Sun Study Tools

Sophomore Architecture Studio: Lighting

Lecture 1:
- Introduction to Daylight (part 1)
- Survey of the Color Spectrum
- Making Light
- Controlling Light

Lecture 2:
- Daylight (part 2)
- Design Tools to study Solar Design
- Architectural Applications

Lecture 3:
- Light in Architecture
- Lighting Design Strategies

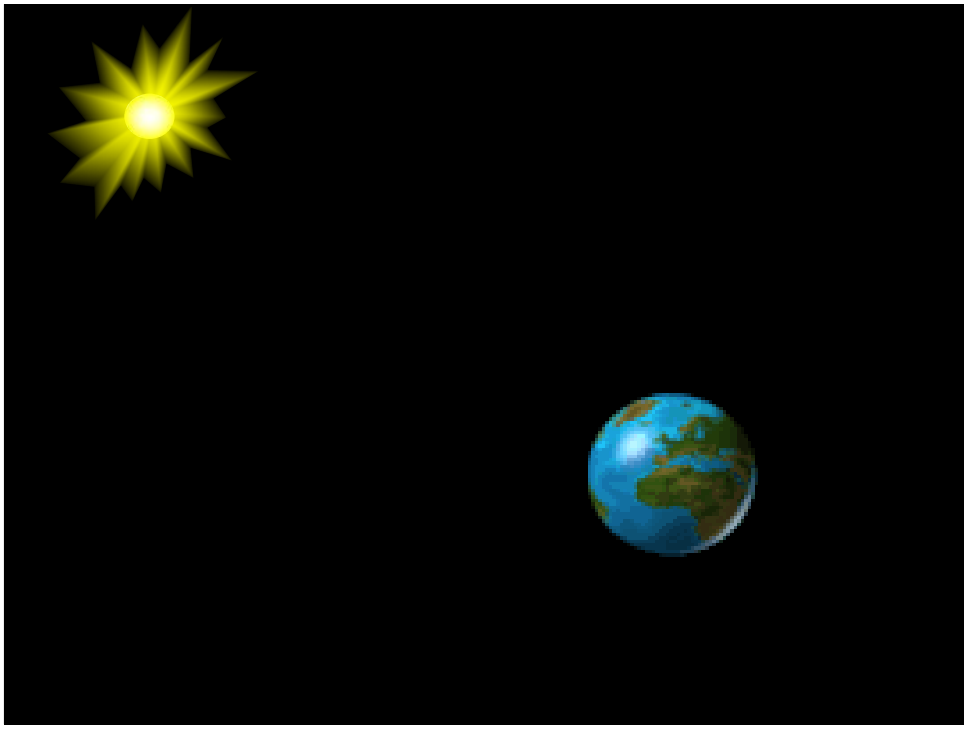
Sun Tool Options

1. Paper and Pencil
2. Build a Model
3. Use a Computer

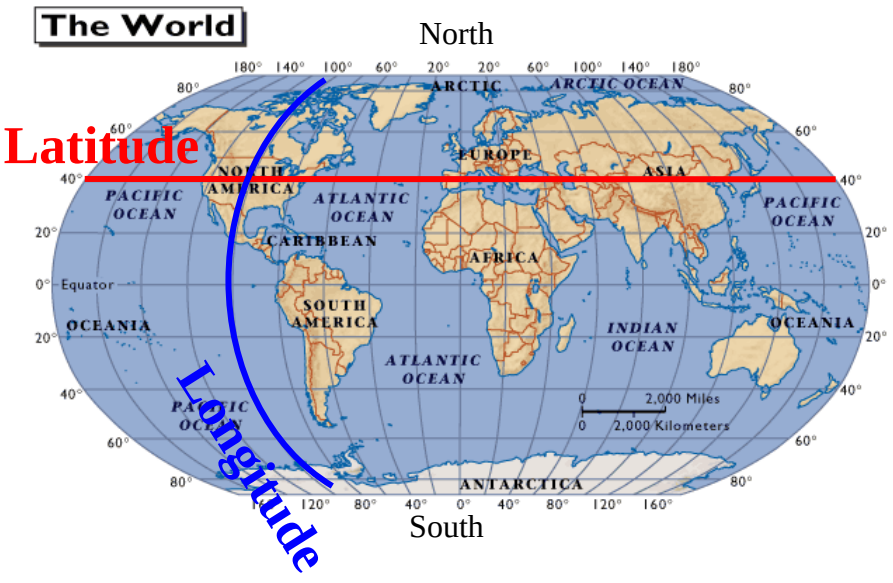
The first step to any of these options is to define….

Where is the site?

Sun Study Tools



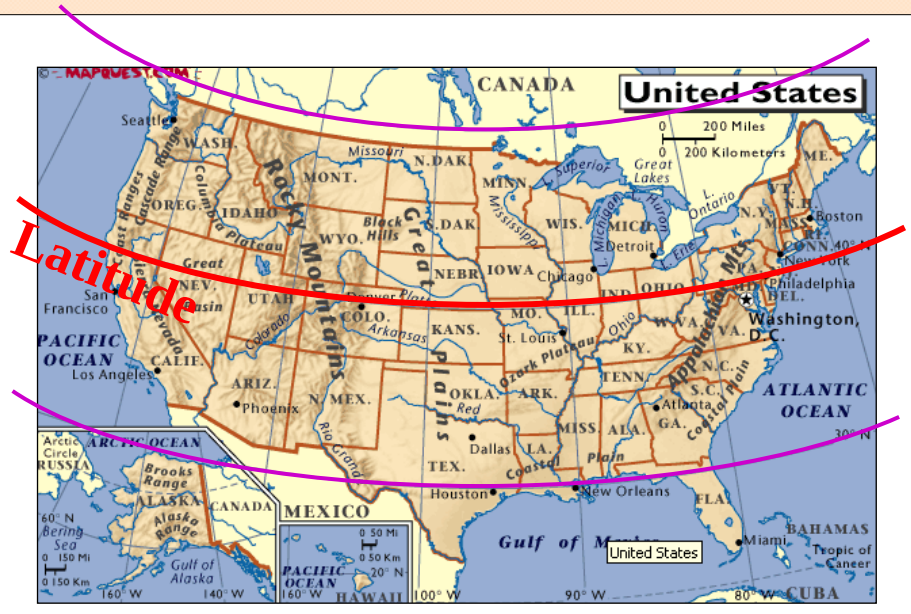
Latitude and Longitude



Sun Study Tools

North America

United States



Sun Study Tools

New York

Site Location

Country/City	Latitude		Longitude	
	Degrees	Radians	Degrees	Radians
Canada				
Ottawa, ON	45	0.79	76	1.33
Montreal, PQ	46	0.80	74	1.29
Toronto, ON	44	0.77	79	1.38
Vancouver, BC	49	0.85	123	2.15
Winnipeg, MB	50	0.87	97	1.69
Mexico				
Mexico City	19	0.33	99	1.73
United States				
Anchorage, AK	61	1.06	150	2.62
Big Rapids, MI	44	0.77	85	1.48
Boulder, CO	40	0.70	105	1.83
Chicago, IL	42	0.73	88	1.54
Cleveland, OH	41	0.72	82	1.43
Dallas, TX	33	0.58	97	1.69
Honolulu, HI	21	0.37	158	2.76
Los Angeles, CA	34	0.59	118	2.06
Miami, FL	26	0.45	80	1.40
New York, NY	41	0.72	74	1.29
Philadelphia, PA	40	0.70	75	1.31
Seattle, WA	48	0.84	122	2.13
Troy, NY	43	0.75	74	1.29
Washington, DC	39	0.68	77	1.34

Latitude and Longitude of Some North American Cities

The site location is specified by a latitude *l* and a longitude *L*. Latitudes and longitudes may be found in any standard atlas or almanac. Chart shows the latitudes and longitudes of some North American cities.

Conventions used in expressing latitudes are:

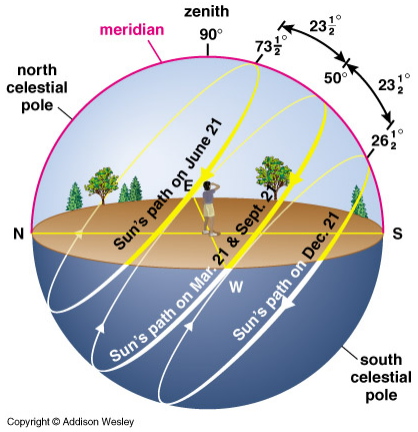
Positive = northern hemisphere
Negative = southern hemisphere

Conventions used in expressing longitudes are:

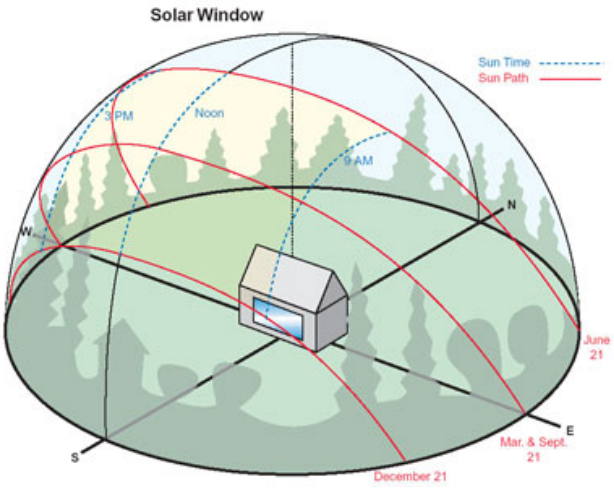
Positive = west of prime meridian (Greenwich, United Kingdom)
Negative = east of prime meridian

Sun Study Tools

Solar Path



Suns Position



The position of the sun is specified by the solar altitude and solar azimuth and is a function of site latitude, solar time, and solar declination.

Sun Study Tools

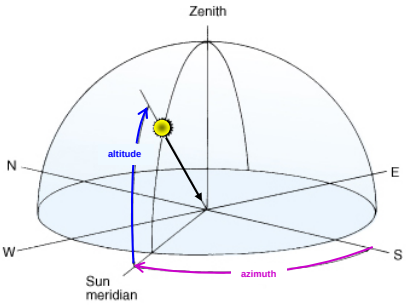
Suns Position

The rotation of the earth about its axis, as well as its revolution about the sun, produces an apparent motion of the sun with respect to any point on the earth's surface.

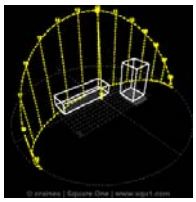
The position of the sun with respect to such a point is expressed in terms of two angles:

solar azimuth, which is the horizontal angle of the sun from due south in the northern hemisphere.

the solar altitude, which is the vertical angle of the sun above the horizon

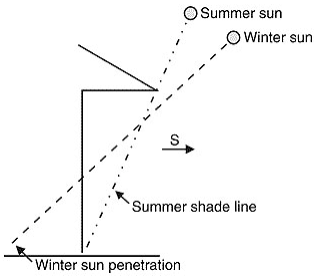


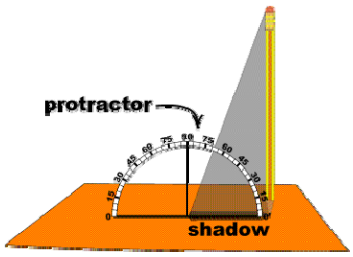
The sun's position in terms of solar altitude (a_l) and azimuth (a_s) with respect to the cardinal points of the compass.



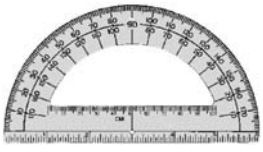
Animation showing changing sun-path on the 21st day of each month for latitude -32°.

Sun Angle: Draw It!



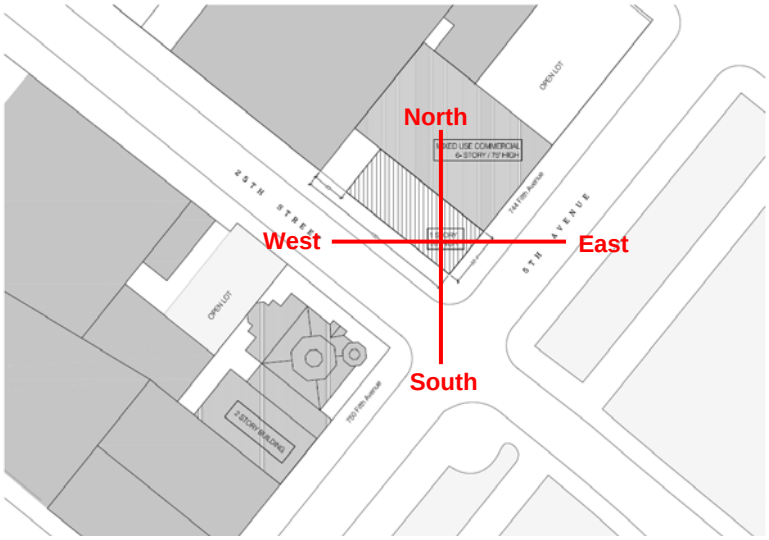


	A	B	C	D	E	F
1	SOLAR ANGLES					
2		Clock time	Azimuth	Altitude	Modified azimuth	
3		9:00	117	31	243	
4		10:00	131	41	229	
5		11:00	150	49	211	
6		12:00	172	53	188	
7		13:00	-163	52	163	
8		14:00	-142	46	142	
9		15:00	-125	37	125	
10		16:00	-113	27	113	
11		17:00	-102	16	102	

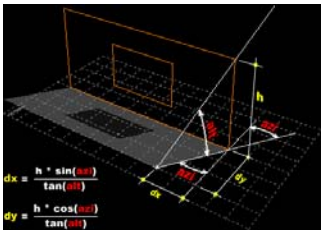


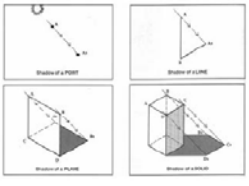
Sun Study Tools

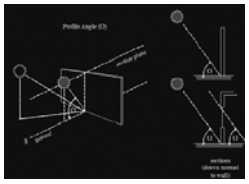
Sun Angle: Draw It!

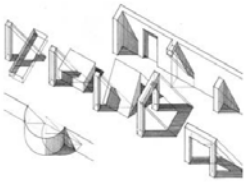


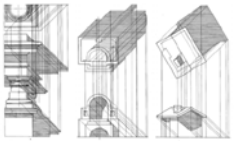
Sun Angle: Draw It!

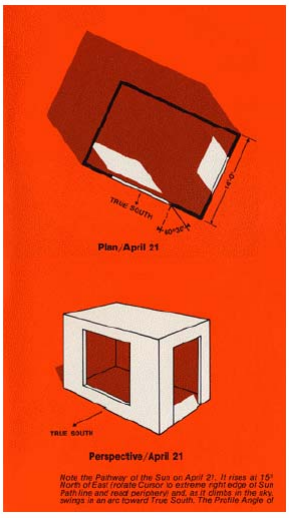




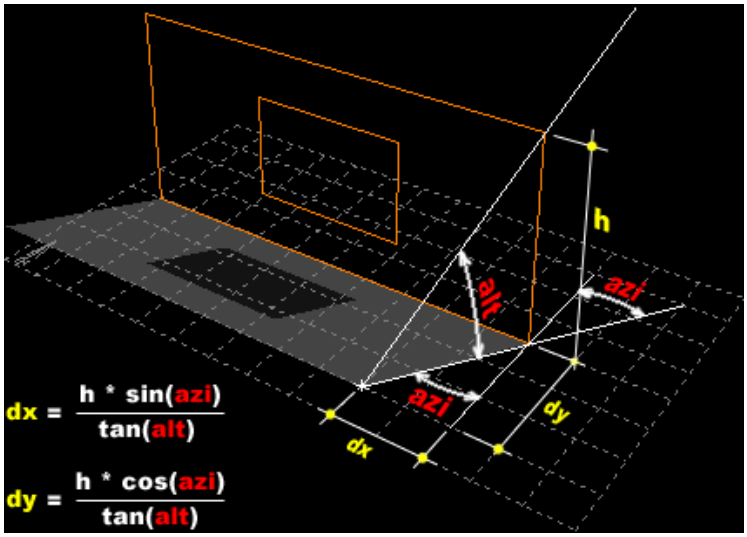






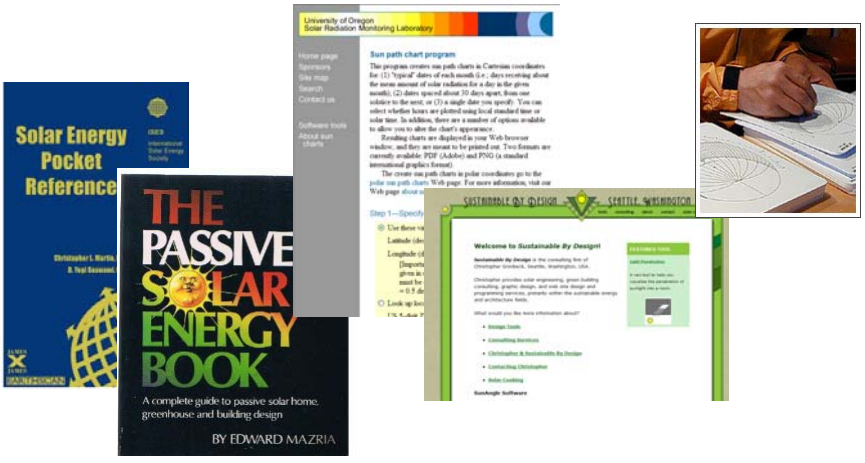


Sun Angle: Draw It!



Find the Sun Position

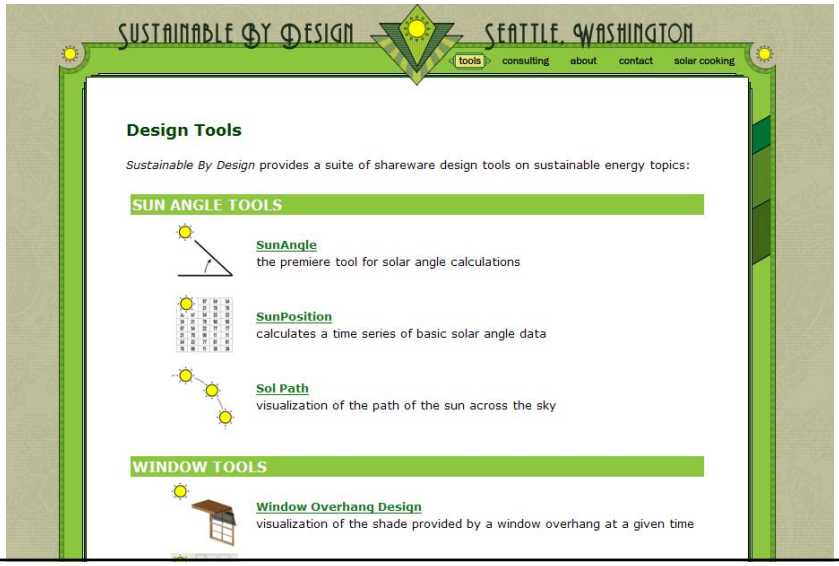
Books - Web: Online Generators - Pilkington Sun Angle Calculator



Sun Study Tools

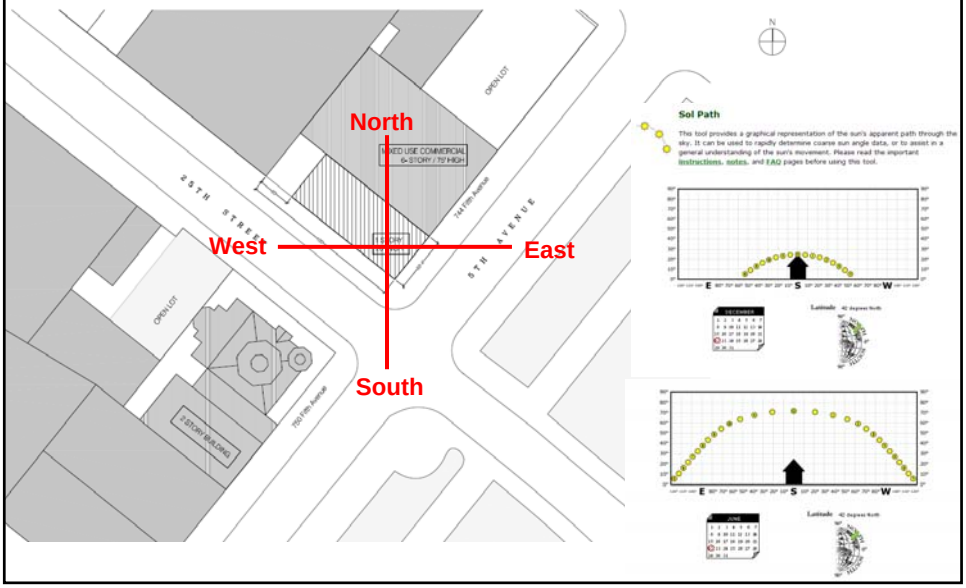
http://www.susdesign.com/

Susdesign.com: Sun Angle Tools

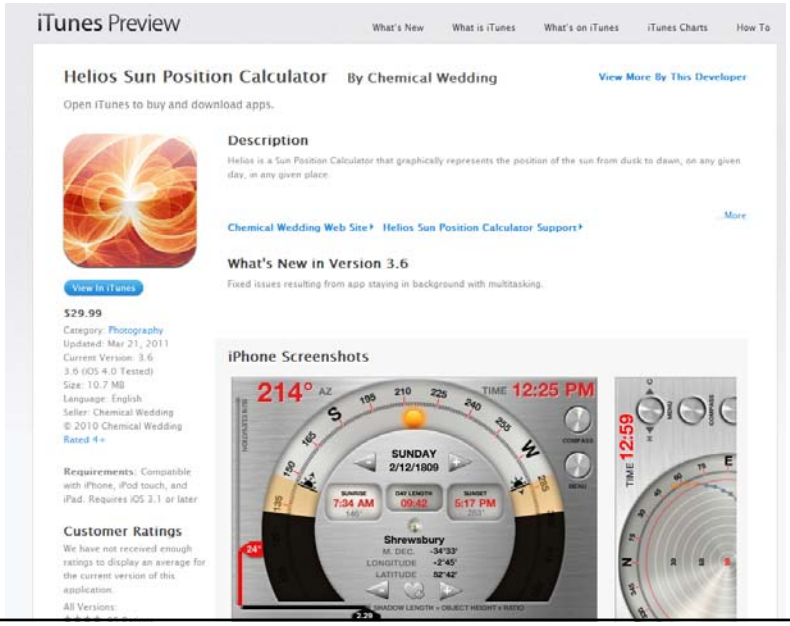


Sun Study Tools

Sun Angle: Draw It!



Yes, there is an App for that!



Sun Study Tools

Pilkington Sun Angle Calculator

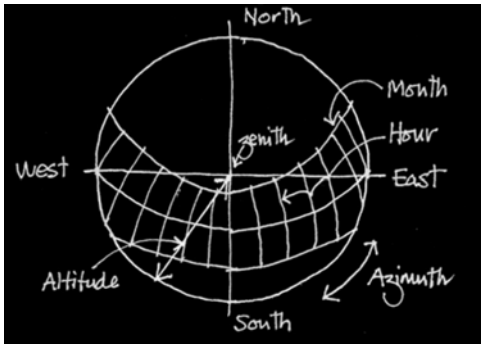
Sun path diagrams can be very useful (they combine coordinates of time and position) and allow analysis of:

1. Sun's position at any time
2. A building's radiation need (using month vs hour grid)
3. Shading from the site - horizon profiles
4. Solar geometry - overlays for profile angle
5. Radiation impact
6. Shading from some shading devices
7. Availability of natural illumination

The Libbey-Owens_Ford Sun Angle Calculator (LOFSAC) - trusted by architects for generations

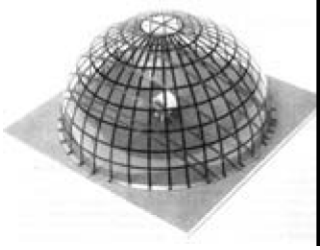
http://www.sbse.org/resources/sac/

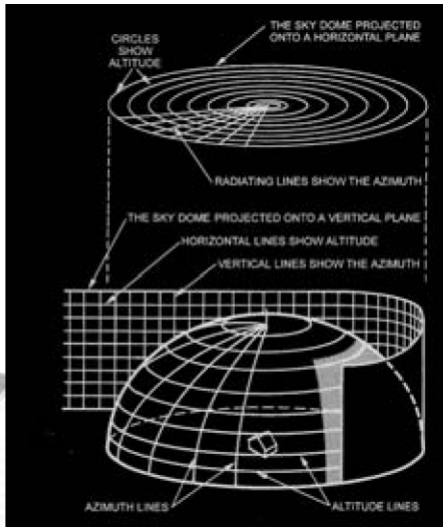
http://www.sbse.org/resources/sac/



Pilkington Sun Angle Calculator

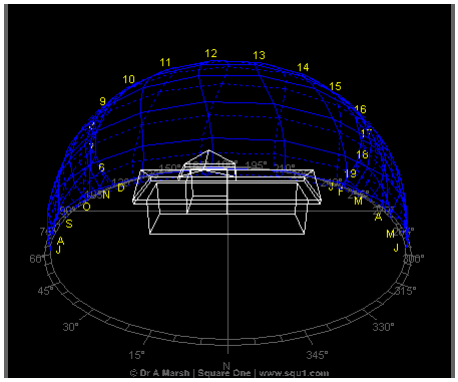
All Sun Path Diagrams represent the hemisphere of sky directly above and relative to the ground plane. Coordinates are altitude and azimuth.





Sun Study Tools

Pilkington Sun Angle Calculator



Sun Angle Calculator

USING THE SUN ANGLE CALCULATOR

Find the latitude of the structure under consideration by using the map inside the back cover. Disassemble the Calculator, and select the Sun Chart nearest that latitude. Place this on top. Add the red Overlay and Cursor and reassemble.

Determining the Profile Angle

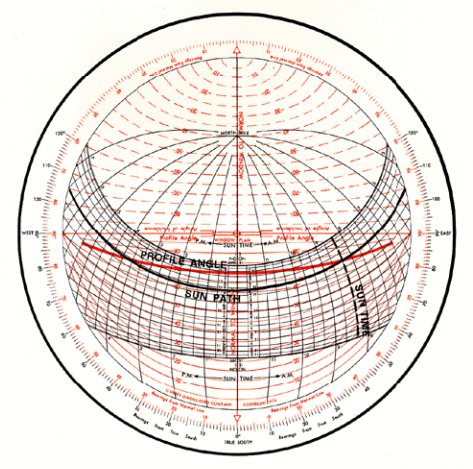
It is necessary to know the Profile Angle to establish the position and dimensions of overhangs and also to determine the penetration of the sun's rays into a room or the length of a shadow cast by an opaque object.

1. Rotate red Overlay to line up the solid line, "Normal to Window," with the orientation of the window indicated on the black peripheral scale, "Bearings from True South."

2. Locate the curved black Sun Path line for the date being considered. Lines are shown for the 1st, 11th and 21st of each month. These dates are adequate for calculating Sun Angles for most architectural design problems. Interpolation can be used for other dates.

3. Follow the Sun Path line to the right or left until it intersects the black Sun Time line for the hour desired. The time lines are marked above and below the date lines. The heavy lines are hours, and the light lines are at twenty minute intervals. The intersection of the Sun Path and the Sun Time lines establishes the Position of the Sun for that day and hour.

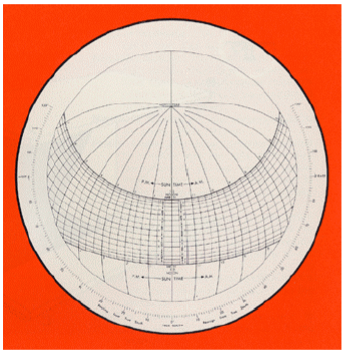
4. The curved red line on the Overlay nearest the Position of the Sun is the Profile Angle. Interpolate if necessary. If the location in question lies between the latitudes of the Sun Charts and more exacting data is desired, find the Profile Angle for the higher and the lower latitude and interpolate.



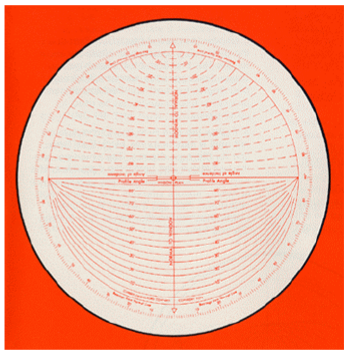
Sun Study Tools

Sun Angle Calculator

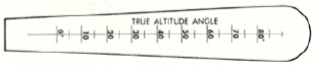
2. Sun Chart
There is a Sun Chart for each four degrees of North latitude from 24 deg to 52 deg. The Charts are printed in black on both sides of the board. The curved lines represent the Position of the Sun on the earth's surface, as seen from above, at that latitude and date. The lines radiating from the North Pole represent Sun Time, with the light lines positioned at twenty minute intervals.



3. Red Transparent Overlay
The circular overlay is applied to all Sun Charts. In the center is a plan view showing the window under study. That part of the Overlay with the solid red lines is used to determine the Profile Angles. That part with the broken red lines is used to find the Angles of Incidence.



4. Cursor
The wedge-shaped Cursor is used for reading the Bearing of the Sun from True South and from Normal to the Window where it intersects the scales along the perimeter of the Sun Chart and Overlay. Its own scale is used to read the True Altitude of the Sun.



Sun Angle Calculator

Bearing of the Sun (Azimuth)

The Angle of the Sun to True South is called Bearing or Azimuth. This is also necessary to determine the position and dimensions of fins, other vertical projections and lengths of overhangs.

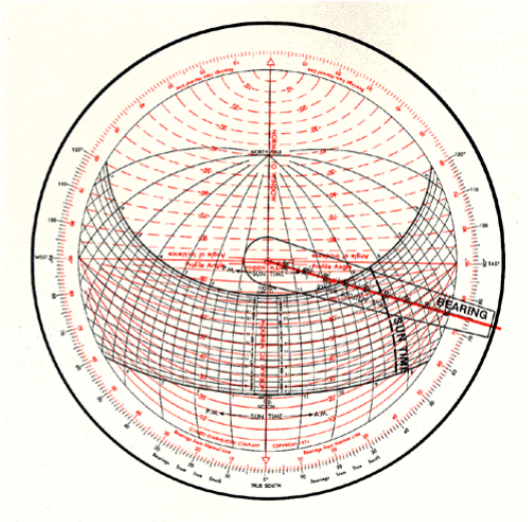
To find the Bearing of the Sun, rotate the Cursor until its centerline intersects the Position of the Sun. The black scale on the periphery of the Sun Chart indicates the Bearing from True South and, on the Overlay, the red scale gives the Bearing from Normal.

True Altitude

True Altitude is read on the Cursor where the center line crosses the Position of the Sun.

Angle of Incidence

The Angle of Incidence of the sun to a window is determined by rotating the Overlay 1800 to the broken red line "Normal to Window" and to the same reading on the peripheral scale. The Angle of Incidence is the broken red line coinciding with the Position of the Sun.



Sun Study Tools

Sun Angle Calculator

Using the Sun Angle Calculator – Example A

Building located in Columbus, Ohio at 40 deg North latitude, with windows facing True South. Time is 9:30 AM on April 21 and December 21. Find the Profile Angle, Bearing of the Sun and True Altitude.

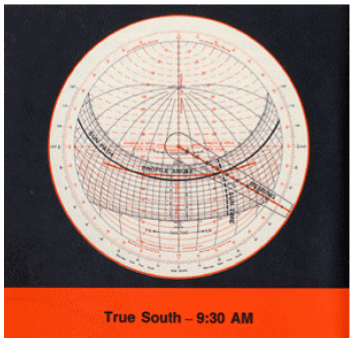
1. Select 40 deg Sun Chart, place on top, add red Overlay and Cursor. Line up solid Normal to Window line with True South on Sun Chart.

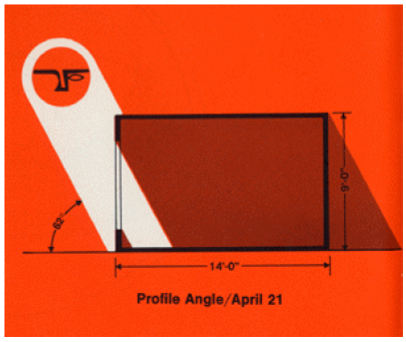
2. Locate April 21 on the curved black Sun Path line and follow across until it intersects the Sun Time line for 9:30 AM. This is the Position of the Sun for that instant.

3. The curved red line intersecting the Position of the Sun is the Profile Angle for that time and date. The reading is 65 deg.

4. To find the Bearing of the Sun, rotate the Cursor until its center line intersects the Position of the Sun. The black scale on the periphery of the Sun Chart indicates the Bearing from True South for April 21 at 9:30 AM is 60 deg 30 min East of True South.

5. True Altitude is read on the Cursor where it intersects the Position of the Sun. True Altitude is 47 deg.


True South – 9:30 AM



Profile Angle/April 21

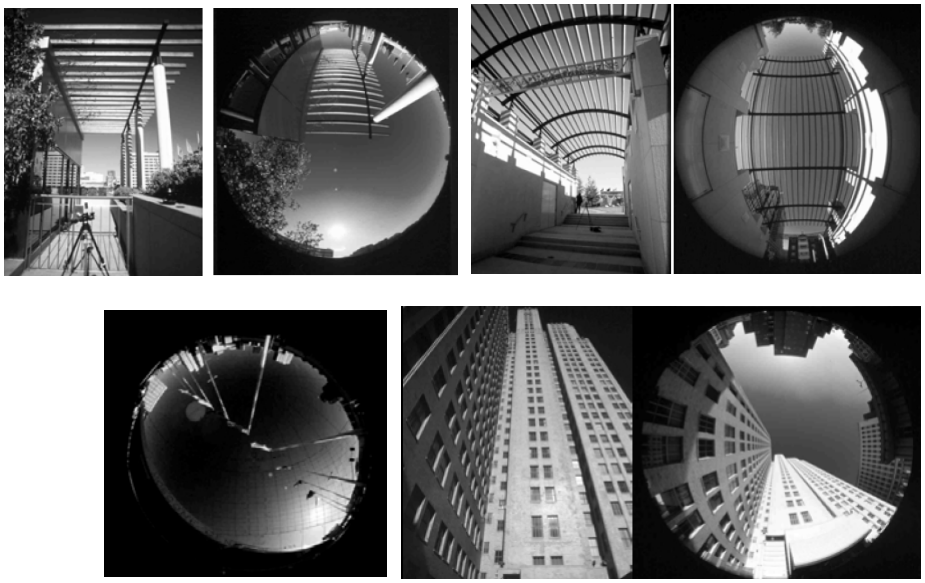
Fisheye Tool

SITE SOLAR ANALYSIS
Tools of the Trade

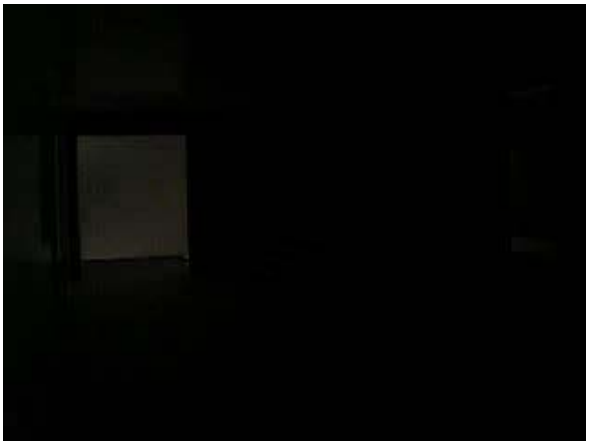
1. Direct Observation of horizon using instruments
2. Fisheye photographs of sky and Sun Path Diagrams (LOFSAC)
3. Horizon shading overlays for Sun Path Diagrams (LOFSAC)
4. Casting Shadows on Architectural Models
5. Casting Shadows in Drawings
6. Using Profile Angles


Take a fish-eye view of the sky dome...

Sun Study Tools



Build A Model



Sun Study Tools

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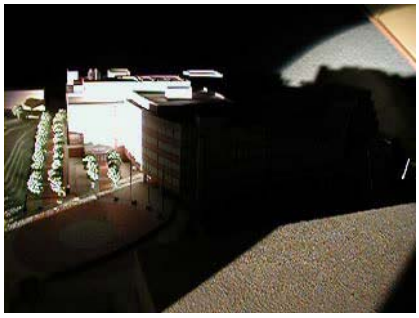


Building a Model

Sun Study Tools

The Heliodon

The heliodon is used to examine how the direct rays of the sun interact with an architect's building design. It is comprised of

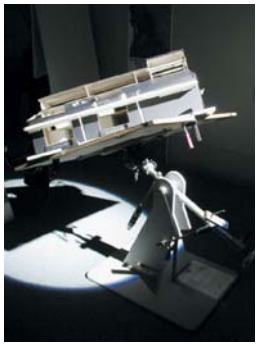
•a tilting/rotating table (the earth)

•a stationary 1000 watt theatrical light source (the sun).

The table can be adjusted to represent the latitude, tilted to simulate any month of the year, and rotated to analyze any time of day.

Typically these studies seek to examine shading devices that eliminate direct sun from areas where visual tasks are critical. Direct sun can cause problems of heat gain and debilitating glare.

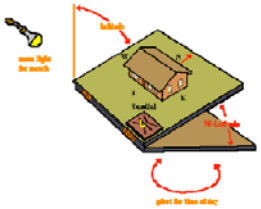
The heliodon takes the guesswork out of complex sun-angle geometry and often will provide surprising results.



Parsons Lighting Lab - Heliodon

The top light is summer, middle is spring/fall and bottom is winter.

The colors of the dichroic lamps should be summer-red, equinox-blue and winter-green. this sequence works best with viewing either the equinox alone (blue), the solstices together (yellow), or all three at once (white). it will also put your knowledge of additive color mixing to the test as students ask which shadow are from which solar position.
hint: shadows are the compliment color.



The table top should be tilted so that the angle between the plane of the table and the plane of the floor corresponds to the co-latitude (90- latitude) of the study site. This will produce an equinox noon altitude that is also the co-latitude.

Some other notes:

1) The study area of the model should be level with the equinox lamp position
2) Make sure the table is in the right position- the ground should be marked with the center of the table.
3) Make sure the lamps are pointing at the tabletop
4) Mount a sundial on the model level in the proper orientation, at a height level with the equinox lamp position, to verify tabletop alignment by rotating the tabletop through a day

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daylighting consultants
665 Broadway, Suite 706E
New York, NY 10012
tel: 212.674.4488 ext. 13

Sky Simulators

the overcast sky simulator

Testing for the overcast condition occurs in a mirror-box artificial sky.

The mirror-box overcast sky simulates a dome of light that provides diffuse light equally from all sides. *Note that a patch of overcast sky is up to 10 times brighter than a section of clear blue sky.*

Method of testing design decisions in the overcast sky is through photography. This allows us to examine

- the perceptual quality of a space,
- the feeling of brightness (diffuse light on vertical surfaces and ceilings), and
- to ensure that a balanced luminous environment (from perimeter to deep interior) is created.

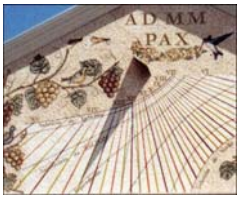
Photocells are used to measure the percentage of available daylight (Daylight Factor) entering a space..

Overcast sky light is ideal for providing gentle, diffuse daylight to building occupants.

Sky Simulators

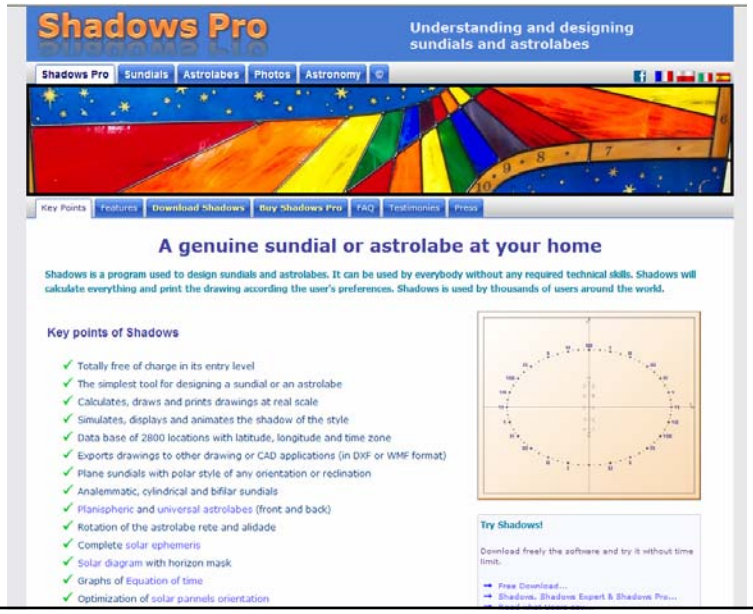
Sun Study Tools

The Sundial

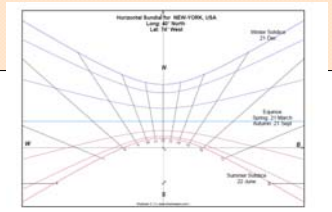


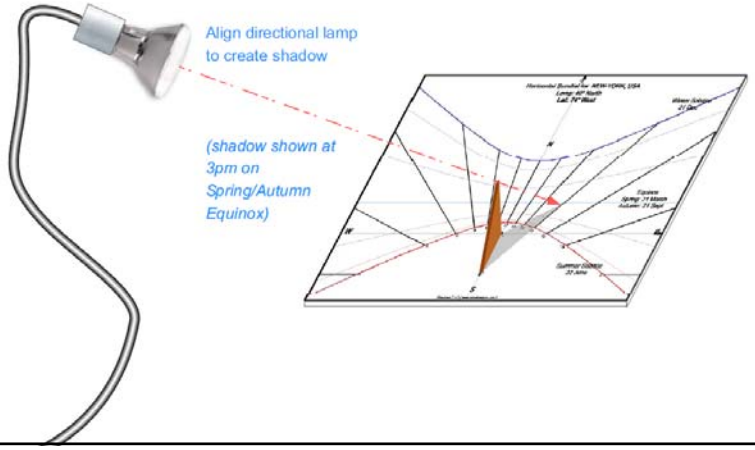
www.shadowspro.com



Sun Study Tools

NYC Sundial





Tip 1

Do not use Foam Core – the material glows and creates light leaks

Use black paper on white board and cover or tape all light leaks

Black Foam Core is expensive.

Sun Study Tools

Tip 2

White Foam Core is reflective and shiny.

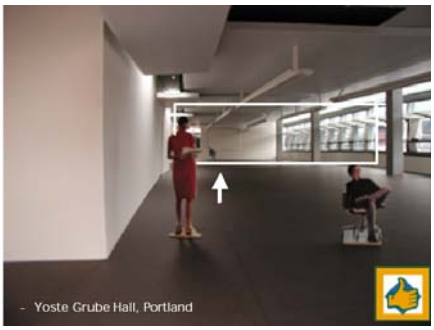
Cover the insides with appropriate surface reflectance or color material.

Tip 3

Make a modular model with interchangeable parts.

Sun Study Tools

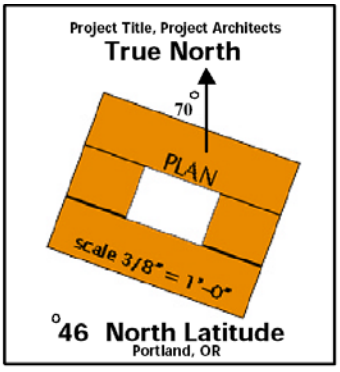
Tip 4

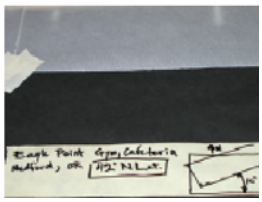


Mirrors can enhance the depth of a model.

Mirrors are useful in large space with respective plans.

Tip 5



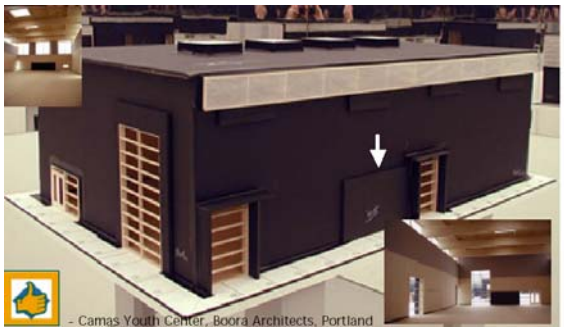


Know true north and latitude.

Draw north arrow on your model.

Sun Study Tools

Tip 6



Include accessible large view ports.

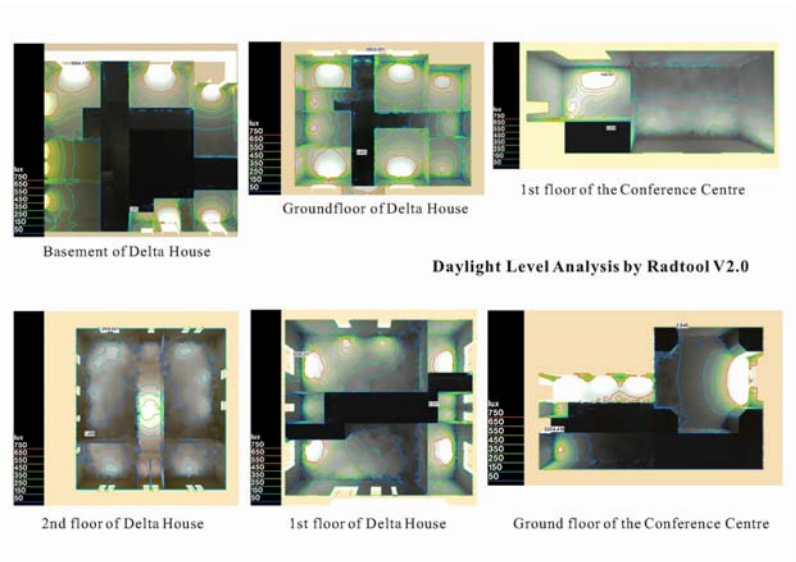
Large enough for use cameras or yield a good view of the interior.

Tip 7

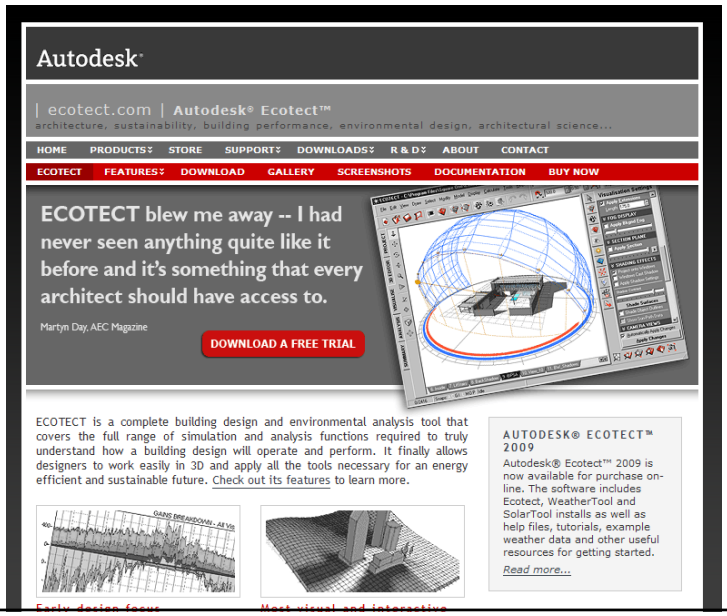
Include people or objects for scale.

Sun Study Tools

Computer Simulation

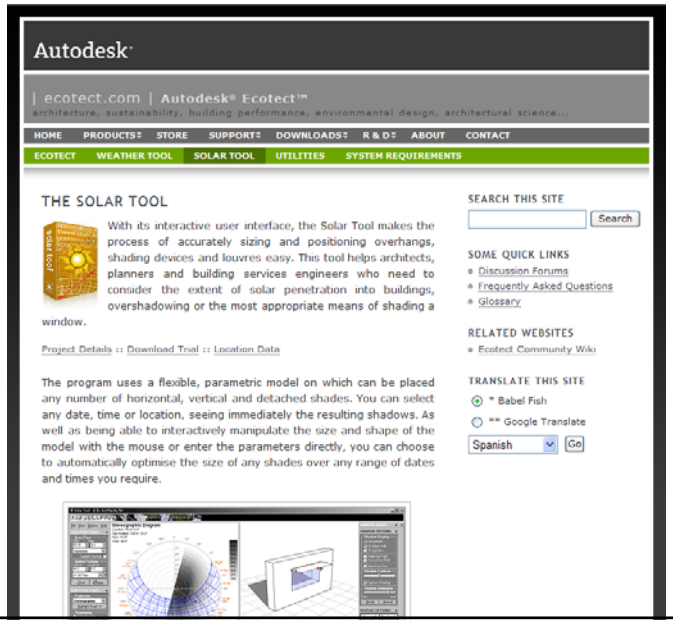


Autodesk: Ecotect *www.ecotect.com*

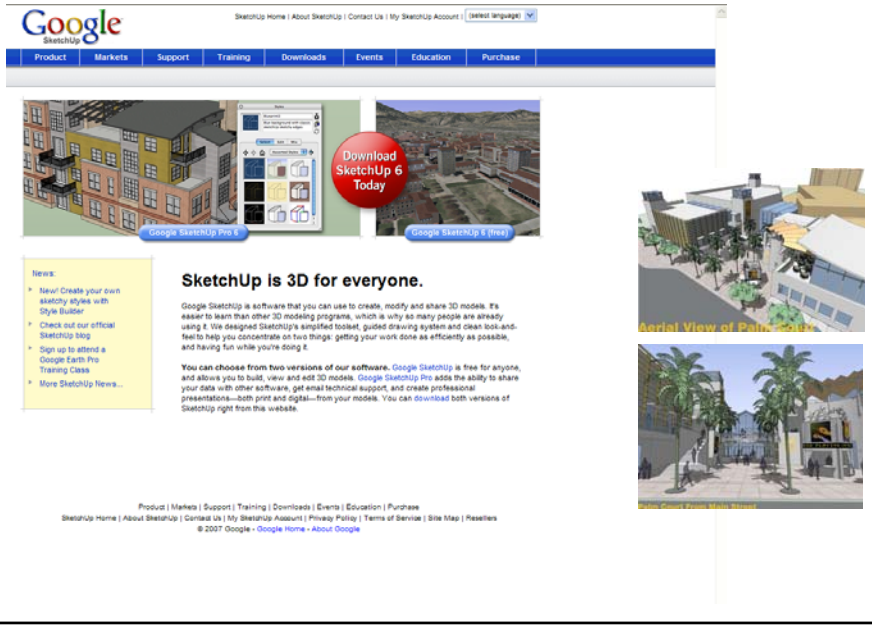


Sun Study Tools

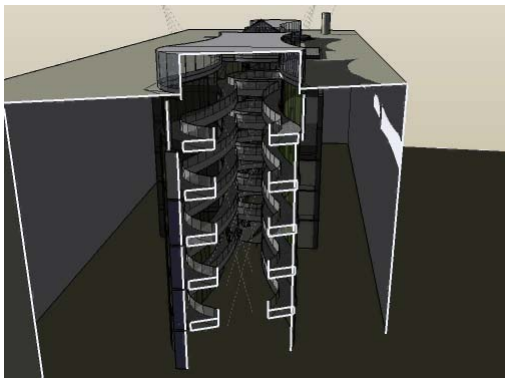
Ecotect: Solar Tool



Google Software: Sketch-up



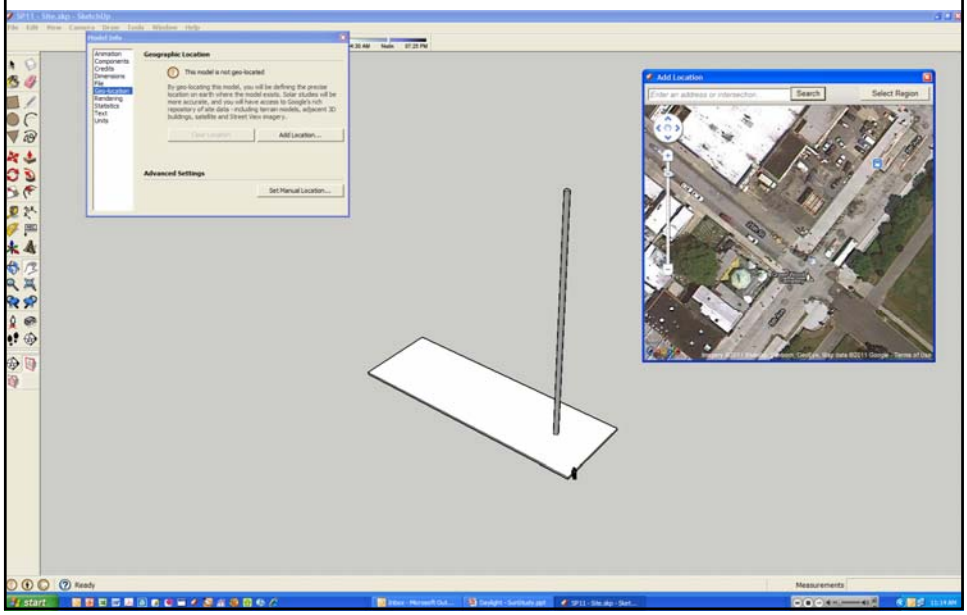
Sun Study Tools



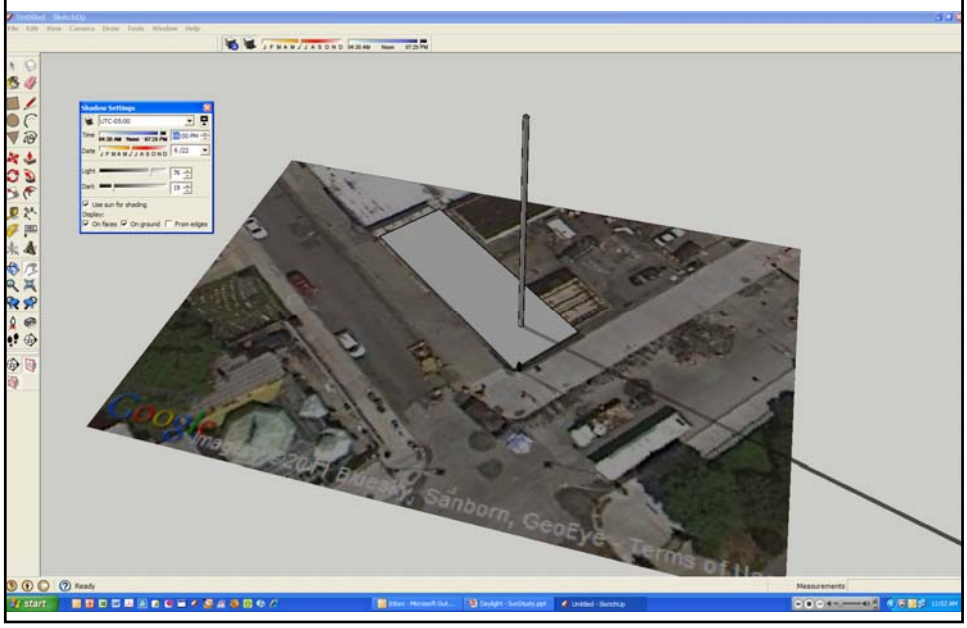
Sketch-up w/Podium Renderings

Sun Study Tools

Sketch-Up: Add Geo Location



Sketch-Up



Sun Study Tools

Type of Daylight Fenestrations

Sidelight (Windows)

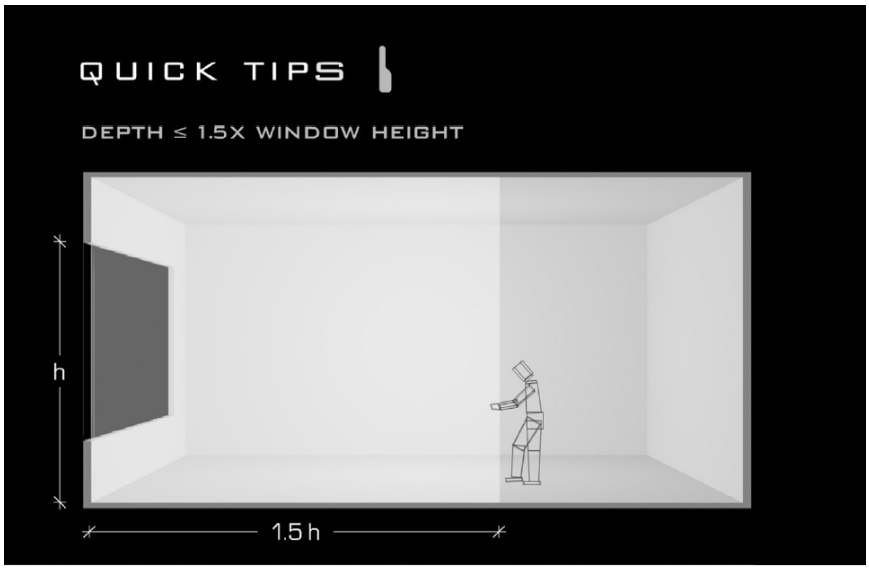
Unilateral Section

Bilateral Section

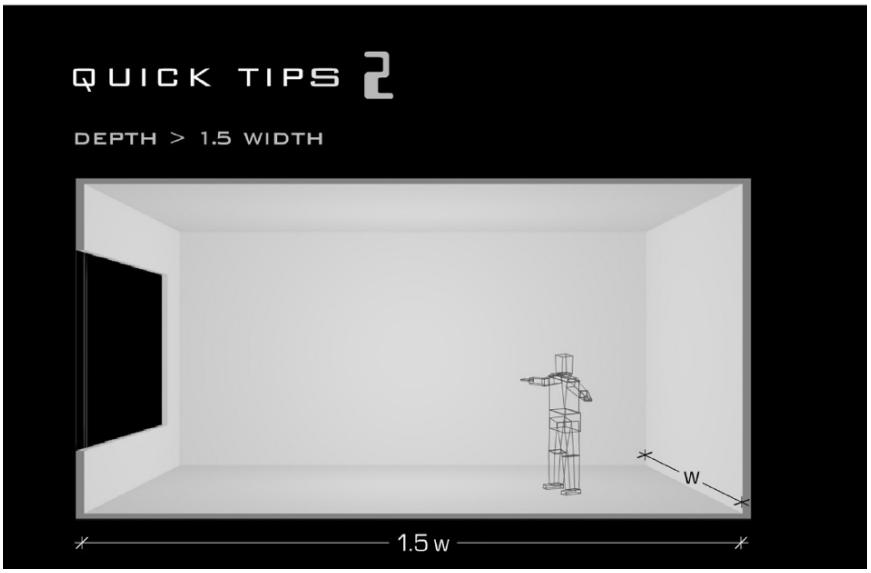
Side Lights

Sun Study Tools

Sidelight Rules of Thumb / Tips

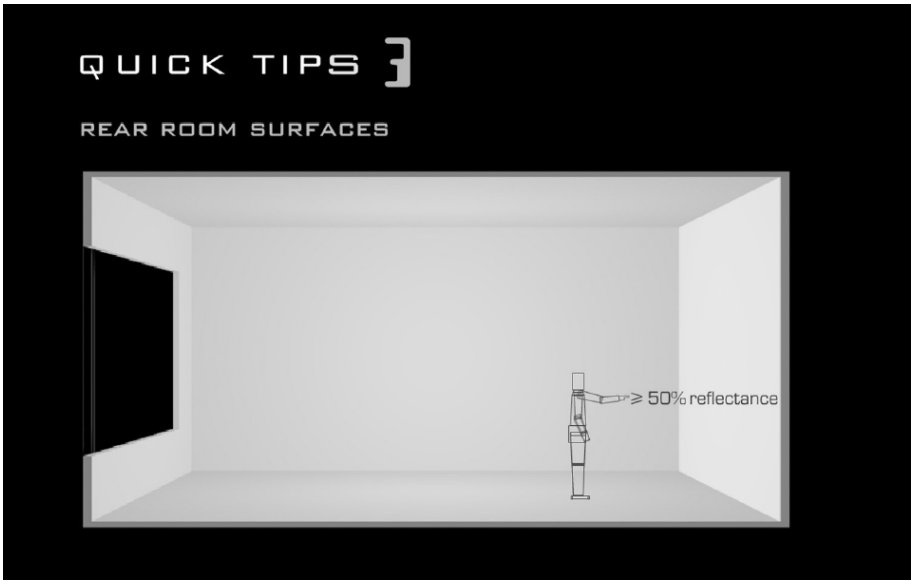


Sidelight Rules of Thumb / Tips

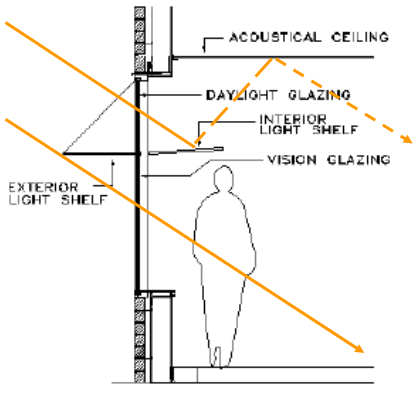


Sun Study Tools

Sidelight Rules of Thumb / Tips

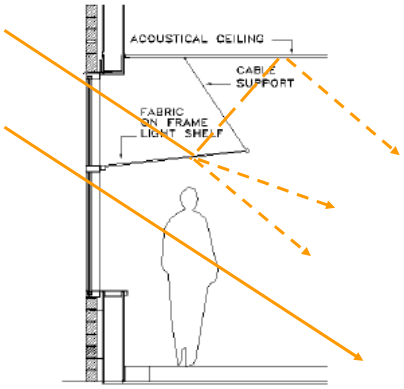


Sidelight Light Shelf



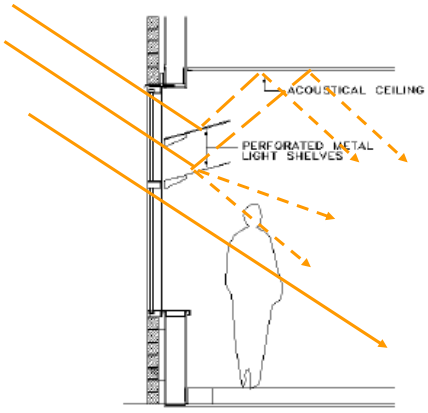
This figure illustrates a standard side-lighting design concept with vision and daylight glazings separated by an interior light shelf.

Sidelight Light Shelf



A simple sidelighting concept with a fabric light shelf was designed for the Sacramento Municipal Utility District (SMUD) headquarters building.

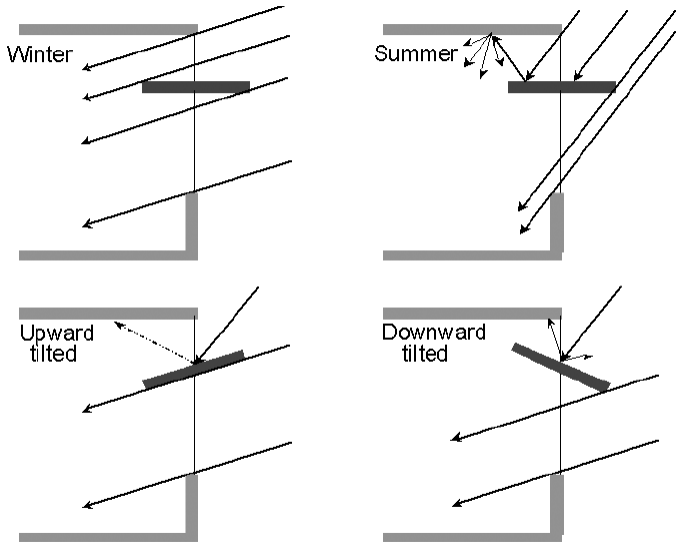
Sidelight Light Shelf



The double light shelf concept is used to provide direct beam daylight control while minimizing light shelf depth.

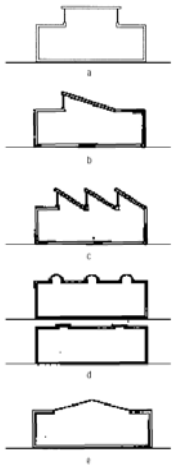
Sun Study Tools

Side Light Shelf



Type of Daylight Fenestrations

Top or Roof lights (Skylights)

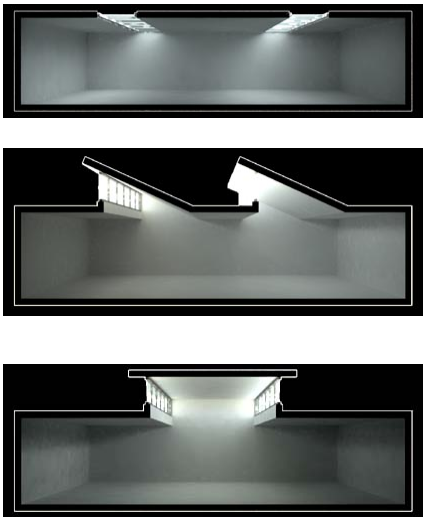


Top lighting provide daylight access through roof top apertures, allowing for optimal separation of vision and daylight glazing. The five basic top lighting concepts are illustrated in the these simplified building sections:

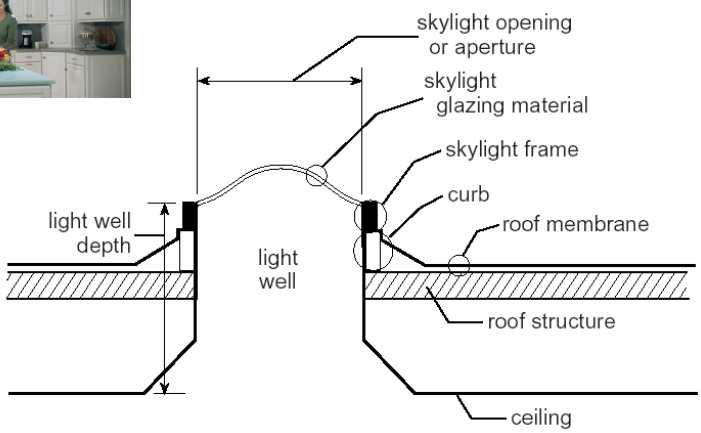
a. Roof monitor
b. Clerestory
c. Saw Tooth
d. Skylight(s)
e. Atrium

Sun Study Tools

Roof Lights

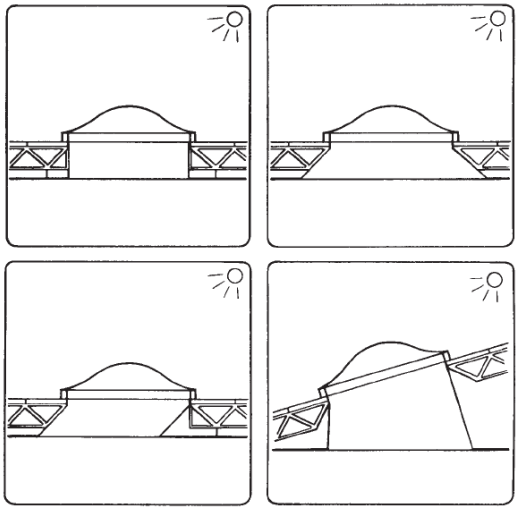


Skylight Construction Terminology



Sun Study Tools

Light Wells



The shape and size of the light well is often determined by the roof and ceiling construction.

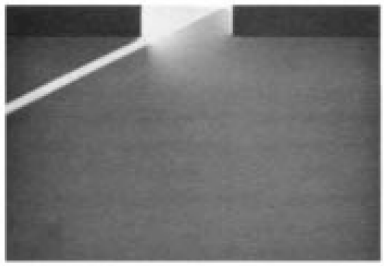
Light wells are a primary component of a skylight system. They bring the light through the roof and ceiling structure, and they simultaneously provide a means for controlling the incoming daylight BEFORE it enters the main space.

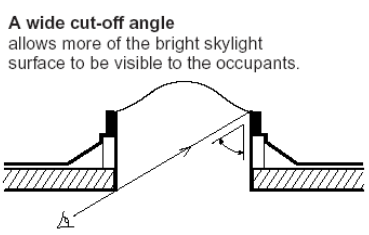
- Similar to the housing of an electric light fixture
- Designed to distribute the light and shield the viewer from an overly bright light source.

Light Well Design

In designing wells for skylights, a number of factors must be considered:

1. **Solar Geometry** – the height and orientation of the sun change both daily and seasonally. The direct sunlight that enters a clear glazing skylight can be prevented from penetrating down to the task surface by light wells.





Sun Study Tools

Light Well Design

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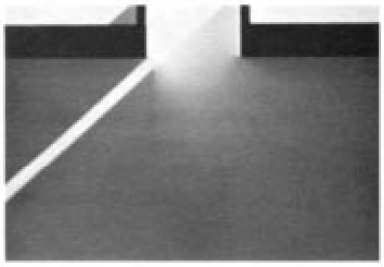
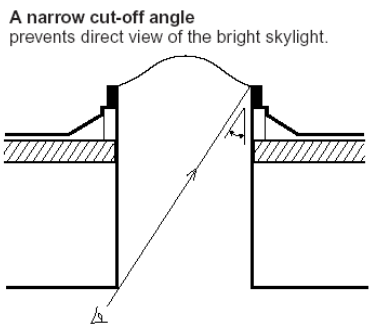
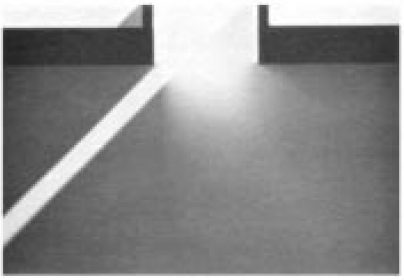


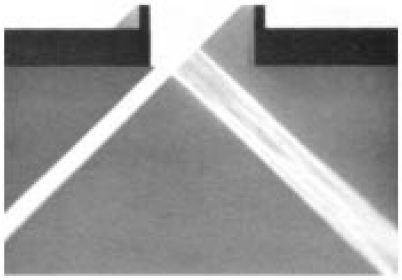


Light Well Design

In designing wells for skylights, a number of factors must be considered:

1. **Surface Reflection** – light wells reflect and diffuse sunlight as it bounces from the skylight to the task surface.



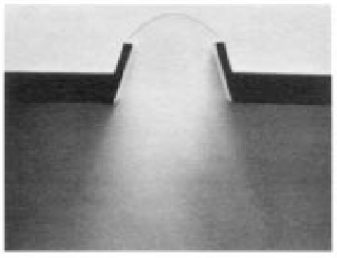


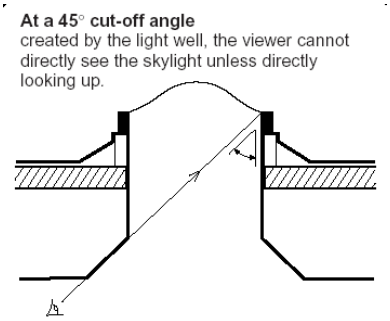
Sun Study Tools

Light Well Design

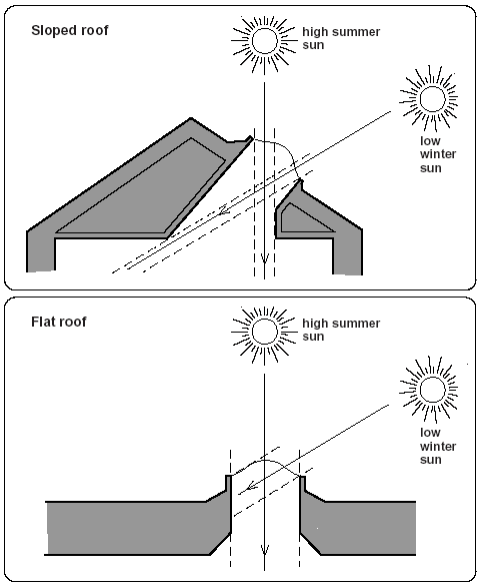
In designing wells for skylights, a number of factors must be considered:

1. **Wall Slope** – the slope of the light well helps to determine the distribution of light in the space.



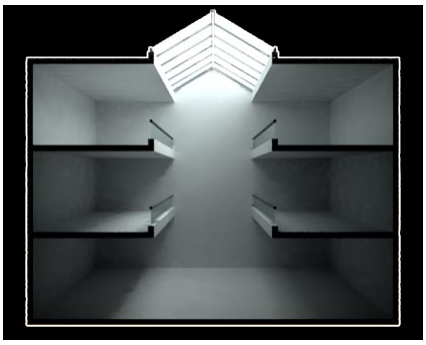


Light Well Design

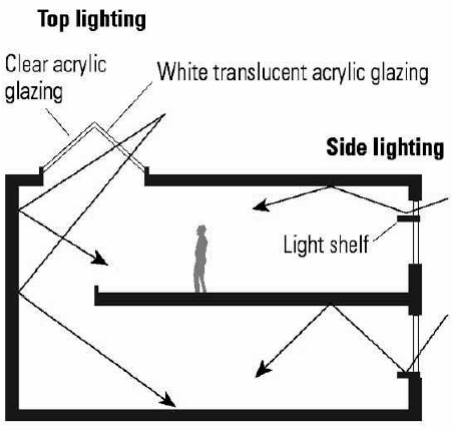


THE SLOPE AND ORIENTATION OF THE ROOF AND THE LIGHT WELL HAVE A MAJOR IMPACT ON HOW MUCH SUNLIGHT PENETRATES INTO THE INTERIOR OF THE BUILDING.

Sun Study Tools



Design Recommendations



This schematic shows a mixture of top and sidelighting strategies in a multi-story building. Quality daylighting designs generally provide daylight from a variety of sources and directions.

Sun Study Tools

Design Recommendations

A number of design strategies should be understood and explored during the design process. These strategies are briefly described below.

1. Increase perimeter daylight zones-extend the perimeter footprint to maximize the usable daylighting area.
2. Allow daylight penetration high in a space. Windows located high in a wall or in roof monitors and clerestories will result in deeper light penetration and reduce the likelihood of excessive brightness.
3. Reflect daylight within a space to increase room brightness. A lightshelf, if properly designed, has the potential to increase room brightness and decrease window brightness.
4. Slope ceilings to direct more light into a space. Sloping the ceiling away form the fenestration area will help increase the surface brightness of the ceiling further into a space.
5. Filter daylight. The harshness of direct light can be filtered with vegetation, curtains, louvers, or the like, and will help distribute light.
6. Avoid direct beam daylight on critical visual tasks. Poor visibility and discomfort will result if excessive brightness differences occur in the vicinity of critical visual tasks.
7. Understand that different building orientations will benefit from different daylighting strategies; for example light shelves which are effective on south-facades are often ineffective on the east or west elevations of buildings.