

Paper Stops Folding Not Because It Gets Thick, but Because It Runs Out of Length

— the thickness grows as 2^n and the required length as 4^n — twelve folds need only **0.4096** m of thickness but **879.0962** m of length — a ratio of **2146.2** — [Paper 389]

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— *From thinking to syncing.* —

Abstract

“Paper cannot be folded more than seven times because it gets too thick”, the explanation runs. This paper shows that the thickness is not what stops it—length is, and by orders of magnitude. No new theorem or law is claimed. First, the thickness grows as $t2^n$ and the required length as $(\pi t/6)(2^n + 4)(2^n - 1)$ (Section 1). Second, twelve folds need only **0.4096** m of thickness but **879.0962** m of length (Section 2). Third, and this is the core of the paper. The ratio of length to thickness itself opens as 2^n : **68.6** at seven folds, **4290.9** at thirteen (Section 2). Fourth, a sheet of A4, **0.297** m along its long edge, folds **6** times; seven would need **0.8778** m (Section 3). Fifth, on thickness alone, **42** folds reach the Moon. Thickness is not the constraint (Section 3). Sixth, the separator is whether the slack taken up by the fold is counted at all (Section 5).

Scope of this paper (scope note): No new theorem or law is claimed—the single-direction folding formula (Gallivan 2002) is known. No origami is designed—alternating folds and actual folding technique are not entered. Only single-direction folding is computed. Materials are not treated—stiffness, tearing and fibre direction are not the subject. Only the geometry is examined. No record is claimed—whether any particular fold count was achieved is not the subject. Thickness is held constant—crushing at the crease is ignored; ignoring it works in the direction of reducing the required length. Area is not treated—alternating folds use both length and width; this paper looks at one direction only. Relation to earlier papers: Paper 386 showed that the rate moves a thousandfold with the solubility fixed—here length dominates by orders of magnitude with the thickness fixed. Paper 362 showed that lifting the stones is not the bottleneck—here the thickness is not the bottleneck. Paper 384 showed that free-space loss is not a loss—in both, the thing that carries the name is not the thing that acts. Paper 300 showed that same-root and different-root can be decided—thickness and length are different-root by that criterion. What is added is putting numbers on thickness and length at six fold counts, showing that the ratio opens as 2^n , bracketing the A4 limit of six folds from both sides, obtaining 42 folds to the Moon on thickness alone, and placing the separator at “is the slack counted”.

1. Notation and the Question

Setting: fold a strip of thickness t in the same direction n times. Each fold needs slack for the paper to wrap around the crease.

$$\text{thickness} = t 2^n, \quad L_{\min}(n) = \frac{\pi t}{6} (2^n + 4) (2^n - 1)$$

Computed for $t = 0.1$ mm, ordinary copy paper.

Observation 1.1

the left expression is 2^n and the right is 4^n . The leading term of $(2^n + 4)(2^n - 1)$ is $2^n \cdot 2^n$ —the exponents differ.

Observation 1.2

when the exponents differ, large n settles which one binds. The ratio opens as 2^n —“too thick” and “not long enough” do not act together.

Observation 1.3

slack is needed because a crease is a half-circle. The inner layers must travel around it——there are 2^n layers, and each travels a radius proportional to 2^n .

Question: when paper stops folding, what has run out?

2. The Ratio Opens from 68.6 to 4290.9

Computation 2.1: thickness and required length at $t = 0.1$ mm (computed in this paper).

Folds n	Thickness [m]	Required length [m]	Length/thickness
7	0.0128	0.8778	68.6
8	0.0256	3.4715	135.6
9	0.0512	13.8060	269.6
10	0.1024	55.0640	537.7
12	0.4096	879.0962	2146.2
13	0.8192	3515.0985	4290.9

Observation 2.2

this is the core of the paper. At twelve folds the thickness is only 0.4096 m——something a child could handle. The required length on the same row is 879.0962 m, a ratio of 2146.2.

Observation 2.3

the last column roughly doubles with each fold. $68.6 \rightarrow 135.6 \rightarrow 269.6 \rightarrow 537.7$ ——since $4^n/2^n = 2^n$, the ratio itself opens exponentially.

Observation 2.4

thirteen folds need 3.5 km. The thickness is 0.8192 m——shorter than a person, while the length crosses a town.

Observation 2.5

in every row the length runs out first. Already 68.6 at $n = 7$ ——there is no crossover; length dominates from the start.

3. Six Folds on A4; Forty-Two to the Moon on Thickness Alone

Computation 3.1: the boundaries (computed in this paper).

Quantity	Value
Long edge of A4	0.297 m
Length needed for 6 folds	0.2243 m (enough)
Length needed for 7 folds	0.8778 m (not enough)
Folds for the thickness to exceed the Moon (384400 km)	42

Observation 3.2

the boundary is bracketed from both sides. Six folds need 0.2243 m and fit; seven need 0.8778 m and do not——one sheet of A4 folds six times in one direction.

Observation 3.3

the familiar “seven” is one more than single-direction folding allows. Alternating folds use the width as well, which raises the count——so “seven” is a statement about the folding method, not about thickness.

Observation 3.4

on thickness alone, 42 folds reach the Moon. $0.1 \text{ mm} \times 2^{42} = 4.3980 \times 10^8 \text{ m}$ —this famous calculation is in fact evidence that thickness is not the constraint.

Observation 3.5

the length required for those same 42 folds exceeds the universe. The 4^{42} side—comparing which runs out first hardly needs a comparison.

4. The Half-Circle Is What Eats the Length

Observation 4.1

a crease is not a corner but a half-circle. The inner layers wrap around it—and that circumference eats the length.

Observation 4.2

the number of layers is 2^n and the radius is proportional to 2^n . Their product is 4^n —two exponentials multiplied: that is what 4^n is.

Observation 4.3

the thickness has no such product. Only the number of layers—so it stops at 2^n .

Observation 4.4

they are different-root by the criterion of Paper 300. Thickness is set by the layer count, length by layer count times radius—two things with different roots stand behind one outcome, “it will not fold”.

Observation 4.5

thinner paper does not change the ratio. t enters both expressions linearly—however thin the paper, length over thickness does not depend on t .

5. Separator: Is the Slack Counted or Not

Observation 5.1

separator—count the half-circle at the crease, or treat it as flat plates stacking.

View	Governing quantity	Requirement at 12 folds
Flat plates stacking	thickness 2^n	0.4096 m
Counting the half-circle	length 4^n	879.0962 m

Observation 5.2

the two requirements differ by 2146.2. The same operation, the same number of times—one choice of view moves the answer by three orders of magnitude.

Observation 5.3

the flat-plate view is correct only in the limit of zero thickness. As $t \rightarrow 0$ the slack vanishes too—but at zero thickness there is no limit on the number of folds at all.

Observation 5.4

the separator can be moved. Fold alternately and both length and width are available—the 4^n then spreads over an area and the count rises.

Observation 5.5

to be honest——both 879.0962 m and 0.8778 m come from a model in which the paper does not crush at the crease. Crushing reduces the requirement——what does not move is that the ratio opens as 2^n and that it does not depend on the thickness of the paper.

Observation 5.6

one last thing——“it gets too thick” names a real quantity and not the one that acts. The thickness does grow as 2^n ——it grows; but what runs out first is the length.

6. Roll Call and Closing

1. Thickness 2^n , length 4^n (Section 1): **different exponents.**
2. 0.4096 m of thickness at twelve folds (Computation 2.1): **a child could handle it.**
3. 879.0962 m of length at the same twelve (Computation 2.1): **a ratio of 2146.2.**
4. The ratio doubles with each fold (Observation 2.3): **68.6 $\rightarrow$ 4290.9.**
5. 3.5 km at thirteen folds (Computation 2.1): **thickness 0.8192 m.**
6. Six folds on A4 (Computation 3.1): **bracketed by 0.2243 m and 0.8778 m.**
7. Forty-two folds to the Moon on thickness (Computation 3.1): **not the constraint.**
8. 4^n is layers times radius (Observation 4.2): **both exponential.**
9. The ratio does not depend on t (Observation 4.5): **thinner does not help.**
10. The separator is whether slack is counted (Observation 5.1): **three orders of magnitude.**

Closing: “paper cannot be folded more than seven times because it gets too thick”, the explanation runs——but the thickness is not what stops it. The thickness grows as $t2^n$ and the required length as $(\pi t/6)(2^n + 4)(2^n - 1)$ ——one is 2^n and the other 4^n , and the exponents differ. At $t = 0.1$ mm, twelve folds need only **0.4096** m of thickness, something a child could handle, while the same row requires **879.0962** m of length——a ratio of **2146.2**. The ratio itself opens exponentially——since $4^n/2^n = 2^n$, it runs $68.6 \rightarrow 135.6 \rightarrow 269.6 \rightarrow 537.7$, roughly doubling with each fold, and reaches **4290.9** at thirteen. Thirteen folds need 3.5 km against a thickness of 0.8192 m——shorter than a person, while the length crosses a town. There is no crossover: already 68.6 at seven folds, length dominates from the start. The boundary can be bracketed from both sides——against the 0.297 m long edge of A4, six folds need 0.2243 m and fit, seven need 0.8778 m and do not. The familiar “seven” is one more than single-direction folding allows,

because alternating folds use the width too; “seven” is a statement about method, not about thickness. On thickness alone **42** folds reach the Moon, and that famous calculation is in fact evidence that thickness is not the constraint. What eats the length is the half-circle at the crease—the inner layers must wrap around it. There are 2^n layers and the radius is proportional to 2^n ; their product is 4^n . The thickness has no such product—only the layer count—so it stops at 2^n . They are different-root by the criterion of Paper 300, two things with different roots standing behind one outcome. And since t enters both linearly, however thin the paper the ratio is unchanged. One thing does the separating—count the half-circle at the crease, or treat it as flat plates stacking. The requirement at twelve folds is 0.4096 m or 879.0962 m—the same operation the same number of times, with one choice of view moving the answer three orders of magnitude. The flat-plate view is correct only at zero thickness, where there is no limit on folds at all. Fold alternately and the 4^n spreads over an area, raising the count. To be honest—both 879.0962 m and 0.8778 m come from a model in which the paper does not crush at the crease, and crushing reduces the requirement. What does not move is that the ratio opens as 2^n and does not depend on the thickness of the paper. One last thing—“it gets too thick” names a real quantity and not the one that acts. The thickness does grow as 2^n ; it grows, but what runs out first is the length.

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