A Guide for Making and Using Demonstration Models for Heliodons

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INTRODUCTION

Heliodons are powerful tools for creating solar responsive designs. They can be used to teach solar geometry, to teach solar strategies, to analyze designs, to create designs, and for presentations where the effectiveness of solar designs can be objectively demonstrated. The purpose of this guide is to help in the production and use of models for teaching solar strategies such as building orientation, building form, window placement and shape, shading devices, solar access, tree placement, and sundial design.

In the following discussion, each model will be described first in regard to its construction (Part A) and then how it can be used to demonstrate solar strategies (Part B).

PART A: CONSTRUCTION OF MODELS

1. The Base Building Model

The base building model will be used to demonstrate various shading and passive solar strategies. Figure 1 shows the base model along with various attachments. The drawings in Appendix A show recommended dimensions which make the base model small enough so that heliodon distortions are minimized yet large enough so that a group of about 15 people can easily see the model demonstrated on the heliodon.

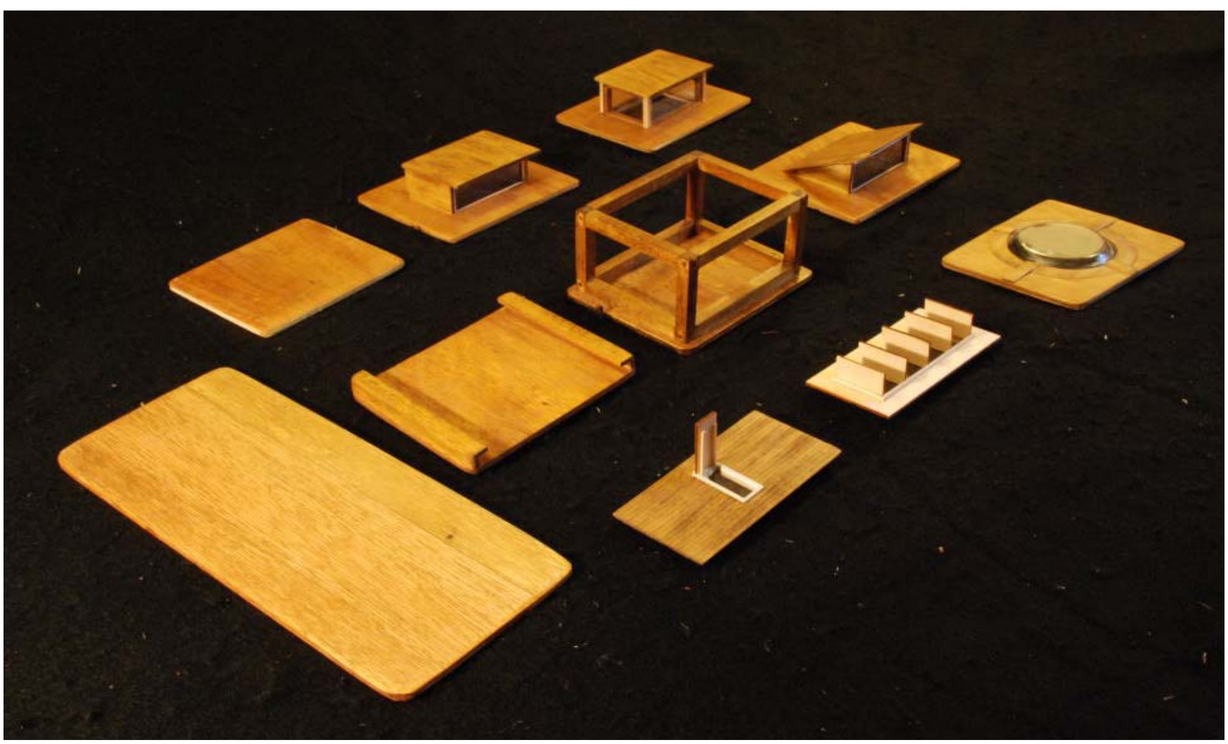


Figure 1

2. The Adjustable Overhang Roof Attachment

Figure 2 shows the "adjustable overhang roof attachment" on the base model. The construction drawings are shown in Appendix B, and Appendix C shows the two overhang inserts that slide easily back and forth in the roof channels. Also make sure that the projections on the underside of the roof attachment fit easily into the top of the base model for stability.

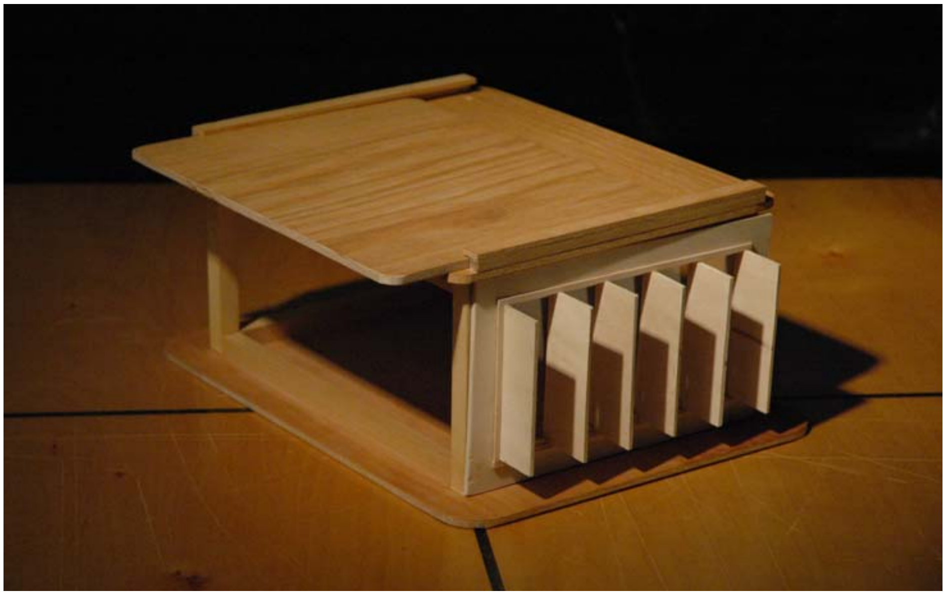


Figure 2

3. The Fin Attachment

Figure 2 also shows the window wall attachment that illustrates the shading performance of fins, and Appendix D shows the construction drawings for this attachment. Make sure that the wall attachment fits easily but snugly into the base building. Do not cut holes for windows. Instead use middle gray paper covered with glossy clear plastic film or tape to simulate glass. Shadow lines are hard to see when the windows are transparent.

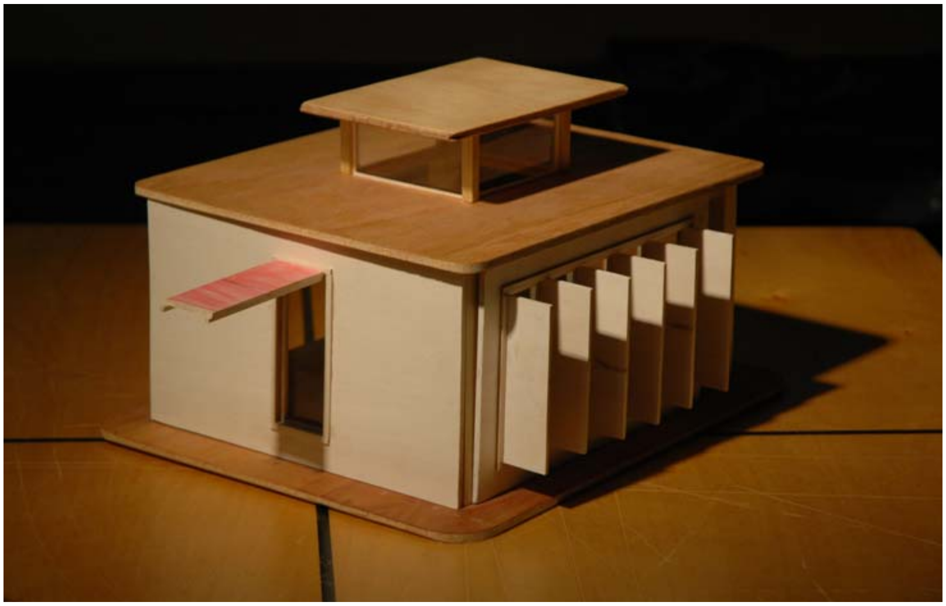


Figure 3

4. The Overhang Same-Width-as-Window Attachment

Figure 3 shows the base model with a tall narrow window with an overhang the same width as the window. Although the overhang is very deep (perpendicular to window), the shading is totally inadequate. Make this attachment the same way as the “fin attachment” except have only one tall window with an overhang the same width as the window and 4 cm deep. As before, do not cut a hole for the window but instead use middle gray paper covered by a glossy plastic film or tape.

5. The Skylight Attachment

Figure 1 also shows the skylight roof attachment. To make such a model, either find a clear plastic bowl about 7 cm in diameter or just have a flat clear plastic skylight (from a solar point of view, there is no difference). On a roof plate (10 × 13 cm), cut a hole to fit the plastic bowl, and glue the bowl to the plate. As always, use projections on the underside of the roof plate that fit into the top of the base model (Appendix B).

6. The Clerestory Attachments

Figure 3 also shows a clerestory roof attachment with glazing in all four directions, and Fig. 1 shows two alternative clerestory attachments. Although in each case the glazing is vertical, the orientation of the glazing varies. In one case there is glazing on all four sides (Figure 3); in the second case there is glazing on both the north and south sides (Fig. 1); and in the case of the sawtooth clerestory, there is glazing in only one direction (Fig. 1). The total glazing area should be the same for each of the three clerestory models, and it should be made of transparent plastic so that puddles of sunlight will form on the floor of the base building. The roof plate for these models is similar to that of the adjustable overhang roof attachment. Be sure to use projections on the underside that will fit into the top of the base model (Appendix B).

7. The Orientation Model

The elongated building shown in Figure 4 illustrates the importance of building form and orientation for window placement, roof solar collectors, dormer orientation, and tree placement. Pre-drilled holes are used to show the consequences of various tree locations.

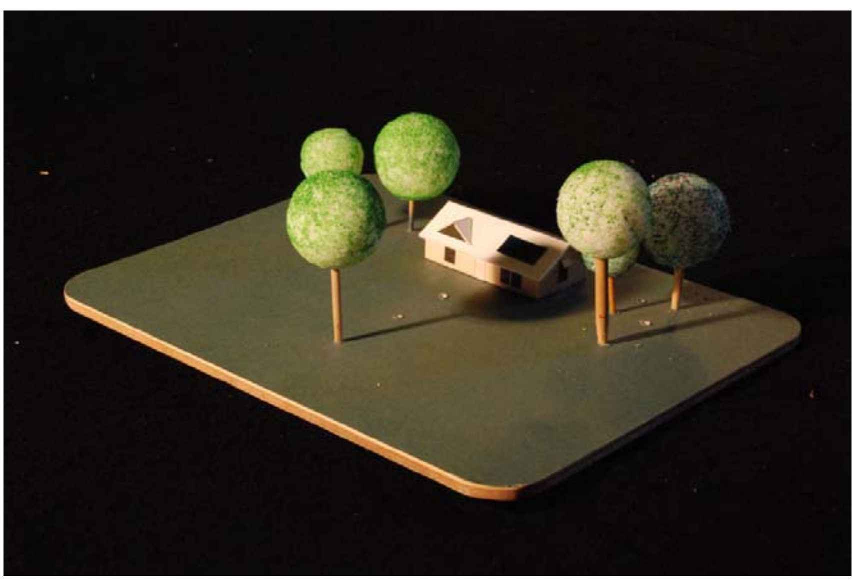


Figure 4

8. The Setback Model

The model shown in Figure 5 illustrates the consequences of building setbacks/projections on solar access. It also illustrates how clerestories can be used to get sunlight to the north side of a building. This model was made to be reversible. The side shown illustrates large setbacks, while the far side illustrates small setbacks. See Appendix E for a construction drawing.

Figure 5

9. The Street Orientation Model for Separate Houses

Figure 6 illustrates how street orientation has a major effect on the energy consumption of houses. As in most suburban developments the long façade of each house faces the street. All buildings, except the one with a solar roof, are glued to the base, which is about 18 cm × 22 cm. The street is about 5 cm wide, and each house is about 2.5 cm × 4 cm.

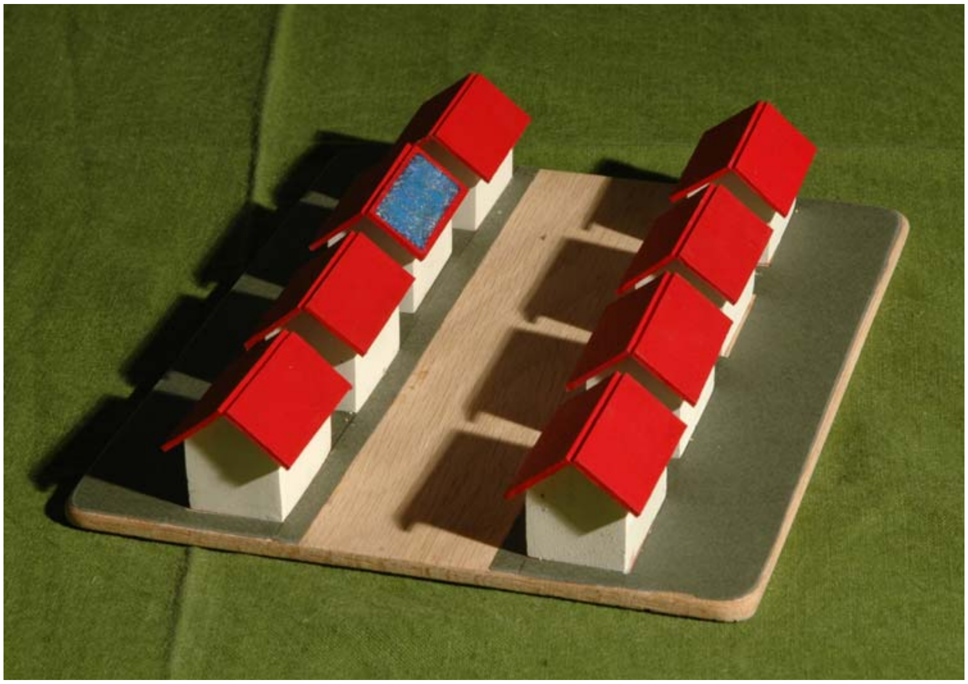


Figure 6

10. The Village Homes Model

Figure 7 illustrates a model based on the site design of the Village Homes subdivision in Davis, California. On a photocopy of the development plan (Appendix F), glue small pieces of balsa wood to represent the houses.

Figure 7

11. The Street Orientation Model for Town Houses

Figure 8 illustrates how street orientation has a major effect on the energy consumption of row houses, apartment buildings, and other contiguous buildings. This model is conceptually similar to the one shown in Fig. 6. Use the front and rear façade drawings of Appendix G.

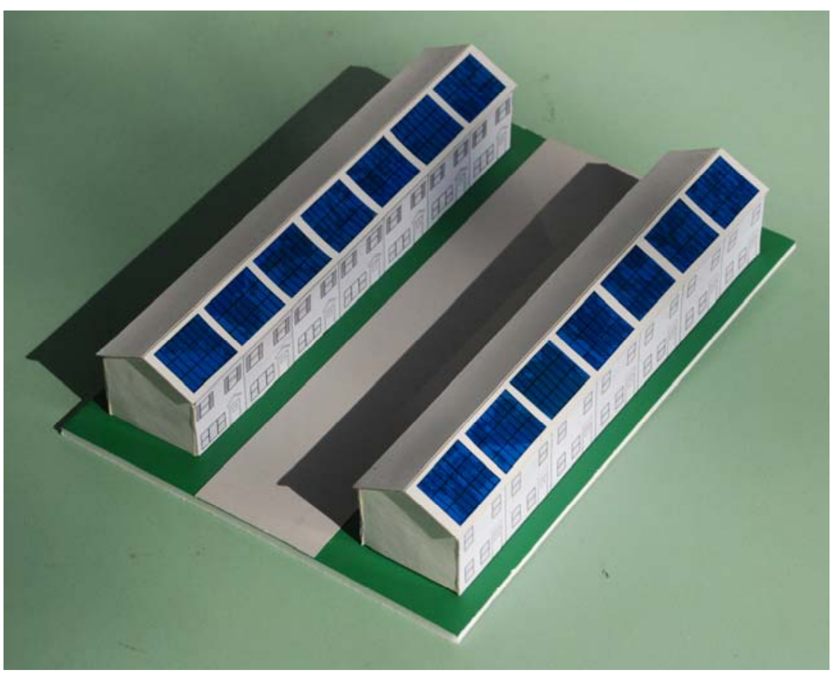


Figure 8

12. The Shadow Pattern Model

In designing a site for a building or a whole subdivision, it is important to know how buildings shade each other and how trees shade buildings (Fig. 9). The shadow pattern model is made of a small board of plastic foam (1 to 2 cm thick), small models of some buildings, and trees with pointed trunks so that they can be stuck into the foam board.

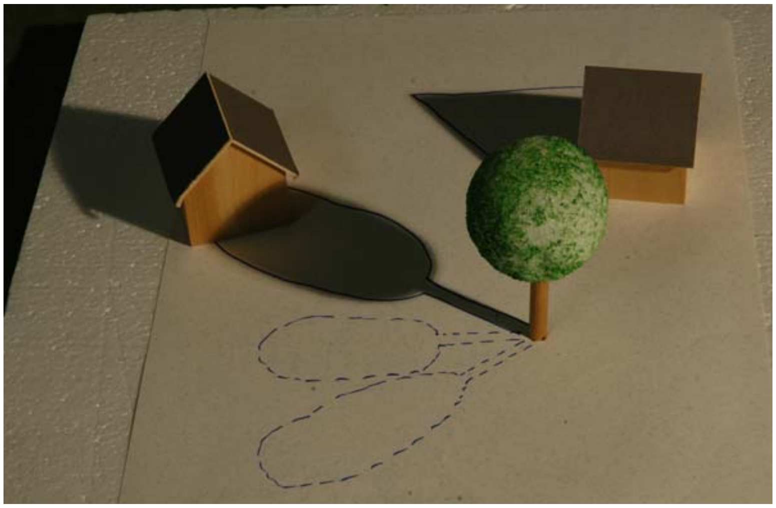


Figure 9

13. The Sun Puddle Model

The model of a room shown in Figure 10 illustrates how the shape and location of sun puddles from a window vary with the time of day and time of year. The red transparent window insert shows how the floor can be turned into a sundial and the window into a gnomon. The walls are transparent so that a large group of spectators can all see the location of the sun puddle. Only 3 walls are used so that it is easy to outline the location of sun puddle(s) with a pen.

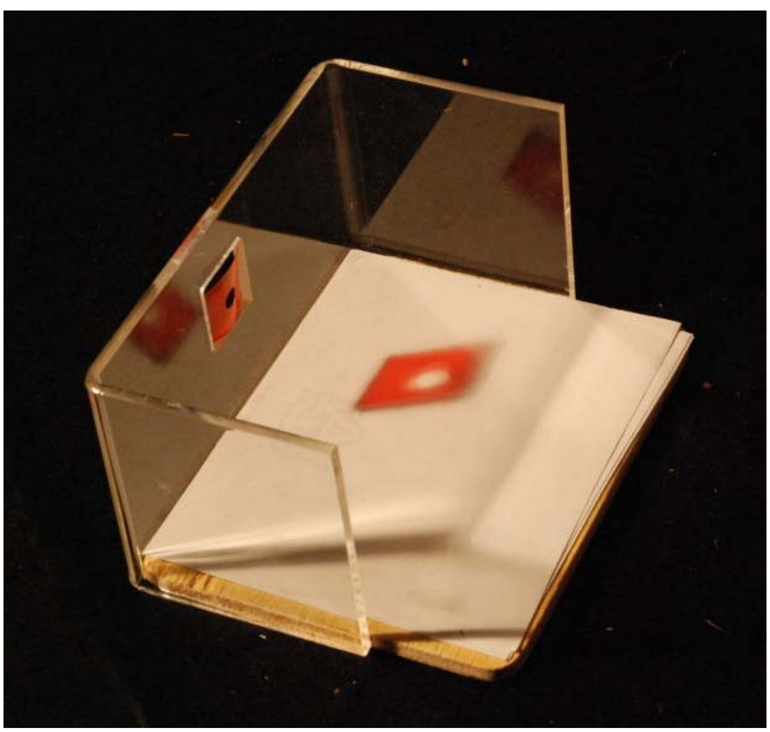


Figure 10

PART B: DEMONSTRATION OF MODELS

The following demonstrations are usually made to illustrate the consequences of various solar strategies at a particular site. Thus, in most cases, the heliodon is adjusted for a particular latitude and then left in that position. However, if there were in interest in seeing how latitude affects solar performance, the following procedures could be repeated for various latitudes.

1. The Base Building Model

The base building is used together with the various wall and roof attachments (Fig. 1). To maximize accuracy when using the heliodon, move the base model so that the wall attachment being examined is placed over the center of the heliodon table (i.e. the base building will be off-center). When using the skylight and clerestory attachments, then center the base building.

2. The Adjustable Overhang Roof Attachment

By rotating the base building, this attachment can be used to understand the performance of overhangs for any orientation (Fig. 2).

a. South Overhang: Place the base model with the roof attachment on the heliodon table so that the south wall is over the center of the table. Use the small overhang insert. Set the heliodon for 12 noon on June 21, and slide the overhang insert out until the window is fully in shade. Now set the heliodon to 12 noon on December 21. Is the window now fully shaded in the summer and fully exposed to the winter sun?

No! June 21 does not represent summer and December 21 does not represent winter. Instead find the date on which the overheated period ends for that particular place and climate (see Chapter 9 of the book *Heating Cooling Lighting: Design Methods for Architects* by N. Lechner). Now set the heliodon to the last day of the overheated period for the site being investigated (e.g. Sept. 21) and readjust the overhang. Note that the overhang required to shade the window for the whole overheated period is much larger than before. Now find the last date of the underheated period for that building site (e.g. March 21). Note how much of the window is shaded by the overhang or the last day of winter when full sunlight is still required.

Because the thermal year and the solar year are out of phase, a fixed overhang cannot both fully shade a window during the overheated period and fully collect sunlight (passive solar) for the whole underheated period. The only good solution is a movable overhang. Very high performance is possible even if the overhang is adjusted only twice a year (i.e. spring and fall). For this reason, adjustable awnings are excellent shading devices. However, if the building and climate are such that there is no underheated period (e.g. large office building in a warm climate), then a fixed overhang would perform very well on the south façade.

b. East or West Overhang: Since east or west windows receive mostly summer sun and little winter sun, the overhang design is based only on summer shading. Since sun angles and solar gain are the same for east and west windows, a discussion of a west overhang will be equally valid for an east window.

Place the model on the heliodon table so that the west window is over the center of the table. Set the heliodon to 1 pm on July 21 (a good month to represent the height of the overheated period). Slide the small overhang insert out until the west window is in shade. Repeat for 2 pm, 3 pm, & 4 pm. Note that by 4 pm the length of the required overhang exceeds the length of the small overhang insert. Now continue with the large insert. The excessively long overhang needed at 5 and 6 pm proves that a horizontal overhang cannot fully shade west (east) windows whereas on the south it can.

Although the horizontal overhang cannot fully shade the east and west windows, it can shade for several hours before and after noon while still providing an unobstructed view. An additional shading device is needed when the sun outflanks the overhang. A vertical trellis or shutters could work for this purpose.

c. North Overhang: Repeat the exercise for the north windows. Note how the sun outflanks the overhang from the east in the morning and the west in the afternoon. Vertical fins are much more useful on north windows than a horizontal overhang. However, the value of a horizontal overhang on north windows varies greatly with latitude. The closer to the equator, the more important the overhang on north windows until at the equator, north and south windows need identical shading.

3. The Fin Attachment

Place the fin wall attachment on the base model (Fig. 2) so that the fin wall is facing west, and it is directly over the center of the heliodon table. Set the heliodon for 1 pm on July 21, and test the model at one hour intervals. The model test shows that not only do fixed fins not shade well, they obstruct the view significantly. It is thus clear that the widely held belief that fins should be used on the east and west is not correct.

Now rotate the building so that the fins face north and the fin wall is again over the center of the heliodon table. Note how well the fins shade the north windows. However, these fins designed for the west are much too large for the north windows. Only small fins are needed on north windows. However, in tropical latitudes the sun will outflank the top of the fins and an overhang is needed in addition to small fins.

4. The Overhang Same-Width-as-Window Attachment

Place this wall attachment on the base model (Fig. 3) facing south with the wall centered over the table. Set the heliodon to 12 noon on July 21. Since the overhang is very deep, it should be shading the whole window. Now set the heliodon to 9 am, and note how the sun has outflanked the overhang from the east. Continue testing the model at one hour intervals. It is thus clear that the window is fully shaded for only a brief period around 12 noon. Thus, an overhang either needs to be much wider than the window or it needs fins to prevent being outflanked. This problem is most acute for tall narrow windows, and it is a minor problem for long horizontal strip windows.

5. The Skylight Attachment

Place the skylight attachment shown in Fig. 1 on the base model and center the base model on the heliodon table. Set the heliodon to 12 noon on June 21. Note the large and bright sun puddle on the floor of the base model. Now set the heliodon to test the next month, July 21, at 12 noon, and continue to test each month at 12 noon until December 21. Not only has the sun puddle moved north inside the base model, but it has become smaller and less bright. Obviously, the skylight faces the high summer sun much more than the low winter sun. Skylights would be great if more summer sun than winter sun were desired inside the building. Unfortunately, since this is never the case, skylights should not be used! Instead bring the sun and daylight in through the roof by means of a clerestory.

6. The Clerestory Attachments

Place the 4-sided window clerestory attachment on the base model (Fig. 3). Set the heliodon to 12 noon, and step from June until December always at 12 noon. Notice that the most sun enters in the winter and the least in the summer. Just what is needed.

Now test a hot summer day such as July 21. Note how the morning sun enters the east clerestory and the afternoon sun the west clerestory. Unlike windows that often face east and west for view, east and west clerestories don't have that excuse for their existence. Since they collect too much summer sun and little winter sun, it is best to leave them out.

Now repeat the above procedure with the north and south clerestory attachment (Fig. 1). Note that more winter sun is collected, because some of the east and west glazing was moved to the south. Although the north glazing is not a large burden in the summer, it is of zero benefit in collecting winter sun. Thus, the best clerestory is usually with all the glazing facing south in climates where winter heating is required and north in those situations where winter heating is not required. A clerestory with glazing facing only in one direction is often made in the form of a "sawtooth" (Fig. 1).

7. The Orientation Model

When the long axis of a building runs east-west, most windows will automatically face north and south. Place the model (Fig. 4) so that the house is over the center of the heliodon table, and its long axis runs east-west. By stepping the heliodon through the hours of a cold winter day such as Jan. 21, it is clear that the south windows see the sun all day. By stepping the heliodon through a hot summer day such as July 21, it is also clear that the morning sun sees few, if any, east windows, and the afternoon sun sees few, if any, west windows. Since the summer sun shines on the roof the whole day, it is important not to have any skylights. Instead a south-facing clerestory in the form of a dormer is ideal.

Also note how with this orientation the roof slopes down to the south which is the requirement for active solar and PV collectors. Thus, an oblong building with the long axis in the east-west direction is ideal.

To understand the correct placement of trees, locate some trees to the south of the building (use the predrilled holes). Now repeat the winter analysis and note how much the trees shade the south façade and roof during the winter. Even if the trees are deciduous, they will still shade 30 to 60% of the sun depending on the tree's species and size.

Now move the trees to the east and west of the building, and repeat the summer analysis. Note how trees can effectively shade those difficult east and west windows. If the trees are too far away to block the high sun just before and after noon, then a horizontal overhang is also needed on the east and west windows.

Repeat the above procedure with the model turned 90 degrees so that the building's long axis runs north-south. Now most windows face east and west which results in much summer overheating and little passive solar in the winter. Furthermore, the roof slopes the wrong way for the correct orientation of dormers and solar collectors.

Thus, correct orientation, which costs nothing, is a free lunch that should always be utilized when the site allows it.

8. The Setback Model

Setbacks shade adjacent buildings or parts of the same building. They can be a serious problem when access to the winter sun is desirable.

Place the setback model (Fig. 5) with the façade of large setbacks facing south with the façade centered over the heliodon table for greater accuracy. Set the heliodon to a cold winter day such as January 21. As the heliodon steps from 8 am to 4 pm, it is obvious how much some of the south windows are shaded from the much needed winter sun because of large setbacks. Now reverse the model so that the small setbacks are facing south. Repeat the above procedure, and notice that the shading of south windows is now minimal.

9. The Street Orientation Model for Free Standing Houses

Place the model (Fig. 6) on the center of the heliodon table with the street in a north-south orientation. Since the long facades are now facing east and west, most windows face east and west. Step through a summer day (e.g. July 21). Note how all morning the many east windows are exposed to the hot summer sun and how all afternoon the many west windows are blasted by the hot sun. Not good!

Now step through a winter day (e.g. January 21), and note that not only are there few south windows but those windows are shaded by the neighboring buildings to their south. Thus, there is almost no passive solar heating. Not good either!

What happens if the street runs east-west? Rotate the model 90 degrees. Repeat the process described above. Note how now there are few east and west windows and how neighboring buildings shade each other in the summer. That's great! Also there are now many south windows getting much winter sun. That's great also!

Thus, the people living on east-west streets are winners both winter and summer at no extra cost, while those living on north-south streets are losers both summer and winter. Does that mean that half of all people have to be losers? See the next model to find out.

10. The Village Homes Model

Place the model (Fig. 7) on the center of the heliodon table with its north arrow pointing north on the heliodon. Note that although the site runs mostly north-south, all houses are on east-west streets. Everyone in the Village Homes development is a winner. Thus, knowledge, not just higher first costs, can save much money, energy, and the planet. There *is* such a thing as a "free lunch."

11. The Street Orientation Model for Town Houses

Place the model (Fig. 8) on the center of the heliodon table. Repeat the procedure used with "the Street Orientation Model for free standing houses" (Fig. 6). With town houses, apartment buildings, and other contiguous buildings, orientation is even more important than with free standing buildings, because *all* windows are either oriented correctly or incorrectly.

12. The Shadow Pattern Model

Tape some white paper on the foam board, and then place the building(s) and tree(s) to reflect a site plan (Fig. 9). Shadow patterns are most often made for Dec. 21 when shadows are longest and sun is desirable. Step the heliodon from 8 am to 4 pm, and trace the shadow(s) cast each hour (Fig. 9). By connecting the shadow(s) for each object, the shadow patterns are created for Dec. 21. It is now easy to see any solar access conflicts that might exist due to trees or buildings.

13. The Sun Puddle Model
All of the previous models demonstrated what happens on the exterior of a building. This model illustrates the location of sun puddles created by windows facing in any direction. The heliodon can show how the shape and location of sun puddles varies throughout the day and throughout the year.

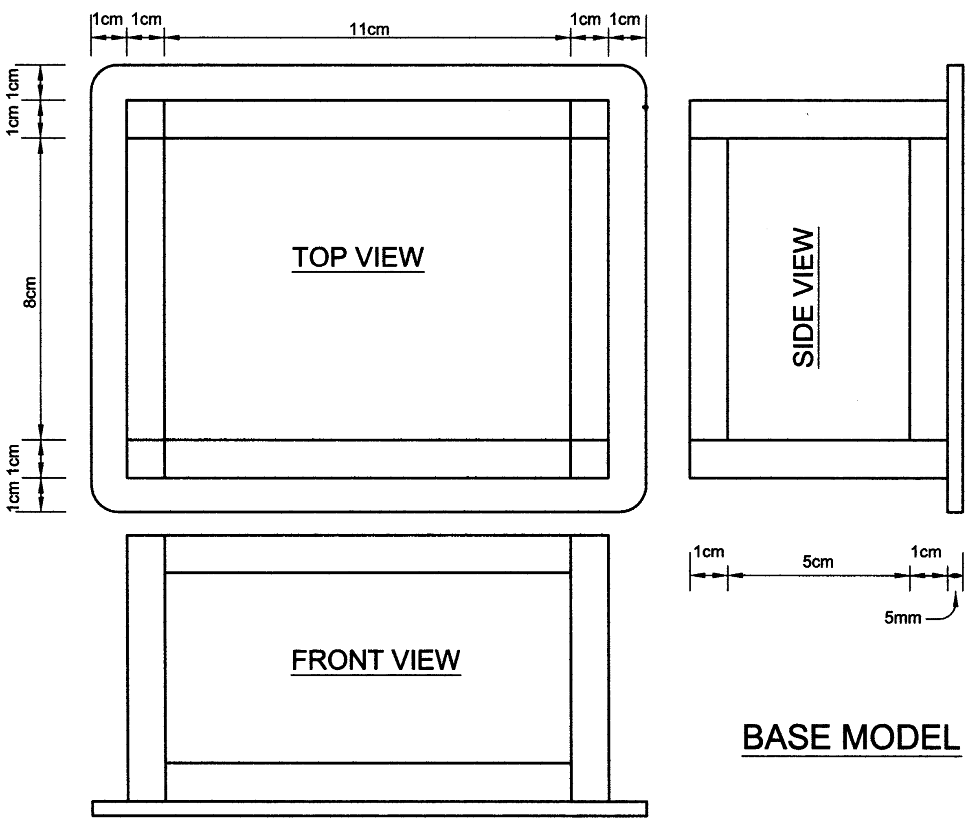
Place the model (Fig. 10) over the center of heliodon table with the window facing south. Set the heliodon for Dec. 21 and step through the day from 8 am to 4 pm. For each hour, trace the location of the sun puddle. Connecting all the sun puddles will create the “solar zone” in the building that receives direct sun on that day.

Repeat the procedure for June 21. Note how small and weak the sun puddles appear. Because of the cosine law and reflection off the glazing, very little sunlight enters even without any shading devices. Repeat this procedure for the equinoxes (March and Sept. 21).

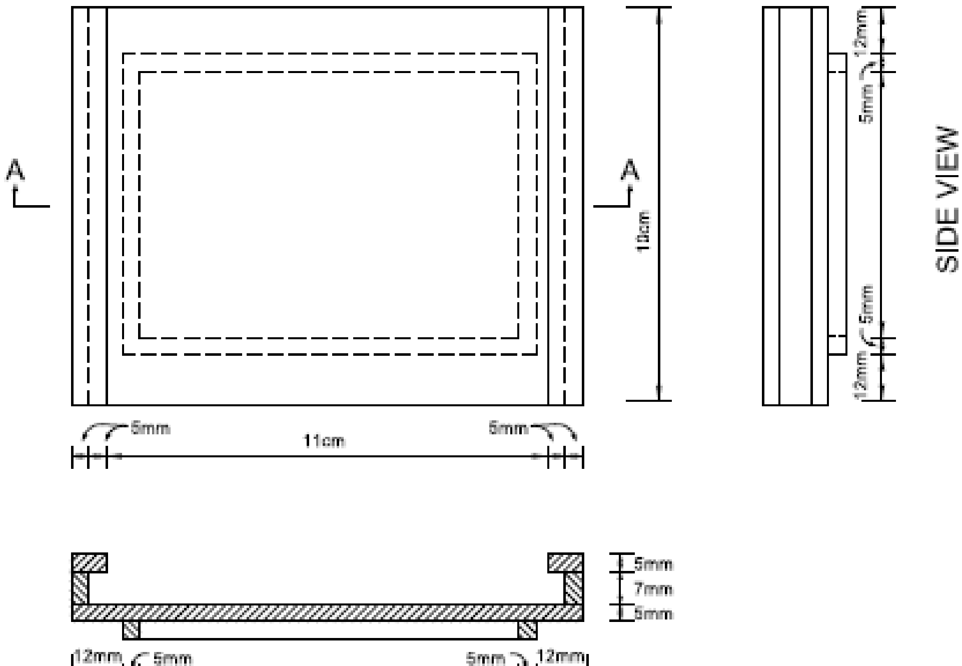
By using a stained glass window inset, a small sun puddle can be projected on the floor. By locating and marking the spots on the floor for each hour of each month, a sundial can be generated.

Conclusion
The above described models are only a starting point. Many more demonstration models can be made. Any solar strategy or idea can be examined on a heliodon simply by making a study model.

Appendices



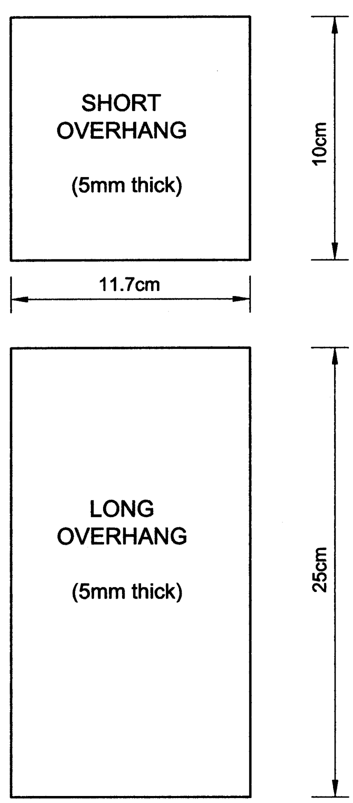
Appendix A



SECTION A-A

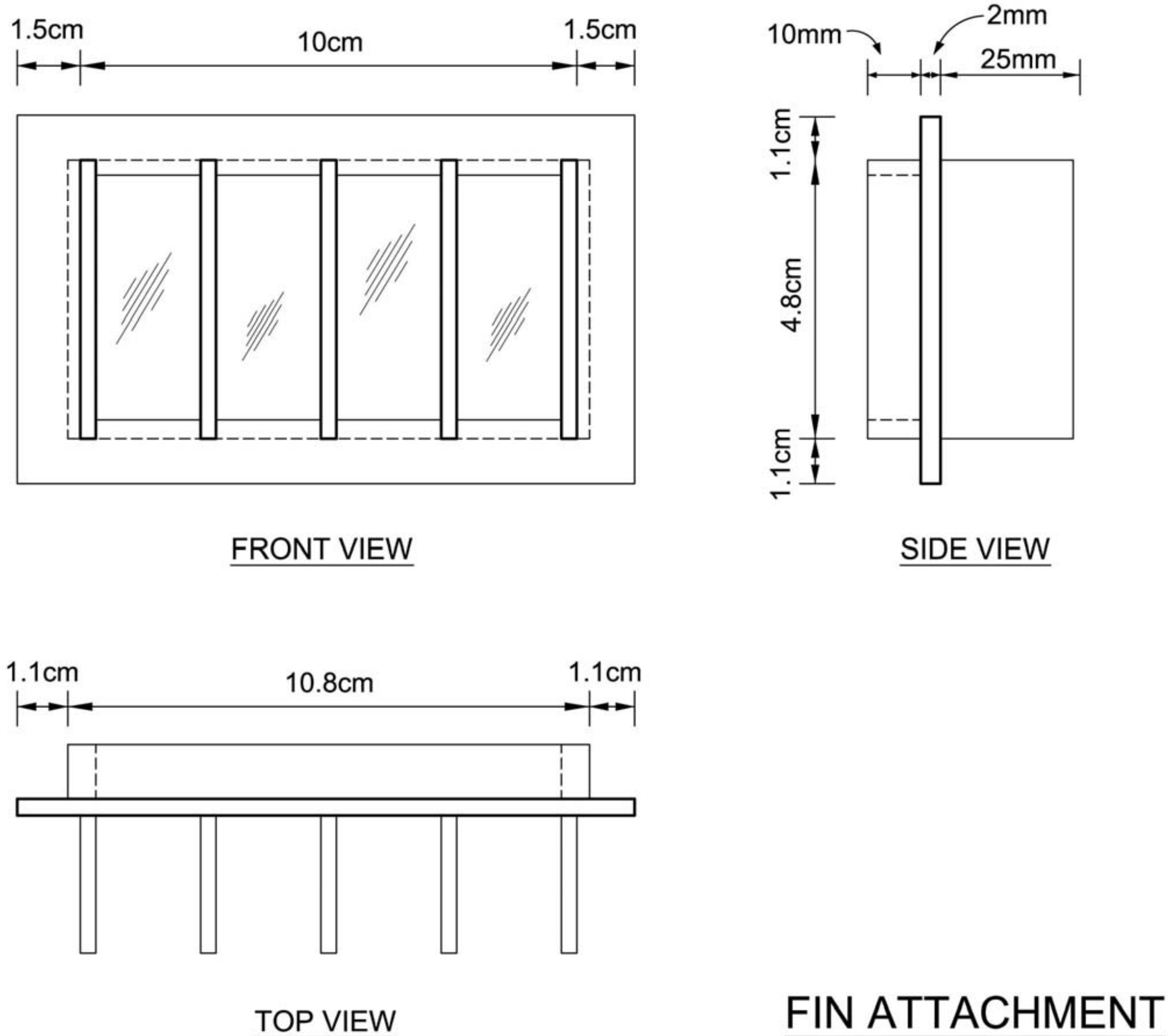
ADJUSTABLE OVERHANG LID

Appendix B



OVERHANG PLATES

Appendix C


1.5cm
10cm
1.5cm
FRONT VIEW
10mm
2mm
25mm
1.1cm
4.8cm
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SIDE VIEW
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10.8cm
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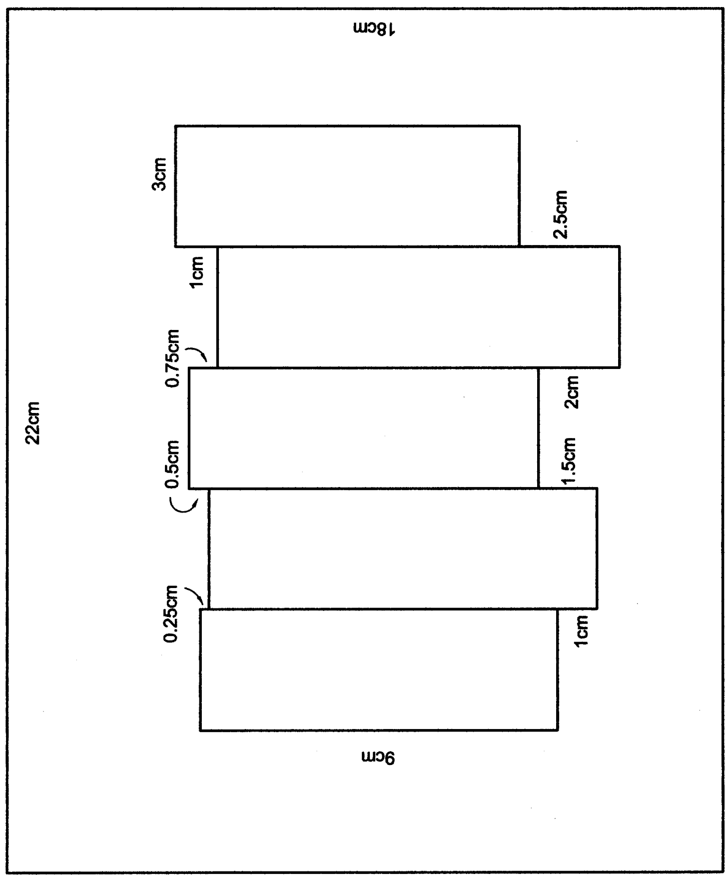
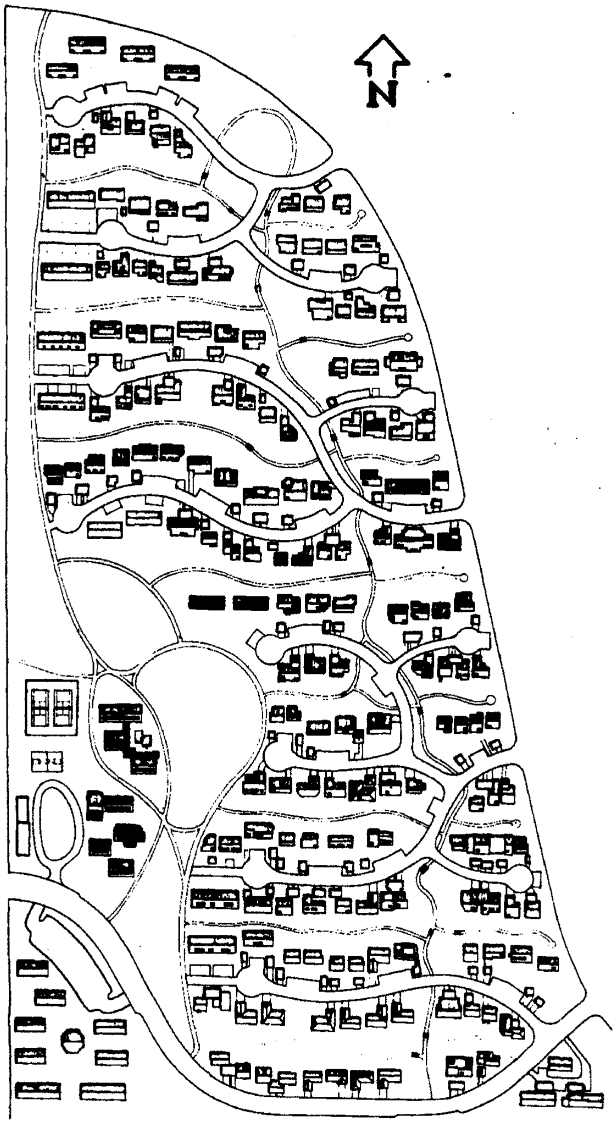
TOP VIEW
FIN ATTACHMENT

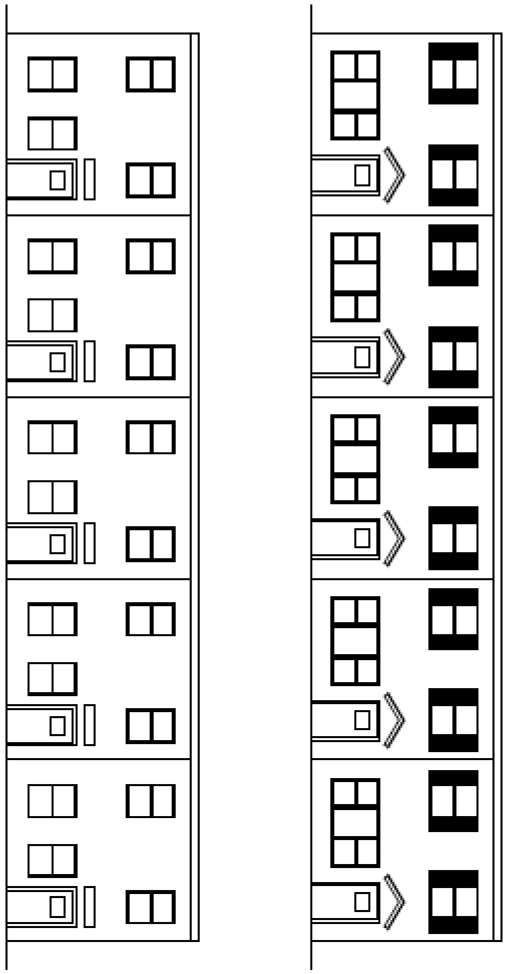
Appendix D



Appendix E



Appendix F



Appendix G