Daylighting Introduction: *What is it, Why use it, and How to Use it*

**Daylight Design**

The art and science of 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.

Daylight design 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.
Daylighting Introduction: What is it, Why use it, and How to Use it

Daylight Design

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

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 (FREE LIGHTING)
- Brings the outdoors in
Daylighting Introduction: *What is it, Why use it, and How to Use it*

### The Benefits of Natural Light

- People require changing stimuli to remain sensitive and alert
  - Gazing out the window at distant objects provides relief for the muscles of the eye
  - Constantly changing nature of daylight satisfies our biological and psychological needs for change
  - Comfort requires moderate changes
    - Monotony (repetitiveness) will cause fatigue, but so will overstimulation.
    - Excessive contrast provides emotional appeal, but it also impairs visual performance
    - The sudden appearance of a beam of sunlight on a task will provide momentary change and relief – but if it remains it will cause visual fatigue and stress

### Windows for 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.
Daylighting Introduction: *What is it, Why use it, and How to Use it*

**Daylight and the Perceptual System**

- Daylight is clearly preferred over electric lighting as a source of illumination*
  - Windows are valued for the daylight, view, and ventilation
  - Windowless spaces are generally disliked (particularly for small spaces)
  - People will give up daylight if it affects their visual or thermal comfort, or loss of privacy

---

*Wells (1967), Manning (1967), and Markus (1967) in the UK; Heerwagen and Heerwagen (1986) in the USA; Veitch (1993) in Canada; and Cuttle (2002) in the UK and New Zealand

---

### Preference for daylight or electric light

<table>
<thead>
<tr>
<th>Factor</th>
<th>Daylight Better</th>
<th>Electric Light Better</th>
<th>No Difference</th>
<th>No Opinion</th>
</tr>
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<tbody>
<tr>
<td>For psychological comfort</td>
<td>88%</td>
<td>3%</td>
<td>3%</td>
<td>6%</td>
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<tr>
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<td>79%</td>
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<td>18%</td>
<td>3%</td>
</tr>
<tr>
<td>and pleasantness</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>For general health</td>
<td>73%</td>
<td>3%</td>
<td>15%</td>
<td>8%</td>
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<td>79%</td>
<td>9%</td>
<td>9%</td>
<td>12%</td>
</tr>
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</tr>
<tr>
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<td>For task requiring fine</td>
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<td>30%</td>
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<tr>
<td>observation</td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

*Wells (1967), Manning (1967), and Markus (1967) in the UK; Heerwagen and Heerwagen (1986) in the USA; Veitch (1993) in Canada; and Cuttle (2002) in the UK and New Zealand*
Sunlight: Health and Happiness Closely Linked

Everyone loves a bright sunny space, but who would have thought that those good ole' natural rays could have such a profound impact on you?

Recent studies reveal that natural light not only brightens your home and work environment, but actually boosts your spirits and keeps you healthier.

An Indoor Society

- Lifestyles today have changed to the extent that as much as 90 percent of our time is spent indoors, away from natural light. Daniel F. Kripke, a researcher with the University of California San Diego, surveyed adults in San Diego, who wore wrist meters to register the amount of sunlight they received during the day.
- The study found that the majority was only exposed to sunlight for less than one hour per day and some did not go outdoors at all during a 48-hour period.

Of course, most of us do not have the luxury of being outdoors as much as we would like. That is why daylighting – techniques which optimise the use of natural light to illuminate interiors – is becoming increasingly popular not only for its ability to dramatically transform a room, but also for its natural healing powers.

Lighten Up: Moods and Light Go Hand in Hand

The power of light to rejuvenate the body and mind – treating everything from lethargy to "winter blues" to clinical depression – has been suspected for thousands of years, but only recently have scientific studies revealed evidence of the correlation.

- One of the largest studies on the use of light to treat clinical depression was published in 1992 in the journal *Biological Psychiatry*. Dr. Kripke administered light treatment to 25 depressed hospitalised patients at a VA hospital.
- Patients who were exposed to natural white light were significantly less depressed than those in artificial light.
- An estimated 90 percent of humans suffer from seasonal mood changes during the winter months and up to 10 percent of those suffer from the condition known as seasonal affective disorder, or SAD, characterized by fatigue, gloom, change in appetite, fitful sleep and despair.
- The most effective treatment for these symptoms is, quite naturally, exposure to more light. Studies indicate that the time between sunrise and sundown is the key factor in SAD, rather than the lack of sunny days or cold temperatures.
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**Productivity: Workers Powered by Daylight**

Lighting for all workers has long been a concern in many European countries, where construction codes dictate the maximum distance a worker can be from a window as well as how much of a building’s light must come from the outdoors. (In the Netherlands, for example, that figure is 37 percent.) These ideas are starting to make their way to the United States, reinforced by data showing that the rewards can extend beyond aesthetics to affect the companies’ productivity and bottom lines.

Some examples include:

- Wal-Mart installed skylights in half of its environmental demonstration store in Lawrence, Kans., resulting in significantly higher sales per square foot in the store’s daylit portion.
- A circuit board manufacturing facility in Southern California found a 45 percent decrease in absenteeism among its employees following a renovation project to daylight its work areas.
- Pennsylvania Power & Light reported absentee rates dropped 25 percent after natural light was introduced to its workforce.
- Workers in one area of Boeing stated natural light improved their ability to detect imperfections in jet panels by 20 percent.
- Lockheed Corp. found its facility, designed with natural lighting techniques, accounted for a 15 percent drop in absenteeism, with productivity also claimed to be significantly increased.
- A study at two federal facilities in the Washington D.C. area questioned nearly 2,000 occupants who sat near an exterior window, finding that less expressed dissatisfaction with their workplace than their counterparts in the inner core of the building. The same respondents also had 10 to 15 percent fewer health complaints.

**The Benefits of Natural Light**

- **Effect of Light on the Immune System**
  - Light
  - Dark

- **Mood**
- **Circadian**
- **Seasonal**

- **Immune System**
**Evolution Under the Sun**

All life on earth evolved under both sunlight and darkness. This light and dark cycle not only allowed for various activities, but evolved to regulate all species circadian rhythm – internal biological clock.

![Evolution Chart]

Invented in 1880 - Only 125 years in our environment!

---

**Physiological Effects of Daylight**

- Daylight is an effective stimulant to the human visual system and human circadian system
- **Circadian Rhythms** (also known as your internal clock) are a basic part of life and can be found virtually in all plants and animals, including humans
  - The role of the circadian system is to establish an internal representation of external night and day
  - The internal representation is not a passive response to external conditions, but rather is **predictive to external conditions of conditions to come**!

*Sight is not needed to control Circadian Rhythms!!!*
- as long as the optic nerve is intact, blind people still receive visible light signals
Daylighting Introduction: *What is it, Why use it, and How to Use it*

### Physiological Effects of Daylight

#### Circadian System
- The human circadian system involves three components:
  - An internal oscillator in your brain
  - A number of external (your eyes, your skin) sensors that reset or entrain your internal oscillator
  - A messenger hormone, **melatonin**, that carries the internal “time” information to all parts of the body thru the blood stream
- In the absence of light, and other cues, the internal oscillator continues to operate but with a period longer that 24 hours
- External stimuli is necessary to reset your internal oscillator to a 24 hour period and to adjust for the seasons
- The light – dark cycle between day and night is one of the most potent of the external stimuli for your internal oscillator

### Light and Humans

*For centuries, it was believed that light only effected our visual acuity - our ability to see. Light enters our eye then converted by our cones and rods in our retina to a chemical, that then travels thru the optic nerve to be processed by the brain.*
Daylighting Introduction: *What is it, Why use it, and How to Use it*

### Light and Humans

Recent research suggests that UV wavelengths are read by ganglion cells in our retina, then travel through the optic nerve to the hypothalamus. Our **circadian rhythm** regulates the production of hormones affecting our immune system.

**Photoneuroimmunology**

Light entering the eye stimulates a cascade of hormones and modifies the human immune system.

**Circa**di**an Rhythm**
- Hormonal changes
  - Pineal: sleep/wake
  - Pituitary: growth, blood pressure, reproduction
  - Adrenal: stress
  - Thyroid: metabolism

### Light = Color
Daylighting Introduction: *What is it, Why use it, and How to Use it*

**Light = Color Spectrum**

- Daylight at Noon
- Afternoon Sun
- Full Moon
- Candle
- Incandescent
- Compact Fluorescent
- Tubular Fluorescent
- Metal Halide
- High Pressure Sodium
- PC Laptop
- PC Monitor
- (indigo nightlight)
Daylighting Introduction: *What is it, Why use it, and How to Use it*

**Daylight Spectrum**

Incandescent Lamps and Natural Daylight produce smooth, continuous spectra.

**Color Spectrum**

Plate 12

Plate 13

Plate 14

Plate 15
Daylighting Introduction: *What is it, Why use it, and How to Use it*

**Light and Humans**

*Circadian rhythm* is an approximate daily periodicity, a roughly-24-hour cycle in the biochemical, physiological or behavioral processes. Disruption to rhythms usually has a negative effect.

| Bright visible light (Blue UV Spectrum) blocks the production of melatonin |
| Darkness (No light above 600nm /Red Spectrum) allows production of melatonin |

Circadian Rhythm
- Imbalance
- Jetlag
- Seasonal Depression
- Shift Work Dysfunction
- Sleep Disturbances
- Carbohydrate Cravings
- Confusion/Poor Coordination
- Malaise/Blues
- Susceptible to Disease

Light at Night is a risk factor for Breast and Prostate Cancer

Chronotherapy, the practice of synchronizing medical treatment with body time, is being used to treat...

- Metastatic Cancer
- Melanoma Cancer
- Lung Cancer
- Breast Cancer
- Prostate Cancer
- Future possible studies on Arthritis, Allergies, Diabetes, Cardiovascular Cancer

The Human Immune Response is Circadian

**B cells** – Allergies are worse in the Morning

**T cells and N-Killer cells** – Cancer Treatment is better Evening
Daylighting Introduction: *What is it, Why use it, and How to Use it*

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**The Light-Cancer Connection**

Habits like watching late-night TV and reading in bed are linked to cancer. Here’s how to protect yourself.

By Catherine Guthrie - Catherine Guthrie writes about women's health from her home in 3-land. She once walked 10 miles of the Pacific Crest Trail.

From 1992 to 1999, Eva Schlenkhammer, MD, worked rotating night shifts in a cancer ward in Vienna, Austria. Her shift included 10 on-duty nights in a month in addition to her regular hours; she learned under banks of flickering fluorescent lights through the darkest hours. "I didn’t think much of it," she says, "until two of my colleagues developed cancer. These were healthy women in their 30s. They really had no risk factors, no family history." She couldn't help wondering: Could working late nights be linked to cancer?

Three years later, Schlenkhammer landed a job at Harvard Medical School in the Channing Laboratory—the perfect place to find an answer to that question. The lab is home to the Nurses' Health Study, one of the largest data bases of women's health information ever amassed. She leaps into medical, work, and lifestyle records gleaned from 78,533 nurses. The end result, published in 2001, was startling: Nurses who worked 20 or more years on night shifts had a 34% higher rate of breast cancer, compared with those who worked exclusively day.

Three years after her initial study made headlines, she followed up by radioactively counting 12 new tumors on night-shift workers and cancer risk. These findings, published last September, were even more jaw-dropping than her original work. On average, her project had uncovered a 48% risk in breast cancer among women on the night shift.

Schlenkhammer had discovered something other researchers had suspected for some time: Exposure to light at night appears to raise the risk of several types of cancer. And evidence suggests that night-shift work isn’t the only risk. Watching TV, sitting in front of the computer, or even reading under a lamp can throw a wrench into the body’s cancer-fighting machinery.

Similarly, light at night stands out as one of the body’s most powerful antioxidants, a hormone called melatonin. Because it’s only active at night, melatonin has been dubbed the “hormone of darkness.” It’s the perfect name for a biological superhero. But if melatonin is the body’s superhero, then light is its nemesis, and research suggests it’s giving the upper hand.

---

"Life under fluorescent light is harming prisoners and staff alike"

After years of trying to bring proper light to an English prison, Michaela Wynn-Jones says the authorities seem content to subject people to such glare and gloom.

Society Guardian, Thursday September 20 2002

"I amazed myself to find a dim in a confined space the size of the average bathroom complete with open window, under a humming fluorescent tube that left no available light source. The only way to stop the glare that is “firing your head” is to paint over the plastic light covering with carbon coated paint, or use strobe lights on the ceiling. In the garden over 120 prisoners who are given to stop the prisoners and put into the garden."

A window will not be enough. The one available will be made of glass or glass that does not allow light in. Some have a 200 watt bulb that is not even close. The long term effects of fluorescent lighting make the prisoners feel a sense of isolation where they now shine brightly and because of the constraints of their cells.

Many prisoners and prison staff don’t have to live in this reality. One wonders whether the physical environment of some of us prisons should perhaps carry a government health warning - for inmates and employees alike.

One prison doctor has said that his car would not have natural daylight in the consulting room that he has to work on in his car’s office. McGuire officers use the orange fluorescent over fluorescent light for the same reason as the prisoners do as because the fluorescent glare fills their head.

Fluorescent lighting was not just to come in such generations. It was a terrorist, emergency feature that was only used to enhance work hours in a room during the second world war.

Violence of some and the general public may think prisoners are not supposed to be upset. Inmates are not just about spending offensive services. They are also
Daylighting Introduction: *What is it, Why use it, and How to Use it*

**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
Daylighting Introduction: *What is it, Why use it, and How to Use it*
Daylighting Introduction: *What is it, Why use it, and How to Use it*

**NYC Weather**

<table>
<thead>
<tr>
<th>Cloudy Days</th>
<th>Sunshine</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="Graph" /></td>
<td><img src="image" alt="Graph" /></td>
</tr>
</tbody>
</table>

Based on data reported by over 4,000 weather stations (city-data.com)

**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, 30 fc on the desktop in an average office, 80 fc on a drawing board, and up to 120 fc for display cases in a supermarket. With some thoughtful and innovative design, natural lighting can potentially provide more than enough light for most applications in almost any type of building.
Daylighting Introduction: *What is it, Why use it, and How to Use it*
## 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

A diagram showing the concept of a skylight.
Daylighting Introduction: *What is it, Why use it, and How to Use it*
Daylighting Introduction: *What is it, Why use it, and How to Use it*

**Skylight**

**Use of Daylight**

- **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
Daylighting Introduction: *What is it, Why use it, and How to Use it*

### 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!**

### Strategies in History

![Daylight strategies for different types of buildings types](image)

Churches
- Pantheon
- Roman Small Church
- Gothic St. Anna
- Ronchamp

Modern Schools
- Linear Atrium
- Cross of Hamburg
- Nucleus
- Courtyards

Office Buildings
- Cellular
- Open Plan
- Group Offices
- Group Offices
Daylighting Introduction: *What is it, Why use it, and How to Use it*

### Strategies in History

![Image 1](https://via.placeholder.com/150)

![Image 2](https://via.placeholder.com/150)

![Image 3](https://via.placeholder.com/150)

![Image 4](https://via.placeholder.com/150)

### Alvar Alto

![Image 5](https://via.placeholder.com/150)

![Image 6](https://via.placeholder.com/150)

![Image 7](https://via.placeholder.com/150)

![Image 8](https://via.placeholder.com/150)
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Joost van Santen

http://home.wanadoo.nl/~joostvansanten/index.htm

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### New York Times Building

![New York Times Building](image)

*Figures 1.1 and 1.2: The New York Times Building, designed by James Turrell, incorporates innovative daylighting techniques.*

### James Turrell

![James Turrell](image)

*Figure 1.3: Examples of James Turrell’s works, demonstrating his innovative use of light in architecture.*
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Daylighting Introduction: *What is it, Why use it, and How to Use it*

**Latitude and Longitude**

The World

North America

North America
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Daylighting Introduction: *What is it, Why use it, and How to Use it*

### Site Location

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
- Negative = east of prime meridian

#### Canada
- Ottawa, ON: 45° 0.79° 76° 1.33
- Montreal, PQ: 46° 0.90° 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, United States: 19° 0.33° 99° 1.73
- 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° 0.46° 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° 0.66° 77° 1.34

---

### Solar Path

---
Daylighting Introduction: *What is it, Why use it, and How to Use it*

**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.

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.

Animation showing changing sun path on the 21st day of each month for latitude -32°.
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### Sun Angle: Draw It!

**Table: Solar Angles**

<table>
<thead>
<tr>
<th>Time (h)</th>
<th>Azimuth</th>
<th>Altitude</th>
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</thead>
<tbody>
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<td>117</td>
<td>31</td>
</tr>
<tr>
<td>10.00</td>
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<td>13</td>
<td>14</td>
</tr>
<tr>
<td>17.00</td>
<td>10</td>
<td>10</td>
</tr>
</tbody>
</table>

**Diagram:**

- North
- South
- East
- West
- Protractor
- Sun angles marked for different times of day.
Daylighting Introduction: *What is it, Why use it, and How to Use it*

Sun Angle: Draw It!

\[
dx = \frac{h \cdot \sin(\text{azi})}{\tan(\text{alt})} \\
dy = \frac{h \cdot \cos(\text{azi})}{\tan(\text{alt})}
\]
Daylighting Introduction: *What is it, Why use it, and How to Use it*

**Find the Sun Position**

- Books - Web: Online Generators - Pilkington Sun Angle Calculator

**http://www.susdesign.com/**

*Welcome to Sustainable By Design!*

Sustainable By Design is the consulting firm of Christopher Gruber, Seattle, Washington, USA.

Christopher provides solar engineering, green building consulting, graphic design, and web site design and programming services, primarily within the sustainable energy and architecture fields.

What would you like more information about?

- [Design Tools](#)
- [Consulting Services](#)
- [Christopher & Sustainable By Design](#)
- [Contacting Christopher](#)
- [Solar Cooking](#)

SunAngle Software
Daylighting Introduction: *What is it, Why use it, and How to Use it*

### Susdesign.com: Sun Angle Tools

**Design Tools**
Sustainable by Design provides a suite of shareware design tools on sustainable energy topics:

- **SunAngle**
  - the primary tool for solar angle calculations

- **SunPosition**
  - calculates a time series of basic solar angle data

- **SunPath**
  - visualization of the path of the sun across the sky

**Window Tools**
- **Window Overhang Design**
  - visualization of the shade provided by a window overhang at a given time

### Sun Angle: Draw It!

[Diagram showing cardinal directions: North, South, East, West]
Daylighting Introduction: *What is it, Why use it, and How to Use it*

Yes, there is an App for that!

**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

http://www.sbse.org/resources/sac/
http://www.sbse.org/resources/sac/
Daylighting Introduction: *What is it, Why use it, and How to Use it*

### 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.
**Daylighting Introduction: What is it, Why use it, and How to Use it**

### Sun Angle Calculator

**Using the Sun Angle Calculator**

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

**Determining the Profile Angle**

1. Rotate red Overlay to line up the solid line, "Normal to Window," with the extension of the window marked on the black peripheral scale. "Bearing 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 North 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 line of interest lies between the latitudes of the Sun Charts, and more accurate data is desired, find the Profile Angle for the higher and lower latitudes and interpolate.

**Sun Angle Calculator**

2. **Sun Chart**  
   There is a Sun Chart for each four degrees of North latitude from 34 degree to 52 degree. The Charts are printed at 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 extending 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 over 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 North to the Window where it intersects the scales along the extension of the Sun Chart and Overlay. Its own scale is used to read the True Altitude of the Sun.
Daylighting Introduction: *What is it, Why use it, and How to Use it*

### 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 distances of two other vertical projections and lengths of overhangs.

To find the Bearing of the Sun, rotate the Cursor until its crosshair 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 Sun Aberration**

The Angle of Incidence of the sun to a window is determined by noting the Overlay and 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 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 date.
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.
Daylighting Introduction: *What is it, Why use it, and How to Use it*

### 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 fisheye view of the sky dome*
Daylighting Introduction: *What is it, Why use it, and How to Use it*

### Building a Model

<table>
<thead>
<tr>
<th>One day’s labor</th>
<th>Several weeks labor</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.jpg" alt="Image" /></td>
<td><img src="image2.jpg" alt="Image" /></td>
</tr>
</tbody>
</table>

**Build A Model**

![Image](image3.jpg)
Daylighting Introduction: *What is it, Why use it, and How to Use it*

**Exterior Video**

![Exterior Video Image]

**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.
### 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.
Daylighting Introduction: *What is it, Why use it, and How to Use it*

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.
Daylighting Introduction: *What is it, Why use it, and How to Use it*

**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.
Daylighting Introduction: *What is it, Why use it, and How to Use it*

**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 and fall and bottom is winter.

The colors of the dichroic lamps should be measured and compared to those of this sequence: black (absent), blue (blue), green (green), red (red), yellow (yellow), or all three at once (white). It will also put your knowledge of additive color mixing to the test as students see which shadows are from which color position.

*Note: shadows are the complement color.*

---

*Note: further notes*

1. The study area of the model should be level with the screen, lamp position
2. Make sure the table is in the right position, ground should be marked with the center of the table.
3. Make sure the lamps are pointed at the table.
4. Mount a sundial on the model level in the proper orientation, at a height level with the equator lamp position, to vary interior illumination by moving the rotating mirror a step.
Daylighting Introduction: *What is it, Why use it, and How to Use it*

**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.
Daylighting Introduction: *What is it, Why use it, and How to Use it*

**The Sundial**

![Images of sundials]

*www.shadowspro.com*

**A genuine sundial or astrolabe at your home**

Shadows is a program used to design sundials and astrolabes. It can be used by everybody without any required technical skills. Shadows will calculate everything and print the drawing according the user's preferences. Shadows is used by thousands of users around the world.

**Key points of Shadows**

- Instantaneous drawing of the sun's path for a certain day
- Calculates, draws and prints drawings on real scale
- Simulates, displays and animates the shadow of the object
- Data base of 2000 locations with latitudes, longitudes and text zone
- Export drawings to other drawing or CAD applications (e.g. DXF or DWG format)
- Plane sundials or solar system 0 orientation or inclination
- Adjustable, rotational and solar sundials
- Sunpath and cardinal directions (dusk and dusk)
- Rotation of the astrolabes and the solar clock
- Compasses, solar equinoxes
- Sunset and sunrise times for any location
- Screens and computer screens
- Rotation of the sunpath and solar clock
- Optimization of solar panels orientation
Daylighting Introduction: What is it, Why use it, and How to Use it

NYC Sundial

Computer Simulation
Daylighting Introduction: *What is it, Why use it, and How to Use it*

**Autodesk: Ecotect**

Ecotect is a complete building design and environmental analysis tool that covers the full range of simulation and analytic functions required to truly understand how a building design will operate and perform. It fully allows designers to work easily in 3D and apply all the tools necessary for an energy efficient and sustainable future. Check out its features to learn more.

**Ecotect: Solar Tool**

With its interactive user interface, the Solar Tool makes the process of accurately screening and positioning overhangs, shading devices and louvers easy. This tool helps architects, planners and building owners ensure that they consider the extent of solar generation in buildings, overbuilding in the most appropriate means of shading a window.

**Autodesk: Ecotect**

www.ecotect.com

**Ecotect: Solar Tool**

www.ecotect.com
Daylighting Introduction: *What is it, Why use it, and How to Use it*

Google Software: Sketch-up

Sketch-Up is 3D for everyone.

SketchUp is a software that you can use to create, edit, and save 3D models. It starts from a simple 2D modeling program, which allows even simple people to already create 3D renderings and models. It allows you to make models of buildings, objects, engineering systems, and other 3D models.

You can also add 3D models to your existing models. This feature allows you to add a 3D model to your existing model, which you can then edit, move, or scale as needed. This feature is very useful for creating presentations with 3D models, which can help you to better understand your models. You can also import 3D models created by others.

Sketch-Up: Add Geo Location

This feature allows you to add geographical information to your 3D models. You can add information such as location, altitude, and other geographical data to your models. This feature is very useful for creating presentations with 3D models, which can help you to better understand your models. You can also import geographical data created by others.
Daylighting Introduction: *What is it, Why use it, and How to Use it*

Sketch-Up
Daylighting Introduction: *What is it, Why use it, and How to Use it*

### Sketch-up w/Podium Renderings

![Sketch-up w/Podium Renderings](image)

### 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.
Daylighting Introduction: *What is it, Why use it, and How to Use it*

### 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.

### Type of Daylight Fenestrations

#### Sidelight (Windows)

- **Unilateral Section**
- **Bilateral Section**
Daylighting Introduction: *What is it, Why use it, and How to Use it*

### Side Lights

![Side Light Diagrams]

### Sidelight Rules of Thumb / Tips

- **Quick Tips**
  - Depth ≤ 1.5x Window Height
  - h
  - 1.5h
Daylighting Introduction: *What is it, Why use it, and How to Use it*

### Sidelight Rules of Thumb / Tips

**Quick Tips 2**

**Depth > 1.5 Width**

![Diagram showing depth compared to width](image1)

**Quick Tips 3**

**Rear Room Surfaces**

![Diagram showing rear room surfaces](image2)
Daylighting Introduction: *What is it, Why use it, and How to Use it*

**Sidelight Light Shelf**

This figure illustrates a standard sidelighting 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.
Daylighting Introduction: *What is it, Why use it, and How to Use it*

**Sidelight Light Shelf**

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

**Side Light Shelf**

- Winter
- Summer
- Upward tilted
- Downward tilted
Daylighting Introduction: *What is it, Why use it, and How to Use it*

**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:

<table>
<thead>
<tr>
<th>a. Roof monitor</th>
</tr>
</thead>
<tbody>
<tr>
<td>b. Clerestory</td>
</tr>
<tr>
<td>c. Saw Tooth</td>
</tr>
<tr>
<td>d. Skylight(s)</td>
</tr>
<tr>
<td>e. Atrium</td>
</tr>
</tbody>
</table>

**Roof Lights**
Daylighting Introduction: *What is it, Why use it, and How to Use it*

**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.
Daylighting Introduction: *What is it, Why use it, and How to Use it*

**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.
Daylighting Introduction: *What is it, Why use it, and How to Use it*

### 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.

![Light well example](image)

*A wide cut-off angle allows more of the bright skylight surface to be visible to the occupants.*

---

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.

![Light well example](image)

*A narrow cut-off angle prevents direct view of the bright skylight.*
Daylighting Introduction: *What is it, Why use it, and How to Use it*

### 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.

![Image of light well design](image1)

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

![Image of light well design](image2)

At a 45° cut-off angle created by the light well, the viewer cannot directly see the skylight unless directly looking up.
Daylighting Introduction: *What is it, Why use it, and How to Use it*

### Glazing Materials (*Window Glass*)

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.
Daylighting Introduction: *What is it, Why use it, and How to Use it*

**Daylight Qualities: veiling reflection**

![Veiling Reflection Images]

**Daylight Qualities: a magical sprite**

![Sprite Images]
Daylighting Introduction: What is it, Why use it, and How to Use it

Daylight Qualities: dynamic daylight

Daylight Qualities: daylight prismatically deconstructed
Daylighting Introduction: *What is it, Why use it, and How to Use it*

**Daylight Qualities: leaking light**

**Daylight Qualities: texture revealed by daylight**
Daylighting Introduction: *What is it, Why use it, and How to Use it*

Daylight Qualities: camera lucida / color mapping daylight

Daylight Qualities: dappled light
Daylighting Introduction: *What is it, Why use it, and How to Use it*

**Daylight Qualities: daylight gradient revealed**

![Daylight gradient images](image1)

**Daylight Qualities: varying penumbra**

![Penumbra images](image2)
Daylighting Introduction: *What is it, Why use it, and How to Use it*

Daylight Qualities: carpet of shadow (pattern)

Daylight Qualities: rhythmic daylight
Daylighting Introduction: *What is it, Why use it, and How to Use it*

**Daylight Qualities: a daylight fixture**

- Images of daylight fixtures in various settings.

**Daylight Qualities: daylighting at the edge of the day**

- Images showing daylighting during the early morning or late evening.
Daylighting Introduction: *What is it, Why use it, and How to Use it*