Shading Strategy

OBJECTIVE

***Control intense direct sunlight to ensure a comfortable workspace*.**

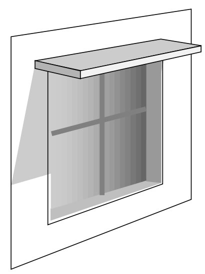
- This is critical for occupant visual and thermal comfort and for minimizing mechanical cooling loads.
- Direct sun is acceptable in less demanding spaces, such as circulation zones, lobbies, eating areas, etc.

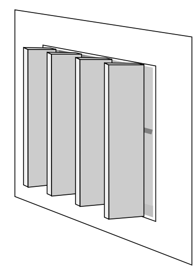
KEY IDEAS

Exterior Devices

- **Use exterior shading**, either a device attached to the building skin or an extension of the skin itself, to keep out unwanted solar heat. Exterior systems are typically more effective than interior systems in blocking solar heat gain.
- **Design the building to shade itself.** If shading attachments are not aesthetically acceptable, use the building form itself for exterior shading. Set the window back in a deeper wall section or extend elements of the skin to visually blend with envelope structural features.
- **Use a horizontal form for south windows.** For example, awnings, overhangs, recessed windows. Also somewhat useful on the east and west. Serves no function on the north.
- **Use a vertical form on east and west windows**. For example, vertical fins or recessed windows. Also useful on north to block early morning and late afternoon low sun.
- **Give west and south windows shading priority.** Morning sun is usually not a serious heat gain problem. If your budget is tight, invest in west and south shading only.
- **Design shading for glare relief as well.** Use exterior shading to reduce glare by partially blocking occupants' view of the too-bright sky. Exterior surfaces also help smooth out interior daylight distribution.

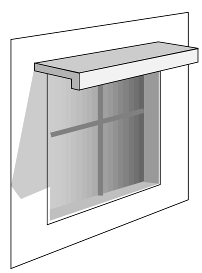
Standard horizontal overhang.

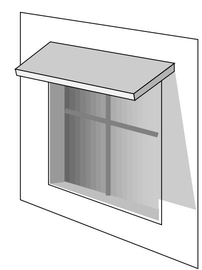




Vertical louvers or fins for east and especially west facades.

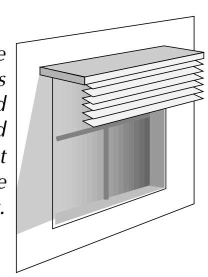
Drop the edge for less projection.

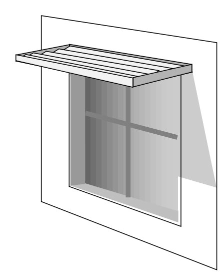




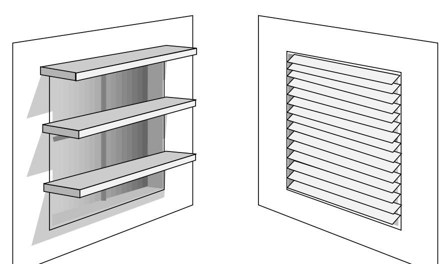
Slope it down for less projection.

Substitute louvers for the solid dropped edge to let in more light.



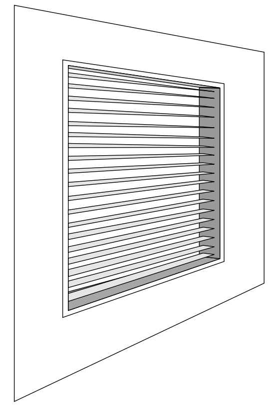


Use louvers in place of solid overhang for more diffuse light while still shading.



Break up an overhang for less projection.

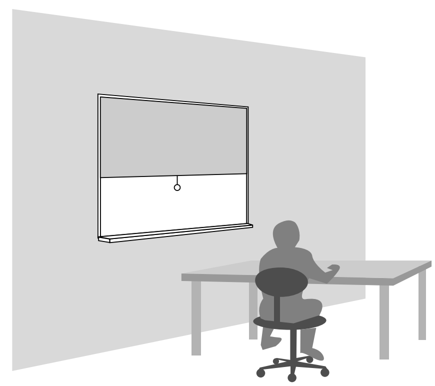
- **The shade's color modifies light and heat.** Exterior shading systems should be light colored if diffuse daylight transmittance is desired, and dark colored if maximum reduction in light and heat gain is desired.
- **Fixed versus movable shading.** Use fixed devices if your budget is tight. Use movable devices for more efficient use of daylight and to allow occupant adjustment; first cost and maintenance costs are higher than with fixed devices. Use movable devices that are automatically controlled via a sun sensor for the best energy savings. Reliable systems have been in use around the world for years and have only recently become available as cost-effective options in the United States.



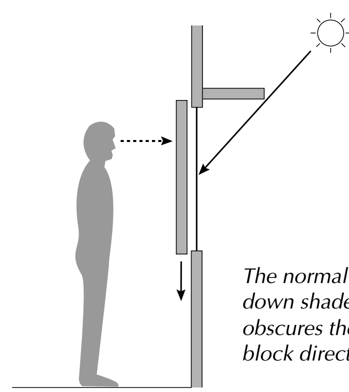
An exterior shade screen fits neatly within window framing, a bit away from the glass. Design for easy removal for cleaning.

In the Window Plane

- **Use exterior shades for a smooth facade.** Exterior shade screens are highly effective on all facades and permit filtered view.
- **Use roller shades for a movable alternative.** Open weave exterior shades are not as effective, but acceptable.
- **Don't rely on dark glazing.** Glazing treatments (reflective coatings, heavy tints, and reflective retrofit film) can be effective at reducing heat transfer. They allow direct sun penetration but with reduced intensity. This may not be an effective shading strategy from an occupant's perspective unless the transmittance is very low to control glare, e.g., 5-10%. Fritted glass, with a durable diffusing or patterned layer fused to the glass surface, can also provide some degree of sun control, depending upon the coating and glass substrate properties, but may also increase glare.
- **Between glass systems.** Several manufacturers offer shading systems (e.g., blinds) located between glazing layers. Some are fixed and others are adjustable. See related comments on interior devices below.



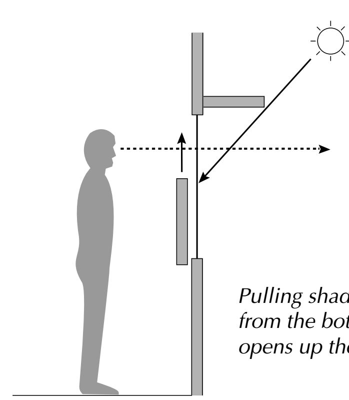
Shades, blinds, and draperies are the categories of interior shading products.



The normal top-down shade obscures the view to block direct sun.

Interior Devices

- **Interior shading alone has limited ability to control solar gain.** All interior systems are less effective than a good exterior system because they allow the sun's heat to enter the building. They also depend on user behavior, which can't be relied upon.
- **If interior devices are the only shading, specify light colors** in order to reflect the sun's heat back out. Light-colored



Pulling shade up from the bottom opens up the view.

blinds or louvers are best. Light-colored woven or translucent shades are acceptable, but may not control glare under bright summer conditions.

- **Interior shading is best used for glare control and backup shading.** Supply user-operated devices that occupants can adjust to their individual comfort needs.
- **Use devices that still allow daylight in.** Blinds and open-weave shades are good choices for filtering but not blocking all light.
- **Don't use dark devices unless exterior shading is used.** Dark-colored interior devices offer only small energy savings. Open-weave shades are easiest to see through if their interior surface is dark, but perform best if their exterior surface is light colored.

INTEGRATION ISSUES

ARCHITECTURE

Projections work well with an articulated or layered facade and can integrate well with structural members.

Exterior screens can make windows look dark.

If interior devices are the only shading, many occupants will always keep them closed. This can mean the window is permanently no longer transparent.

Use exterior shading to avoid the facade clutter of variously adjusted interior coverings.

INTERIOR

Choose light-colored window coverings for best energy savings and comfort.

Choose interior window treatments that allow occupants to make adjustments for individual comfort needs.

HVAC

Good shading provides cooling load reductions. The mechanical engineer should perform calculations that include shaded windows, but acknowledge that not all shading systems will be deployed when needed.

LIGHTING

Shading devices modify the intensity and distribution of daylight entering the space. Lighting design scheme and placement of control zones may be affected.

COST-EFFECTIVENESS

Proper shading devices can be partially or fully paid for by reduced cooling equipment and cooling energy costs. However the likelihood of proper use by occupants must be accounted for. Mechanical engineer should calculate these savings. Compare to any additional construction costs for the shades and calculate simple payback for the shading.

Automated movable systems can have an added maintenance cost and a higher first cost relative to other shading schemes. However, the operation should be more reliable than with manually operated systems. Careful calculation of expected energy savings are needed to determine cost-effectiveness for this approach.

OCCUPANT COMFORT

Direct sun in the workplace is almost always a comfort problem. Uncomfortable occupants will be less productive, close their window coverings, bring in energy-using portable fans, and reduce thermostat setting if possible. Good shading means occupants will have minimal complaints.

Shading reduces glare. Exterior elements partially shield occupants' view of the bright sky. Screens, glazing treatments, and shades reduce the brightness of the window. Exterior elements and venetian blinds reduce contrast by sending some light deeper into the space (improving distribution).

! PROVISOS

A controlled and limited use of sunlight may be appropriate in some cases.

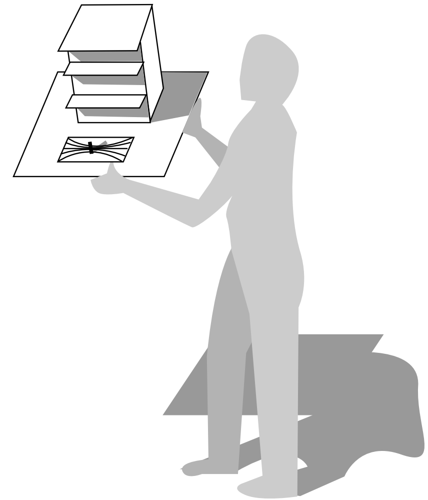
Direct sunlight:

- aids the growth of plants.
- provides strong illumination that enhances details, texture, shape, and color.
- gives a dynamic vitality to a space through its daily variation—especially beneficial in relieving institutional monotony in schools, hospitals, and public buildings.
- provides a visual and emotional link to the outdoor world.
- provides a real and suggested warmth in winter.

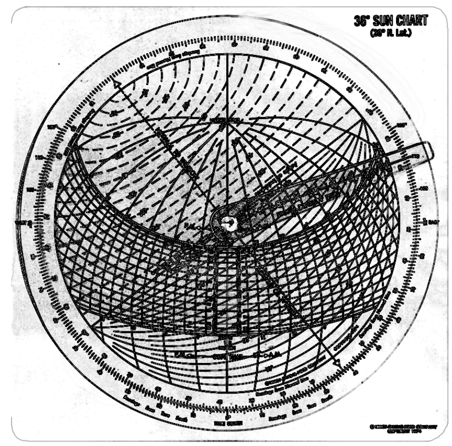
Direct sunlight may be more appropriate in circulation areas, transition areas and other spaces that do not contain critical visual tasks. Be sure to account for the peak cooling and annual cooling cost of such designs.

Be sure to balance the needs for sun control against the usefulness of daylight admittance. Some sun control strategies may severely reduce daylighting opportunities.

TOOLS & RESOURCES



Physical model study with a sundial.



For more exact sizing, use the LOF Sun Angle Calculator.

- **Sizing Equations.** Use the equations given on page 5-7 for a simple start at sizing overhangs and fins.
- **LOF Sun Angle Calculator.** A more thorough and accurate method uses this easy manual tool (available for $10 from Libbey Owens Ford, Exhibit and Display Center, Toledo, OH, (419) 470-6600). A booklet explaining how to use the tool for sizing is included.
- **Scale Model.** Test your preliminary shading scheme with a simple model. Evaluate whether glare and direct sun are successfully controlled, and make adjustments as necessary. Model studies are especially useful for complex architectural shading forms, which are hard to analyze on paper. Proper model studies are not difficult but do require some knowledge of solar geometry. A simple approach is to use a sundial (see next page). Document results with a camera. Alternatively, contact your local utility or school of architecture for possible assistance or consult one of the books below.
- **Shading Masks.** Use this simple graphic method to study and document shading device performance over the entire year, all captured in a single diagram that is easy to construct. See *Architectural Graphic Standards* for instructions.
- **Engineering Software.** Once the shading scheme is established (geometry of exterior elements is determined or an interior system is selected), use mechanical engineer's standard software to calculate cooling load with and without the proposed shading. The mechanical engineer or energy consultant must accurately model the impacts of the shading scheme. Computed savings can then be compared to added costs for the shading, for a simple payback calculation. This will be a conservative estimate, as there is no credit taken for savings associated with comfort (unshaded occupants will turn down thermostats or bring in electric fans).
- **Manufacturer Technical Literature and Product Reps** are free sources of information . Begin with "sun control" section in Sweets catalog to identify product choices and suppliers.
- **Books**

  Sun, Wind, and Light by G.Z. Brown (John Wiley & Sons, 1985) offers more thorough explanations of some tools and ideas described here, in a friendly format.

  Architectural Graphic Standards (John Hoke ed., AIA and Wiley & Sons 1994) has a section on shading masks, with instructions.

  Solar Control and Shading Devices by Olgyay and Olgyay (Princeton University Press, 1957) looks a bit dated, but still contains sound information and a nice collection of shading mask examples.

  ASHRAE Handbook of Fundamentals (American Society of Heating, Refrigerating, and Air Conditioning Engineers, any edition) is a highly technical source for generic solar heat gain coefficient data and all other aspects of building and fenestration energy behavior.

  Residential Windows by John Carmody, Stephen Selkowitz, and Lisa Heschong (Norton 1996) includes a section on using shading systems.

Sundials

Scale models can be studied outdoors under direct sun or indoors using a lamp as a simulated sun. To position the model accurately relative to the sun, place a sundial beside the model and adjust the model position until the desired time is shown on the sundial.

a) Build a simple model with accurate geometry. You can study the whole building or just a portion of the facade.

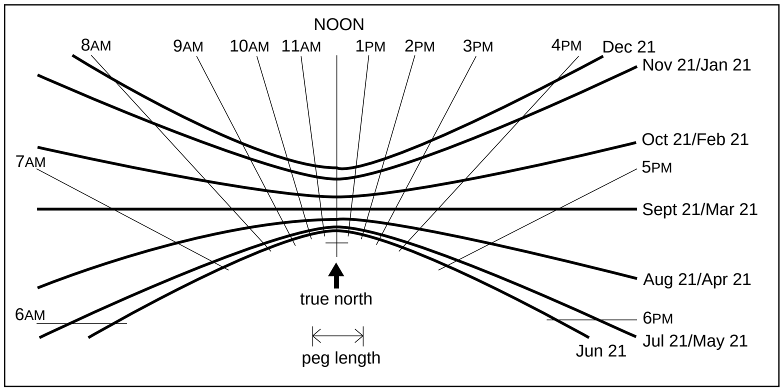
b) Select the sundial with latitude closest to your site (use 32° for Southern California, 36° for Central, 40° for Northern). Mount a copy of the sundial on your model (enlarge for more accurate positioning). It should be horizontal, oriented properly with true south on the model, and in a position where it will not be shaded by the model (flat roof or southern portion of model base are good places). Note that true north is typically depicted on city property line zoning maps, not magnetic north.

c) Make a peg the length shown and mount it on the cross mark just under the June 21 curve (a straight pin works well for this).

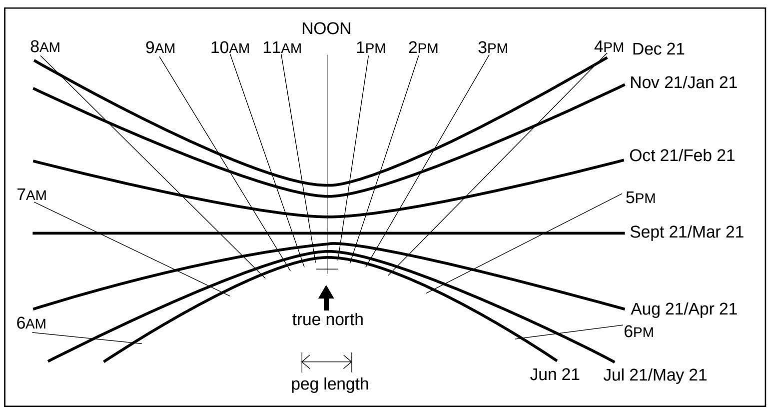
d) Take the model in the sun and tilt it so that the end of the peg's shadow falls at various intersections of the time and day lines. For example, when the model is tilted so that the peg shadow ends at the intersection of the 3 PM line and the October 21/February 21 curve, then the sun and shadow effects you observe are exactly as they will be at that time on both those days. You can now quickly see how well your shading scheme works all year round.

e) Have an assistant take photographs. Adjust design details as necessary.

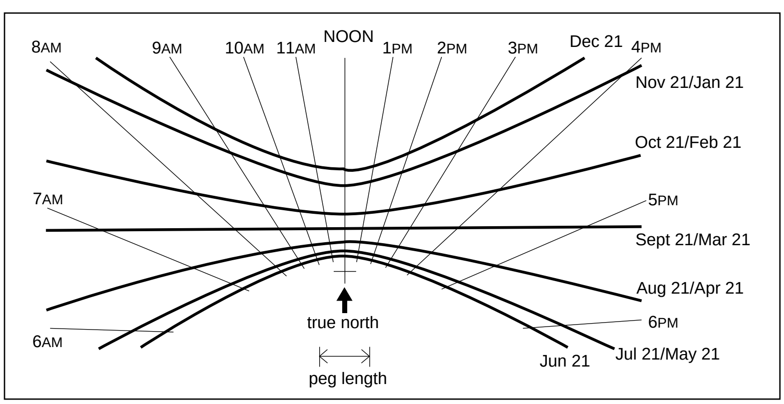
Source: G.Z. Brown, *Sun, Wind and Light: Architectural Design Strategies*, Wiley & Sons, 1985.



Sun Path 32°N



Sun Path 36°N

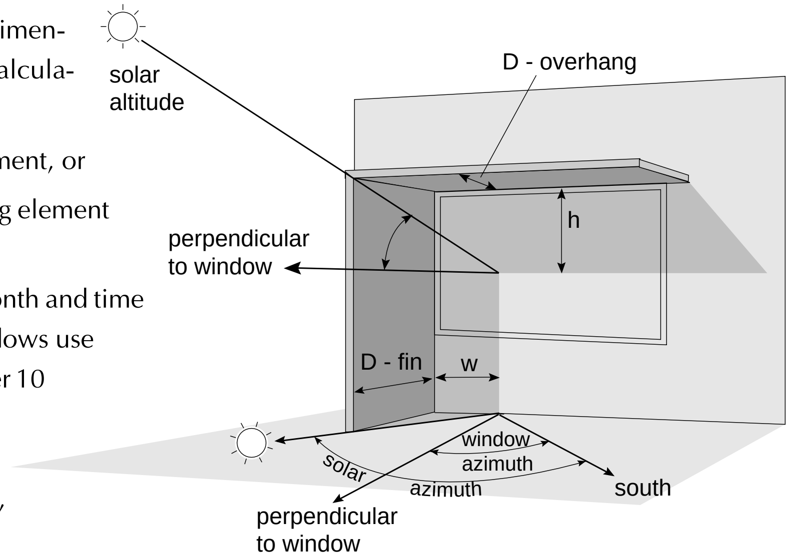


Sun Path 40°N

Sizing Overhangs and Fins

Use these equations to find starting dimensions for shading elements. Do the calculations to find:

- depth required for a shading element, or
- extent of shadow cast by a shading element with given depth.



1. For each facade, select a critical month and time for shading. Suggested: south windows use September noon, east use September 10 am, west use September 3 pm, or ask mechanical engineer for estimate of peak cooling time in east, south, and west zones.
2. Find solar altitude and azimuth for target month/hour from the sun path diagrams (page 8).
3. Use the formulas below to size overhang, fin, or both. Results are a ***minimum*** starting point.
4. If overhang is too big, try breaking it into several smaller elements or dropping part of it down for an equivalent depth, as shown in Key Ideas.
5. If sizing overhang for east or west window, you may notice that a fin must be added for adequate shading; otherwise overhang becomes unreasonably deep.
6. Test solution with a physical model and sundial (page 6).
7. Improvements: Extend ends of overhang wider than window or use a continuous element. Make overhang deeper or add another horizontal element part-way down the window. Add vertical elements to the scheme.

For an overhang: $$h = \frac{D \times \tan(\text{solar altitude})}{\cos(\text{solar azimuth} - \text{window azimuth})\ ‡}$$

- For total shade at your target month/hour, set h to height of window from sill to head and solve for D, required overhang depth.
- For partial shade, set h to acceptable height of shadow (perhaps 2/3 of window height) and solve for D, required overhang depth.
- With a given overhang, set D to its depth and find h, the height of shadow it will cast at your target month/hour.

For a fin: $w = D \times \tan(\text{solar azimuth} - \text{window azimuth})$ ‡

- Solve for either w, width of shadow, or D, depth of fin, as with the overhang equation

‡ Be sure to observe proper signs. If both solar and window azimuths are on the same side of the south vector, then both values are positive. If they are on opposite sides of south, then set one azimuth as negative. For example: solar azimuth - (-window azimuth) = solar azimuth + window azimuth.

Source: David Ballast, *The Architect's Handbook of Formulas, Tables, and Mathematical Calculations,* Prentice Hall, 1988.

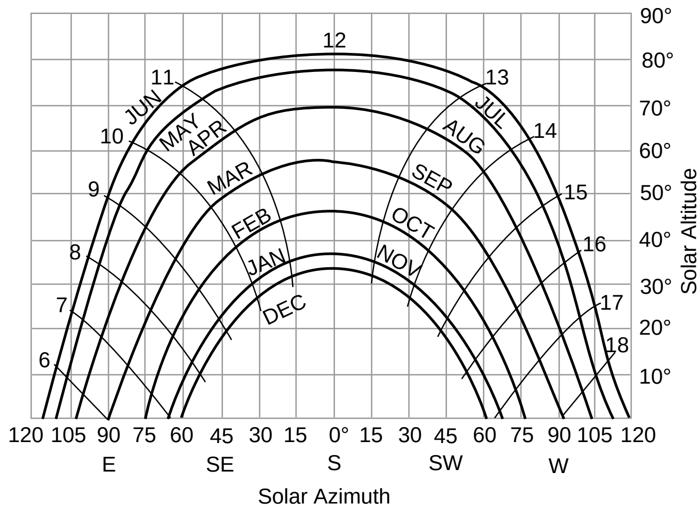
Sun Path Diagrams

Use a Sun Path Diagram to find solar altitude and azimuth for any given time, to help in sizing shading devices.

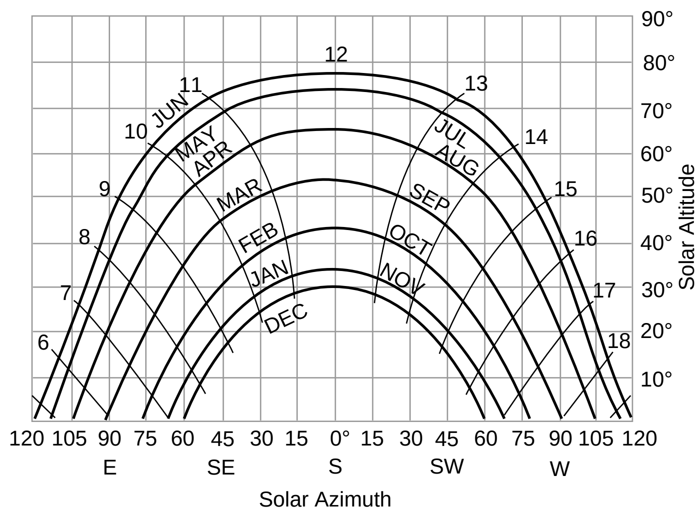
Choose the sun path diagram with latitude closest to your site (use 32° for Southern California, 36° for Central, and 40° for Northern).

Find the intersection of the two curves corresponding to the month and hour of interest. From this point, read solar altitude from scale at right and read solar azimuth from scale below. This is the sun's position at that month and hour.

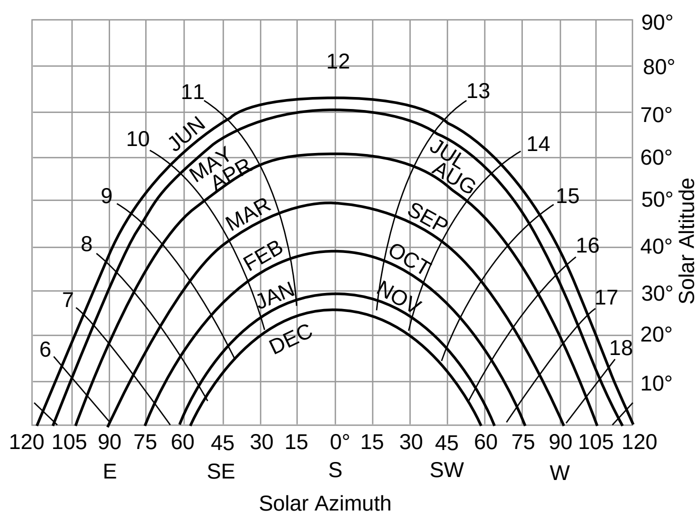
Source: Claude Robbins, *Daylighting: Design and Analysis*, Van Nostrand Reinhold, 1986.



Sun Path 32°N



Sun Path 36°N



Sun Path 40°N

☑ CHECKLIST

1. Characterize your shading needs. Long axis running east-west: shading is relatively simple (overhang or deep reveal on south may be all that's needed). Large area of glazing on west: shading becomes more critical and more difficult if daylight is to be maintained. Budget design time accordingly. You must know your true north orientation.
2. Review options for shading and select a basic approach (exterior vs. interior, an architectural projection, an off-the-shelf attachment, blinds, drapes, shades). A different strategy may be appropriate for each facade.
3. For exterior schemes, calculate preliminary size of projections. Use rules of thumb given here or use LOF Sun Angle Calculator method.
4. Refine with LOF Sun Angle Calculator (if still working on paper) or through quick physical model studies (for easier 3-D analysis).
5. Select an interior shading product and get solar heat gain coefficient data from manufacturer literature or product reps (see Sweets for starters). See ASHRAE Fundamentals for tables of generic products.
6. Get solar heat gain coefficient data for preliminary glazing selection from manufacturer literature, product reps, or generic table in Section 4, GLAZING SELECTION, or in ASHRAE Fundamentals.
7. Mechanical engineer calculates cooling load by hand or with computer model, accounting for exterior shading elements and proper solar heat gain coefficients for glass plus interior coverings. For venetian blinds, see ASHRAE Fundamentals for proper treatment of angle-dependent solar heat gain coefficient.
8. Mechanical engineer provides a rough estimate of savings due to shading. Get preliminary first cost estimate for shading and compute simple payback.
9. Provide description of shading scheme to lighting designer.

If you have...

no time

1. Minimize window area on east and west.
2. Use sizing rule of thumb for a horizontal projection or reveal on south windows.
3. Use sizing rule of thumb for a vertical projection or reveal on west windows.
4. If no exterior shading is possible, a lower solar heat gain coefficient for the glazing will be mandatory (see Section 4, GLAZING SELECTION), and interior shading will be required as well.
5. For best occupant comfort, provide either a light-colored venetian blind or light-colored translucent shade on all windows in occupied areas. For energy savings, these are desirable to include even with exterior shading; they are mandatory if there is no exterior shading.

a little time

In addition to above:

1. Use the LOF Sun Angle Calculator method for preliminary sizing of exterior projections instead of rule of thumb, or to refine schematic design after using rule of thumb.
2. Browse through Sweets catalog for ideas on shading strategies and products.
3. If undecided on best shading approach to take, a mechanical engineer's simple calculations can help compare cooling reductions with different options.

more time

In addition to above:

1. Build a physical model and test under sun for best final design of exterior shading.
2. Mechanical engineer takes special care to properly model shading elements and solar heat gain coefficients in computer calculations.
3. If large area of east or west glazing, mechanical engineer performs more complex calculations to determine cost-effectiveness of an automated exterior system.
4. Mechanical engineer helps explore opportunities for cooling equipment downsizing through optimum shading. Refine shading design to yield smallest possible cooling equipment.