Architecture 575a: Systems: The Thermal Environment
Prerequisite: None
Time: Spring Semester, Tuesdays from 1:30 – 4:20 PM
Location: "WAH B1" (this is the large room in the basement of Watt Hall)
Professor: Kyle Konis, Ph.D, AIA

- Office: WAH 312a
- Email: kkonis@usc.edu
- See course website on Blackboard

Credit hours: 3 Units
Grading: ABCDEF with + / - where applicable

Course Overview
Lectures and exercises applying the scientific principles governing the thermal environment and human physiology to contemporary issues of environmentally responsive building energy concepts and systems.

Introduction and Purposes
This course applies the fundamental scientific principles governing the thermal environment and human physiology to contemporary issues of environmentally responsive building design and resource efficiency. It exposes students to the technologies and strategies to control the indoor environment as well as the basic analyses needed to inform design decision-making and examine project performance. The course will cover the laws of thermodynamics, heat transfer and solar geometry in the context of building design and operation, and occupant comfort. The course will focus on the building as an environmental filter, where environmentally responsive design strategies are used to minimize the size and operation of mechanical HVAC and lighting systems. Following these steps, energy efficient mechanical systems, controls and renewable energy technologies will be covered as a supplement to these strategies.

Learning Objectives / Goals

- Understanding of the fundamental scientific principles governing the thermal environment.
- Awareness of environmentally responsive design strategies and building systems for controlling the indoor environment to provide comfort and delight while minimizing resource consumption.
- Ability to conduct basic analyses using hand calculations and software simulation tools in a design context.

Required Text
Weekly readings will be assigned from the required text and from supplemental handouts and online resources. The required textbook for this course is:

- Heating, Cooling, Lighting: Sustainable Design Methods for Architects, 3rd Edition. Norbert Lechner. Wiley, 2009. ISBN-13: 978-0470048092. https://library.usc.edu/uhtbin/cgisirsi/x/0/0/5?searchdata1=2815635{CKEY}

Reference Texts (not required)
These texts will be useful for you to refer to during the semester for additional detail on specific topics.

- Adaptive Thermal Comfort: Principles and Practice. Fergus Nichol, Michael Humphreys, and Susan Roaf. Routledge, 2012. ISBN-13: 978-0415691598.
- Environmental Design: An Introduction for Architects and Engineers. Randall Thomas. Taylor & Francis, 2006. ISBN-13: 978-0415363341.
- Thermal Delight in Architecture. Lisa Heschong. MIT Press, 1979. ISBN-13: 978-0262580397.
- The Passive Solar Energy Book. Robert Mazria. Rodale, 1979. ISBN-13: 978-0878572373.
- The Green Studio Handbook. Allison Kwok and Walter Grondzik. McGraw Hill, 2011. ISBN-13: 978-0080890524.
- Sun, Wind & Light: Architectural Design Strategies, 2nd Edition. GZ Brown and Mark DeKay. Wiley, 2000. ISBN-13: 978-0471348771.
- Sundials: Their Theory and Construction. Albert Waugh. Dover, 1973. ISBN-13: 978-0486229478.
- Sundials: History, Theory, and Practice. René R. J. Rohr. Dover, 1996. ISBN-13: 978-0486291390.
- Mechanical and Electrical Equipment for Buildings. Wiley, 2009. ISBN-13: 978-0470195659.
- Low Energy Cooling for Sustainable Buildings. Ursula Eicker. Wiley, 2009. ISBN: 978-0-470-69744-3
- Thermally Active Surfaces in Architecture. Kiel Moe. Princeton Architectural Press, 2010. ISBN-13: 978-1568988801.

Required Software (free to download, but student must have PC with Rhino software)

1. Grasshopper
   http://www.grasshopper3d.com/

2. Ladybug and Honeybee plugins to Grasshopper
   Created by Mostapha Sadeghipour Roudsari
   http://www.grasshopper3d.com/group/ladybug

3. Follow these instructions to download and install Radiance, Daysim, and OpenStudio
   https://github.com/mostaphaRoudsari/ladybug/blob/master/resources/Installation_Instructions.md

Assignments

Assignments will consist of energy, resource, load and ventilation calculations, site/climate analysis using software tools, site/climate analysis using observation and hand-held measurement devices, case study research on precedents for environmentally responsive building design, software simulation and analysis of building energy and comfort, visualization of quantitative performance data, and evaluation of buildings using hand-held devices and subjective evaluations.

Grading

The grading for the course will be based on the following percentages:

3 quizzes administered randomly throughout the term	10%
Bi-weekly assignments (6)	60%
Final project	30%

Course Calendar
Note, readings should be completed by the date shown on the calendar. All chapter references refer to the required text.

Wk	Day	Topic	Assigned	Due	Readings
1	Class	Course introduction, imperatives, goals and strategies.			Ch.1
1	Lab	Install Ladybug / Honeybee etc.			
2	Class	Climate analysis for bioclimatic design: historic precedent, climatic parameters.	Asn#1		Ch.5
2	Lab	Physical, subjective, and software-based tools/techniques for examining climate.			
3	Class	Heat transfer with the body, principles of thermal comfort, and psychrometrics.	Asn#2	Asn#1	Ch.4
3	Lab	Review of psychrometrics and the psychrometric chart.			
4	Class	The Sun: solar geometry and site shading. Investigation using handheld devices.			Ch.6
4	Lab	Site solar orientation / overshadowing analysis using LB/HB.			
5	Class	Solar radiation, physical principles, units of analysis, design considerations.	Asn#3	Asn#2	Ch.7
5	Lab	Site solar radiation analysis using LB/HB.			
6	Class	Heat flow through materials and assemblies. Basic physical principles.			Ch.3
6	Lab	Assembly 2d heat flux modeling using THERM.			
7	Class	High-performance building envelopes. Heat flow through the thermal envelope.	Asn#4	Asn#3	Ch.15
7	Lab	Introduction to whole building energy modeling.			
8	Class	Principles of thermal mass and application in buildings.			
8	Lab	T.B.D.			
9	Class	Introduction to low and Zero Net Energy (ZNE) buildings		Asn#4	
9	Lab	T.B.D.			
10	Class	Spring Recess			
10	Lab	Spring Recess			

11	Class	High performance glazing and façade systems.	Asn#5		Ch.13
11	Lab	Annual facade performance analysis using software simulation.			
12	Class	Principles and strategies of solar control for facade shading system design.			
12	Lab	Facade shading system design using LB/HB.			
13	Class	Natural ventilation and passive cooling: principles, systems, and ventilation design.	Asn#6	Asn#5	Ch.10
13	Lab	Passive cooling building case studies.			
14	Class	Integration of energy-efficient HVAC systems in high performance buildings.			Ch.16
14	Lab	Integration of radiant heating and cooling in design.			
15	Class	Integration of on-site renewable energy systems.		Asn#6	Ch.8
15	Lab	Energy analysis using PV Watts tool.			
16	Class	Present Final Class Projects			
16	Lab	Present Final Class Projects			

Assignment #1: Case Study of Historic Precedent for Bioclimatic Design.
Students will produce scale architectural plan and section drawings of their grandparents' house, documenting the environmental design strategies and energy systems implemented to enable a comfortable indoor environment. Students will additionally present a detailed verbal (non-quantitative) description of the climate where it is located and consideration of how patterns of domestic use and living were influenced by climate. Finally, a small site-plan diagram will be shown to show the relationship of the dwelling to its surrounding context.

Assignment #2: Global Climate Analysis for Bioclimatic Design.
Each student will be randomly assigned a climate from the global collection of Energy Plus Weather (EPW) files and perform an annual climatic analysis of their assigned location. Students will present a brief description of the region, identify and document the critical aspects of climate that should be considered for design, and propose a schematic design for a small residential project.

Assignment #3: Site Solar Analysis.
Students will model specific urban sites and produce a report examining factors of sun position and movement, solar radiation, overshadowing and sky-view factor in relation to local climate and the programmatic needs of the project and project site. Students will then present a list of schematic design strategies for appropriate solar control and daylight

access for a project encompassing both built and landscape elements. Students will respond to a series of questions regarding the appropriate development of all major building facades to appropriately control and utilize incident solar radiation.

Assignment #4: Thermal Energy Modelling and Analysis.
Students will demonstrate understanding of building envelope (window, opaque walls, floor, roof) heat transfer through basic hand calculations. Students will conduct 2D R-value calculations for several common material assemblies. Students will then complete a 2D heat flow analysis of facade curtain wall assembly (thermal bridge) using the software tool THERM. Based on simulation outcomes, students will provide suggestions for improving the thermal resistance of the assembly. Students will then model the building envelope of their schematic design from Assignment #2 and perform an annual thermal analysis.

Assignment #5: Facade Shading System Design and Radiation Analysis.
Using the solar geometry components in LB for Grasshopper, students will design an exterior solar shading system for a facade or roof aperture. Students will use the solar geometry and radiation analysis components to provide a rational for how the system is developed to filter energy (light, heat) appropriately for its site, orientation and program.

Assignment #6: Exploration of Natural Ventilation and Thermal Mass.
Models will be elaborated to explore natural ventilation strategies thermal mass. Students will examine the applicability of active thermal mass for improving annual comfort and energy performance for their design and specific climate.

Final Project: Case Study in Thermal Experience as a Design Driver
Students will explore historic architectural examples of buildings and landscapes designed to deliver explicit thermal experiences. Based on research, students will propose a contemporary design concept serving the residents of Los Angeles.

Midterm and Final
Midterm grade will be based on weekly assignments completed by week 8. The class does not have a final exam. Instead, students will complete a final class project.

Extra Credit
There is no extra credit awarded for this course.

Late Work
No late work will be accepted with the exception of extreme circumstances (documented medical or personal emergency). Consequently, if you choose to miss a class, it is your responsibility to determine what assignments you have missed and turn them in before they are due. There will be no makeup quizzes.

Work Requirements
This will be a challenging course that will require consistent engagement throughout the term and timely completion of assignments. This class is designed to require 2 hours of

focused out-of-class work for each hour of in class instruction. Because the class meets for 3 hours each week, you are expected to contribute 6 hours of out-of-class time each week to readings and assignments.

Statement for Students with Disabilities
Any student requesting academic accommodations based on a disability is required to register with Disability Services and Programs (DSP) each semester. A letter of verification for approved accommodations can be obtained from DSP. Please be sure the letter is delivered to me (or to TA) as early in the semester as possible. DSP is located in STU 301 and is open 8:30 a.m.–5:00 p.m., Monday through Friday. The phone number for DSP is (213) 740-0776.

2010 Imperative Statement
The USC School of Architecture faculty has voted to accept the 2010 Imperative; to improvement of ecological literacy among the students and faculty and to achieve a carbon-neutral design school campus by 2010. To that end, this class will address issues of carbon neutrality and supports the following goal for all designs produced in the USC School of Architecture:

“The design should engage the environment in a way that dramatically reduces or eliminates the need for fossil fuel.”

This does not mean that no other issues are to be addressed. Precisely to the contrary, all design issues are fair game, but in the background, all will be considered within the generalized goal of reducing or eliminating the need for fossil fuel.

Religious Holidays
The University recognizes the diversity of our community and the potential for conflicts involving academic activities and personal religious observation. The university provides a guide to such observances for reference and suggests that any concerns about lack of attendance or inability to participate fully in the course activity be fully aired at the start of the term. As a general principle students should be excused from class for these events if properly documented and if provisions can be made to accommodate the absence and make up the lost work. Constraints on participation that conflict with adequate participation in the course and cannot be resolved to the satisfaction of the faculty and the student need to be identified prior to the drop add date for registration. After the drop add date the University and the School of Architecture shall be the sole arbiter of what constitutes appropriate attendance and participation in a given course. Any student concerned about missing class for a recognized religious holiday should bring this matter up with your instructor at the start of the semester. A list of recognized religious holidays may be found at: http://www.usc.edu/programs/religious_life/calendar/.

Statement on Academic Conduct and Support Systems

Academic Conduct

Plagiarism – presenting someone else's ideas as your own, either verbatim or recast in your own words – is a serious academic offense with serious consequences. Please familiarize yourself with the discussion of plagiarism in *SCampus* in Section 11, *Behavior Violating University Standards* https://scampus.usc.edu/1100-behavior-violating-university-standards-and-appropriate-sanctions. Other forms of academic dishonesty are equally unacceptable. See additional information in *SCampus* and university policies on scientific misconduct, http://policy.usc.edu/scientific-misconduct.

Discrimination, sexual assault, and harassment are not tolerated by the university. You are encouraged to report any incidents to the *Office of Equity and Diversity* http://equity.usc.edu or to the *Department of Public Safety* http://adminopsnet.usc.edu/department/department-public-safety. This is important for the safety of the whole USC community. Another member of the university community – such as a friend, classmate, advisor, or faculty member – can help initiate the report, or can initiate the report on behalf of another person. *The Center for Women and Men* http://www.usc.edu/student-affairs/cwm/ provides 24/7 confidential support, and the sexual assault resource center webpage http://sarc.usc.edu describes reporting options and other resources.

Support Systems

A number of USC's schools provide support for students who need help with scholarly writing. Check with your advisor or program staff to find out more. Students whose primary language is not English should check with the *American Language Institute* http://dornsife.usc.edu/ali, which sponsors courses and workshops specifically for international graduate students. *The Office of Disability Services and Programs* http://sait.usc.edu/academicsupport/centerprograms/dsp/home_index.html provides certification for students with disabilities and helps arrange the relevant accommodations. If an officially declared emergency makes travel to campus infeasible, *USC Emergency Information* *http://emergency.usc.edu* will provide safety and other updates, including ways in which instruction will be continued by means of blackboard, teleconferencing, and other technology.