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**

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 effects their visual or thermal comfort, or loss of privacy


## 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>
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<td>For psychological comfort</td>
<td>88%</td>
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<td>3%</td>
<td>6%</td>
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<td>For office appearance and pleasantness</td>
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<td>3%</td>
<td>15%</td>
<td>8%</td>
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<tr>
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<td>79%</td>
<td>9%</td>
<td>9%</td>
<td>12%</td>
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<tr>
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<td>49%</td>
<td>21%</td>
<td>27%</td>
<td>3%</td>
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<tr>
<td>For task requiring fine observation</td>
<td>46%</td>
<td>30%</td>
<td>18%</td>
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</tbody>
</table>

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

### 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.

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### 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:

- Walmart installed skylights in half of its environmental demonstration store in Lawrence, Kansas, resulting in significantly higher sales per square foot in the store’s day lit 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
Daylighting Introduction: *What is it, Why use it, and How to Use it*

**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.

Invented in 1880 - Only 135 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*
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 thru 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.

**Circadian Rhythm**
- **Pineal**: sleep/wake
- **Pituitary**: growth, blood pressure, reproduction
- **Adrenal**: stress
- **Thyroid**: metabolism

---

**OPTICKS: OR, A TREATISE OF THE Reflections, Refractions, Inflexions and Colours of LIGHT.**

By Sir *Isaac Newton*, Knt.

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

**Light = Color**

![Light Spectrum Diagram]

**Daylight Spectrum**

Incandescent Lamps and Natural Daylight produce smooth, continuous spectra.
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**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*

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

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 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 Indiana. She once called 911 for the Pacific Crest Trail.

From 1993 to 1999, Eva Schernhammer, MD, worked rotating night shifts in a cancer ward in Vienna, Austria. Her shifts included 12 all-nighters a month in addition to her regular hours; she labored under banks of flickering fluorescent lights during 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, Schernhammer elected to 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 banks of women's health information ever amassed. The study, published in 2001, was startling: Nurses who’d worked 30 or more years on night shifts had a 30% higher rate of breast cancer, compared with those who’d worked exclusively day shifts.

Three years after her initial study made headlines, she followed up by methodically reviewing 11 new trials on night-shift workers and cancer risk. Those findings, published last September, were even more jaw-dropping than her original work. On average, her peers had uncovered a 48% rise in breast cancer among women on the night shift.

Schernhammer 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 in the wee hours may be enough to throw a wrench into the body’s cancer-fighting machinery.”

Simply put, light at night snuffs out one of the body’s most powerful anticancer crusaders, 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 superpower. But if melatonin is the body’s superpower, then light is its nemesis, and research suggests it’s passing the upper hand.

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

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

Annika Wynn-Jones asks why the authorities seem content to subject people to such glare and gloom.

Imagining living up to 23 years a day in a confined space the size of an average bathroom complete with open toilet, under a humming fluorescent tube that is your only available light source. The only way to stop the glare that's "killing your freshness" is to paint over the plastic light-covering with consumd oil paints, or use opaque paper, or the regulating orange safelight filter the authorities give you in an attempt to stop the headaches and glare.

A window will not be much help; the one available will be made of frosted glass that cuts the light to a barely acceptable level, and may have a 24-hour a day card away from it, cutting the light even more.

Imagine waking in a basement or an office, with virtually no natural daylight left to comfort someone and render fluorescent lighting. Imagine living in an environment where light's never totals dark because of the constraints of "safety."

Many prisoners and prison staff do not have to imagine all that. In their reality. One wonders whether the physical environment of some of our prisons should perhaps carry a governmental health warning for inmates and employees alike.

One prison doctor has so little natural daylight in his consulting room that he had to switch on his lights and close the covering window in order to make the light work. Custodians often have the orange safelight over fluorescent light things in the same way as the prisoners do because the relentless glare gives rise to headaches.

Fluorescent lighting was significant in coming into such general use it was a temporary, emergency fixture that was only ever intended to last for hours working 24 hours a day during the second world war.

Victims of crime and the general public may think prisoners are not supposed to be healthy, but those are not just about healing offenders' health. 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*

**NYC Weather**

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
**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

![Skylight Diagram]
Daylighting Introduction: *What is it, Why use it, and How to Use it*

**Skylight**

![Skylight Diagram]

**Skylight**

![Skylight Diagram]
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 type of buildings types

- **Churches**
  - Pantheon
  - Roman Small Church
  - Gothic Basilica
  - Ronchamp

- **Modern Schools**
  - Linear Atrium
  - Cross of Hamburg
  - Nucleus
  - Courtyard

- **Office Buildings**
  - Cellular
  - Open Plan
  - Group Offices
  - Group Offices
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### Strategies in History

![Images of historical daylighting strategies]
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**Strategies in History**

![Diagram](image)

**Alvar Alto**

![Images of Alvar Alto's work](image)
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### Luis Barragán

[Images of Luis Barragán's work]

### Louis Kahn

[Images of Louis Kahn's work]
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**Louis Kahn**

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**Le Corbusier**

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

Le Corbusier

[Images of Le Corbusier's architectural designs]

Steven Holl

[Images of Steven Holl's architectural designs]
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New York Times Building
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*

### North America

![North America Map]

### United States

![United States Map]
Daylighting Introduction: *What is it, Why use it, and How to Use it*

**New York**

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

### Site Location

<table>
<thead>
<tr>
<th>Country/City</th>
<th>Latitude</th>
<th>Longitude</th>
</tr>
</thead>
<tbody>
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<td></td>
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</tbody>
</table>
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### Solar Path

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.

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

**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.

**Sun Angle: Draw It!**

<table>
<thead>
<tr>
<th>Time</th>
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<th>Altitude</th>
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</tbody>
</table>
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**Sun Angle: Draw It!**

![Sun Angle Diagram]

**Sun Angle: Draw It!**

![Sun Angle Diagram with Calculations]

\[
\begin{align*}
dx &= \frac{h \cdot \sin(\text{azi})}{\tan(\text{alt})} \\
dy &= \frac{h \cdot \cos(\text{azi})}{\tan(\text{alt})}
\end{align*}
\]
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**

Sun Angle Calculator

**Using the Sun Angle Calculator**

Find the interior of the structure under consideration by using the map inside the back cover. Disassemble the Calculator, and select the Sun Chart nearest the latitude. Place Sun on top. Add the red Overlaid and Center 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 percentage of the sun's rays into a room or the length of a shadow cast by an opaque object.

1. Restore red Overlaid to line up the solid line, "Normal to Window," with the center of the window indicated on the black peripheral circle. "Bearings From True South."

2. Locate the curved black Sun Path line for the date being considered. Lines are shown for the 1st, 15th, and 31st of each month. These 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 hourly lines are hours, and the tight 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 Overlaid 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 lower latitude and interpolate.
Daylighting Introduction: *What is it, Why use it, and How to Use it*

### Sun Angle Calculator

2. Sun Chart
   - There is a Sun Chart for each four degrees of North latitude from 24 degree 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 time. 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 wavy 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 Noreast 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.

---

### 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

---

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**

**Bearing of the Sun (Altitude)**

The Angle of the Sun to True South is called Bearing or Altitude. This is also necessary to determine the position and dimensions of this, often 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 180° 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 – Example A**

Building located in Columbus, Ohio at 40° North latitude, with windows facing True South. Time is 9:30 AM on April 21 and December 21.

1. Find the Profile Angle, Bearing of the Sun and True Altitude.
   - Select 40° Sun Chart, place on top, add red Overlay and Cursor. Line up solid Normal to Window line with True South on Sun Chart.
   - 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.

2. The curved red line intersecting the Position of the Sun is the Profile Angle for that time and date. The reading is 60°.

3. 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 00° deg.00 min East of True South.

4. True Altitude is read on the Cursor where it intersects the Position of the Sun. True Altitude is 47°.
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**Susdesign.com: Sun Angle Tools**

**Autodesk: Ecotect**

[Links to Susdesign.com and Autodesk Ecotect]
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**Ecotect: Solar Tool**

With its interactive user interface, the Solar Tool makes the process of accurately sizing and positioning windows, shading devices and louvers easier. This tool helps architects, planners and building services engineers who need to consider the extent of solar penetration into buildings, overshadowing or the most appropriate means of shading a window.

The program uses a flexible, parametric model on which can be placed any number of horizontal, vertical and detached shadows. You can select any date, time or location, seeing immediately the resulting shadows. As well as being able to interactively manipulate the size and shape of the model with the mouse or enter the parameters directly, you can choose to automatically optimize the sizes of any shadows over any range of dates and times you require.

**Computer Simulation**

*Daylight Level Analysis by Radtool V2.0*
Daylighting Introduction: *What is it, Why use it, and How to Use it*

**Google Software: Sketch-up**

SketchUp is 3D for everyone.

SketchUp is a 3D modeling software developed by Google. It is used for creating 3D models of buildings, landscapes, and other projects. SketchUp is known for its user-friendly interface and ease of use, making it accessible to people with varying levels of technical expertise.

**Sketch-Up: Add Geo Location**

SketchUp allows users to add geospatial data to their models, enabling them to create accurate and detailed representations of real-world locations. This feature is particularly useful for architects, urban planners, and designers who need to incorporate real-world geographical information into their projects.
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Sketch-Up

Sketch-up w/Podium Renderings
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Yes, there is an App for that!

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

### Parsons Lighting Lab - Heliodon

- The top light is summer, middle is spring fall and bottom in winter.
- The colors of the discolor lamps should be measured and verified against the colors of the sky.

#### Some notes:
1. The model should be placed on the table.
2. The table should be at the angle of the model and the table.
3. Make sure the table is level with the table.
4. Mount a lamp on the table and observe the light on the table.

#### 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

- the overcast sky simulator
- Testing for the overcast condition occurs in a mirror-box artificial sky.
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**The Sundial**

[Images of sundials and shadows]

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**www.shadowspro.com**

[A screenshot of Shadows Pro software]

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A genuine sundial or astrolabe at your home

Shadows is a program used to design sundials and astrolabes. It can be used by non-technical users as well as by technical professionals. Shadows calculates everything and prints the drawings according the user's preference. Shadows is used by thousands of users around the world.

Key points of Shadows:

- Truly free of charge in its entry level
- The simplest tool for designing a sundial or an astrolabe
- Calculators, draw and prints drawings at real scale
- Simulates, displays and animates the shadow of the style
- Generates views from locations with latitude, longitude and time zone
- Digital drawings to other drawing or CAD applications (e.g. AutoCAD)
- Where sundials with protractor instead of sun imitations or reposition
- Inclinations, cylindrical and hollow sundials
- Week and universal astrolabes (front and back)
- Rotation of the astrolabe and reticles
- Complete solar instruments
- Solar disc with horizon scale
- Graphs of Equinoxes settings
- Optimization of solar panels orientation
Daylighting Introduction: What is it, Why use it, and How to Use it

NYC Sundial

Align directional lamp to create shadow

(shadow shown at 3pm on Spring/Autumn Equinox)

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

Building a Model

*One day’s labor*

- St. Joseph’s Hospital, NIBI

*Several weeks labor*

- Tacoma Art Museum, OSKA, Seattle
# Daylighting Introduction: What is it, Why use it, and How to Use it

<table>
<thead>
<tr>
<th>Build A Model</th>
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<tbody>
<tr>
<td>![Image]</td>
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<tr>
<th>Exterior Video</th>
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<tbody>
<tr>
<td>![Image]</td>
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</table>
Daylighting Introduction: *What is it, Why use it, and How to Use it*

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

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

**Tip 5**

Know true north and latitude.

Draw north arrow on your model.

**Tip 6**

Include accessible large view ports.

Large enough for use cameras or yield a good view of the interior.
Daylighting Introduction: *What is it, Why use it, and How to Use it*

**Tip 7**

Include people or objects for scale.

---

**Sky Simulators**

- Ecklund Hall, ARC Architects, Seattle
Daylighting Introduction: What is it, Why use it, and How to Use it

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.

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

### Type of Daylight Fenestrations

**Sidelight (Windows)**

- **Unilateral Section**
- **Bilateral Section**

**Side Lights**

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

### Sidelight Rules of Thumb / Tips

**Quick Tips 1**

DEPTH ≤ 1.5X WINDOW HEIGHT

![Diagram of Quick Tips 1](image1)

**Quick Tips 2**

DEPTH > 1.5 WIDTH

![Diagram of Quick Tips 2](image2)
Daylighting Introduction: *What is it, Why use it, and How to Use it*

Sidelight Rules of Thumb / Tips

![Diagram of Quick Tips for Sidelight Light Shelf](image)

Sidelight Light Shelf

This figure illustrates a standard sidelighting design concept with vision and daylight glazings separated by an interior light shelf.
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**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.
Daylighting Introduction: *What is it, Why use it, and How to Use it*

### Side Light Shelf

- **Winter**
- **Summer**
- **Upward tilted**
- **Downward tilted**

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

**Roof Lights**

[Images of roof lights]

[Images of roof lights]

[Images of roof lights]
Daylighting Introduction: *What is it, Why use it, and How to Use it*

**Light Well Design**

- **Sloped roof**
- **Flat roof**

**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.**

**Skylight Construction Terminology**

- skylight opening or aperture
- skylight glazing material
- skylight frame
- curb
- roof membrane
- roof structure
- ceiling

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

**Light Wells**

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.*

**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.

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

![Diagram of light well](image1)

A narrow cut-off angle prevents direct view of the bright skylight.

---

**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.

![Images of light well](image2)

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

![Diagram of light well design with text: At a 45° cut-off angle created by the light well, the viewer cannot directly see the skylight unless directly looking up.]

**Light Well Design**

Circular mirrors adhere to the inner walls of a skylight above the dining area, bouncing light and bringing the room yet more illumination.
Daylighting Introduction: *What is it, Why use it, and How to Use it*

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**Joost van Santen**

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

James Turrell

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

### Solar Tubes

[Image of solar tubes]

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

**Daylight Qualities: a magical sprite**

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

Daylight Qualities: daylight prismatically deconstructed

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

### Daylight Qualities: texture revealed by daylight

![Images of various materials and textures illuminated by daylight.]

### Daylight Qualities: camera lucida / color mapping daylight

![Images of buildings and interiors with camera lucida effects.]
Daylighting Introduction: *What is it, Why use it, and How to Use it*

**Daylight Qualities: dappled light**

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

### Daylight Qualities: varying penumbra

![First image of varying penumbra](image1.png)
![Second image of varying penumbra](image2.png)
![Third image of varying penumbra](image3.png)
![Fourth image of varying penumbra](image4.png)

### Daylight Qualities: carpet of shadow (pattern)

![First image of carpet of shadow](image5.png)
![Second image of carpet of shadow](image6.png)
![Third image of carpet of shadow](image7.png)
![Fourth image of carpet of shadow](image8.png)
Daylighting Introduction: *What is it, Why use it, and How to Use it*

### Daylight Qualities: rhythmic daylight

- [Image of rhythmic daylight patterns]

### Daylight Qualities: a daylight fixture

- [Image of daylight fixtures]

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Daylight Qualities: daylighting at the edge of the day