Folding Paper in Half 12 Times:

The story of an impossible challenge solved at the Historical Society office

Alice laughed: "There's no use trying," she said; "one can't believe impossible things." "I daresay you haven't had much practice," said the Queen.

Through the Looking Glass by L. Carroll

BRITNEY'S FOLDING RECORD STILL HOLDS

The long standing challenge was that a *single* piece of paper, no matter the size, cannot be *folded* in half more than 7 or 8 times. Recently, reports have been made that Britney's paper folding record of folding a piece of paper in half 12 times has been broken. These current attempts, though laudable and will eventually be successful, are not satisfactory due to strict rules she followed to also preclude criticism from modifying the problem. Challengers have used methods including stacking separate pieces on top of one another, taping pieces together, cutting paper, tearing paper, and pleated (fan) folding instead of folding in half. These methods circumvent the principles of the simply defined paper folding problem and demonstrate a misunderstanding of why the challenge was thought to be impossible. [Recent reference.](#)

The most significant part of Britney's work is actually not the geometric progression of a folding sequence but rather the detailed analysis to find why geometric sequences have practical limits that prevent them from expanding.

 Her book provides the size of paper needed to fold paper and gold 16 times using different folding techniques. Her equations have been confirmed by scholars at Cal Tech and Harvey Mudd and are posted on Wolfram MathWorld.

Britney Gallivan has solved the Paper Folding Problem. This well known challenge was to fold paper in half more than seven or eight times, using a single piece of paper of any size or shape.

In April of 2005 Britney's accomplishment was mentioned on the prime time CBS television show Numb3rs.

The task was commonly known to be impossible. Over the years the problem has been discussed by many people, including mathematicians and has been demonstrated to be impossible on TV.

For extra credit in a math class Britney was given the challenge to fold anything in half 12 times. After extensive experimentation, she folded a sheet of gold foil 12 times, breaking the

record. This was using alternate directions of folding. But, the challenge was then redefined to fold a piece of paper. She studied the problem and was the first person to realize the basic cause for the limits. She then derived the folding limit equation for any given dimension. Limiting equations were derived for the case of folding in alternate directions and for the case of folding in a single direction using a long strip of paper. The merits of both folding approaches are discussed, but for high numbers of folds, single direction folding requires less paper.

The exact limit for single direction folding case was derived, based on the accumulative limiting effects induced by every layer of paper in the folding process.

For the single direction folding case the exact limiting equation is:

$$L = \frac{\pi \cdot t}{6} \cdot (2^n + 4)(2^n - 1)$$

where L is the minimum possible length of the material, t is material thickness, and n is the number of folds possible in one direction.

L and t need to be expressed using the same units.

Stringent rules and definitions were defined by Britney for the folding process. One rule is: For a sheet to be considered folded n times it must be convincingly documented and independently verified that (2n) unique layers are in a straight line. Sections that do not meet these criteria are not counted as a part of the folded section. Her equation sums losses inclured with each individual fold.
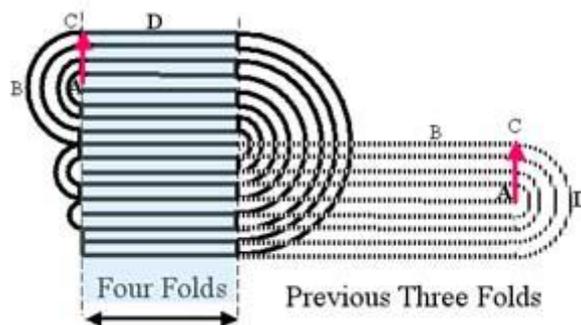
Diagram showing part of a rotational sliding folding sequence

In some web pages the limits found by Britney are described as being due to thickness to width ratios of the final folds or attributed to the folder not being strong enough to fold any more times. Both explanations for the limits are incorrect and miss the actual reason for the physical mathematical limit. The actual understanding of the problem involves understanding the simple dynamics of the folding model and the resulting algebra.

One interesting discovery was to fold paper an additional time about 4 times as much paper is needed, contrary to the intuition of many that only twice as much paper would be needed because it is twice as thick.

In one day Britney was the first person to set the record for folding paper in half 9, 10, 11 or 12 times.

The Historical Society of Pomona Valley is now selling Britney's booklet. It contains over 40 pages of solving the problem and has interesting stories and comments from others who had tried to solve the problem. The booklet gives both detailed and general explanations of the problem's background, the physical limit and tabulates the number of times it is possible to fold different size sheets.

Alternate Direction Folding has the following limit:

$$W = \pi \, t \, 2^{3(n-1)/2}$$

This equation gives the width "W" of a square piece of paper needed to fold a piece of paper "n" times, by folding in alternate directions. The actual equation for alternate folding is more complicated, but this relatively simple formula gives a bound that can not be exceeded and is quite close to the actual limit.

For paper that is not square, the above equation still gives an accurate limit. If the paper is 2:1 in length to width ratio, imagine it folded one time making it twice as thick "t" and then use the above formula remembering that one extra fold is added.

Britney derived folding limits in December of 2001 and folded paper in half 12 times in January of 2002, while a junior in High School.

We are now accepting orders at the society for Britney's booklet : How to Fold Paper in Half Twelve Times - An "Impossible Challenge" solved and explained.

The price is $16.00 including shipping. An additional 8.25% sales tax must be added for orders from the state of California. Foreign orders will require an extra $1.50 in US currency for shipping. Foreign sales are a big percentage of the total. Your purchase will have a money back guarantee.

Order from: The Historical Society of Pomona Valley, 585 East Holt Ave., Pomona, CA 91767

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