BCA ACADEMY

Solar Modelling

(21st Intake)

School of Graduate Development and Management



The Education and Research arm of the Building and Construction Authority

Solar Modelling

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Topic Overview

1. Passive Design
2. Tutorial on Solar Modeling
3. Tutorial on Daylighting Modeling

Passive Design

Passive Design

- The harnessing of nature's energy to provide for comfort and function without having to tap on power supply from the grid.

- Solar Modelling / Daylighting Modelling / Energy Modelling is effective in assessing the effectiveness of the passive design of a building.

Passive Design

- Principles to apply passive design
  - Reducing Heat Transmittance
  - Passive Solar Cooling
  - Bringing in Daylight

COMFORT

Thermal comfort factors

- Air temperature
- Mean Radiant Temperature
- Air motion
- Relative humidity



Physiological factors

- Activity
- Age
- Health

Insulating factor - clothing

"Thermal comfort - that condition of mind which expresses satisfaction with the thermal environment"

ASHRAE Standard 55

THERMAL COMFORT

- Thermal Comfort
  - "that condition of mind which expresses satisfaction with the thermal environment."

    ASHRAE Standard 55

- Important goal of designers

Passive Design

- Reducing Heat Transmittance
- Passive Solar Cooling
- Bringing in Daylight

Reducing Heat Transmittance

- Less heat entering the building will result in less air conditioning power to keep cool, which is a major consumer of electricity.

HEAT GAIN IN BUILDING

EXTERNAL HEAT SOURCE

- Heat transfer through building walls, windows and roof
- Solar Radiation transmission through glass windows
- Air Infiltration or Ventilation Load

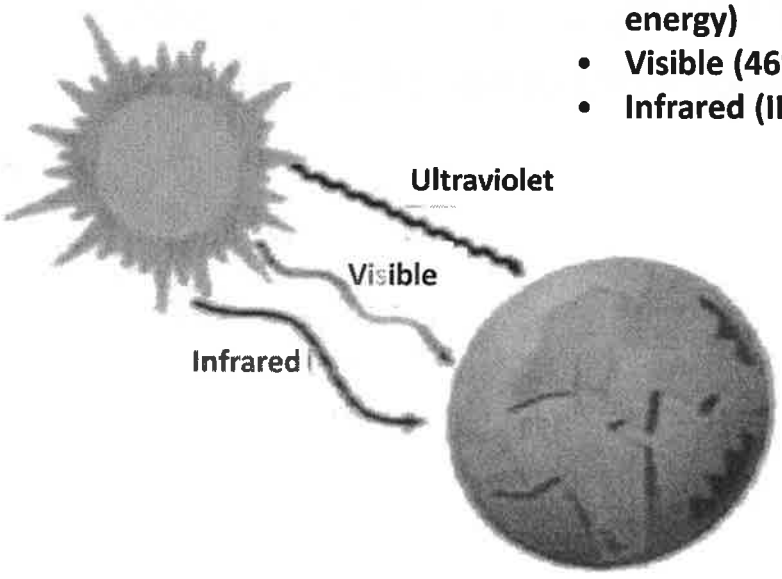
INTERNAL HEAT SOURCE

- Occupancy or Human Load
- Lighting Load
- Equipment – motors, computers, kitchen equipment

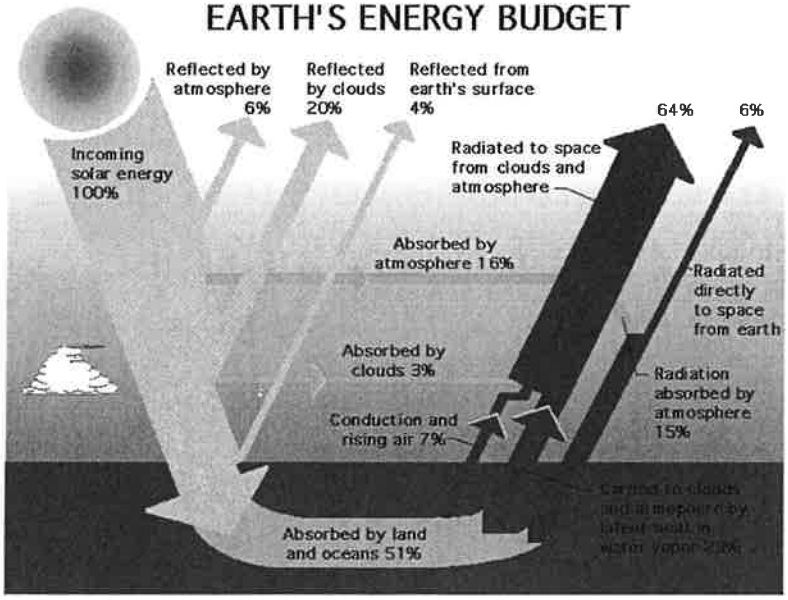
Solar Radiation

The sun transmits solar radiation which comprises

- **Ultraviolet (9% of the total solar energy)**
- **Visible (46%)**
- **Infrared (IR) (45%)**



Solar Radiation



http://asd-www.larc.nasa.gov/erbe/components2.gif

In addition to solar radiation there is terrestrial radiation that is made of heat radiating from the surfaces of materials that have been warmed by the sun

SOLAR HEAT GAIN IN BUILDING

Solar heat - largest heat gain component

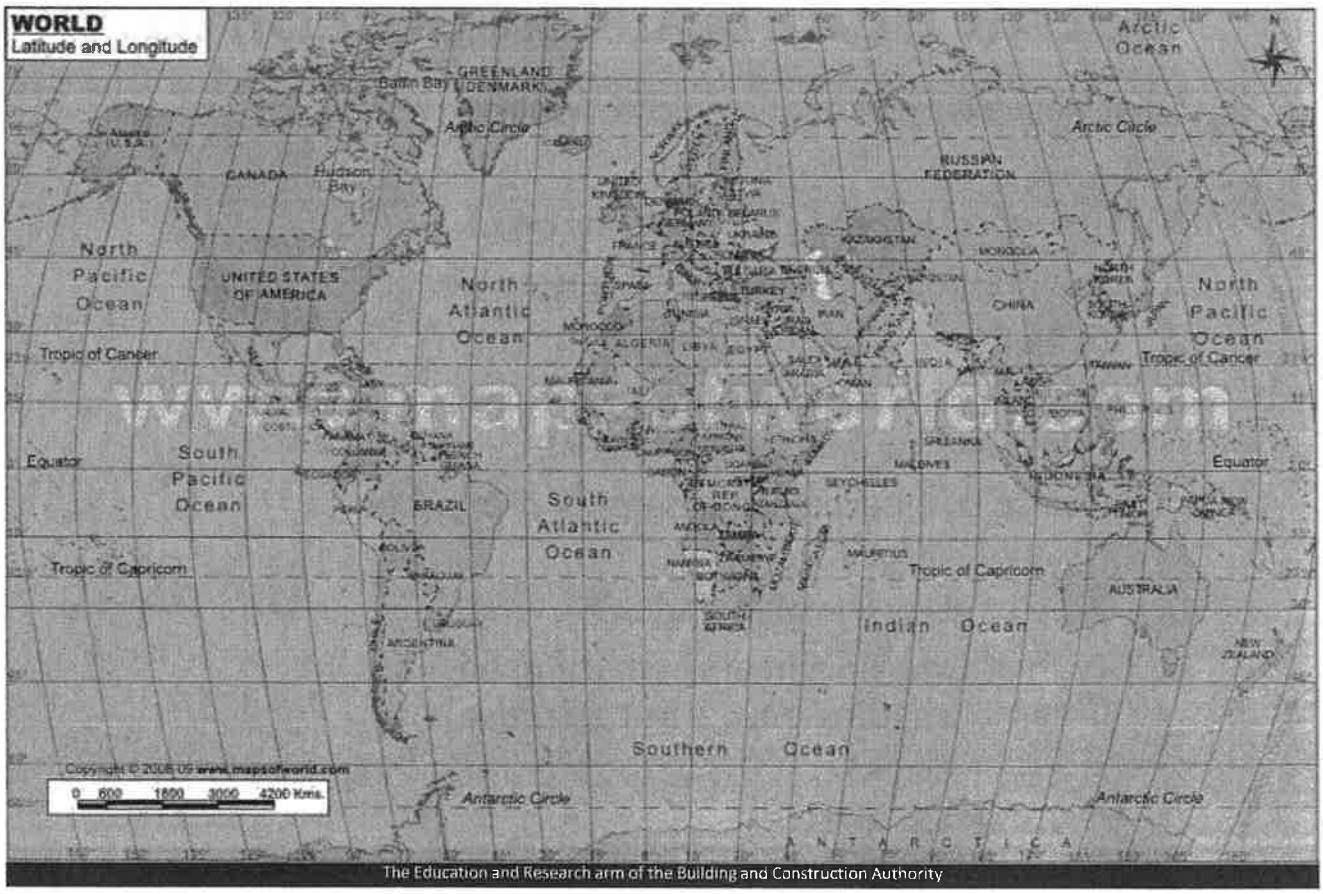
Amount of solar heat gain depends on :

1. Geographical Location (latitude and longitude)
2. Orientation of building
3. Area of wall/roof/ windows exposed to sun (Windows to Wall Ratio - WWR)
4. Choice of external wall material properties (U value W/m^2K)
5. Type of glass (U value and SC)
6. Type of External shading device used (internal shading device not effective)

Building Envelope

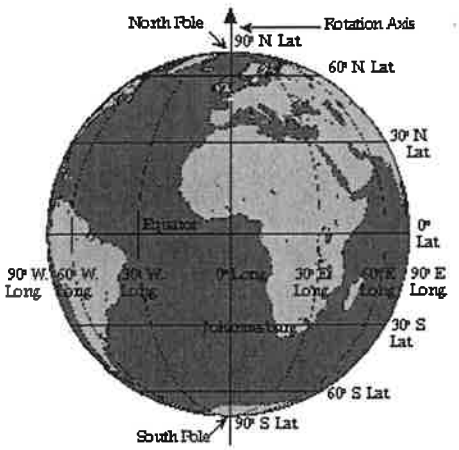
Geographic Location

- Latitude, elevation and the presence of ocean currents are three natural factors that affect the temperature at a particular location.



Geographic Location

- Latitude
  - Areas close to the equator, or 0° latitude, receive the direct rays of the sun. These direct rays provide the most radiant energy.
  - Areas near the equator have a warm climate.
  - Polar regions have a cold climate.

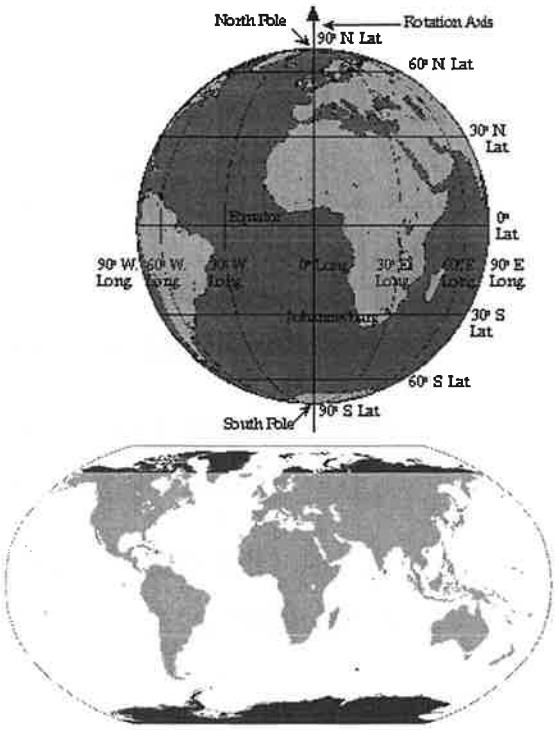


Geographic Location

- Climate Zones
  - The Earth's climate can be divided into general climate zones according to average temperatures.
  - 3 major climate zones on the Earth are
    - Polar
    - Temperate
    - Tropical

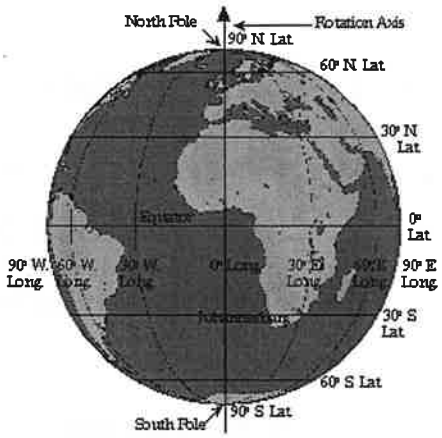
Geographic Location

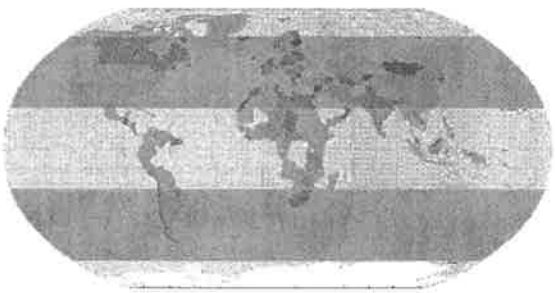
- **Polar Zones**
  - Extends from the pole to about 60° latitude
  - Ave yearly temperature is below freezing
  - Receive less intensive solar radiation



Geographic Location

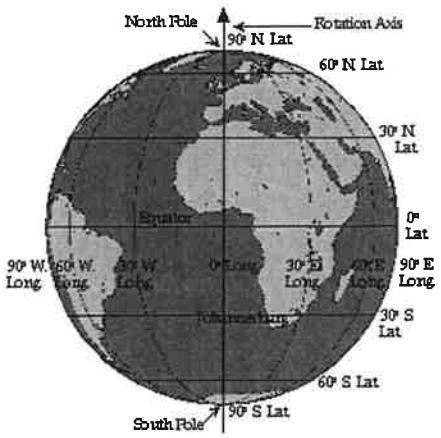
- **Temperate Zones**
  - Between 60° and 30° latitude
  - In the areas of the temperate zones farther from the equator, snow is common in the winter
  - In the areas of the temperate zones closer to the equator, rain normally falls all year round.
  - Ave temperatures range from 5°C to 20°C

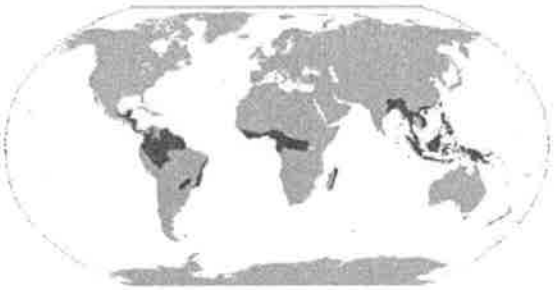




Geographic Location

- **Tropical Zones**
  - Extend from 30° to the equator
  - Also known as low-latitude climates
  - High temperatures and high humidity
  - The ave. temperature during the coldest month of the year does not fall below 18°C





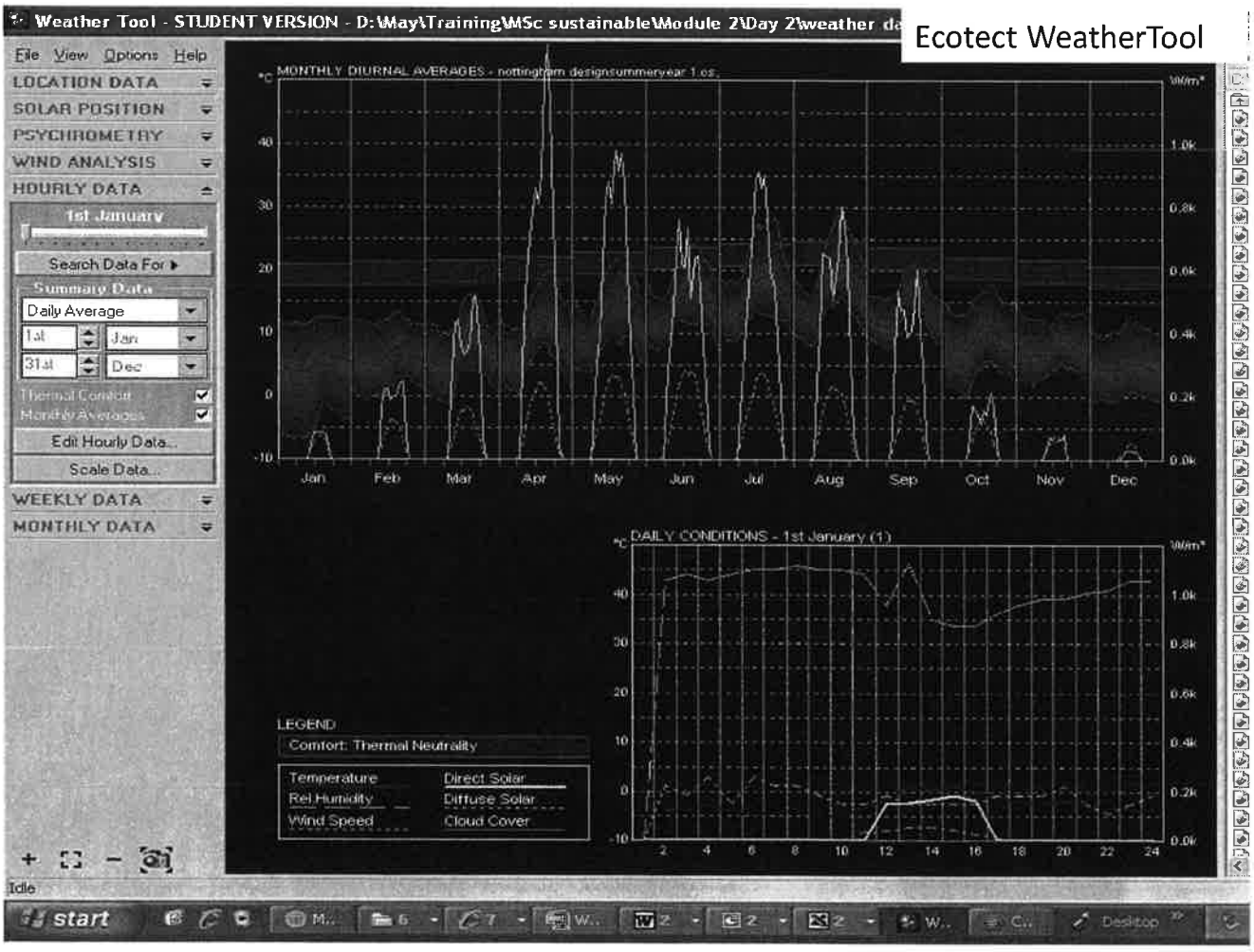
Weather data

- Energyplus
  - https://energyplus.net/weather

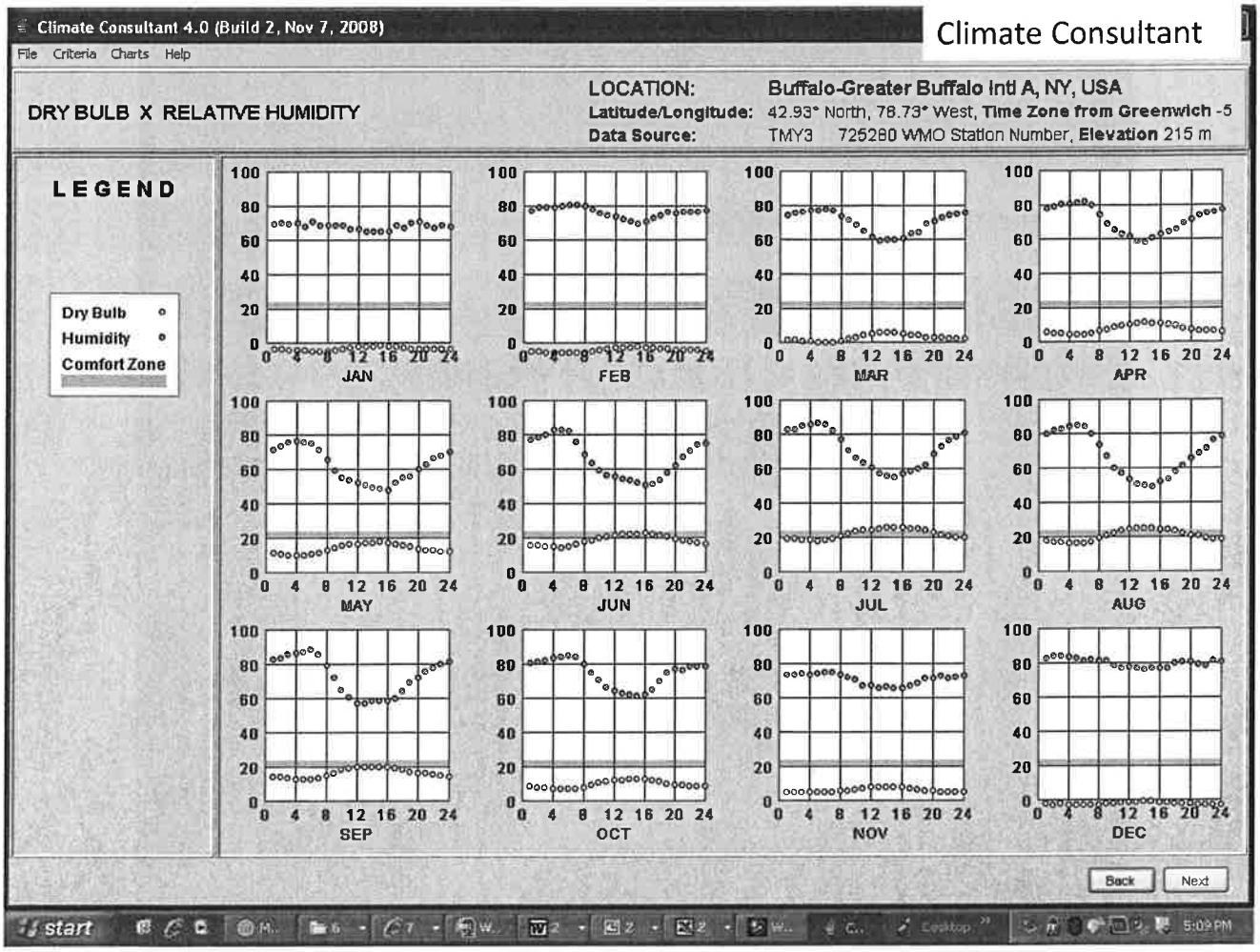
(Go to Google > Type Energyplus weather data)

Weather data

- To understand the data better, need to be able to visualise them
  - Ecotect WeatherTool
    - *.wea
  - Climate Consultant
    - http://www.energy-design-tools.aud.ucla.edu/
    - *.epw



Ecotect WeatherTool



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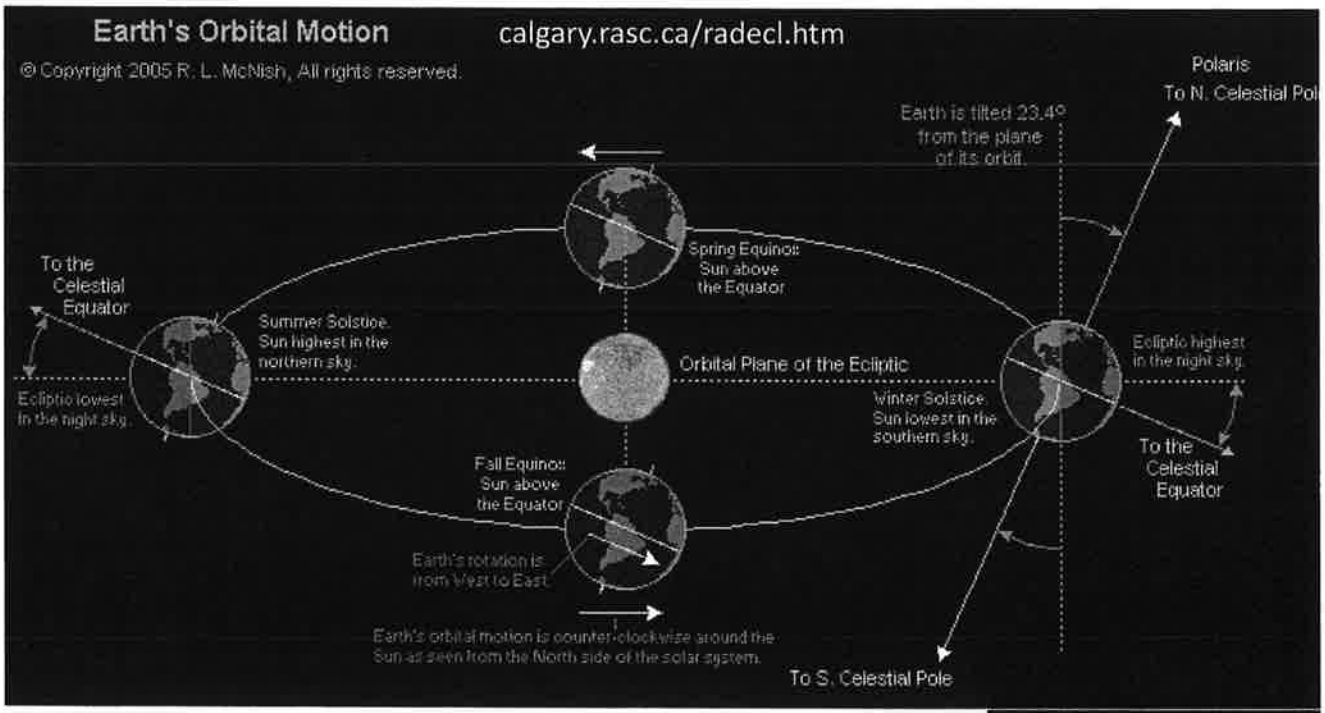
Sun Exposure

- SUN PATH
  - The relative position of the sun is a major factor in the heat gain of buildings
  - Sun path is the seasonal-and-hourly positional changes of the sun (and length of daylight) as the Earth rotates, and orbits around the sun

ADEMY


How does the Earth rotate and orbit the Sun?


Earth's Orbital Motion
calgary.rasc.ca/radecl.htm
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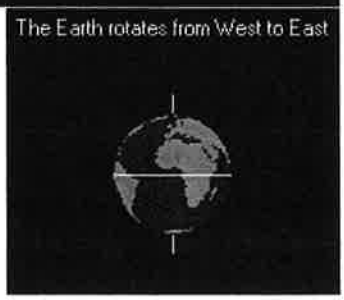
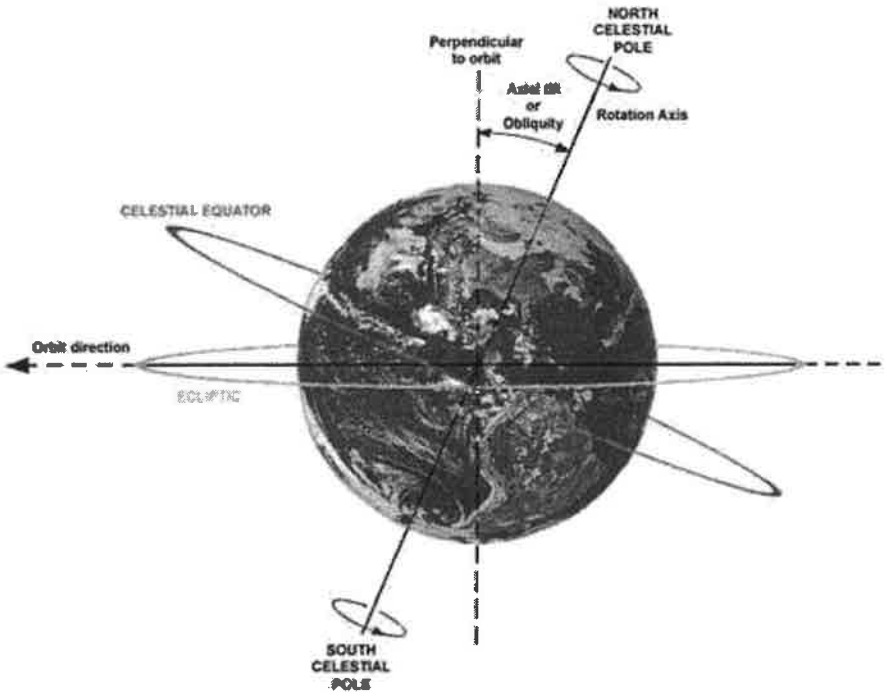
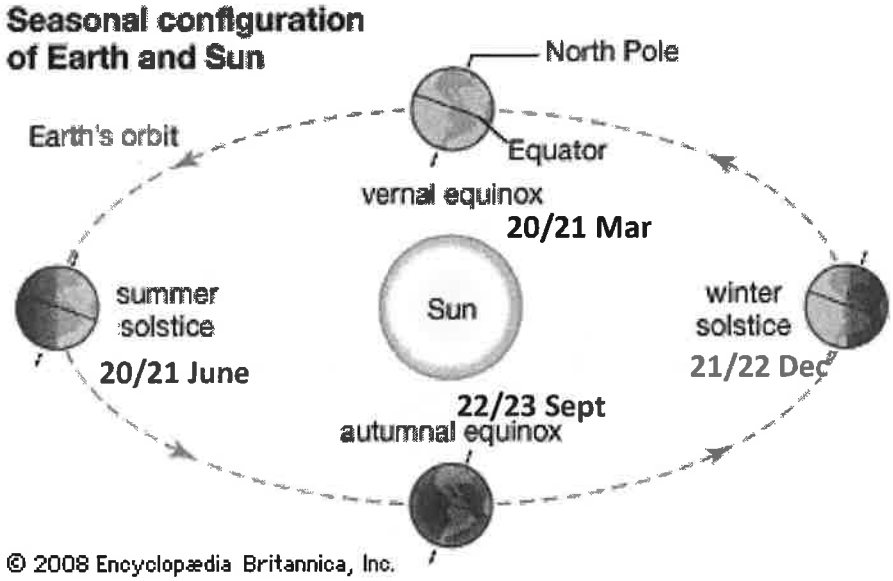
Polaris
To N. Celestial Pol
Earth is tilted 23.4°
from the plane
of its orbit.
Spring Equinox
Sun above
the Equator
To the
Celestial
Equator
Summer Solstice
Sun highest in the
northern sky.
Orbital Plane of the Ecliptic
Ecliptic highest
in the night sky.
Ecliptic lowest
in the night sky.
Winter Solstice
Sun lowest in the
southern sky.
To the
Celestial
Equator
Fall Equinox
Sun above
the Equator
Earth's rotation is
from West to East.
Earth's orbital motion is counter-clockwise around the
Sun as seen from the North side of the solar system.
To S. Celestial Pole


The Earth rotates from West to East



http://www.sciencebuddies.org

Equinox and Solstice



3.EarthSunRelationships.mov

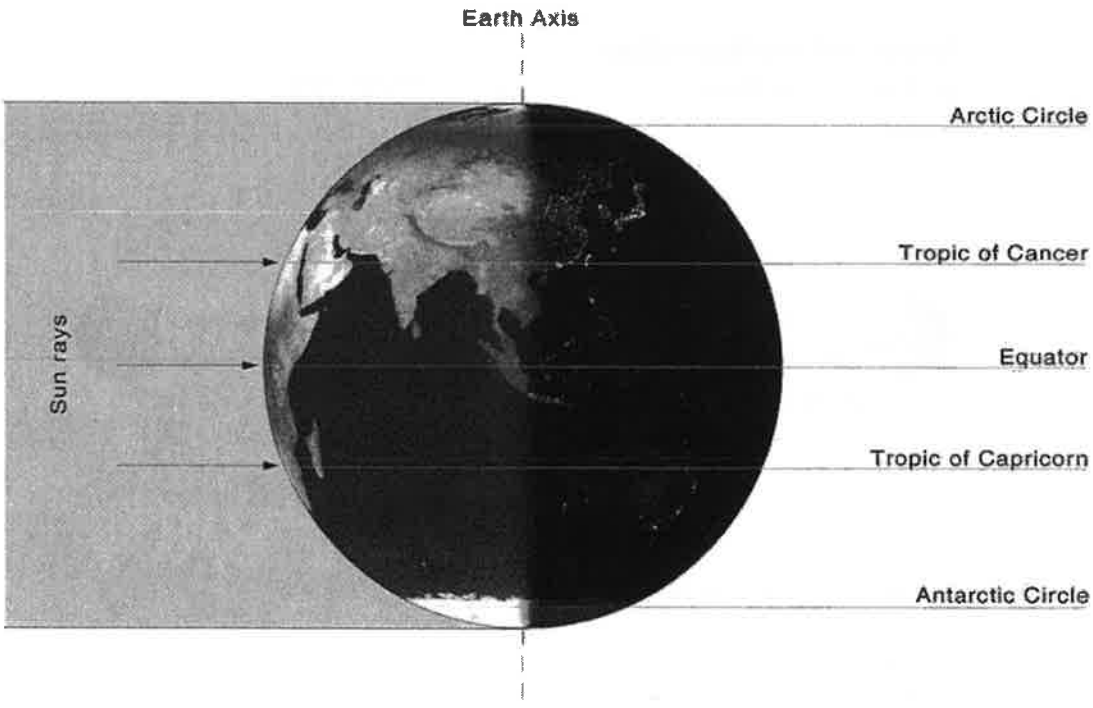
http://www.britannica.com

Equinox

- An **equinox** occurs twice a year, when the tilt of the Earth's axis is inclined neither away from nor towards the Sun: the centre of the Sun being in the same plane as the Earth's equator
- The name "equinox" is derived from the Latin, means 'equal' 'night', because around the equinox, the night and day are approximately equally long
- For northern hemisphere in 2010:
  - Spring Equinox – 20 Mar
  - Autumn Equinox – 23 Sept

http://en.wikipedia.org/wiki/Equinox

Equinox

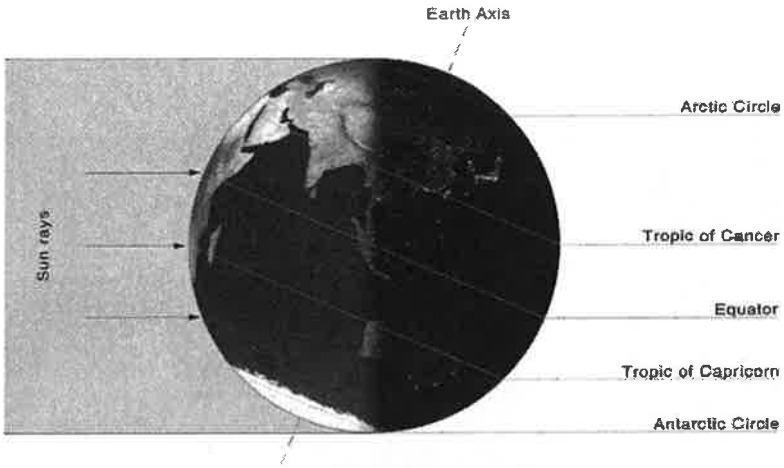


Solstice

- A **solstice** happens twice each year, when the tilt of the Earth's axis is most inclined toward or away from the Sun

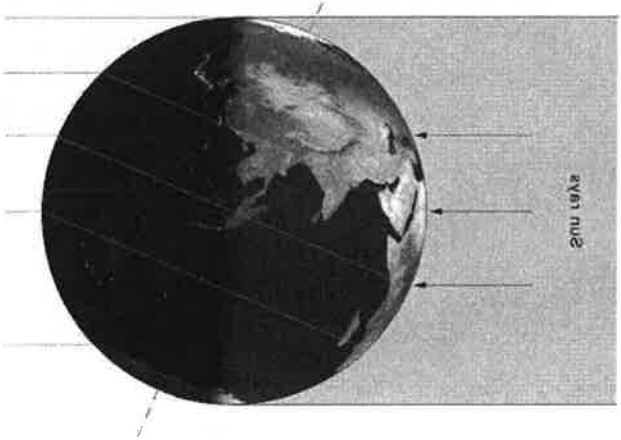
- For northern hemisphere in 2010:
  - Summer Solstice – 21 June
  - Winter Solstice – 21 Dec

http://en.wikipedia.org/wiki/Solstice



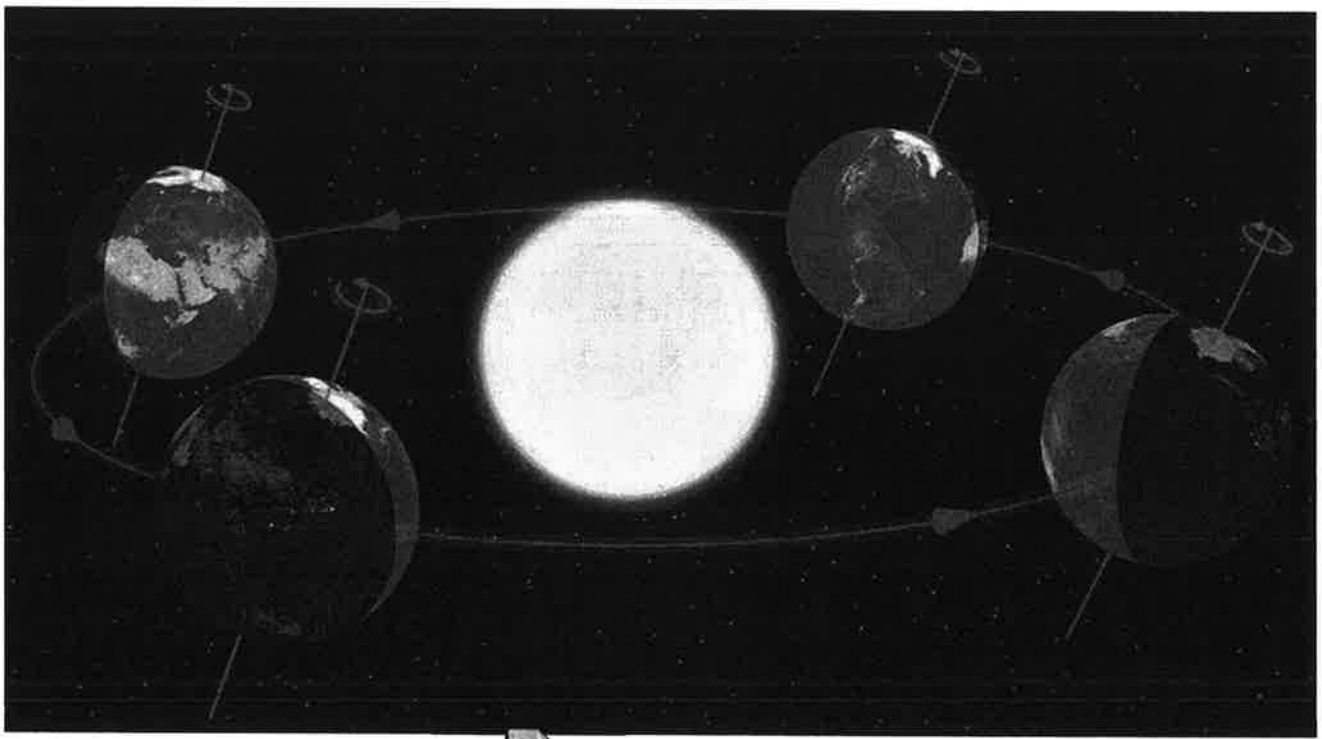
Winter Solstice

Earth Axis



Summer Solstice

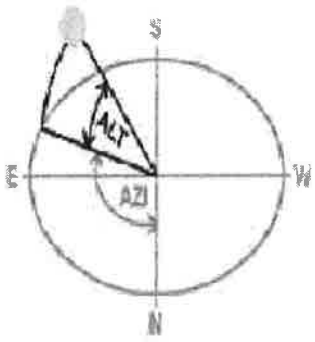
date and time of solstices and equinoxes								
year	Equinox Mar		Solstice June		Equinox Sept		Solstice Dec	
	day	time	day	time	day	time	day	time
2004	20	06:49	21	00:57	22	16:30	21	12:42
2005	20	12:33	21	06:46	22	22:23	21	18:35
2006	20	18:26	21	12:26	23	04:03	22	00:22
2007	21	00:07	21	18:06	23	09:51	22	06:08
2008	20	05:48	20	23:59	22	15:44	21	12:04
2009	20	11:44	21	05:45	22	21:18	21	17:47
2010	20	17:32	21	11:28	23	03:09	21	23:38
2011	20	23:21	21	17:16	23	09:04	22	05:30
2012	20	05:14	20	23:09	22	14:49	21	11:11
2013	20	11:02	21	05:04	22	20:44	21	17:11
2014	20	16:57	21	10:51	23	02:29	21	23:03
2015	20	22:45	21	16:38	23	08:20	22	04:48
2016	20	04:30	20	22:34	22	14:21	21	10:44
2017	20	10:28	21	04:24	22	20:02	21	16:28

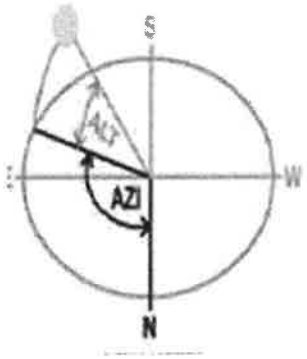


7.Sunangle.mov

Position of the Sun

- The sun's apparent position in the sky vault is defined by 2 angles





Altitude is the angle between the sun and the ground, measured in the vertical plane. It ranges from 0° to 90°

- Any point on the horizon has zero altitude
- Zenith has an altitude of 90 °

Azimuth is the angle between the sun's projection and the North

- North: 0 or 360°
- East: 90°
- South: 180°
- West: 270°

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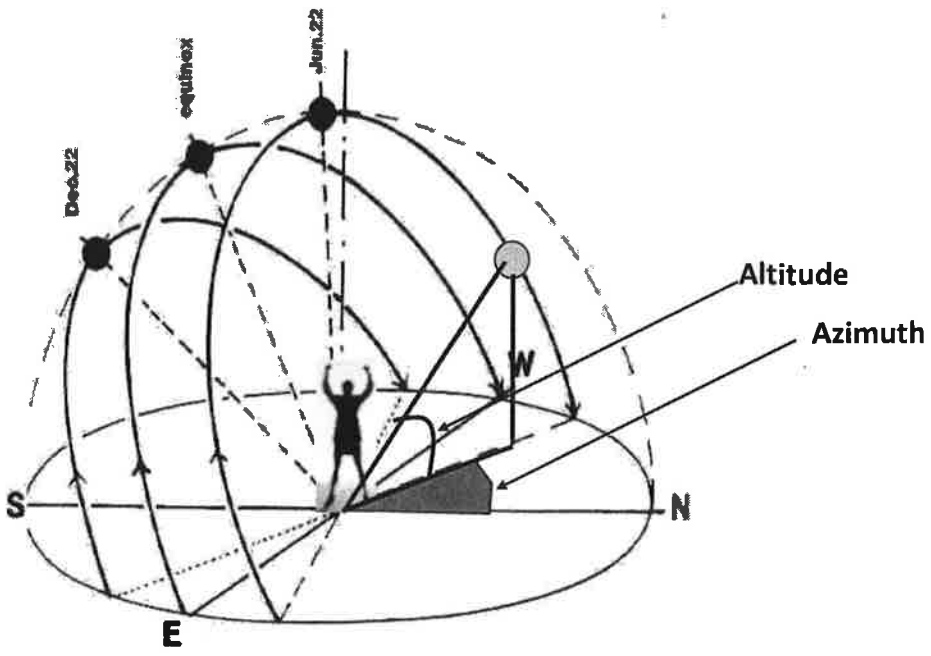
Position of the Sun



NORTHERN HEMISPHERE

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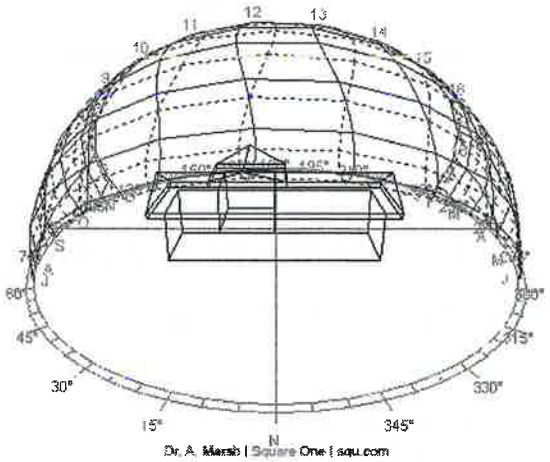
Sun path Diagrams

- Represents annual changes in the path of the Sun through the sky within a single 2D diagram
- The solar altitude and azimuth can be read off directly for any time of the day and day of the year

Note that this diagram is for a location in Southern Hemisphere



http://squ1.org/wiki/Sun_Path_Diagram

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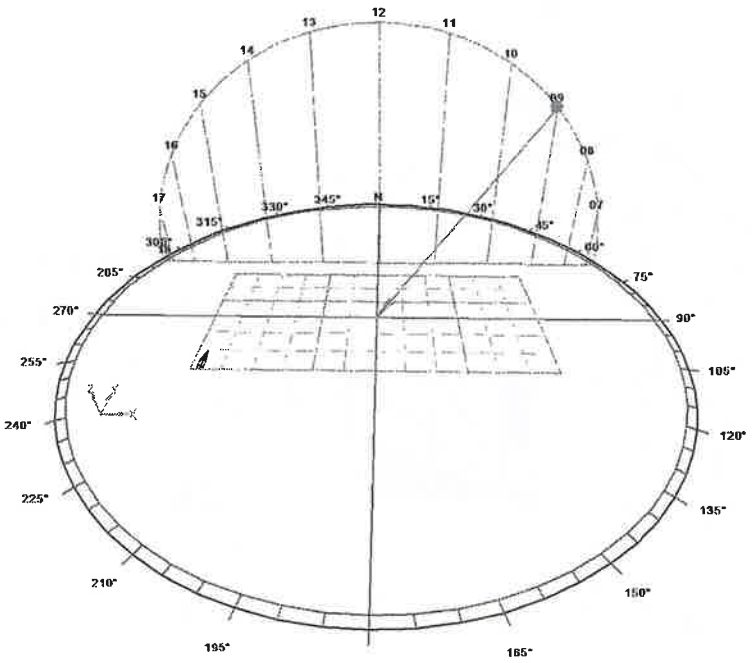
Daily Sun Path – Summer Solstice

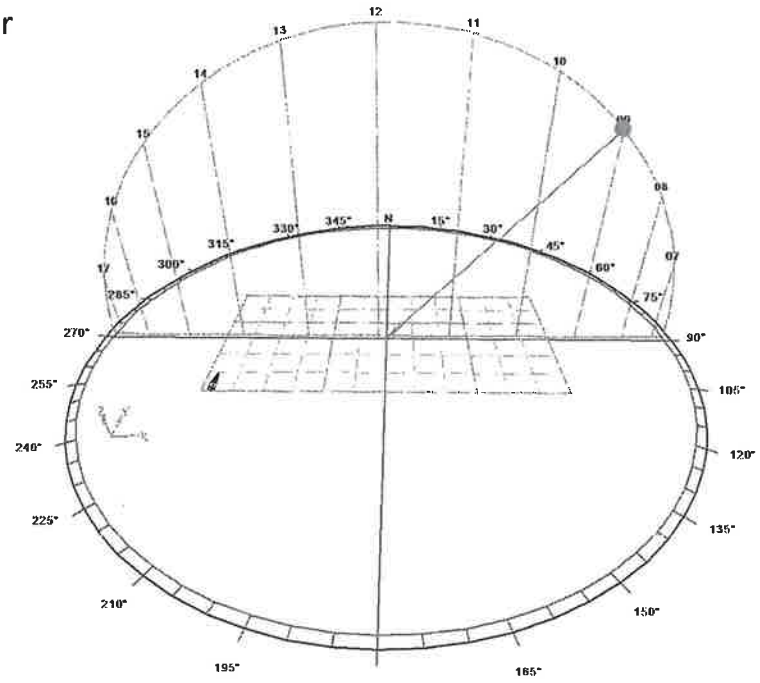
At equator



SUN to SUN

Daily Sun Path – Autumn Equinox

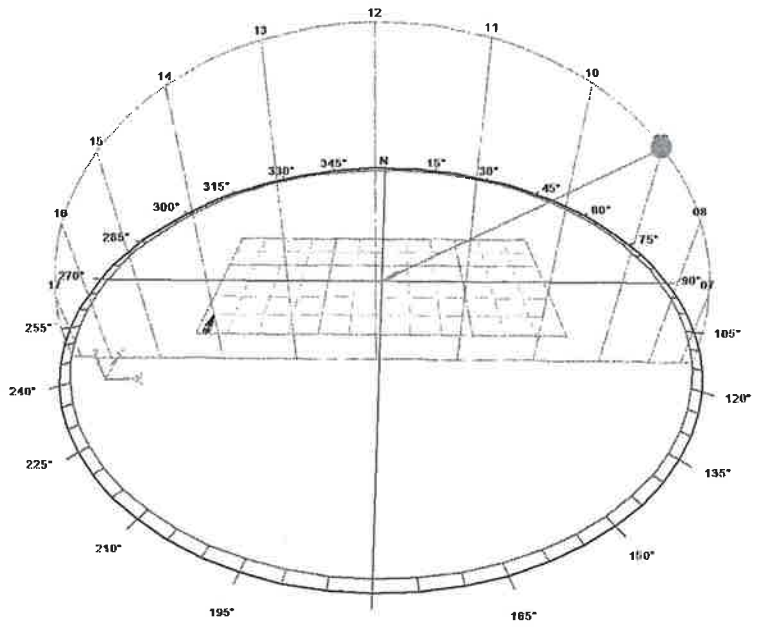
At equator



Sept

Daily Sun Path – Winter Solstice

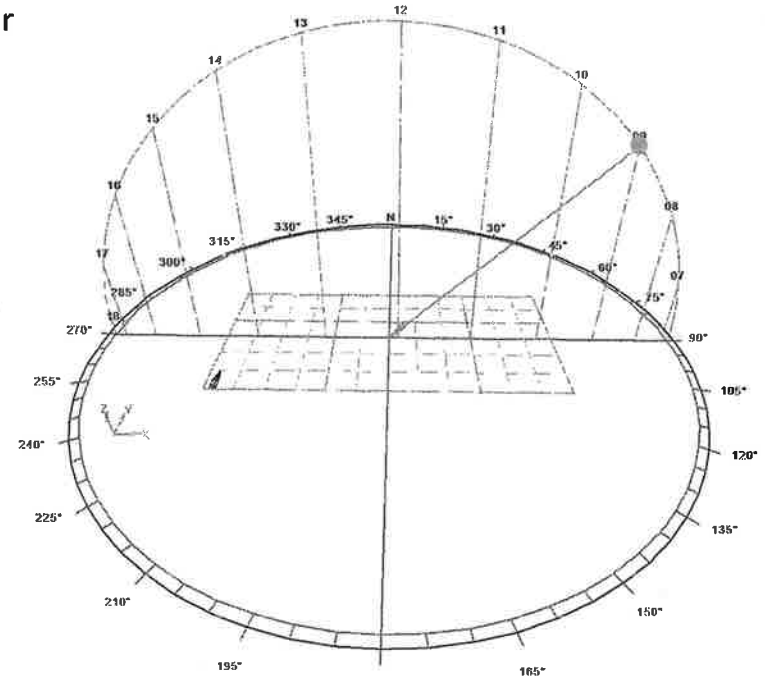
At equator



SE to SW

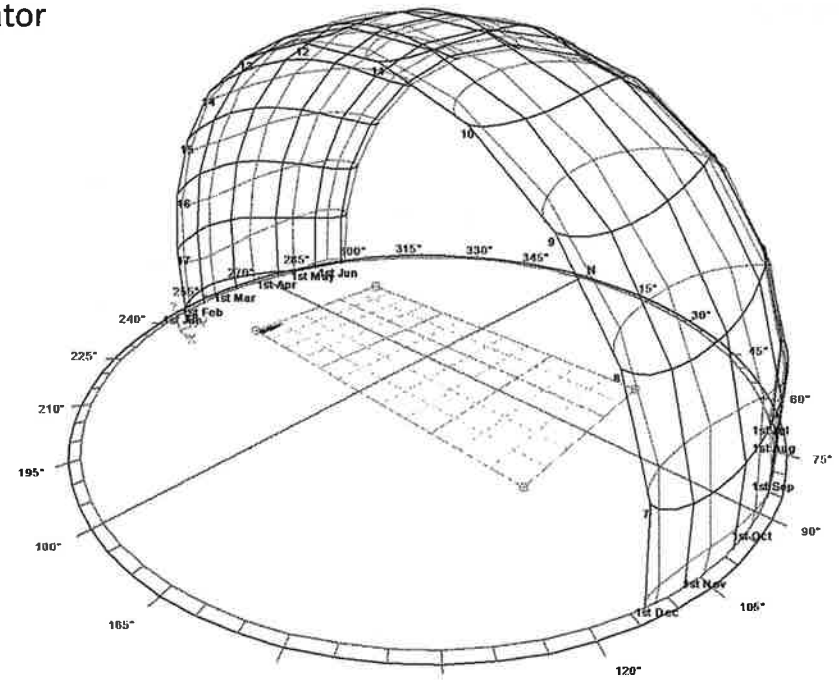
Daily Sun Path – Spring Equinox

At equator

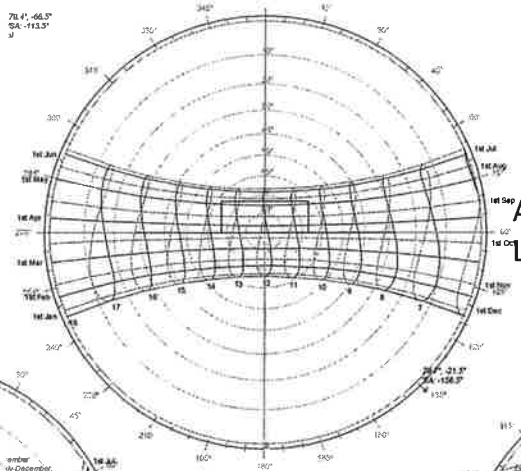


Annual Sun Path

At equator

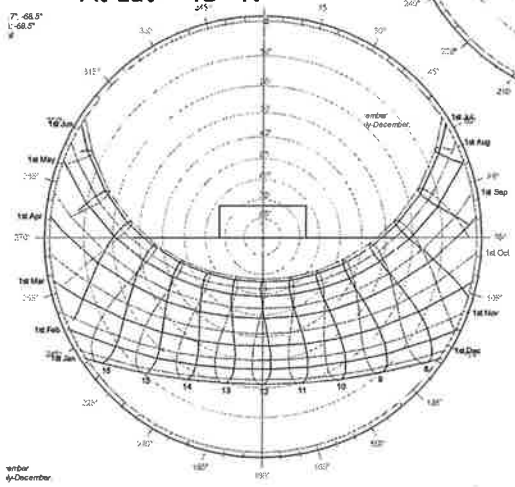


Stereographic Sun path Diagrams

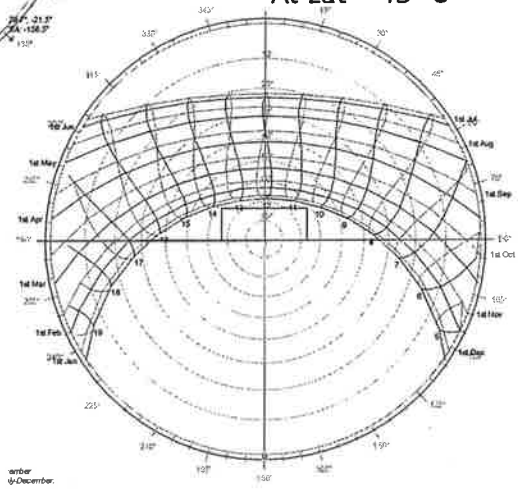


At equator
Lat = 0°

At Lat = 45° N



At Lat = 45° S



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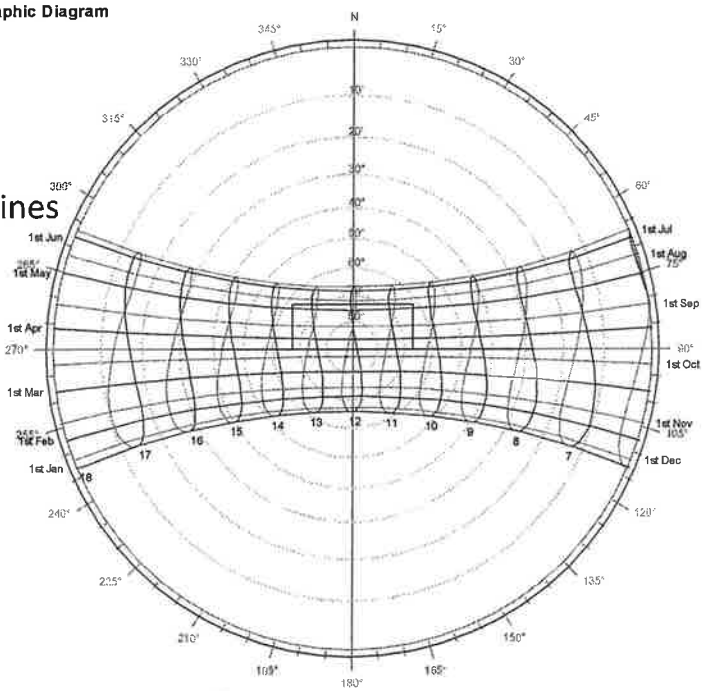
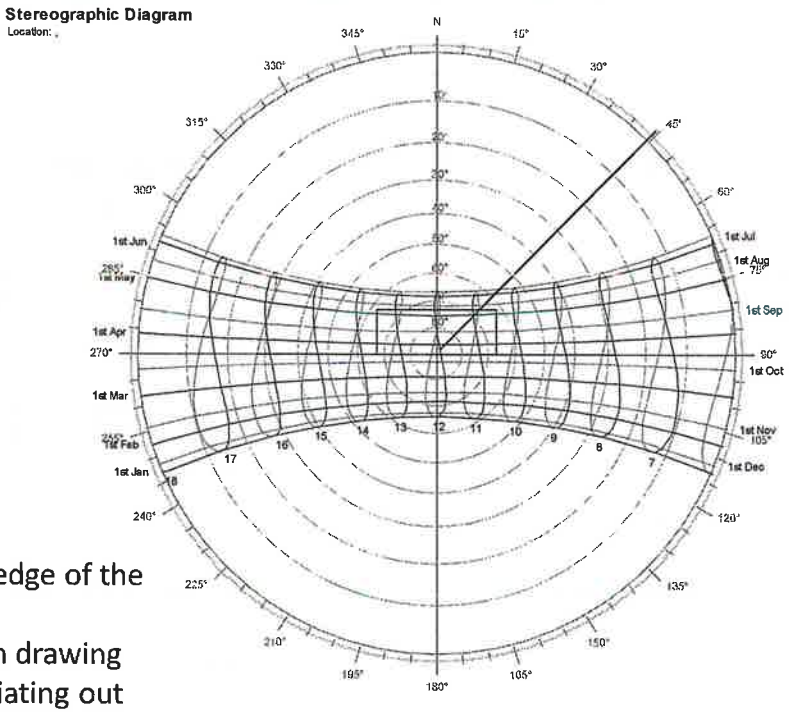
Stereographic Sun path Diagram



Altitude Lines

Altitude angles are represented as concentric circular lines

Stereographic Sun path Diagram

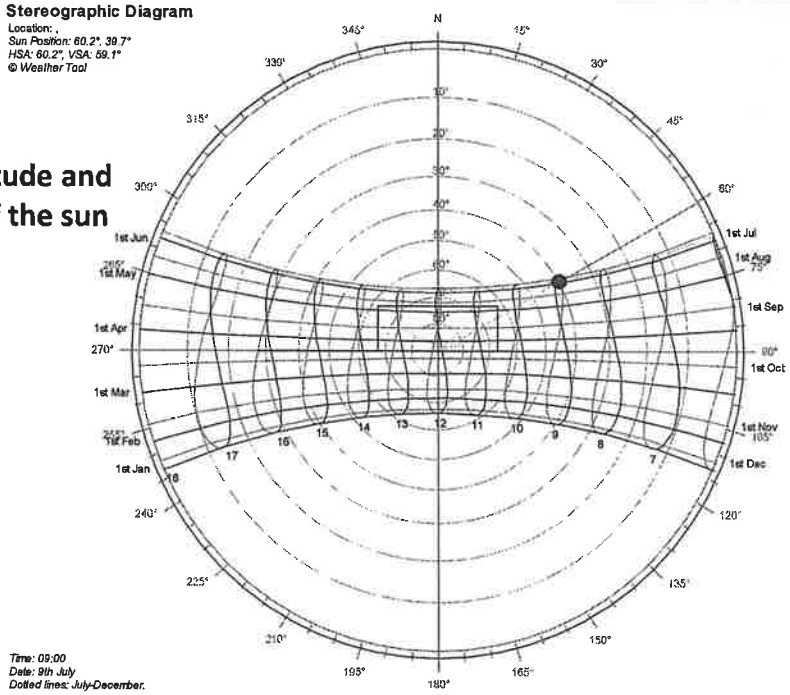


Azimuth Angles

- Run around the edge of the diagram
- Can be read from drawing straight lines radiating out from the centre

Stereographic Sun path Diagram

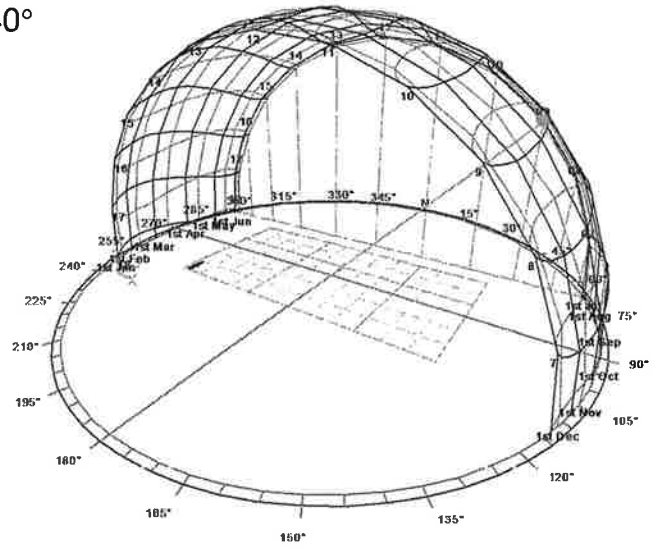
What are the altitude and azimuth angles of the sun at this position?



solid line - Sun [illegible] June
[illegible] July to Dec

Sun position

Altitude: 60°
Azimuth: 40°



Sun position

Altitude: 60°
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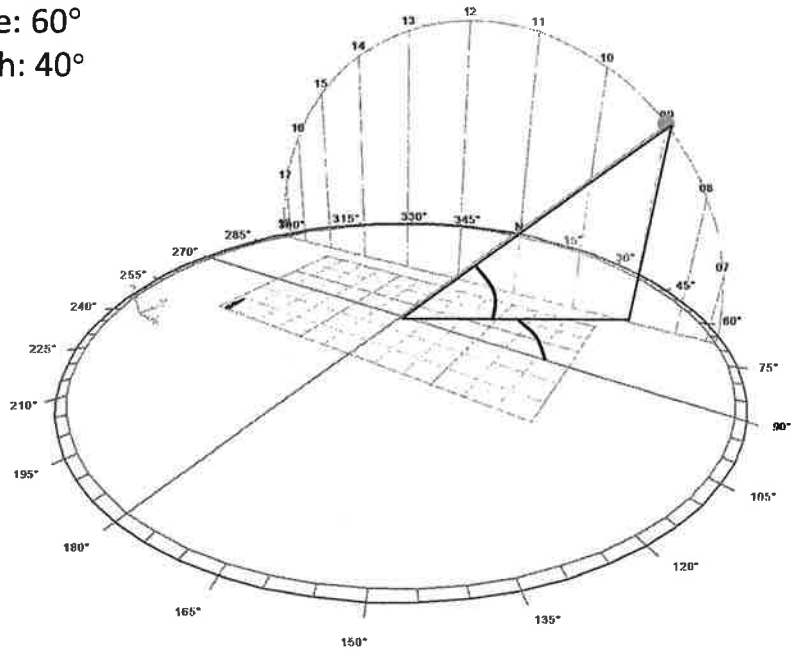

Stereographic Sunpath Diagram

Relating Sun Positions with day and time of the year

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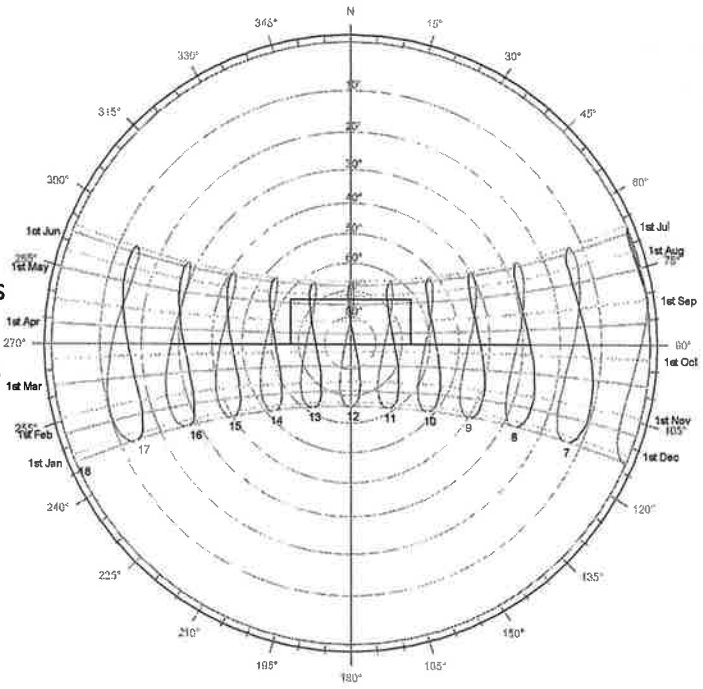
Stereographic Sunpath Diagram

Month Lines

- Represent the path of the sun on a particular month
- 12 lines, each showing 1st day of the month
- Jan to June shown as solid lines
- July to Dec shown as dotted lines

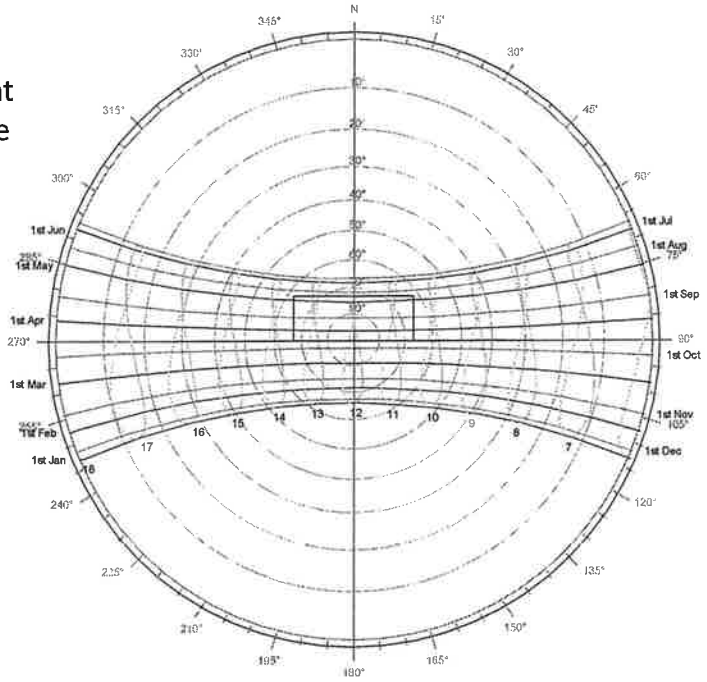


The Education and Research arm of the Building and Construction Authority

Stereographic Sunpath Diagram

Hour Lines

- Represent the position of the sun at a specific hour of the day
- Dotted portion indicates the sun position in the 2nd half of the year



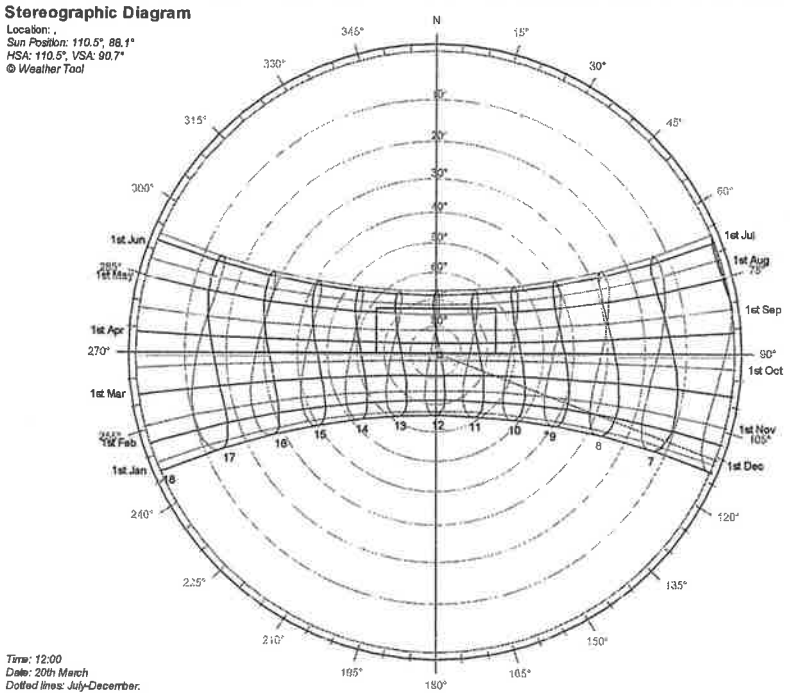
Stereographic Sunpath Diagram

For the location of

– Latitude = 0° , Longitude = 0°

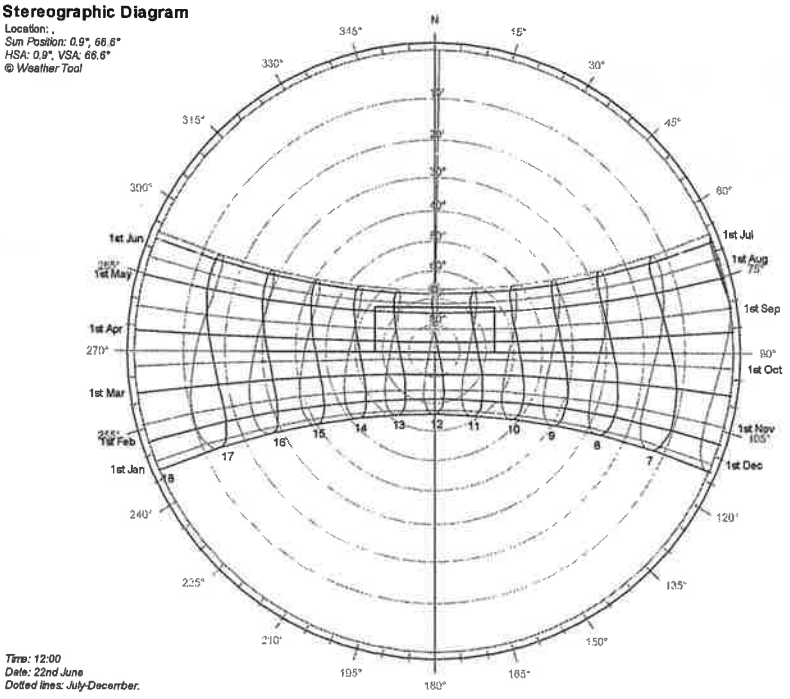
- Find the position of the sun on the 2 solstices and 2 equinoxes, at 12pm

Stereographic Sunpath Diagram – At 0°



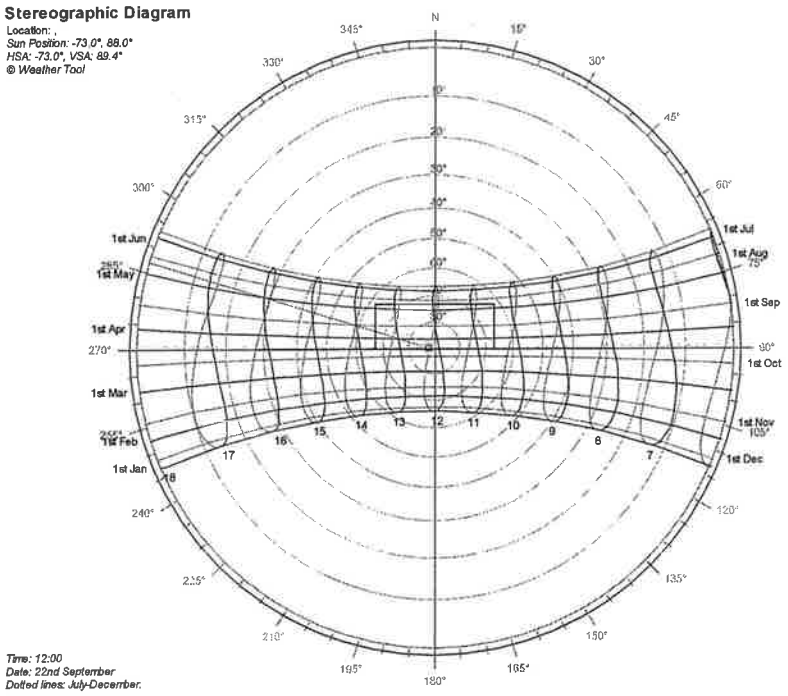
Spring Equinox

Stereographic Sunpath Diagram – At 0°



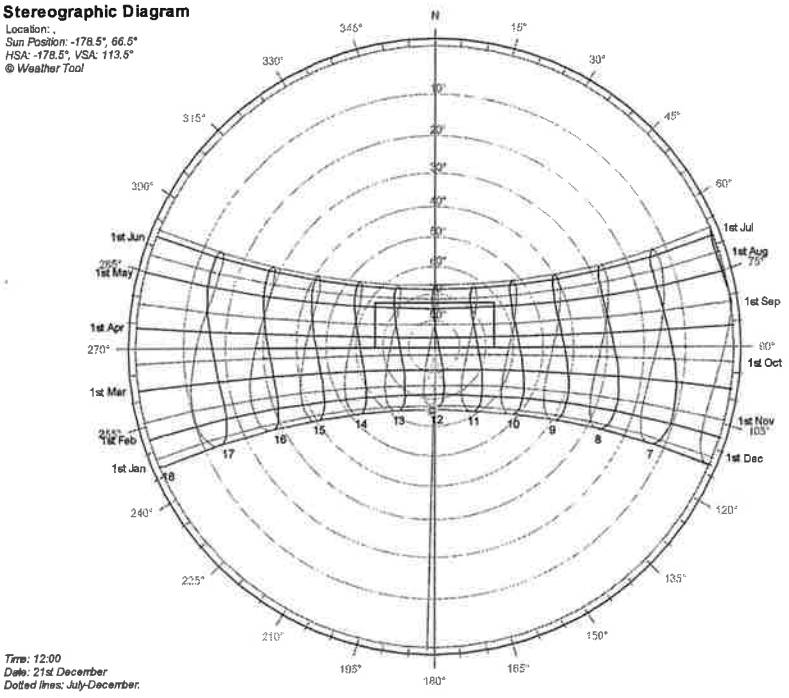
Summer Solstice

Stereographic Sunpath Diagram – At 0°



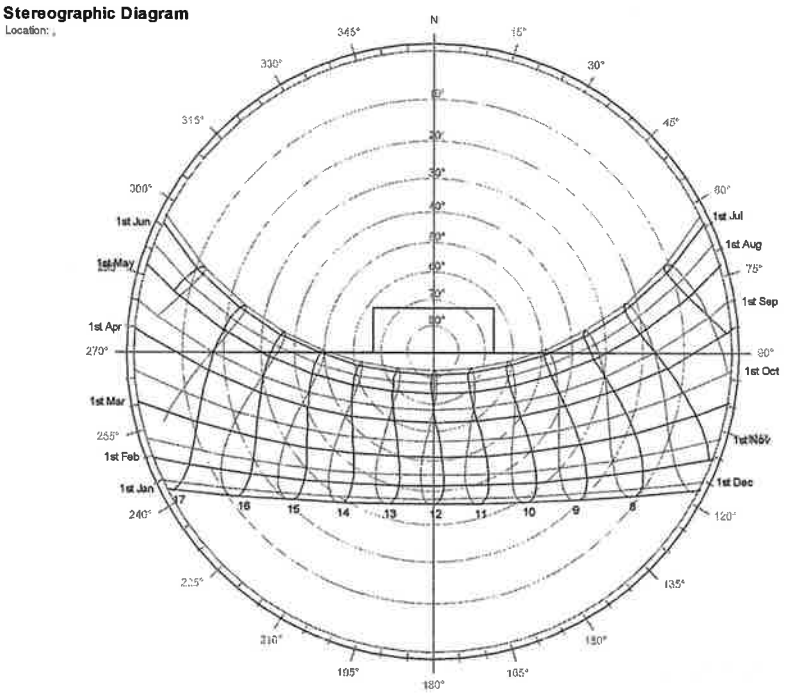
Autumn Equinox

Stereographic Sunpath Diagram – At 0°

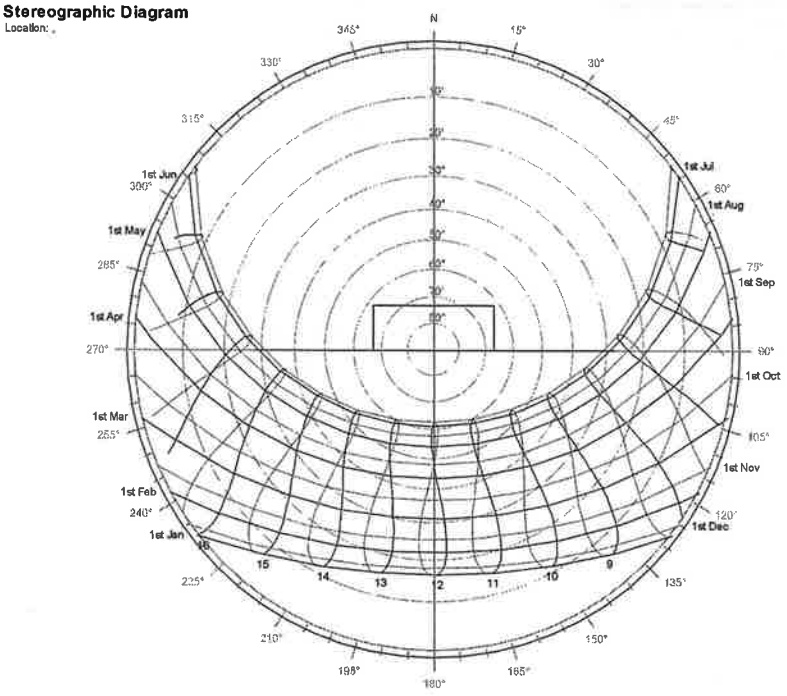


Winter Solstice

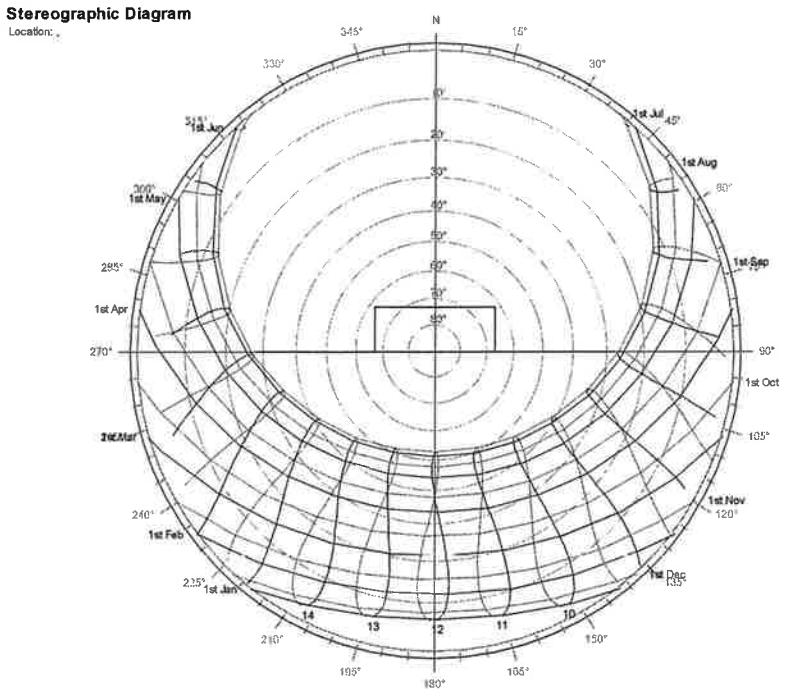
Stereographic Sunpath Diagram – At 30°N



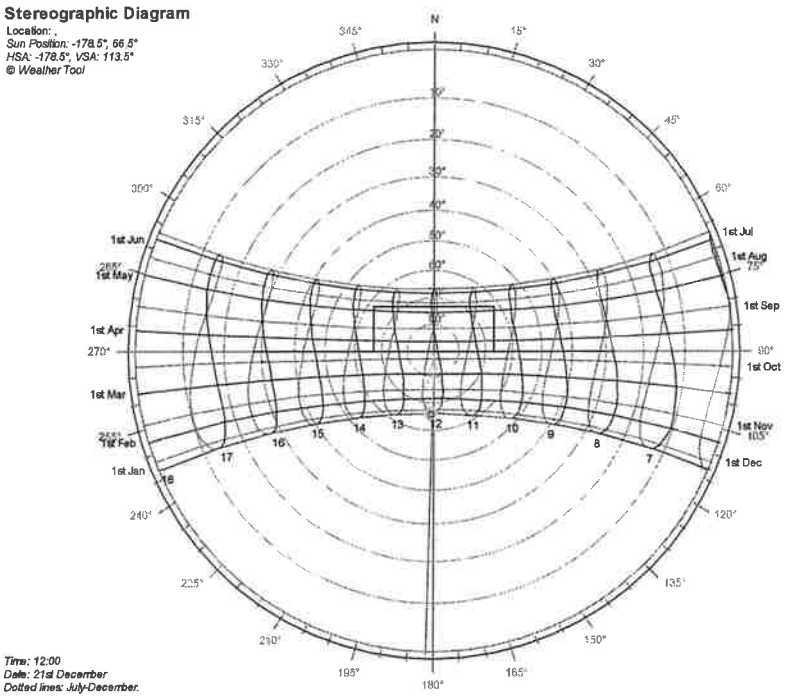
Stereographic Sunpath Diagram – At 50°N



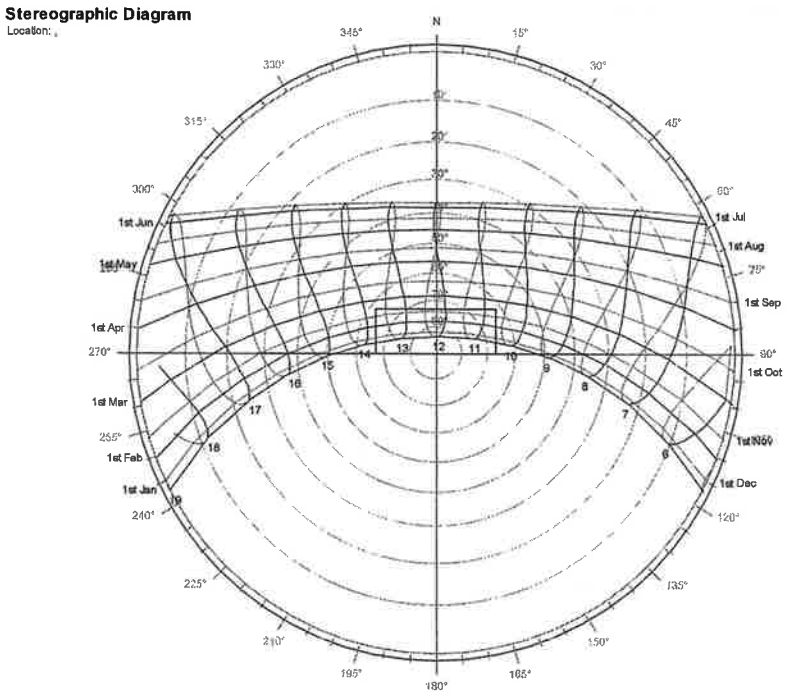
Stereographic Sunpath Diagram – At 60°N



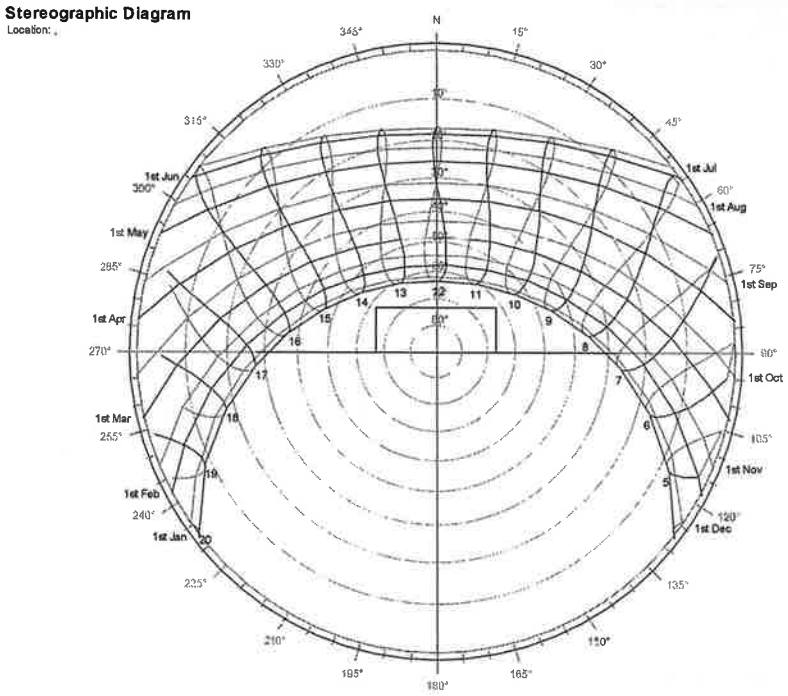
Stereographic Sunpath Diagram – At 0°



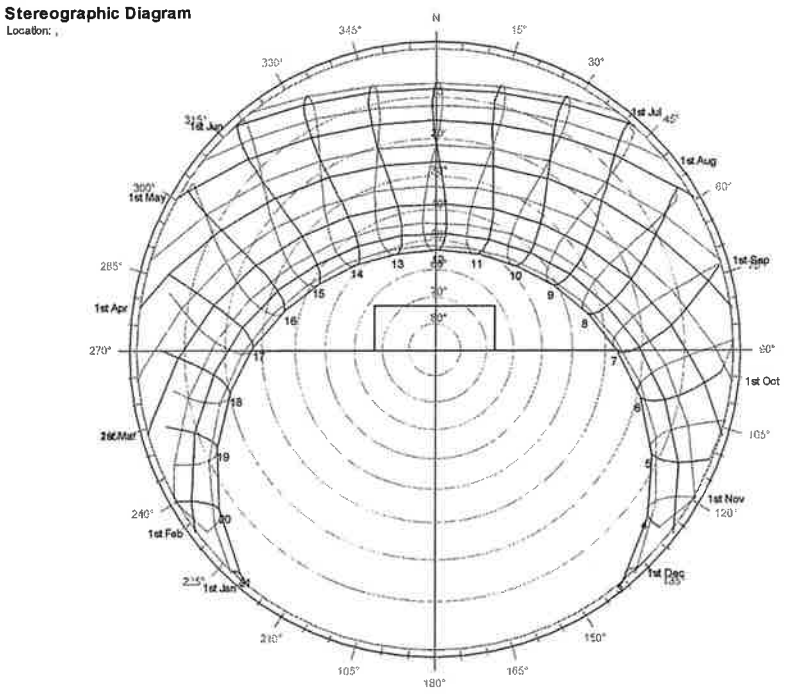
Stereographic Sunpath Diagram – At 30°S



Stereographic Sunpath Diagram – At 50°S



Stereographic Sunpath Diagram – At 60°S



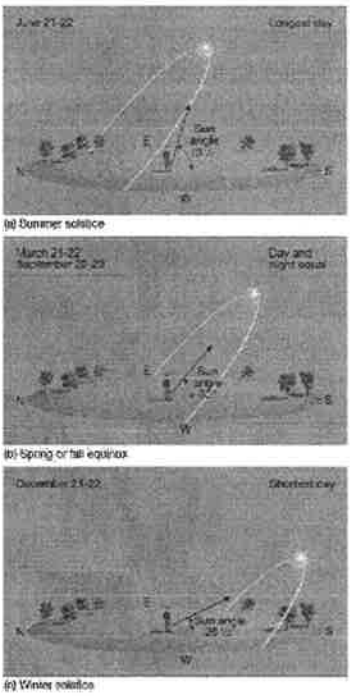
BCA ACADEMY

Make sure you get the right diagram for the right latitude

The Education and Research arm of the Building and Construction Authority

Orientation of Building

- To reduce solar heat
  - Shorter walls on E-W facings
  - Less glass on E-W facings
- To increase solar heat
  - Northern Hemisphere
    - Longer wall on S facing
    - More glass on S facing
  - Southern Hemisphere
    - Longer wall on N facing
    - More glass on N facing



Daily paths of the Sun for a place located at 40°N latitude

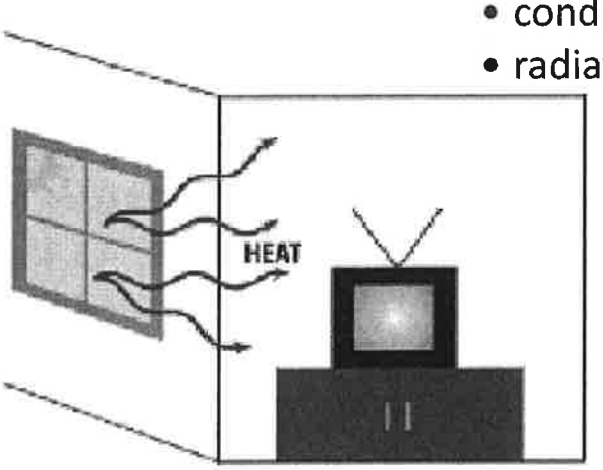
Building Envelope

- The separation between the interior and the exterior environments of a building.
- Controls the flow of energy between the interior and exterior of the building.
- Consists of the building's foundation, walls, roof, windows, and doors.

Building Envelope

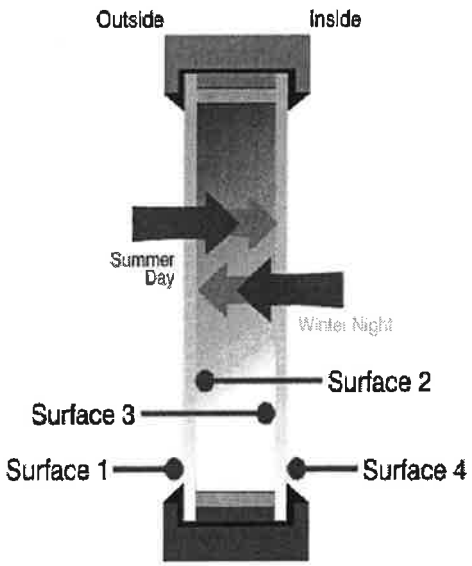
Heat is transferred from the building envelope to the interiors primarily by

- conduction through walls/roofs
- conduction through glass
- radiation through glass



Building Envelope

Conduction = Heat Flow through Materials

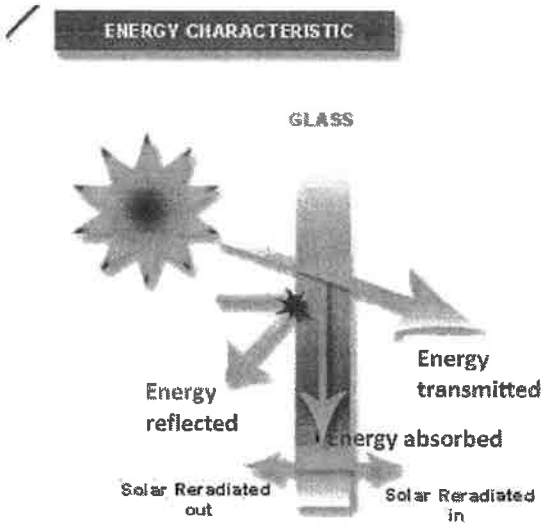


Conduction is the transfer of thermal energy through the window and wall from the warmer side to the colder side.

The greater the difference in temperatures, the more heat flow.

Building Envelope

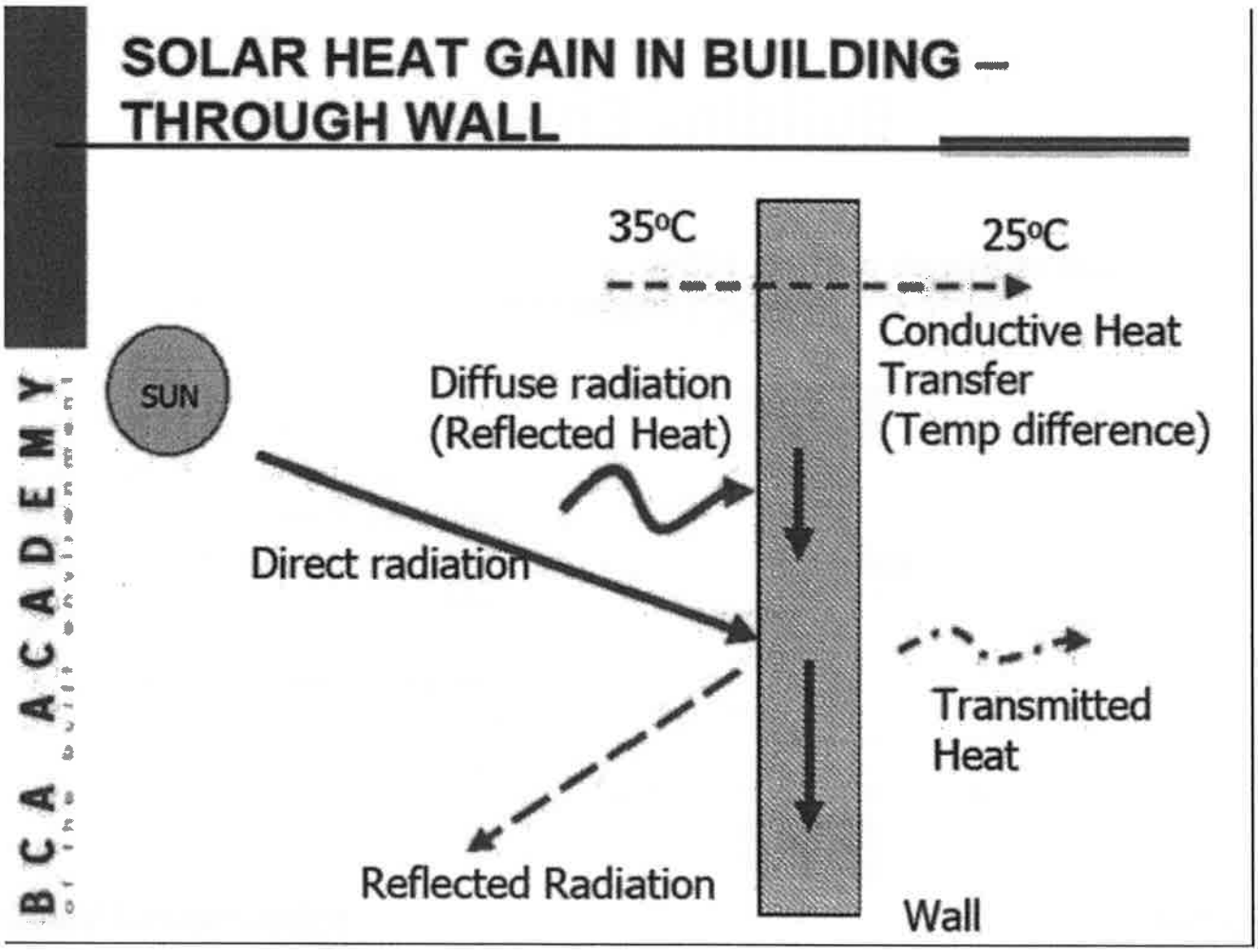
Radiation

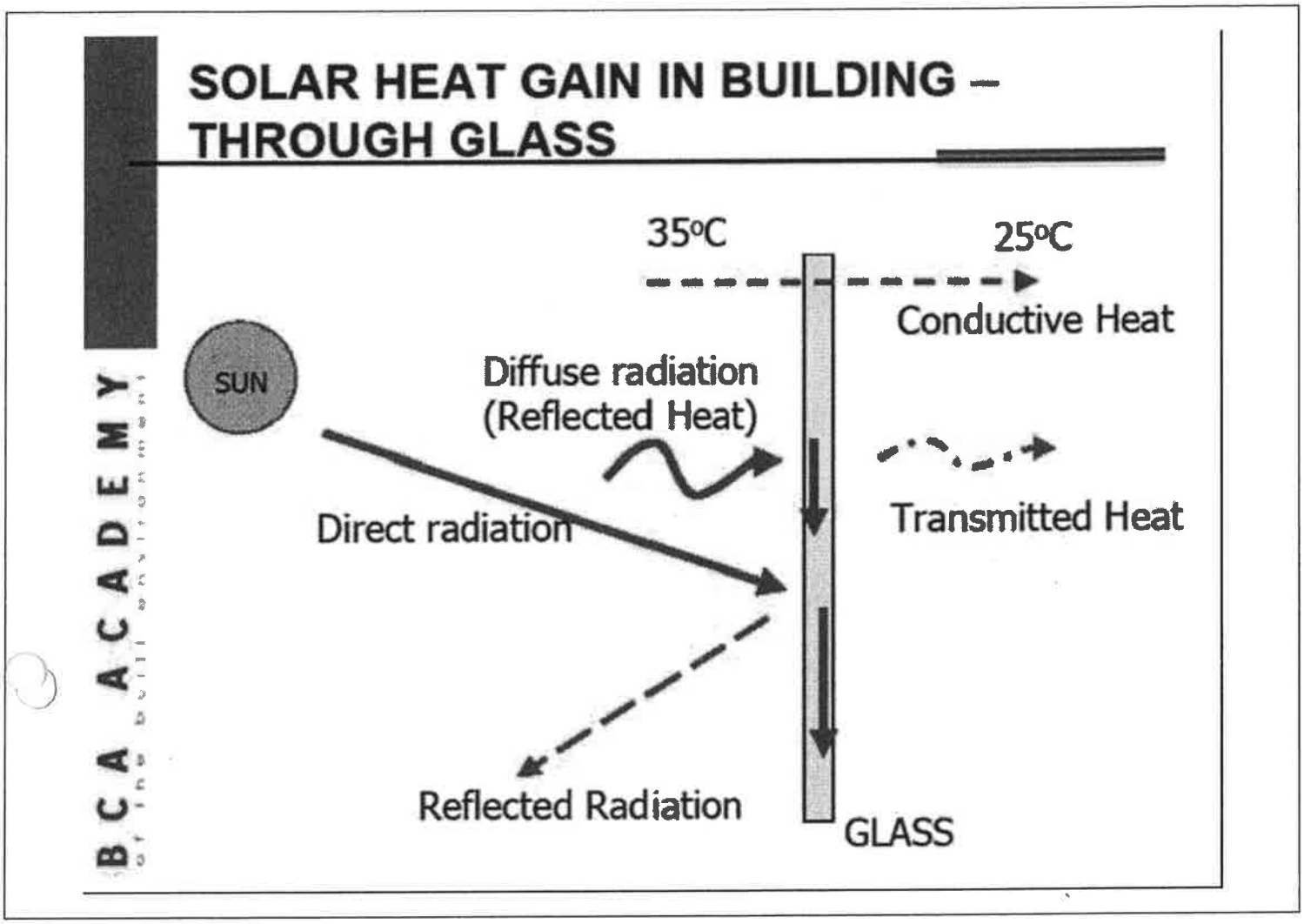


When sunlight strikes a sheet of glass, some of the solar radiation is transmitted straight through, some is reflected and some is absorbed by the glass.

The heat energy absorbed by the glass is then radiated to both the inside and outside as infrared radiation.

http://www.amfg.co.id/





Building Envelope

- To reduce heat gain into building through conduction:
  - Reduce U value of walls/ roof/ windows (glazing)
- To reduce heat gain into building through radiation:
  - Reduce SC (Shading Coefficient) of windows

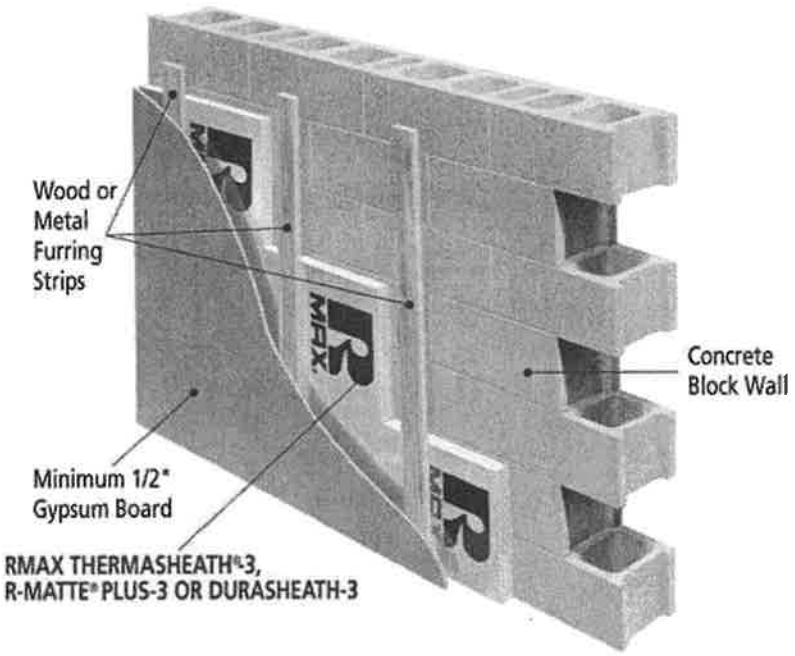
U Value

- Different wall and glass materials have varying ability to conduct heat, specified by the U-value (Overall Thermal Transmittance)
- Unit: W/m^2K
- The lower the U-value, the less heat is transmitted
- e.g., U value for:
  - 230mm brickwall: about 2 W/m^2K
  - 200mm concrete wall: about 1 W/m^2K
  - 6mm single glaze glass: about 6 W/m^2K
  - double glaze glass: about 3 W/m^2K

U Value - walls

- U value can be reduced by
  - For wall
    - Increased thickness
    - Cavity (not common in Singapore)
    - Insulation

U Value - walls



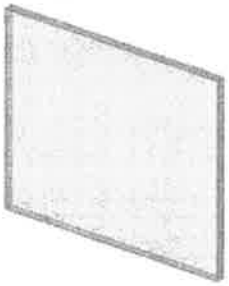
http://www.rmaxinc.com/

U Value - glazing

- U value can be reduced
  - For glazing
    - Increased thickness
    - Air gap (double-glazed)
    - Argon gas gap
    - Low-E (emissivity) glass

U Value - glazing

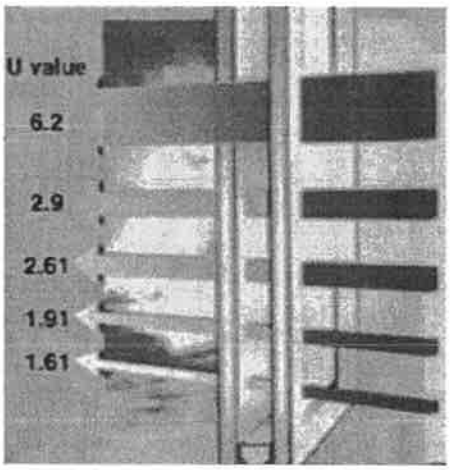
- Single Glaze Glass





- Double Glaze Glass

www.propertycert.net/images/double_glazing.jpg



Shading Coefficient (SC)

- The total amount of solar energy that passes through a glass relative to a 3 mm thick clear glass under the same design conditions

- Lower values indicate better performance in reducing heat gain

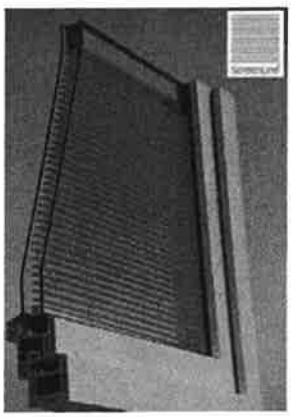
Shading Coefficient

1. The amount of radiation transmitted through a window can be reduced by the properties of the glass.

2. The amount of radiation incident on a window can be reduced through the use of external shading, thereby reducing the amount of radiation transmitted through the glass.

Shading Coefficient

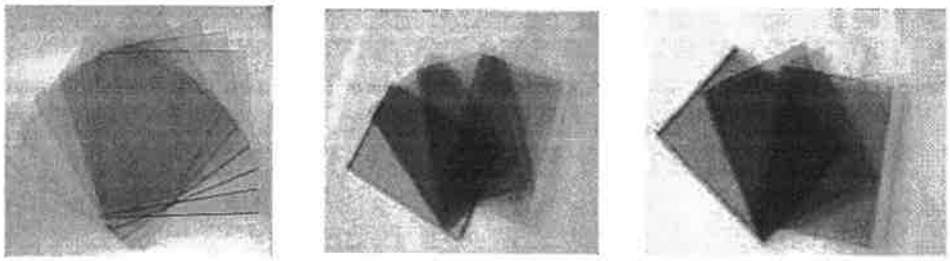




Glass can provide solar control through a number of ways such as

- body-tint
- lamination with tinted interlayers
- special coatings
- double-glazed units incorporating blinds

Shading Coefficient



Body-tint

One of the most basic (and cheapest) ways to reduce solar heat gain through glass is using toned or body-tinted glass.

Body-tinted glass absorbs a greater proportion of solar radiation than clear glass, allowing less direct radiation to pass through.

The absorbed heat is then radiated to inside and outside.

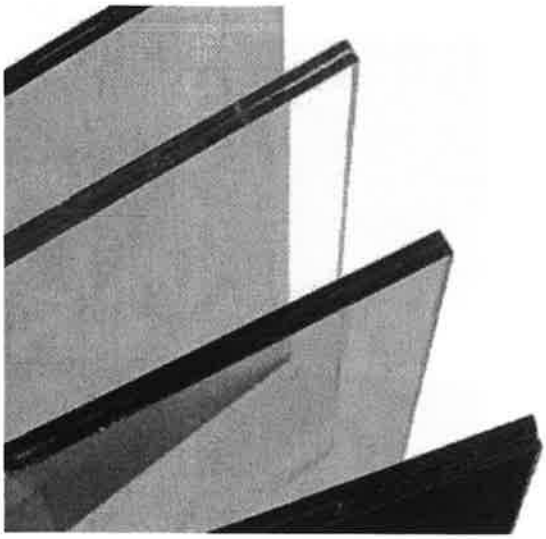
Shading Coefficient

Laminated glass is produced by heatfusing a layer of plastic (PVB) between two panes of float glass.

It is often used as safety glass to prevent shattering.

The PVB is usually clear or translucent, but can also contain colour.

Laminated glass blocks 99% of transmitted UV light.

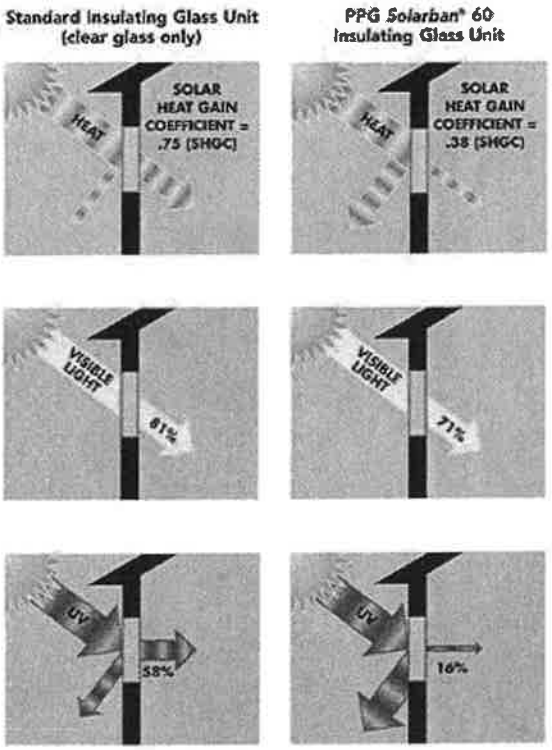


Lamination

Shading Coefficient

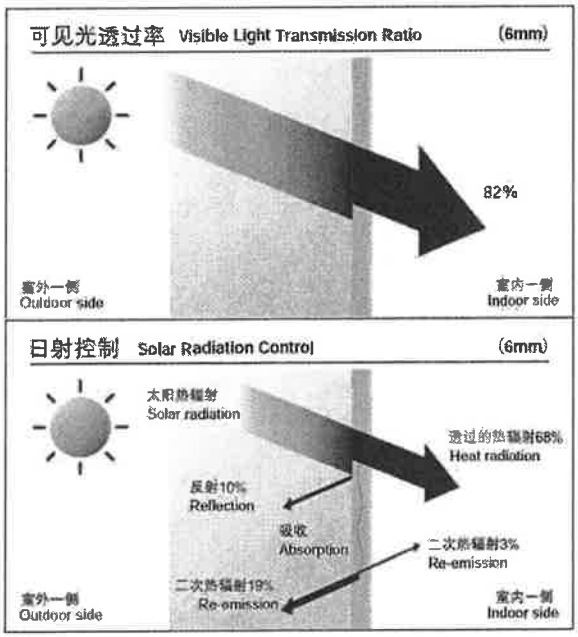
Low- e Coating

- Low-e stands for Low Emissivity
- The emissivity of a material is the relative power of its surface to emit heat by radiation
- Applying a low-e coat minimises the amount of heat absorbed by the glass, as well as heat being radiated into the building.
- It can also block some of the solar radiation transmitted through glass.



http://www.capitolwindowanddoor.com/services-door-window.html

Shading Coefficient



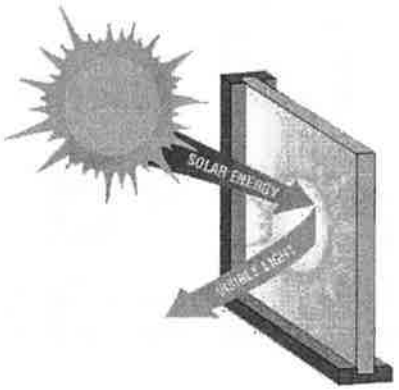
"NSG CVD Low-E" 在不影响透明度的情况下，可以将与浮法平板玻璃同等的太阳能吸收到室内。

Without harming transparency, NSG CVD Low-E passes the same amount of solar energy indoors as ordinary float glass does.

Low - e Coating

Shading Coefficient

Reflective Coating



- Solar heat gain can be reduced by reflective glass which increases the proportion of incident solar heat that is reflected away from the glass.
- However, highly reflective glass can create a problem of glare for neighbouring buildings.

Shading Coefficient

Performance of Tinted and Low-e Glass

Product Description	Light		Solar Radiant Heat				Shading Coefficient			U value (W/m²K)	U value (W/m²K)
	Transmittance	Reflectance	Direct Transmittance	Reflectance	Absorptance	Total Transmission	Short Wavelength	Long Wavelength	Total	Air-filled	Argon-filled (90%)
Pilkington Insulight™ (with 6mm Pilkington Optifloat™ inner pane and 16mm 90% argon filled cavity -											
Pilkington Optifloat™ Tint											
6mm 75/79 Green	0.67	0.12	0.39	0.08	0.53	0.48	0.45	0.10	0.55	2.7	2.6
6mm 49/58 Bronze	0.44	0.08	0.38	0.07	0.55	0.48	0.44	0.11	0.55	2.7	2.6
6mm 43/58 Grey	0.39	0.07	0.36	0.07	0.57	0.46	0.42	0.11	0.53	2.7	2.6
6mm Pilkington Arctic Blue™	0.48	0.08	0.31	0.06	0.63	0.40	0.36	0.10	0.46	2.7	2.6
Pilkington Suncool™											
6mm 70/40	0.70	0.10	0.38	0.28	0.34	0.43	0.44	0.05	0.49	1.4	1.1
6mm 70/35	0.69	0.16	0.34	0.34	0.32	0.37	0.39	0.04	0.43	1.3	1.1
6mm 66/33	0.65	0.15	0.32	0.32	0.36	0.36	0.37	0.04	0.41	1.3	1.1
6mm Silver 50/30	0.49	0.39	0.28	0.42	0.30	0.31	0.32	0.04	0.36	1.4	1.1
6mm Blue 50/27	0.50	0.19	0.24	0.35	0.41	0.28	0.28	0.05	0.33	1.3	1.1

Shading Coefficient

Performance of Reflective Glass

TECHNICAL DATA

Code	[mm]	Light Transmittance	Light Reflectance (out)	Light Reflectance (in)	Direct Energy Transmittance	Energy Reflectance (out)	Energy Absorption (in)	UV Transmittance	Solar Factor	Shading Coefficient	U value Summer W/(m²K)	U value Winter W/(m²K)	Relative Heat Gain W/m²
T-SS108	6	11	39	38	9	33	58	9	0.21	0.24	4.47	4.64	186
T-SS114	6	15	32	36	13	27	60	12	0.25	0.29	4.65	4.78	219
T-SS120	6	21	24	31	19	20	61	18	0.32	0.36	4.85	4.94	265
T-SS208	6	8	30	40	5	17	78	3	0.20	0.23	4.52	4.55	180
T-SS214	6	11	25	38	7	15	78	4	0.23	0.27	4.70	4.70	207
T-SS220	6	18	18	30	12	11	77	7	0.29	0.33	4.97	4.94	247
T-SS508	6	6	20	40	4	15	80	3	0.21	0.24	4.58	4.58	187
T-SS514	6	11	16	35	8	12	80	6	0.25	0.29	4.79	4.76	220
T-SS520	6	13	14	32	10	11	79	7	0.28	0.32	4.99	4.94	241

Remarks:
• All values are in percentage except U and RHG.

Shading Coefficient

Sunshading

Besides changing the properties of glass, solar gain can also be reduced by introducing sunshading elements on the façade.

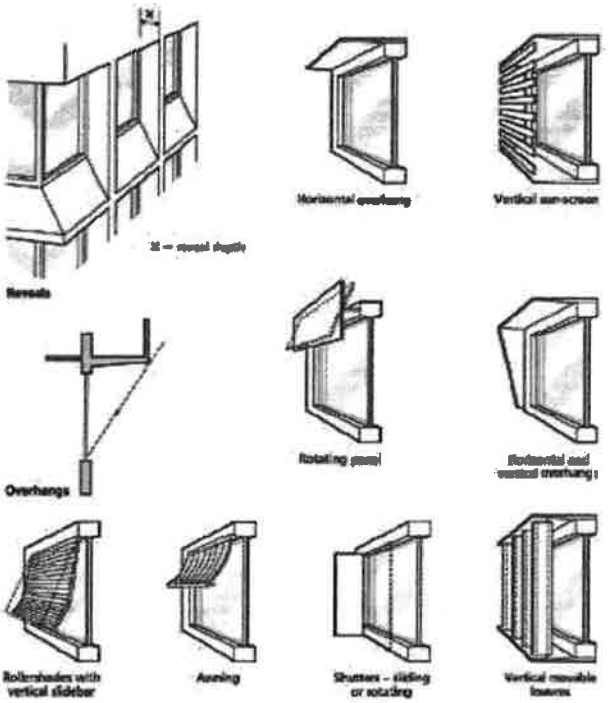
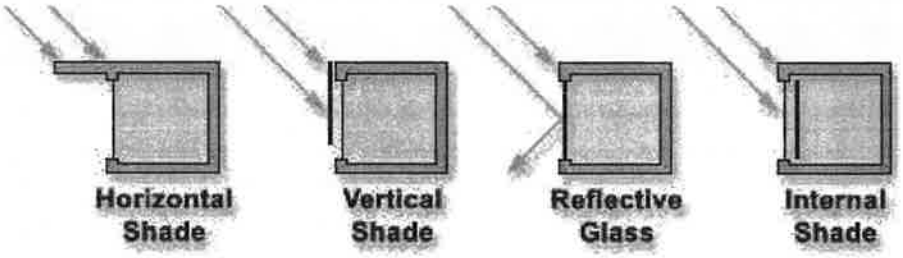


Fig 9.2.3 - Various forms of external shading devices
http://daylight.sportscotland.net/

Shading Coefficient

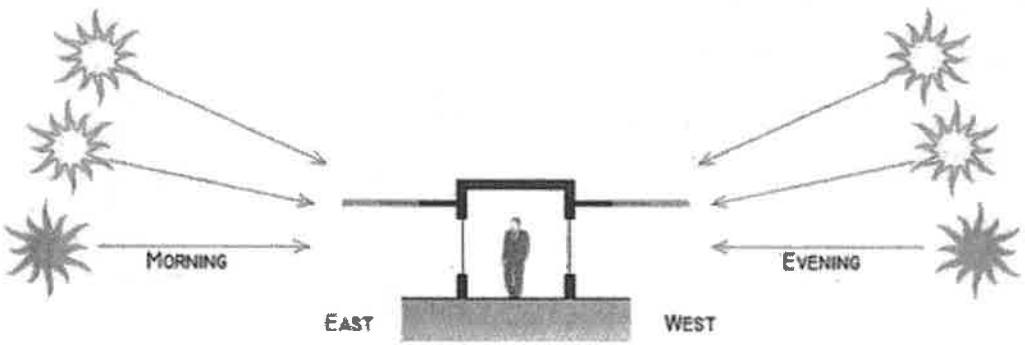
The Fundamental Shading Strategies



http://squ1.org

Shading Coefficient

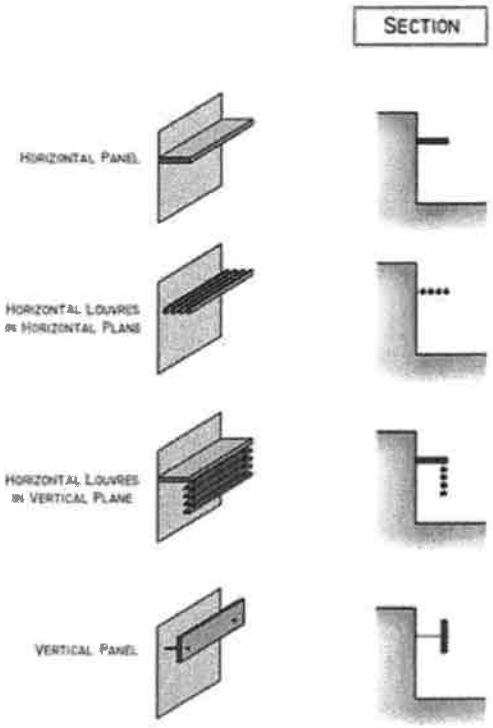
Horizontal Shade



www.architecture.uwaterloo.ca

Shading Coefficient

Horizontal Shade

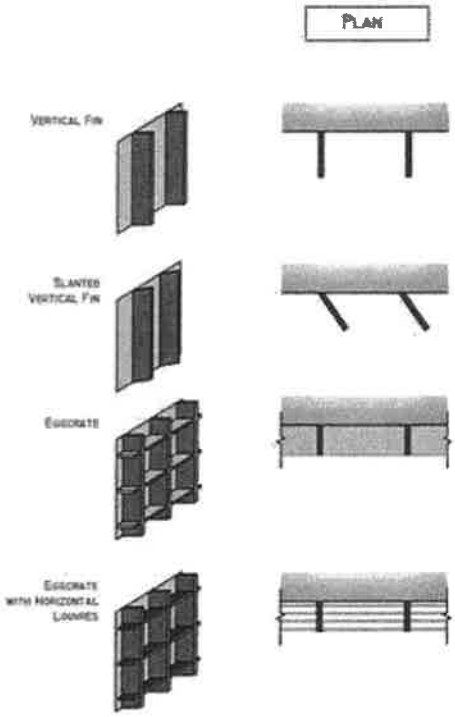


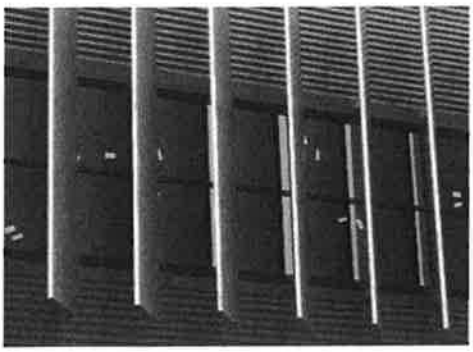


http://www.zawya.com/

Shading Coefficient

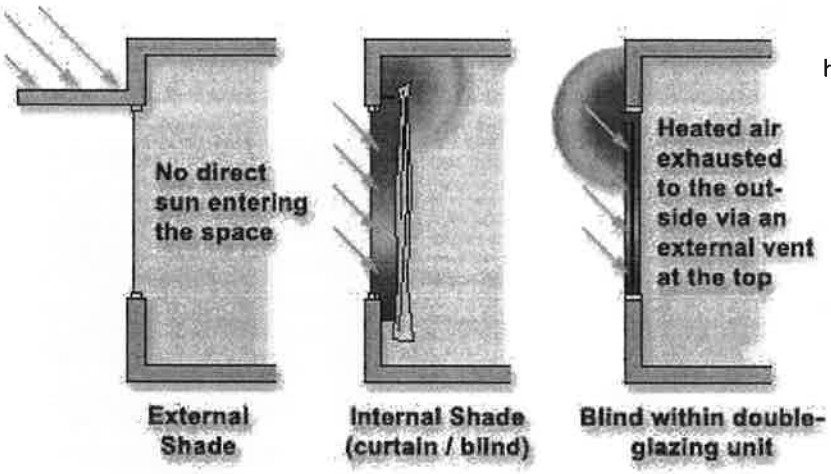
Vertical Shade





http://www.sgi-architectural.com.au/

Shading Coefficient



http://squ1.org

- Both external and internal shades control heat gain.
- External shades are more effective than internal shades because they block the solar energy before it enters the window.

ENVELOP THERMAL TRANSFER VALUE (ETTV)

- Measures the heat gain through the building envelope, in W/m^2
- Measures the energy efficiency of the building design
- BCA's regulation requires air-conditioned buildings to have **ETTV < 50 W/m^2**
- Important consideration for Green Mark

Passive Design

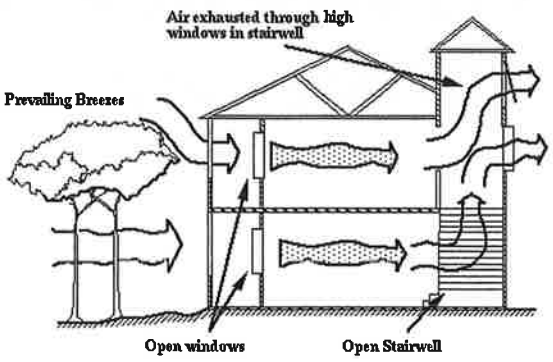
- Reducing Heat Transmittance
- Passive Solar Cooling
- Bringing in Daylight

Passive Solar

- Passive solar energy means that mechanical means are not employed to utilize solar energy
  - Passive Solar Heating
  - Passive Solar Cooling

Passive Solar Cooling

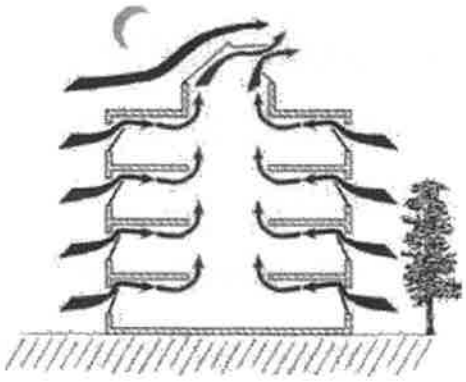
- **Cooling by ventilation**
  - Make the outlet openings slightly larger than the inlet openings.
  - Place the inlets at low to medium heights to provide airflow at occupant levels in the room.



http://passivesolar.sustainablesources.com/

Passive Solar Cooling

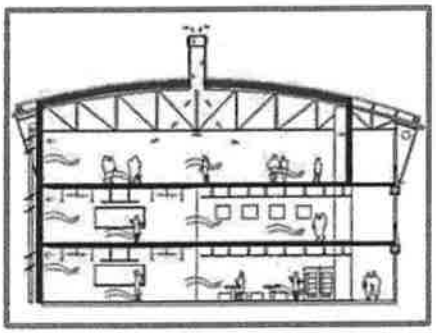
- **Stack effect**
  - When there is a temperature difference between two adjoining volumes of air, the warmer air will have lower density and be more buoyant thus will rise above the cold air creating an upward air stream.



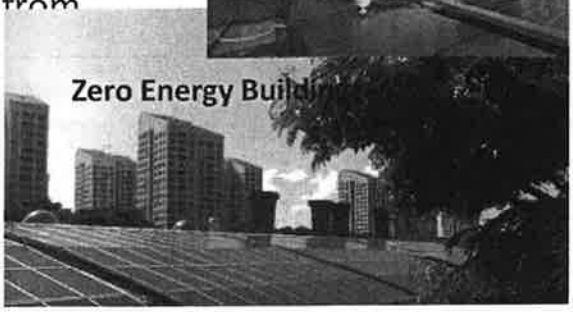
http://www.dyerenvironmental.co.uk

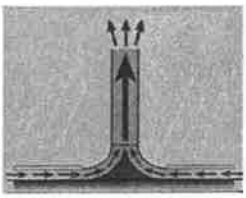
Passive Solar Cooling

- **Solar Chimney**
- (Thermal Chimney, or solar assisted stack ventilation system)
  - Use of heated air to induce ventilation
  - Heat builds underneath the roof surface, rises and flows out through the chimney
  - This creates a negative pressure in the rooms, inducing cooler air from outside to enter the spaces.









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Passive Design

- Reducing Heat Transmittance
- Passive Solar Cooling
- Bringing in Daylight

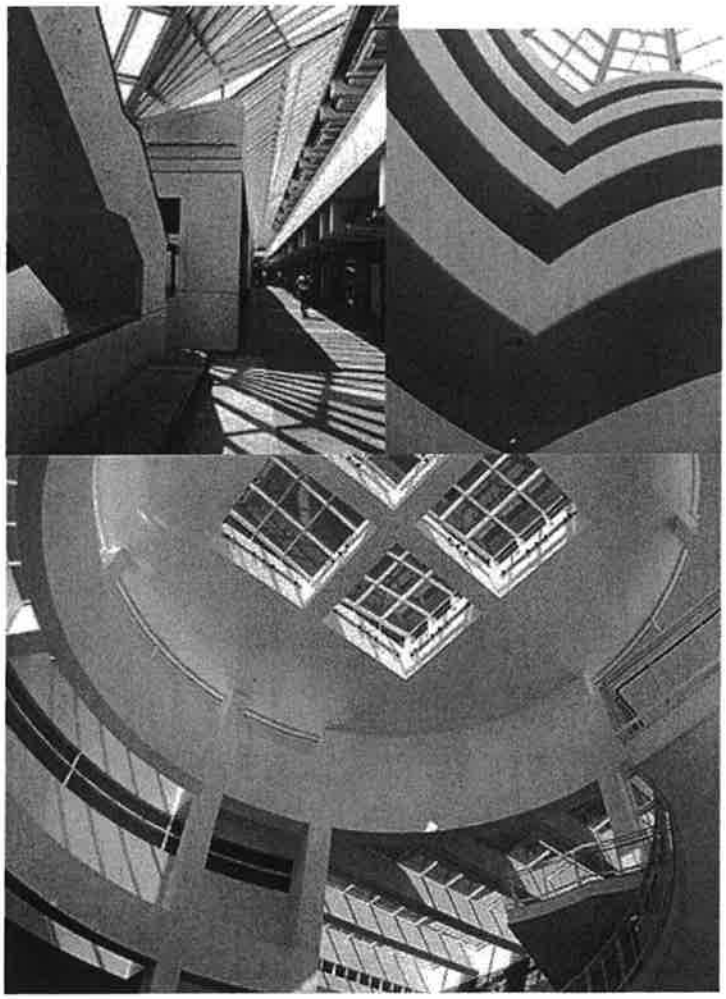




Lloyd's of London, 1986



SAS headquarters,
Stockholm, Sweden
1988







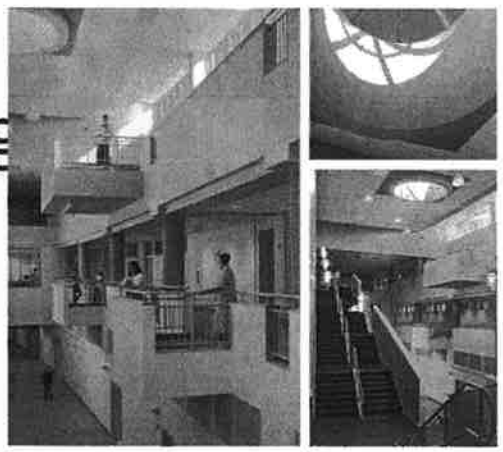


Gymnasium

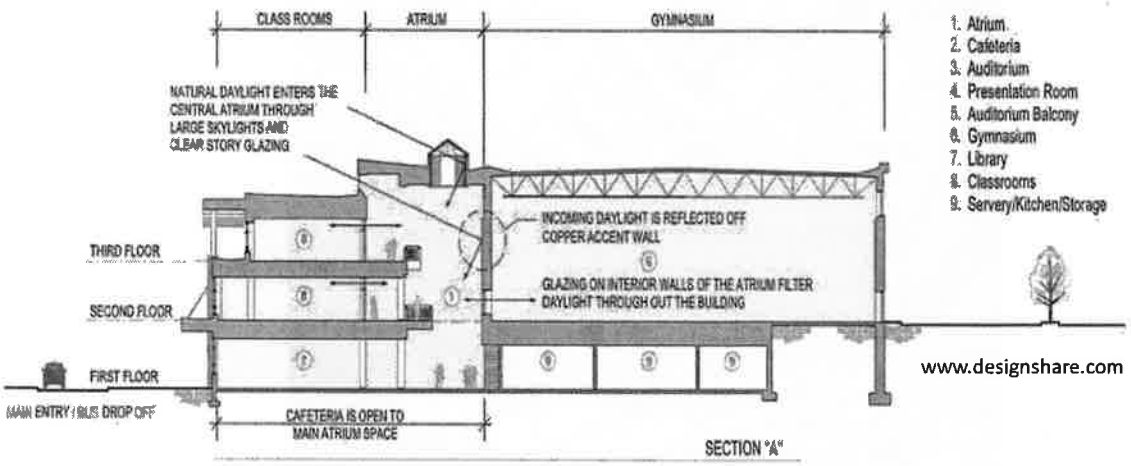


University Library

Daylighting



High School



SECTION "A"

CROSS SECTIONS

Daylighting

The efficient use of natural light in order to minimise the need for artificial light in building

Daylighting

- Why Daylight?
  - Energy
    - Reduce electrical lighting loads by up to 70%
    - Reduce emissions of CO_2, hence reducing greenhouse effect and global warming
  - Comfort and well-being of occupants
    - Physiologically, daylight is an effective stimulant to the human visual system
    - Psychologically, daylight and a view are much desired
    - Better quality of life, contributing to feeling of wellbeing
    - Better health, productivity and performance

Daylighting



Daylight refers to the level of DIFFUSE natural light.

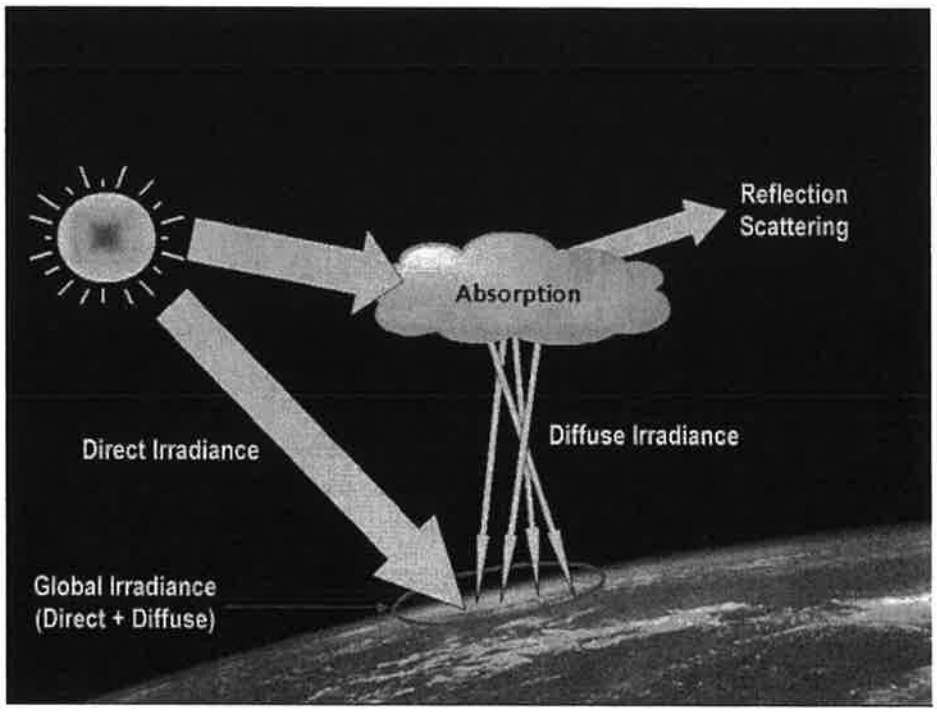


Sunlight refers to the level of DIRECT sunshine.

http://squ1.org

Daylighting

Direct and Diffuse Radiation



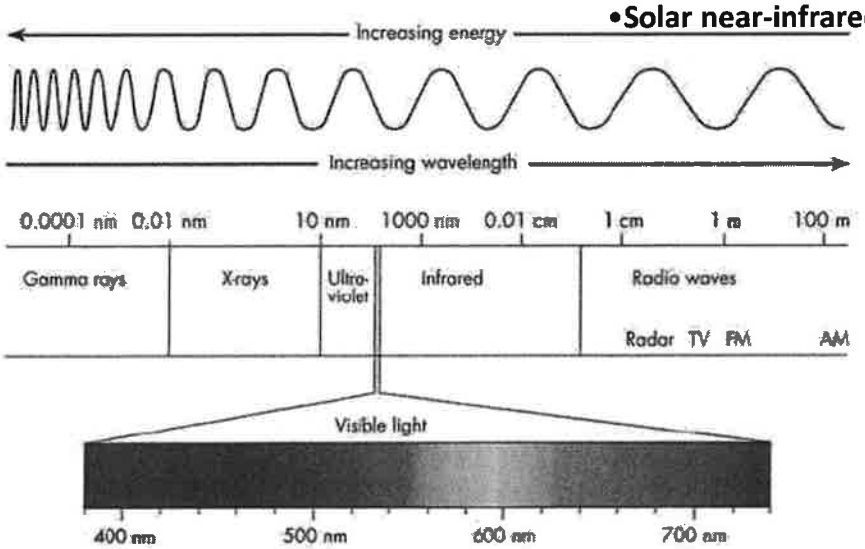
laser physics

Daylighting

- Light
  - A form of electromagnetic radiation
  - That create a visual sensation

Daylighting

The sun transmits solar radiation which comprises
•ultraviolet (9% of the total solar energy)
•visible (46%)
•Solar near-infrared (IR) (45%)

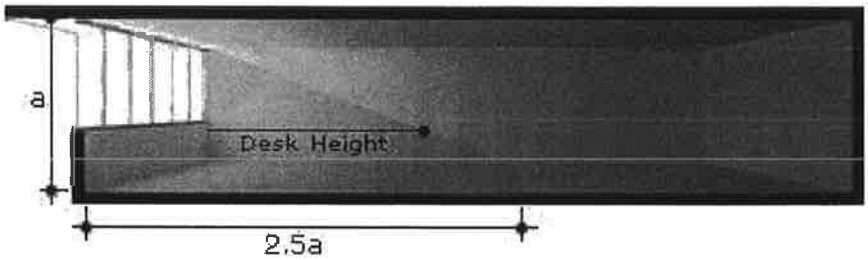


Daylighting



Useful daylighting will only reach a distance of 2.5 times the window height.

In a standard office building with a window height of 2.5m, this means a maximum of about 5-7m.



http://squ1.org

Daylighting









Dark interior corners can be overcome to some extent by adding windows on multiple sides of the room

Skylights give excellent daylight levels, but it is difficult to control the direct beam solar radiation from the Sun when it is directly overhead.

http://squ1.org

Effect of Window position on

- Daylight distribution
- View





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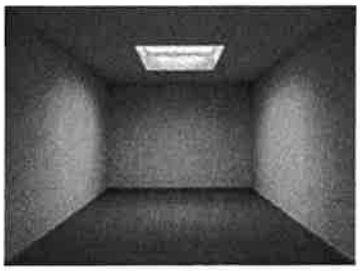

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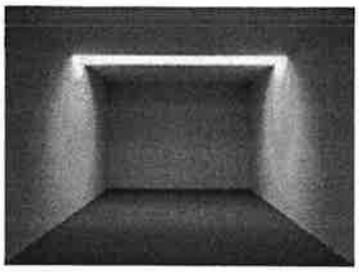

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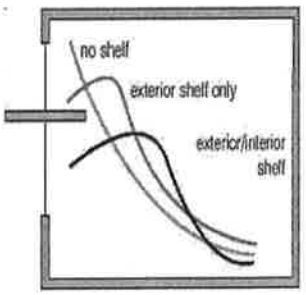
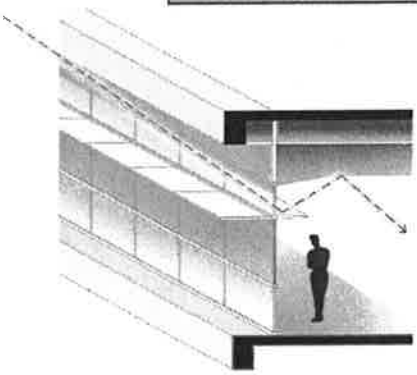
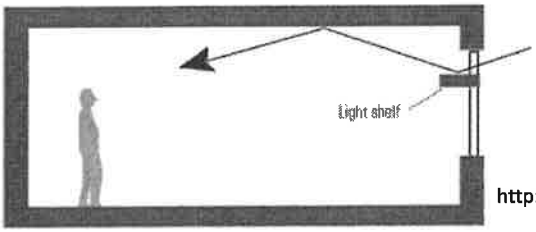
Daylighting

- **Light Shelf**
  - Highly reflective surfaces that reflect daylight to penetrate deep into space.
  - This horizontal light-reflecting overhang is placed above eye-level and has a high-reflectance upper surface.
  - This surface is then used to reflect daylight onto the ceiling and deeper into a space.

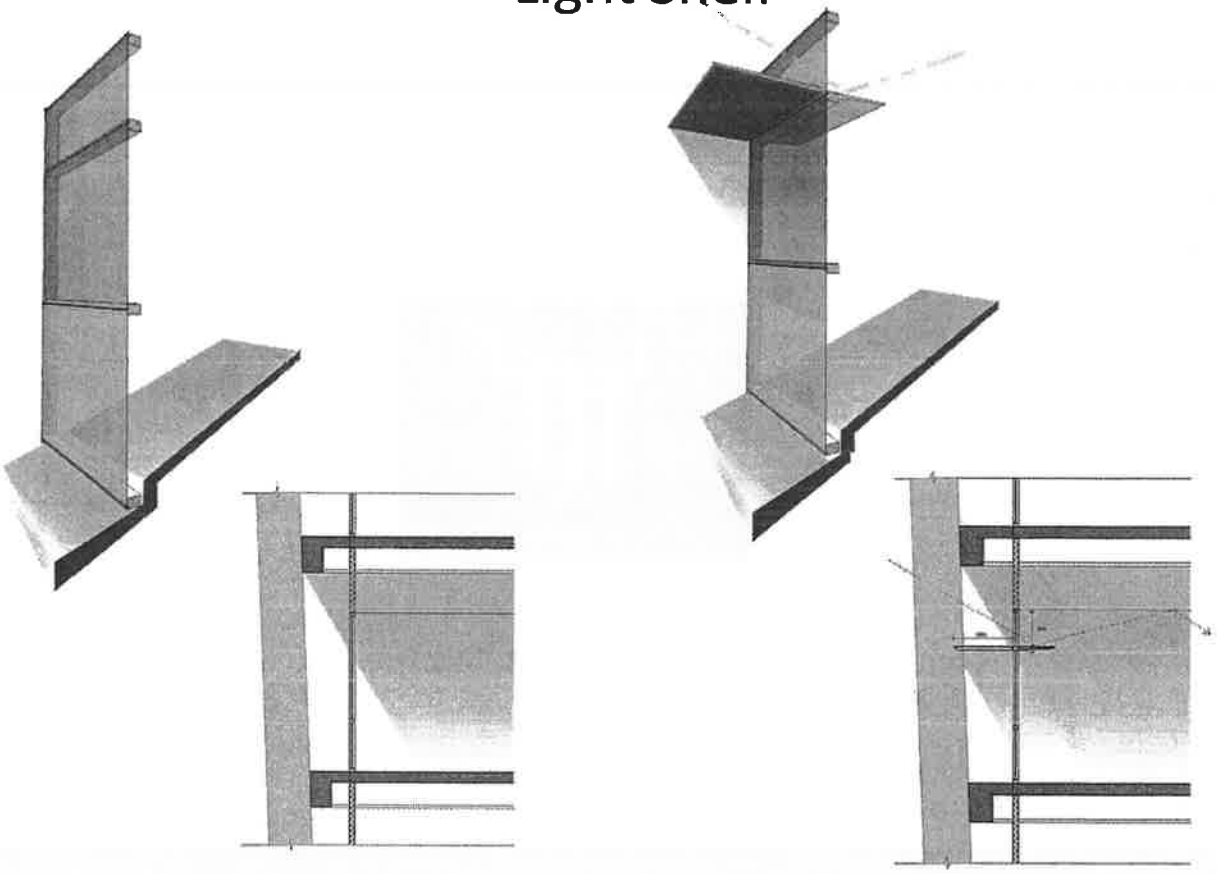






http://www.mge.com

Light Shelf



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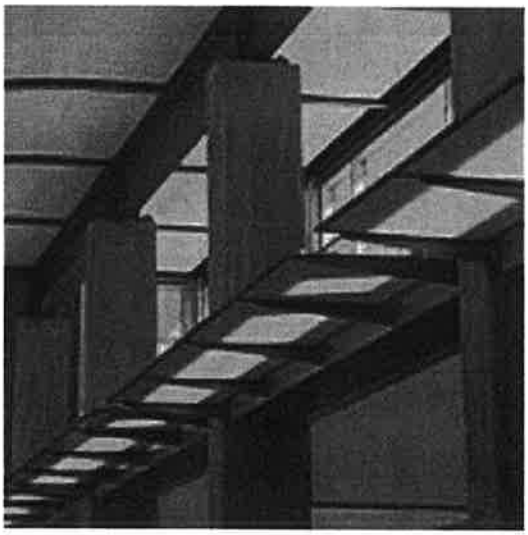
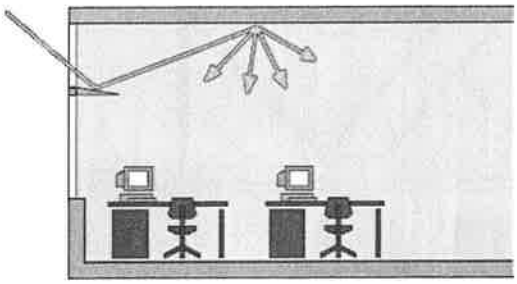
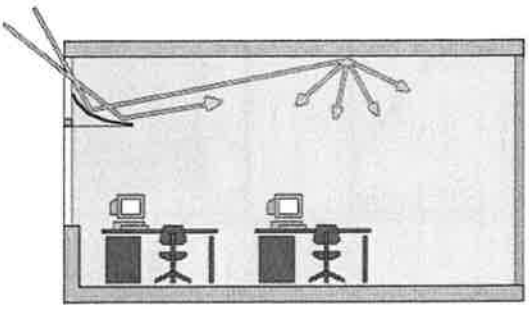
Light Shelf





Light Shelf





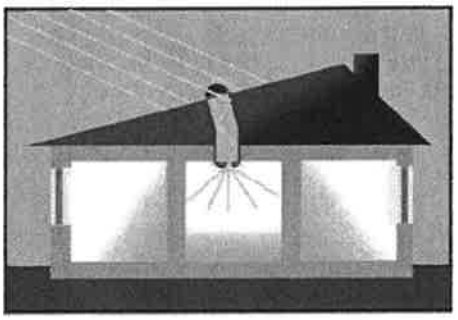
http://www.schorsch.com

The efficacy of light shelves can be significantly enhanced through a specifically curved shape design

Light Tube

- **Light Tubes** (or Light Pipes) use a special lens designed to amplify light

- Sunlight is channeled through a tube coated with a highly-reflective material, then enters the living space through a diffuser designed to distribute light evenly



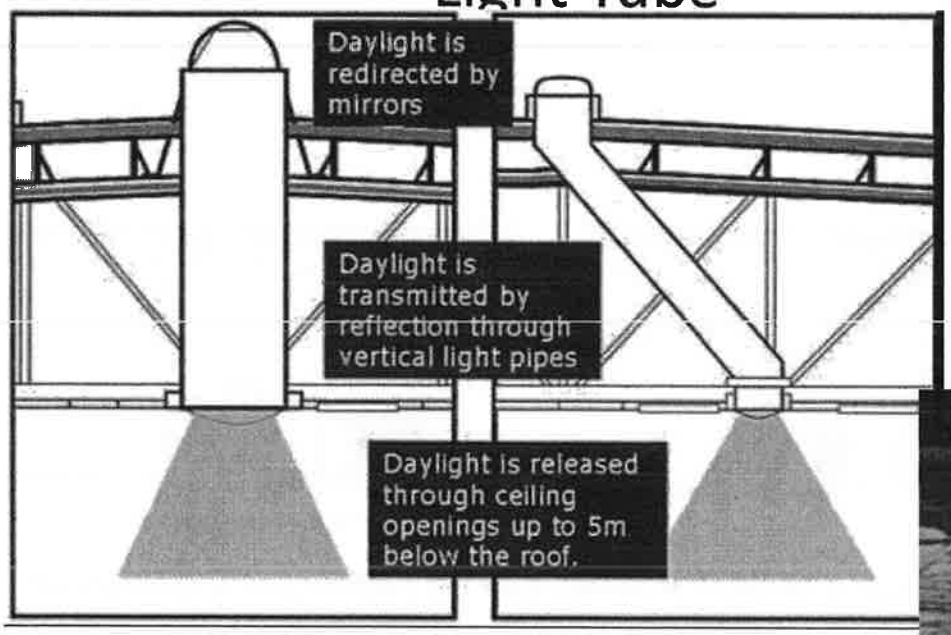
greenedmonton.ca



www.optenso.com



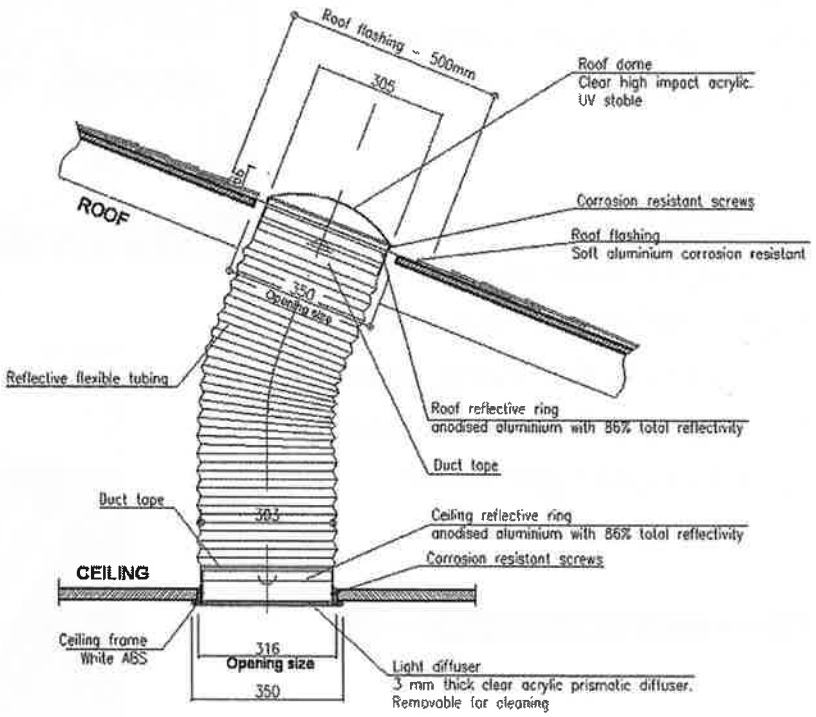
Light Tube





Zero Energy Building

Light Tube



http://www.tubzzz.com







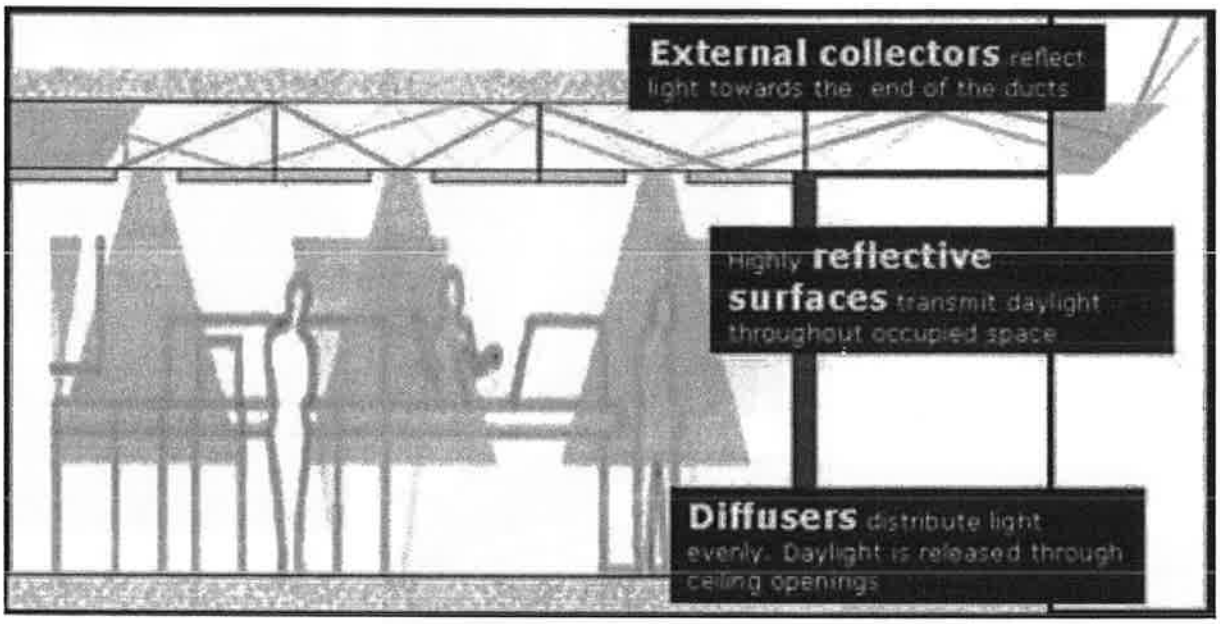




Mirror Duct

- A simple system that uses duct made of highly reflective material to bring in natural light into the space
- Capture direct sunlight through external collectors.
- Light is channeled into horizontal reflective ducts within the false ceiling which then exits through the ceiling apertures above a user.
- Such light is usually glare-free.

Mirror Duct

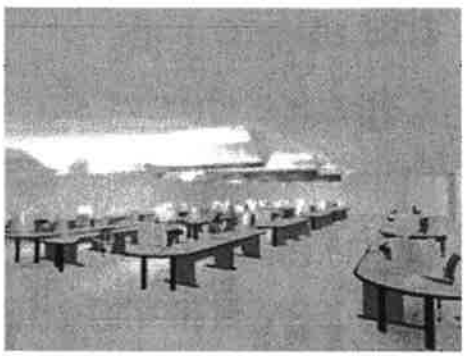


Light Tube

Before



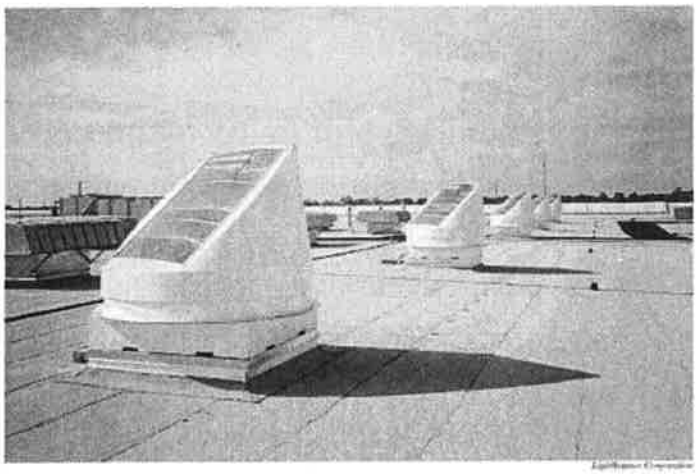
After



www.treehugger.com

Light Tube

With Sun Tracking



http://www.oikos.com

Daylighting

- General principles when designing daylighting
  - Control glare
  - Consider thermal implications
  - Select fenestration
  - Maximize ceiling heights
  - Consider window locations
  - Employ light shelves
  - Provide task lighting
  - Encourage effective lighting control

Daylighting

- Shading & good glass performance is essential in cutting down heat gains

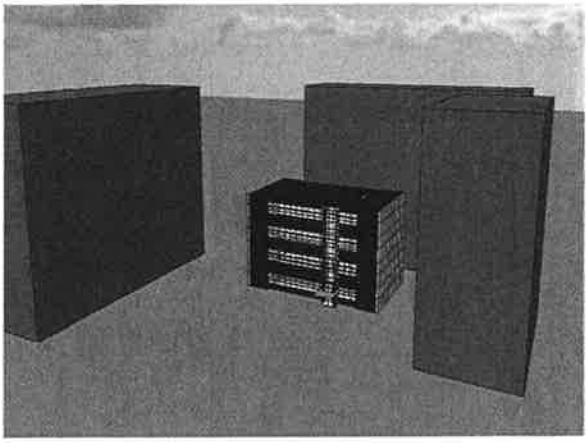
- Daylighting and reducing solar gains often come in conflict
  - Trade-off between daylighting and heat gain generally results in glazing ratio of 35% to 55%
  - Below 20% results in excessive artificial lighting
  - Above 60% results in excessive heat gain

Tutorial on Solar Modeling

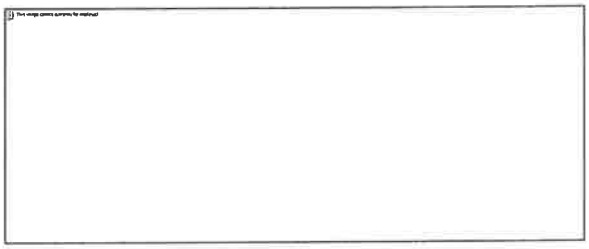
Tutorial 1: Solar Shading Images using SunCast

Create timed images for Solar Shadow Analysis on a particular day for the Model below:

Location: Singapore



Step 1: Setting up of climate weather data file using APLocate



APLocate can be accessed when in ModelIT application and can also be accessed by double clicking the weather file name at the bottom right of the Virtual Environment irrespective of the application mode.

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Tutorial 1: Solar Shading Images using SunCast

a) Design Weather

The design weather file is used for calculating the heating and cooling loads. Design weather data is taken from the ASHRAE database and the values can be customised as well. The file contains minimum and maximum temperature, humidity and solar radiation values for the year across all the months. The design weather data is normally used for HVAC equipment sizing purpose, click on "Acquire design weather" to proceed.



b) Simulation Weather Data:

This hourly weather data is used by ApacheSim to perform dynamic thermal simulation. It is available for all the calendar days of the year. Annual climate files are used for simulation and IES have a large database for all parts of the world. Two file formats can be read in IES <VE>: ***.fwt** which is the IES <VE> proprietary file type and ***.epw** which is a US Department of Energy file format.

This weather data will also be used for solar insolation calculation in SunCast. The SingaporeIWEC weather data will be used in this case.



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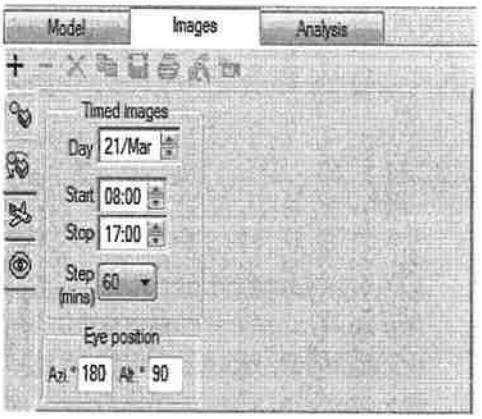
Tutorial 1: Solar Shading Images using SunCast

Step 2: Switch to SunCast and perform timed images run for a typical day.

Adjusting the Azimuth and Altitute value allow you to adjust the viewing angle of the images generated. We will do a plan view on 21st March and the time range from 08:00 to 17:00 for this study, so we will input Azimuth 180, Altitude 90.



Under the images tab one can generate single image for a specified date and time or a series of images over a particular day. One may want to refer the sun up and down times table available in SunCast tools tray in order to set the appropriate time for generating solar shading images.



Once the time range and date is set, simply press on the " + " button to generate a series of images showing the shadow position on every time step.

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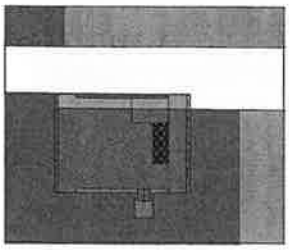
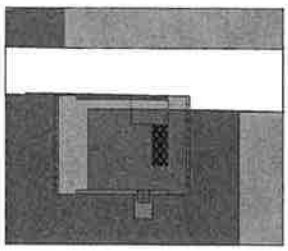
Tutorial 1: Solar Shading Images using SunCast

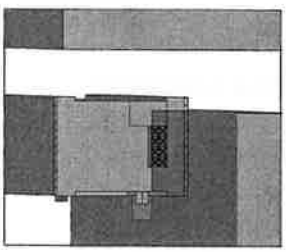
March 21st



March 21st



March 21st



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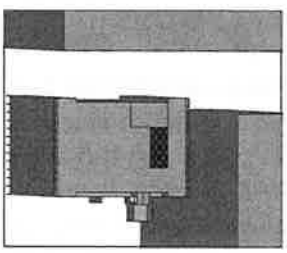
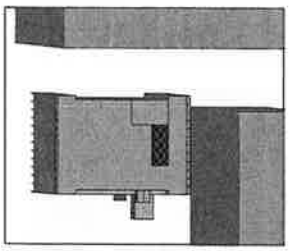


March 21st



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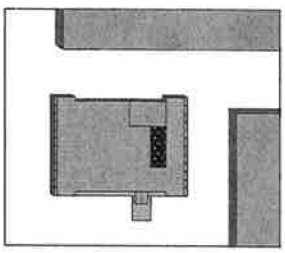

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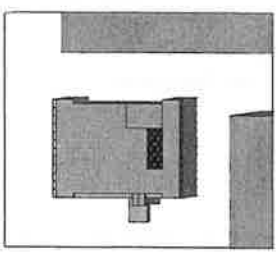

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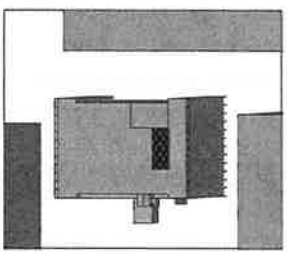

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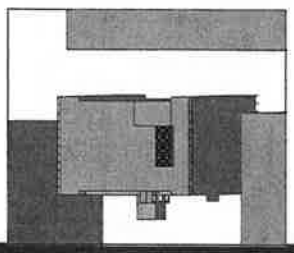
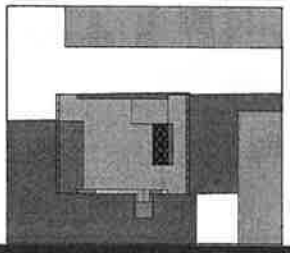


March 21st



All images can be saved as image (.emf or .wmf) files for further use.

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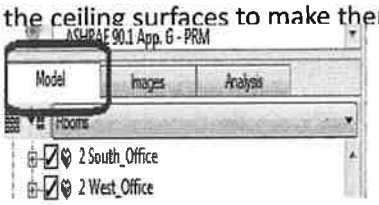
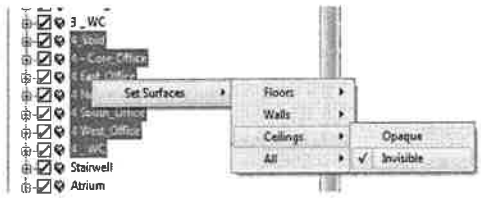
Tutorial 1: Solar Shading Images using SunCast

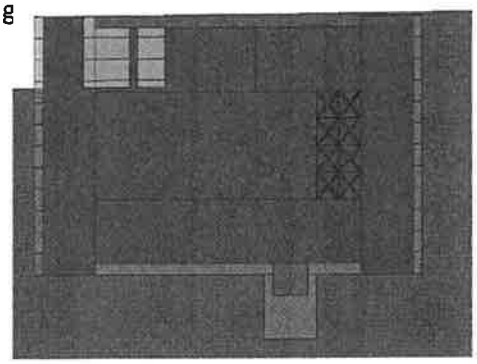
The images can also be generated with certain surfaces turned invisible to allow a better look into the solar penetration inside the room.

To do that you should first return back to the "Model" tab, select the room(s) of interest, for this tutorial demo purpose, select all the rooms on level 4, right click to bring up the side menu and select the ceiling surfaces to make them invisible.





*Note: Turning a surface invisible does not ignore the physical geometry of the surface, shading will still be casted, and this option is to make the selected surface invisible for the solar penetration images g

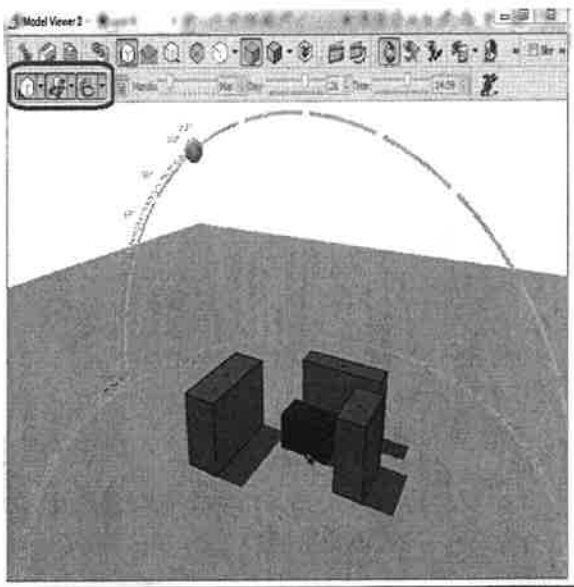


The bright patches indicate the area of the floor received direct sunlight, the remaining is shaded.

Tutorial 1: Solar Shading Images using SunCast

IES VE now have a new ModelViewer II which is used to do model rendering and solar shading animation. This give an interactive experience for analysing solar modelling. You can start off by pres g the ModelViewer II button on the top menu. The button looks like

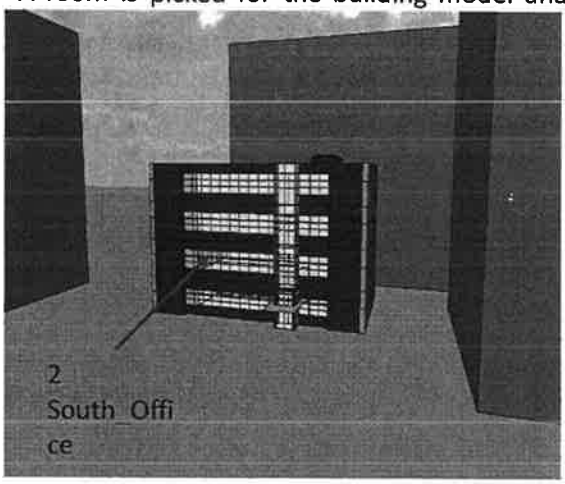
Once opened, you can toggle the shadow visibility, shadow animation and solar arc appearance. The shadow animation can be recorded as .AVI file for further use.



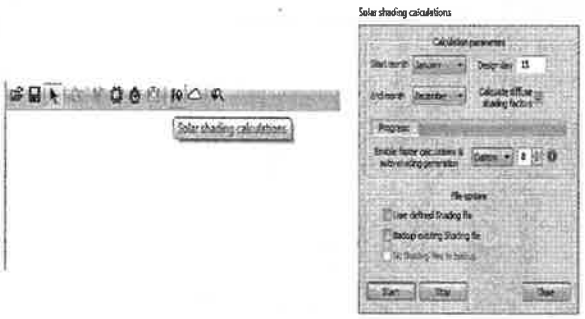
Tutorial 2: Performing Solar Shading Calculations

To understand how solar radiation impact have on building energy consumption, it is necessary to understand how much heat will be gained from the solar radiation through window openings, including direct and diffuse radiation. This will result in the room temperature fluctuation and hence affect the thermal comfort and air conditioning load.

A room is picked for the building model analyse the reduction in solar gain due to the shading



Step 1: Perform solar shading calculations



This calculation use design day approach to analyse the shaded area per month and the default picks the middle day of each month. The reason for this is because the shadow movement on this day will be similar to the

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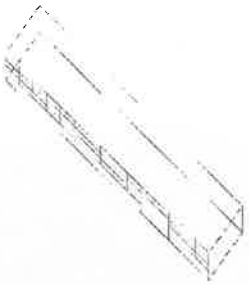
Tutorial 2: Performing Solar Shading Calculations

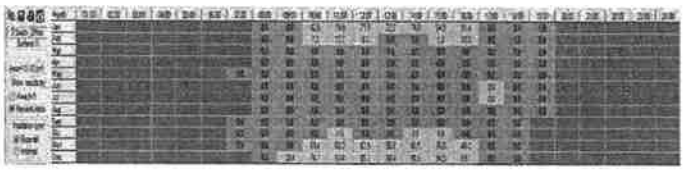
Step 2: Analyse the area percentage under shade by inspecting different façade surfaces.

For inspecting any surface after the solar shading calculations have been performed, it is necessary to go down to Space (Surface mode) Level of decomposition. Only at this level of decomposition the solar shading calculation results can be analysed.

Below surface is the external wall below the shade for "2 South_Office" zone. You can use the level tools on the fixed tool bar to move up/down between levels of decomposition after selecting a zone from mode' vser.



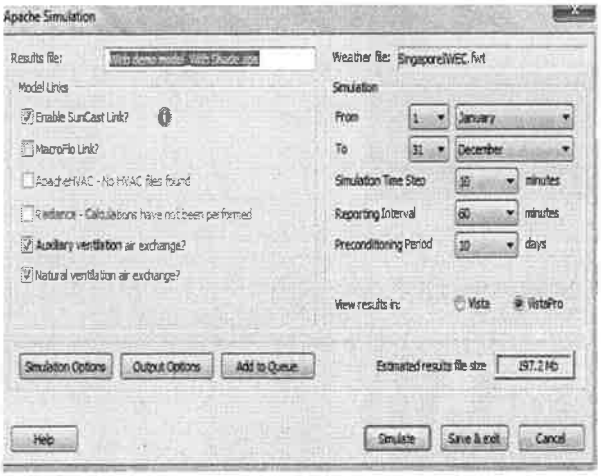


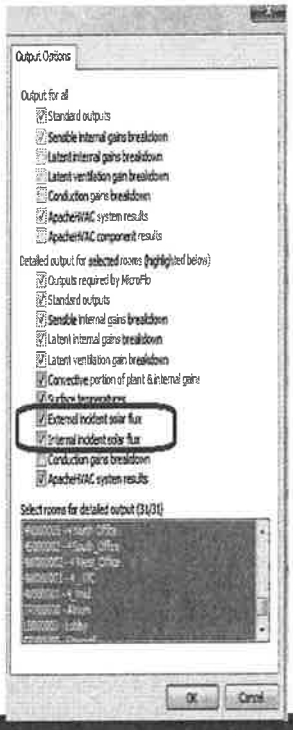


The above table indicates the percentage area of the selected façade that is receiving direct solar radiation throughout the year for all the months at different times of the design day. You may save or copy the results to an excel sheet for comparison or reference. You can now perform an Apache dynamic thermal simulation with the solar shading file in order to analyse solar gain for selected zone.

Tutorial 2: Performing Solar Shading Calculations

Step 3: Performing ApacheSim dynamic thermal simulation with SunCast link





The result files of dynamic thermal simulation are automatically stored in <VE>. You can now perform another simulation without the external shading device and compare the solar gain result for the two cases.

In the "Output Options" button, you will be able to select the External and Internal incident soalr flux before running dynamic thermal simulation. This will be recorded in the results and be able to view the result when you have selected the room surface

Tutorial 2: Performing Solar Shading Calculations

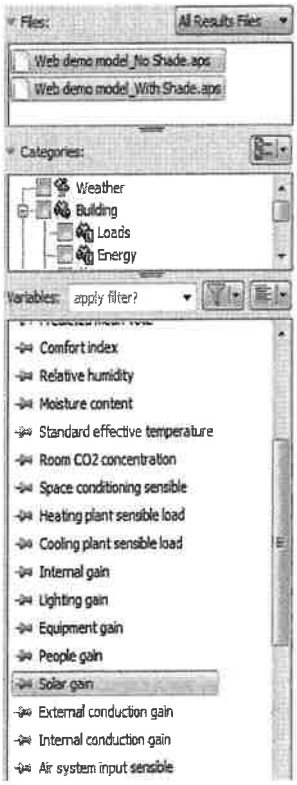
Step 4: Turning of the shading device by using the layer property





The Layers can be turned off when in ModelIT module using the layer properties tool.

You can now perform another solar shading calculation like before and then run a dynamic thermal simulation with the SunCast link checked to compare the results as below:

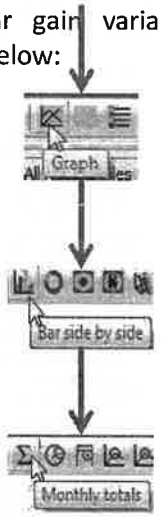


Step 5: Comparing "Solar Gain" results in VistaPro application

Select both the results file by holding control key and selecting the two files one by one. Select zone from room browser. From the list of available room variables you can now search and select "Solar Gain" variable.

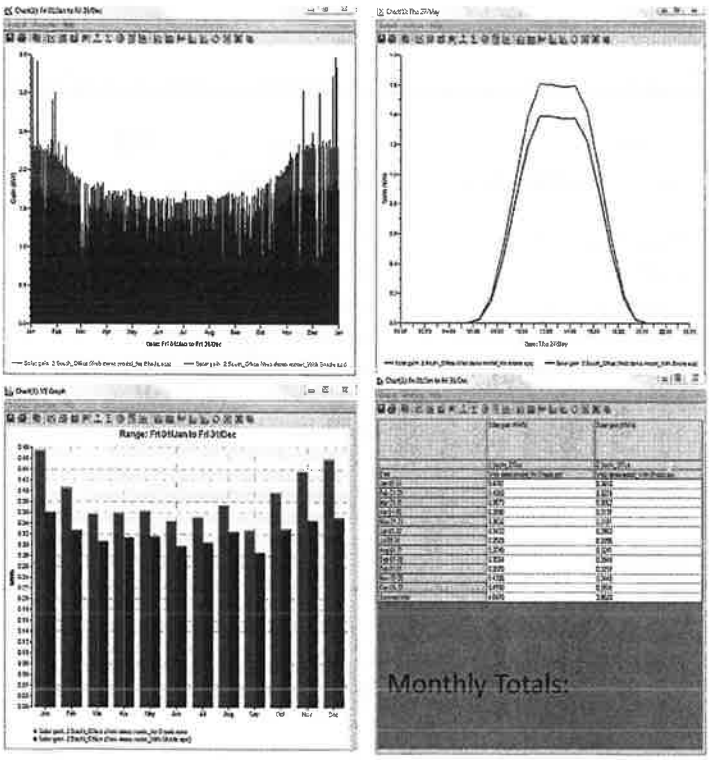
Tutorial 2: Performing Solar Shading Calculations

There are different display options to view results available in VistaPro. You may want to view graphical results and do a monthly total for the solar gain variable which is shown below:



Chose a date/date range from the calendar on right hand bottom side when in VistaPro application. The range can be set by holding shift key while selecting any two dates one after the other.

Graphical Results:



There is a reduction in solar gain equal to approximately 0.8 MWh for the year which will be a reduction in cooling load because of external shading devices.

Tutorial 3: Solar Energy and Solar Exposure Analysis

Activity 3: For the building model perform solar energy and exposure analysis and determine the building surfaces that will be receiving minimum summer heat. Also give recommendations based on location of active or passive solar equipment.

Step 1: Perform solar energy analysis in SunCast



You can decide on the duration of the analysis period (Full Year, Single Day, Single Month and Date Range). For energy perspective, it is recommended to carry out Full Year solar exposure analysis for a clearer picture on the passive solar strategies. However please note that the simulation time will be significantly higher especially with complex model geometry.

The "Calculate diffuse shading factors?" option allow further account for diffuse radiation being blocked by the shading devices as the window openings are not being exposed to the sun more.

You are also able to adjust the "Hi-resolution grid?" setting to create finer area for more in depth analysis on which part of the façade is more exposed to the sun.

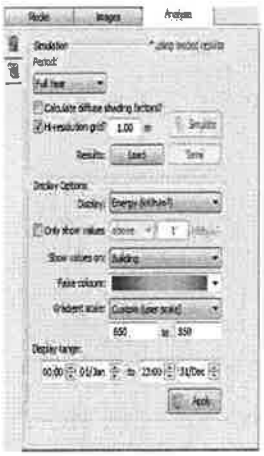
For tutorial purpose, we will use a grid size of 1m x 1m and run a Full Year analysis.

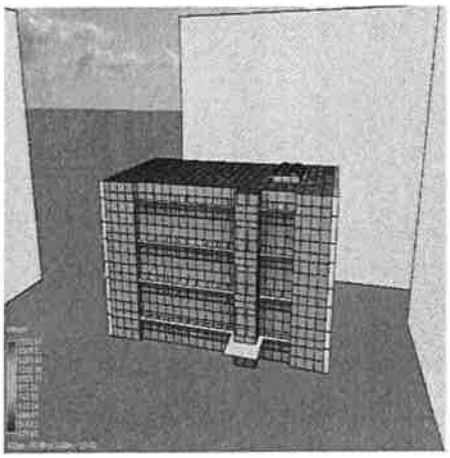
Tutorial 3: Solar Energy and Solar Exposure Analysis

After the simulation is performed, you can set the display options and the display range to view the energy values in absolute, relative or custom scale for different surfaces of the model.

The simulation capture the result for the whole building, user can choose to display the result as a whole or only walls, windows, roofs or doors.

Also, note that the energy/exposure values can be calculated for only room object type and other object types like local shade, topographical shade, or adjacent building are considered as shadow casting objects only.





From the analysis one can state that the overhang shading objects on the South facing facade help to reduce the solar energy reaching the windows below by around 200kWh/m2. The other facades orientation have also been shaded by the surrounding blocks, these can consider using shading objects to maintain a balance on cost and performance.

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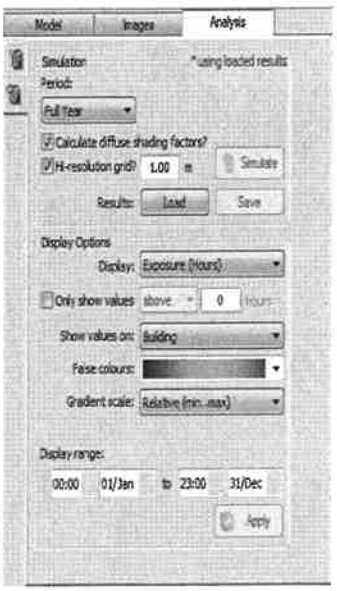
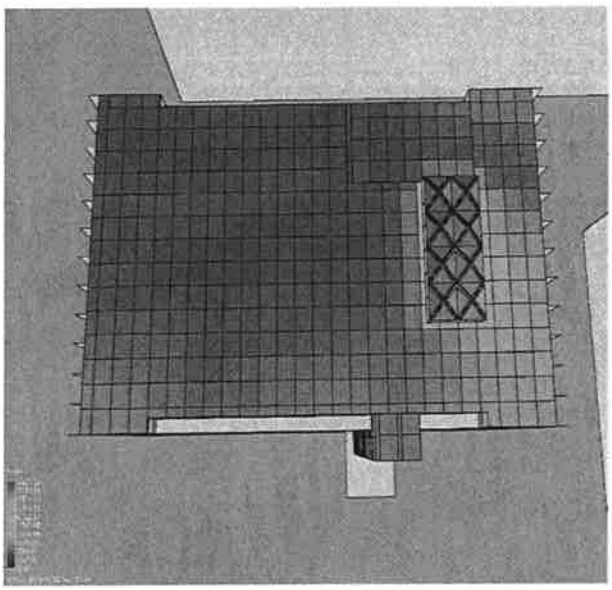
Tutorial 3: Solar Energy and Solar Exposure Analysis

Step 2: Solar exposure analysis



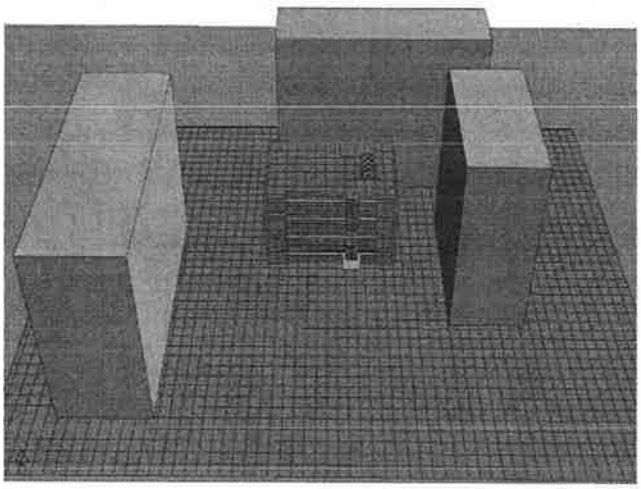


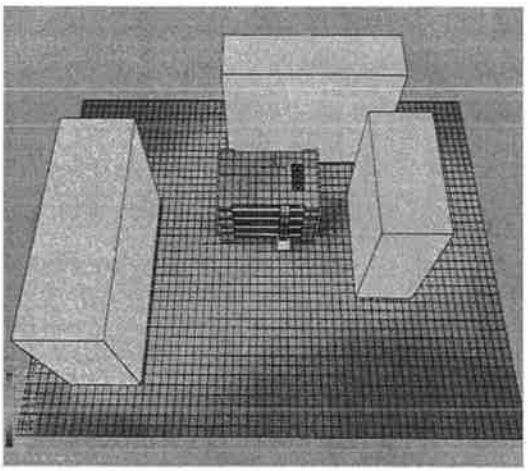
From the solar exposure and solar energy analysis the left hand side of the roof will receive the maximum solar radiation with high exposure levels throughout the year. So one can think of placing passive/active solar equipment at this location.

Tutorial 3: Solar Energy and Solar Exposure Analysis

Beside looking at the solar exposure on building façade, one can expand this to urban scale to analyse the solar exposure on a site.

To do this, one will require a room to be drawn below the building. We can create a simple rectangular room with a plan height of -1m and a room height of 1m. To avoid long simulation, one can adjust the high resolution grid to 2m x 2m instead.



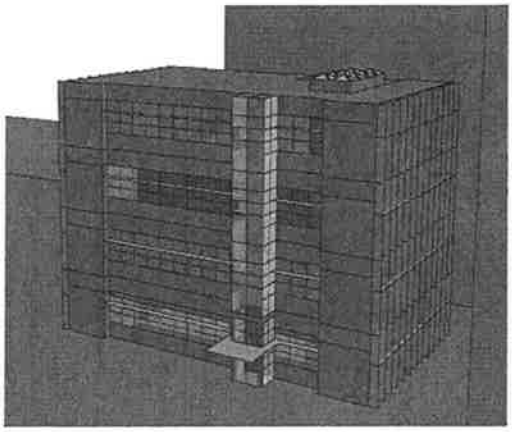


This analysis can help designer understand which part of the site will receive high solar radiation and can be particularly useful in landscape design when deciding different type of plantation, activity areas for occupants etc.

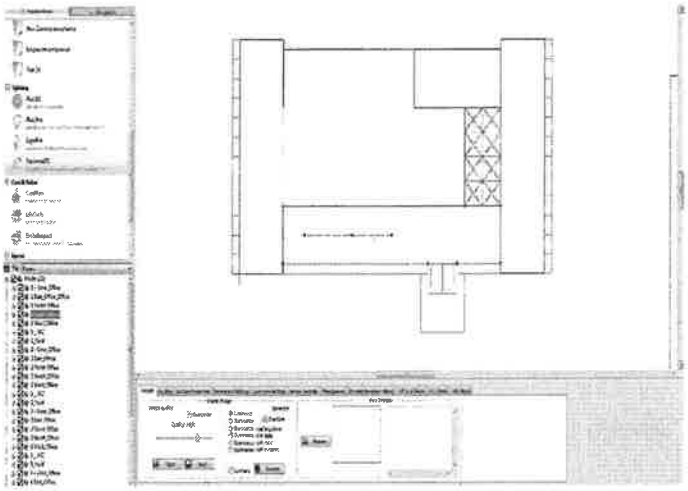
Tutorial on Daylighting Simulation

Tutorial 1: Daylight analysis

Activity 1: For the below Model perform daylighting analysis for the 1 South_Office room.



Step 1: Select classroom zone from Model Browser when in RadianceIES application shown as below:



Step 2: Select the illuminance simulation under the create image setting to perform daylighting analysis.

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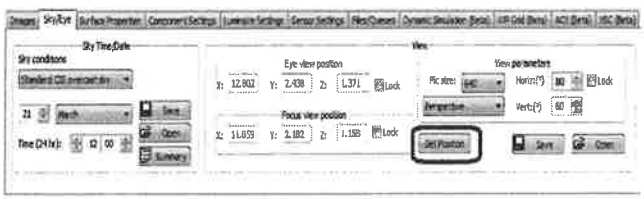
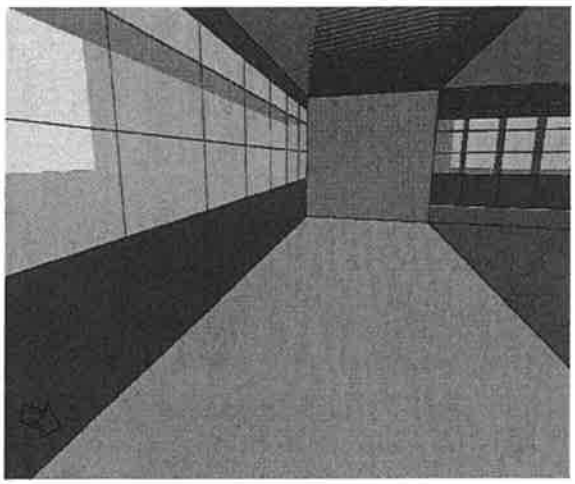
Tutorial 1: Daylight analysis

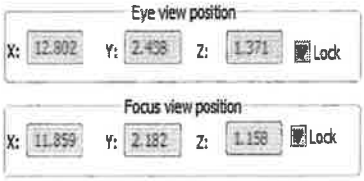
Step 3: Set the view parameters and Sky condition under the sky/eye tab as shown below:





Sky condition can be set to 'Standard CIE overcast sky' and you can also use the 'Get Position' tool under the view parameters in order to set the view parameters. For the first illuminance simulation run the view parameter has been set using 'Get Position' as below. For demo purpose, we will set the simulation date and time to 21st March 12:00.

You may now lock the eye view position setting for the selected view parameters



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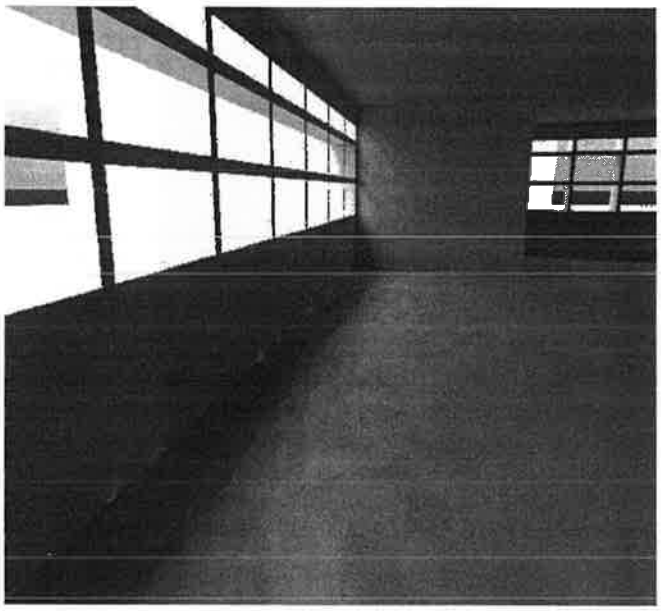
Tutorial 1: Daylight analysis

Step 4 : Perform illuminance simulation for daylighting





Illuminance is used to calculate lux or daylight factor (DF).

'Image Statistics' can then be viewed for the illuminance image generated.

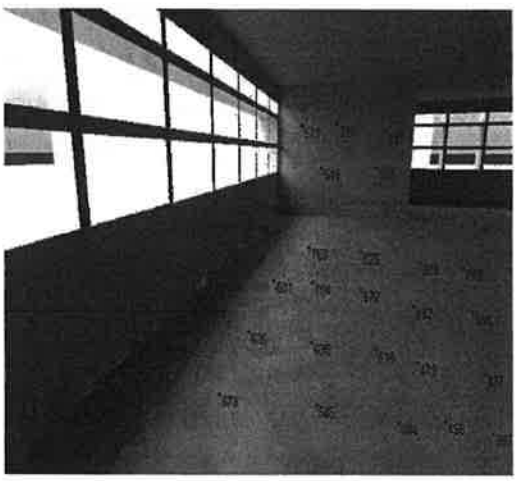
Once the result images are generated, user can click on anywhere in the image to view the result.

Tutorial 1: Daylight analysis

Step 5: Viewing the results for the illuminance image







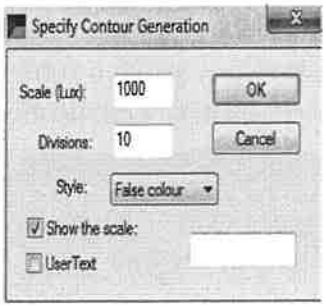
Selecting the statistic option will display the minimum, maximum, average, uniformity and diversity result. Clicking anywhere on the image will show the simulated result.

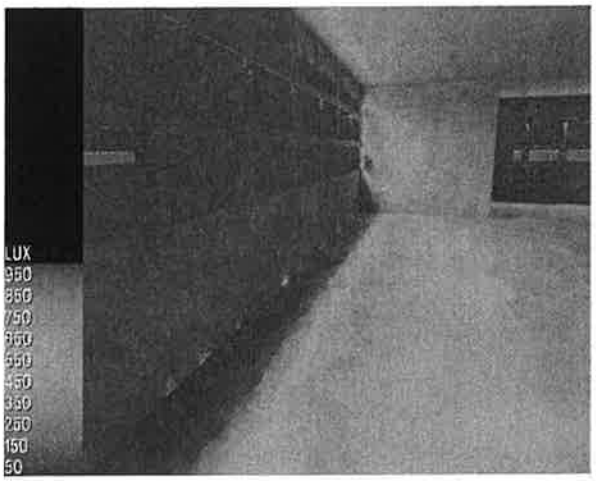
When analysing daylight quality, beside looking at the minimum lux level, uniformity is also important as good daylight design should allow even distribution of daylight into the room hence a higher value of uniformity.

Tutorial 1: Daylight analysis

Viewing the results as false colour contours:







Beside false colour, result can also be displayed as contour line and contour bands for result presentation.

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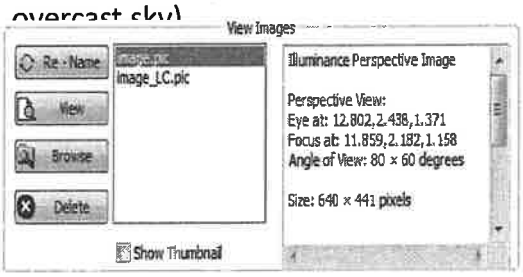
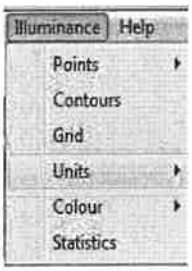
Tutorial 1: Daylight analysis

Viewing the daylight factor related results

Open the illuminance result file again and choose the unit as daylight factor (*Note: daylight factor can only be displayed if the illuminance analysis is carried out using overcast sky)







View the image statistics again to view results for DF



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Tutorial 1: Daylight analysis

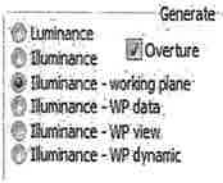
Step 6: Viewing daylighting results at a Working Plane

For most daylight assessment requirement, it is required to study the daylight penetration on the work plane height in order to determine areas that can achieve sufficient daylight performance. Therefore it is common to use illuminance – working plane analysis.

First setup working plane height: Green Mark require to carry out an analysis on working plane height of 0.85m



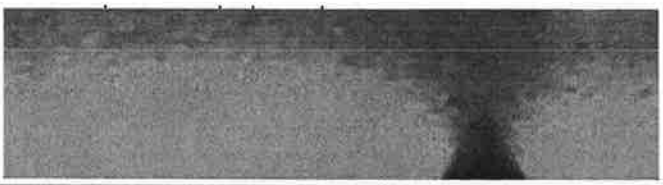
You can then perform a illuminance – working plane simulation





For any plan view images, it can also generate threshold limit , which you can use to show the percentage of

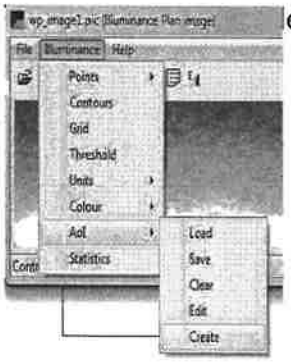


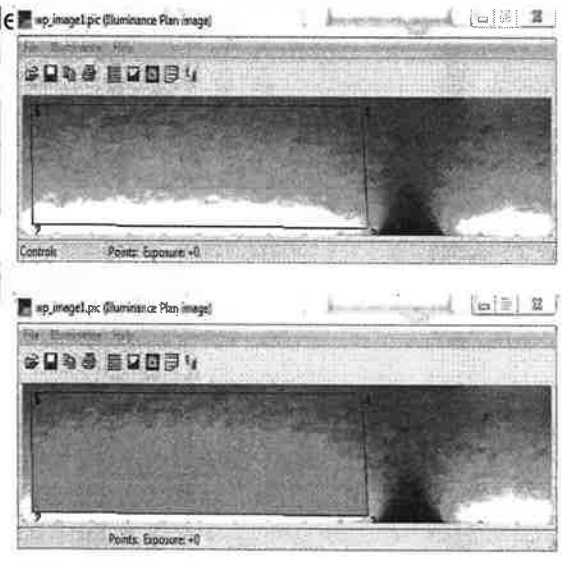


Tutorial 1: Daylight analysis

For plane images, we can also create an Area Of Interest (AOI) zone to analyse the result for that particular area only. This can be used to help eliminate dark corners that might affect the overall daylight uniformity.

To create the AOI, choose to create AOI from the top menu and start tracing the area left







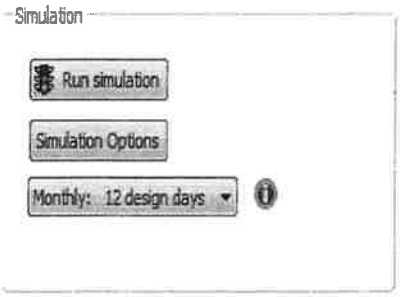
Beside the whole image, the statistic can show a summary of the results within the AOI.

Tutorial 2: Dynamic daylight simulation

Dynamic daylight simulation is a new option within VE Radiance.

The drop-down combo provides five time-step options:

Full year: 365 days - full 365 days
Full year: Holidays profile - Simulate for days that are not flagged as Holidays
Full year: Weekdays only - Monday to Fridays over full year (assume 1st January is Monday)
Monthly: 12 design days - use single "design" day per month (15th of Month)
Weekly: every 7 days - use every 7th day (starting on 1st January)



In the "**Results**" section the "**Summary**", "**Process**" and "**Time View**" buttons are inactive unless a single zone for which an annual results file exists.



Tutorial 2: Dynamic daylight simulation

The "**Process**" button pops-up the following dialog

There are 3 options available:

Annual Sunlight Exposure (ASE) -

The ASE is a metric that describes the potential for visual discomfort in interior environments. It is defined as the percent of an analysis area that exceeds a specified illuminance level more than a specified number of hours.

Spatial Daylight Autonomy (sDA) -

The sDA is a metric describing annual sufficiency of daylight levels in interior environments. It is defined as the percent of an analysis area that meets a minimum illuminance level for a specified fraction of the operating hours per year. It reports a percentage of floor area that exceeds a specified illuminance level, e.g. 300 lux for a specified amount of annual hours, e.g. 50% of the hours from 8.00am to 6pm.

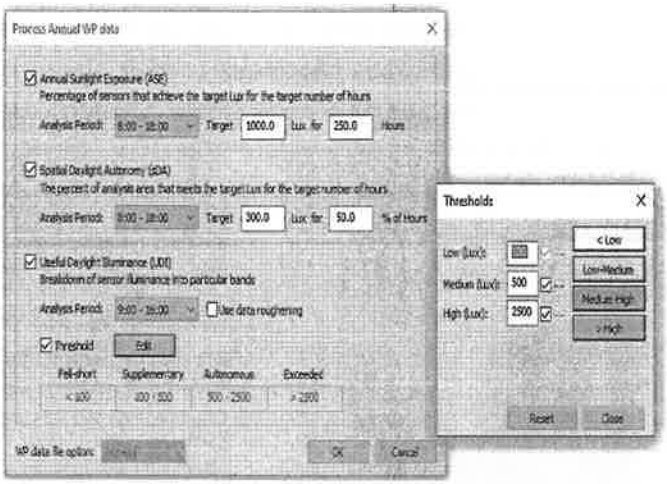
Preferred threshold:	sDA300/50% ≥75% of analysis area
Nominally acceptable threshold:	sDA300/50% ≥55% of analysis area

Tutorial 2: Dynamic daylight simulation

Useful Daylight Illuminance (UDI) -

UDI is a metric where the illuminances are categorized into bands that are considered "useful" by occupants. These bands are, by default:

less than 100 - fell short
100 – 500 - supplementary
500 – 2500 - autonomous
greater than 2500 - exceeded

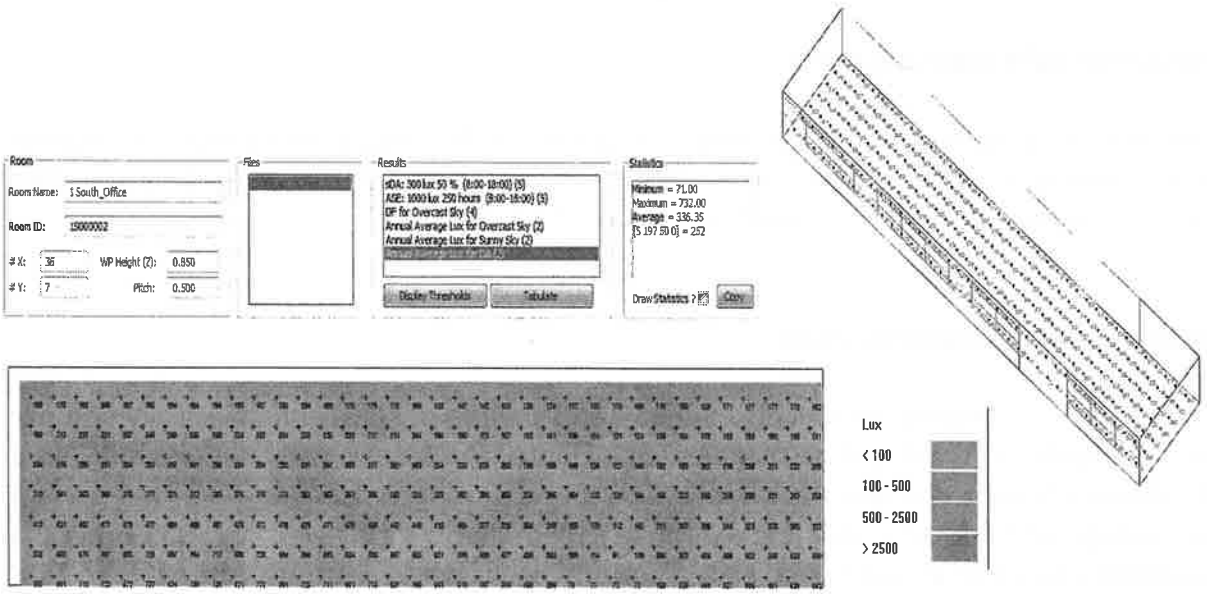


With each of these options the user can select a specific analysis period from a drop-down menu, and for the UDI the threshold ranges can be edited (e.g. in some UDI studies the ranges are specified as "less than 100", "100 to 2000" and "greater than 2000"). The "threshold" can be edited by enabling the "Threshold" check-box and clicking the "Edit" button – this pops up the following dialog:

All of these options create a "WP data" file (or append data to an existing file) which the user can view by going into the "WP Grid" tab.

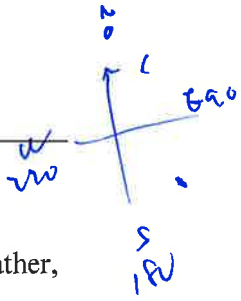
Tutorial 2: Dynamic daylight simulation

When a simulation from the Results section is selected the results are displayed automatically at the Model level. The results values will be visible at the surface level of decomposition (down a level from a Model level).



The "Tabulate" output creates a text file showing the results for each grid point with a separate column for each results set

THANK YOU



Project 1

In this project, students would analyse, with the use of **IES,** the climate type, weather, solar insolation and daylight penetration experienced by a building situated at 2 different geographical locations, and then make recommendation on the suitable passive design strategy.

Description:

Part 1 – Comparison of Weather data and passive design strategies

1) Select a location with a climate type different from Singapore
2) Show comparison between Singapore and this location. Your comparison should include, but not restricted to the followings:

    a. Latitude and longitude
    b. Climate type
    c. Daily average dry bulb temperature
    d. Daily average RH
    e. Annual average wind speed
    f. Prevailing wind direction
    g. Daily global irradiance
    h. Sun Path (compare the differences)

3) Recommend the suitable passive design strategies for each location

Part 2 – Comparison of Daylight and Solar irradiation

1) For each location chosen in part 1, perform the following analysis
    a. Overshadow analysis (9AM, 12PM & 4PM at 22 December and 22 June)
    b. Daylight Analysis at desk level
    c. Carry out Daylight Autonomy and assess whether the daylight coverage is more than 40% of the area. sDA 500lux/50%>40% of applicable area at 1 South Office room.
    d. Insolation Analysis for all facades
2) In the powerpoint,
    a. show the 4 views of the building
        - plan view
        - side view
        - front view
        - perspective view
    b. Show the contour plot of the daylight and insolation analysis for both locations (6 drawings altogether).
    c. Compare and discuss on the daylight and insolation levels for both cases. You should refer to the sunpath in your discussion.
    d. Suggest a way to improve the daylight analysis within the room.

Assessment:

Students will be assessed based on the content, specifically, the quality of the comparison and recommendation.

Please submit your pdf/ppt to the following email address by 7 July 2017.

Alanfoo999@gmail.com