Origami Physics: Circularity of Plane Shapes

AdeBanjọ Oriade

CSAAPT, AAPT-SEPS, NJAAPT Spring 2026 Joint Semi-Virtual Meeting
Department of Physics & Astronomy
Interdisciplinary Science Learning Laboratory
UD, Newark, DE

April 19, 2026

Origami Physics: Circularity of Plane Shapes

Circularity is a measure of roundness of a plane shape. Circularity is a 2D measure. It has a 3D counterpart, sphericity. I will be sharing how I use the concept of circularity to engage students learning science. Students start by recording their predictions about the circularity of a list of plane shapes. Students predict the ranking of the circularity of the shapes. They also make quantitative predictions, answering questions like "How much more circular is one shape in comparison to another?". Reasons for the qualitative and quantitative predictions they make are opined.

Next, they collect and analyze data from shapes they folded. There are a number of ways to compute the circularity of a plane shape in the literature. A few methods for computing circularity will be discussed. I will share reasons for the definition ($4\pi \frac{Area}{Perimeter^2}$) I use in class. The shapes students fold includes heptagons, hexagons, pentagons, rectangles, squares (no folds), and various triangles.

In conclusion students reflect on the results of their experimentation. They compare measured and analyzed data with prior predictions. This activity can be adapted to a laboratory experience focused on measurement and error propagation.

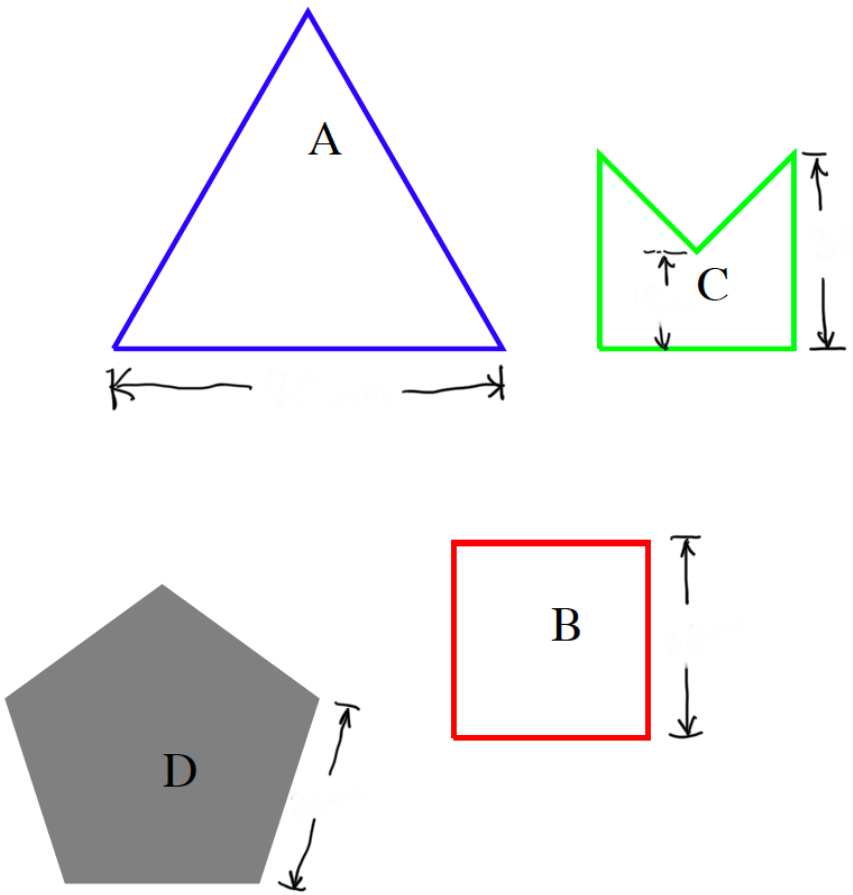
Hook

- Used as differentiating quantitative shape factor in medical and biological imaging. [1]
- Used in engineering, design and manufacturing for quality control. Precision Machining.
- Computer vision and image analysis. Shape recognition. Surface analysis.
- Secondary data challenging to estimate qualitatively and more so quantitatively. [2]

[1] Kang et al. *Circularity for Small Renal Tumor Diagnosis*, Korean J Radiol 2021;22(5):735-741 https://doi.org/10.3348/kjr.2020.0865

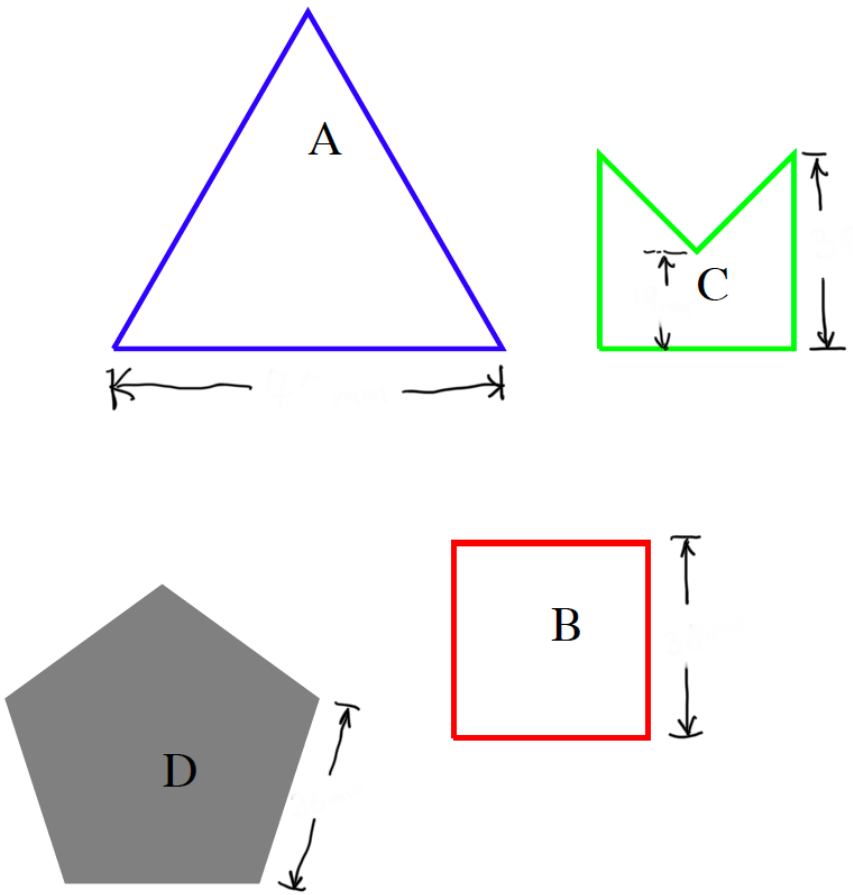
[2] Define: primary, secondary, tertiary... meta data. Lab design for non-science majors.UD Course: Origami Science PHYS/SCEN 115 Banjo Oriade; Primary Text and source of inspiration: **project Origami, 2nd Edition, Thomas Hull, CRC Press, 2013**

Rank the shapes from smallest to largest Area.



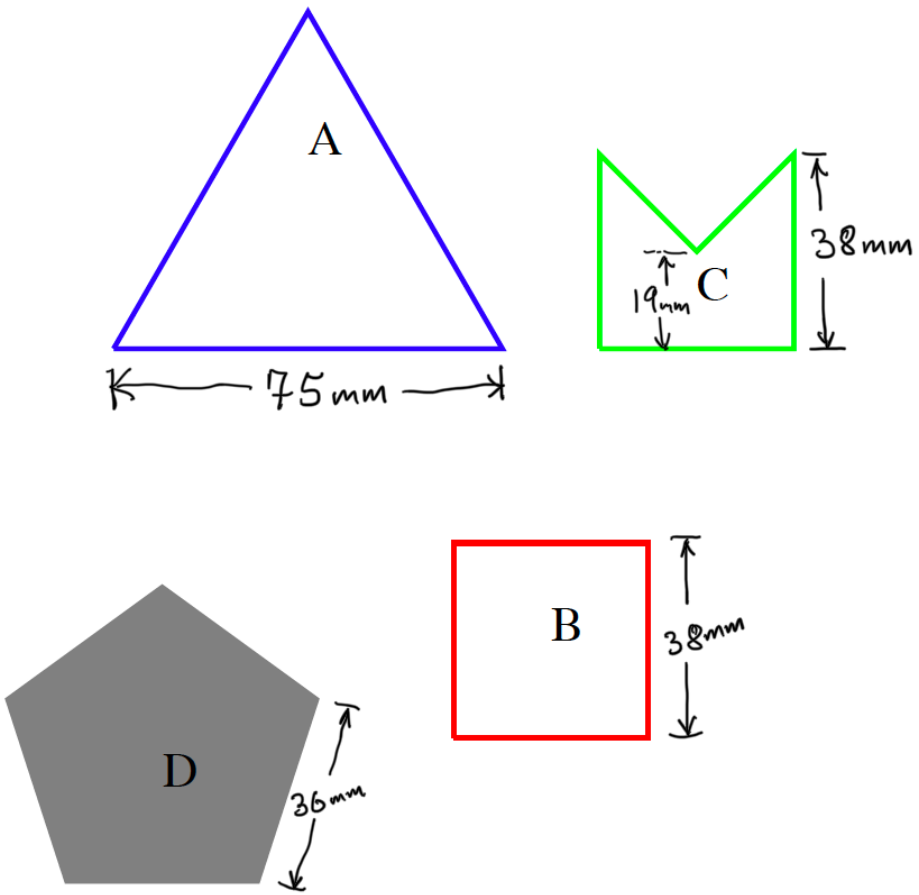
Difficulty Level: Easy

Rank the shapes from smallest to largest Perimeter.



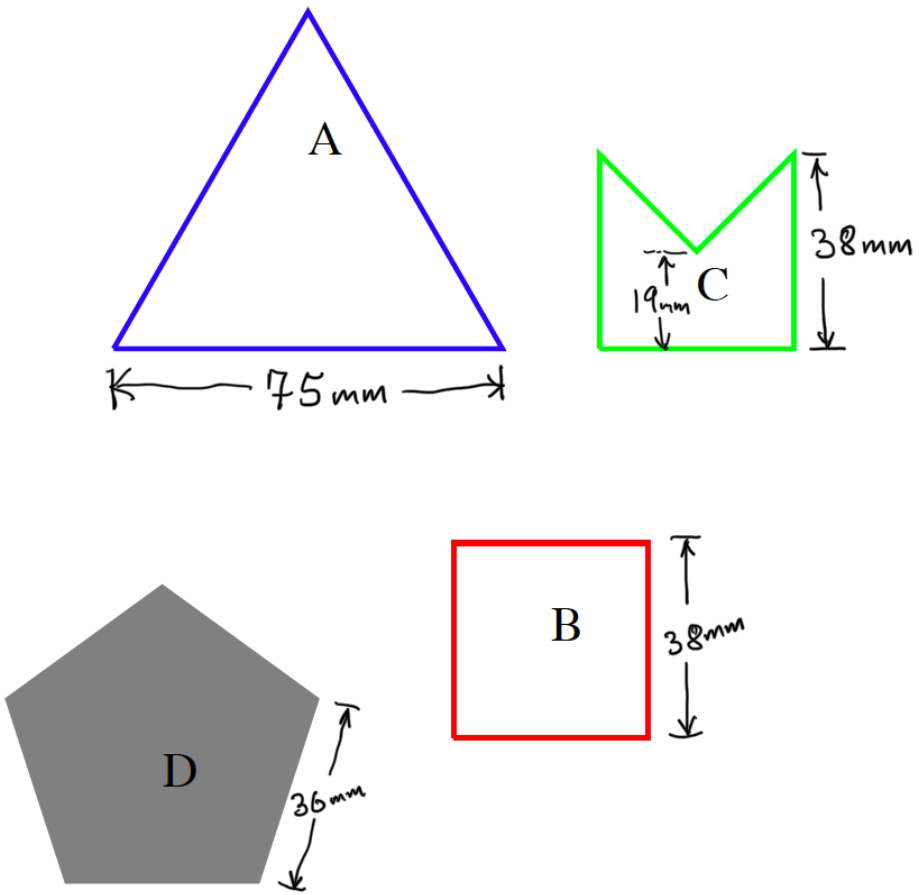
Difficulty Level: Medium

Rank the shapes from smallest to largest Circularity.



Difficulty Level: Challenging

Estimate the percentage Circularity of the shapes.



Difficulty Level: Challenging

Student Comments and Feedback from other similar activities

- Self-checking predictions, self-driven learners. Motivation.
- A competition, a race.
- Cooperation, team building ice-breaker.

First compute the plane shape's perimeter, P, and area, A.

- Equi-perimeter, circle maximum circularity c_{r1}.

$$r_{eff,1} = \frac{P}{2\pi}\ ;\ c_{r1} = \frac{A}{\pi r_{eff,1}^2}$$

- Equi-area, circle maximum circularity c_{r2}.

$$r_{eff,2} = \sqrt{\frac{A}{\pi}}\ ;\ c_{r2} = \frac{2\pi r_{eff,2}}{P}$$

- Equi-perimeter, circle minimum circularity c_{r3}.

$$r_{eff,1} = \frac{P}{2\pi}\ ;\ c_{r3} = \frac{\pi r_{eff,1}^2}{A}$$

- Equi-area, circle minimum circularity c_{r4}.

$$r_{eff,2} = \sqrt{\frac{A}{\pi}}\ ;\ c_{r4} = \frac{P}{2\pi r_{eff,2}}$$

Roundness [3]

- Equi-perimeter definition

$$\text{Triangle } c_{r1T} = \frac{\sqrt{3}\pi}{9} = 60.5\% \text{ ; Square } c_{r1S} = \frac{\pi}{4} = 78.5\%$$

- Equi-area definition

$$\text{Triangle } c_{r2T} = \frac{\sqrt{\pi}}{3^{\frac{3}{4}}} = 77.8\% \text{ ; Square } c_{r2S} = \frac{\sqrt{\pi}}{2} = 88.6\%$$

[3] Is roundness not an all or nothing measure ?

- Students are motivated to learn science by doing science.
- Physical quantities presenting an element of surprise are good hooks for student-centered learning.
- Analysis of error propagation, during computation of circularity from primary data.
- This exercise can be further simplified to involve two shapes. An example is my shapes B and C.
- Thank you for your time and attention.

Questions ?