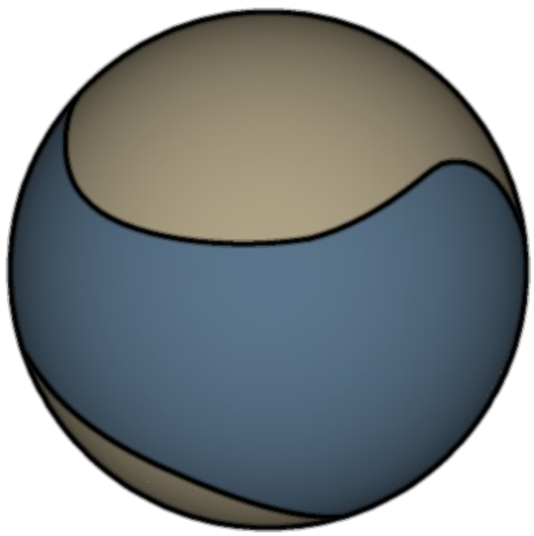
The Complete Homemade Juggling Beanbag Guide

2-Panel Baseball Chapter

Small file size version (150dpi patterns & images)



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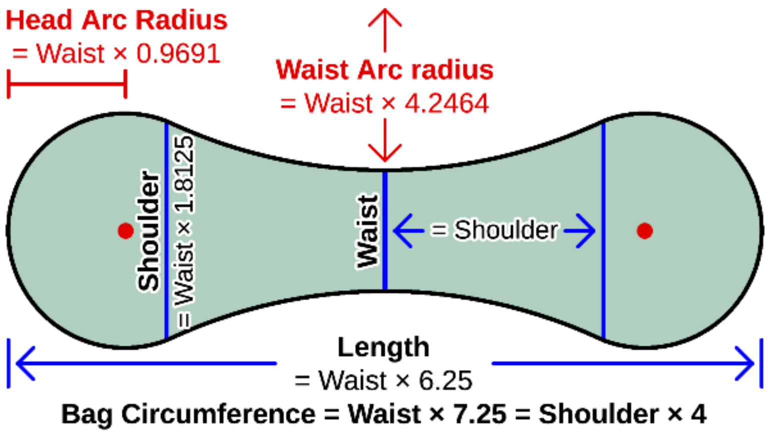
2-PANEL BASEBALL INSTRUCTIONS



I made the right-most ball with marine vinyl (a leather-like material) and a single-needle baseball stitch. More photos here.

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Design Notes

This is the panel structure of the original Hacky Sack by Wham-O from the 1980s, and of baseballs. This design is arguably superior to the 4-panel designs because the compound curvature of the seam and its greater uniformity make the bag feel somewhat more spherical. It also looks great.

The panel shape is much more complicated to draw, however, and the bag is **more difficult to assemble** due to having concave and convex curves connecting to each other. You cannot simply lay the panels flat together and sew along the seam as you can with the other designs in this guide; you must continually adjust the panels as you sew to keep the curves aligned at the point you're sewing, and this greatly increases the difficulty of sewing them correctly and preventing distortions in the seam.

I designed this panel shape myself and it is not exactly the same as the one used for baseballs, but it is close and does form a fairly good ball. I think the baseball panel shape requires a partially hand-drawn or function-based curve whereas mine uses circular curves. **My design can be thought of as a simplified version of the baseball shape** that is much easier to define and draw.

For a thorough explanation of how I designed this panel shape and verified that it fit together into a good sphere, and for a comparison between it and the true baseball panel shape, see the last section of this chapter titled "How I Developed This Design". The comparison is in the "Comparing my panel shape to the official shape" subsection along with photos of actual baseball covers. You could use those images to sketch an alteration to my curvature to see if that results in a better beanbag shape. (Fold your pattern in quarters so you can sketch and cut the altered curves just once rather than duplicating them three times.)

With non-elastic fabrics **this design may feel somewhat squarish** at the profile shown on the right. A flexible, stretchy fabric tightly filled should enable it to bulge out into a better sphere. **For stiff, non-stretch fabrics, pressing the completed bag against a hot iron along the seam will help reshape it into a better sphere and smooth the seam.** Filling the bag loosely also helps it feel rounder.

The balls I made with non-woven fabrics (marine vinyl and felt) took on a **minor egg shape**. Not enough to be a problem for juggling, but it is noticeable. My denim and corduroy bags with the cords running along the panel length have not exhibited this. I think the weave's direction of stretch counteracts the egg-tendency.

Supplies

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- **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.

Making the Panels

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1. You will need 2 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.
2. Use the smaller, stitching template to trace the stitching pattern within each cutting pattern, being sure to center it well. **I recommend adding marks in the seam allowance at the eight endpoints of the pattern framework** (included in the ready-to-print patterns), as shown on the blue panel illustration below, to aid in keeping the patterns of both panels in sync as you sew.
3. Cut out the panels.

Assembly

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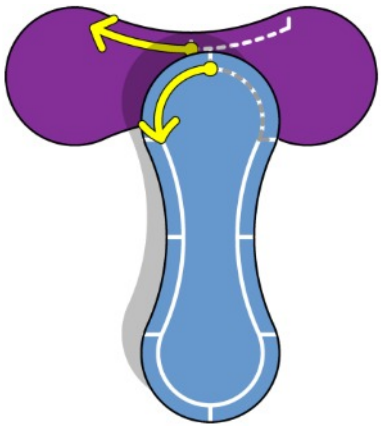
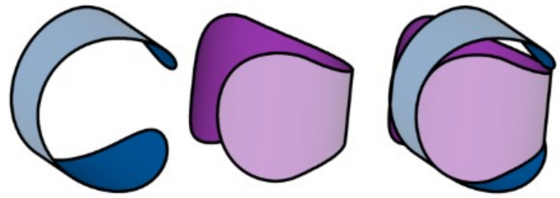
I found a forum in which someone asked for assembly instructions for this design. The photos from the response follow my written instructions. Ideally **you should have eight markers along the edge** on the back of each panel as shown on the blue panel below **to help you match the curves to each other as you sew**. Because of the continual adjustment of the panels needed as you sew, it would be difficult without markers to proceed at an equal rate on each curve and prevent distortions in the seam. **The markers are at the endpoints of the Length, Waist, and Shoulder lines**, which are the framework used to draw this shape. The ready-to-print patterns include these markers. The **seam length between all the marks is equal**, so the marks of each panel should meet each other in the assembled bag.

Note that on the blue panel the front stitching pattern (the dashed line) would actually be on the reverse side, which is the front of the panel.



This is how the two panels fit together. Initially, the front sides will be inside the ball (unless you are sewing the panels edge to edge with no seam allowance as on an actual baseball).



First, **decide where you're going to start stitching on both panels and in which direction** and then use the stitching template to **draw stitching lines on the fronts of the two panels behind that point**. This is **depicted by the dashed lines** on the panels above. Make them as long as the opening you will need at the end to turn the bag right side out through. You will **use these lines to help you sew the final opening closed from the outside**. 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 edge) 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.

Aside from that, **assemble the panels as shown in the photos below**, ignoring the gather applied to the seams (unless this is what you want). Make sure the fronts of the panels are together and remember that the center of each convex curve will align with the center of a concave curve. You will have to continually adjust the panels as you sew to keep the patterns aligned at the point you're stitching.

When all that remains is a small opening having the front stitching lines along it, **turn the bag right side out**. 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**.

Note that to **reduce the number of stitches you need to make from the outside**, you can make extra stitches before turning the bag out, closing the bag further, but 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**.

Consider ironing the seam allowances flat; see the **General Information and Techniques** chapter under "Better Seams by Ironing". This design's seam can be pressed fairly easily *after* turning the bag out by sticking your finger inside the bag, separating the seam allowances, and pressing them against the iron.

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").

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

Photos by vettehunter123 (Travis Iden) from http://modified.in/footbag/viewtopic.php?t=14125

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. The patterns are reduced by 5.77% 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 105% to get the intended ball size.**

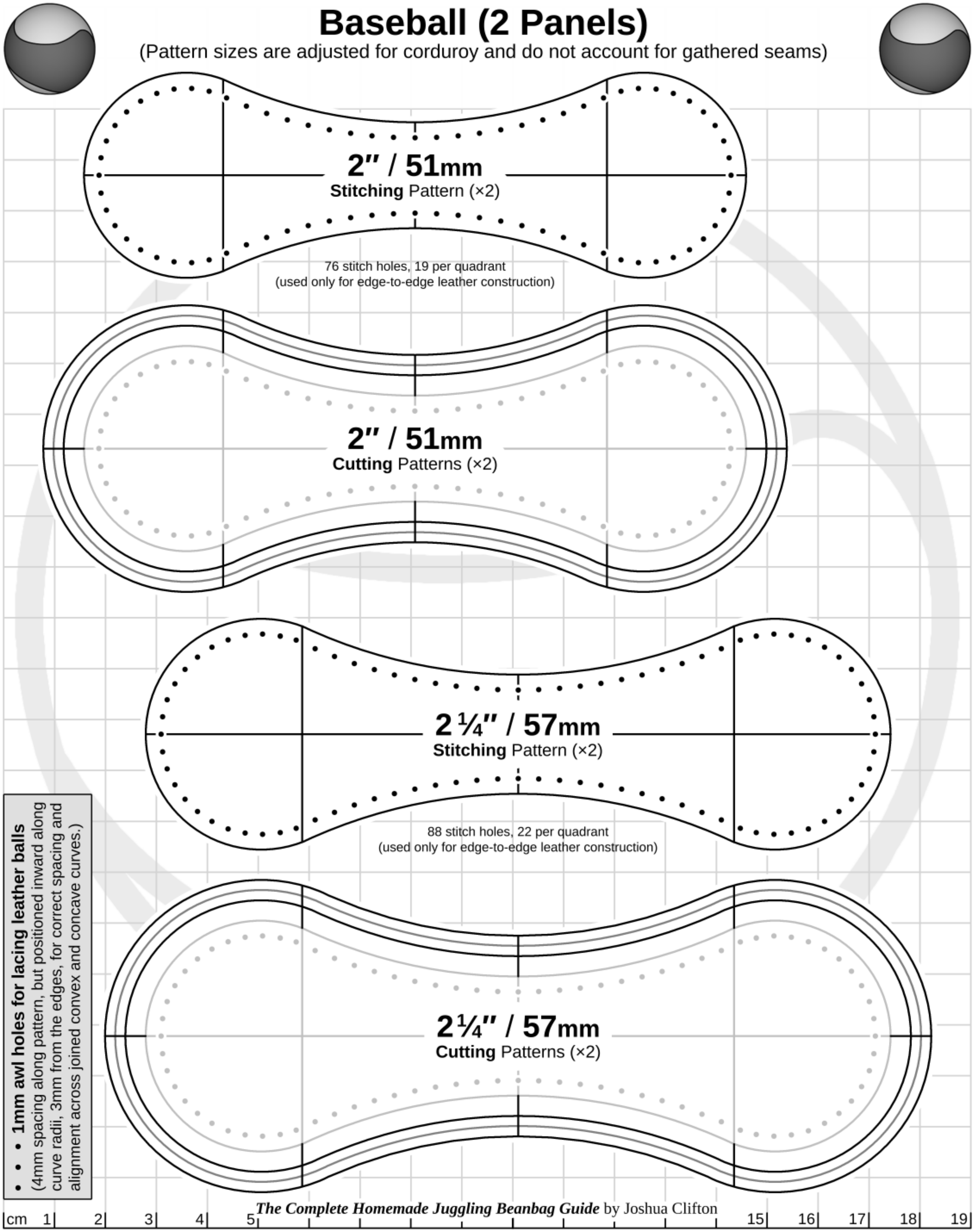
To make the templates, I recommend cutting out the portions of the paper with the patterns you want and using glue or double-sided tape to attach them to your template material, and then cutting along the patterns.

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%


Baseball (2 Panels)
(Pattern sizes are adjusted for corduroy and do not account for gathered seams)
2″ / 51mm
Stitching Pattern (×2)
76 stitch holes, 19 per quadrant
(used only for edge-to-edge leather construction)
2″ / 51mm
Cutting Patterns (×2)
2 ¼″ / 57mm
Stitching Pattern (×2)
88 stitch holes, 22 per quadrant
(used only for edge-to-edge leather construction)
2 ¼″ / 57mm
Cutting Patterns (×2)
• 1mm awl holes for lacing leather balls
(4mm spacing along pattern, but positioned inward along curve radii, 3mm from the edges, for correct spacing and alignment across joined convex and concave curves.)
cm 1 2 3 4 5 15 16 17 18 19
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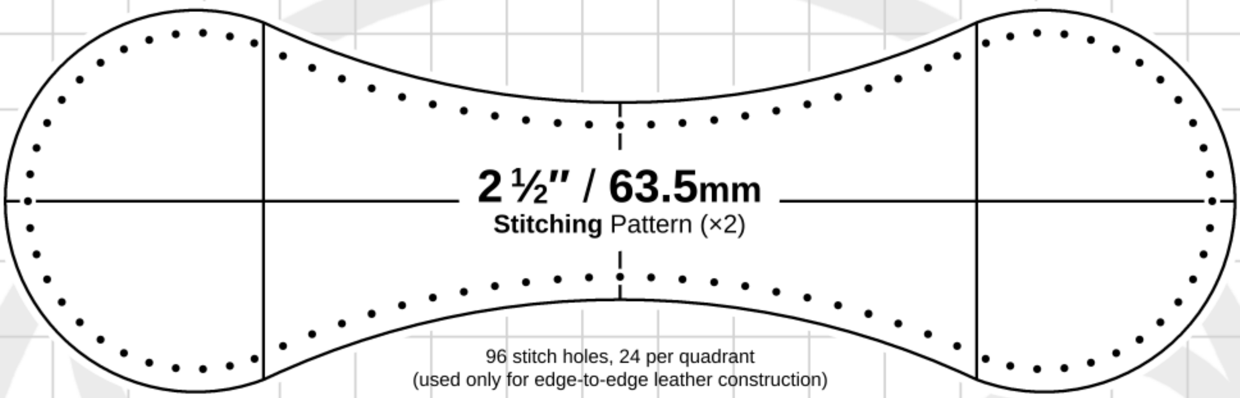
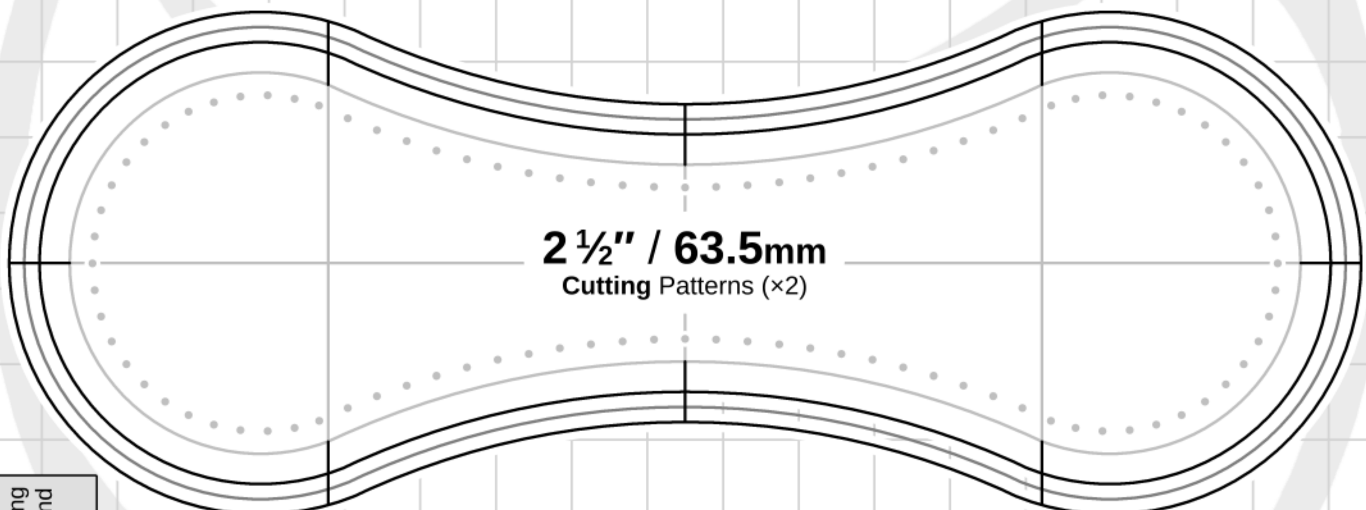
Baseball (2 Panels)

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



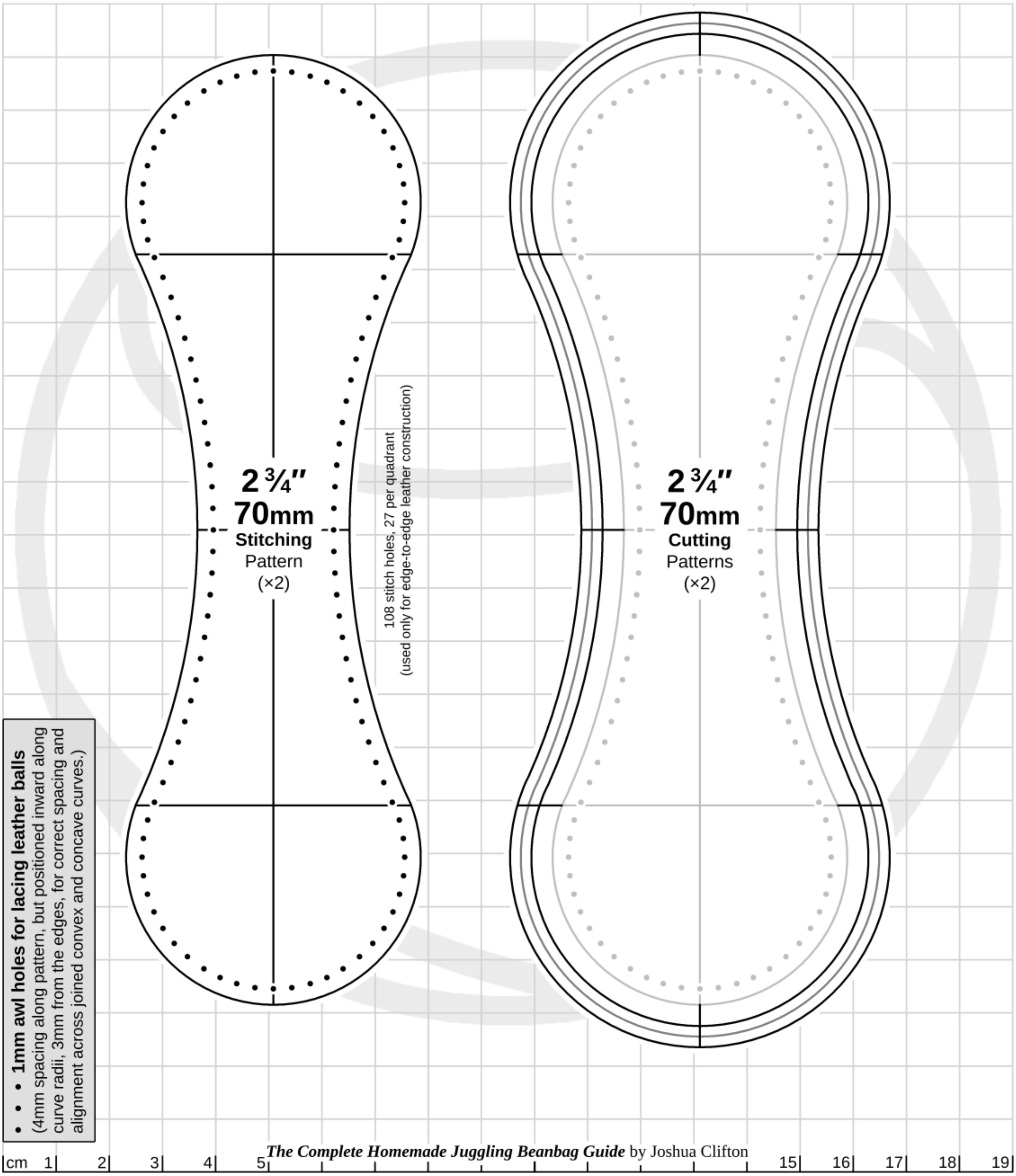


- **1mm awl holes for lacing leather balls**
  (4mm spacing along pattern, but positioned inward along curve radii, 3mm from the edges, for correct spacing and alignment across joined convex and concave curves.)

cm 1 2 3 4 5 15 16 17 18 19

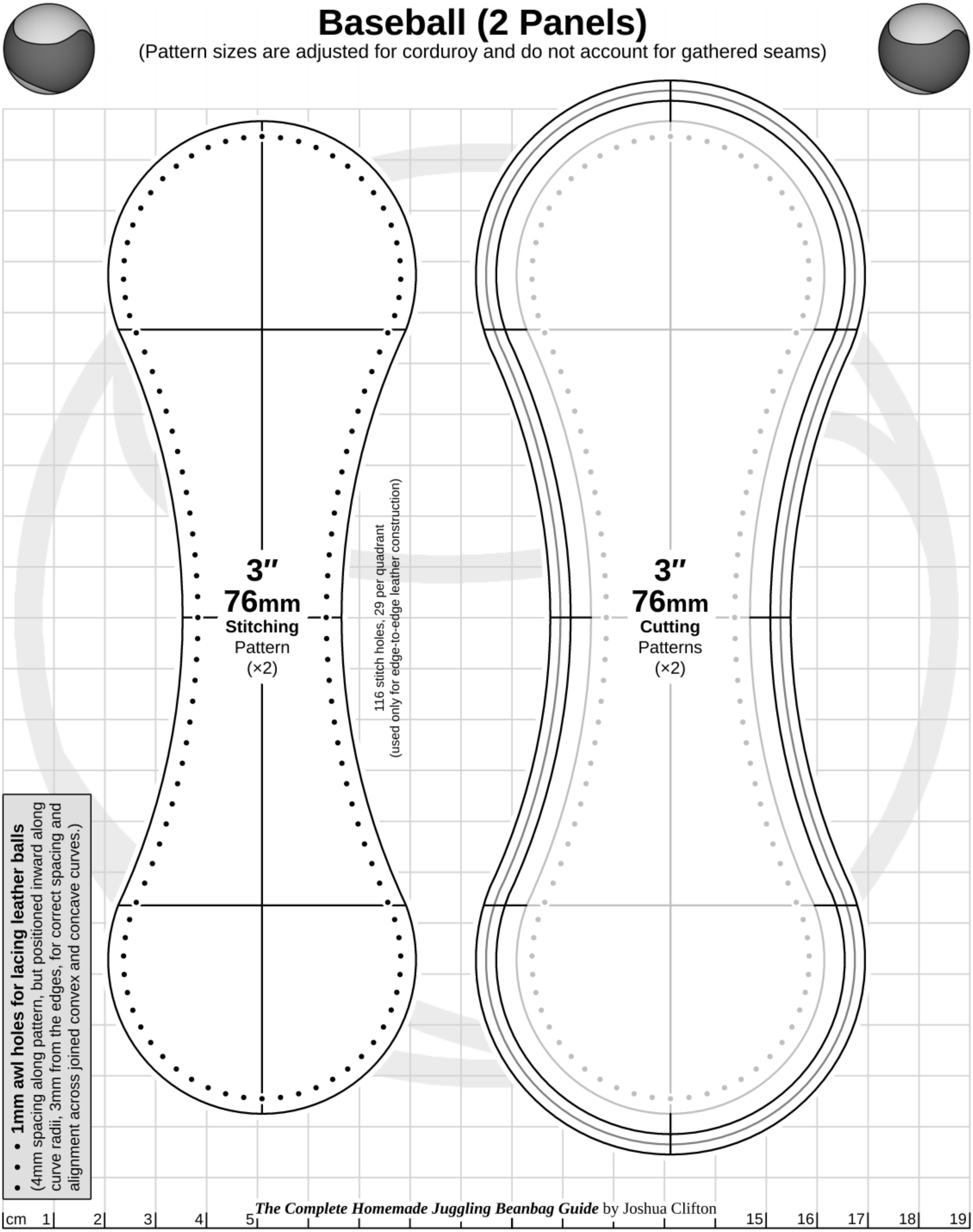
Baseball (2 Panels)

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



Baseball (2 Panels)

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



Sizing Formulas for Drawing the Pattern

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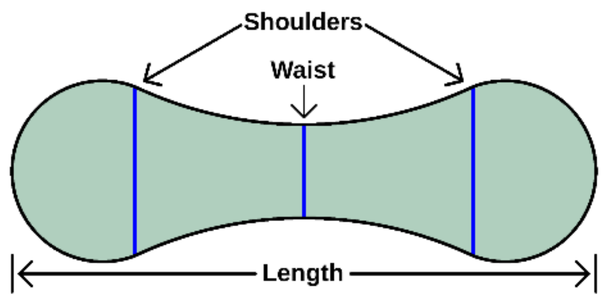
The next section has a table of pre-calculated pattern measurements for all ⅛″ diameter increments from 1 ¾″ – 3″. Following that are the drawing instructions. If you do not need to create a custom size, skip to that. I provide printable measuring tapes at the end of the *General Information and Techniques* 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 circumference of the bag is measured in two ways: *Length* + *Waist* and 4 × *Shoulder width*. The Shoulder points will be aligned when the panels are sewn together. The width of the Shoulders is equal to their distance from the center. Note that the Shoulders are not located at the apexes of the head curves, but are at the point where the convex curves at the ends and the concave curves at the waist meet. The curves are circular. I define the panel size by its Waist and I define the other measurements in terms of the Waist. For more information about this design, including the mathematics behind the sizing formulas, see the last two sections of this chapter.

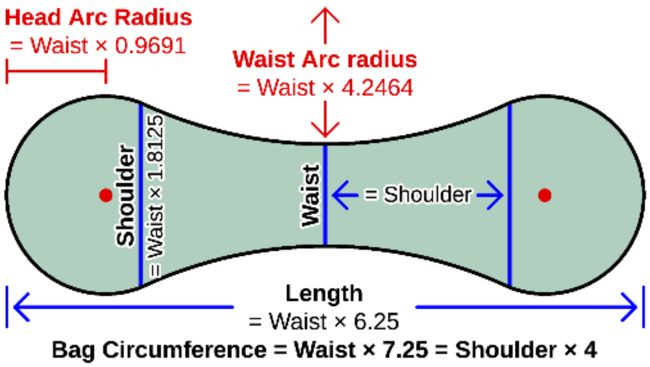
Adjusting for the influence of fabric types on beanbag size

My corduroy beanbag was **4.098% – 7.440%** larger than the mathematical prediction depending on whether I filled it loosely or over-filled it, based on the average of three measurement directions. I target halfway between the min and max inflations when sizing my patterns, which is **5.77%**. This makes my adjustment factor **1.0577**. When made with a thin, non-stretch fabric, this design will be almost the mathematically correct size (I measured 1.25% larger when tightly filled). My original denim bag was 5 – 9.5% larger for an average of 7.25%.

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”.

Sizing formulas

Below are the formulas to calculate the pattern construction elements (*Diameter* is your target ball diameter, π = 3.1416). The value in orange is my adjustment factor. **Don’t forget to multiply the final result by 25.4 if you need to convert inches to millimeters.**



- **Waist = *Diameter* × *π* ÷ 7.25 ÷ 1.0577**

  (≈ *Diameter* × 0.4333 ÷ 1.0577)
- **Length = 6.25*w***
- **Shoulder (and Shoulders' distance from center) = 1.8125*w***
- **Head Arc Radius = 0.9691*w***
- **Waist Arc Radius = 4.2464*w***

Arc length for spacing awl holes

To calculate the length of the curved edges between each shoulder endpoint, use the following formulas, plugging in the appropriate arc radii and Shoulder width from the calculations above (if you are assembling the ball like a real baseball with the panels edge to edge and no seam allowance, and are therefore placing the awl holes within the stitching pattern, reduce the arc radii by the distance between the awl holes and the edge, and reduce the Shoulder by twice that). If you are working with Radians, omit the $\pi/180$. Multiply each result by 2 and sum them for the total edge length. Since the arcs are nearly equal (the Waist arc is 0.0314% shorter), you really need only calculate one of the following.

$$\textbf{Head Arc Length} = \left(2\left(180-\arcsin\left(\frac{(0.5)\,Shoulder}{Head\ Arc\ Radius}\right)\right)\right)(Head\ Arc\ Radius)\left(\frac{\pi}{180}\right)$$

$$\textbf{Waist Arc Length} = \left(2\arcsin\left(\frac{Shoulder}{Waist\ Arc\ Radius}\right)\right)(Waist\ Arc\ Radius)\left(\frac{\pi}{180}\right) \qquad \frac{\pi}{180} \approx 0.0175$$

Table of Pre-Calculated Pattern Measurements

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Below are stitching pattern measurements for each ⅛″ diameter increment from 1¾″ to 3″. The values in the **Adjusted** columns account for my 1.0577 adjustment factor. The adjusted values decrease the **Base** pattern size so that you will get a more accurate finished size when using 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, draw the same framework with the same Waist, Length, and Shoulders, but increase the Head Arc Radius by the desired seam allowance and *decrease* the Waist Arc Radius by the same amount. 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	**Waist** (mm)		**Length** (mm)		**Shoulder width & distance** (mm)		**Head Arc Radius** (mm)		**Waist Arc Radius** (mm)	
	Base	**Adjusted**	Base	**Adjusted**	Base	**Adjusted**	Base	**Adjusted**	Base	**Adjusted**
1¾″ (44.5mm)	19.261	**18.210**	120.383	**113.815**	34.911	**33.006**	18.666	**17.648**	81.791	**77.329**
1⅞″ (47.6mm)	20.637	**19.511**	128.981	**121.945**	37.405	**35.364**	20.000	**18.909**	87.633	**82.852**
2″ (50.8mm)	22.013	**20.812**	137.580	**130.075**	39.898	**37.722**	21.333	**20.169**	93.475	**88.376**

Finished Diameter	**Waist** (mm)		**Length** (mm)		**Shoulder width & distance** (mm)		**Head Arc Radius** (mm)		**Waist Arc Radius** (mm)	
	Base	**Adjusted**	Base	**Adjusted**	Base	**Adjusted**	Base	**Adjusted**	Base	**Adjusted**
2⅛" (54.0mm)	23.389	**22.113**	146.179	**138.204**	42.392	**40.079**	22.666	**21.430**	99.317	**93.899**
2¼" (57.2mm)	24.764	**23.413**	154.778	**146.334**	44.886	**42.437**	24.000	**22.690**	105.159	**99.423**
2⅜" (60.3mm)	26.140	**24.714**	163.376	**154.464**	47.379	**44.795**	25.333	**23.951**	111.002	**104.946**
2½" (63.5mm)	27.516	**26.015**	171.975	**162.593**	49.873	**47.152**	26.666	**25.212**	116.844	**110.470**
2⅝" (66.7mm)	28.892	**27.316**	180.574	**170.723**	52.366	**49.510**	28.000	**26.472**	122.686	**115.993**
2¾" (69.9mm)	30.268	**28.616**	189.173	**178.853**	54.860	**51.867**	29.333	**27.733**	128.528	**121.517**
2⅞" (73.0mm)	31.643	**29.917**	197.771	**186.982**	57.354	**54.225**	30.666	**28.993**	134.370	**127.040**
3" (76.2mm)	33.019	**31.218**	206.370	**195.112**	59.847	**56.583**	32.000	**30.254**	140.213	**132.564**

How to Draw the Panel Shape

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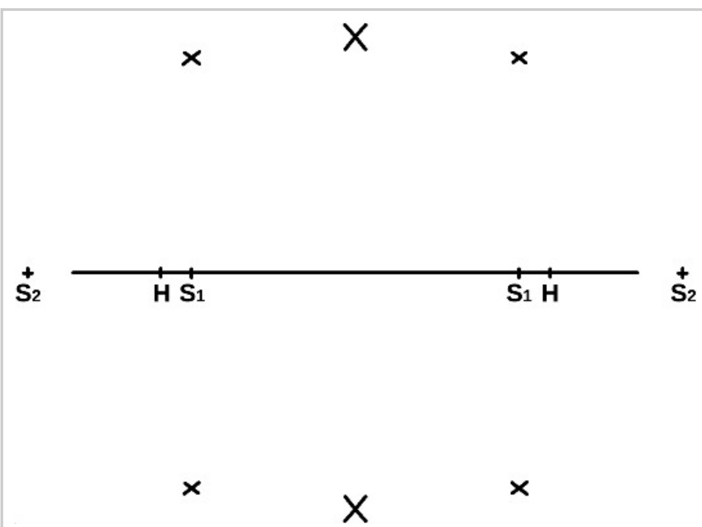
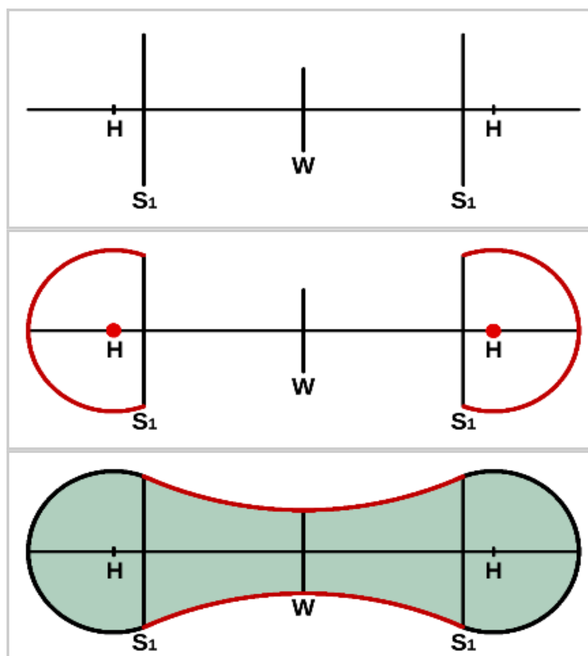
The panel shape is composed of a pair of convex curves at the ends and a pair of concave curves at the waist, both of which are circular. Below is a pictorial summary of the procedure for drawing the shape by hand which is referenced in the written directions. Not all of the steps are shown. SketchUp 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.





Manual directions

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

1. Draw a horizontal line for the panel's **Length**, and mark compass points that are located the distance of **Head Arc Radius** in from each end (labeled H for "Head" in the illustrations).

2. *Locate the line's center and draw the Waist:* Use a compass placed at each end of the line in turn and, using any radius that is significantly longer than half the line, draw small arcs above and below the center of the line to form a pair of Xs as shown in the first illustration. Use the X points to draw a vertical line for the **Waist** width centered on the horizontal line (labeled W in the illustrations). Then mark compass points that are located the distance of **Waist Arc Radius** beyond each end of this line (not labeled).

3. *Draw the Shoulders (optional):* The shoulder points are not necessary for drawing the panel but will produce reference points to help you keep the panels aligned when you sew them together. Mark a pair of points (S_1 for "Shoulder" in the illustrations) that are located **Shoulder** distance out from either side of the center, and then another pair that are the same distance further beyond each of those points (S_2).

   Place the compass on point S_2 and the center of W in turn and draw an X above and below each S_1 point as you did for the waist. Use the Xs to draw the vertical Shoulder lines through the S_1 points (the lines only need to be the length of **Shoulder**, but their length will not be used for anything but markers at the edges of the panel, so they can be longer).

4. *Draw the Head arcs:* Set the compass on one of the H marks on the line, extend it to the near end of the Length line (to **Head Arc Radius**) and draw an arc that extends from one end of the Shoulder line to the other, or, if you didn't draw Shoulders, draw at least three quarters of a circle (look at the illustrations for a reference). Draw the same arc on the other end.

5. *Draw the Waist arcs:* Place the compass on one of the Waist arc compass points (not shown in the illustrations) above or below the center of the Length line. Extend it to the near end of the Waist line (to **Waist Arc Radius**) and draw an arc that intersects each of the Head arcs, completing one side of the panel. Draw the same arc on the other side.

6. To draw a cutting pattern, draw everything the same but increase the radius of the Head arcs by the desired seam allowance (I use 8mm) and *decrease* the radius of the Waist arcs by the same amount.

SketchUp directions

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

1. Draw a horizontal line for the panel's **Length**. Draw lines the length of **Head Arc Radius** inward from each end of this line to mark the circle centers for the head arc (labeled H for "Head" in the illustrations).

2. Draw a vertical line for the **Waist** and center it at the middle of the horizontal line (labeled W in the illustrations). Then draw lines of length **Waist Arc Radius** extended from each end of the waist line. These locate the circle centers for the waist arcs.

3. *Draw the Shoulders (optional):* Draw lines the length of **Shoulder** out from the center to mark where the two shoulders will be (S_1 for "Shoulder"). S_2 are not needed. Draw vertical **Shoulder** lines centered on points S_1. These Shoulder lines are not necessary for drawing the panel but will produce reference points to help you keep the panels aligned when you sew them together.

4. *Draw the Head arcs:* Draw circles centered on each H point that extend to the near end of the Length line (radius = **Head Arc Radius**).
5. *Draw the Waist arcs:* Draw circles centered on each end of the Waist Arc Radius line (not shown in the illustrations) that extend to the near end of the Waist line (radius = **Waist Arc Radius**). The Head and Waist arcs should intersect each other at the shoulder endpoints (if you drew them) and produce the panel shape. You can also use the arc tool in conjunction with the Length, Waist, and Shoulder endpoints to draw the arcs. In that case you don't have to mark the four circle centers.
6. To draw a cutting pattern, draw everything the same but increase the radius of the end circles by the desired seam allowance (I use 8mm) and decrease the radius of the waist circles by the same amount.

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

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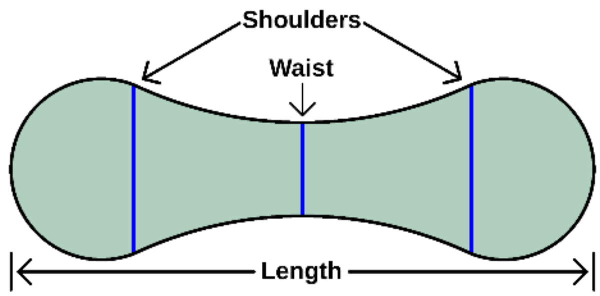
This section describes the math involved in drawing patterns to produce specified beanbag sizes, and creating the pattern sizing formulas. *(The numbers in tiny, right-justified typeface are my computer calculator's unrounded values which I display rounded to six places for brevity.)*

Panel framework



The circumference of the bag is measured in two ways: *Length* + *Waist* and 4 × *Shoulder width*. The Shoulder points will be aligned when the panels are sewn together. The width of the Shoulders is equal to their distance from the center. Note that the Shoulders are not located at the apexes of the head curves, but are at the point where the convex curves at the ends and the concave curves at the waist meet. The curves are circular. For a more in-depth explanation of this framework and its derivation, with extensive illustrations, see the next section, "How I Developed This Design".

I define the panel size by its Waist and I define the other measurements in terms of the Waist. The panel's length is 6.25 × Waist, which makes the circumference of the bag equal to 7.25 × Waist. The Shoulder width and the shoulders' distance from the center is equal to 1.8125 × Waist. I also define the arc radii by the Waist size. To summarize the framework:

Waist (*w*) = $\left(\frac{\textit{Circumference}}{7.25}\right)$

Panel Length = 6.25*w*

Shoulder Width & Distance from Center = 1.8125*w*

Arcs

The formula to calculate the radius of a circular arc (found on Wikipedia[3]) is as follows (c = chord or width of the arc, h = height of the arc from chord to apex):

$$r = \frac{c^2}{8h} + \frac{h}{2}$$

Let w be the Waist width. The chord of the head curves is the shoulder width, or 1.1825w. The height of the head curves is calculated below.

Head curve Height = $\frac{\textit{Panel Length}}{2} - \textit{Shoulder Width} = 3.125w - 1.8125w = \mathbf{1.312500w}$

3 https://en.wikipedia.org/wiki/Arc_(geometry)

So the radius formula is

$$\textbf{Head curve Radius} = \frac{(1.8125w)^2}{8(1.3125w)} + \frac{1.3125w}{2} \approx \mathbf{0.969122}\boldsymbol{w}$$

0.969122023809523809523809523809523809 52

The height of the waist curve is shoulder minus waist divided by 2. Defined in terms of the waist it is

$$\textbf{Waist curve Height} = \frac{Shoulder - w}{2} = \frac{1.8125w - w}{2} = \mathbf{0.406250}\boldsymbol{w}$$

The chord of the waist curves is simply 2 × Shoulder, and the shoulder has already been defined in terms of the waist. So the radius formula is

$$\textbf{Waist curve Radius} = \frac{((2)(1.8125w))^2}{8(0.406250w)} + \frac{0.406250w}{2} \approx \mathbf{4.246394}\boldsymbol{w}$$

4.2463942307692307692307692307692

Cutting pattern adjustment

To make a cutting pattern, simply increase the head arc radius and decrease the waist arc radius by the desired seam allowance. The circle centers and framework remain the same.

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How I Developed This Design

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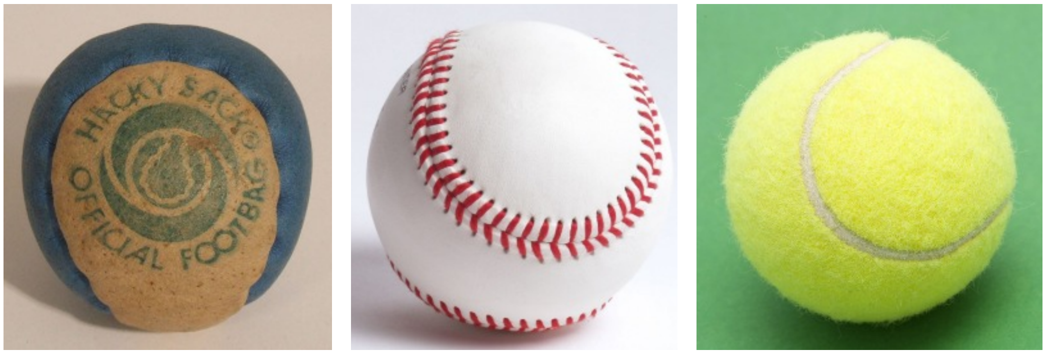


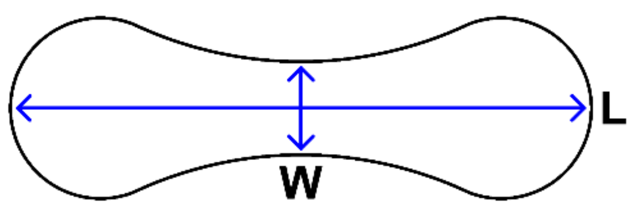
Image sources, respectively: http://www.ebay.com/itm/221263945612?_trksid=p2048036, http://mvpsportschannel.com/blog/summer-slam-baseball-trigg-county/, http://www.freeimageslive.co.uk/free_stock_image/tennis-ball-green-jpg

This is the panel structure used for baseballs and it was used for the original Hacky Sack by Wham-O (shown above on the left). It is also similar to the shape of the groove on tennis balls, and, if you divide the panels into quarters, you will get a structure similar to that of basketballs (but basketballs use different curves and panel proportions).

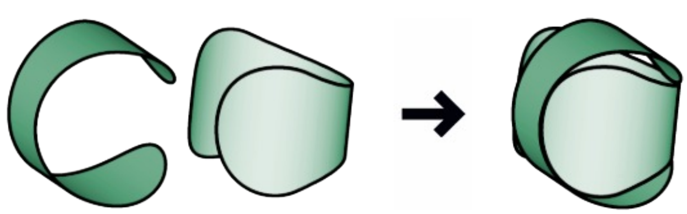
Until January, 2014 (17 months after publishing the first edition of this guide) I had no interest in this design because I thought it would be greatly inferior to the other designs in terms of roundness and uniformity. Also, I had no understanding of how to design the panel shape. Then I read a PDF scan of a hand-written article from 1979 by John Diebold entitled “Designing patterns for juggling beanbags”[4] (copied at the end of this section). This article gave a technical discussion of the design with illustrations. Some important aspects of the design were missing from the article and I had to figure them out, but it was a great start and it motivated me to try the design.

Figuring out the panel proportions

As Diebold states, “Sphericity is approximated in the two-piece beanbag by ensuring that the circumference in three orthogonal directions is the same.” Diebold defines two basic dimensions of the panel shape as waist (W) and length (L). The circumference of the bag is $W+L$.



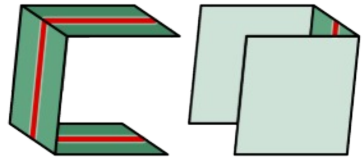
The panels fit together as shown below.



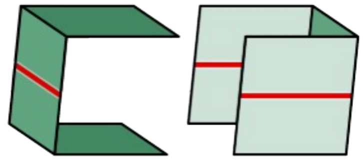
4 http://www.ldeo.columbia.edu/~johnd/John_D_juggling_beanbags.pdf

The panels can be approximated as shown below to make the three orthogonal circumferences easier to understand. The circumferences are shown by the red lines.

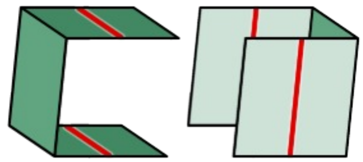
XY-plane circumference



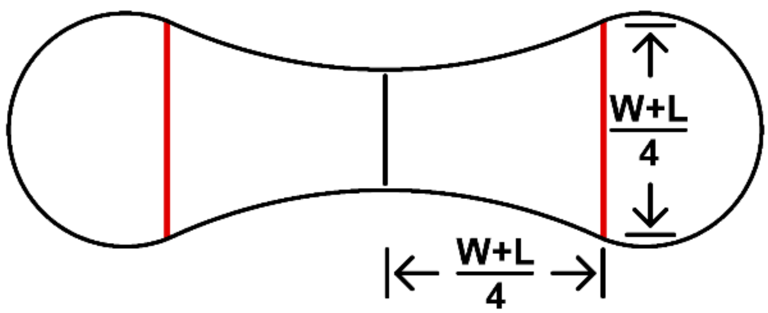
XZ-plane circumference



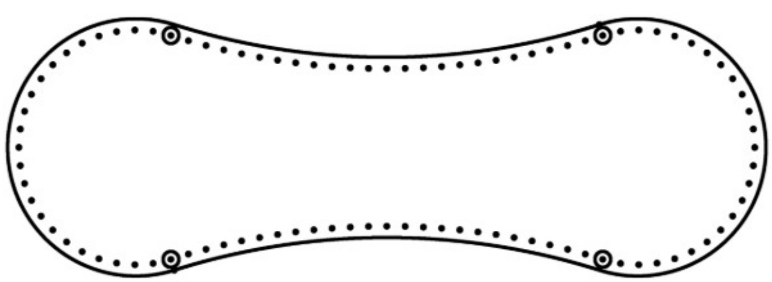
YZ-plane circumference



For the third circumference (YZ-plane), the red lines are located one quarter of the circumference distant from the middle of the panels and are one quarter of the circumference in length. I call these the "Shoulders". For the actual panel, the shoulders are located as shown below. Note that one quarter of the circumference is greater than one quarter of the panel length and so the lines are off-center within the panel halves. The shoulders mark the point where the concave waist curves and convex end curves meet each other.



One important aspect of the panel shape is the ratio of the waist to the length. Diebold says that the best results are obtained when the length is about 6W. He does not explain this or discuss the relative results of other ratios, however, and the example with which he immediately follows that statement has $L = 6.85W$. He then shows several more examples with other ratios. Peter Billam has patterns for 2-panel beanbags[5] and they use $L = 4.675W$ (measured in Photoshop). Billam's design is shown below.



Peter Billam's two-panel pattern (http://web.archive.org/web/20231105094249/https://pjb.com.au/jug/leatherballs.html)

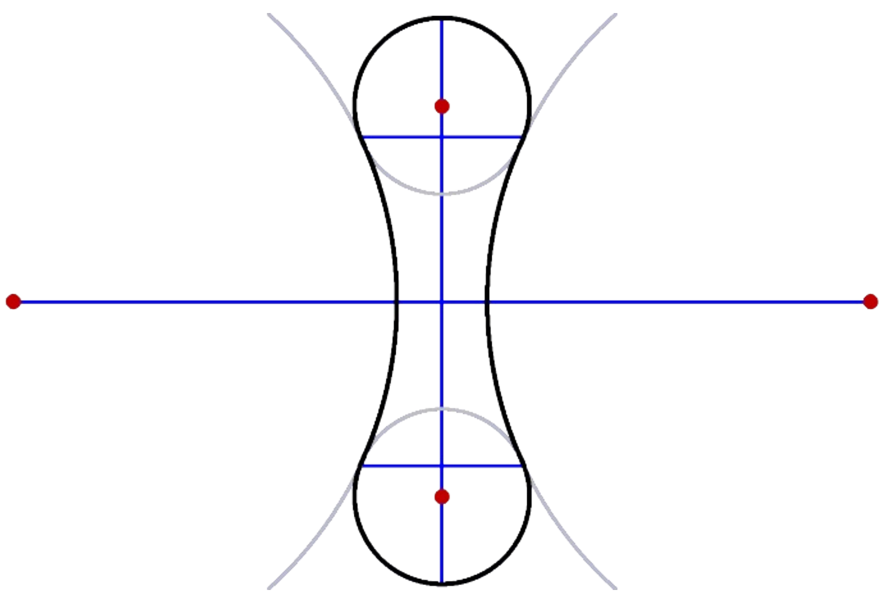
5 http://web.archive.org/web/20231105094249/https://pjb.com.au/jug/leatherballs.html

I spent a day or two trying to decide if there is any non-arbitrary choice for the ratio. I finally realized that one missing aspect of Diebold's discussion was the length of the arcs. The convex arcs on the ends of the panels must be the same length as the concave arcs at the waist so that when the panels are sewn together the shoulders will line up and form the correct circumference.

I found (using an arc length formula and trial and error) that these arcs, when circular, match only when $L = 6.25W$. (Actually, the waist arcs are shorter by 0.031%, but that's close enough. Using further experimentation and SketchUp measurements I narrowed the exact ratio down to between 6.23 and 6.24.) $L = 6W$ makes the waist arcs longer by 0.84%, which is close enough for a beanbag, but not quite enough for a perfectionist, and while the mismatch in arc length is insignificant, the change in ratio will perhaps make a slightly significant difference in the look of the bag. $L = 4.675W$, incidentally, makes the waist arc longer by 7.46% which is a difference of 7.3mm in a tennis ball-sized bag. So, the arc length consideration yields the non-arbitrary choice I needed. My illustrations use the 6.25 ratio.

Figuring out the curves

A second missing aspect of the discussion is the nature of the curves. I used circular curves by default because they are simple and I had no reason to use any other, nor any good way to draw a different type of curve. Billam appears to have used circular curves as well. But Diebold appears to have used hand-drawn curves, most of which do not look very circular. An elliptical or function-based curve would change the arc lengths and possibly allow a different W:L ratio to work. I don't know what effect they would have on the shape of the bag, though. Below is my design framework with the circles. The red dots are the circle centers.



The circles intersect at the ends of the shoulder lines. The formula to find the circle radii (found on Wikipedia[6]) is as follows (c = chord or width of the arc, h = height of the arc from chord to apex):

$$r = \frac{c^2}{8h} + \frac{h}{2}$$

6 http://en.wikipedia.org/wiki/Arc_%28geometry%29

For the waist curve, the chord is the distance between the shoulders and the height is (*shoulder length* – *waist*) ÷ 2. For the end curves, the chord is the length of the shoulders and the height is the distance from the shoulder to the end of the panel.

Now that I have made a 2-panel beanbag I find I actually prefer it to the 4-panel orange peel ball design, except that it is harder to make. It feels better in my hand and is more spherical and has a more uniform seam structure. It also looks more attractive to me. When made with two different colors it reminds me of the yin-yang symbol, particularly at the angle shown in the third column of photos below.

Below are different angles of the baseball design made of two different fabrics. The first is my original one made of a slightly stretchy denim and the second is my new one made of non-stretch corduroy. As you can see, they are very round except around the shoulders of the panels. The squareness of the photos in the fourth column is about how the orange peel ball looks from the poles when made with stiff fabric. The beanbags pictured are not broken in, though. Maybe with enough use they would round out more. I also wonder if a different type of curve could eliminate the angularity at the shoulders.

Comparing my panel shape to the official shape

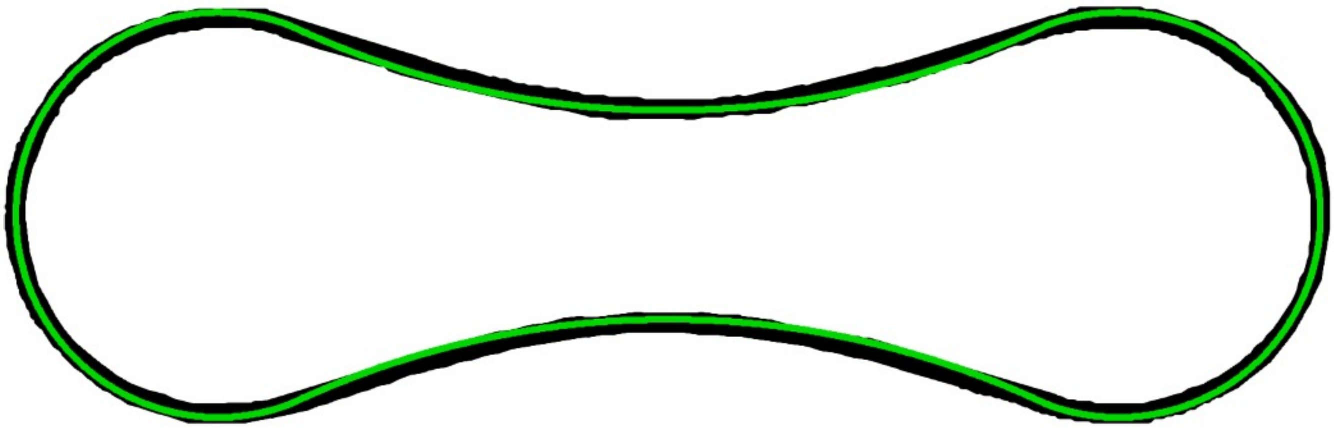
I have not yet been able to find an official definition of the baseball panel shape. Just today (2/10/2014, over a week after designing my bag) I found an article by Richard B. Thompson from 1998 entitled "Designing a Baseball Cover"[7] (which I have not fully read or analyzed) that gives an in-depth, theoretical, mathematical analysis of the baseball panel shape. Following is a quote from the first page of the article.

> In the 1860s C. H. Jackson patented a pen and ink drawing of a plane shape that could be used to form the cover of a baseball. This shape is still in use today on all major league baseballs. According to Bill Deane, a Senior Research Associate with the Baseball Hall of Fame, Mr. Jackson's design was produced by "trial and error." In practical terms, he wanted

7 Best document source I have found: https://www.semanticscholar.org/paper/Designing-a-Baseball-Cover-Thompson/15f5ea08094c4273dad63d2e85fe285b4b65aed0.

> a piece of leather that could be sewn to an identical piece and then stretched to cover the yarn-wound core of a ball.

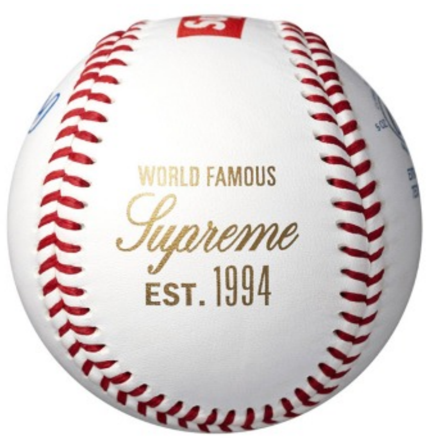
Wolfram MathWorld says of this article, “Thompson's attribution of the current design to trial and error development by C. H. Jackson in the 1860s is apparently unsubstantiated, as discovered by George Bart.”[8] Anyway, after the above paragraph Thompson includes what are supposedly Jackson’s sketches of the baseball panel shape for the patent. I took a magnified screenshot of one of the panels pictured, touched it up a bit in Photoshop and then overlaid my panel shape to compare them. Following are the two shapes, with mine in green over Jackson’s.



C. H. Jackson’s panel shape in black with mine overlaid in green.

My shape and Jackson’s are nearly identical and have the same waist:length ratio, but the curves are slightly different. Jackson’s curve is smoother and more level across the shoulders. That is where the two different curves of my design meet and cause a somewhat abrupt change in curve.

When I look at actual baseballs, this difference in the shape of the curve appears even more pronounced. The ends of the panels seem to be slightly elongated and more level across the shoulders compared to mine. The few photos and videos I’ve been able to find that show an unwrapped baseball panel confirm this. The waist curve is shaped slightly like a wide V and the end curves look somewhat elliptical. Below are the best depictions of this I could find.



Baseball photo from http://www.freshnessmag.com/2012/04/12/supreme-x-rawlings-official-league-baseball-player-preferred-glove-available-now/. Baseball panel photo from http://thedevilishdish.blogspot.com/2013/07/baseball-bracelet-how-to.html.

8 http://mathworld.wolfram.com/BaseballCover.html

Frame from Discovery Channel's "How It's Made" episode on baseballs (https://www.youtube.com/watch?v=phCBDOXexfs). Captured @ 1:06.

When I learned that actual baseball panels have such a different shape from mine, I began to think that I might not have created as good a design as I thought. This was in March, 2014, well after I had done all the write-up for the design explanation and instructions and felt mostly settled in my mind about it. I wondered if the squareness of the bag was due to poor design rather than the limitations of forming a sphere out of two flat panels. I even considered demoting the baseball design into the "Other Designs and Variations" chapter (now titled "Chapter 4 – Other Juggling Bag and Footbag Designs") until I figured out how to correct it, or at least making note of the fact that my design was not excellent but merely an inferior, approximated version of the baseball concept. This was rather disappointing.

I decided that I needed to think of a way to confirm whether or not my panel shape could fit together around a true sphere. The method I chose was to fit paper panels around a tennis ball. I measured a tennis ball I have and drew a panel that was sized exactly to that circumference.

I printed and cut out two panels and taped their ends to the ball. I then carefully molded the panels to the surface of the ball, creating uniform creases around the edges. At that point, when I tried to match the edges of the panels to each other, they seemed not to match very well around the shoulders and seemed to confirm that the true baseball panel shape would fit better. But to be sure I was fitting them together correctly and not shifting the panels while pressing the edges down, I taped the edges of the panels together at small intervals around the entire seam.

At the end, to my great relief, the panel edges fit together roughly perfectly with uniform snugness around the tennis ball and with the shoulders perfectly aligned. This assures me that my panel shape does form an excellent ball, allowing for the creasing or stretching distortion needed to make the panels spherical.

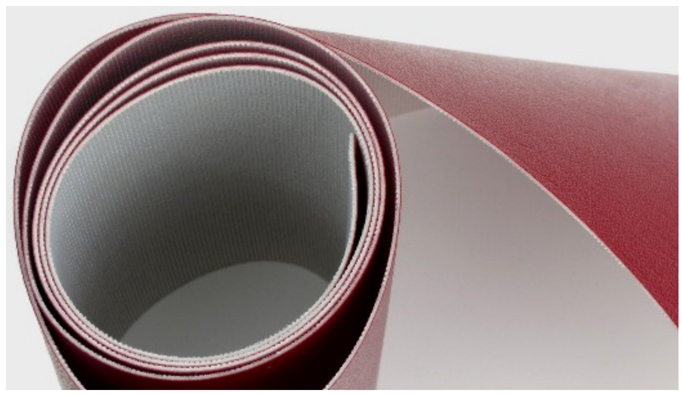
Going back to Richard Thompson's article, on page 58 under the heading "Real Baseballs" the author discusses measurements taken from a freshly cut leather panel of the shape used by Rawlings for their National League baseballs, and the *W*:*L* ratio was 1:6.21 (1.196″ × 7.426″). So that is further confirmation that I am at least using the official ratio (or very nearly).

I don't know yet how to define the true baseball panel shape. I think it would require a function-based curve, but perhaps it would be possible to approximate it with several different circular curves joined together. Unless I find a simple way to define and draw a better curve, I'm willing to accept a possibly slightly inferior one for the sake of design simplicity.

You could experiment with hand-sketching an alteration to my curvature to more closely match the official curvature. I haven't felt up to making more experimental 2-panel bags yet to see if this would improve their shape.

My new faux leather baseball

Using paper to verify that the panel shape fits together into a good sphere is not really a good method. In April, 2021, five months after publishing this second edition guide, I bought a material called marine vinyl and made a baseball-style beanbag with it. The vinyl is 1mm thick, pretty stiff, and slightly stretchy. It simulates leather well. I did not use a seam allowance but placed the panels edge to edge as on a real baseball. I stitched them using the baseball stitch which I modified to use only one needle instead of two. My pattern made a good ball when I packed it tightly enough (with Poly-Pellets) to stretch out the vinyl.



Marine vinyl (I used a white variety for the baseball)

The marine vinyl has so far been a good, durable material. We have played catch with the ball several times, even over asphalt pavement, and it has hardly a blemish even after the many times we missed catching it and it hit the pavement or trees at high speed.

I did notice that, after being broken in, the ball took on a slightly elongated shape. (The middle photo above shows a hint of this, but the angle isn't quite right to properly judge the shape, and I took the photo before breaking in the bag.) I did not know whether this was due to a flaw in my panel design or to the nature of the two-piece structure. It was not enough to be a problem, and is really only a nit-pick like all of the shape imperfections I describe in my designs. It was hardly noticeable when handling and throwing the ball, and most people would probably not notice or care, but to me it was visually apparent.

Months later I was browsing Flying Clipper's website, and on their FAQs Interesting Info page under "Footbag and Juggle Ball Trivia & Thoughts" I found the following description of the original Hacky Sack that leads me to believe this is an issue inherent to this panel structure when there is not a rigid ball within the panels as in a baseball to force them into a spherical shape:

> Footbags were originally made from cowhide, internally hand-stitched and filled with high density plastic pellets. It was common to have to look through a bin of 100 hacky sacks® to try and find the one that you thought you could break-in. The two piece construction of the original hacky sacks did not lend itself to a round sphere. We used to say that hacky sack® was proof positive that the egg came first!
>
> Flying Clipper was among the first to branch out to create new and different designs focusing on roundness, durability and all around footbag play. We are the oldest continually operating footbag manufacturer on the planet.

I am currently (10/29/2021) developing and testing a theory as to why the panel shape might, in fact, be to blame. Richard B. Thompson's math-derived pattern, which I just made into a felt ball for the first time, makes a perfectly round ball. The curvature is much higher between the shoulders and waist, and it has a different L:W ratio. I think I am beginning to see why my lower curvature in that zone might pull the head of the joined panel downward at the edges, narrowing the ball toward the end. I need to do more experimentation to find out for sure.

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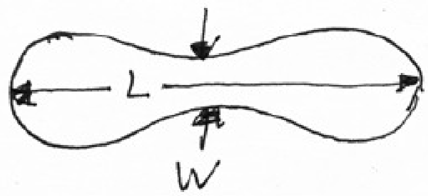
"Designing patterns for juggling beanbags" by John Diebold

Source: http://www.ldeo.columbia.edu/~johnd/John_D_juggling_beanbags.pdf

Designing patterns for juggling beanbags 24/12/79

by John Diebold

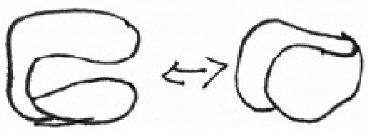
Sphericity is approximated in the two-piece beanbag by ensuring that the circumfrence in three orthogonal directions is the same. This type of beanbag is made of two identical pieces, like a baseball. We define the two basic dimensions as W and L, for waist (width) and length, respectively:



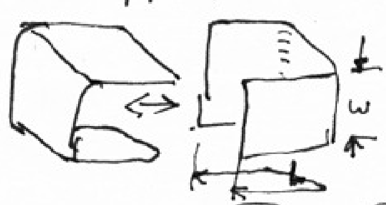
The circumfrence should be L+W. The usual diameters and circumfrences are:

DIA	L+W
2.25"	7.07"
2.38"	7.48"
2.50"	7.85"

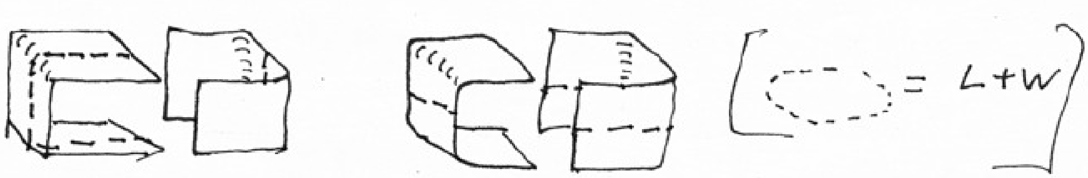
These pieces fit together so:



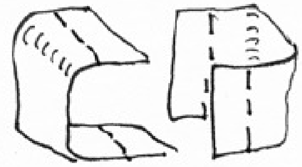
and can be approximated by:



The similarity of the pieces ensures that two directions, shown by dotted lines, are equal in circumfrence



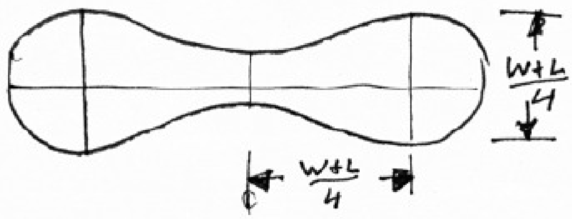
The other dimensions which must add up to L+W are, obviously, these:



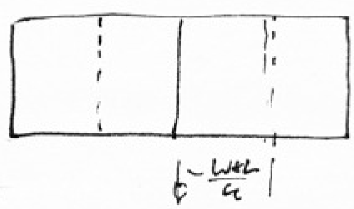
and these lines should fall near the midpoint of the quadrant's perimeter.

24/12/79 (2)

in the pattern, the location of these lines is determined thus:

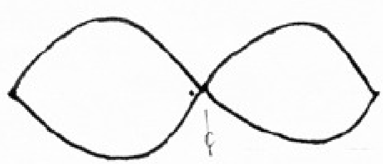


shapes can be quite variable. one extreme is when $L=3W$, the cube.

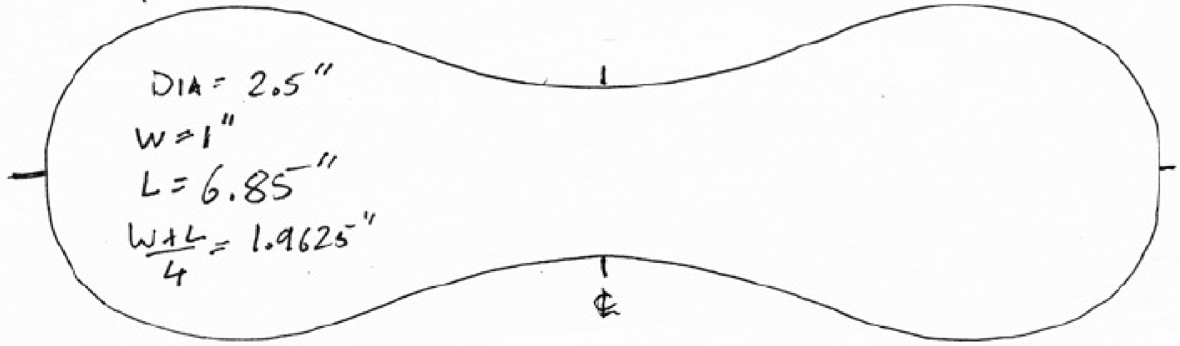


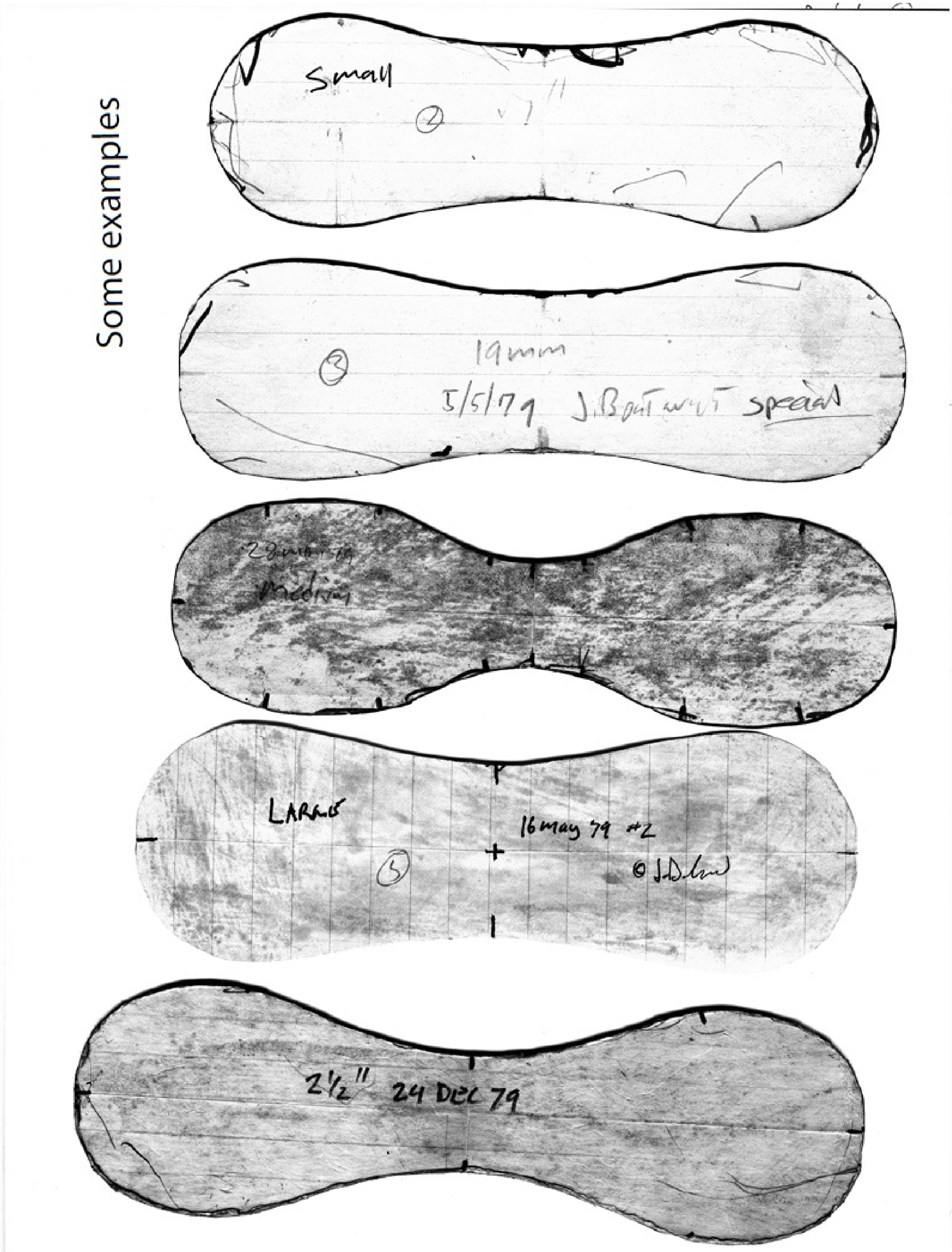
Another is $L=\infty W$, or $W=0$, the "orange peel"

max accuracy ⇒ max. segments
see: mandolins + Cameron Powers' Lady guitars



each of these produces squarish edges. The best results for 2 pieces are obtained with a ratio of about $L=6W$



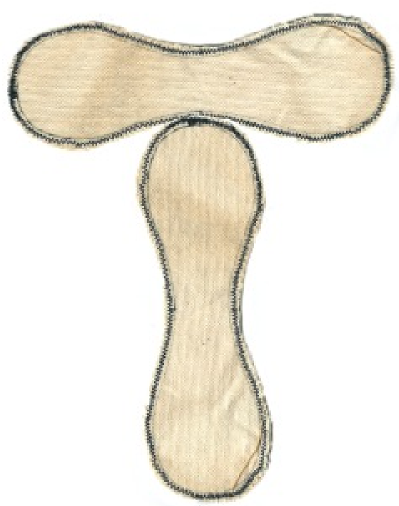


"Designing patterns for juggling beanbags", page 3 of 4

how to make the juggling beanbag

Trace the pattern six times onto heavy canvas duck or other suitable fabric. Remember to make four marks where the two centerlines intersect the sewing line. Cut the pieces out, leaving about 1/4" of fabric outside the outlines. use a sewing machine and run a zigzag stitch around the 1/4" extra strip, to prevent future fraying:

For each ball, put the two halves together like this, with centerline marks aligned, and start sewing along the outlines. using a large strong crewel needle and good heavy button thread or light twine. Make sure the centerline marks line up as the sewing progresses:



Continue sewing until there is a remaining gap of about 3/4". Leave the threaded needle hanging, and use a dowel, ballpoint pen or other tool to turn the nearly-finished ball right side out. Using a funnel, fill the ball with something - bran works well, rice is possible. Then using the "invisible stitch", finish sewing the ball. If a somewhat floppy ball is desired, you're done. If you want to create a taut ball, go over the seam again, from the outside, using the baseball stitch. This will cinch up any looseness - this added step is the key to making the once-famous Diebold juggling beanbag. Sew two more balls, and juggle.