The Complete Homemade Juggling Beanbag Guide

12-Panel Simplified Volleyball/Cube Chapter

Small file size version (150dpi images)

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This is part of a multi-document guide. Hyperlinks with the icon[1] open other guide documents[2], if they are saved to the same folder (**CTRL+Click** opens them in a new tab).

Visit my website to download those, and check back occasionally for revisions and corrections:

www.joshuaclifton.com/juggle

Compare the Last Edited date above on the right with the one on the web page to see if I have submitted changes.

Please contact me with your thoughts! Feedback on this project would be helpful and encouraging. You may also request custom patterns or other help with your project.

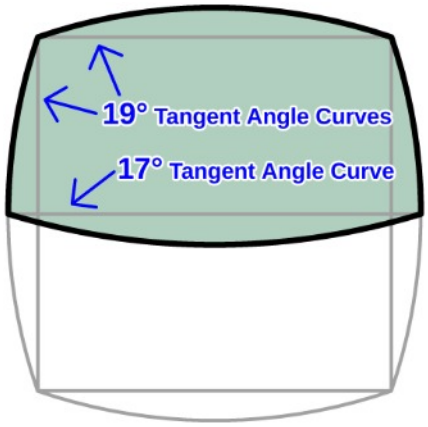
If this guide is useful to you, please **consider donating at my website** linked on the left. I am not monetizing the guide, and I am in need of income.

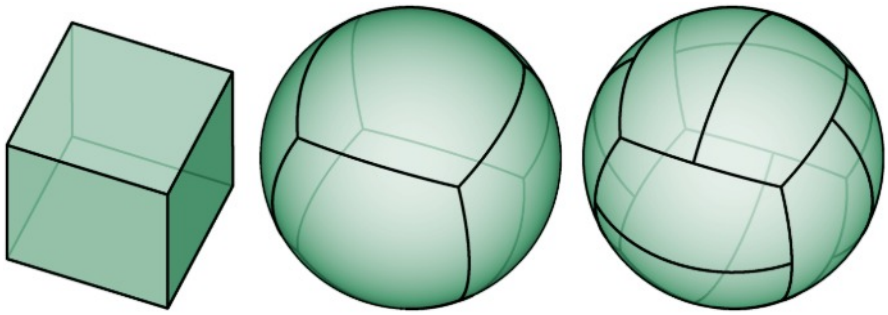
My website also provides blank **color arrangement diagrams** for experimenting with new arrangements in an image editor.

1 Icon from https://freesvg.org/vector-illustration-of-external-link-icon

2 **If the linked PDF does not open at the specified location**, keep it open, switch to the previous PDF's tab, and click the link again. **Cross-document links may not work in mobile PDF readers.** In that case you must open the document yourself and find the linked topic.

12-PANEL SIMPLIFIED VOLLEYBALL/CUBE INSTRUCTIONS





These illustrations show the panel shape and how this design is related to the cube. Each panel of the spherical cube is divided in half, and the new edges between them are curved outward. This makes it much rounder than the cube, gives it unique color arrangement possibilities, and makes it resemble a volleyball.

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Design Notes

The panel shape for this design is half of a circular square with the new edge curved outward. As can be seen on the right, the seam structure of this ball is a halfway transition between a spherical cube and a spherical Deltoidal Icositetrahedron. When the faces of the cube are divided into halves, the Simplified Volleyball is the result. When they are divided again in the other direction, the result is the four kite-shaped panels of the Deltoidal Icositetrahedron.

Like the cube, this shape has a balanced stretch by its structural nature, as long as the panels are oriented correctly. But unlike the cube, it is almost perfectly spherical even with stiff fabrics. This is achieved by that additional curved seam in the middle of each face. Uri Yurman described the ball made with his pattern as "ridiculously round" (at least compared to the 6-panel cube design). It is a little less smoothly round than the regular dodecahedron (at least with stiff fabrics), but is much easier and simpler to assemble. It is probably also better suited to sewing with a sewing machine due to its simpler seam structure.

Supplies

- **For the templates**
  - Cardboard or Template Plastic, Scissors, Glue Stick or Double-Sided Adhesive Tape (to attach the pattern to the template material). **For drawing the pattern by hand:** Paper, Compass, metric Ruler, fine-point Pencil.
- **For the beanbag**
  - Fabric, Needle and durable Thread, Scissors, Fabric Marker or soft Pencil, beanbag Filler, Funnel.
- **For your information**
  - Unless you are experienced with this sort of thing, I recommend that you browse through the **General Information and Techniques** chapter (in the ***01 – Homemade Juggling Beanbag Guide – Index & Supplementary Chapters*** document) before starting. You may find some tips there that will improve your experience and your beanbags.

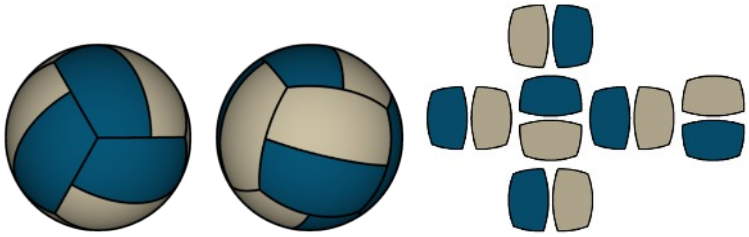
Printing and Drawing the Pattern

Later in this chapter I provide ready-to-print patterns. (When printing them, be sure to tell the Print Dialog to print only the page(s) you want so you don't print the entire document.) After those are sizing formulas, pre-calculated pattern measurements, and instructions for drawing the pattern yourself. Click the hyperlinks or look to the Chapter Index to locate those sections.

Color Arrangements

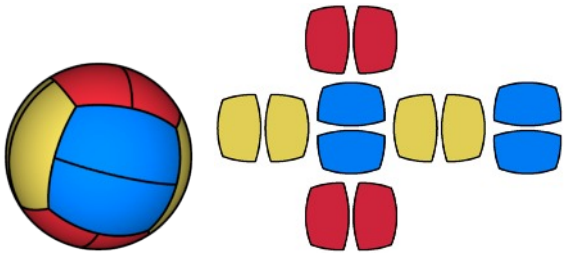
Following are my own color arrangement ideas for this design, **grouped by the number of colors they use**. On the right is what a single-color ball looks like. This beanbag and photo are by Uri Yurman. This shows off the volleyball-like panel structure.

2 colors



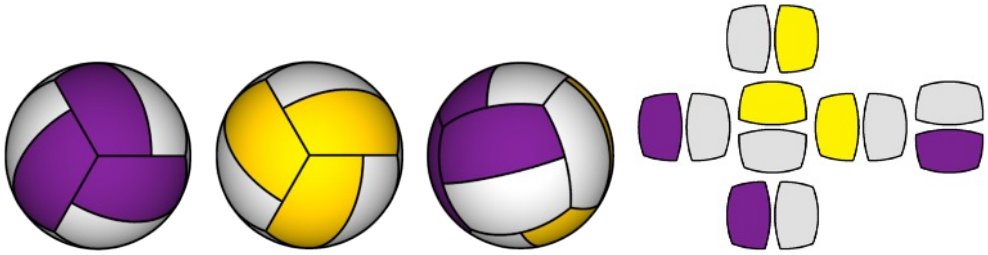
#1: Pinwheels. Two pinwheel shapes on opposite sides of the ball, one in clockwise orientation and the other in counter-clockwise, with a contrasting color on the remaining panels.

3 colors

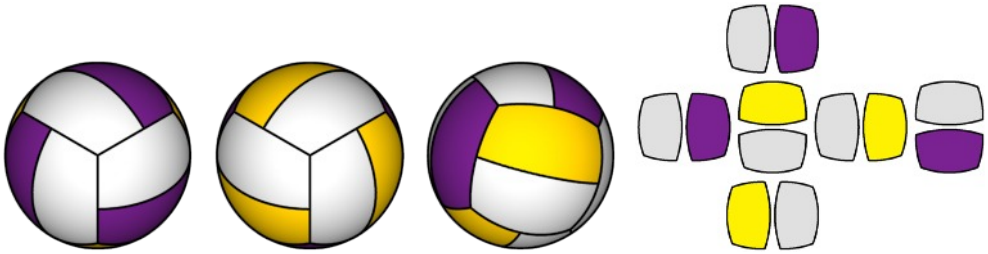


Beanbag and photo by Uri Yurman

#2: Cube. Each of the three colors on opposite pairs of panels, forming a cubic layout.

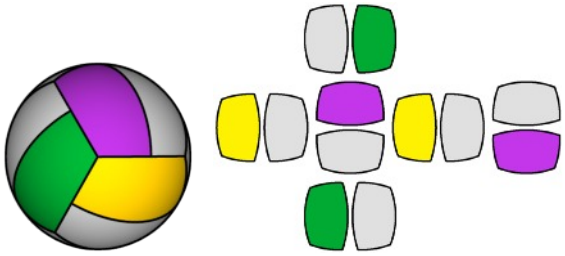


#3: Dual Pinwheels. Like the 2-color Pinwheels arrangement, but each pinwheel is a different color.

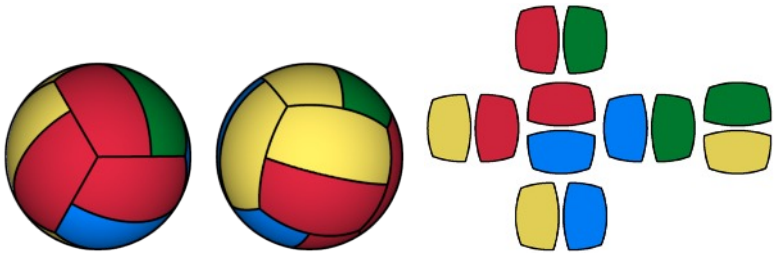


#4: Bi-Color Zig-Zag. In this case the pinwheels are a background color and the two bold colors alternate between them. One side of the ball will have a pinwheel surrounded by color A and other side's pinwheel is surrounded by color B.

4 colors

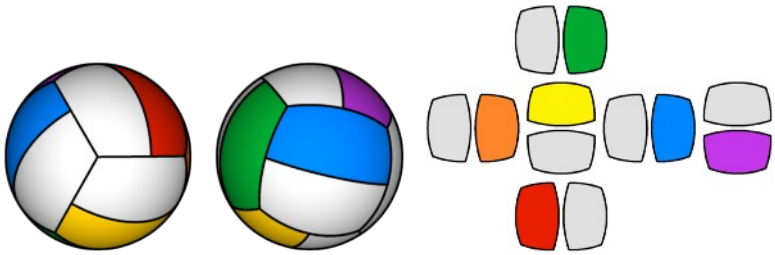


#5: Tri-Color Pinwheels. Same as the 2-color Pinwheels arrangement, but each pinwheel is composed of three colors. **You could also make each pinwheel a different set of colors for a total of 7 colors.**



#6: Tessellation of Pinwheels. Each of the four colors forms a pinwheel, and the entire surface of the ball is composed of pinwheels.

7 colors



#7: Six-Color Zig-Zag. Same as the Bi-Color Zig-Zag arrangement but the zig-zag is formed from six non-repeating colors.

Cutting Out the Templates

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To make an exterior type template, simply use scissors to cut along the pattern. If you want to make a stencil (interior) type, you will need to use an X-Acto knife.

If you use a thick marker to trace the patterns, remember to **stitch on the side of the pattern lines where the edges of the template were** (inside the lines for exterior templates, outside the lines for stencil or combo), so you don't change the size of the ball. If the marker soaks through the fabric you're using, however, you will need to stitch inside the patterns to hide the lines within the seams. In that case, when using stencil or combo templates, cut out the templates' interiors slightly outside the lines, shifting the edges outward by the width of the marker lines. Then the edges of the patterns they produce will be correctly positioned for stitching inside them. For combo templates, shift the outer edges by the same amount to maintain the same seam allowance.

I recommend keeping the inner part that you cut out of stencil or combo templates for use in drawing the front stitching patterns. Step 2 of the Assembly instructions explains why.

Making the Panels

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1. You will need 12 panels, and **you will be tracing the patterns onto the back of the fabric (the side that will be inside the bag)**. If you use a cutting template, first trace that.

   If you are using something like **corduroy, denim, or a striped fabric, or other woven fabric**, I recommend **orienting the template so that the fabric's grain/cords/stripes run from short side to short side**. This will help with the volleyball aesthetic.

2. Use the smaller, stitching template to trace the stitching pattern within each cutting pattern, being sure to center it well (centering it allows you to align the patterns more easily as you sew, but is not otherwise important).

3. Cut out the panels.

Assembly

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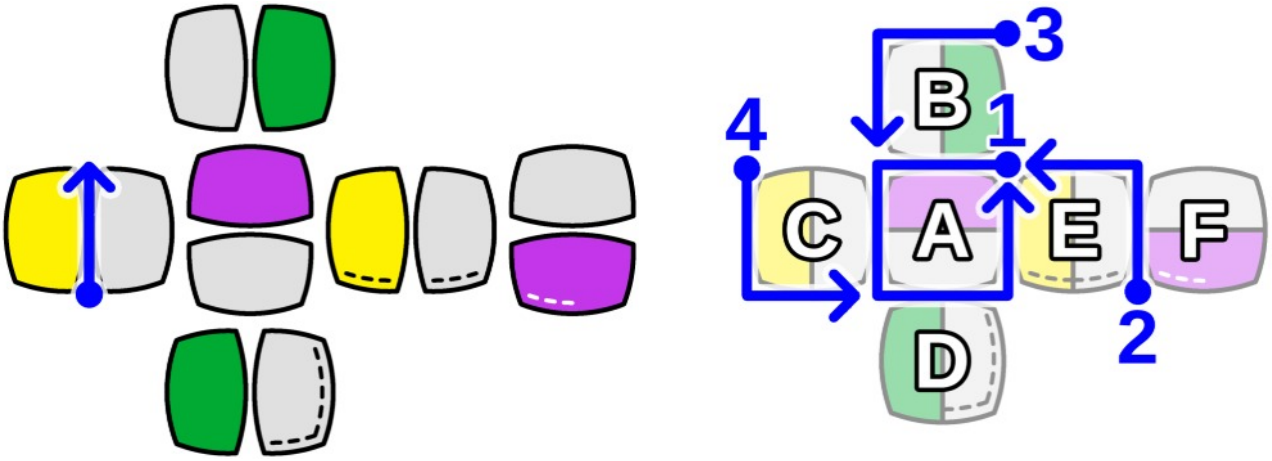
My preferred method of assembly is depicted below and uses 10-11 threads. **The letters in the second illustration indicate the sequence in which the two-panel patches are attached**. **Each numbered stitching path in that illustration is a new thread**, but if your thread is long enough you can continue #1 into #2 (reversing 2's direction) and even across the D-F seam (if you don't need that seam open to turn the bag out through) and down the second leg of #4 (C-D). The final seam or two (D-E and optionally D-F) will be sewn from the outside along the dashed lines in the layout diagram.

I am right-handed and so the diagrams are oriented for stitching toward the left. In case you are left-handed or prefer the opposite orientation, I included **left-handed versions below the instructions**.



1. **Lay the panels out as shown** in the left diagram above (I prefer to place them front face up) and **arrange them according to your color pattern**.

2. Use the stitching template to **draw stitching lines on the *fronts*** of the four panel edges shown with dashed lines in the diagram. My stitching pathway will leave these four edges partially unsewn so the bag can be turned out between them. They will then be **sewn from the outside following the front stitching lines**. (If you use a thin or flexible fabric and don't need such a large opening, just skip marking the bottoms of D and F.) Be sure to align the template as well as possible with the stitching patterns on the backs.

   If you want to **hide the stitching lines within the seams**, sketch them a millimeter or two nearer to the panel edges and stitch slightly inside them (toward the middle of the panels). **If you use a Stencil or Combo type template,** use the inner portion that you cut out of the template to draw these patterns, since the main template will cover the area near the edge.

   I have found it helpful to **add marks along the front stitching lines for each stitch** so that I can more easily keep the exterior stitches even with each other and not get a skewed seam. I space the stitch marks ⅛″ (3mm) apart. If you **make these marks on your template first**, you can more easily transfer them onto these and future panels.

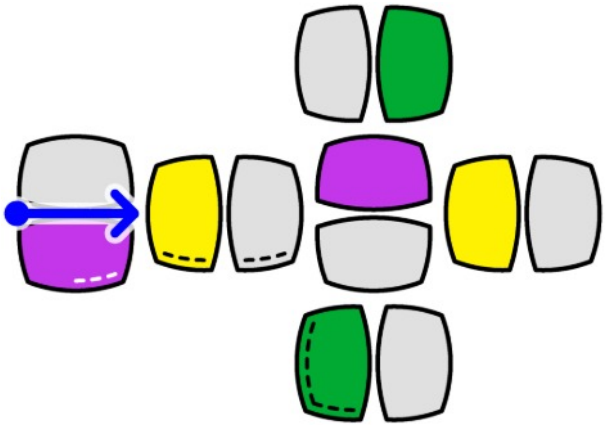
3. **First, sew each pair of panels together as indicated by the arrow on the left-most pair.** This creates six two-panel, rounded square-shaped patches that can then be assembled like a cube.

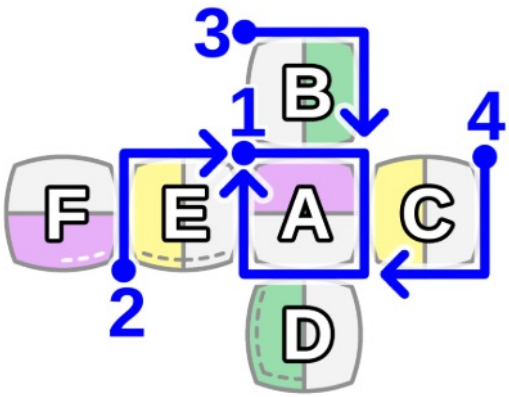
   When you later sew these patches together and you reach the 3-way seam intersections in the middle of each patch's edge and have to **cross the perpendicular seam**, I recommend

referring to the "Stitching Techniques" section of the **General Information and Techniques** chapter under "Crossing seam intersections...". The retreating stitches I recommend at the intersections help to tightly and cleanly close the vertices.

4. Before proceeding, **consider ironing the seam allowances of each patch flat**; see the **General Information and Techniques** chapter under "Better Seams by Ironing".
5. **Stitching Path #1:** Start with patch A and sew side patches B-E to each of its edges. **Sew them with their front faces together** so the bag will be inside out.
6. **Stitching Path #2:** Add patch F and sew it to E, stitching toward B, and then continue down the side of E, attaching it to B. (Or continue the previous thread up the B-E seam and then across E-F, reversing path #2. You can then proceed across the D-F seam if you don't need that one open for turning the bag out.)
7. **Stitching Path #3:** Sew B to F, stitching toward C, and then continue down the side of B, attaching it to C. Tie and trim the thread.
8. **Stitching Path #4:** Proceeding around the cube in the same manner as the previous two steps, sew C to F and then continue down the side of C, attaching it to D. Tie and trim the thread. At this point the remaining open seam(s) should be the one(s) with the front stitching lines.
9. Start a new thread at either end of the final open seam(s) and **sew a few starter stitches to make it easier to continue from the outside**. If you don't need the entire opening to turn the bag out, continue to sew as much as you don't need. To **reduce the number of stitches you need to make from the outside**, you can make extra stitches and then loosen them to allow the panels to spread enough to turn the bag out. Then you can pull them tight again from the outside. If you want to do this, or if you want to be able to loosen the last several stitches enough to push a funnel between them, **your final thread will need several inches of extra length**.
10. If you are ironing the seam allowances, iron the remaining seams and intersections now.
11. **Turn the bag right side out through the opening**. A good method for this is to use the back end of a pen or other slender tool to push the fabric through the opening from the opposite side and then either invert the bag around the tool, or remove the tool and work the bag through with your fingers. **Be gentle so as not to pop any stitches**.
12. **Pull out the last stitch so that the thread is on the outside** where you can get to it. Continue sewing the opening closed following the front stitching lines. For help, see the "Stitching Techniques" section of the **General Information and Techniques** chapter under "Backstitch from the exterior Approaches". Fill the bag at some point during this final sewing with a funnel. I find it helpful to **put some filler in first to prevent the bag from collapsing** while I sew, and to hold the seam allowances in place and give me something to push the needle against.

    You can sew the entire opening closed before fully filling the bag, which prevents the filler from spilling back out while you sew. Just loosen the last several stitches enough to push the funnel between them, or at least to push some filler in with your fingers. Then re-tighten the stitches (see "Tips on finishing the bag").





Left-handed diagrams. Just move the right-most panel pair to the left side to convert my layout arrangements to this one.

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Ready-to-Print Patterns

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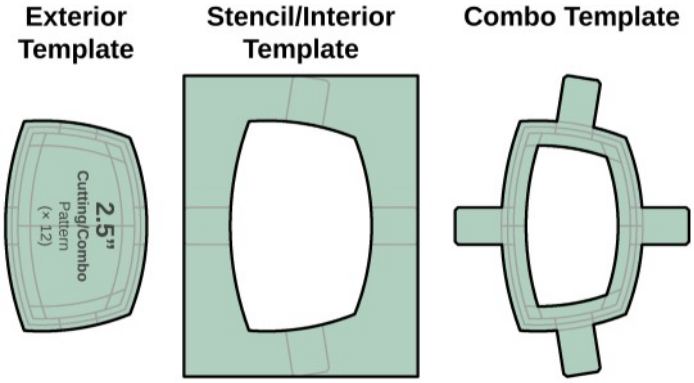
The pattern pages are 8.27"×11" (210mm×279mm) to fit both "Letter" and "A4" sizes. ***Make sure the print is not being scaled to fit the printer margins*** *(select Default/None scaling/Actual size/Ignore printer margins). To verify correct sizing,* ***compare the centimeter grid to a ruler*** *and adjust the next print if necessary. (Note that PDF viewers and printers can both contribute to slight size inaccuracy.)*

On the following pages are patterns for beanbag diameters from 2″ – 3″ in ¼″ increments, and a 7″ pattern for scaling to larger sizes. The patterns are reduced by 6.3% from the mathematical calculation to account for the inflation in size I observed in my corduroy bag. **If you use a completely non-stretch fabric, I recommend enlarging the pattern to about 106% to get the intended ball size.**

To make the template, I recommend cutting out the portion of the paper with the pattern you want and gluing or taping it to your template material, and then cutting along the pattern.

The cutting patterns have 4mm, 6mm, and 8mm allowances so you can choose the amount that works best for your fabric and preference (the lighter, 6mm pattern is a hair under ¼″), and they include **tabs for the optional combo type template** (stitching pattern on the inside, cutting pattern on the outside, with the tabs to help you hold it down). Two tabs may be sufficient with a rigid enough template.

The examples on the right show the **three ways you can cut out the Cutting/Combo templates** (using the 8mm allowance). Remember that the cutting patterns have slightly different curve radius to panel size proportions from the stitching patterns (they are parallel, not proportional), so you should not use them as stitching patterns.



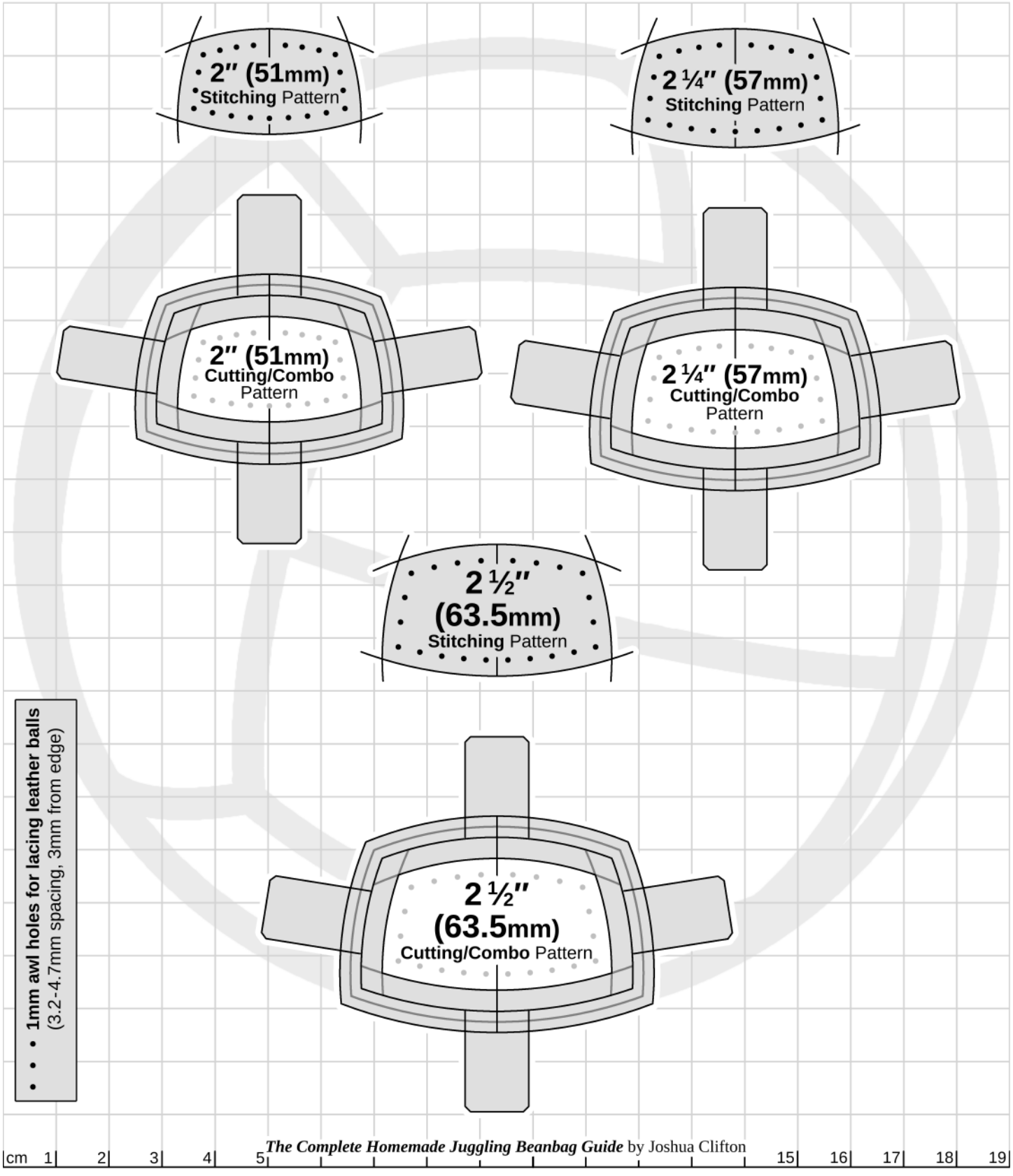
To produce other pattern sizes or correct an incorrectly sized beanbag, adjust the size scaling in the print dialog. For example, to reduce my 2.5″ pattern to the 2.3″ size recommended by the Juggling Store for small hands and numbers juggling, divide 2.3 by 2.5, multiply the result by 100, and that is your scale (92% in this case). If your beanbag ends up not being the expected size, see the **General Information and Techniques** chapter under "Adjusting/Scaling a Pattern to Produce an Accurate Ball Size" for help with correcting it.

The table below provides the scaling for the ⅛″ increments between my ¼″ sizes. The centimeter grid can be used to verify correct scaling.

Target Diameter	Print this pattern size	At this scale
1¾″ (44.5mm)	2″	87.5%
1⅞″ (47.6mm)	2″	93.8%
2⅛″ (54.0mm)	2¼″	94.4%
2⅜″ (60.3mm)	2½″	95%
2⅝″ (66.7mm)	2¾″	95.4%
2⅞″ (73.0mm)	3″	95.8%

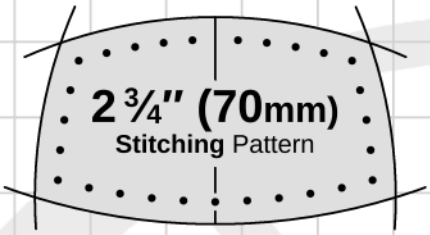
Simplified Volleyball/Cube (12 Panels)

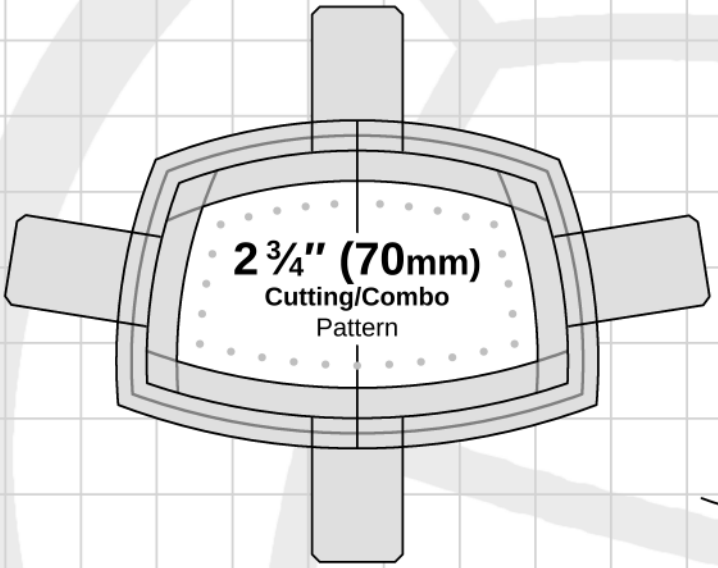
(Pattern sizes are adjusted for corduroy and do not account for gathered seams)

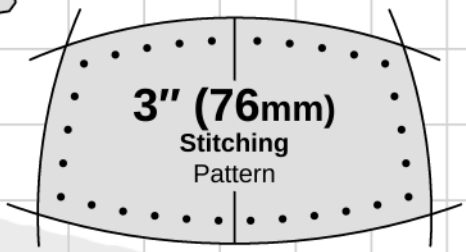


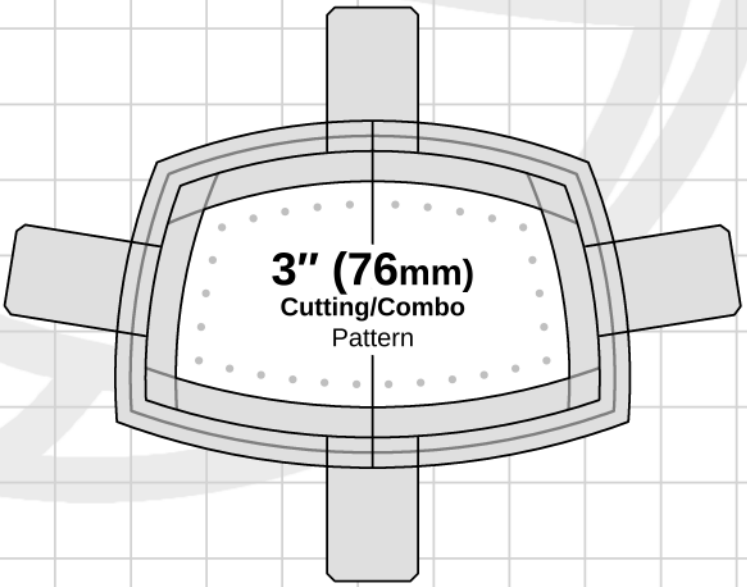
Simplified Volleyball/Cube (12 Panels)

(Pattern sizes are adjusted for corduroy and do not account for gathered seams)

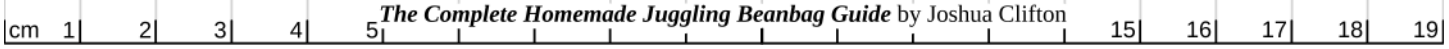








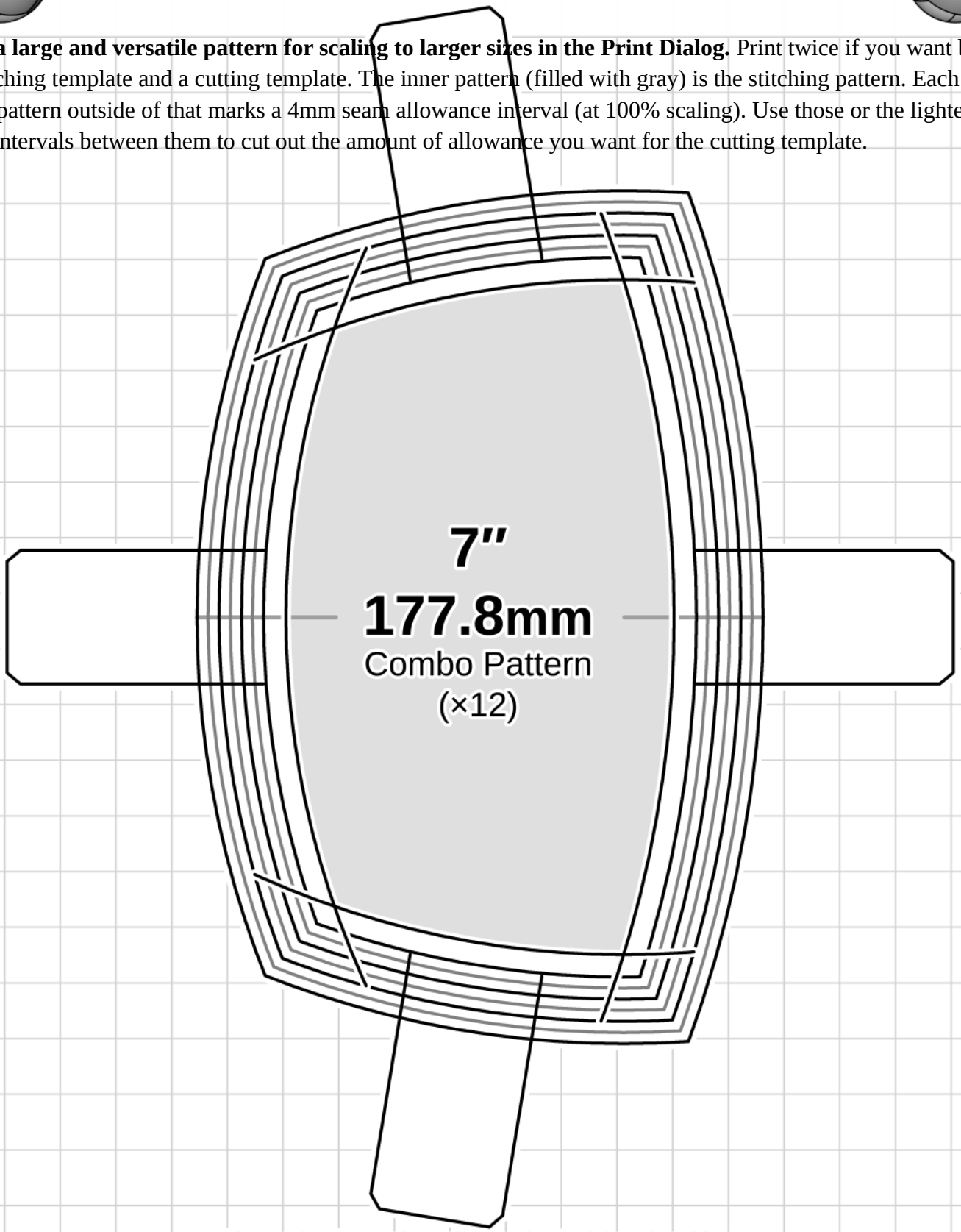
• • • **1mm awl holes for lacing leather balls**
(3.2-4.7mm spacing, 3mm from edge)



Simplified Volleyball/Cube (12 Panels)

(Pattern sizes are adjusted for corduroy and do not account for gathered seams)

Extra large and versatile pattern for scaling to larger sizes in the Print Dialog. Print twice if you want both a stitching template and a cutting template. The inner pattern (filled with gray) is the stitching pattern. Each dark pattern outside of that marks a 4mm seam allowance interval (at 100% scaling). Use those or the lighter, half-intervals between them to cut out the amount of allowance you want for the cutting template.



Blank Color Arrangement Diagrams

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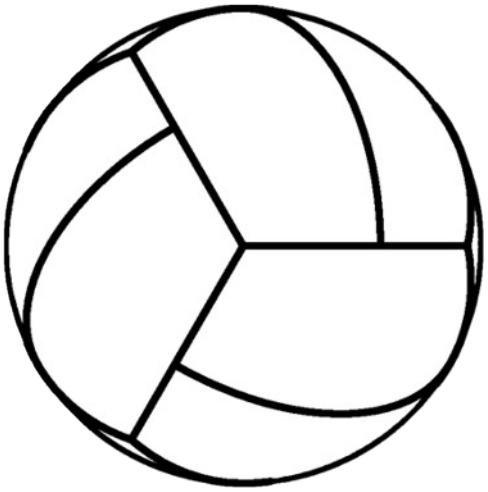
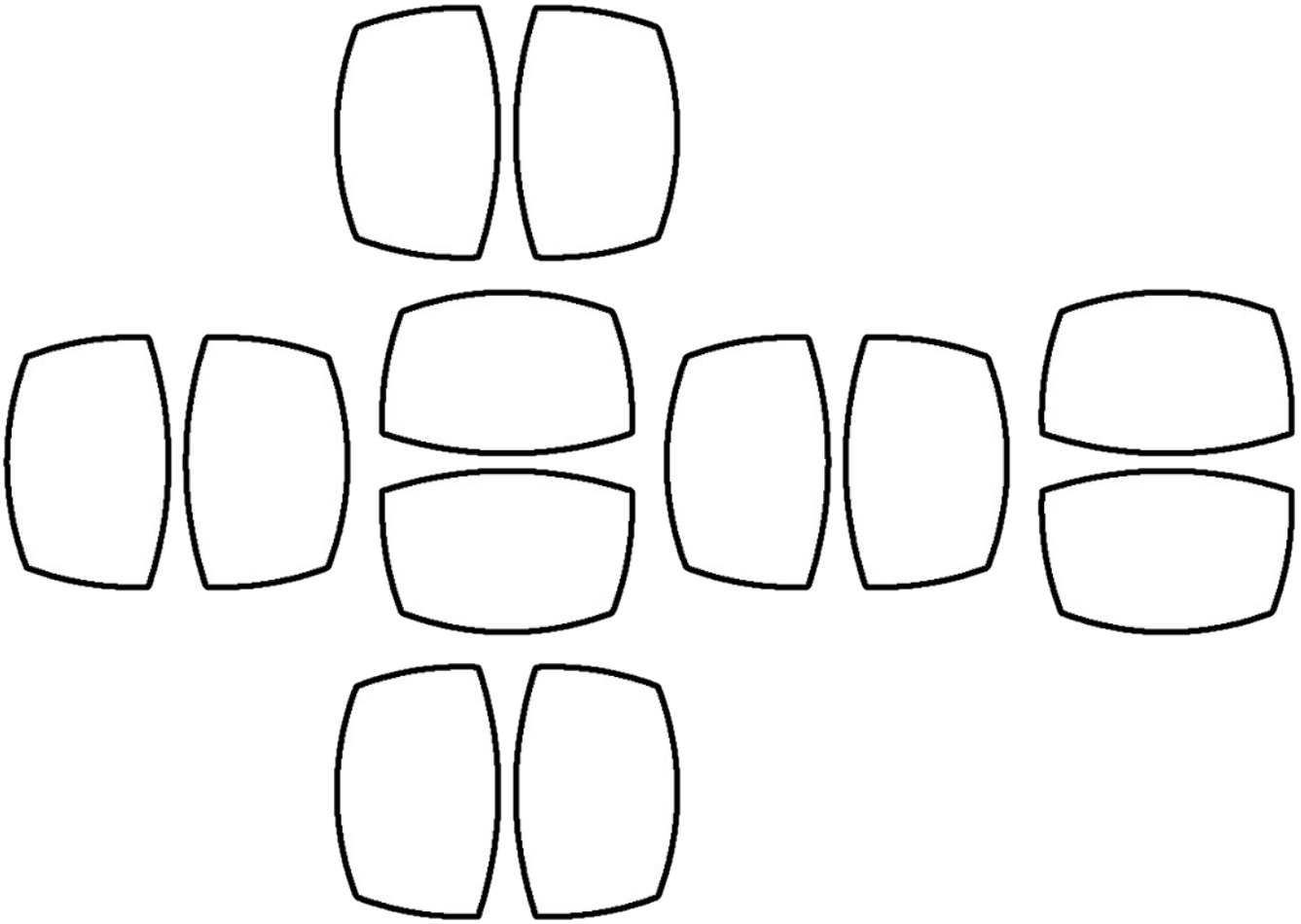
These are the ball and assembly layout diagrams I used for my color arrangement illustrations. You can use these to experiment with your own arrangements. I also offer PNG format diagrams for download on my website that you can use in an image editor. If they are unavailable, you can capture a screenshot of this page or export the image and then color it in an image editor. Or you can just print it and color it by hand.





Sizing Formulas for Drawing the Pattern

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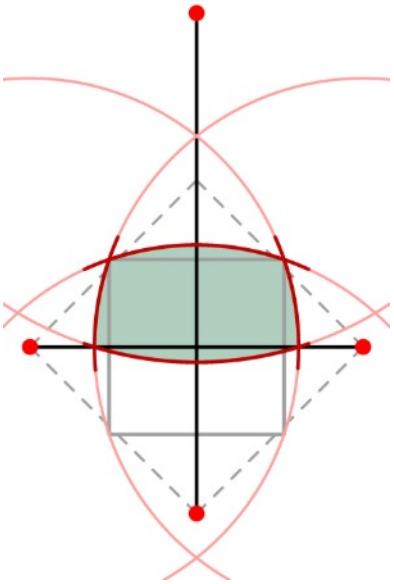
The next section has a table of pre-calculated pattern measurements for all ⅛″ diameter increments from 1¾″ – 3″. Following that are the drawing instructions. If you do not need to create a custom size, skip to that. I provide printable measuring tapes at the end of the **General Information and Techniques** chapter in case you care to measure your beanbags. The "Mathematics" section has explanations of all the formulas and ratios, and expresses their values in higher precision.

Design summary



The panel shape is formed by drawing two perpendicular lines, the ends of which are the circle centers/compass points for the arcs that form the panel shape. See the "How to Draw the Panel Shape" section for illustrations of this.

Adjusting for the influence of fabric types on beanbag size

The bag I made with thick corduroy was **4.572 – 8.009%** larger than the mathematical prediction depending on whether I filled it loosely or over-filled it. I target halfway between the min and max inflations when sizing my patterns, which is **6.3%**. This makes my adjustment factor **1.063**.

The bag I made with my design testing fabric (fairly thin, moderately stiff, tightly-woven, non-stretch), was exactly the mathematical size when moderately filled. So if you are using a fabric like this, I recommend that you use the Base value in the measurement tables rather than the Adjusted value.

I use the adjustment factor to adjust the pattern size to produce a more accurate finished size when using my fabric and stitching techniques. If you gather the seams, use a different fabric, or do anything else that changes the size of the bag, you may need to figure out your own adjustment factor. For help, see the **General Information and Techniques** chapter under "Adjusting/Scaling a Pattern to Produce an Accurate Ball Size".

As I understand it, based on past beanbag experiments with denim, corduroy, and felt, the bag size is affected by fabric attributes as follows. The folding of the fabric at the seams will cause thick, firm fabrics like denim to shrink the bag size by a few percent unless the fabric has some stretch. Folding thin or loosely woven fabric doesn't consume as much of its size. Stretchy fabric will result in a larger size unless you fill it loosely. So, depending on the nature of your fabric, you may have to adjust the pattern sizes.

Sizing formulas

Below are the formulas to calculate the pattern construction elements (*Diameter* and *Circumference* refer to your target ball size). The value in orange is the adjustment factor. **Don't forget to multiply the final result by 25.4 if you need to convert inches to millimeters.**

- **Side Circle Center Distance** (guide square diagonal) **= *Diameter* × 1.1839 ÷ 1.063**
  = *Circumference* × 0.3769 ÷ 1.063
- **Guide Arc Radius** (guide square side) **= *Diagonal* ÷ $\sqrt{2}$ ≈ *Diagonal* × 0.7071**
- **Mid Arc Stick Length = *Diameter* × 1.1870 ÷ 1.063**
  = *Circumference* × 0.3778 ÷ 1.063
- **Sq Arc Radius = *Side Circle Center Distance* × 0.8065**
- **Mid Arc Radius = *Mid Arc Stick Length* × 1.0457**

Arc (edge) length for spacing awl holes or stitch marks

To calculate the length of the curved edges, use the following formula, plugging in the Arc Radii you calculated above. (19° and 17° are the angles between the arcs, or rather tangents thereof, and the edges they span.) If you are working with Radians, omit the $\pi/180$.

$(Sq\ Arc\ Radius)(2)(19)(\frac{\pi}{180})$ **≈ Sq *Arc Radius* × 0.6632**

$(Mid\ Arc\ Radius)(2)(17)(\frac{\pi}{180})$ **≈ Mid *Arc Radius* × 0.5934**

Table of Pre-Calculated Pattern Measurements

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The table below has stitching pattern measurements for each ⅛″ diameter increment from 1¾″ to 3″. The values in the **Adjusted** columns account for my 1.063 adjustment factor. The adjusted values decrease the **Base** pattern size so that you will get a more accurate finished size when using corduroy or something similar (a soft, flexible, moderately thick fabric). If you are using a firm denim or a thin, but non-stretch fabric, use the Base value instead.

To draw the cutting pattern, use the same Circle Center Distance, Guide Arc Radius (which just forms the vertical Circle Center Distance), and Mid Arc Framework Stick Length, but increase the two arc radii by the desired seam allowance (I use 8mm). Then center the four new arcs at the same four points. The cutting pattern will be larger than, but parallel to, the stitching pattern.

Finished Diameter	**Side Circle Center Distance** (guide square diagonal) (mm)		**Guide Arc Radius** (guide square side length) (mm)		**Mid Arc Framework Stick Length** (mm)		**Sq Arc Radius** (mm)		**Mid Arc Radius** (mm)	
	Base	**Adjusted**	Base	**Adjusted**	Base	**Adjusted**	Base	**Adjusted**	Base	**Adjusted**
1¾″ (44.5mm)	52.625	**49.507**	37.212	**35.006**	52.761	**49.634**	42.443	**39.928**	55.171	**51.902**
1⅞″ (47.6mm)	56.384	**53.043**	39.870	**37.507**	56.529	**53.179**	45.475	**42.780**	59.112	**55.609**
2″ (50.8mm)	60.143	**56.579**	42.528	**40.007**	60.298	**56.724**	48.507	**45.632**	63.053	**59.316**
2⅛″ (54.0mm)	63.902	**60.115**	45.186	**42.508**	64.066	**60.270**	51.538	**48.484**	66.994	**63.023**
2¼″ (57.2mm)	67.661	**63.651**	47.844	**45.008**	67.835	**63.815**	54.570	**51.336**	70.935	**66.731**
2⅜″ (60.3mm)	71.420	**67.187**	50.502	**47.509**	71.604	**67.360**	57.602	**54.188**	74.875	**70.438**

Finished Diameter	**Side Circle Center Distance** (guide square diagonal) (mm)		**Guide Arc Radius** (guide square side length) (mm)		**Mid Arc Framework Stick Length** (mm)		**Sq Arc Radius** (mm)		**Mid Arc Radius** (mm)	
	Base	**Adjusted**	Base	**Adjusted**	Base	**Adjusted**	Base	**Adjusted**	Base	**Adjusted**
2½″ (63.5mm)	75.179	**70.724**	53.160	**50.009**	75.372	**70.905**	60.633	**57.040**	78.816	**74.145**
2⅝″ (66.7mm)	78.938	**74.260**	55.818	**52.510**	79.141	**74.451**	63.665	**59.892**	82.757	**77.852**
2¾″ (69.9mm)	82.697	**77.796**	58.476	**55.010**	82.910	**77.996**	66.697	**62.744**	86.698	**81.560**
2⅞″ (73.0mm)	86.456	**81.332**	61.134	**57.511**	86.678	**81.541**	69.728	**65.596**	90.639	**85.267**
3″ (76.2mm)	90.215	**84.868**	63.792	**60.011**	90.447	**85.086**	72.760	**68.448**	94.579	**88.974**

How to Draw the Panel Shape

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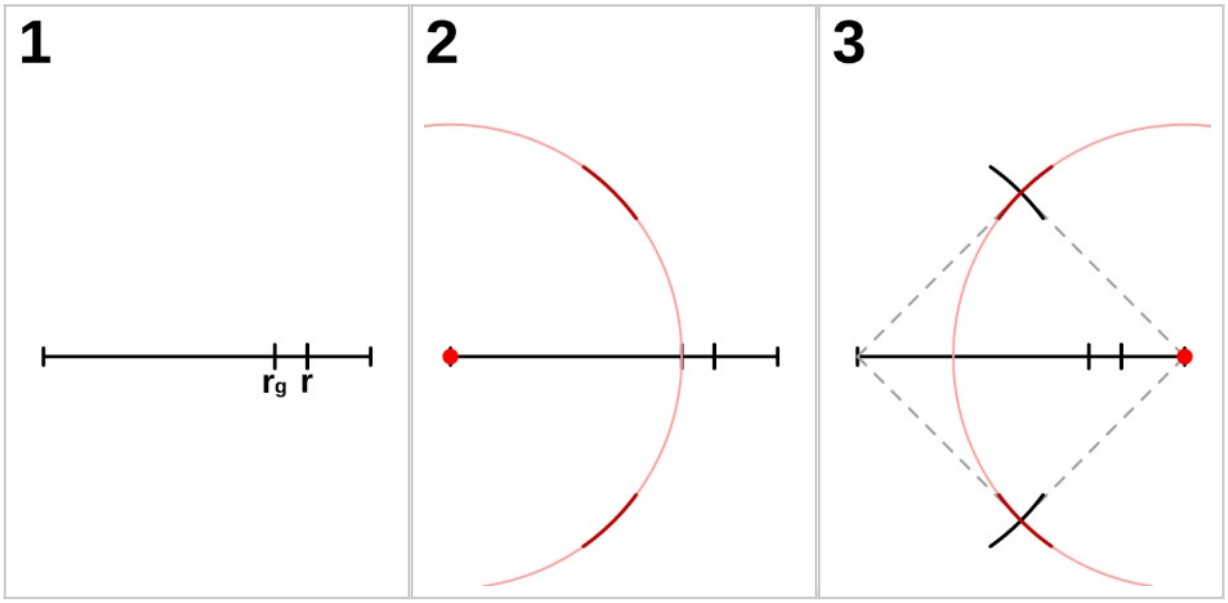
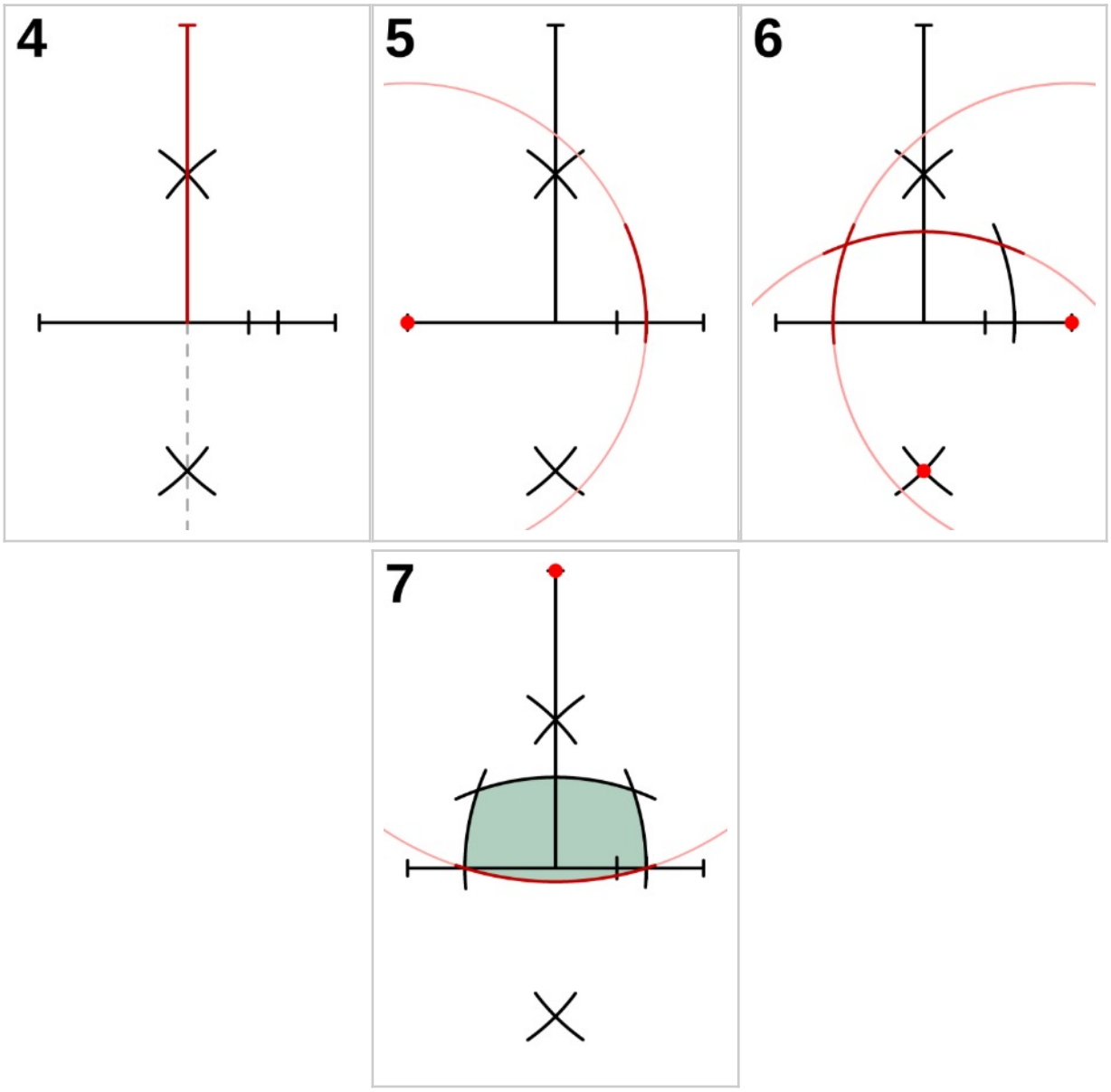
The illustrations below show my drawing method and are oriented toward drawing the shape by hand. Their numbers correspond to the step numbers in the manual directions. The SketchUp directions follow the manual directions. To conserve your template material, I recommend that you draw the pattern on paper and then glue or tape the pattern to your template material before cutting it out.





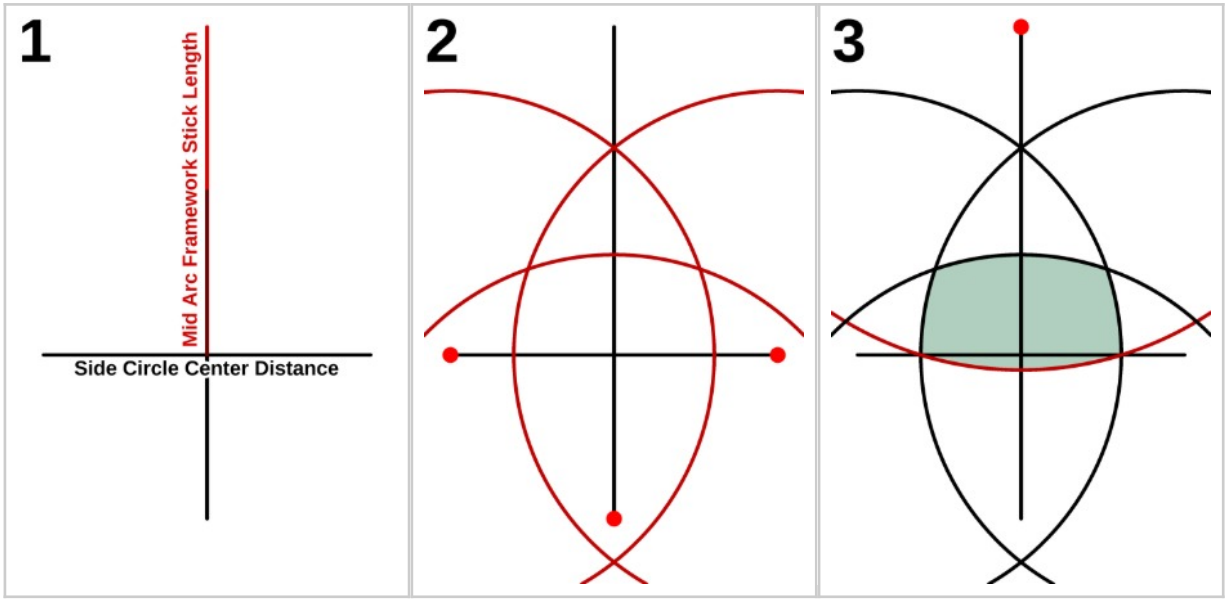
Illustrations for the manual directions. The numbers correspond to the step numbers.

Manual directions

(The terms in bold refer to columns in the pattern measurement table above.)

1. Draw a horizontal line of length **Side Circle Center Distance** and mark each end of it. Also mark two points along it: r_g, which is the distance of **Guide Arc Radius** from one end, and r, which is the distance of Sq **Arc Radius** from the same end. You will use these marks to extend the compass to the correct radii.
2. Extend the compass to the **Guide Arc Radius** mark (r_g), and from that endpoint of the line draw partial arcs above and below the middle of the line.
3. Place the compass on the opposite endpoint and draw two more arcs to produce two X-shaped intersections. You have now formed the four corners of the Guide Square, depicted in Illustration 3 by the dashed gray lines
4. Align a ruler to the two arc intersections and mark a point at **Mid Arc Framework Stick Length** above the center of the horizontal line.

5. Extend the compass to the **Sq Arc Radius** mark (*r*), and from that endpoint of the line draw an arc that meets the horizontal line and extends above it as shown in Illustration 5.
6. Place the compass on the opposite endpoint and draw another, matching arc, and then at the bottom X intersection and draw a third arc that intersects the previous two arcs.
7. Position the compass at the top point of the vertical line, extend it to where the side arcs intersect the horizontal line, and draw an arc from one of those intersections to the other. The radius of this arc should be equal to (or very nearly equal to) **Mid Arc Radius**. This completes the pattern shape.
8. To draw a cutting pattern, increase the Arc Radii by the desired seam allowance (I use 8mm) and then draw four arcs centered at the same four points.



SketchUp directions

(The terms in bold refer to columns in the pattern measurement table above.)

1. Draw two perpendicular lines of length **Side Circle Center Distance** and center them on each other. Replace the top line segment with a line of length **Mid Arc Framework Stick Length**. This results in the framework shown in the first illustration. The four endpoints of these lines are the circle centers of the arcs that form the panel shape.
2. Draw circles of radius **Sq Arc Radius** centered at both endpoints of the horizontal line and the bottom endpoint of the vertical line.
3. From the top endpoint of the vertical line draw a circle whose radius reaches the intersections of the two side arcs and the horizontal line. Its radius should be equal to (or very nearly equal to) **Mid Arc Radius**. This completes the pattern shape.
4. To draw a cutting pattern, use the same circle centerpoints, but increase each of their radii by the desired seam allowance (I use 8mm).

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Mathematics Behind the Relationship Between the Pattern Parameters and the Ball Size

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This section describes the math involved in drawing patterns to produce specified beanbag sizes, and creating the pattern sizing formulas. *(The numbers in tiny, right-justified typeface are my computer calculator's unrounded values which I display rounded to six places for brevity.)*

I discuss in the "How I Developed This Design" section why I chose the particular curves I use for this pattern. This pattern is based on half the circular square from the spherical cube. The new edge between the halves is curved to allow the panels to bulge outward. The square's curves produce a 19° tangent angle to its edges and the middle curve produces a 17° angle to the square's midline.

Using my edge arc radius formula and sagitta formula from Chapter 5, I can calculate the radius needed to produce those arcs, and the height of their apexes over the chord, or polygon edge. These are the first steps toward calculating the guide square, whose corners are three of the circle centers for the arcs, and the location of the fourth, different arc for the bottom of the shape.

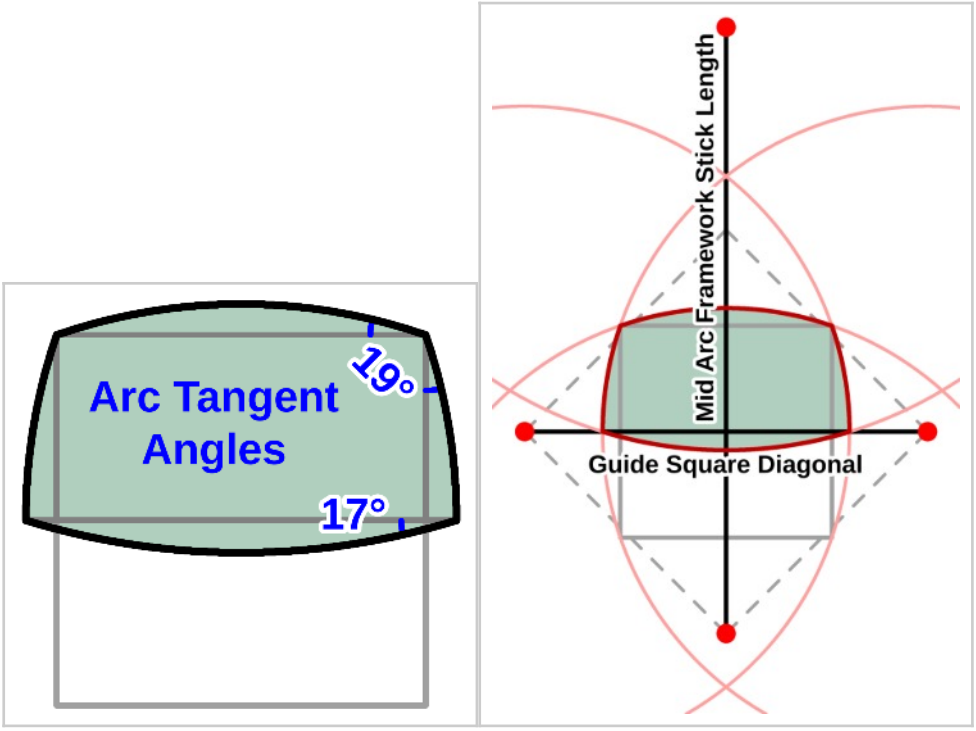
s = inner square side length

Square Arc Radius, r_s = $\frac{0.5\,s}{\sin 19°} = \frac{0.5\,s}{0.325568}$ **≈ 1.535777*s***

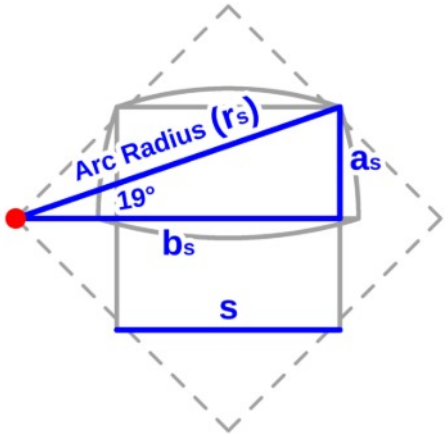
Square Arc Sagitta, g_s = $r_s - \frac{0.5\,s}{\tan 19°}$ **=** r_s – 1.452105*s* ≈ **0.083671*s***

Mid Arc Radius, r_m = $\frac{0.5\,s+g_s}{\sin 17°} = \frac{0.583671\,s}{0.292372}$ **≈ 1.996333*s***

Mid Arc Sagitta, g_m = $r_m - \frac{0.5\,s+g_s}{\tan 17°}$ **=** r_m – 1.909103*s* ≈ **0.087230*s***



Calculating the distance between the circle centers (Guide Square's Diagonal) involves solving a right triangle as shown below. The arc radius is the hypotenuse, side *a* is half of the square's side length, and I need to solve for side *b*. After that, I can subtract the square's side length to get the portion of *b* that extends beyond the square, and add that back to the value of *b* to get the total distance.

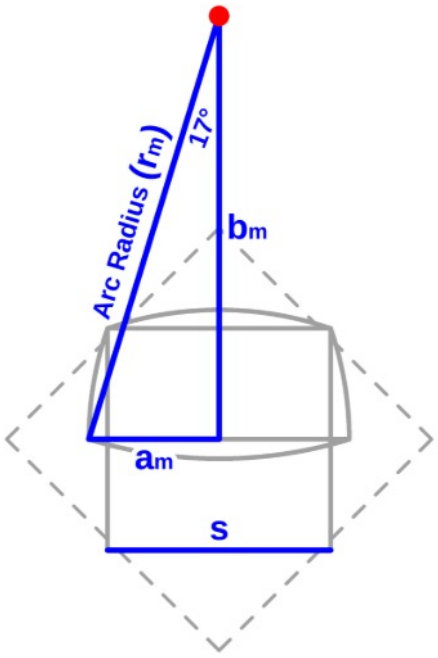


$r_s \approx 1.535777s$ (calculated earlier)

$a_s = 0.5s$

$b_s = \dfrac{a}{\tan 19°}$ or $\sqrt{r_s^{\,2} - a^2}$ ►

$b_s = \dfrac{0.5\,s}{0.344328}$ or $\sqrt{(1.535777\,s)^2 - (0.5\,s)^2} \approx 1.452105s$



$r_m \approx 1.996333s$ (calculated earlier)

$a_m = 0.5s + g_s = 0.5s + 0.083671s = 0.583671s$

$b_m = \dfrac{a}{\tan 17°}$ or $\sqrt{r_m^{\,2} - a^2}$ ►

$b_m = \dfrac{0.583671s}{0.305731}$ or $\sqrt{(1.996333\,s)^2 - (0.583671\,s)^2} \approx 1.909103s$

Guide Square Circumradius (center to corner) ≈ 1.452105*s* – 0.5*s* **≈ 0.952105*s***

Guide Square Diagonal (distance between circle centers) ≈ 2(0.952105*s*) **≈ 1.904211*s***

I define the circumference of the ball as

Ball Circumference = Pattern Height(4) + Mid Arc Length(2)

The height of the pattern is half the height of the inner unit square, or 0.5*s*, plus both sagittas, which I calculated at the beginning of this section.

Pattern Height, *h* ≈ 0.5*s* + g_s + g_m **≈ 0.670902*s***

Mid Arc Length, *L* ≈ $\dfrac{2(17°)(r_m)(\pi)}{180} = \dfrac{(34°)(1.996333\,s)(3.141593)}{180}$ **≈ 1.184648*s***

Ball Circumference, *C* = 0.670902*s*(4) + 1.184648*s*(2) **= 5.052902*s***

Once I have the ball's size expressed as a ratio of a unit square, I can express the arc radii and circle center distances in terms of it.

Inner Square Side Length, *s*, in terms of *C* ≈ $\frac{1}{5.052902}C$ **≈ 0.197906*C***

Guide Square Diagonal, d_g ≈ $(1.904211s)(0.197906)$ **≈ 0.376855*C***

Guide Square Side Length (used for locating second pair of circle centers with a compass)

= $\frac{d_g}{\sqrt{2}} \approx \frac{0.376855}{1.414214}$ **≈ 0.266477*C***

Mid Arc Stick Length, b_m $\approx (1.909103s)(0.197906)$ **≈ 0.377823*C***

I will define the arc radii in terms of the framework that defines the circle centers, d_g and b_m:

Square Arc Radius ≈ $\frac{1.535777\,s}{1.904211\,s}$ **≈ 0.806516d_g**

Mid Arc Radius ≈ $\frac{1.996333\,s}{1.909103\,s}$ **≈ 1.045692t_m**

Cutting pattern adjustment

To make a cutting pattern, simply increase the arc radius by the desired seam allowance. The guide square remains the same.

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How I Developed This Design

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Left: Photo by me of an exercise ball at NRG Fitness. **Middle and Right:** Beanbags and photos by Uri Yurman.

I lost interest in my beanbag hobby for five months starting in February, 2024. My depression has been very bad and I no longer cared at all about this hobby. I figured that was the end of it. It had been getting stale, anyway, and I had been wanting a new hobby. I still haven't found one, though. Under the depressive weight and numbness, almost nothing in life interests me.

Back in February, 2022 I found the 14″ exercise ball shown below at NRG Fitness in West Chester, OH. Its panel structure is like a 12-panel volleyball (an actual volleyball has 18 panels, three at each cube face instead of two). It is essentially the same as the "Volley Bag" shown below on the right that I found online many years ago, and which I always hoped to figure out. I like this panel structure. I took photos of the exercise ball, hoping it could help me figure out the panel shape.

Left Two: Photos by me of the exercise ball at NRG Fitness. **Right:** Volley Bag photo from ~~http://www.jugglingstore.com/volley-bag-737.html~~ [no longer available]

But I've always lacked a concept for how to design the curves for a pattern like that. I also lacked the motivation to perform all the design and experimentation work that would be required. Sewing is usually very tedious and unpleasant for me, and I knew this design would require me to make a lot of test balls to figure out the best curvatures.

In March, 2024, a fan of my Homemade Juggling Beanbag Guide, Uri Yurman (an Israeli beanbag maker and juggling performer: Facebook, Instagram, Twitter), with whom I had been corresponding for a couple years, began working on a 12-panel cube design for his juggling beanbag business. He asked me for color arrangement ideas, so I created several of them and sent them to him. I later offered them to my audience in a short PDF.

A 12-panel cube is much rounder than a 6-panel cube, and it is easier to design and assemble than the Volley Bag would be, and yet has some of the same aesthetic. The Volley Bag has convex curves that attach to concave curves. Sewing the two together is difficult because the panels cannot be laid flat

against each other and sewn along matching patterns. They require continual adjustments of each panel to match them up at the point that is being stitched.

Uri finished his pattern design process later in March and began sending me photos of his beanbags, two of which are shown at the beginning of this section. They looked quite good. This made me interested in designing my own pattern for it. But I still lacked any actionable motivation.

Finally, in August, 2024 I became motivated to begin the design process for the 12-panel cube. From March 6th to the 17th I designed and sewed nine 3″ beanbags and decided on my final design. I then made a 2.5″ beanbag with my final pattern. After that I made one with corduroy for the photos, and one with felt to test my design with a mildly and uniformly stretchy fabric.

The longest curve of the pattern has to be designed separately from the other three. Those three match, except that the two short, side curves are half of the medium curve.

I began by using my spherical cube pattern as a basis. I divided the shape in half and then added an arbitrary curve to the new edge. I had no idea how steep this curve needed to be, apart from Uri's findings, so I started with low curves and worked up to steeper ones so that I would have a good feel for the effects of the curvature on the shape of the ball. I later decided to slightly steepen the cube's original curves by a 1° tangent angle to eliminate the very slight hint of cubeness at the corners.

I began by using a 6° tangent angle. I then tried 9° and 12°. But I drew those three patterns incorrectly. Instead of making the middle-curve meet the side curves at their midpoints, I made it meet the midpoint of the inner square's edge. This made the panels too narrow by about 1mm (the patterns' width was ~31mm instead of ~32mm), and meant that the actual corner angle I was using was steeper than intended by 16%. Those experiments were not wasted, however. They enabled me to eliminate those three curves. Even with the error, it was obvious that I needed a steeper curve.

When I began drawing the patterns correctly, I started with a 14° curve. I then increased the angle to 16°, and finally 18°. The 16° curve was practically perfect, but I could see subtle indications that I needed a steeper curve. The 18° curve was just as slightly too much. So I chose 17° for my final design.

I also, as I mentioned, experimented with increasing the cube's original curve. My spherical cube pattern uses an 18° tangent angle curve, producing a full corner angle of 126°. I could see a very slight hint of cubeness on my beanbag's cube corners, so I increased the tangent angle to 19°. While both were almost identical, and very spherical, I could see that 19° was slightly better, but was just on the verge of being too steep. So this seemed perfect.

To judge the results of my patterns, I carefully examined and compared the balls' profiles against a backlight, and felt and examined the seams and intersections. I conducted all my examinations of the final three balls both when filled to a moderate firmness (just to the point where they were not at all slack), and also when tightly stretched out to the reasonable limit of my non-stretch testing fabric. I spent a few days examining and comparing each ball as I continued to sew new balls.

I looked at how the two different types of seams were shaped, and whether they conformed to the ball's ideal circular profile, and I examined the shape and amount of protrusion of the vertices.

Below is an illustration comparing all the curves, including Uri's curves. I never actually tried his curves. His fabric, assembly, and method of judging between balls evidently called for steeper curves,

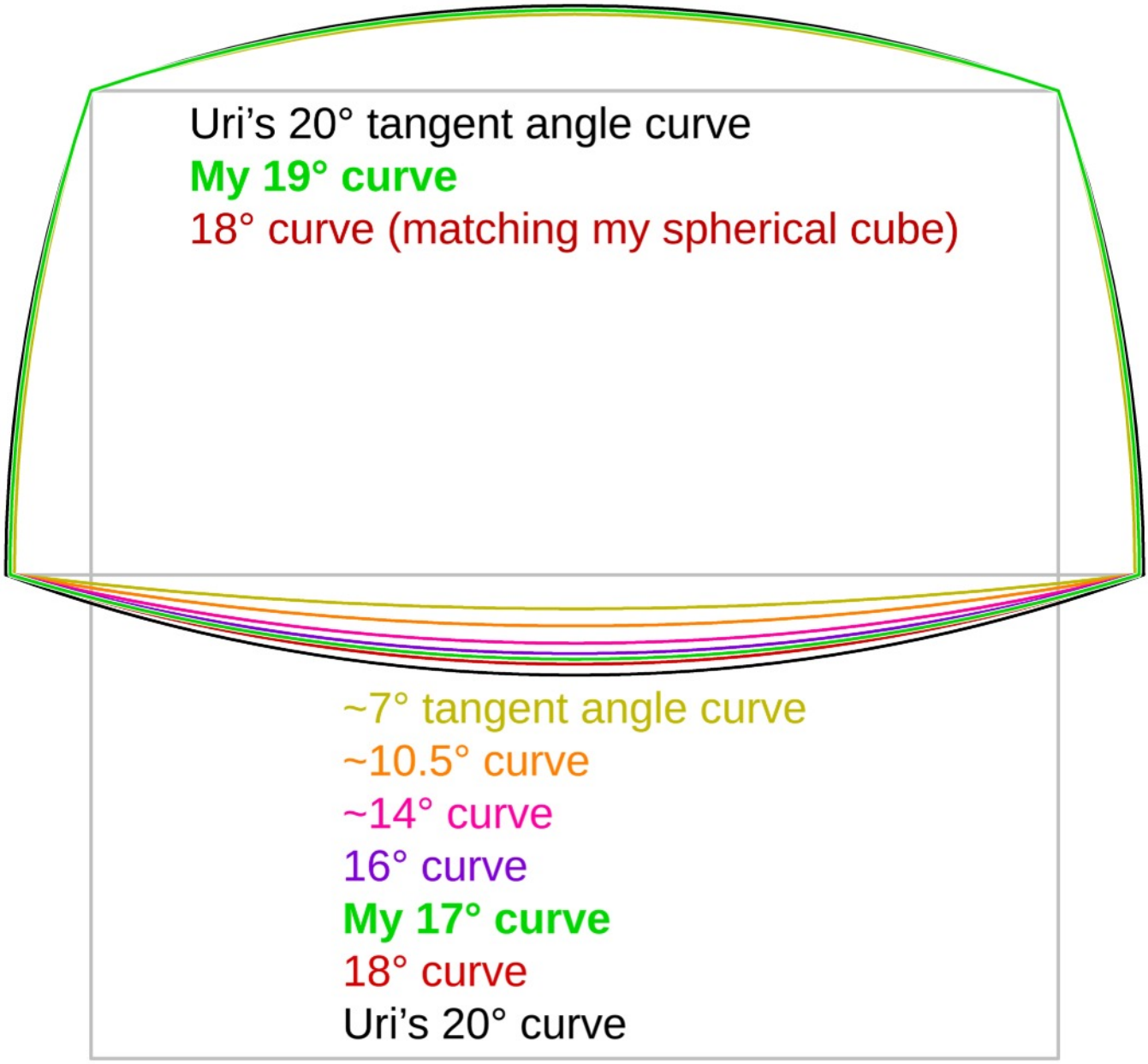
especially the longest curve. I believe I have already hit the upper limits of the curves' steepness that will produce an optimal ball.

Uri's cube edge curve is only 1° steeper than mine and that would not make a significantly noticeable difference. His middle curve is 3° steeper, however, and in my experiments my 2° increments produced very noticeable differences.

So Uri's ball will be bulgier in the middles of the cube faces. A fabric with a little stretch will mostly eliminate this difference, though. I selected my design testing fabric specifically to minimize the amount of distortion it allows in the ball shape so that I can see exactly what my patterns are producing. It is of moderate thickness and is stiff, tightly woven, and non-stretch. This fabric is basically a worst-case scenario. If my patterns can produce a good sphere with a fabric that can't stretch or distort much, they will only produce a better sphere when the fabric can stretch, which smooths out defects.

In the corduroy ball I made the seams are just a tad too bulgy, especially the mid-panel seams, and the corners are pulled in a little too far, indicating too much curvature of the cube edge curves. They are pretty much perfect in the testing fabric ball, though, (the cube edge seams seem very slightly too steeply curved) so it's mostly a matter of the stretchiness of the corduroy, and probably the weave orientation I used.

To me, the corduroy ball confirms that my curves are steep enough, and I don't need to try Uri's. I even seriously considered lowering the curves by 1°, especially the cube edge curve, but decided the over-steepness was too slight to be worth it, and it does help eliminate the protrusion of the cube corners. The felt ball I made was too stretchy and imprecise to help with this decision, but it was an excellent ball.



The curves I experimented with, compared to Uri Yurman's pattern in black. I did not actually try his shape because I found the upper limits of the curves to be lower than his. The approximated tangent angles were from my incorrectly-drawn patterns. The intended angles were 6°, 9°, and 12°.

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