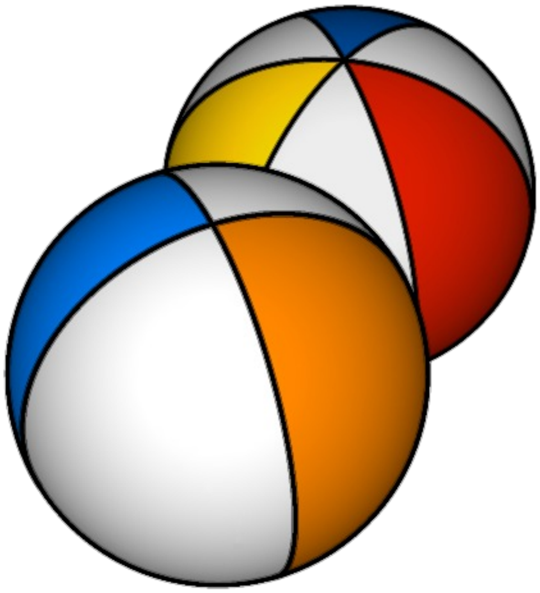
The Complete Homemade Juggling Beanbag Guide

4 & 6-Panel Orange Peel Ball Chapter

Small file size version (150dpi patterns & images)



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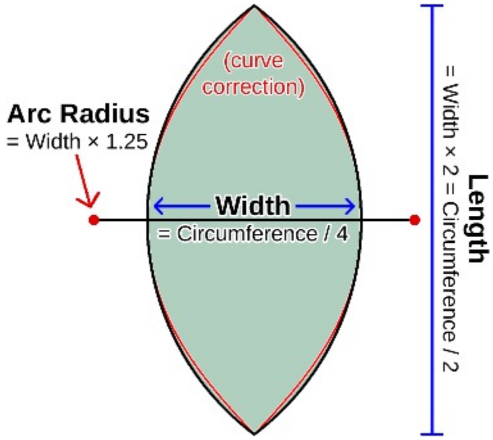
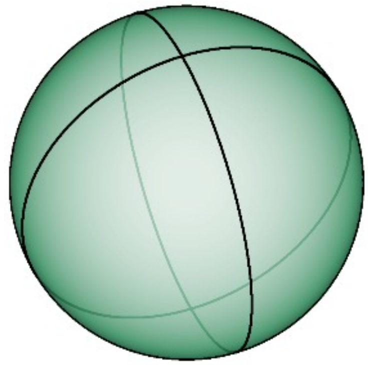
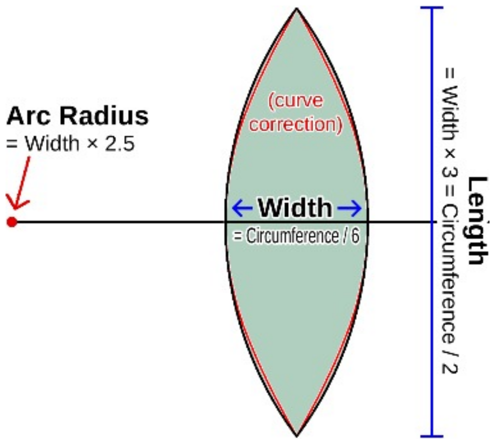
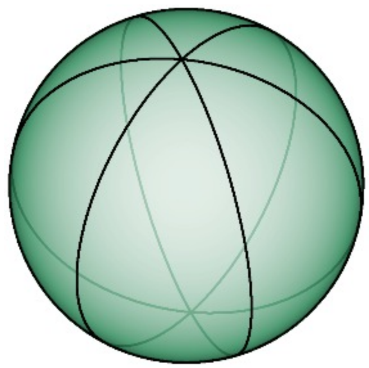
4 & 6-PANEL ORANGE PEEL BALL INSTRUCTIONS, WITH N-PANEL PATTERN DRAWING INSTRUCTIONS









Chapter Index

Design Notes

The shape of this type of beanbag (with any number of panels) is technically called a hosohedron, and the shape of the panels (with a circular curvature) is called a lens, or, more specifically, a symmetric lens (I now use a Bézier-style curve, not a circular arc). **The panel shape is commonly called an “orange peel”**, though, and is **used in quilting**. The portion of a hosohedron each panel covers (mathematically speaking, but not in practice since a flat panel cannot become truly spherical) is called a spherical lune.

Continued on the next page

Shape characteristics

Profile comparison. I kneaded these bags to break them in a bit, and filled them just to the point of being full but not stretched. (These are the true-color photos. The photos elsewhere in this guide with brightly colored panels were colorized in Photoshop.)

These are the simplest panels to draw (if you stick to the circular design), simplest to assemble, and the 4-panel version is tied with the tetrahedron for quickest beanbags to make. However, having only four panels, it is **somewhat cubic around the equator** (at least when made with a stiff or non-stretch fabric) and has a non-uniform feel due to the sparse and strictly longitudinal seams. The beanbag pictured is not broken in, though, apart from being kneaded. Some heavy use would probably round it out somewhat. You can also **press the ball against a hot iron along all the seams to round them a little.**

A flexible, stretchy fabric would be better for the 4-panel design because it will allow the panel faces to bulge out and more closely match the seams, which have an approximately circular profile, and produce a better sphere. **Filling the bag loosely also helps it feel rounder** because your grip reshapes it.

The 6-panel version is more nearly round around the equator (hexagonal rather than square). You can also make an orange peel ball with even more panels. I provide general formulas for designing the orange peel shape for any panel multiple (see "How to Design Orange Peel Balls with Any Number of Panels"). Be aware that the numerous panel tips crowded together at the poles are difficult to work with and may cause the poles to pucker inward a bit when using a thick fabric. If you value an excellent sphere and are willing to sew more panels, there are designs with better sphericity and seam uniformity than this one. The only merit I see in a six or eight-panel orange peel ball is the attractive stripiness of it.

If you want the 4-panel orange peel ball look but with a better shape, **just make an Octahedron and arrange the colors in 2-panel stripes**. The octahedron requires only a moderate amount of additional work and makes an excellent sphere (even with a circular curve, which is easier if you're drawing the pattern yourself).

The effect of woven fabric's grainline orientation on the ball shape

Woven fabric does not stretch equally in all directions, and so its orientation on beanbag panels can be important. **This design is especially sensitive to woven fabric's grain direction** due to having large panels that are parallel to each other and encircle half the ball. A minor issue is that **if the grain is not**

well aligned on all panels, the bag will be somewhat lopsided. Be sure to align the patterns precisely with the grain. More importantly, in my experimental 4-panel bags made with corduroy, which stretches mostly at a 45° angle to the cords and slightly across them, but not parallel to them, **I got a very different result depending on how I oriented the patterns in relation to the cords**.

When the corduroy cords ran from panel tip to panel tip as I recommend, the bag had a great shape. When I oriented the pattern with the cords running from side to side, the bag had an elongated, barrel shape with overly blunt poles. When I oriented the pattern with the cords at a 45° angle, the bag had a lemon shape with somewhat pointed poles.

Denim's cords run at a 45° angle to its grain, so I made two bags with denim from a pair of jeans to see which cord orientation works better. The first had the cords oriented tip to tip and the second had the grainline oriented tip to tip (the cords at a 45° angle). When softly filled the two bags are nearly the same and are quite acceptable. The first just has a minor lemon shape. When firmly filled the first bag became less lemon-shaped and has a very nice shape. The second bag became flat at the poles and wider across the equator (from seam to seam) than from pole to pole, as if it had been squashed a bit. So either orientation works, but my preference is for the cords running tip to tip. A more loosely woven denim might produce a more prominent lemon-effect, though. The denim I used is pretty dense.

Another issue with using woven fabrics for this design is that with a fabric like corduroy, with the cords running from tip to tip, the bag will swell more around the equator than from pole to pole due to the corduroy stretching more across the cords than along them. This causes a tightly filled bag to have a flattened shape from pole to pole like the second denim bag described above. The bags pictured at the beginning of this section are not filled tightly and do not exhibit this very much, but a 6-panel bag I made with a different color of corduroy in place of the black panels, which apparently had a somewhat different weave, exhibited a greater flattening effect.

Pattern curvature: Circular curve vs my corrected curve

My ready-to-print patterns have a manually-adjusted curvature that improves the beanbag shape over the basic, circular design. If you draw the patterns yourself, you can use the instructions and illustrations I provide for adjusting the circular starting curve to produce the corrected curve. If you are not picky about having the best sphere possible, however, you can just use the simpler, circular curves and still get a decent result, especially with a flexible, stretchy fabric.

With a non-woven fabric such as felt, which is what I experimented with, the two 4-panel curvatures (circular and hand-corrected) will produce roughly equally good spheres when filled tightly, but when filled loosely, the circular curve will produce a somewhat elongated shape from pole to pole. With a woven, non-elastic fabric and the patterns oriented parallel to the fabric's lengthwise grain, and depending on how tightly you fill it, the circular-curve beanbag will be flat or even concave at the poles, with seams that shrug their shoulders on either side of the vertices. Orienting denim's 45° cords from tip to tip (rather than the lengthwise grain) will actually counteract the circular curve's poor shape to some extent because a 45° grain orientation causes the poles to become more acute.

The poor shape of the circular panel bag is due to the **over-wide angle at the tips of the panels formed by the circular curves**. See the "The problem with a circular curve" topic in the "How to Design Orange Peel Balls with Any Number of Panels" section of this chapter for more in-depth information.

Supplies

Back to Chapter Index

- **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

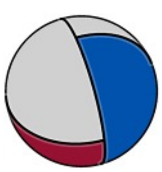
Back to Chapter Index

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

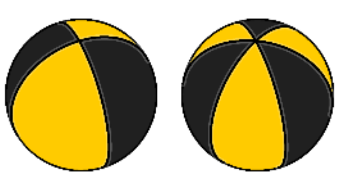
Back to Chapter Index

Below are nine color arrangements for both the 4-panel and 6-panel designs, grouped by the number of colors they contain. Since there are so few arrangements, I mixed the two designs together. Some arrangements work for both, some do not. The images give examples of each arrangement.



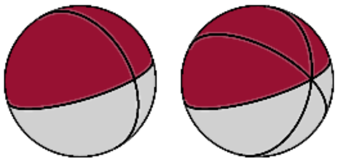
Here's a silly idea: Try misaligning the hemispheres by 90°. I haven't tried it, but I think it will work (a non-woven fabric will work better because the grain of a woven fabric will, I think, give the bag a somewhat asymetric shape).

2 colors



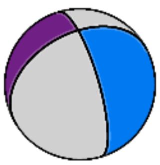
#1: Alternating Stripes of contrasting colors.

#2: Dual-Width Stripes. 6-Panel only. My own invention: one color on two opposing panels, the other on two opposing pairs of panels.



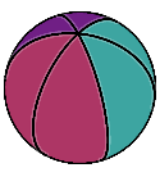
#3: Hemispheres. One hemisphere (two/three adjacent panels) of each color.

3 colors



#4: Alternating Stripes (3-color variation). 4-Panel only. Color A on a pair of opposite panels and colors B and C on the other pair. The 6-panel design has a 4-color version of this arrangement.

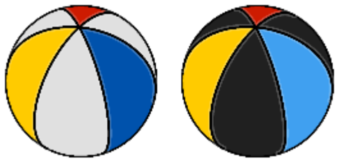
#5: Repeating Trio. 6-Panel only. A repeating sequence of three colors. Each color is opposite its match.



#6: Three Pairs. 6-Panel only. Each color on a pair of adjacent panels, forming the look of a 3-panel ball.

#7: Dual-Width Stripes (3-color variation). 6-Panel only. Same as the 2-color Dual-Width Stripes arrangement, but each two-panel stripe (or single-panel stripe, if you prefer) is a unique color.

4 colors



#8: Classic Beach Ball. 6-Panel only. A neutral background color on three non-adjacent panels, and each remaining panel a unique, bold color.

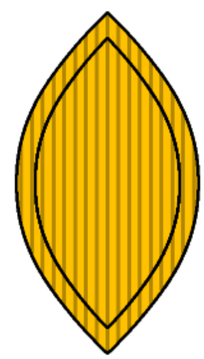
Max colors

#9: Each panel a unique color.

Making the Panels

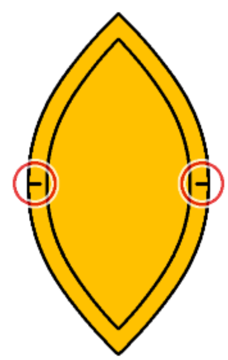
Back to Chapter Index

1. You will need 4 or 6 panels (depending on which version you choose), 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.

   This design is very sensitive to fabric grain orientation. For woven fabrics, **I recommend orienting the pattern so that the fabric's lengthwise/straight grain, or the cords of corduroy, run from tip to tip**. If you orient the grain widthwise, or at a 45° angle, you may get a barrel or lemon-shaped bag, respectively. (The cords of denim run at a 45° angle to its grain, but orienting them parallel to the panels still works well enough, at least with a tightly woven denim). Also, **make sure the patterns are aligned precisely.** If they are aslant in relation to the grain, the bag will be a little lopsided.

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).

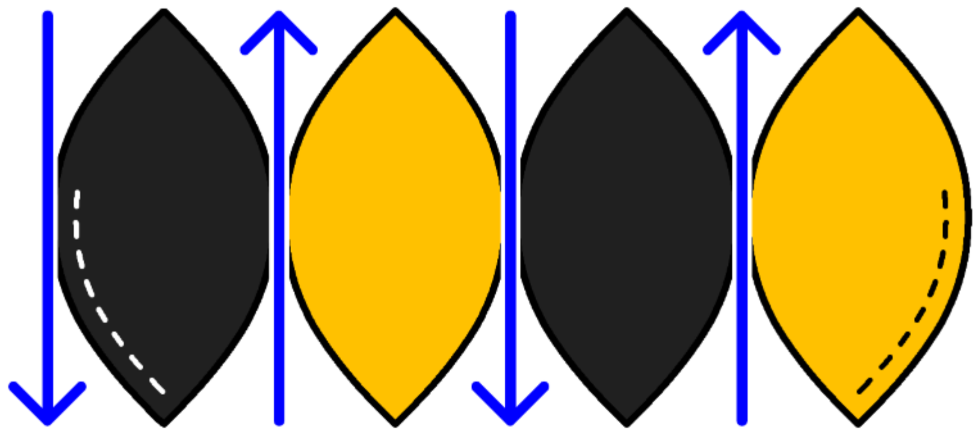
   I find it helpful to **mark the middle of the panel sides** using the width line on the template. This helps me to ensure that I am keeping the panels aligned and proceeding at the same rate on both panels I am sewing. With thick fabrics one panel tends to get misaligned with the other so that I reach the end of one panel and still have a stitch or two left to make on the other.

3. Cut out the panels.

Assembly

Back to Chapter Index

My assembly method below can use as few as one thread if you cut it long enough and continue it from one seam to the next. The method consists of sewing the panels together either from one end of the row to the other, or, as I prefer, sewing separate pairs together and then joining the pairs. The final half seam, indicated by the dashed lines, is left open so the bag can be turned out through it. That section will be closed from the outside along the dashed lines, which are drawn on the front faces of the panels. Though the illustration shows only four panels, the instructions apply to any number of panels.



1. **Lay the panels out as shown** in the 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 partial stitching lines on the *fronts*** of the two outer panel edges (the dashed lines in the illustration). My stitching pathway will leave this portion of the final seam partially unsewn so the bag can be turned out through it. It will then be **sewn from the outside using the front stitching lines**. 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 seam**, sketch them a millimeter or two away from the template (nearer to the panel edges) and stitch slightly inside them (toward the middle of the panels).

   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. **Select a pair of panels** from either end of the row and **sew them front faces together** along one edge, being sure not to sew the edge that has the front stitching line.
4. **Add the next panel to the pair**, placing the new panel front face to front face with the panel that does NOT have the front stitching line. I suggest turning the pair right side out first so the front faces are exposed. This makes the new panel easier to join to them. **As an alternative**, do what I prefer and **sew the next pair of panels together, and then join the finished pairs**.
5. **When you have joined all panels**, I recommend using the second method in the "Closing seam intersections tightly" topic of the **General Information and Techniques** chapter's "Stitching Techniques" section. **4-way and above intersections take a little extra care if you want them**

tightly closed and elegant-looking. In short, **stitch each panel tip to the one diagonally opposite it (the thread will form an X across the intersection) and cinch them together**.

6. If you did not leave a hanging thread at one end of the opening, start a new one. Either way, **sew the opening closed until you have just enough** through which to turn the bag out, making sure that the remaining opening is the part with the front pattern marked on it. 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**.

7. At this point **consider ironing the seam allowances flat**; see the **General Information and Techniques** chapter under "Better Seams by Ironing".

8. **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**.

9. **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").

10. **To reshape the finished bag into a better sphere and reduce angularity and lumpiness at the seams, press it against a hot iron along all the seams** (be sure to use an appropriate heat setting).

Back to Chapter Index

Ready-to-Print Patterns

Back to Chapter Index

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 4-panel and 6-panel patterns for beanbag diameters from 2″ – 3″ in ¼″ increments, and 7″ patterns for scaling to larger sizes. These patterns use my corrected curves, not circular curves. The patterns are reduced by 5.46% and 5.85%, respectively 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 104% to get the intended ball size.**

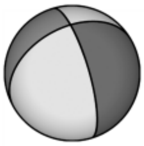
To make the templates, I recommend cutting out the portions of the paper with the patterns you want and using glue or double-sided tape to attach them to your template material, and then cutting along the patterns.

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 cutting pattern is a hair under ¼″). Remember that the cutting patterns have slightly different 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.

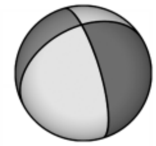
The table below provides the scaling for the ⅛″ increments between my ¼″ sizes. The centimeter grid can be used to verify correct scaling.

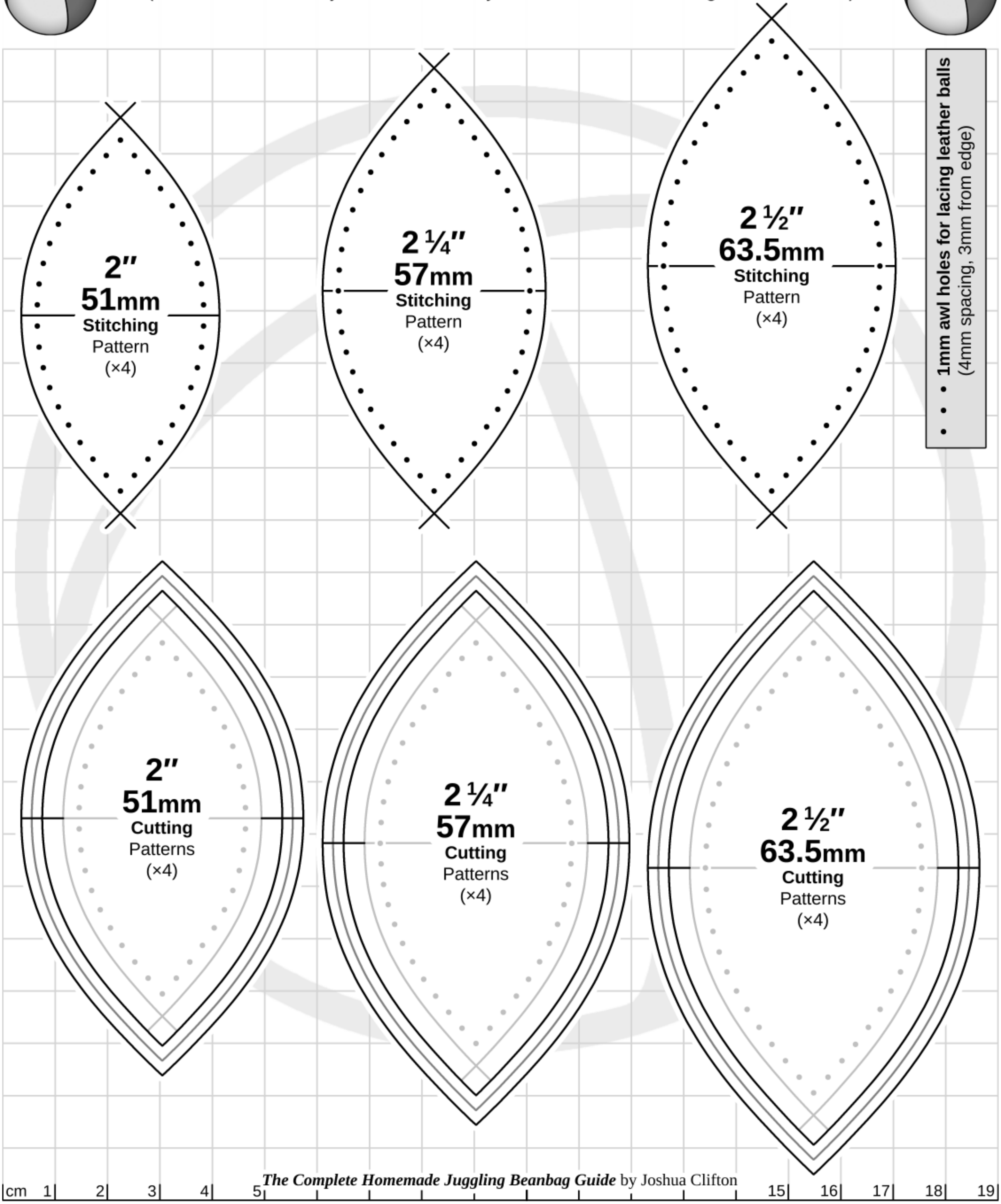
Target Diameter	Print this pattern size	At this scale
1¾″ (44.5mm)	2″	87.5%
1⅞″ (47.6mm)	2″	93.8%
2⅛″ (54.0mm)	2¼″	94.4%
2⅜″ (60.3mm)	2½″	95%
2⅝″ (66.7mm)	2¾″	95.4%
2⅞″ (73.0mm)	3″	95.8%



4-Panel Orange Peel Ball/Beach Ball

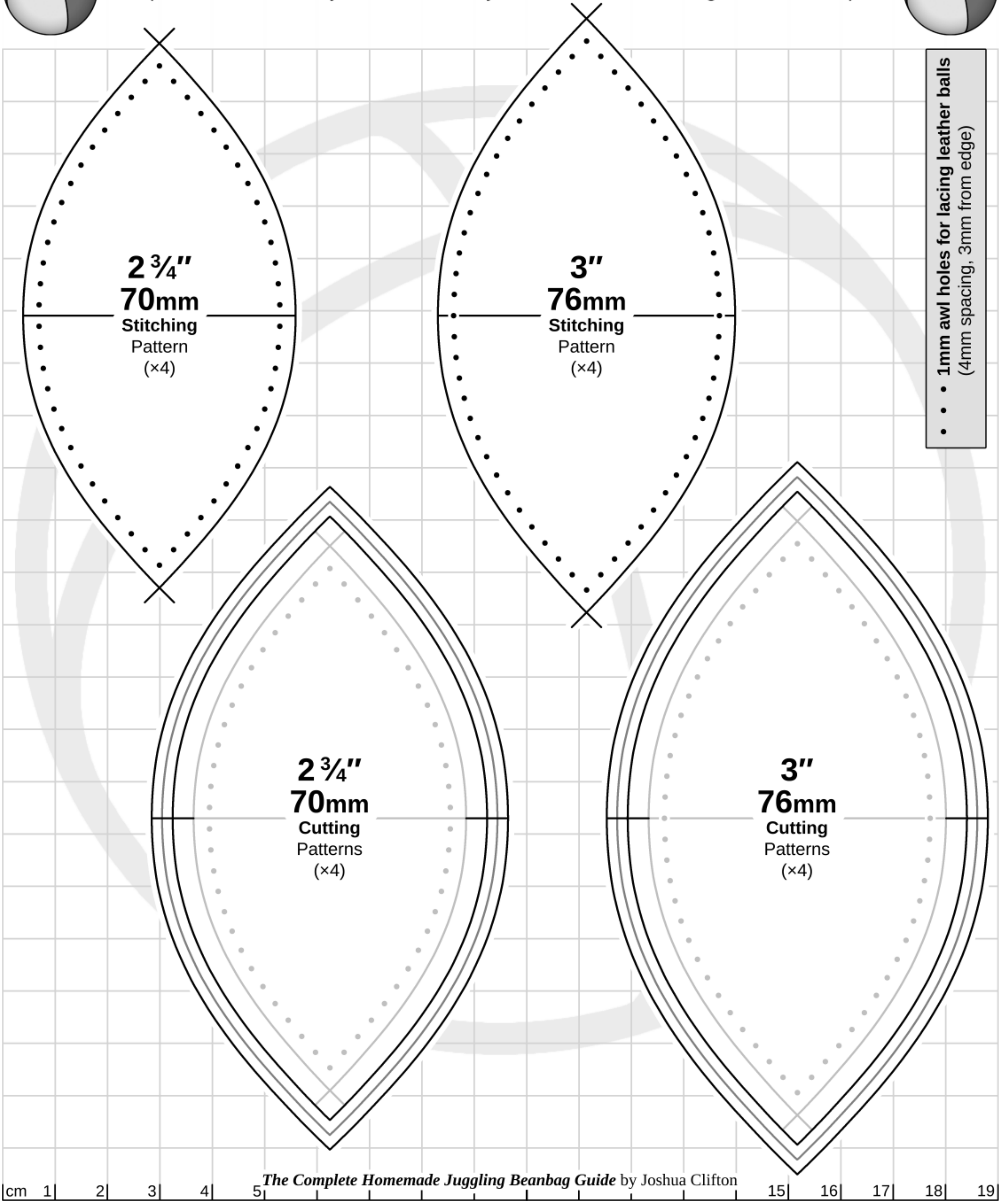
(Pattern sizes are adjusted for corduroy and do not account for gathered seams)





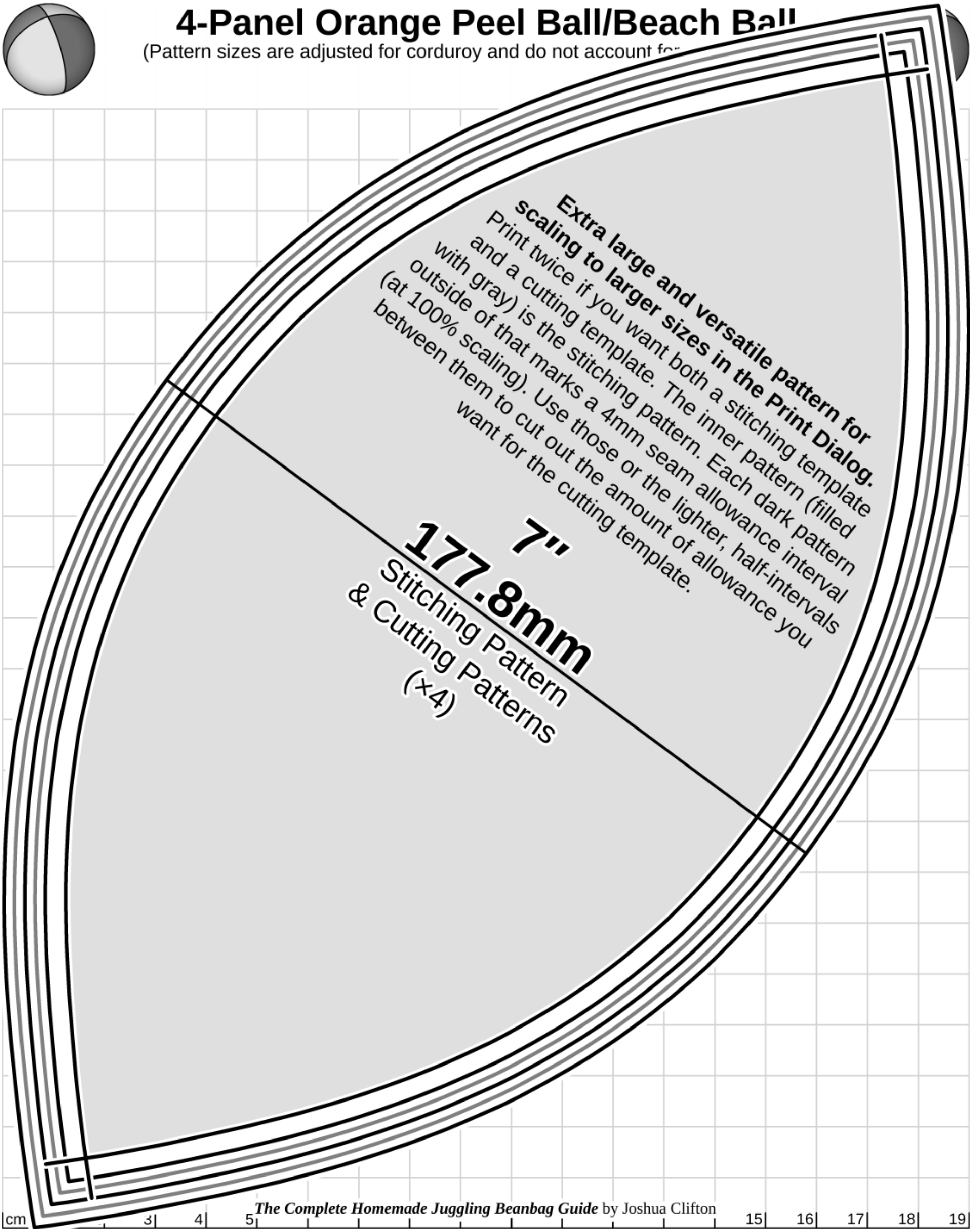
4-Panel Orange Peel Ball/Beach Ball

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



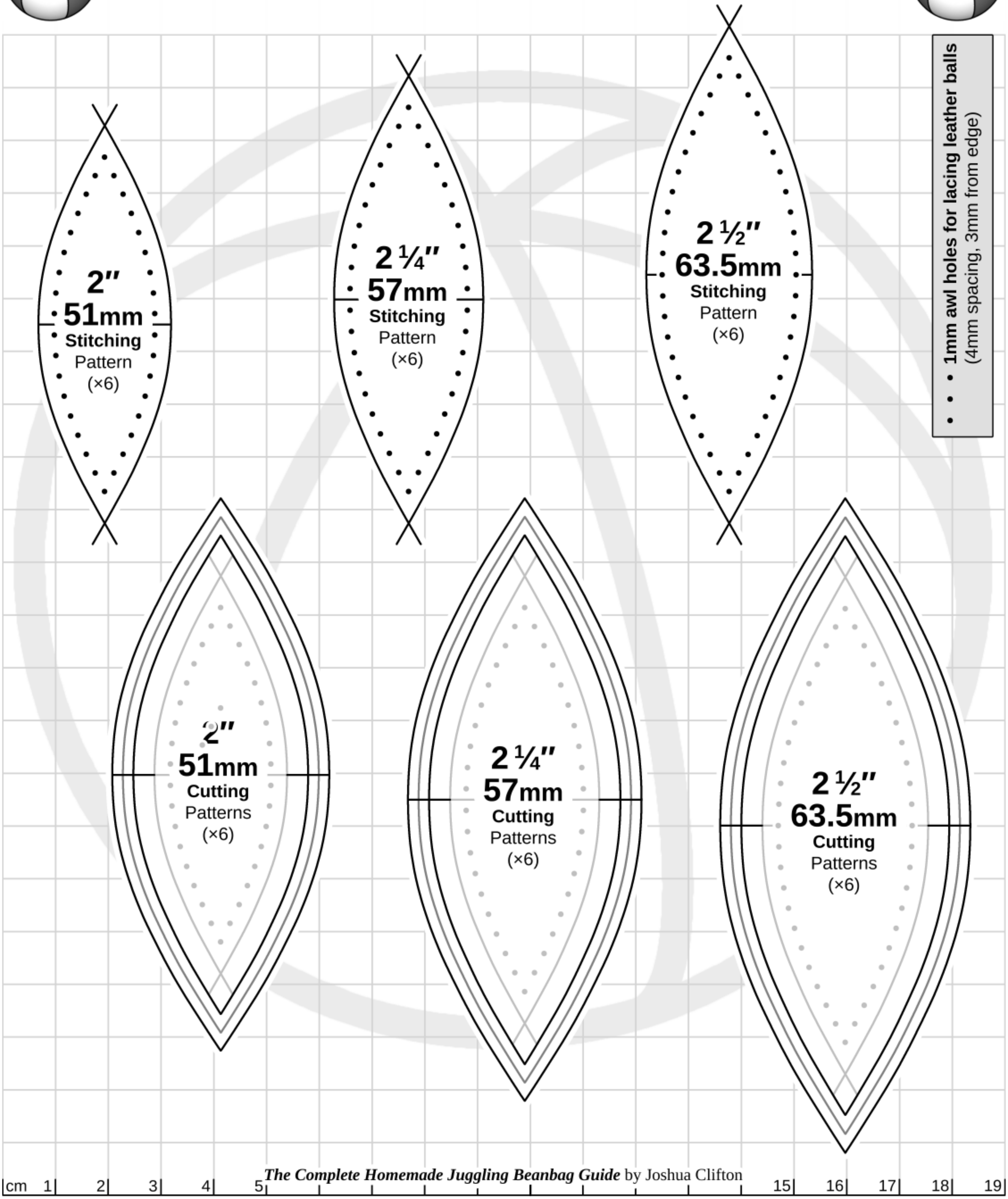
4-Panel Orange Peel Ball/Beach Ball

(Pattern sizes are adjusted for corduroy and do not account for



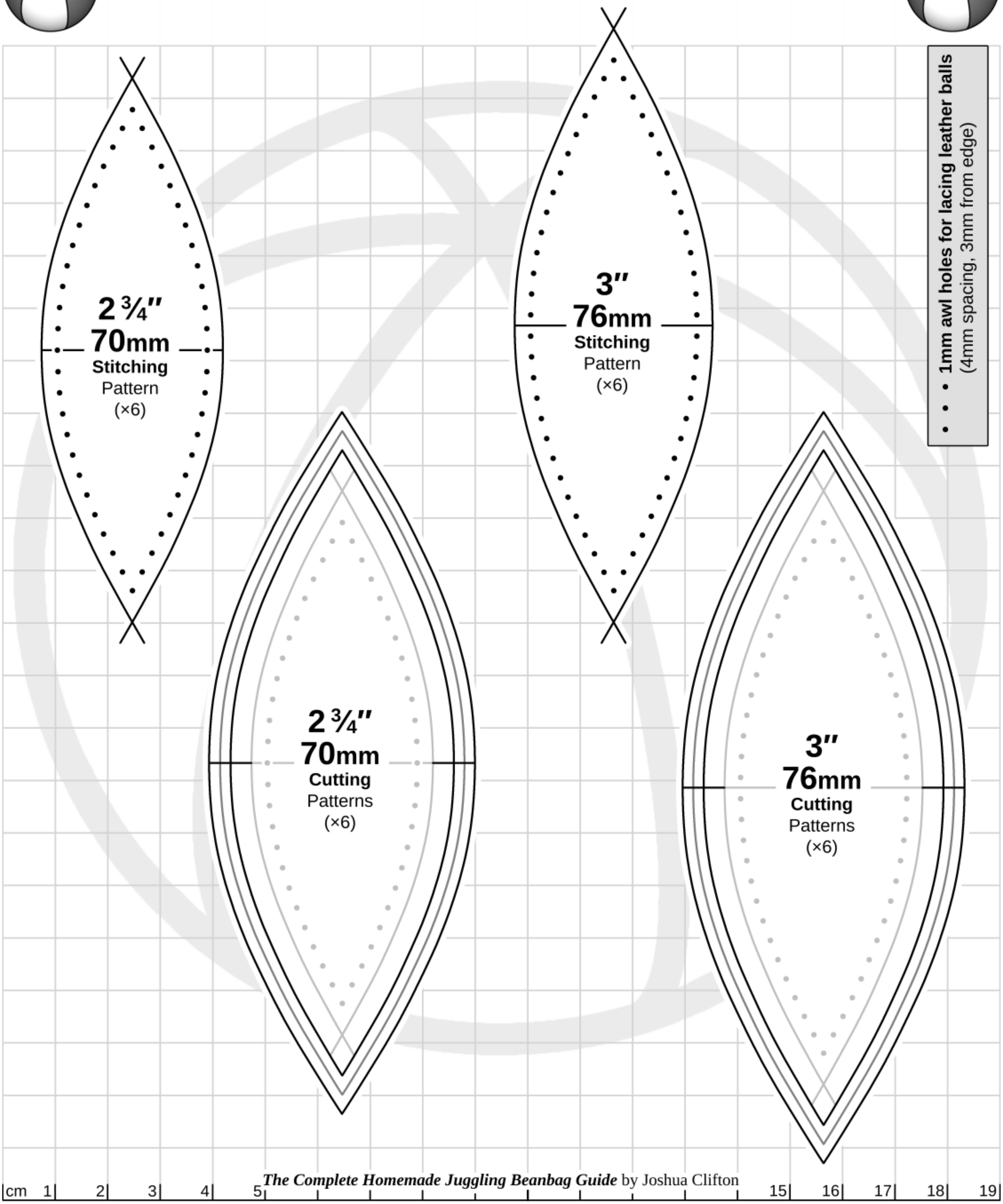
6-Panel Orange Peel Ball/Beach Ball

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



6-Panel Orange Peel Ball/Beach Ball

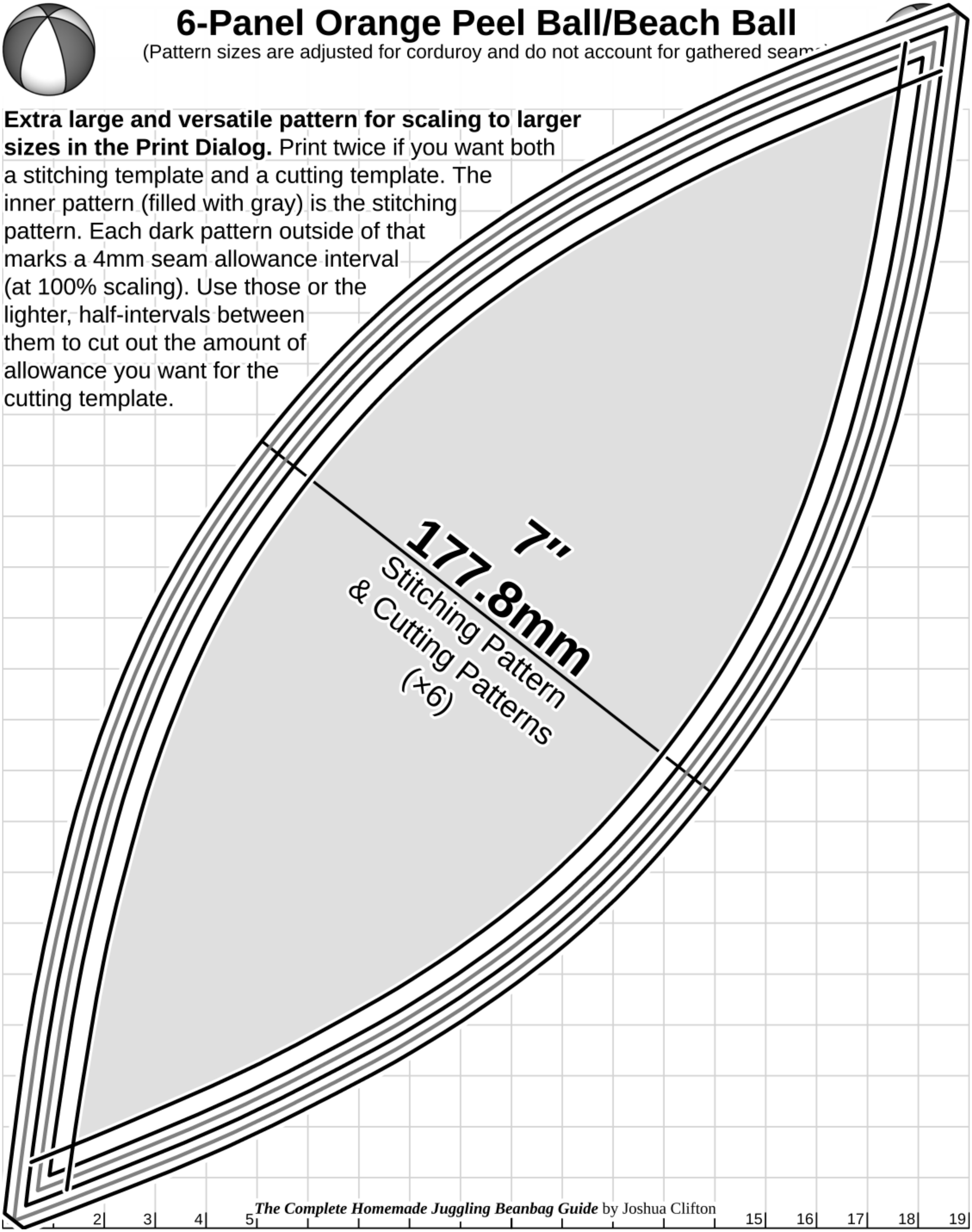
(Pattern sizes are adjusted for corduroy and do not account for gathered seams)



6-Panel Orange Peel Ball/Beach Ball

(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.



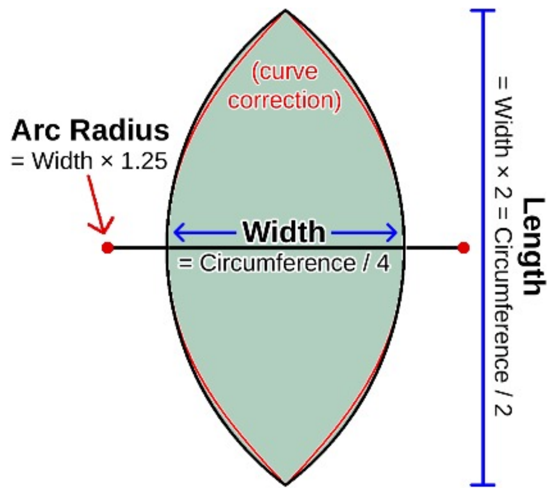
Sizing Formulas for Drawing the Patterns

Back to Chapter Index

The next section has tables of pre-calculated pattern measurements for all ⅛″ diameter increments from 1¾″ – 3″. Following those 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.

Design summary

The circumference of the bag is composed of two panel lengths around the "poles" or vertices, and four or six panel widths around the equator. So, for the 4-panel version, the length must be twice the width, and for the 6-panel version the length is three times the width. The basic curves are circular, but circular curves will not produce a very good ball shape. A soft, somewhat stretchy cloth will be forgiving enough to make the circular curve work moderately well, at least for four panels. The section titled "Adjusting the Circular Curve into a Bézier Curve" has instructions and illustrations for correcting the curve either by hand or with a Bézier curve.



I define the panel size by its width and express all measurements in terms of the width. Its length is determined by the radius of the circular curves that form its basic shape. To form the 4-panel shape, for example, the curve radius must be *Width* × 1.25. Thus, by placing two points that are *Width* × 1.5 apart, setting a compass to *Width* × 1.25, and drawing an arc from each point, you get the basic panel shape.

Adjusting for the influence of fabric types on beanbag size

The 4-panel bag I made with a thick corduroy using my corrected curve was **4.29 – 6.63%** larger than the mathematical prediction depending on whether I filled it loosely or over-filled it. The one I made with the circular curve was 7.97 – 9.95% larger. The 6-panel bag was **4.53 – 7.17%** larger. I target halfway between the min and max inflations when sizing my patterns, which is **5.46%** and **5.85%**. This makes my adjustment factor **1.0546** and **1.0585**.

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".

The 4-panel beanbag I made years ago with thick, stiff, non-stretch denim was 4.6 – 9.4% larger depending on whether I filled it loosely or over-filled it. I don't know why the range is so much wider with the denim. I will use the adjustment factors from the corduroy since that is consistent with the sizing of the other designs. (The corrected-curve 4-panel bag I made with a fairly thin, stiff, tightly-woven, non-stretch fabric was -0.54% – +4.20% larger, and the circular-curve bag was -1.31% – +4.61%

larger. The 6-panel bag had an average adjustment factor of 1.97%. But those were just for analyzing the shape characteristics of the bag.)

Sizing formulas for the 4-panel bag

Below are the formulas to calculate the pattern construction elements (*Diameter* is your target ball diameter, $\pi = 3.1416$). 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.**

- **Panel Width (w) = *Diameter* × π ÷ 4 ÷ 1.0546 (≈ *Diameter* × 0.7854 ÷ 1.0546)**
- **Arc Radius (r) = 1.25w**
- **Circle Center Distance = 2r – w = 1.5w**

The compass points are located **$r - w = 0.25w$** distant from each side of the panel.

Sizing formulas for the 6-panel bag

Below are the formulas to calculate the pattern construction elements (*Diameter* is your target ball diameter). 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.**

- **Panel Width (w) = *Diameter* × π ÷ 6 ÷ 1.0585 (≈ *Diameter* × 0.5236 ÷ 1.0585)**
- **Arc Radius (r) = 2.5w**
- **Circle Center Distance = 2r – w = 4w**

The compass points are located **$r - w = 1.5w$** distant from each side of the panel.

Tables of Pre-Calculated Pattern Measurements

Back to Chapter Index

Below are 4-panel and 6-panel stitching pattern measurements for each ⅛″ diameter increment from 1¾″ to 3″. The values in the **Adjusted** columns account for my adjustment factors. The adjusted values decrease the **Base** pattern size so that you will get a more accurate finished size when using a thick fabric like corduroy or denim. If you are using a thin, non-stretch fabric and do not intend to over-fill it, use the Base value instead.

To draw the cutting pattern, use the same Circle Center Distance, but increase the Arc Radius by the desired seam allowance (I use 8mm). The cutting pattern will be larger than, but parallel to, the stitching pattern.

4-Panel Pattern

Finished Diameter	**Width** (mm)		**Circle Center Distance** (mm)		**Arc Radius** (mm)		**Resulting Length** (mm) (for double-checking)	
	Base	**Adjusted**	Base	**Adjusted**	Base	**Adjusted**	Base	**Adjusted**
1¾″ (44.5mm)	34.911	**33.103**	52.366	**49.655**	43.639	**41.379**	69.822	**66.207**
1⅞″ (47.6mm)	37.405	**35.468**	56.107	**53.202**	46.756	**44.335**	74.809	**70.936**
2″ (50.8mm)	39.898	**37.833**	59.847	**56.749**	49.873	**47.291**	79.796	**75.665**
2⅛″ (54.0mm)	42.392	**40.197**	63.588	**60.296**	52.990	**50.246**	84.784	**80.394**
2¼″ (57.2mm)	44.886	**42.562**	67.328	**63.842**	56.107	**53.202**	89.771	**85.123**
2⅜″ (60.3mm)	47.379	**44.926**	71.069	**67.389**	59.224	**56.158**	94.758	**89.852**
2½″ (63.5mm)	49.873	**47.291**	74.809	**70.936**	62.341	**59.113**	99.746	**94.581**
2⅝″ (66.7mm)	52.366	**49.655**	78.550	**74.483**	65.458	**62.069**	104.733	**99.310**
2¾″ (69.9mm)	54.860	**52.020**	82.290	**78.030**	68.575	**65.025**	109.720	**104.040**
2⅞″ (73.0mm)	57.354	**54.384**	86.031	**81.576**	71.692	**67.980**	114.707	**108.769**
3″ (76.2mm)	59.847	**56.749**	89.771	**85.123**	74.809	**70.936**	119.695	**113.498**

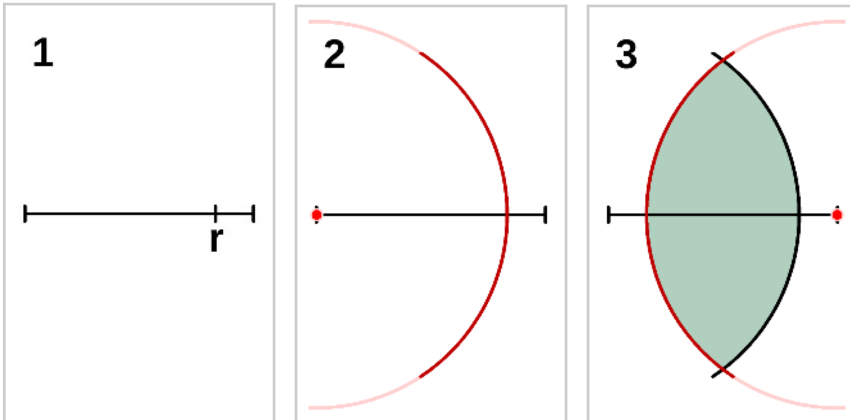
6-Panel Pattern

Finished Diameter	**Width** (mm)		**Circle Center Distance** (mm)		**Arc Radius** (mm)		**Resulting Length** (mm) (for double-checking)	
	Base	**Adjusted**	Base	**Adjusted**	Base	**Adjusted**	Base	**Adjusted**
1¾″ (44.5mm)	23.274	**21.988**	93.096	**87.951**	58.185	**54.969**	69.822	**65.963**
1⅞″ (47.6mm)	24.936	**23.558**	99.746	**94.233**	62.341	**58.896**	74.809	**70.675**
2″ (50.8mm)	26.599	**25.129**	106.395	**100.515**	66.497	**62.822**	79.796	**75.386**
2⅛″ (54.0mm)	28.261	**26.699**	113.045	**106.797**	70.653	**66.748**	84.784	**80.098**
2¼″ (57.2mm)	29.924	**28.270**	119.695	**113.080**	74.809	**70.675**	89.771	**84.810**
2⅜″ (60.3mm)	31.586	**29.840**	126.344	**119.362**	78.965	**74.601**	94.758	**89.521**
2½″ (63.5mm)	33.249	**31.411**	132.994	**125.644**	83.121	**78.527**	99.746	**94.233**
2⅝″ (66.7mm)	34.911	**32.982**	139.644	**131.926**	87.277	**82.454**	104.733	**98.945**
2¾″ (69.9mm)	36.573	**34.552**	146.293	**138.208**	91.433	**86.380**	109.720	**103.656**
2⅞″ (73.0mm)	38.236	**36.123**	152.943	**144.491**	95.590	**90.307**	114.707	**108.368**
3″ (76.2mm)	39.898	**37.693**	159.593	**150.773**	99.746	**94.233**	119.695	**113.080**

How to Draw the Panel Shape

Back to Chapter Index

The basic panel shape is a pointed ellipse or orange peel shape whose height is twice its width for the 4-panel design or three times its width for the 6-panel design, and has circular sides. The illustrations below depict the method of drawing it using the 4-panel shape. To correct the curvature to form a more spherical bag shape, see the next section. To conserve your template material, I recommend that you draw the pattern on paper and then glue/tape the pattern to your template material before cutting it out.



Manual directions

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

1. Draw a line of length **Circle Center Distance** and mark each end. Make a second mark the distance of **Arc Radius** from one end of the line (labeled *r* in Illustration 1) which will be used to extend the compass to the correct radius. If you make the same mark on the other end, the distance between the inner marks will be the panel's **Width**.
2. Use the radius mark to adjust the compass to the **Arc Radius**. Draw an arc that extends from directly above to directly below the center of the line.
3. Without changing the compass radius, draw the same arc from the other end of the line. This should result in a pointed ellipse or orange peel shape. Check its length against the value in the table under **Resulting Length** to be sure you drew it correctly. This is your stitching pattern.
4. To draw a cutting pattern, draw everything the same but increase the compass radius by the desired seam allowance (I use 8mm) and then draw the larger arcs from the same two points.

SketchUp directions

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

1. Draw a line of length **Circle Center Distance**.
2. Draw circles of radius **Arc Radius** centered at each end of this line. The intersection of the circles forms the orange peel-shaped panel. Check its length against the value in the table under **Resulting Length** to be sure you drew it correctly.
3. To draw a cutting pattern, start with the same initial line, but increase the circle radii by the desired seam allowance (I use 8mm).

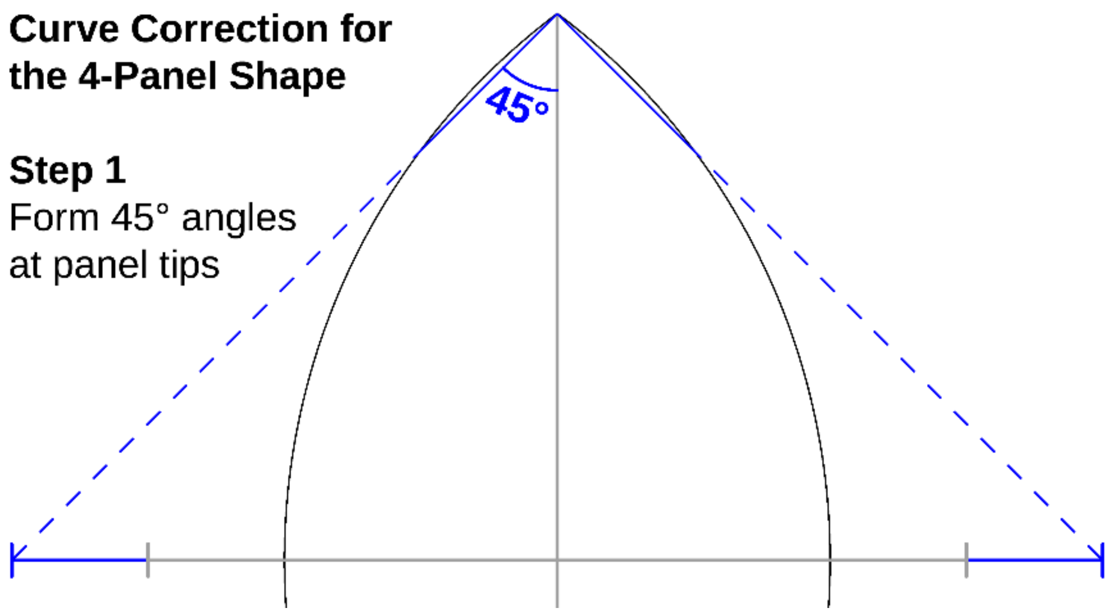
Adjusting the Circular Curve into a Bézier Curve to Correct the Angle and Curvature at the Panel Tips

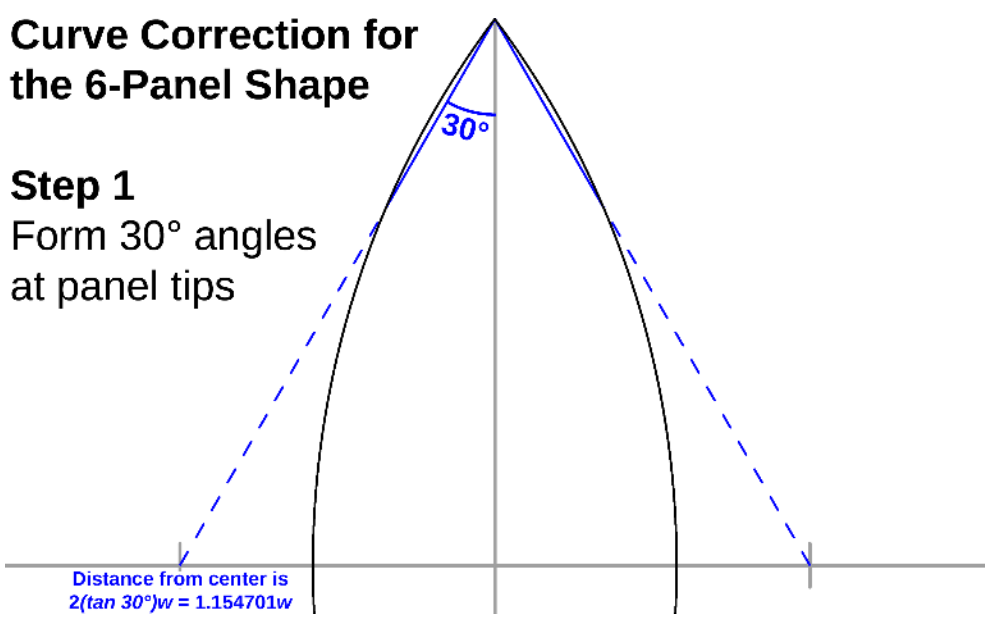
Back to Chapter Index

If you want to make the extra effort to improve the shape of the panels, resulting in a better sphere, here is the method for the 4-panel and 6-panel designs. To calculate the angle needed at the pattern tips for other panel-count designs, divide 360 by the number of panels, and divide the result by 2. To form that angle, you can either use a protractor, or mark a point along the horizontal line that is $2(\tan \theta°)w$ distant from the center of the panel (θ is the angle and w is the panel width), and draw a line from the panel tip to that point. This is illustrated by the dashed lines.

If you are drawing this on paper, I recommend that you create just one angle and one corrected curve, and then fold your design in quarters to cut it out so you can duplicate that curve rather than drawing it three more times. In SketchUp you can simply copy and flip your design to duplicate the curve.

Step 1: For the 4-panel shape, form 45° angles on either side of the panel tips (shown in blue) resulting in a 90° total angle. For the 6-panel shape, form 30° angles.

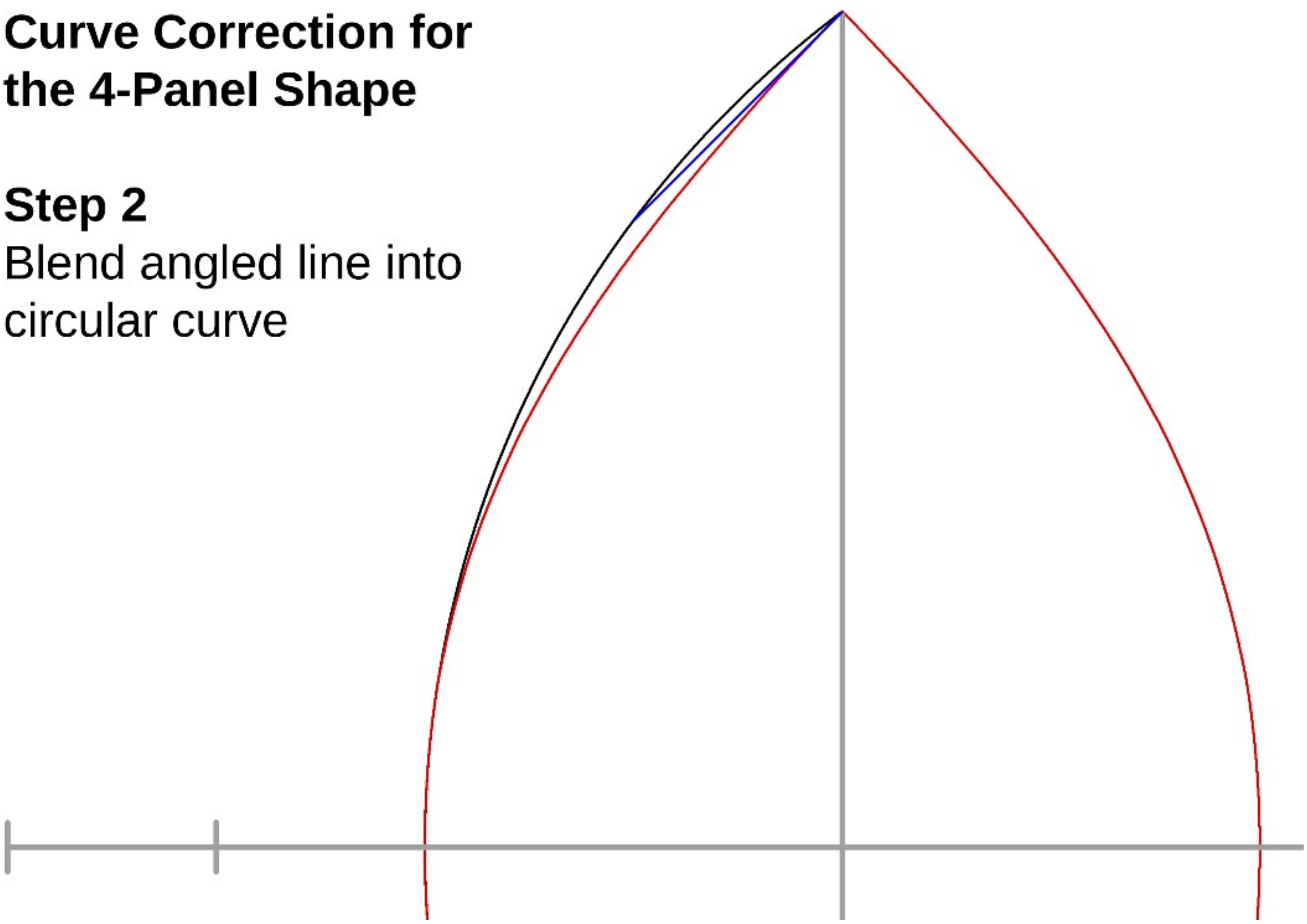




Step 2: Sketch an adjusted curve that merges gently from the angled line into the circular curve so that the new curve blends with the circular curve before the apex, creating a smoothly rounded apex. Try to match my curves shown below in red (the 6-panel shape is on the next page). You can do this by hand, or in SketchUp using a Bézier curve plugin[3].

The left sides of my illustrations include the angle line and circular curve for reference. The right sides show just the corrected curve. These curves are the ones I created for my ready-to-print patterns after several experimental curves that I made into beanbags to figure out the nature of blended curve that worked best. To see Marylis Ramos' patterns and how their curvatures look compared to mine, look for the 4-panel and 6-panel curve comparison illustrations in the "Second Edition update" topic in the "How I Developed This Design" section.

Keep in mind that the bag's shape can change drastically depending on the fabric's direction of grain and stretch. My shape works best when the fabric's lengthwise/straight grain, or the cords of corduroy, run from tip to tip. Be aware that the cords of denim do not run parallel to the grain, but at a 45° angle. Denim still worked fairly well with the patterns parallel to the cords in my experiment, but you may get a minor lemon shape depending on the particular denim used.

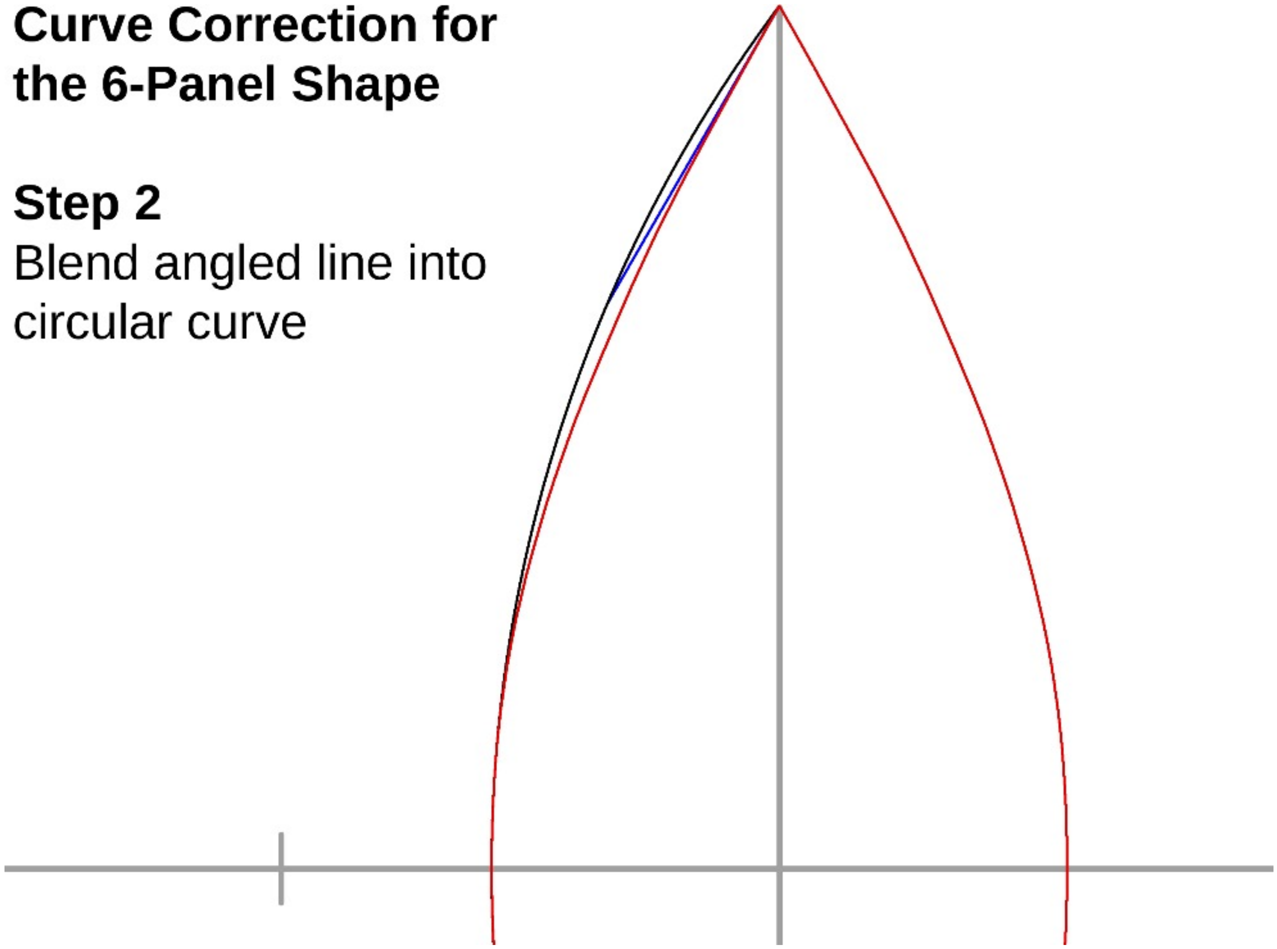


3 I recommend **BezierSpline by Fredo6**, but there are others.

Curve Correction for the 6-Panel Shape

Step 2

Blend angled line into circular curve



How to Design Orange Peel Balls with Any Number of Panels

Back to Chapter Index

Left photo from https://higginsbrothers.com/en/juggling-balls-beanbags/24-hb-8-panel-juggling-ball-140g-275-inch.html, my own beanbag on the right.

You can use the orange peel ball concept to make juggling bags with any number of panels greater than two (it technically works for two, but a 2-panel ball would be more of a pillow than a ball and the panel shape is simply a circle). The above examples use eight-panel configurations, and I read a blog in which a guy said he made one with five panels. He may have used Marylis Ramos' patterns[4]. She provides 3 and 5-panel patterns, in addition to 4, 6, and 8. (If you want to use alternating colors or a repeating sequence of colors, you will have to use a non-prime number of panels.)

There are two rules for the design of the orange peel shape (the *stitching* pattern, not the *cutting* pattern):

1. *Length* × 2 = *width* × *number of panels* = *circumference of the ball*. That is, the length of the panel must be half of the ball's target circumference and the width must be equal to the circumference divided by the number of panels.

2. There needs to be a continuous curve from tip to tip. A circular arc will work well enough if you're not picky, but the ball will have a bit of a barrel or apple shape, with flattened or even concave poles. Using a soft, stretchy fabric will help.

   Technically, the angle at the vertex formed by the intersection of the two arcs should equal 360 ÷ number of panels. A circular arc will give you the basic curve you need, yielding the correct length and width, but it produces the wrong curvature and forms too wide an angle at the vertices, preventing them from fitting together to form a spherical shape. For the best shape, you need to modify the curve to correct the angle. Instructions for doing that are in the panel shape drawing instructions in the previous section.

Once you have decided on the number of panels you want to use and their width (w), and calculated the circle radius (r), the easiest way to draw the basic panel shape (by hand or with SketchUp) is to draw a line of length $\mathbf{2r - w}$, set the compass to the required radius (if you're drawing the pattern manually), and then draw the arcs/circles from each end of the line. Their overlap zone forms the panel shape. These steps are depicted below the formulas.

To confirm you drew the panel correctly, measure it and make sure it follows the first of the two design rules above. Remember that this method creates the stitching pattern. To make the cutting pattern, simply draw everything the same but increase the arc/circle radius by the desired seam allowance.

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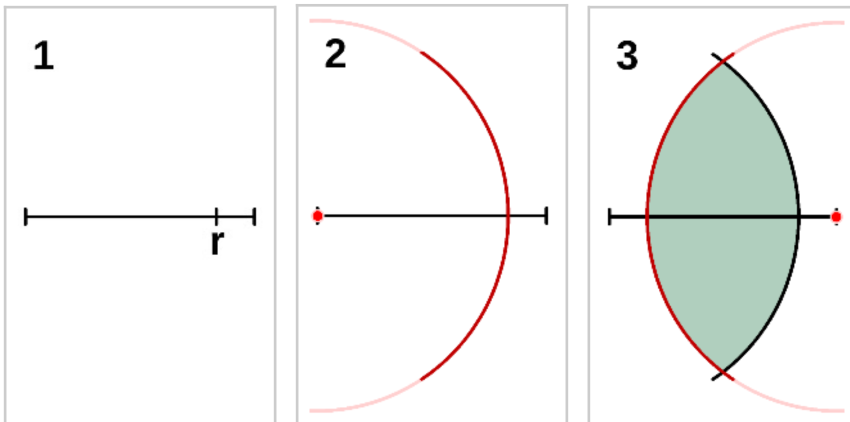
4 "Sewing Patterns for Jugglers" Orange Segment Series. Also available on my own server.

Panel design formulas

(π = 3.1416, n = number of panels)

- **Ball Circumference = *Ball Diameter* × π**
- **Panel Length (l) = *Circumference* ÷ 2**
- **Panel Width (w) = *Circumference* ÷ n**
- **Arc Radius (r) = $(w^2 + l^2) \div 4w$**
- **Distance between compass points = $2r - w$**



Steps to draw the basic, circular panel shape for the 4-panel design

A blogger I found called The Shishi Girl wrote an article on making 6-panel felt balls using this panel shape[5], which she calls "peels". Happily, I learned from one of the commenters, Katherine, of the formula to calculate the radius of the circle that will form the curve for an orange peel ball panel. (Before I learned the formula I used a tedious, trial-and-error method of finding the radius.) The Shishi Girl's theory on the basic shape of the peels is included at the end of this section. Apparently, she did not have a problem with using the circular curve. Felt is probably able to distort enough to overcome the curvature problem.

The problem with a circular curve

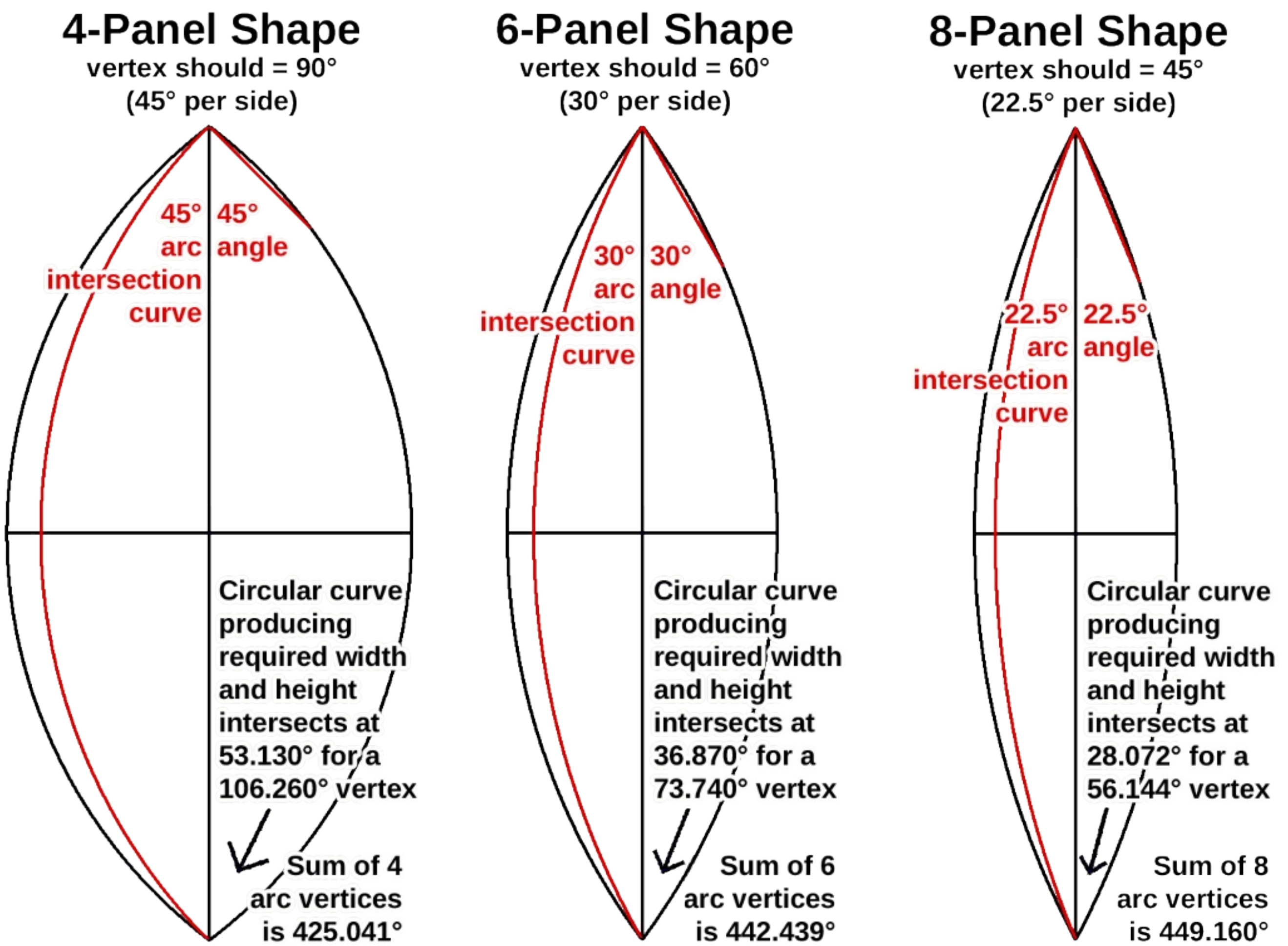
As I mentioned earlier, while a circular curve will give you the basic curve you need, yielding the correct width and length, it forms too wide an angle at the vertices and the wrong curvature, and so the poles of the bag will tend to pucker inward due to the seams curving upward too steeply from them. This makes the bag flattened or even concave at the poles. For the best shape, you need to modify the curve to correct the angle. The difference will not be very great with a soft, stretchy fabric, though.

When I made an eight-panel bag to confirm that the panel design theory worked for that many panels, the bag turned out fairly well and did confirm the theory, but, because of the over-wide angles of the panel tips and the thick, stiff denim I used, the poles dimpled inward significantly as shown on the right, making the overall shape of the bag slightly like an apple. That might be due in part to the crowded seam allowance corners, though.

5 https://shishigirl.blogspot.com/2008/12/basic-geometry-ii.html

A photo of my 8-panel orange peel ball is at the beginning of this section, but at that angle the apple shape is not apparent.

Following are illustrations of the problem with the circular curves. The black outer shapes are the basic panel shapes with circular curves. The angles produced (by the tangents to the arcs, technically) are noted at the bottom right of each image. Their sums should equal 360°, but are instead much higher. The curves in red on the left side are the circular curves that produce the correct angle at the vertex. As you can see, they make the panels much too narrow. The red angled lines on the top right show what the correct angles look like as a straight line. A corrected curve would blend this line with the circular curve, producing a continuous curve that has the correct angle and becomes circular as it approaches the apex (see my illustrated directions for doing this in the previous section).



To calculate the arc radius needed to produce the correct angle at the vertex, I used the tangent chord angle theorem (read the "Curved-Edge Faces" section of Chapter 5 for a fuller discussion of this). Following is the formula to calculate the radius (c = chord, which in this case is the length of the panel, θ is the angle between it and the tangent to the arc that forms one side of the panel):

$$r = \frac{0.5c}{\sin\theta°}$$

To calculate the angle produced by an existing arc, the formula needs to be solved for the angle:

$$\theta° = \arcsin\left(\frac{0.5c}{r}\right)$$

High panel-count orange peel ball vertex issue

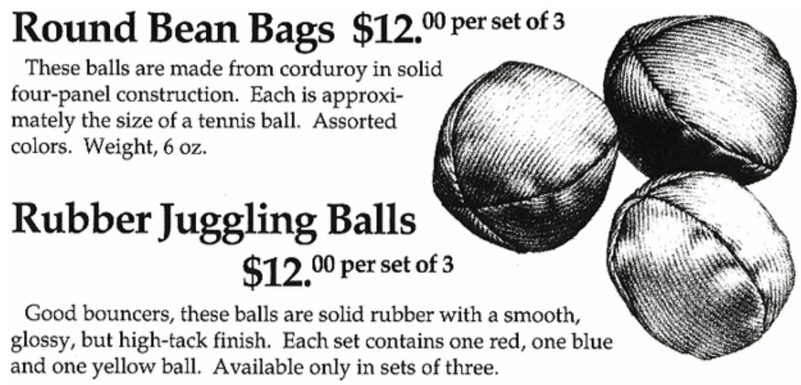
One problem with my 8-panel orange peel ball was getting all the panel tips to pull together and make a tight formation at each pole with each tip aligned with its opposing tip (I'm very picky). The way I sewed them, stitching the panels only to the ones adjacent to them and not also to the one opposite them, allowed them to separate slightly and the poles looked messy as shown below on the left.

To solve the problem in this case, I used a doubled thread for strength (my single thread broke) and from outside the bag I put stitches into each panel tip, stitched across to the opposite panel, and pulled the two tightly together. I continued this around the pole a couple of times to produce a tight, uniform formation. The result is shown below on the right. I could have done this from the inside before turning the bag out if I had thought of it. I do that now on all 4-way and above vertices and I always get vertices like the one on the right. See the **General Information and Techniques** chapter under "Closing seam intersections tightly" for instructions.


Back to Chapter Index

How I Developed This Design (the 4-Panel Version)

Back to Chapter Index



Original advertisement from “The Flying Apparatus Catalogue” by Klutz, scanned by me

Original inspiration

This is my first design, which I developed in the mid-1990s when I was in my mid-teens. I got the idea for it from some corduroy, four-panel juggling bags sold in the Klutz Flying Apparatus catalog (the catalog ad is shown above). I badly wanted them but I didn’t want to cough up the dough ($12 for a set of three plus shipping, and I wanted two or three sets). All I currently had were angular cube bags made of duck canvas by Jugglebug (right). The corduroy ones looked much rounder and more elegant. I decided to do what I often do in this kind of situation: make them myself.

My Jugglebug beanbags

Before I could do that, though, I had to figure out the shape and proportions of the panels and how to draw them. I had no experience with or understanding of this design, and so all I had to go on were the small, black and white images of the beanbags from the catalog. It took me weeks of experimentation and failed attempts to realize how simple it is to draw the panel shape. (***Second Edition edit:*** *It turns out that only the inferior version of the panel shape is simple. To make a better bag shape, the panel shape is more complicated as discussed in the previous section under “The problem with a circular curve”.*)

Original, circular panel shape development

My initial idea after some pondering was that the ratio of the width to the length should be 1:2, which was correct since the circumference of the finished bag would be composed of four panel widths around the equator but only two panel lengths across the poles. So I drew a stick skeleton of the shape with a vertical line forming the length and a horizontal line, half the length of the vertical, centered on it to form the width. Then all I had to do was draw the orange peel shape around this frame.

I drew the curved sides of the panel free-hand because I had no better idea how to do it. I had rarely ever used a compass and that is probably why it did not immediately occur to me to use one. I had also not studied whatever advanced mathematics would be required to understand that the edges of a circularly curved lemon shape, when wrapped around a sphere, would produce the correct, circumscribing curve I needed. I still do not really understand this; I just know it works. Despite all of this, I should have known that drawing an arbitrary curve had to be the wrong approach, but though I had subtle misgivings about it, I tried it anyway.[6]

(***Second Edition correction:*** *As I mentioned before, some years after writing this, when I gained more knowledge, I learned that the circular curve does not actually work quite right – it produces too wide an angle at the corners. I think the reason it worked for me is that I was using denim and orienting the cords from panel tip to panel tip. This orients the grain at a 45° angle, which I now know causes the bag to stretch longitudinally and become narrower at the poles, taking on a lemon shape. I think this compensated for the over-wide angles at the panel tips, which would normally make the bag flat or concave at the poles, resulting in a pretty good sphere. I did not understand the effects of grain orientation until many years later in 2021.*)

In my first attempt, I drew the curves too steep at the ends which resulted in the panels and, consequently, the beanbag, being too narrow at the ends. When I saw the finished, slightly lemon/football-shaped bag, I unfortunately decided that my perfectly logical width:length ratio must be flawed. This began a series of experiments with different width:length ratios and styles of curves.

At some point I must have figured out that the angle at the corners needed to be 90° because I began drawing the ends of each side as straight lines to form right angles and only curving them in the middle. I hoped this in combination with the right width:length ratio would flatten those malformed vertices.

After I had assembled or partially assembled over a dozen different bags and even bought a styrofoam ball around which I fitted paper models, I finally realized that the arbitrary curve was the problem. The only way to make a non-arbitrary curve was by using a compass. (After I began drawing the sides with a compass, I marked the templates “All Round” to differentiate them from the ones with partially straight sides.) I had to use trial and error to determine the radius that would intersect both the vertical and horizontal endpoints of my stick frame.

It took a little longer and the assembly of a collection of five identical beanbags (which are now at my grandparents’ house for kids to play with) to come full circle with the realization that, with the circular curves, my original width:length ratio should work (by this time I had settled on a different ratio with a slightly shorter length).

After that, there was just the matter of deciding on the best size of the beanbag. I wanted the inflated bag to be as close as possible to the size of a tennis ball because I liked that size for juggling (I also do not like to choose things arbitrarily and the tennis ball gave me a nice, non-arbitrary choice). This was complicated by the seam circumference being much larger than the panel face circumference. So, I would make a bag, fill it to a comfortable firmness, and spend a few days tossing it around and comparing it to a tennis ball, trying to decide if I would like it better if it was a different size.

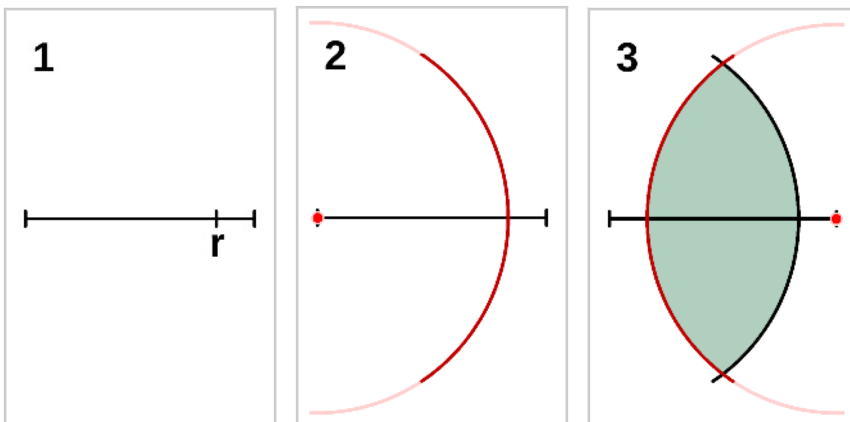
I decided on a panel size of 1⅞ by 3¾ inches and made nine beanbags of this size. When I later began making twelve-panel bags, I decided on a panel size that made the new bags a little larger than the

6 *[I wrote this footnote for the first edition, while I was still using circular arcs for the orange peel shape.]* When writing this document I felt foolish for having tried to draw a free-hand curve rather than thinking of using a compass, and I didn’t like admitting to it. But I have found through my web research that this is actually by far the most common way to draw this panel shape (by amateurs). I have seen PDF patterns that are obviously drawn free-hand (example), and rather poorly in some cases (example), and I have seen written instructions that explicitly say to form the curve by hand and give no formula or radius for the curve, or specify the angle at the panel’s corner (example). So far I have never seen anyone provide a mathematical definition or even a description of the orange peel panel’s shape, or any explicit instruction to use a circular curve. (Edit: I finally found one six months after writing this; see The Shishi Girl’s “Construction of a Ball From Flat Peels” document at the end of this chapter.)

four-panel bags. When I compared these new bags to my old, smaller bags, I found that I liked the larger size better. Conveniently, the panel size that would make the four-panel bags the desired size happened to be a nice, simple, 2 by 4 inches.

Second Edition note: *It turns out that the reason I preferred the larger size was not because of the size, but the weight. I have found that I actually prefer a smaller size, as long as it is heavy enough (see the "Filler and Beanbag Weight" section of the* ***General Information and Techniques*** *chapter).*

Eventually, I learned a shortcut to drawing the patterns that did not involve drawing two perpendicular lines (one marking off the width and the other the length of the shape) as guides for the curves. I now only need one line (the width) because I know how to calculate the radius of the arc that will be exactly the right vertical distance from the center of the line. The illustrations below depict the basic steps. The red dots are the compass points or circle centers.



The arc radius is given by $\mathbf{r = (w^2 + l^2) \div 4w}$ and the length of the horizontal line is $\mathbf{2r - w}$. (w = panel width and l = panel length.)

Second Edition note: *Ironically, roughly 25 years later, my research and deeper understanding of the orange peel ball panel shape have lead me to draw it using all elements of my original approaches. I draw circular curves for the basic shape, I draw straight lines forming 90° angles at the panel tips, and then "hand" draw (on the computer) an arbitrary Bézier curve that merges from the straight lines into circular curves. I discuss and illustrate this in the "Second Edition update" topic farther on in this section.*

Stitching technique – inventing my own stitch

My stitching technique went through its own evolution. I started out with a basic running stitch (that and the whip stitch were the only stitches I knew as I had only a rudimentary knowledge of sewing), but I found that this resulted in the finished seams looking unappealingly rippled. I figured this was because each stitch pulled the fabric toward itself and there was no opposing stitch to pull the fabric back. So I tried using a double running stitch: I stitched from one end to the other and then back the other direction so that each new stitch was on the opposite side from the first stitch. This helped, but not enough to satisfy my perfectionist nature.

Finally, after much thought, I came up with a new stitch that was based on the double running stitch concept and which worked perfectly. The method for this stitch is described in the "Stitching Techniques" section of the **General Information and Techniques** chapter. This new stitch made the seams perfectly smooth and, because half the stitches are backwards, they sort of locked themselves against the fabric and stayed tighter.

When I decided to write the first, informal draft of these instructions (which I wrote during that time), I wanted to give a name as well as a description to my stitch. My mom had several sewing books from her younger years and I figured that since a stitch as good as mine probably didn't originate with me, I might find it (or one similar to it) in one of those books. Well, it was in one of the books and it was called the "Backstitch". I think that's pretty cool: *I invented the Backstitch!* (I just wasn't the first to do so.)

Alternate methods of designing an orange peel panel

Back to Chapter Index

Six months after writing the first edition of this guide I found for the first time a mathematical definition given for the orange peel ball's panel shape, and it happened to match my theory in terms of curvature and panel proportions (see The Shishi Girl's "Construction of a Ball From Flat Peels" document at the end of this chapter). It wasn't until 11 months after that (February, 2014) that I found any more.

The two people whose articles I found at that time gave alternate theories. One of them, "Geoff 42", uses an elliptical curve and even provides a table of pre-calculated pattern dimensions and a pattern dimension calculator[7], but it only provides calculations for 6-panel balls, and Geoff does not explain the derivation of the design or give the underlying formulas. The other, Matt Hirsch, suggests building a curve based on calculations of the circumference of a sphere at different latitudes[8]. Hirsch's method was linked to from a web article about building a large-scale orange peel ball[9], but the author of that article did not use the suggested method. Following is Hirsch's description of the method.

> Think of each section [or orange peel panel] as a constant angle slice of the surface of the sphere. So to draw a section, find the distance subtended on the surface of the sphere at that given latitude for the given number of sections. For example,
>
> Diameter (D) = 9
>
> Circumference (C) = 28.274
>
> 8 arcs. Each arc is 45 degrees (probably a little big), and so covers 45/360ths = 1/8th of the circumference, so it is 3.534 at the middle, and 0 at the ends. Now to find the width of the section at other locations, find the circumference of the circular slice of the sphere at that height. As you go from 0 to 90 degrees from the pole to the equator, the diameter of one slice of the sphere is d = D * sin(theta). Pi*d is the circumference at that latitude. 1/8th of that is the width of the slice at that angle.

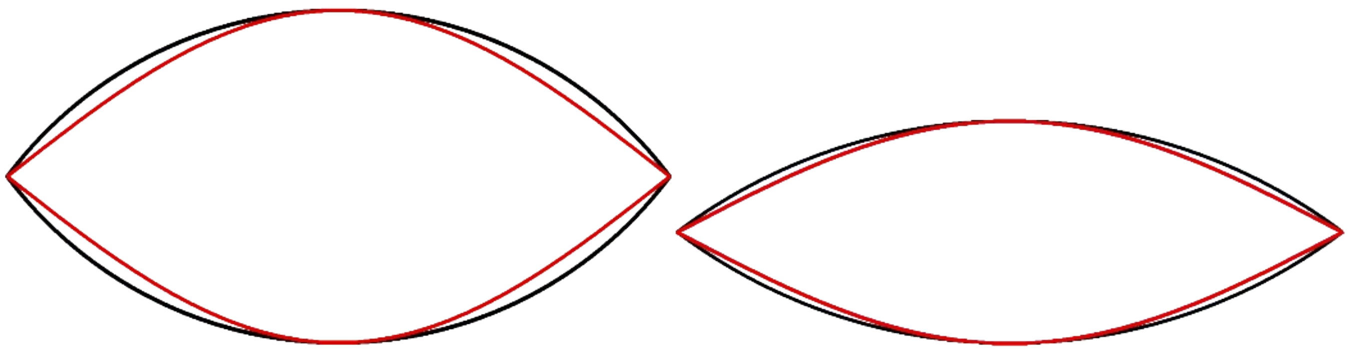
This method produces a curve that is steeper near the ends than the circular curve. Below are comparisons using the four-panel and six-panel shapes. The shapes in red are the result of the latitudinal circumference method with the width calculated every 5° (producing 36 segments from end to end). In the following subsections I also compare these shapes to the new corrected curvatures I designed in 2021. The latitudinal circumference method doesn't work well at all for the four-panel shape, but my new six-panel shape is very close to the latitudinal circumference shape. Hirsch's method is prescribed for an eight-panel ball, and it may work for that many panels.

7 http://g42.org/xwiki/bin/view/Main/HowToSewASphere; calculator located at http://g42.org/xwiki/bin/view/Main/HowToSewASphereDerivation

8 http://fab.cba.mit.edu/classes/863.12/people/catherine/matt.txt

9 http://fab.cba.mit.edu/classes/863.12/people/catherine/makesomethingbig.html

I would have included Geoff's elliptical design in the comparisons, but I have no way to draw it on the computer, and drawing it manually using thumbtacks for the curve foci and a string to create the curve would be tedious and difficult. Geoff's computer-drawn illustration that accompanies the calculator, which I would have used, does not have the same shape as the photos of his actual template, having ends that are much more rounded than the pointed ones in the photos. I think the computer-drawn illustration is simply a true ellipse whereas the design method effectively produces two ellipses that overlap by roughly 80% and whose intersection forms the panel shape. When I overlap the computer-drawn diagram with itself according to how (I think) it should be based on the locations of the foci, I still do not get a shape that looks like the photo, leading me to believe that the ellipse in the diagram is not drawn strictly according to Geoff's method, but is only an approximated visual aid.



Four-panel and six-panel shapes. The circular designs are in black and the latitudinal circumference designs are inside them in red.

My initial assumption based on the above comparisons was that the latitudinal circumference method would produce somewhat sharp and protruding vertices on the bag much like my earliest, failed attempt in the 1990s. The circular design produces what appear to be perfectly round seams on the finished bag[10] with no vertex prominence at all, and I wouldn't want that to change.

Several months after writing the preceding paragraph, I finally got around to constructing a 4-panel bag based on the latitudinal circumference method. The result confirmed my assumption. The bag's panel-face profile has a very slight lemon or football shape. The sharper curvature of the middle portion of the panels' curve (the waist) results in seams that appear somewhat angular like a rounded V rather than circular and therefore the seam profile of the bag has as much prominence and acuteness at the waist as it does at the vertices, giving that profile almost a rounded square shape with the ball's two vertices and two equatorial peaks forming the four corners. I had greater difficulty in flattening the seam allowances out due to this sharper curvature which caused more severe puckering of the fabric.

Second Edition update – improving on the circular panel curvature

Back to Chapter Index

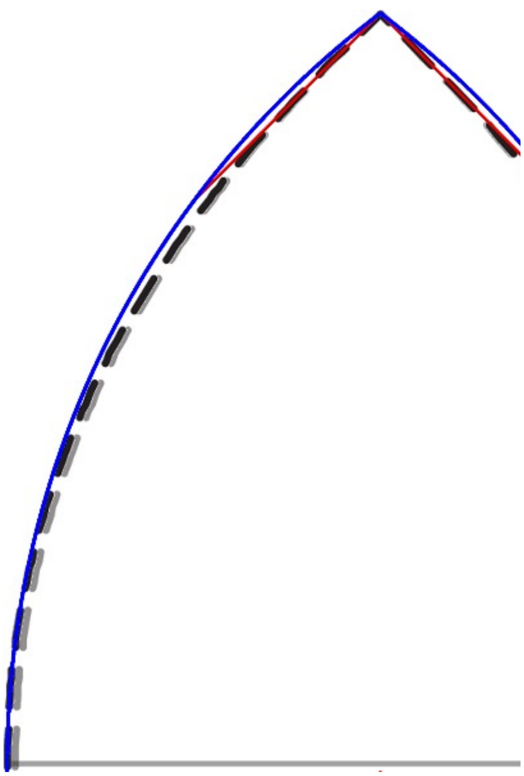
I wrote all the preceding documentation in the first published edition of this guide. I now understand why the latitudinal circumference design does not work well. For the 4-panel design, the tangent angle at the curve intersections should be 90° so that the sum of the four vertices is 360°. For the 6-panel it should be 60°. The angles produced by the latitudinal circumference method are only about 76.3° and 55.3°. As will be seen later, though, the 6-panel latitudinal circumference shape is very close to my newly designed shape and would work fairly well with the right fabric – much better than the 4-panel version. This method would probably work almost perfectly for an 8-panel ball, which is what Hirsch prescribed it for.

10 Only because, as I learned in 2021, I was using denim with the cords oriented from end to end, which orients the grain at a 45° angle.

It is possible, though, that if I hadn't been using denim with the grain at a 45° angle, my experimental 4-panel bag would have turned out better. I only began understanding the effect of grain orientation in early 2021. The 45° grain causes the panels to stretch lengthwise, making the bag longer and narrower at the poles. Even with the correct panel shape the bag will have a bit of a lemon shape. As I mentioned before, it was probably this that made the circular curves work for me as it would have compensated for the flattened profile the circular curve normally produces.

Anyway, as I discussed in the previous section, the best way I now know of to create the panel curve is to start with a circular arc, form the correct angle as a straight line from the vertex, and then draw a curve that gently merges from the straight line into the circular arc. See my directions for drawing the corrected curve for illustrations of this.

Marylis Ramos has a PDF set of juggling bag patterns[11], and it was a comparison to her superior octahedron pattern on a Reddit thread[12] that inspired the second edition guide with redesigned pattern shapes. I had found her patterns during my research on the first edition, but I did not know how she derived her panel shapes. She has the most professional and precise-looking patterns of all that I have encountered, so I used her patterns as a reference and basis of comparison for my new panel curves (I did not copy hers, but created my designs independently, and even deviated from them significantly in some designs, but hers gave me something to aspire to or improve on).



Ramos' 4-panel orange peel pattern has a non-circular curve and it produces a better beanbag shape. Ramos' curve matches an overlaid 90° angle at the panel tips, so she likely designed her curve according to the same method I developed. In the comparison on the left, the circular pattern, in solid blue, is overlaid on Ramos' pattern. The red lines at the corners form the 90° angle for reference. The horizontal gray line is the midline.

Ramos' pattern is slightly narrower in relation to its length than mine. A pixel measurement of a magnified view revealed her width to be 49% of the length instead of 50%. Perhaps this was unintentional, or it might have been intended to compensate for fabrics like corduroy that stretch latitudinally more than longitudinally, making the ball larger around the equator than across the poles. I scaled the patterns in Photoshop so that the lengths matched. The faded dashed pattern is Ramos' original pattern and the black one is widened by 2.1% to match the 1:2 proportions of the circular pattern.

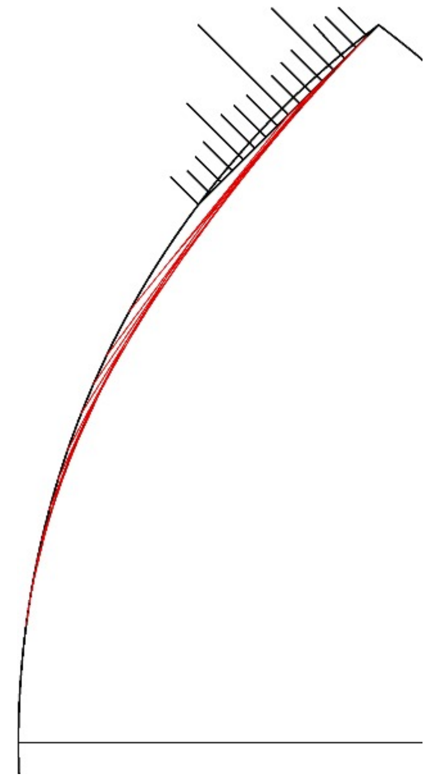
Creating a Bézier-style curve alteration

In February, 2021, two and a half months after publishing the second edition, I finally found the motivation to design my own corrected curve. Drawing arbitrary curves in SketchUp Make is difficult

11 "Sewing Patterns for Jugglers" Orange Segment Series and Polyhedra Series.

12 https://www.reddit.com/r/juggling/comments/2l4pwe/making_your_own_beanbags_some_advice_and_creative/. See 2nd comment, by ds300.

and tedious [I did not until months later know about Bézier curves, and though SketchUp Make does not include a Bézier curve tool, I just learned of a plugin that would have have provided the tools I needed[13]]. My method, depicted below, was to divide the 45° angle line into segments, and then draw lines from selected endpoints to points either on the circular curve or on other lines so that in the end I create a curvature I like that is composed of small facets. Then I erase the excess lines outside that curve.



After I see the resulting curve, I often create one or more additional layers of facets over the previous ones, or remove facets and redraw them, to adjust the curvature. The illustration on the right shows what my curve #4 (from later on in July) looked like before I cleaned it up. The individual lines forming the curve facets are so numerous that most of them cannot be distinguished. The final curve has 29 facets between the tip and where it meets the circular curve.

I created three different curves during that February, but only tested the first two by making them into beanbags. I originally published the first curve I created. The second hugged the circular curve more closely. The third curve was about in the middle between those. Based on the first two, and some experiments with other fabrics, I decided the first curve was about perfect. It also happened to closely follow Ramos' curve (when her proportions are widened to match mine). I made 12 beanbags in all for that project, some with my adjusted curves and some with circular curves for comparison.

I made my first few test bags with my design testing fabric (thin, stiff, tightly woven, non-stretch). When I began making corduroy models, I found that the fabric's grain orientation made such a huge difference in the shape of the bag that I needed a non-woven fabric with enough stretch to simulate corduroy or soft leather so as to be sure the resulting shape was due only to the panel curvature. So I used a thick, sturdy felt for my final test bags.

I compared the designs both when loosely filled and when tightly filled. The differences were more apparent when the bags were loosely filled. I describe the differences made by the curvatures and by the orientation of the fabric's grain in the "Design Notes" section at the beginning of this chapter.

My first curve seemed almost too narrow near the tips when I used my design testing fabric. That is why I decided to try a curve that stayed wider as it merged into the circular curve. But the same curve made the poles of the corduroy bag slightly flat. The felt bag was perfect. So it seemed that my first curve was actually a perfect balance for all fabric types.

Correcting my first adjusted pattern curvature

But then in July, while designing the 6-panel shape, I discovered that I had made a mistake in designing the 4-panel shape. For some reason, when I made the first beanbag with my design testing fabric, I had cut the panels at a 45° angle to the fabric grain. I suppose I thought that would give me the most balanced result.

13 I now use the **BezierSpline plugin by Fredo6** to draw Bézier curves.

But as I discovered in later experiments with fabric grain orientation, the grain direction can drastically change the shape of the bag (though I didn't at the time think that my design testing fabric would have a significant bias effect). By that time, I had forgotten that I had cut the panels of the original bag at a diagonal orientation, and because that fabric has such a high thread count, it was not visually obvious. So I never caught my mistake before publishing my pattern.

I refilled that original bag as part of my analysis of the 6-panel shape and happened to notice the diagonal grain. The diagonal grain is what gave the bag its slight lemon shape, which I suspected and then confirmed by making a new 4-panel bag with the same template but with the lengthwise grain oriented along the panels' length. That, like the corduroy bag, had flattened poles with high shoulders.

So I immediately began working on redesigning the 4-panel shape. I had made three experimental curves during my first iteration, so my first new curve was #4. I nearly chose that one as the best of the three new curves I drew. But in the end I modified it, creating curve #7, and that was my best curve.

Curve #4 seemed slightly too bulgy around the shoulders, and so I created #5, which undercut it by a lot, to find the limit in that direction. That curve was much too flat between the tip and where it began to curve into the circular curve, and produced a beanbag that had almost a rounded square profile. So I created curve #6 to still undercut #4, but stay closer to it than to #5.

As can be seen in the full comparison farther on in this section, curve #6 is very close to #4, yet it made a significant difference in the shape of the beanbag. I almost chose #6 instead of #4. The bag made with my design testing fabric using curve #6 was a little rounder than #4 when tightly filled, but when moderately filled it had a slight lemon shape. #4, conversely, was perfectly round when moderately filled but when tightly filled it had very slightly flattened poles and high shoulders, giving its profile a hint of a barrel shape, but not bad.

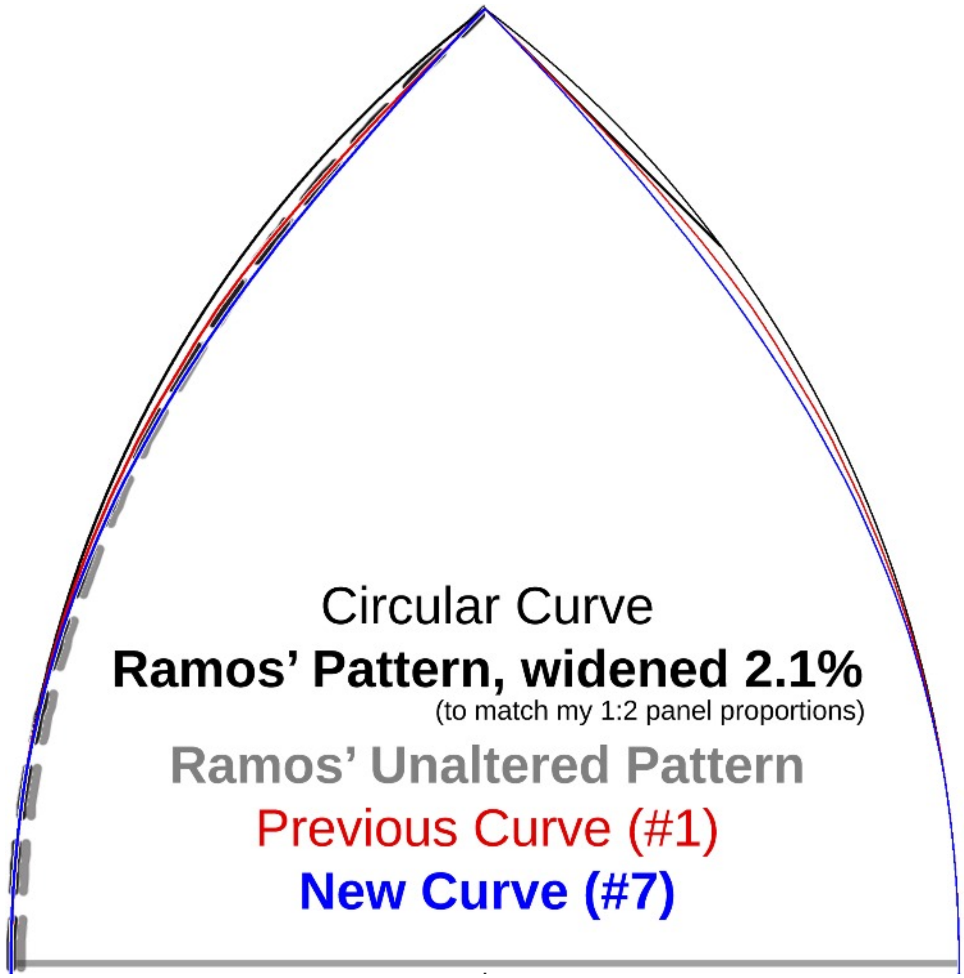
I thought the corduroy version would flatten out more at the poles, but the #4 corduroy beanbag turned out perfectly. I was already leaning toward #4 because I liked the look of the pattern curvature more. But just to be as sure as possible, I made a #4 bag with felt before submitting the new pattern so I could see how the pattern would look with a non-woven fabric. When I first filled it, it had a slight lemon shape when loosely filled, and while it rounded out pretty well when tightly filled, it still didn't have as round a profile as the #1 felt bag.

The difference was not enough to be a problem for juggling, but it might be if the ball were used decoratively. I began to worry that, at least for non-woven fabrics, I needed a curve more like Ramos' pattern, about in the middle between #1 and #4. However, before trying to draw such a curve and making beanbags, or at least including both patterns in this guide, which would add complication, I kneaded both bags for a few minutes to see what they would do when the panels were allowed to reshape. After doing that, the #1 bag began to display a hint of the barrel shape that the woven fabric bags had, and the #4 bag became perfectly round. This was a great relief.

The more I thought about it, though, the more convinced I became that I needed to adjust the curve slightly, giving it more roundness in the two-thirds zone nearest the tip. After I deflated the felt bag a bit, its seams still had too flat a profile in that area. They did not quite have a continuous circular curve.

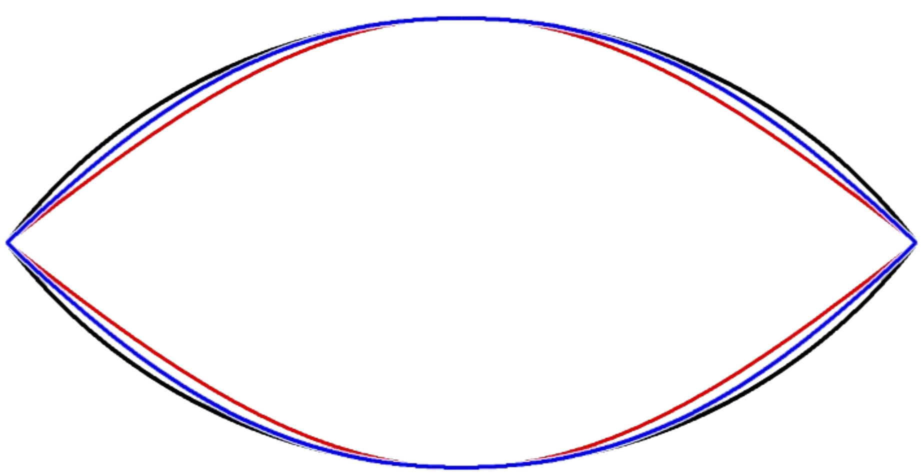
I eventually felt motivated to create my new curve #7. This time, rather than creating it from scratch as I always had in the past, I developed a technique for adjusting the existing curve by building new facets outside of it (previously, I could only build facets on the inside of a curve). I tweaked it obsessively a few times and then printed it and made a felt bag with the resulting template. My adjustment was so small that I did not know if it would produce any perceptible change in the ball shape. But I worried that if I altered it more drastically, it would be too close to my #1 curve and produce a poor shape in woven fabrics.

Fortunately, it worked out exactly as I hoped, producing a barely, but definitely, discernible improvement. It took ten experimental beanbags to correct curve #1, for a total of 22 to design the 4-panel curve. The image on the right shows how much more I altered my pattern curvature from the original circular curve to correct #1 (my first submitted non-circular curve).



My original adjusted curve in red and my corrected curve in blue. The left half is overlayed on Ramos' pattern. The right half uses thinner lines for more precision.

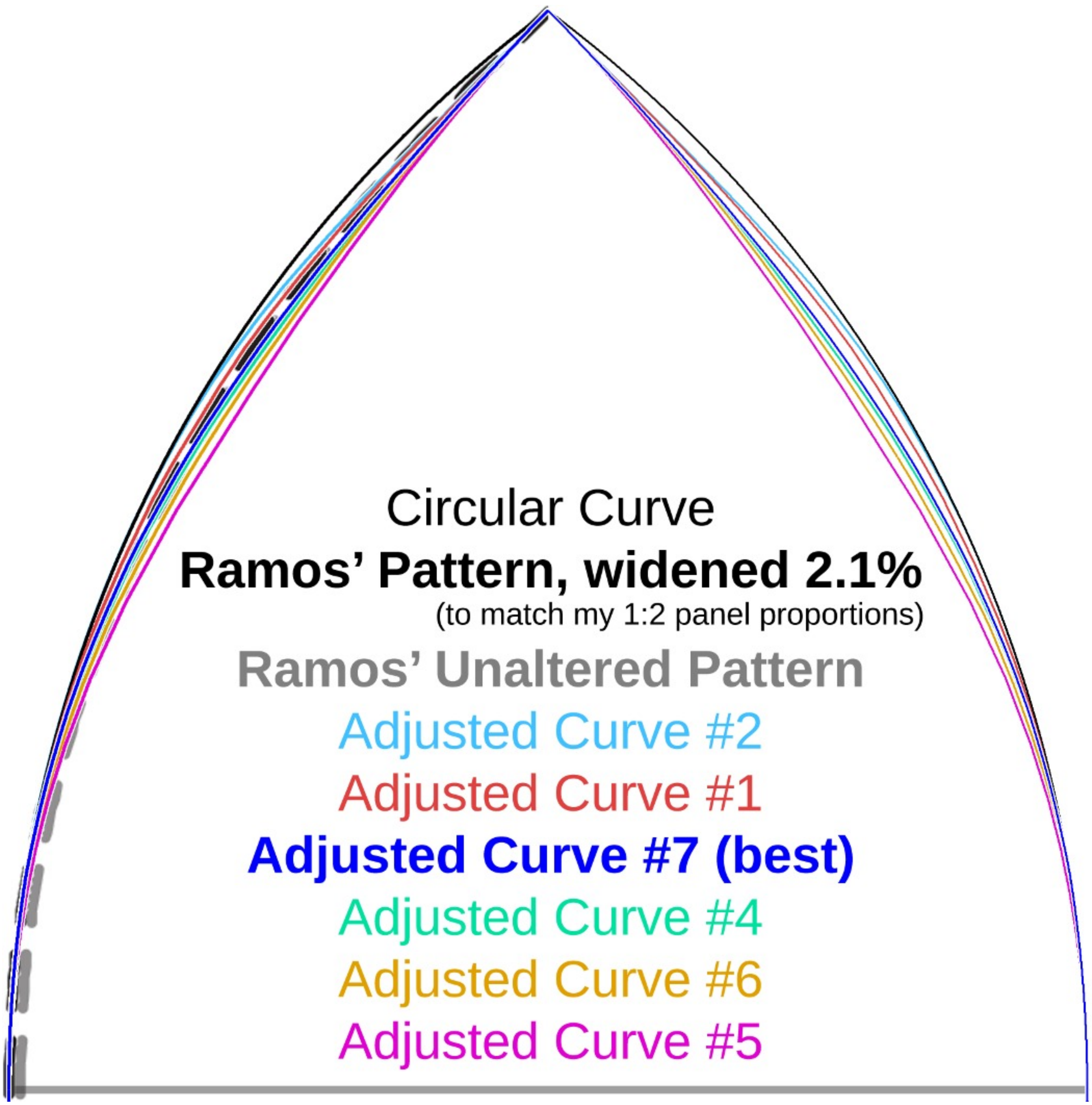
I decided to compare my curve to the latitudinal circumference method discussed earlier, since that is the most logical alternative method I have encountered. That method does not work well for the 4-panel design, but it appears likely to work better for the 6-panel design, as I show later.



The circular design in black, the latitudinal circumference method in red, my curve in blue.

The image below shows all the curves I experimented with. The left half of the image uses thicker lines and is overlaid on Ramos' pattern. The right half shows just my curves and uses thinner lines for a more precise depiction. (Curve #3 is omitted because I did not make a beanbag with it; it was almost identical to #2, but backed off from the circular curve by a hair).

Note how similar #4, #6, and #7 are. I was amazed, as I have been while working on other designs, by how much difference in ball shape can result from a tiny change in panel shape. The widest variance between the edges of my #4 and #6 templates (which are sized for 2.5″ diameter bags) is 0.3mm. Between #4 and #7 it is only 0.2mm. The three templates are almost indistinguishable. I calculated those variances using my full-size SketchUp models.

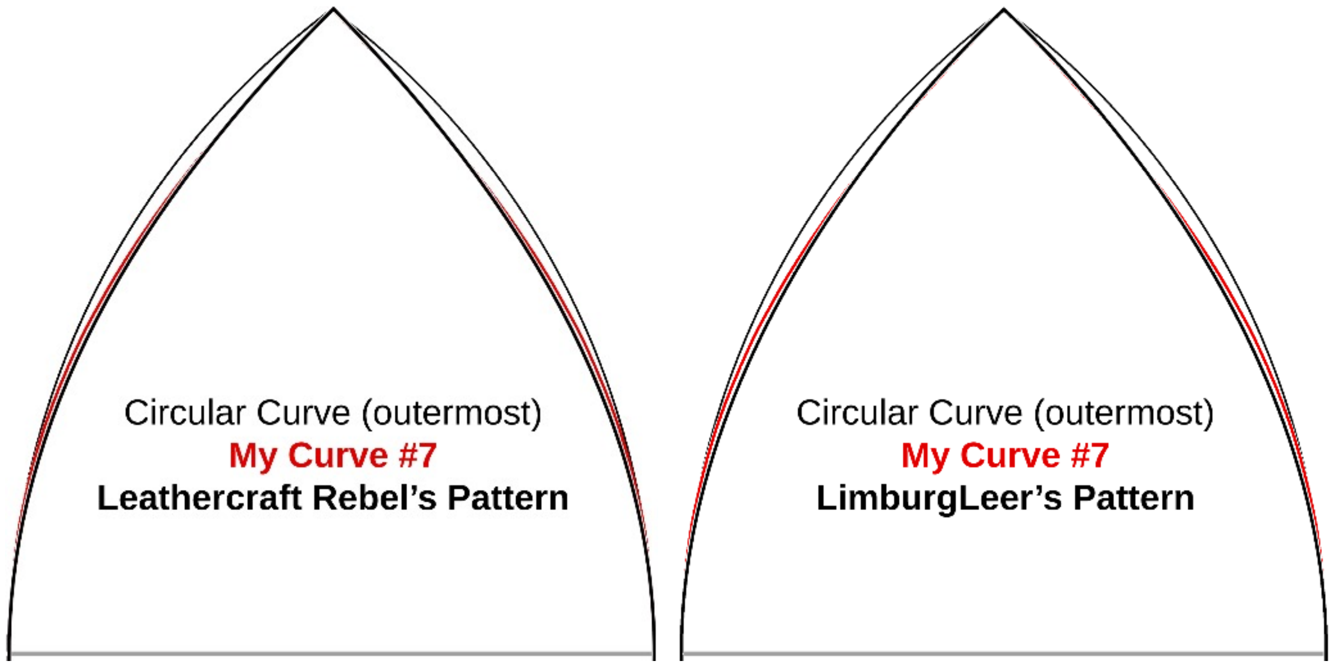


All 4-panel curves with which I experimented. Left half is overlayed on Ramos' pattern. Right half uses thinner lines for more precision.

Two more pattern comparisons

Back to Chapter Index

In my continuing, casual quest to find other people's patterns to compare to mine and learn things from, I found two more in late 2023/early 2024. These are available for purchase. The URLs are below the comparison images.



Leathercraft Rebel's pattern purchase page: https://www.etsy.com/listing/1102565971/

LimburgLeer's pattern purchase page: https://www.etsy.com/listing/808490919/

Continued on the next page

Creating a 6-panel pattern

In July, 2021 (the same month I corrected my 4-panel pattern), I decided to experiment with corrected curves for the 6 and 8-panel designs. The discovery of my erroneous 4-panel pattern, however, diverted me for over a week and by the time I corrected that and finished the 6-panel design, I decided to submit those two and leave the 8-panel for another time. I need a break.

Unfortunately, I cannot simply scale down my 4-panel shape width-wise to produce the narrower shapes for higher panel count designs. I tried that. When I scale my 4-panel shape to the width of the 6-panel shape, the angle at the tip is reduced from 90° to 67.4°, which is higher than the 60° I need, and it bulges out too far, remaining much too close to the circular curve. It would probably work well enough for a quick-and-dirty beanbag, but I want better than that. So for each pattern I must perform the full process of designing the curve from scratch and making and analyzing test bags.

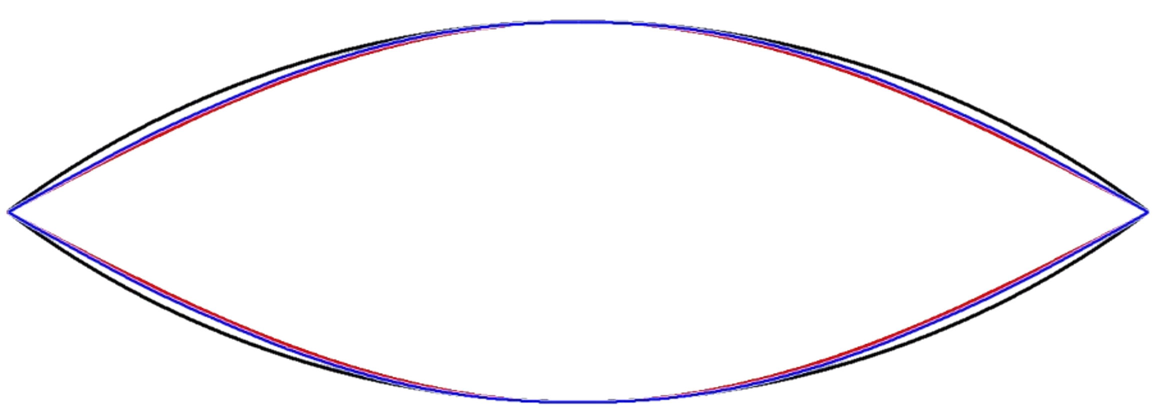
I created three different curves for the 6-panel shape. Curve #3 was perfect. It made an excellent sphere with my design testing fabric, felt, and corduroy. My first curve was almost an exact match to Ramos' pattern (when hers is widened to the 1:3 proportions), but was a little too bulged between the middle and tip, producing slightly flattened vertices.

Curve #2 had a hint of acuteness at the vertices, so I created #3 as a balance between the two curves. But I was unsure whether #2 or #3 would work better for corduroy. Because of my experience with the 4-panel design in which my design testing fabric bag was acute at the vertices but the corduroy bag was flat, I assumed this would be the case with the 6-panel design, and so I thought I might want the design testing fabric bag to be slightly too acute.

But it had been almost five months since I had worked on the 4-panel design and so to refresh my memory of its shape, I refilled that bag (I keep all bags I make, deflated, in case I need to refer to them again). That was when I discovered that I had oriented those panels diagonally to the fabric grain.

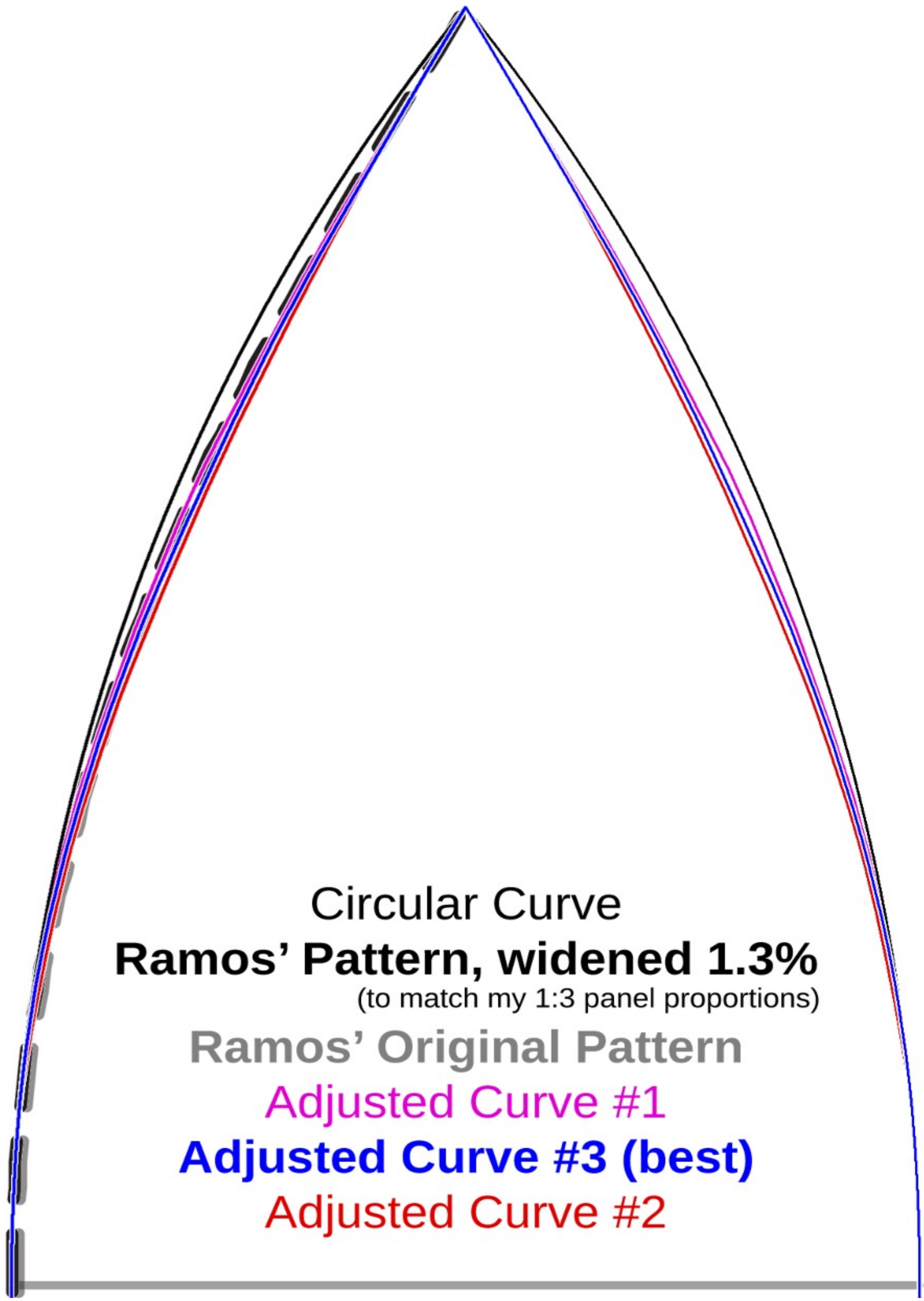
After analyzing and solving the 4-panel issue, I knew that the #3 curve for the 6-panel design was what I wanted because the corduroy bag would likely respond about the same to the pattern (and it did). I was glad because I didn't really like the look of the #2 curve. The two thirds or so closest to the vertex looked too flat, and the portion that merged with the circular curve looked too narrow and abrupt. The #3 curve looked perfect. Before submitting it, I even tweaked it by minuscule amounts in a few places to improve its look (but not enough to perceptibly alter the shape of the bag it would produce). I made seven beanbags in all for this design.

Below is my curve compared to the latitudinal circumference method.



The circular design in black, the latitudinal circumference method in red, my curve in blue.

Here is a comparison of all three 6-panel curves I created, with the left half overlayed on Ramos' pattern.



All 6-panel curves with which I experimented. Left half is overlayed on Ramos' pattern. Right half uses thinner lines for more precision.

Back to Chapter Index

“Construction of a Ball From Flat Peels” by The Shishi Girl

Back to Chapter Index

From the article “Basic Geometry II” (https://shishigirl.blogspot.com/2008/12/basic-geometry-ii.html). This was the first mathematical definition I found for the orange peel shape. It confirmed my own design theory, which I had arrived at many years before I discovered this in 2013.

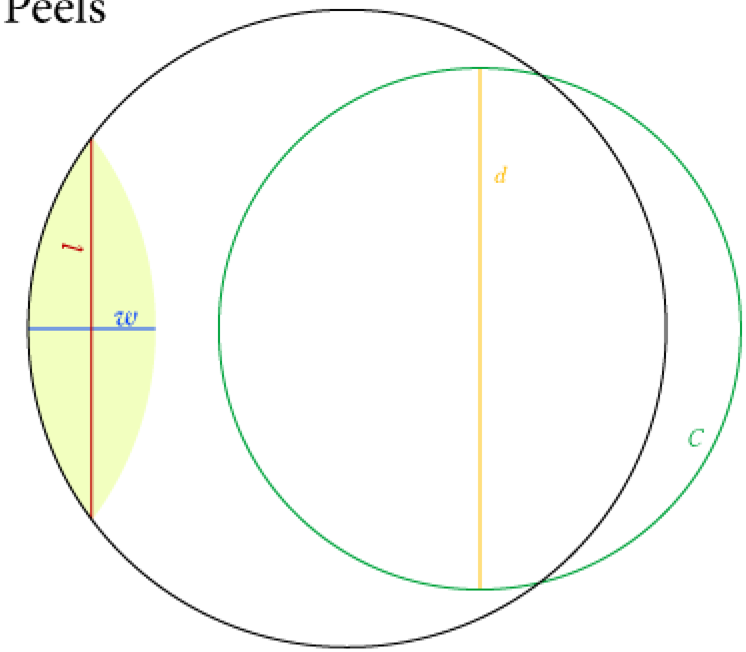
Construction of a Ball From Flat Peels

the mathematics of a correct sphere

To build a ball from “peels” you must make pieces such that the width (w) multiplied by the number of peels (p) is equivalent to the circumference (C) of the ball; also, the length of each peel (l) must be equivalent to 0.5(C).

For a six-peel ball, the equations are:
$w = C/6$ and l=0.5(C)

Additionally, the arc of the peel’s edge must be equivalent to the natural arc of a circle.



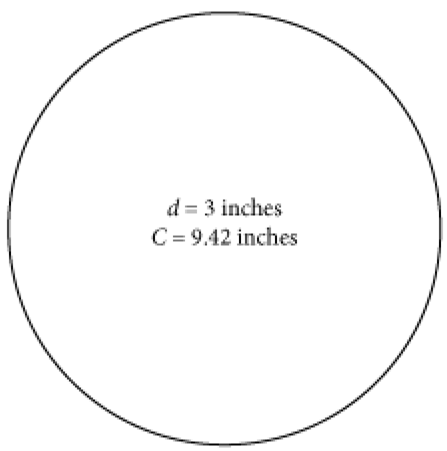
For a ball of diameter 3 inches:

$w = [(3)(3.14)]/6$
$w = (9.42)/6$
w = 1.57 inches

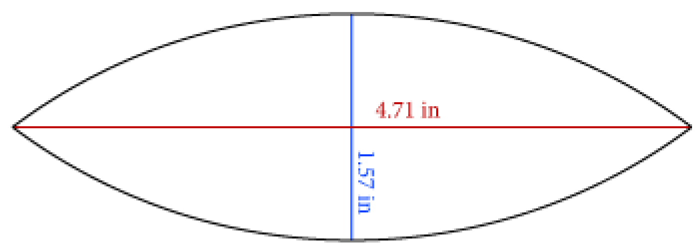
and

$l = 0.5(9.42)$
l = 4.71 inches

the shishi girl



3-inch diameter circle



“peel” pattern for a 6-piece ball with a diameter of 3 inches

softie tutorial pictures and additional help can be found at shishigirl.blogspot.com