Egg-streme Parachuting

Flinn STEM Design Challenge™

6

Introduction

Parachutes are used in many different ways—the armed forces use parachutes for various jump missions, NASA uses parachutes to safely land space crafts and adrenaline-seekers use them to jump out of planes! Design and build a parachute out of everyday materials that will protect an egg from crash landing.

Concepts

- Gravity
- Drag
- Newton's second law
- Terminal velocity

Background

A parachute is designed to slow the movement of objects—typically the descent of falling objects, such as a skydiver or spacecraft. Parachutes consist of three main parts. The *canopy* is the upper portion of the parachute that increases air resistance. *Suspension lines* connect the canopy of the parachute to the *harness*, which firmly holds the person or object in place. The air resistance created by the canopy is known as *drag*, a type of friction acting opposite to the motion of the object. An example of drag is the force you feel on your hand when you stick it out of a moving car's window. If your hand is flat with your palm facing down, your hand does not feel much drag and will glide easily through the air. As you rotate your hand upward, air will push your hand back.

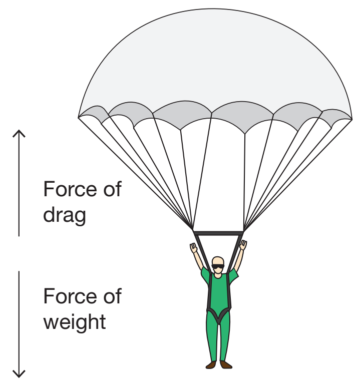


Figure 1.

Parachute canopies were historically made of a silk material—however, they are now commonly made from nylon. Nylon is a strong, durable fabric that doesn't add much weight to the parachute. A canopy that weighs too much can make the parachute fall too fast. On the other hand, a canopy that isn't strong enough may tear or collapse. If air pressure inside the canopy becomes too great, the parachute may begin to sway from side to side as a means of allowing air to escape. To prevent this, a hole or vent is sometimes present in the center of the canopy to increase stability and allow the parachute to fall straighter. The size of the canopy is also a large influence on the effectiveness of a parachute. The surface area of a canopy affects the force of drag during free fall (see Equations 1 and 2).

$$A_{\square} = l \bullet w \qquad \textit{Equation 1}$$

where: $A_{\square}$ = area of a rectangle
l = length of side
w = width of side

$$A_{\bigcirc} = \pi r^2 \qquad \textit{Equation 2}$$

where: $A_{\bigcirc}$ = area of a circle
r = radius of circle

Newton's second law states that the overall acceleration of an object depends on the object's mass and the net force acting upon the object. In other words, force is equal to mass (kg) times acceleration (m/s^2), or $F=ma$. There are two main forces acting upon a skydiver (see Figure 1). The downward force is attributed to weight due to gravity. In this regard, weight is the product of the skydiver system's mass and the acceleration due to gravity ($a = 9.8\ m/s^2$). Drag is the force acting in the upward direction and is most substantially a result of the canopy. The net force of a system is the sum of all forces acting upon the object. In this case, the net force is equal to the force of weight plus the force of drag (see Equation 3).

$$F_{net} = F_{weight} + F_{drag} \qquad \textit{Equation 3}$$

Experiment Overview

The purpose of this activity is to design and construct a parachute that can carry an egg safely to the ground. Each group will examine the influence a canopy's surface area has on the drag produced and overall acceleration of the egg.

Pre-Lab Questions

1. Describe the forces acting on a parachute in free fall.
2. Two skydivers jump out of a plane. One skydiver keeps his body in a straight line with his toes pointing downward while the other stretches out to be parallel to the ground. Which of the two feels the most drag?
3. A skydiver with equipment has a total mass of 87.3 kg. At one point during a jump, the skydiver is accelerating downward at 1.50 m/s^2.

   a. Determine the net force acting on the skydiver at that point.

   b. Determine the force due to drag on the system using Newton's second law.
4. A skydiver jumps out of a plane from a height of 3800 meters. It takes 6 minutes to reach the ground. What is the average velocity of the skydiver (in m/s)?

Materials

Balance, electronic
Meter stick
Paper clips, 2
Plastic bag, 4″ × 6″
Plastic egg
Scissors
String
Tape
Timer or stopwatch
Tissue paper, 3 sheets
Washers, 2
Water

Safety Precautions

All items in this procedure are considered nonhazardous. If an egg leaks on the floor, clean up the spill immediately to reduce the risk of a slippery surface. Wear safety glasses. Wash hands thoroughly with soap and water before leaving the laboratory. Please follow all laboratory safety guidelines.

Procedure

Part A. Introductory Activity

1. Obtain three sheets of tissue paper and a pair of scissors.
2. Cut one canopy that is 15 cm × 15 cm and one that is 30 cm × 30 cm.
3. Cut four pieces of string for each canopy to act as suspension lines. Strings should be equal in length to one another and the same length as the longest side of the canopy.
4. Tape a piece of string to each corner of the tissue paper.
5. Flip the paper over so the side with tape is facing the table. Pull each string in order to make them meet evenly in the center of the paper. Tie the strings together in a loop knot at the end (see Figure 2).

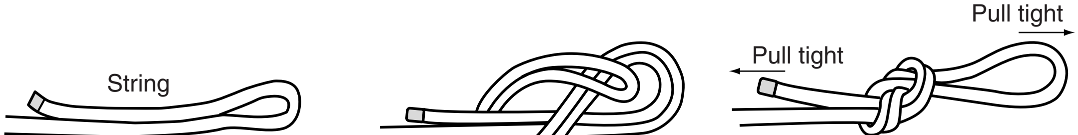


Figure 2.

6. Hook two metal washers to a paper clip. Loop the paper clip through the tied end of the suspension lines.
7. Drop both parachutes from the same height. Repeat drops to observe parachute behavior.
8. Record your observations in Table 1 on the *Egg-streme Parachuting Worksheet.*
9. Construct two new parachutes of varying size, to test. Record observations in Table 1.

Part B. Design Challenge

Design and construct a parachute that is able to carry an egg safely to the ground. If the parachute does not travel slowly enough, the egg will crack upon impact. What variables may be changed to slow the egg's fall?

Use the engineering and design questions from the *Egg-streme Parachuting Worksheet* to guide your design plan. Write and draw pictures on a separate sheet of paper as needed.

1. Complete steps 1–3 after completing the Introductory Activity.
2. Detail your design plan in step 4 on the worksheet.
3. Build your design. Complete step 5 on the worksheet.
4. Prepare parachute for testing:
   a. Fill a plastic egg with water by submerging the two pieces of the egg in the water in the beaker. Note: The egg may have small holes in each end. Cover the holes inside with tape or clay. Connect the two egg pieces together while they are submerged and full of water. To obtain a "weak" egg, it may be necessary to connect the two pieces loosely. It may take practice to determine the minimum tightness the two egg pieces need to be so that they stay together in the egg basket, but still crack open when the egg hits a rigid surface.
   b. Place the water-filled plastic egg into a plastic bag. Dry off the outside of the plastic bag if necessary.
   c. Obtain a 25-cm piece of string. Tie loop knots at both ends.
   d. Tie the plastic bag closed using a looping knot (see Figure 3).
   e. Connect the parachute's suspension lines to the bag basket containing the egg using a paperclip or in the manner your team sees fit.

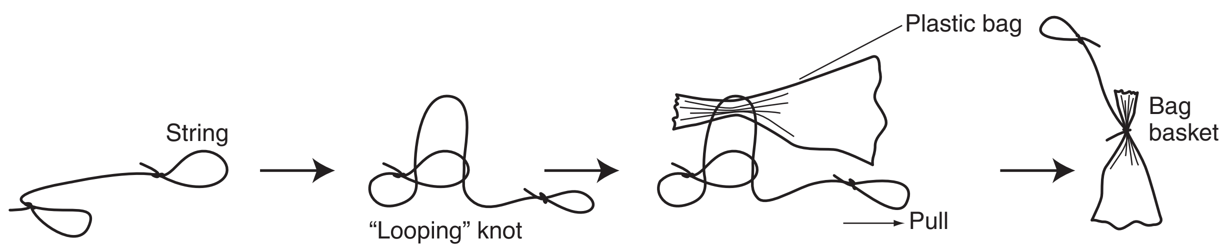


Figure 3.

5. Record the mass of the parachute system.
6. Test your parachute. Your instructor will determine the drop height for testing.
7. Use a stopwatch to time the duration of the fall. Record drop height and drop time in Table 2.
8. Did your egg survive? Check thoroughly for water leaks. Record results in Table 2. If the egg leaked, clean up bag basket and refill the egg with water.
8. Make revisions to your design based on the first test. Complete step 6 on the *Egg-streme Parachuting Worksheet*.
9. Re-test your parachute and record observations.

Disposal

Consult your instructor for appropriate disposal procedures.

Name: ______________________________

Egg-streme Parachuting Worksheet

Engineering and Design Questions

1. Define the problem: What is the goal of your parachute design?

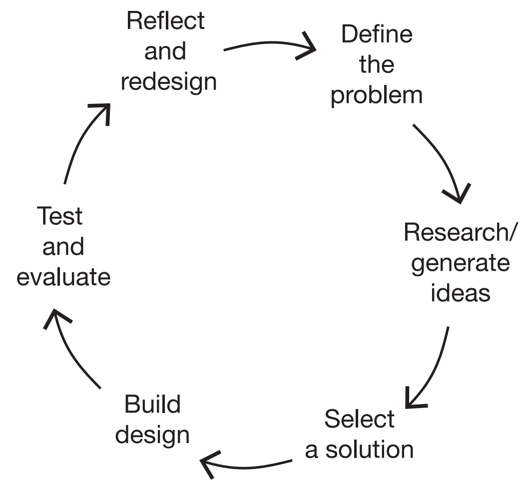


Figure 4. Engineering Process

2. Research/generate ideas: Using what was found in the *Introductory Activity*, name some factors that influence the speed of a parachute in free fall. What caused the parachute to fall more slowly?

3. Research/generate ideas: Parachute canopies can be made out of many different types of materials. Brainstorm various everyday materials that can be used in the design of your parachute. What materials do you believe will work best? Why?

4. Select a solution: Below, detail the design plan for your parachute. Include materials used, estimated measurements, and your reasoning for each design decision. For instance, how will the canopy size chosen benefit your design? What shape will your canopy be?

5. Build your design: Draw and label a sketch of the final design.

6. Reflect and redesign: What modifications were made to your design for the final test?

Data Tables

Table 1. Introductory Activity

Variable	Alteration	Observations
Canopy size	Constructed canopies of two different sizes: 15 cm × 15 cm 30 cm × 30 cm	

Table 2. Design Challenge

Trial	Mass, kg	Fall distance, m	Drop Time, s	Average Velocity, m/s	Egg Observations
1					
2					

Table 3. Surface Area vs. Acceleration

Trial	Surface Area of Canopy, cm^2	Average Acceleration, m/s^2	Drag, N
1			
2			

Table 4. Class Data

Group	Trial	Surface Area of Canopy, cm^2	Average Acceleration, m/s^2	Drag, N
1	1			
	2			
2	1			
	2			
3	1			
	2			
4	1			
	2			
5	1			
	2			
6	1			
	2			
7	1			
	2			
8	1			
	2			
9	1			
	2			
10	1			
	2			
11	1			
	2			
12	1			
	2			
13	1			
	2			
14	1			
	2			
15	1			
	2			

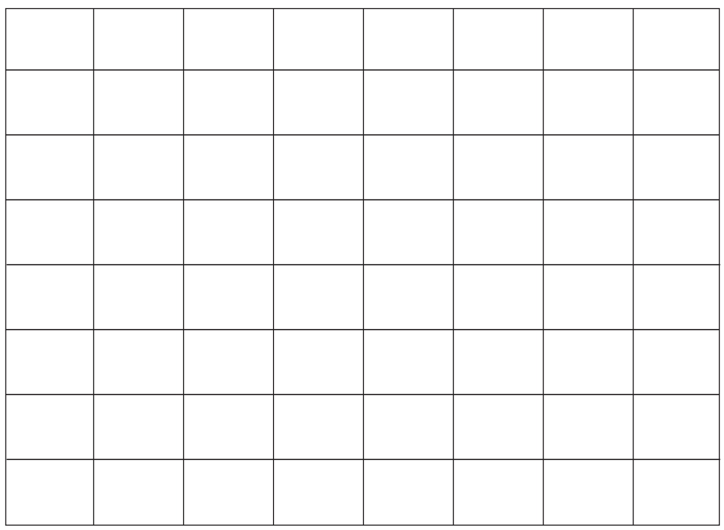
Post-Lab Questions

1. Calculate the average velocity of the egg for each trial. Record in Data Table 2.
2. Calculate the surface area of the parachute canopy for each trial using Equation 1 or Equation 2 from the *Background* section. Record in Data Table 3.
3. Calculate the average acceleration of the egg for each trial using the equation below. Record in Data Table 3.

$$a = 2d / t^2 \qquad \textit{Equation 4}$$

where a = acceleration
d = distance, meters
t = time, seconds

4. Calculate the force due to drag on the system for each trial using Newton's second law. Record the values in Data Table 3.
5. Add data from Data Table 3 to the Class Data Table 4. When complete, one member will graph the data with surface area on the *y*-axis and acceleration on the *x*-axis. The other will graph surface area on the *y*-axis and drag on the *x*-axis. Clearly label each axis—don't forget units! *Note:* Graph the absolute values for acceleration and drag.



6. Describe the relationship between the surface area of the canopy to both the acceleration of the egg and drag produced.
7. What variables in the parachute's design, other than surface area, could have influenced the overall acceleration during free fall?