4.401 Architectural Building Systems – Course Syllabus

Term:	Fall 2014
Department:	Architecture
Instructor:	Christoph Reinhart (creinhart@mit.edu)
Teaching Assistant:	Jeff Geisinger (jgeis01@mit.edu)
Time & Location:	Lecture - Mondays 9.30 - 11:00, Room 1-150 Lecture - Mondays 9:30 - 11:00, Room 1-150 Lab - Fridays, 10:00 - 12.00, Room 9-250

Course Description

The primary focus of this course is the study of the thermal, luminous and acoustic behavior of buildings. The course examines the basic scientific principles underlying these phenomena and introduces students to a range of technologies and analysis techniques for designing comfortable indoor environments. Students will be challenged to apply these techniques and explore the role energy and light can play in shaping architecture.

Following a review of how to analyze a site's climate and local energy mix, the first part of the course is dedicated to the principles of heat storage and heat flow in and around buildings. Basic manual and computer-based methods to predict the energy use of buildings will also be discussed. In order to introduce students to the effective use of computer simulations during design, a *Building Optimization Game* that mimics a LEED design charrette will be organized during class on October 22. During the game, students will compete in groups who develops the building with the lowest energy use within a given cost budget. The second part of the course will introduce students to the art and science of lighting buildings along with rules of thumb and computer-based methods for analyzing daylight within and around buildings. The last part of the course consists of introductions to natural ventilation concepts and building acoustics.

The course format consists of semiweekly lectures and weekly labs. Individual and group assignments as well as in-class presentations and exercises will help students to study the use of environmental technologies in contemporary buildings.

Learning Objectives

The course aims to help students to:

- understand and apply the scientific principles underlying the thermal, luminous and acoustic behavior of buildings,
- learn to evaluate the pros and cons of a range of technologies for creating comfortable indoor environments,
- conduct a series of design analysis workflows regarding climate, building energy use and daylighting and
- acquire the knowledge required to critically discuss/present the environmental concept of a building.

Requirements

The following deliverables will be required to pass this class:

- Attendance of semiweekly lectures and Friday Labs.
- Timely completion of assignments. Late assignments will not be accepted.
- Completion of a group course project. The course project will be to develop and present an environmental concept for a small office building. Project presentations should include:
    - Overall design approach and environmental features
    - Thermal analysis and predicted energy use
    - Daylighting analysis
- Preparation of 20 minute in–class group presentations on one of the AIA Cote Top Ten Projects 2014 (http://www.aiatopten.org/). Presentations should have the following format:
    - Overview of the main environmental features of the building
    - Discussion of predicted energy use
    - Daylighting massing study of the building
    - Discuss what you like and/or dislike about the building and its environmental concept (5 minutes).
- Active participation in class discussions.

Methods of Assessment:

Grades will be determined based on:

- Quality and timely submission of completed assignments (45%).
- Course project presentation (30%)
- Case study presentation (15%).
- Participation in class discussions (10%).
- Members of the winning groups in the 'Building Optimization Game' on Oct 22 will receive additional 10% points.

Please familiarize yourself with MIT's Academic Integrity Expectations at http://web.mit.edu/academicintegrity/.

Software

Throughout the course we will be using the following software packages.

- Rhino 5 forms the CAD backbone of all environmental analysis tools that we will be using in this class. Students should therefore ideally have working version of Rhinoceros 5 installed on their laptops or workstations. You can install a 90 day demo version of Rhino 5 from http://www.rhino3d.com.
- Grasshopper (latest release): Some of the plugins further require Rhino's parametric scripting environment Grasshopper, which can be downloaded free of charge from http://www.grasshopper3d.com/.
- DIVA-for-Rhino is a daylighting and energy modeling plug-in for Rhino (http://diva4rhino.com/). We will be using DIVA for assignments on solar radiation and daylighting. Students may request free licenses for their laptops from the DIVA-for-Rhino web site or use DIVA on the MIT lab computers.
- Archsim Energy Modeling is a Grasshopper plugin that supports multi-zone building energy modeling using the US department of Energy's EnergyPlus whole building simulation engine. (http://archsim.com/)
- Ladybug is another Grasshopper plugin that support the display of annual climate files used for building and daylighting simulations. To run the plugin you will need to install Phython for Grasshopper (www.food4rhino.com/project/ghpython) and the plugin itself (http://www.grasshopper3d.com/group/ladybug)

Bibliography

Information required for completing the assignments will be provided through the lecture notes, selected online materials as well as the *Daylighting Handbook Volume I* which can be purchased on the book's web site (http://www.daylightinghandbook.com/) or directly from the instructor. The following list of textbooks is recommended for additional reading.

- Chartered Institution of Building Services Engineers (CIBSE), *AM10 Natural Ventilation in Non Domestic Buildings*, 2005 (http://www.brebookshop.com/details.jsp?id=31399)
- G. Z. Brown and Mark DeKay, *Sun, Wind & Light: Architectural Design Strategies* (3rd edition), John Wiley & Sons, 2014
- Roger Benham, *Architecture of the well-tempered environment* (2nd edition), The University of Chicago Press, Chicago, ISBN 0-226-03698-7 (paperback), 1984 (~$35)
- Norbert Lechner, *Heating, Cooling, Lighting: Design Methods for Architects* (2nd edition), John Wiley & Sons, ISBN: 0-471-24143-1 (hardcover), 2001
- Manfred Hegger, Matthias Fuchs, Thomas Stark, Martin Zeumer, *Energy Manual: Sustainable Architecture*, Construction Manuals, Bikhäuser, 2008
- J L M Hensen and R Lamberts (Editors), *Building Performance Simulation for Design and Operation*, Taylor & Francis, 2011
- K Voss, *Net Zero Energy Buildings: International Comparison of Carbon-Neutral Lifestyles*, Detail green Books, 2012

Week	Monday Lecture (9.30 – 11.00, Room 1-150)	Wednesday Lecture (9.30 – 11.00, Room 1-150)	Reading*	Friday Lab (10.00 – 12.00 9-250)	Assignment (due date)
1		**Sep 3** L01 Course Introduction | Energy Use in Society		**Sep 5 Hand out** HOBO data loggers + Software Overview [Geisinger & Reinhart]	Ass 1 – Essay & Personal Carbon Balance (Sep 5)
2	**Sep 8** L02 Energy Use in Buildings	**Sep 10** L03 Understanding Climate – Solar Radiation	DH1, DH3, DH6	**Sep 12 DIVA Shading Study +** Ladybug [Reinhart & Mackey]	Ass 2 – Direct Shading and Sunpath Diagrams (Sep 17)
3	**Sep 15** L04 Wind Understanding Climate - Temperature and Rel. Humidity | Climate Consultant	**Sep 17** L05 Thermal Comfort + Case Studies	IBPSA3	**Sep 19** Student Holiday (no lab)	Ass 3 – Psychrometric Chart (Sep 24)
4	**Sep 22** L06 Thermal Mass & Heat Flow	**Sep 24** L07 Insulation Materials		**Sep 26** ArchSim I Shoebox [Dogan & Geisinger]	Ass 4 Best Insulation Value (Oct 1)
5	**Sep 29 L08** Radiation Maps Active and Passive Solar	**Oct 1** Instructor Traveling (no class)	DH9	**Oct 3** DIVA II Radiation Maps + ArchSim II PV [Geisinger + Dogan]	Ass 5 – Internal Gains and Designing a PV System (Oct 8)
6	**Oct 6** L09 Window Technologies and Internal Gains	**Oct 8** L10 Infiltration and Manual Load Calculations	IBPSA5; JPBPS Paper (online)	**Oct 10** Envelope Game [Reinhart & Geisinger]	Ass 6 Envelope Game Results (Oct 15)
7	**Oct 13** No Class (Columbus Day)	**Oct 15** Instructor Traveling (no class)	IBPSA2	**Oct 17** ArchSIm III Multi-Zone Energy Models [Dogan & Geisinger]	
8	**Oct 20** L11 Static Shading | Energy Simulations (extra lecture)	**Oct 22** L12 Simulation Game	DH7	**Oct 24** MIT Family Weekend (no lab)	Ass 7 – Simulation Game Presentation (Oct 27)
9	**Oct 27** L15 Simulation Game Student Presentations	**Oct 29** L16 HVAC Systems		**Oct 31** Daylit Area Exercise + HDR Workshop [Reinhart & Geisinger]	Ass 8 – Daylit Area Study & Basic Photometry (Nov 5)
10	**Nov 3** L17 Photometry, Daylight and Daylighting	**Nov 5** L18 Daylight Availability Rules of Thumb and Massing Studies	DH2, DH4, DH5	**Nov 7** Material Properties + DIVA III Daylight Availability Calculations [Reinhart]	Ass 9 - Daylit Availability Study (Nov 12)
11	**Nov 10** L19 Daylight Simulations & Metrics	**Nov 12** Electric Lighting + Controls	IBPSA9	**Nov 14** Individual Course Project Discussions [Reinhart]	
12	**Nov 17** Natural Ventilation - Physical Principles; Manual Methods	**Nov 19** Natural Ventilation - Simulation Approaches	CIBSE	**Nov 21 AIA Presentations:** Sustainability Treehouse | Packard Foundation Headquarters | U.S. Land Port of Entry	
13	**Nov 24 AIA Presentations:** ASU Student Health Services | Bud Clark Commons | Bushwick Inlet	**Nov 26 AIA Presentations:** Edith Green Gateway Center | SUNY-ESF | J & F Angeles Law Center		**Nov 28** Thanksgiving (No Lab)	
14	**Dec 1** Discuss Course Projects [Reinhart]	**Dec 3** Final Project Presentations			
15	**Dec 8** Building Acoustics I	**Dec 10** Building Acoustics II			

*) DH = Daylighting Handbook I; IBPSA = Building Performance Simulation for Design and Operation (from course Reader); CIBSE = AM10 Natural Ventilation in Non Domestic Buildings