

Architecture 4.411
Building Technology Laboratory
Spring 2004

Assignment 10 Daylighting in Houses in Gujarat, India

April 14 and 15, 2004

Please read Chapter 3 (sections 1-6 and 10 only), Chapter 5 (sections 1-12 only, unless you are ambitious), and Chapter 7 of our textbook, Joseph Murdoch's *Illuminating Engineering*.

Please take a set of base-case measurements in your Gujarati house, as follows:

1. Select either the Minolta illuminance meters or the LiCor photometers for measurements. We have plenty of LiCor meters and their smaller size and cable that separates the sensor from the meter body make them the meter of choice.
2. Choose measurement locations within your model and make holes in the base for the sensors. Plan on about 4-6 points in each model, more if there is a second floor.
3. Choose an orientation for the house (N, S, E, W), referenced to the normal direction from the front of the house. This orientation should match the orientation of the real house that is being modeled, if the real orientation is known.
4. Attach a sun-peg diagram to a horizontal surface on the model, accounting for the chosen orientation. Sun-peg diagrams, which are matched to latitude, can be found in many books on solar buildings, including Norbert Lechner's *Heating, Cooling, Lighting: Design Methods for Architects*. A suitable version will be provided in lab.
5. Take a set of sunny-day data for the base-case model. Sunny-day measurements should be taken at each point for three times of day (9 am, noon, 3 pm) and three dates (June 21, September 21 and December 21). Tilt the model manually. For each date and time, measure the illuminance on the base of your model, outside the building (i.e., the "horizontal" illuminance). If the sky condition varies, take an exterior horizontal illuminance reading before and after your interior measurements. The exterior reading will be useful for normalizing the data, which reduces the impact of meter errors and also permits the results to be extended to somewhat different solar luminances.
6. Add another set of points for a cloudy day, taken with your model flat on the ground. Measure the illuminance on the ground, outside your model. Note the time for the cloudy day measurements and calculate the solar altitude (for Cambridge, not Gujarat, because your cloudy day measurements will be made with the model flat on the ground). With some care, you can substitute a shady location for a cloudy day,

but beware of anisotropies due to the source of the shading. You will later compare this measurement with a prediction based on the position of the sun.

7. Supplement the data with visual observations that might, for example, identify areas inside the house that are subject to strong direct solar radiation.
8. Repeat steps 5 and 7 twice, taking two more sets of data with the model rotated such that you cover three of four (N, S, E, and W) orientations. You will need to adjust the position of the sun-peg diagram. Feel free to take measurements in all four directions, which would be terrific but is not required. If symmetries are such that two directions are redundant, do not unnecessarily repeat your measurements.

The due date for this assignment will be discussed in lab. In the following phase we will modify the models, based on what we learn from the initial round of measurements and what we learn of daylighting design. In particular, we will pay attention to small roof openings, which have not been investigated in the past and which may offer a design solution that provides satisfactory light and is cheaper than clerestory windows.

Notes on Desired Lighting Levels:

There are several approaches to determining the desired amount of light in a space. For each of them, keep in mind that people are involved and light is needed to help them perform tasks appropriate for the space. Lighting level studies are based on how well people can perceive and interpret visual information and the extent to which they are uncomfortable with excessive light.

The first and most common approach to specifying required amounts of light is based on *illuminance*, the luminous flux per unit area falling on a surface. Illuminance is measured in lumens per square meter (lux) or lumens per square foot (footcandles), where the lumen is a measure of luminous flux akin to the Watt. A point source of one candela emits 4π lumens. A good discussion of these terms can be found section 1.7 of Murdoch.

Tables of required illuminances for different tasks can be found in Murdoch but the primal source is the two-volume IES *Lighting Handbook*. The IES is the Illuminating Engineering Society. We have two versions of the handbook; please favor the more recent, two-volume set. In the Reference Volume you will find, in Appendix A, an extensive list of illuminance categories for various activities in building interiors. The list goes on to consider outdoor activities as well, including shuffleboard and skeet shooting. For each indoor activity there is a triplet of numbers, in both lux and footcandles. Which to choose? Check out page A-19 to learn the answer, which depends on the age of the occupants, the importance of speed and/or accuracy, and the reflectance of the task background.

As described in chapter 5 of Murdoch, these numbers were derived from studies of visual performance based on the optical size of an object, the time allowed to view it, the contrast between the object and its background, and the luminance of the object.

Illuminance guidelines do not of themselves address conditions that produce visual discomfort and also can be abused by designers who insist on uniform levels throughout a space, even though, for example, tasks may concentrated on desktops.

An approach that addresses visual comfort is one that constrains variation in surface luminance. A brightly illuminated task surrounded by a dark background can lead to eye strain as the viewer shifts the field of vision. The constraints are presented as allowable ratios and are found in the Applications Volume. Take a look at chapter 6 for educational facilities.

Luminance ratios can also be abused. Bright light is not always unpleasant. The brilliance of a chandelier or the warm of bright sunlight may be so welcome that we readily accept and even welcome the associated high luminance levels. Noted lighting designer William Lam, educated at MIT and a Cambridge resident, has written persuasively about biological needs for light and how these needs can inform lighting design. This material is found in his first book, *Perception and Lighting as Formgivers for Architecture*. His second manuscript, *Sunlighting as Formgiver for Architecture*, is equally valuable in its treatment of window and skylight design.

Finally, a recent effort has been made within academia to directly relate luminance and contrast to visual performance for a single task, that of comparing lists of nearly identical numbers. These studies have shown that visual performance, as measured by a metric that combines speed and accuracy, is quite sensitive to either luminance or contrast when either variable is increase from near-zero values, and then is quite insensitive to further increases. Of course, task luminance must be related to illuminance from a light source, via the reflectivity of the task, in order to use this information to design a lighting system.