Lesson Title-Tumblewing Design Challenge

5.ETS1: Engineering Design

Plan and carry out tests on one or more elements of a prototype in which variables are controlled and failure points are considered to identify which elements need to be improved. Apply the results of tests to redesign the prototype.

Introduction

A **tumblewing** is a type of glider which rotates about an axis and exhibits **lift** as the tumblewing alternates between **flying** and **stalling (free fall)**. One common example of a tumblewing is confetti which "tumbles" as it falls. The alternating flying and stalling of the confetti creates the visual appeal.

Objectives:

1. Students will explain the forces of flight as they relate to the tumblewing.
2. Students will design, construct, test, modify, and re-test their tumblewing.

Prior Knowledge:

Students need to be familiar with the four forces of flight: weight/gravity, lift, thrust, and drag and other key terms.

- **Weight/gravity**-the force pulling an object towards the Earth's surface
- **Thrust**-the force pushing an object forward
- **Lift**-a force which pushed an object upward (in a tumblewing this is ridge lift)
- **Drag**-the force that acts opposite to the direction of motion-caused by friction and differences in air pressure
- **Flying**-achieved when weight/gravity and drag are not greater than lift and thrust
- **Stalling**-when an aircraft does not have enough lift to continue in flight
- **Engineering Design Process**-a series of steps used while solving a problem

Technology & Engineering Design Challenge

I.Challenge

In this engineering design challenge, you will work in small groups (2-3 students) and will be given the materials needed to design and build a tumblewing that can travel at least 30' (9.1 meters).

II.Criteria and Constraints

- The tumblewing must be constructed from phonebook paper and tape
- The tumblewing must be constructed from no more than 1 single sheet of phone book paper
- The tumblewing must be powered by nothing other than the air deflected from one piece of cardboard (12" x 12")
- Team members may "drop" the tumblewing to start flight but may not touch the tumblewing following the initial drop
- Team members may modify the tumblewing shape

III. Materials

- 5 pieces of phone book paper
- Tape
- Scissors
- Tumblewing templates

IV. Evaluation

- 10 points: Built and flies more than 30' (9.1 meters)
- 9 points: Built and flies less than 20' (6.1 meters)
- 5 points: Not completed or launched-effort shown
- 0 points: No effort shown

Procedure:

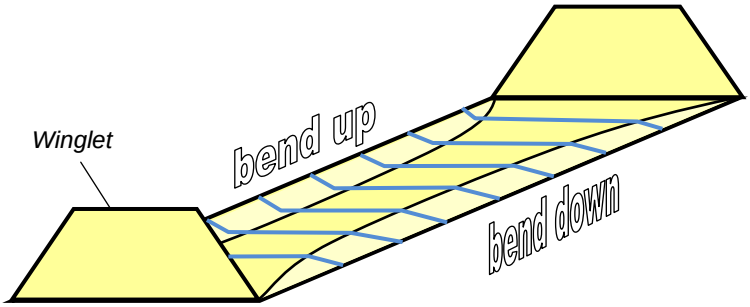
- Phenomenon: Show a video of an F-18 Hornet flying and stalling
- Ask students to describe what they are observing and why it is occurring.
- Discuss the four forces of flight
- Explain the design challenge
- Construct the tumblewing (see attached pdf-tips for flying are also included)
- Use the tables to **test** and **evaluate** the variables **one at a time** and **record** the results (see attached pdf)
- After testing and evaluating, **analyze** the data. Look through the trials for each variable and as a team decide what combination of measurements will produce the longest flight for the tumblewing.
- **Write an argument** as to which combinations of variables will produce the longest flight for the tumblewing. (Example: *Based on our experiments, we have chosen to make our final tumblewing 4" long and 2" wide with side folds on ½ "and end folds of 1". When using these measurements, we recorded the longest flights with our tumblewing.*)
- Describe each principle of flight as it related to the tumblewing. What provides each force and how do they interact with each other?

  How it works: There are four forces that act on an object in flight: weight/gravity, lift, thrust, and drag. In order for an object to stay airborne the lift must overcome the weight/gravity and the thrust must overcome the drag. If the tumblewing is simply dropped, it will spin on its axis and slowly descend-in this case the drag and the weight/gravity will slowly bring the tumblewing down. If you walk behind the tumblewing with a piece of cardboard, you push air in front of the cardboard (upward draft in air is called ridge lift) which acts as an upward lifting force as well as a forward thrust force. Balancing these forces allows the tumblewing to maintain steady flight.)
- Groups present their findings with the class

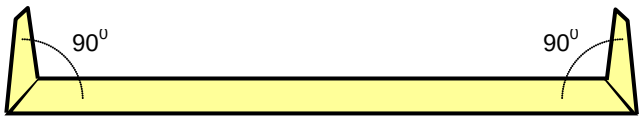
Folding Instructions

1. Tear a page out of the phone book (make sure it's not an important page)
2. Print this page, lay it on top of the phone book paper and trace over the design (opposite) with a ballpoint pen pressing firmly
3. Carefully cut out the tumblewing design
4. Fold the winglets (outer edges) up at 90 degrees as illustrated below
5. Bend the leading edge (front) <u>down</u> slightly and the trailing edge (back) <u>up</u> as illustrated

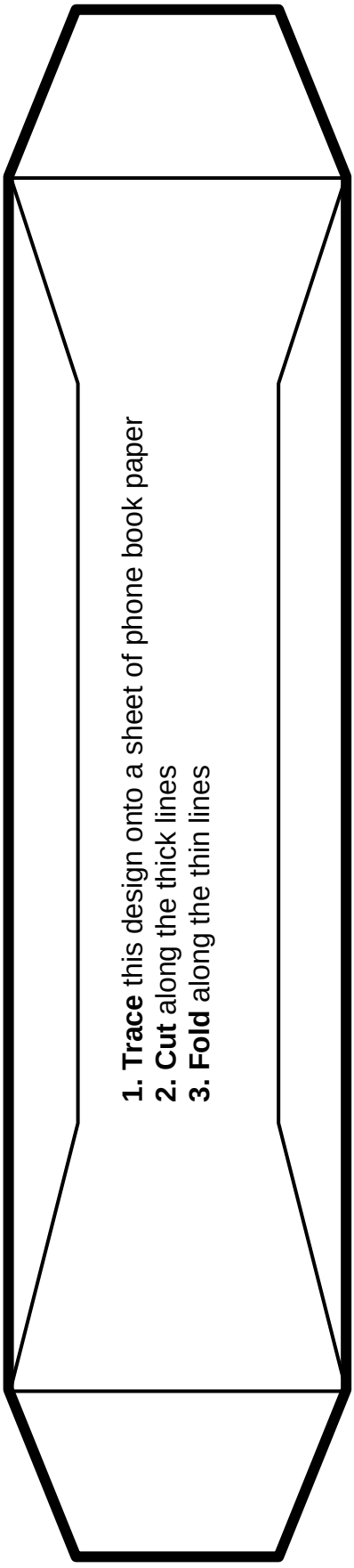
The tumblewing will only fly straight if it is symmetrical



FRONT VIEW

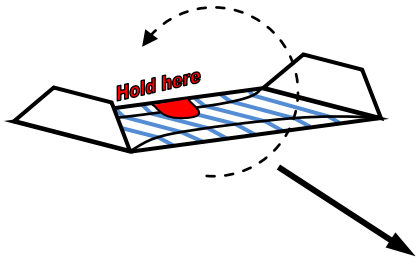


Winglets must be bent at 90° like this for a straight flight path



Test Flight Instructions

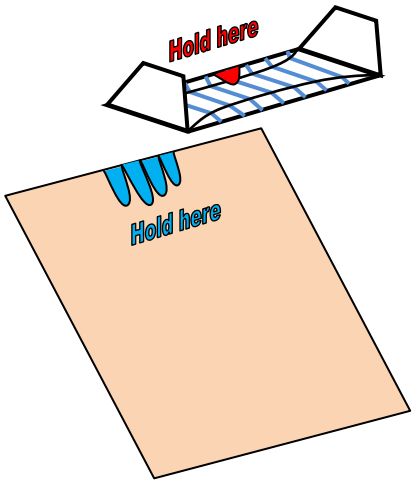
Check that your tumblewing falls forwards in a straight line before attempting to fly it with a paddle



1. Hold the tumblewing by the trailing (folded up) edge between your index finger and thumb as shown
2. Release the tumblewing: it should fall forwards and away from you in a straight line, tumbling backwards as it descends
3. If your tumblewing curves to the left or right as it falls, make sure the winglets are both folded up at 90 degrees

Flying Instructions

Flying requires a large, still space such as an empty hall. The slightest breeze makes steering a tumblewing almost impossible.

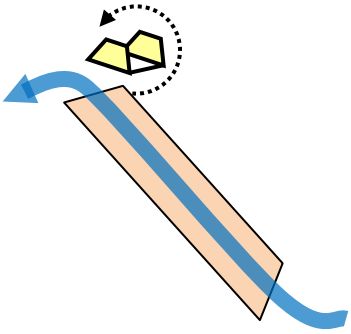


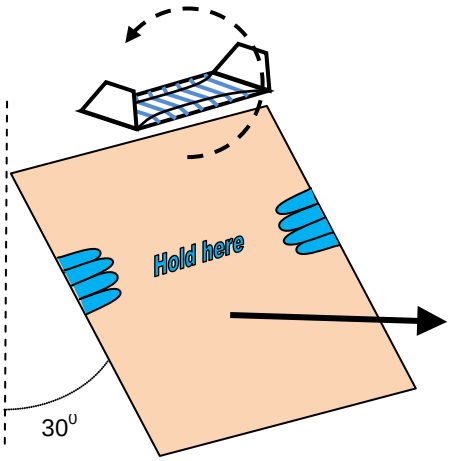
Launching

1. You'll need a paddle made from a large piece of flat cardboard around 50cm × 60cm or bigger (at least as big as the top of a pizza box)
2. Hold the cardboard paddle by the top edge as shown
3. Hold the tumblewing above and slightly in front of the paddle
4. Release the tumblewing so that it falls away from you
5. Quickly change your grip so you are now holding the paddle as shown, with the bottom edge tilted slightly further forward at about 30 degrees
6. Chase the tumblewing with your paddle, walking at just the right speed to keep it hovering near the top edge of your paddle – steer the tumblewing by turning the paddle

How it works & Tips for flying

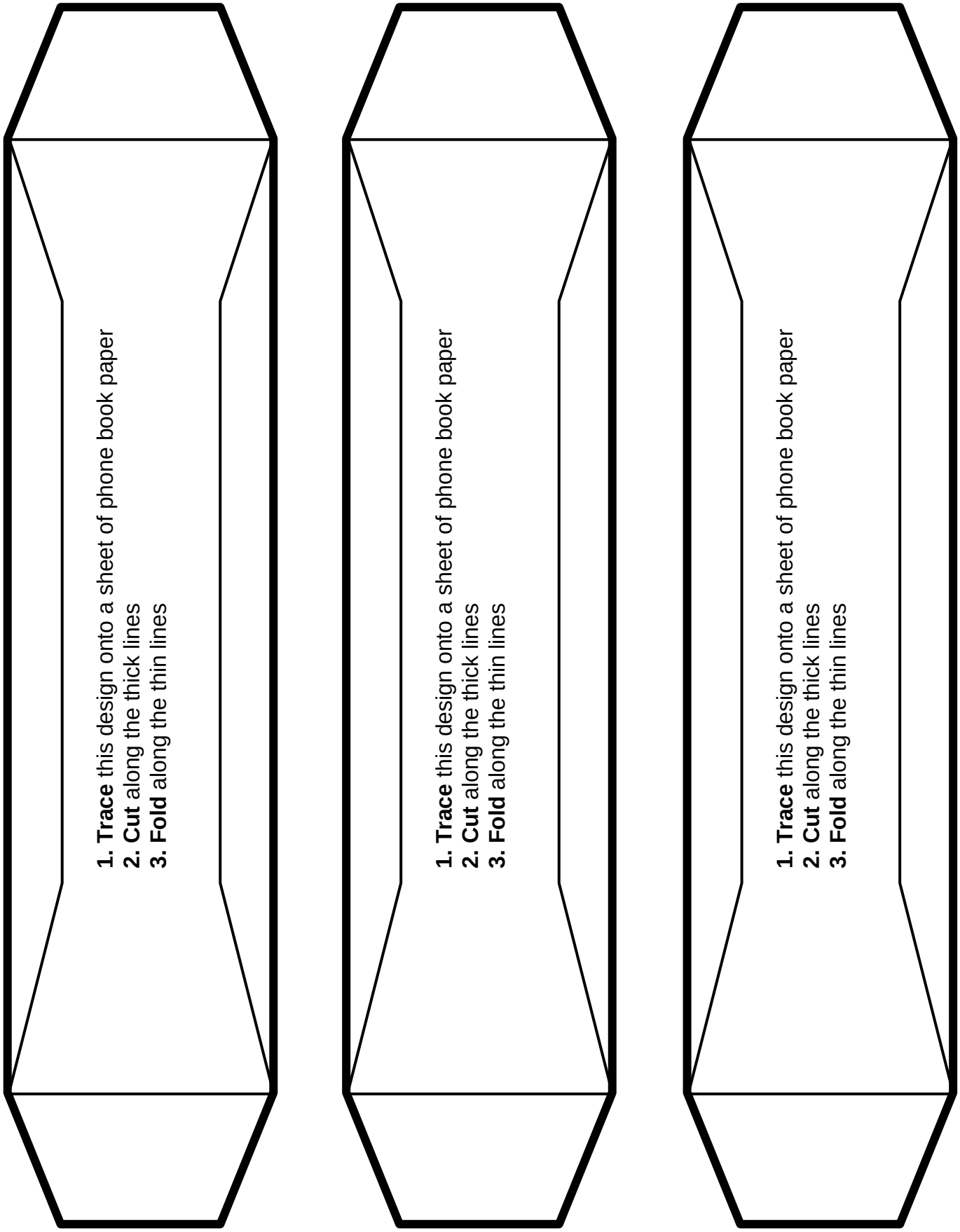
As you walk forward, air rushes up and over the paddle. This rising air prevents the tumblewing from falling to the floor. If your tumblewing falls too fast, walk faster or tilt the paddle further forward. If your tumblewing flies up and over the top of the paddle, walk slower.





Flying

Photocopy this page and cut in thirds
(one template required per student)



Example

Trial #	Length of tumblewing	Width of tumblewing	Fold length (ends)	Fold length (sides)	Results (how far did it go)
Ex. 1	*5”*	*2”*	*¼”*	*1/8”*	*12’*
Ex. 2	*5”*	*2”*	*½”*	*1/8”*	*10’*
Ex. 3	*5”*	*2”*	*1”*	*1/8”*	*9’’*

Test different **fold lengths (sides)** here

Trial #	Length of tumblewing	Width of tumblewing	Fold length (ends)	**Fold length (sides)**	Results (how far did it go)
1					
2					
3					
4					

Test different **fold lengths (ends)** here

Trial #	Length of tumblewing	Width of tumblewing	**Fold length (ends)**	Fold length (sides)	Results (how far did it go)
1					
2					
3					
4					

Test different overall tumblewing **widths** here

Trial #	Length of tumblewing	**Width of tumblewing**	Fold length (ends)	Fold length (sides)	Results (how far did it go)
1					
2					
3					
4					

Test different overall tumblewing **lengths** here

Trial #	**Length of tumblewing**	Width of tumblewing	Fold length (ends)	Fold length (sides)	Results (how far did it go)
1					
2					
3					
4					