Sons.
4. Grondzik, W.T. and Kwok, A.G., 2014. *Mechanical and electrical equipment for buildings*. 12th Ed. John Wiley & Sons.
5. Heschong, L., 1979. *Thermal delight in architecture*. MIT press.
6. Kwok, A. and Grondzik, W. 2015. *The green studio handbook: Environmental strategies for schematic design.* Routledge.
7. Lechner, N., 2014. *Heating, cooling, lighting: Sustainable design methods for architects*. John Wiley & sons.
8. Morony, J.J., 2005. *Adobe and latent heat: A critical connection*. In *Second Annual Conference, Adobe Association of the Southwest, Northern New Mexico Community College, El Rito, New Mexico*.
9. Rempel, A.R. and Rempel, A.W., 2016. *Intrinsic evaporative cooling by hygroscopic earth materials*. Geosciences special issue: Geoscience of the Built Environment 6(3), 38pp.
10. Reynolds, J., 2002. *Courtyards: aesthetic, social, and thermal delight*. John Wiley & Sons.