

Creating Sliceforms with 3D Modelers

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Abstract

3D or CAD modeling programs can provide tools for the beginner to quickly create mathematical models known as sliceforms, or, in the terminology of computer graphics, raster surfaces. This tutorial and workshop provides the novice with the tools and procedures for modeling and physically constructing these models using their PC, a printer, craft knife, glue and paperboard.

Sliceforms – to borrow the term coined by John Sharp – is a technique utilized by Alexander von Brill and Felix Klein in the construction of mathematical surfaces from cardboard. These forms, produced in Munich circa 1870, sold throughout the world to mathematics educators. Later the technique was used to construct extremely strong wooden surfaces for press-molding or vacuum-forming sheet material into contoured surfaces.

The construction method uses cross-section curves from the surface laid out along an orthogonal, x,y grid so that the curves intersect at each grid crossing. The curves present as the edges of planar slices of the volume enclosed by the surface. A series of x slices then intersect a series of y slices to promulgate the surface and its volume. CAD modeling programs permit the creation of the surface and tools for generating cross-sections. These cross-sections may then be printed onto a cover weight stock, cut out and assembled in the proper order so as to replicate the cross-sections produced by the modeling program.



Figure 1: John Sharp, *Sliceforms*. **Figure 2:** Charles and Rae Eames, press mold form for aircraft fuselage.
Figure 2: Charles and Rae Eames, fuselage segment pressed from mold.

This workshop/tutorial uses Rhino v.3, available for free download at www.rhino3d.com. This is a fully functional demo copy with no time limit, but limited to 25 saves. The tutorial assumes familiarity with using the Windows PC interface.

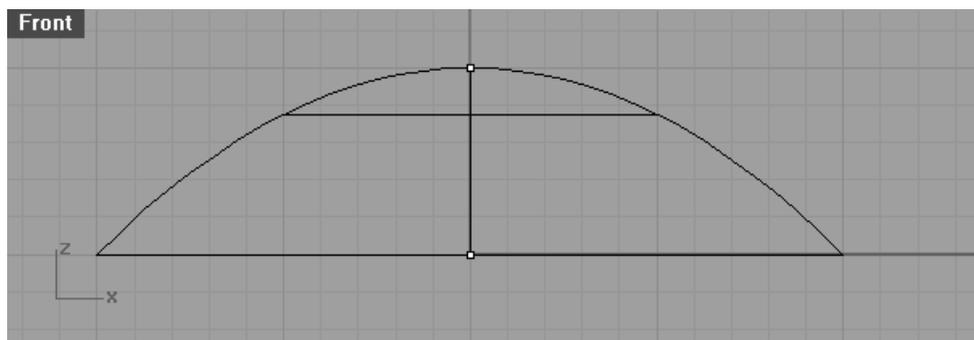
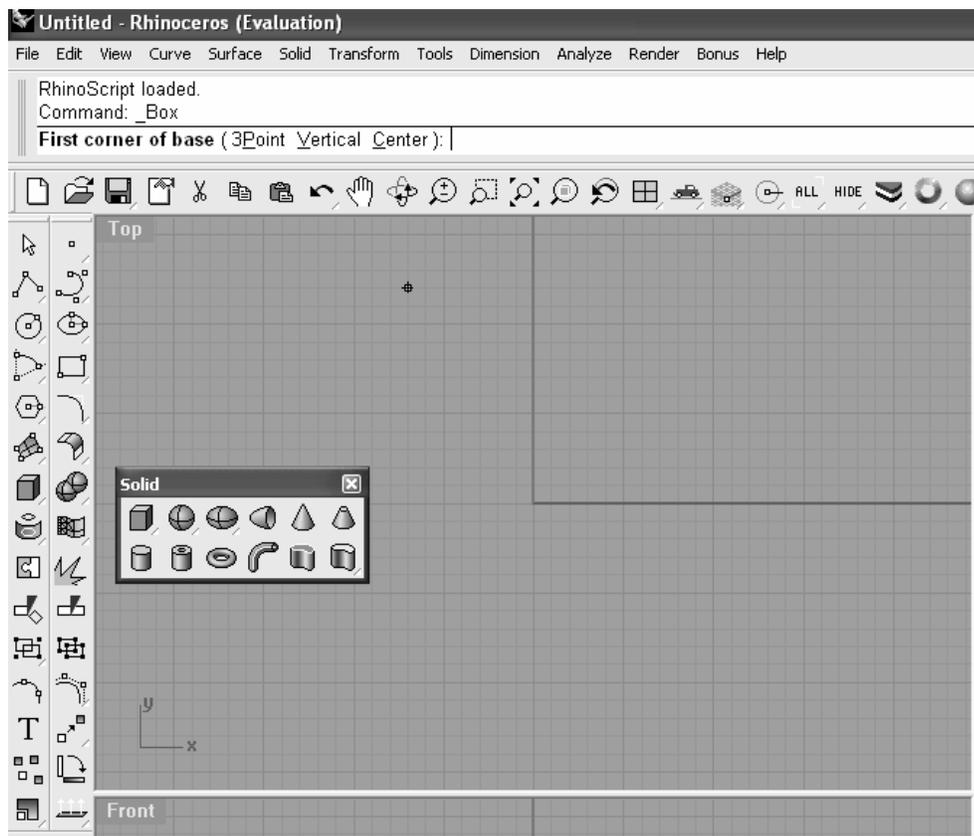
Creating the Surface/Solid

This workshop will use geometric solids already available for insertion into the graphic. These are known as geometric primitives and their normal function is to combine with other such primitives to represent more complex objects. Rhino features, among its primitives, spheres, ellipsoids and paraboloids. This tutorial will use the paraboloid.

1. Open Rhino and the default window should appear with a number of menus and tool icons.



Click on the Box icon in the left toolbar and right click on the parabolic surface in the fly-out toolbar. This will give the option of creating the parabolic solid by first clicking on a vertex point and then on a focus point



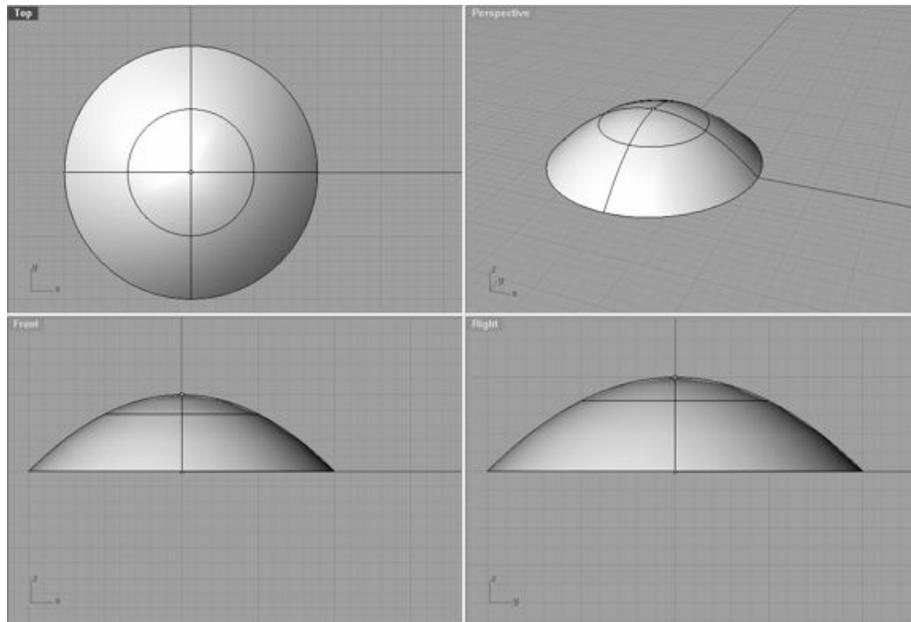
- There will be four viewports on the screen labeled Top, Front, Right and Perspective. Click in the Front view to set the vertex and then drop down to set the focus. Now slide the mouse to on side and click to set the rim of the paraboloid.



(Note that it is easiest to click on the grid points and to set the vertex on the green y axis and the focus on $0,0$ point of the grid. The third click to set the rim should then be on the red x axis. To aid in this precise placement activate the **Snap** button on the Snap Menu at the bottom of the screen.)

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The paraboloid will appear in wireframe mode in all four windows. To ensure that it fits well into all windows right click on the Zoom Extents icon in the top toolbar. To aid in visualizing this solid click on the Shaded Viewport icon in the top toolbar. Shade each viewport by first clicking in the viewport and then clicking on the icon. Right clicking this icon will return the viewport to wireframe.



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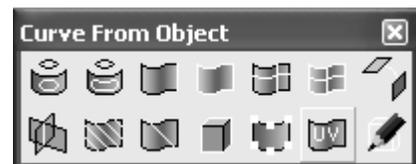
Click on the surface to select it. (Note: when selected the wireframe turns yellow.) Now click on the Solid Tools icon in the left toolbar and in the fly-out window click on the Cap Planar Holes icon. This closes the base of the parabolic surface and it becomes a solid.



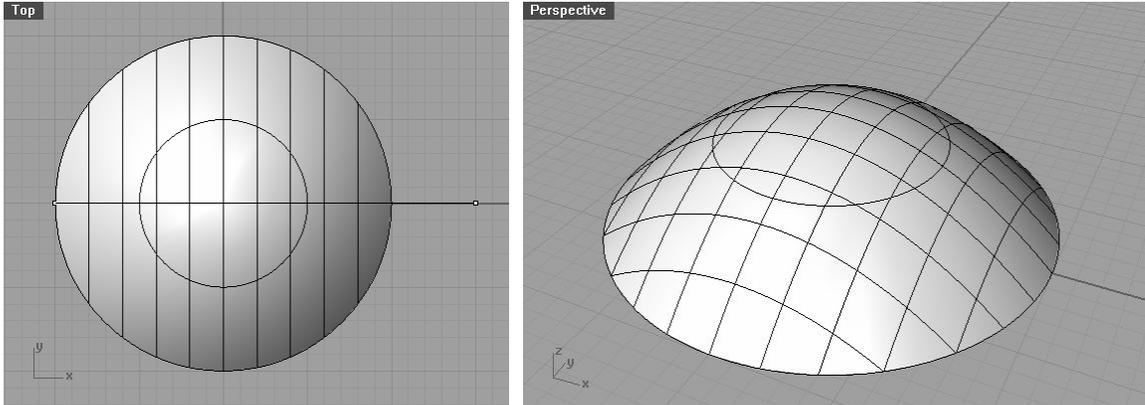
Slicing the Surface

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The next step is to generate the cross-sections of the paraboloid. Select the paraboloid and then click on the Curve from Object icon and click on the Contour icon in the fly-out window.



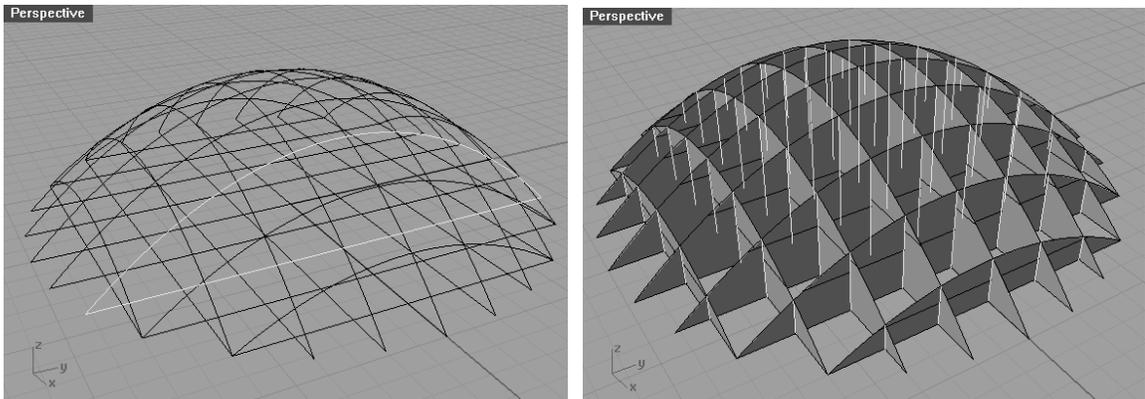
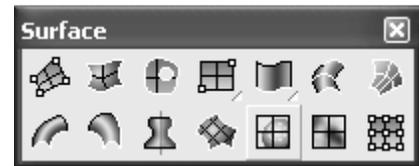
- There will be a prompt in the Command line above the toolbars: "Contour plane base point." Working in the top window, click on the left end of the paraboloid. A second prompt reads: "Direction perpendicular to contour planes." Now click at a horizontal (along the x axis) to the right. The final prompt reads: "Distance between contours." Type in the desired spacing between contours. In the example below that distance was 2, which equals 2 grid units.



The program will automatically draw in the contours. Repeat this process in the y direction.

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 Select the paraboloid and delete by hitting the delete key. This will leave the contour curves. Select all of these curves. Now click on the Surface icon in the left toolbar and choose the Surface from Planar Curves icon.



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 The contour curves are now section planes and the result is a preview of the sliceform to come. Select all of these planes and from the Curves from Objects menu choose the Intersection icon. This command draws a line through each intersection.

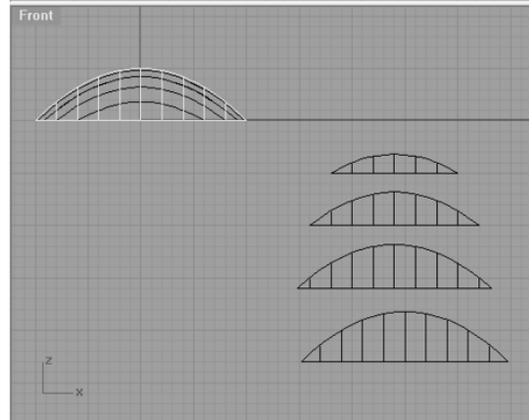
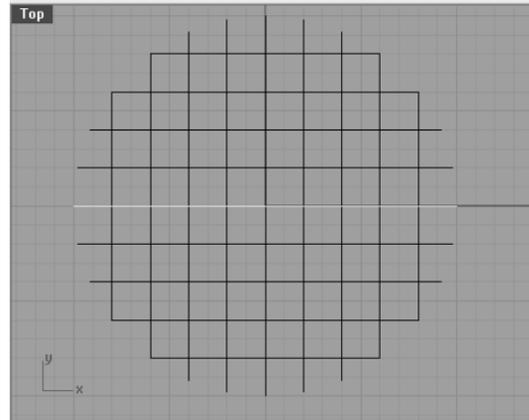
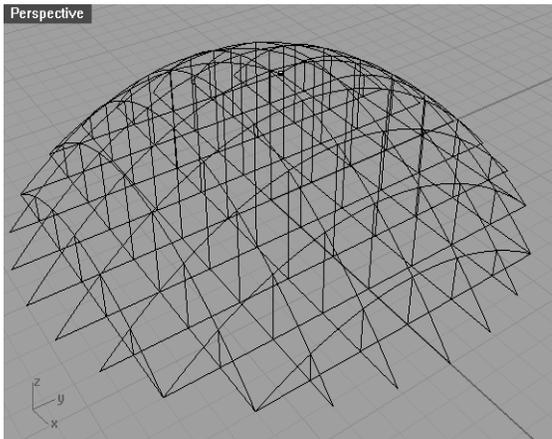
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 Click on the All icon in the top toolbar and choose select Select Surfaces from the fly-out window. This will select each planar section, but not the curves. Delete to leave only the curve sets.

10. For the next few steps work in the Top and Front viewports. Drag the selection arrow to form a box moving from left to right. Dragging from this direction will select only those items entirely within the selection box. (Dragging right to left will select any item the box touches.)



By this means select each x -oriented slice, one at a time, in sequence from the Top view and copy each to the empty space in the lower half of the Front view. To copy: click on the copy icon in the left toolbar and drag the selection to a new position



Repeat this procedure with the y -oriented slices, dragging their copies into the lower half of the Right view port.

11. The Front view port now displays the x slices and the Right view port displays the y slices. In addition there are lines to mark each intersection of slices. To ease the manufacture of the physical sliceform will require one more step.

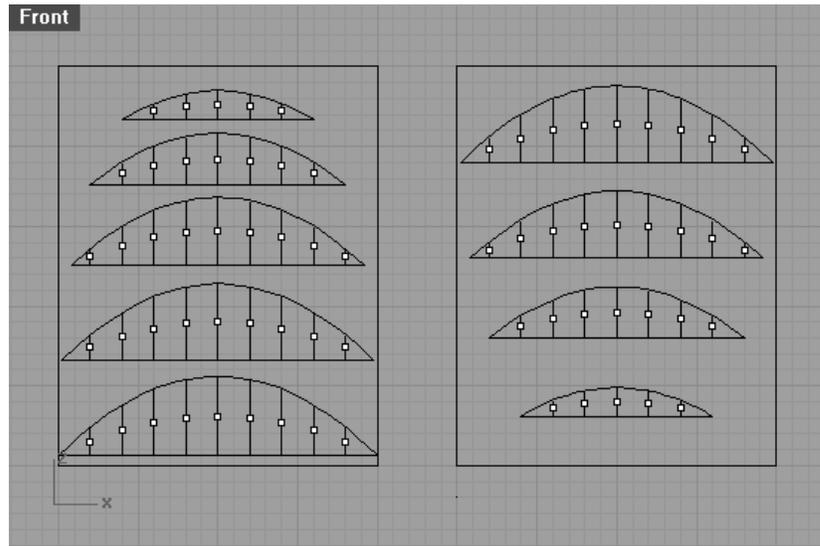
Go to the Snap bar at the bottom of the screen and activate **Osnap** (object snap). Then choose the midpoint object snap only. Click on the Point icon in the left toolbar and choose the Multiple Points tool. This tool permits the placement of points with each click of the mouse. Click on each intersection line and a point will snap to its midpoint.



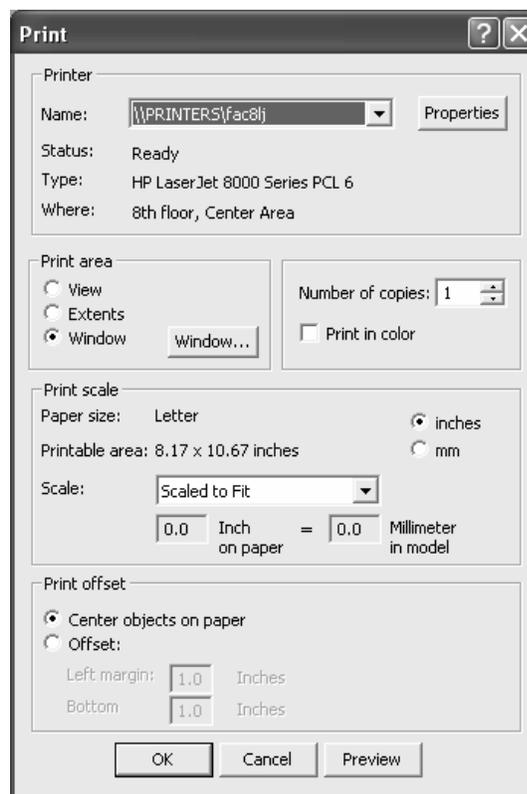
Printing the Slices

The slices are now ready to print, using a heavy paper stock, a cover weight or higher, and an ink jet printer (laser printers cannot manage heavy papers).

12.  To prepare for printing, select and drag the individual slices into vertical groups and draw a rectangle around them, similar in proportion to a standard sheet of paper. The Rectangle tool resides in the left tool bar. Click on the icon and then click and drag and click again to draw the framing rectangle. Keep the Snap tool active. The exact same rectangle should be used to frame each grouping of slices! Use the copy tool if necessary to ensure this congruency of rectangles.

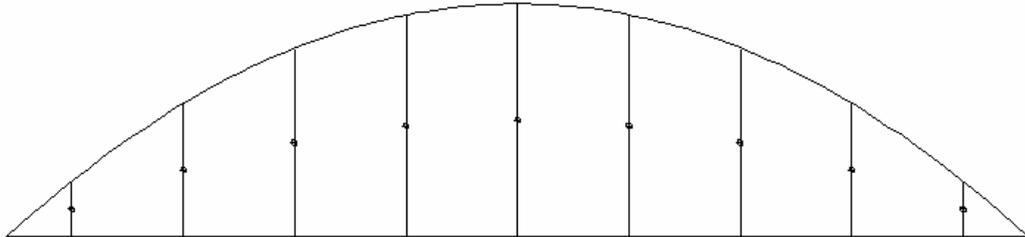


13. Go to the File menu and choose Print. The following window will appear:



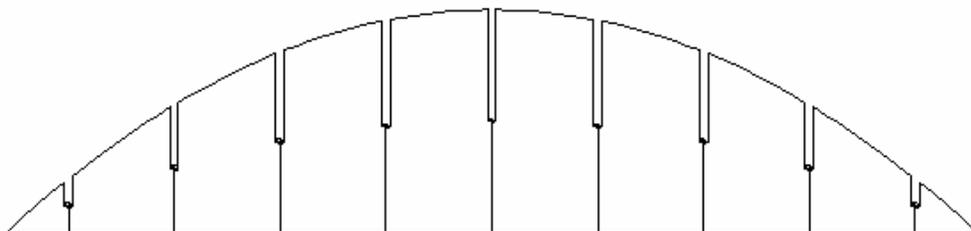
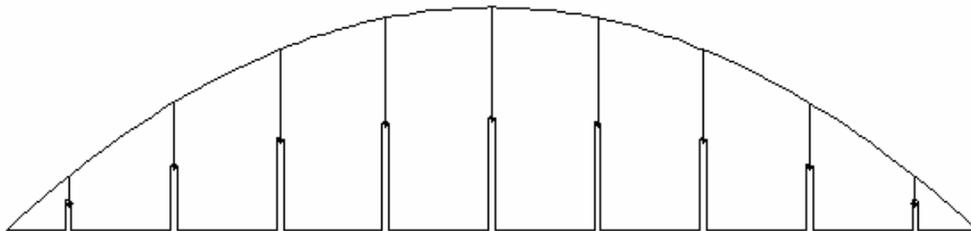
In the Print area sub-menu select Window then click on the Window... button. The Print menu will disappear and a cursor will appear that is to be clicked and dragged to match the framing rectangles. The Print menu now reappears.

In the Print scale sub-menu make sure the Scale box reads, “Scaled to Fit” and click OK. The image within the rectangle will print to fit the page. Repeat this to print each group of slices. The fact that the framing rectangles determine the print area and that they are all the same will ensure that the slices are all printed to the same scale. A typical slice would appear as below:



Assembling the Sliceform

14. It is a good idea to label the direction – x or y – of the slices, as well as their numbers in sequence, by lightly penciling these in on each. Cut out the slices with a craft knife. The slices must now have slots cut at each intersection with the x slices slotted from below and the y slices slotted from above (or vice versa). These slots must be cut as thinly as possible, but with a double cut to assure some breadth to the slot. The sliver of paper curling up from the slot should look like a thread. The points at the middle of each line of intersection marks the extent of these slots.



15. Assemble by inserting the bottom-slotted slices into the top-slotted slices being careful to maintain the position of the slice within the model. Like an accordion this arrangement will collapse flat. To make the structure rigid glue the bottom edge of the slices to a board. In the case of the sample paraboloid, a circular base of the diameter of the paraboloid would work well, too.

