Arch Studio: Daylight Characteristics and Design

The Benefits of Natural Light

Everyone from scientists and teachers to optometrists and dermatologists are now touting the benefits of natural light.

Following are some of the positive effects sunlight is credited with providing:

- Improves moods and combats depression
- Boosts energy and increases production levels
- Makes interior spaces appear larger
- Renders colours true
- Reduces eyestrain
- Conserves energy
- Brings the outdoors in

Principle Characteristics of Daylight

- Daylight is **Variable**
  - The color of daylight changes with the time of day
  - The cleanliness of the atmosphere effects daylight
  - The interrelation (or bouncing of light) of the surrounding objects
- The intensity of the sun changes with:
  - the time of day....
  - the time of year...
  - the latitude of the site
- The luminance (or brightness) of daylight depends on whether the light is coming from an overcast sky, from a clear sky only, or from a clear sky and direct sunlight

Daylight Components

- Daylight has two components
  - **Sunlight**: the directional beam emitted by the sun
    - directional
    - piercing and very strong, warmer in both temperature and color
    - gives shape to a building
    - need to control its direct penetration into critical visual task areas
    - Spaces illuminated by the rays of eastern and western sunlight radically change on a daily, hour-by-hour basis and are extremely difficult to adapt for critical visual task environments
  - **Skylight**: the diffuse reflection of light particles in the atmosphere
    - can be diffuse light of the clear, cloudy, or overcast sky
    - can be similar in all orientations
    - is soft, cool in both temperature and color
    - Spaces illuminated with diffuse southern sunlight change on a seasonal basis and are adaptable to critical visual tasks

On a clear summer day, outside light levels can be as high as 10,000-12,000 fc on a horizontal surface, whilst on a dark overcast winter day this might fall to around 400-500 fc (depending on the latitude of the location).

The required light levels inside a building range from 10 fc in an access corridor, up to 75 fc for a drawing board, and up to 150 fc in the display cases in a supermarket. With such demanding and diverse daylighting needs, it is clear that we need to provide more than enough light for most applications in almost any type of building.
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Sunlight

Skylight

Skylight

Skylight
Use of Daylight

• **Direct Sunlight** is usually an impractical source for interiors for task lighting
  - Constantly changing
  - Will require shielding to block direct glare and heat gain
  - Sunlight, for critical seeing, can cause…
    - excessive luminous differences that result in discomfort and poor visibility
    - high contrast in the field of view inhibits the eyes ability to adjust
    - leads to visual fatigue
    - disturbing the accommodation needed for clear vision

• **Skylight** is a useful source without shielding
  - Gradual changes thought the day
  - Diffuse
  - With building configuration or controls skylight can acceptable for horizontal task lighting or displaying art
    - It is used with less control to light noncritical seeing area such as corridors, stairwells, cafeterias, and seating areas

Daylight Light vs Views

A view of the sky provides information about the time of day, which helps maintain our biological cycles.

Varying light as a cloud passes in front of the sun provides stimulation, which helps reduce monotony.

Daylight and view do not necessarily go together and often are achieved through different openings.
The criteria for producing a view to the exterior are different from the criteria for producing good interior daylight.
Daylight Summary

- Diffuse Skylight is best for interior illumination
- Direct Sunlight requires control and shading to be useful
- Humans need daylight for their health and Circadian Rhythm
- Daylight has been proven to be a valuable asset to the built environments productivity

- Daylight is FREE lighting!

Light = Color

Spectral Power Distribution Curves (SPD) provide the user with a visual profile of the color characteristics of a light source. They show the radiant power emitted by the source at each wavelength or band of wavelengths over the visible region (380 to 760 nm).
The art and science of proper daylighting design is not so much how to provide enough daylight to an occupied space, but how to do so without any undesirable side effects.
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Daylight Design

It is more than just adding windows or skylights to a space. It is the careful balancing of heat gain and loss, glare control, and variations in daylight availability.

Successful daylighting designs will pay close attention to the use of shading devices to reduce glare and excess contrast in the workspace.

Daylight Design

Window size and spacing, glass selection, the reflectance of interior finishes and the location of any interior partitions must all be evaluated.

Strategies in History

Daylight strategies for different type of buildings types

Strategies in History

Daylight strategies for different type of buildings types
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Alvar Alto

Luis Barragán

Louis Kahn

Louis Kahn
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<th>New York Times Building</th>
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### Arch Studio: Daylight Characteristics and Design

#### Joost van Santen

![Joost van Santen Images]

#### James Turrell

![James Turrell Images]

### Type of Daylight Fenestrations

**Sidelight (Windows)**

- Unilateral Section
- Bilateral Section
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Sidelight Rules of Thumb / Tips

QUICK TIPS
DEPTH < 1.5x WINDOW HEIGHT

Sidelight Rules of Thumb / Tips

QUICK TIPS
DEPTH > 1.5 WIDTH

Sidelight Rules of Thumb / Tips

REAR ROOM SURFACES
50% reflectance
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**Sidelight Light Shelf**

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

**Side 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.
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**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 these simplified building sections:

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

**Skylight Construction Terminology**

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.

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

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

3. **Wall Slope** – the slope of the light well helps to determine the distribution of light in the space.
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Light Well Design

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 from 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.
The simplest method to maximize daylight within a space is to increase the glazing area. However, three glass characteristics need to be understood in order to optimize a fenestration system:

- **U-value** represents the rate of heat transfer due to temperature difference through a particular glazing material.
- **Shading Coefficient (SC)** is a ratio of solar heat gain of a given glazing assembly compared to double-strength, single glazing. (NB: A related term, Solar Heat Gain Factor (SHGF), is beginning to replace the term Shading Coefficient)
- **Visible Transmittance (Tvis)** is a measure of how much visible light is transmitted through a given glazing material.

Glazings can be easily and inexpensively altered to increase both thermal and optical performance. Glazing manufacturers have a wide variety of tints, metallic and low-emissivity coatings, and fritting available. Multi-paned lites of glass are also readily available with inert-gas fills, such as argon or krypton, which improve U-values.
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Daylight Qualities: veiling reflection

Daylight Qualities: a magical sprite

Daylight Qualities: dynamic daylight
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Daylight Qualities: daylight prismatically deconstructed

Daylight Qualities: leaking light

Daylight Qualities: texture revealed by daylight

Daylight Qualities: camera lucida / color mapping daylight
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Daylight Qualities: dappled light

Daylight Qualities: daylight gradient revealed

Daylight Qualities: varying penumbra

Daylight Qualities: carpet of shadow (pattern)
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Daylight Qualities: rhythmic daylight

Daylight Qualities: a daylight fixture

Daylight Qualities: daylighting at the edge of the day
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Latitude and Longitude

North America

United States

New York
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### Site Location

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<th>Latitude</th>
<th>Longitude</th>
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<tr>
<td>Mexico City</td>
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Conventions used in expressing latitudes are:
Positive = northern hemisphere
Negative = southern hemisphere

Conventions used in expressing longitudes are:
Positive = west of prime meridian
Negative = east of prime meridian

<table>
<thead>
<tr>
<th>Latitude and Longitude of Some North American Cities</th>
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<tr>
<td>Latitude</td>
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<td>Troy, NY</td>
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### Solar 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.

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 altitude**, which is the vertical angle of the sun above the horizon,
- **Solar azimuth**, which is the horizontal angle of the sun from due south in the northern hemisphere.

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

Sun path diagrams can be very useful if they combine coordinates of time and positions and allow analysis of:

1. Sun 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 - overview for profile angle
5. Radiation impact
6. Shading from some shading devices
7. Availability of natural illumination

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

Sun Angle Calculator

2. Sun Chart
   There is a Sun Chart for each hour of the year (latitude from 23 degrees to 12 degrees). The chart represents the sunrise and sunset times. It shows the duration of the sun above the horizon, the sun’s altitude, and the sun’s azimuth. The time scale is divided into twenty-minute intervals.

3. True Transparent Overlay
   The section shows the angle of the sun. The sun’s angle is shown as a dot on the chart. The dot is labeled with the time of day.

4. Crosshair
   The crosshair is used for marking the position of the sun. It shows the angle of the sun in degrees.

Using the Sun Angle Calculator

Find the latitudes of the structures and then use the sun’s altitude. Determine the Sun Chart and select the True Chart. Mark the time and crosshair and compare.
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Sun Angle Calculator

Using the Sun Angle Calculator – Example A
Building begins in Columbus, Ohio at 60° North latitude. Draw a line for True South. Time is 9:30 AM on April 21 and December 21.
First the Profile Angle, Bearing of Sun and True Altitude.
1. Select 40 degree Sun Chart, place on top, add red Overlay and Cursor. Line up solid Normal to Waders line with True South on Sun Chart.
2. Locate April 21 on the curved black Sun Perimeter and follow arrow until it intersects the Sun Time line for 9:30 AM. This is the Bearing of the Sun for Sun chart.
3. The curved red line intersecting the Position of the Sun is the Profile Angle for that time and date. The marking is 65°.
4. To find the Bearing of the Sun, route the Cursor until a crossing line intersects the Position of the Sun. The black scale on the perimeter of the Sun Chart reduces the Bearing from True South the April 21 in 9:30 AM to 60° East of True South.
5. True Altitude is found on the Cursor where it intersects the Position of the Sun. True Altitude is 47°.

Sun Angle Calculator

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
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Computer Simulation

Software: Square One

Software: Sketch-up
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http://www.susdesign.com/

Sustainable By Design is a small business providing scientific, design, multimedia, and communications services to the environmental community, with a focus on the solar energy, architecture, and green buildings fields. Sustainable By Design has been in business since 1990, and is located in Seattle, Washington.

We offer a number of software design tools (available in the menu in the upper right), and provide consulting services including energy analysis, writing, graphic design, brand development, web design, and software development.

October 2004: New available is the Sunangle Professional Suite, featuring a new, standalone version of sunangle with added features and comprehensive technical documentation for advanced users.

http://www.susdesign.com/sunangle/

http://www.susdesign.com/sunpath/index.html

Please read all instructions and notes before using this calculation tool. ©2002 Christopher Crossfield, christopher@edesigns.com
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.
Sundials

Building a Model

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.
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**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.

**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.
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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.

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.
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GreatBuildings.com

BetterBricks.com

Websites

DesignLight.org
http://www.desiglights.org/skylighting.html

Lighting Research Center
http://www.lrc.rpi.edu/programs/daylightdividends/